Green Makes a Bold Comeback! Inventory Results of 101 Natural Forests in the Middle Hills of Nepal over Two Decades

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Abstract

Repeated forest-resource inventories provide indispensable information to evaluate, for example, the mean growth rate of stands and changes in tree-species composition in an area. This paper presents a summary of such longitudinal forest inventory data in the Middle Hills of Nepal, where deforestation has been an issue. Our first inventory was implemented between 1997 and 1999 and measured 3839 plots of 100 square meters (m^2). Our second inventory was conducted between 2014 and 2016 and measured 3765 plots of 100 m^2. We found that over these two decades, the number of trees per hectare (ha^{-1}) significantly improved. The number of stands ha^{-1} with diameter at breast height (DBH) of 10 centimeters (cm) and above went from 361.2 in the first inventory to 466.2 in the second inventory. We also found that not only the number of stands but also the quality of stands significantly improved. The number of stands with DBH of 30 cm and above ha^{-1} increased from 72.9 to 99.6. The mean alpha diversity, the number of trees species in a plot, rose to 2.1 from 1.6 in the initial inventory. In sum, "green has made a bold comeback in the Middle Hills". Our indices evaluating the intensities of human activities on the plots suggest that these improvements in forest-resource conditions may be due to the decreased use of forests in the Middle Hills over these two decades.

Key words: Forest Inventory, increases in the number of stands, less grazing, the Middle Hills

INTRODUCTION

Forests are an essential component of the earth's eco-system (Betts *et al.* 2017). They also contribute to national economies through producing timber and non-timber forest products. Moreover, in some rural areas, people directly depend on local forests for maintaining their everyday livelihoods. For example, as of 2014, among the 122 households (HHs) the authors surveyed in 6 villages in the Western Nepal, 78 HHs (63.9%) used firewood every day to cook their food and 112 HHs (91.8%) used it to prepare feed for their domestic animals.[1] Forest conditions, not only in terms of area but also quality, often matter to these eco-, national, and local economic functions of forests.

Evaluating the impacts of various factors on forest conditions, therefore, has been an important research topic. For such research, we need longitudinal forest-inventory data collected at least over a decade to observe, for example, changes in timber volume and species composition. In this respect, Awoke and Mewded (2019) utilised such longitudinal data to evaluate the impacts of conservation efforts on the changes in woody species composition in a dry evergreen Afromontane forest, while

1 Refer to Tachibana *et al.* (2019) about the surveys on these 122 HHs.

Templeton *et al.* (2019) did so about the impacts of urbanisation on vegetation composition in urban and suburban forests.

This paper reports a summary of such longitudinal forest inventory data in 101 natural forests in the Middle Hills of Nepal. The Middle Hills (or Middle Mountain) is a physiographic zone extending over the average altitude range between 700 and 2,000 meters.[2] It occupies about 30 per cent of the area of the country (Gurung 2008, pp.54-55). As its name indicates, the Middle Hills has rugged geography filled with continuous hills. Forest degradation has been an issue in the area (Metz 1991; Acharya *et al.* 2011).

Our first inventory was conducted between 1997 and 1999, and the second inventory between 2014 and 2016, nearly two decades later. Over these years, the Middle Hills experienced significant changes: the expansion of community management of forests (Acharya 2002), civil war (Lecomte-Tilouine 2013), new road constructions, and outmigration of the young population to foreign countries to pay remittances (World Bank 2011; Gellner and Hausner 2018, p.17). Fox (2018), for instance, provided a case study on population dynamics in a village in the Middle Hills over the decades.

It is difficult to identify and separate out the impacts of each of these significant changes. The main goal of this paper is, as a first step, to describe an overall change in forest conditions in the Middle Hills over these two decades.

2 In official statistics, the area of Middle Hills is also referred to as "Middle Mountains".

Results presented with this data are the changes in the tree density and species composition. While presenting them, we discuss whether human disturbances in the forests were associated with the changes in tree species diversity. In addition, our second inventory results are compared with those of the recent comprehensive official forest-resource inventory in the Middle Hills: the Forest Resource Assessment Nepal (FRA Nepal) (DFRS 2015). Our main findings can be summarised in a single phrase: Green Has Made a Bold Comeback!

MATERIALS AND METHOD

Sampled Forests

The first inventory between 1997 and 1999 was jointly conducted by the researchers of International Food Policy Research Institute (IFPRI) and those from the Institute of Forestry (IOF) of Tribhuvan University. It was a part of the large-scale research project comparing natural resource management in Asia and Africa: 'Property Rights and Natural Resource Management' (Otsuka and Place 2001). The first, third, and fourth author attended the joint study from its initial phase. These three authors planned and implemented the second inventory between 2014 and 2016 to analyse the changes in forest conditions over the two decades.

In the first inventory, the unit of data collection is a forest as defined by the users. If a physically continuous forest patch is divided and separately utilised by the two different user groups, the continuous patch is considered to be two forests. Naturally, some of the sampled forests were or came to be over the administrative boundaries: e.g., ward and Village Development Committee (VDC) before the local administration reform that came into effect after the local elections in 2017 and/or current municipality (*palika*).[3] It also merits to be emphasised that the area under our investigation is forestland: classified by the government of Nepal as *sarkari ban* (government forest). This is the most important difference between our inventory and that by the FRA Nepal which randomly sampled wooded land, not necessarily forest land, utilising satellite images.

In the first inventory, based on the aerial photographs in 1992/96, 104 forest patches (including shrub land) having an area of more than 10 hectares (ha) were randomly sampled. The minimum forest size of 10 ha was necessary for the experienced technician in the project to interpret the aerial-photographs with a hand-held stereoscope for crown cover, tree maturity, etc.[4] In randomly sampled forests, 53 forests were chosen from the accessible area, and the other 51 were chosen from a remote area. The researchers defined remoteness by the distance from local markets and motorable roads. Specifically, the remote forests were at least 15 kilometers (km) away from the district capitals, which were usually main local markets, and 10 km away from passable all-season roads. During the first inventory, in most cases, it required about a one-day trek after leaving a vehicle to reach a remote forest.

The sampling stratification based on the remoteness in the first inventory was intended to capture the impacts of external pressures on both forest resource conditions and the management system. For example, due to budget and human resource constraints, the Divisional Forest Offices (DFOs) had mainly assisted the management of forests accessible from the major roads (Edmonds 2002).

The sampled forests were selected from all the districts in each of the previous five development regions except for the Mid-western Development Region (MDR).[5] Due to the disturbances by the Maoist movement, the sampled forests in the MDR were concentrated in the three districts viz. Salyan, Surkhet and Dailekh districts, which were relatively safe at the time of the first inventory. In addition, no sample forests were taken from the Sindhupalchok district in the previous Central Development Region (CDR) for not sampling plantation forests by the Nepal-Australia Community Forestry Project.

Figure 1 shows the rough locations of our sample areas, and Table 1 presents the management systems of our sampled forests at the time of the first and second inventories. The mean area of our 101 sample forests was 116.3 ha with standard deviation of 210.2. As was expected, at the time of the first inventory, there was a clear difference in the DFOs' activities between the remote and accessible forests. The details and major findings of the first inventory were summarised in Tachibana and Adhikari (2009).

3 In the first inventory, 27 forests lie over more than one ward and 3 forests lie over the two VDCs.

4 One sampled forest happened to be with the area of less than 10 ha, i.e. 7.5 ha.

5 The five development regions were replaced by seven provinces following the elections in 2017.

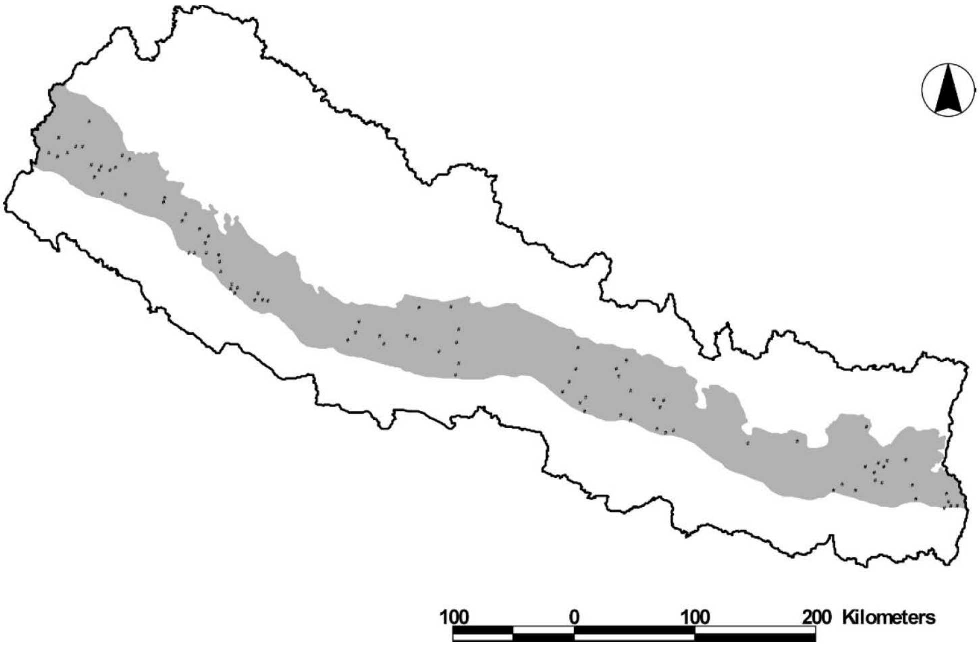

FIGURE 1
THE MIDDLE HILLS (SHADED AREA) AND THE SAMPLE FORESTS (DOTS)
Source: Prepared by the authors.

Figure 1: Sampled 101 Forests

Table 1: Management Systems of the 101 Sample Forests

Under the control of	First Inventory 1997-1999 Total	Accessible Area	Remote Area	Second 2014-2016
Community Forest Users Group (CFUG) registered at the DFO	46	35	11	85
Informal CFUG	26	12	14	13
Directly by the DFO	29	5	24	3
Total	101	52	49	101

In the second inventory between 2014 and 2016, out of the 104 sampled forests in the first inventory, we lost 3 forests. We excluded one forest in the Kathmandu Valley because it was converted to a public park which was situated in an urban area. One forest in the CDR was excluded because the area was transferred to a private cement factory for limestone quarrying. For one sample forest, the enumerators of the second inventory lost many of the original inventory sheets, and the entered data subsequently had an array of discrepancies. In this paper, we focus on the remaining 101 forests.

Sampled Plots

In principle, sampling intensity for forest inventory should be determined based on the variance of the variable of interest, for example, timber stock per hectare (ha^{-1}) in plantation area (Avery and Burkhart 1994). During the design phase of the first inventory, two difficulties were encountered. First, the purpose was to evaluate the condition of natural forests, from where people extracted multiple resources including timber, firewood, leaf litter, fodder, place for grazing, and medicinal plants among others. Thus, we were interested in several variables such as timber volume, crown cover, and diversity in tree species. In the 1990s, there was no published data describing the variances of such multiple variables for the forests in the Middle Hills of Nepal. Second, the budget did not allow the team to measure small preliminary samples in each forest to determine the variances of these variables.

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

The fourth and the most drastic assumption was that by measuring one percent of the unit, we could make satisfactory precise inferences about its forest-resource condition. That is, to evaluate the forest-resource condition of a unit, we measured a sample plot with the area of 100 square meters (m^2). Lastly, we applied the following ordinary formula of sampling from a finite population to determine the sample size:

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

Here, n is the number of sample plots, N is the forest area in hectares, [ ] is the Gauss sign which indicates the largest integer not exceeding the numbers in it. In this formula, we set the population ratio of good forest-resource condition at 50 per cent, which made the possible variance the largest. Again, due to the budget constraint, we set the target precision E at 10 per cent. Examples of sample size are shown in Table 2. Admittedly, our measurement intensity, 1 per cent and below of the total forest area, is low. However, it should be noted that our measurement intensities were, in general, higher than those adopted by the forest inventories in Nepal before the 2000s.[6]

6 See, for example, Forest Research and Survey Center and Forest Resource Information System Project (HMGN 1994) which reports the official forest inventory in a district in Nepal. Their measurement intensity was about 0.4 per cent of accessible forests (defined by the slope), and 0.1 per cent of the total forest area.

Table 2: Number of Inventory Plots (n) in a Forest with N ha Area

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

In each forest, based on field observations, the forest area was stratified by tree species and stand size. The cruising lines were set in each stratum crossing various topographical conditions, and sampled plots were set on specified intervals on these lines. In case of steep and dense forests however, the enumerators could not reach the plot on the cruising line and measured the area nearest to that point.

It is important to note that during the first inventory, location coordinates by Global Positioning System (GPS) were not taken. At that time, GPS equipment was expensive and took a long time to obtain measurements. In the second inventory, the team therefore went back to the same forest patches but not to the same plots. In the second inventory, the GPS coordinates of all the plots were recorded.

Inventory

The inventory team consisted of the graduates and undergraduate students from the IOF. The second author was a team leader for the second inventory. In the field, we hired local guides mainly through the community forest user groups (CFUG).

In the sampled plots, on the prepared sheet, the team recorded the local names of the tree species, diameter at breast height (DBH) and height of all the stands with DBH of 10 centimeters (cm) and above. Tree species were identified either by the enumerators or the local guides. In each plot, DBH was measured for all the stands while the height was measured for one stand by a hand-held digital clinometer. The heights of the other stands were estimated based on the measured tree. The enumerators also ranked and recorded the impact of human activities, e.g., lopping and leaf-litter collections, on the plots.

Following the inventory, based on the local name, the altitude of the forest (the first inventory: measured by aerial photo analysis) or the altitude of the measured plots (the second inventory: from the GPS coordinates), the first author identified the scientific names of the measured tree stands. In the first inventory, he referred to Nepal-Australian Community Forestry Project (NSCFP 1994), Shrestha (1989), and Storrs and Storrs (1998) for the scientific names. In the second inventory, as well as these three references, the first author utilised Manandhar (2002).

RESULTS

Number of Stands Per Hectare

Table 3 summarises the number of plots and stands measured during the inventories. In the first inventory between 1997 and 1999, we measured 13,866 stands over the 3,839 sample plots that were set in the 101 sample forest. In the second inventory between 2014 and 2016, we measured 17,554 stands over the 3,765 sample plots. Over the two decades, some sample forests lost area to road construction etc., which resulted in smaller numbers of measured plots in the second inventory.[7]

7 One may argue that the inventories show loss of forest area (deforestation) in the Middle Hills over the decades, which invalidates our main conclusion. This quality vs quantity issue will be addressed in another paper with the data of trees on the private farm lands.

Table 3: Number of Measured Plots and Stands

	Inventory of the 101 Forests		FRA Nepal in the Middle Hills[a)]
	First 1997-1999	Second 2014-2016	
Number of Plots Measured	3839	3765	873
Area (ha)	38.39	37.65	109.6
Plots with No Stands (Shrub only)	374 (9.7%)	177 (4.7%)	NA
Number of Stands Measured	13866	17554	

Source: DFRS (2015), pp.31-34

We calculated sample statistics in two different methods. In the first method, we calculated sample statistics over the plots. In the second method, sample statistics were at first calculated in each of the 101 forests. Then the means and the standard deviations were calculated over the 101 forests. Although the results are not widely different between these two methods, the first method neglected correlations across the plots in the same forest: i.e. statistics from a stratified sample without considering the stratification. The second method essentially assumes a forest as one patch: variations in tree density are, for example, over the 101 forests. In this paper, to compare our results with those of the FRA Nepal, which randomly sampled plots without considering forest patches, we show the sample statistics calculated by the first method.

Table 4 summarises the number of stands (DBH $\geq$ 10 cm) per hectare (ha^{-1}) in the two inventories and that of the FRA Nepal. The number of stands ha^{-1} in the 101 forests increased by more than 100: from 361.2 to 466.2. Although the standard deviations are large, this difference between the first and the second inventory is statistically significant at the 1 per cent level.

Table 4: Average Number of Stands (DBH $\geq$ 10 cm) ha^{-1}

	Inventory of the 101 Forests		FRA Nepal in the Middle Hills[a)]
	First 1997-1999	Second 2014-2016	
DBH ≧ 10 cm	361.2 (282.6)[b)]	466.2 (298.6)	429.3
DBH ≧ 30 cm	72.9 (100.2)	99.6 (124.8)	50.1
Stand that can produce 3 boles of 182 cm	247.0 (275.8)	291.4 (256.4)	150.3
Basal Area (m^2)	17.9 (16.9)	24.9 (19.7)	

a) Calculated from Table 15 of DFRS (2015).

b) In parentheses are the standard deviations over the plots.

The average stand density in the second inventory, 466.2 stands ha^{-1}, is close to the one obtained by the FRA Nepal: 429.3. Caution is required, however, to evaluate these close numbers because we could not clearly understand the sampling method of the FRA Nepal. If the FRA sampled only the plots with significant tree covers in the satellite images, the sample plots in this research have on average more tree resources than the ones surveyed by the national inventory. As is shown in Table 3, due to our definition of forest, 177 plots of our second inventory (4.7% of the total plots) were on the shrub land without any tree stands.

Table 4 indicates that not only the stand density but also the quality of stands improved over the two decades. In Nepal, the stands with DBH of 10 - 30 cm are classified as 'poles', and those with DBH $\geq$ 30 cm are classified as 'trees'. In Table 4, the number of 'trees' increased by about 26 ha^{-1}: from 72.9 to 99.6. Unlike the case of stand density, in terms of 'tree density', there was a large difference between the second inventory and that of FRA. The result of the second inventory is nearly double of that found in the FRA: 50.1 trees ha^{-1}. In fact, even the 'tree density' of the first inventory (72.9 ha^{-1}) was larger than that of the FRA. Good quality stands that can produce 3 or more boles of 180 cm, which the enumerators visually judged at the plots, shows qualitatively similar results to those about 'trees'.

Tree Species

In the first inventory, we had identified 134 species, including an 'unknown' category among the 13,866 measured stands. In the second inventory, we identified 136 species among the 17,554 stands.[8] Table 5 reports the major findings on the species diversity from our two inventories and that of the FRA. *Shorea robusta*, a deciduous broad-

8 This result of the second inventory may change because, as of August 2019, we are still checking and correcting some parts of the inventory data set.

leaved species whose local name is *Sal*, was the most common species found in our inventories. Its ratio to the total number of measured stands was 32.1 per cent in the first inventory and 29.5 per cent in the second inventory. *S. robusta* was the most common stand identified by the FRA, too, but with a much smaller ratio than those identified by this research: i.e. 18.8 per cent. In the first inventory, a species of pine, *Pinus roxburghii* (local name *Khote Salla)*, followed *Shorea robusta* in numbers with the ratio of 19 per cent.[9] This is different result from that of FRA (DFRS 2015, Table 13) where the ratio of *P. roxburghii* is 7.9 per cent and is ranked as the 5th most common species in the Middle Hills.

Table 5: Indices of Tree Species

	Inventory of the 101 Forests		FRA Nepal
	First (1997-1999)	Second (2014-2016)	in the Middle Hills[a)]
Mean Alpha Diversity:	1.6	2.1	NI
Number of Species per Plot	(1.0)	(1.3)	
(Standard Deviation)			
Stand Ratios			
Shorea robusta	32.1%	29.5%	18.8%
Pinus roxburghii	19.1%	NI	7.9%
Rhododendron arboreum	6.5%	4.6%	10.6%

a) Calculated from Table 15 of DFRS (2015)

The differences between our inventories and the FRA in terms of the ratios of *S. robusta* and *P. roxburghii* are likely to be due to our 52 sample forests which were located in the accessible areas at the time of the first inventory. Because of these 52 forests, our inventory plots are on average located at the lower altitudes of the Middle Hills (mean 1306.8 m with standard deviation 513.9), which may have been located lower than the plots of the FRA. Both *S. robusta* and *P. roxburghii* grow at relatively lower altitudes in the Middle Hills. A supporting observation is that in the FRA, the most common tree species second to *S. robusta* was *Rhododendron arboreum*, which usually grows in high altitudes (above 1,400 m reported in Manandhar 2002, p.395; above 2,300 m reported in Storrs and Storrs 1998, p.236).

The top of Table 5 reports the mean alpha diversity (species richness), which is the number of different tree species in a plot. It rose from 1.6 in the first inventory to 2.1 in the second inventory. Although the standard deviations are large, the difference is statistically significant at the 1 per cent level.

9 As of August 2019, the ratio of *P. roxburghii* in the second inventory has not been calculated. This is because a few enumerators of the second inventory recorded four different species simply as *Salla*: *P. roxburghii*, *Pinus wallichiana* (local name *Gobre salla*), *Pinus patula* (local name *Pate salla*), and *Taxus wallichiana* (local name *Lauth salla*). After a follow-up field survey, we will calculate the ratio of *P. roxburghii* in the second inventory.

DISCUSSION

This study is the first, to the best of knowledge of the authors, to compare the results of large-scale tree inventories in the Middle Hills that were separated by more than a decade. We found that both the number of stands ha^{-1} and species richness (alpha diversity) significantly improved between our first inventory conducted between 1997 and 1999 and the second inventory between 2014 and 2016. Our findings provide background information for more detailed inventories in specific small areas (e.g., Puri *et al.* 2013; Oli and Subedi 2015) and large-scales analyses based on satellite images (e.g., Oldekop *et al.* 2019).

Many things have changed in the Middle Hills between the first and second inventories. There were two major changes that were related to the local use of forest resources. First, at the time of the second inventory, much of younger population, particularly males, was working abroad for a relatively long period. The remittances from these workers became a large income source in rural HHs (World Bank 2011).

Second, many roads were constructed in the Middle Hills over the two decades. Many remote forests in the first inventory were no longer considered remote during the second inventory period. For example, at the time of the first inventory, the average traveling time, of our respondents in the accompanying social surveys, from the sampled remote-forest area to the nearest market town was 342 minutes (min). It was reduced to 123 min at the time of the second inventory. Interestingly, the corresponding traveling times from the forests in the accessible areas as of the first inventory increased from 53 min to 69 min. This is because even in the accessible areas, many people walked to the nearest market town through shortcut paths at the time of the first inventory. At the time of the second inventory, many people came to use public transportation for going to the nearby market towns.

These two changes made the rural population in the Middle Hills less dependent on forest resources. At the time of the first inventory, more than 90 per cent of the HHs collected firewood as their main fuel for heating and cooking (CBS 1996, pp.38-39). Thanks to the income from remittances and access to transportation, at the time of the second inventory, many HHs already used liquid petroleum (LP) gas for cooking. Thanks to the remittances, a part of rural HHs also lost interest in agricultural production. The roads also gave the farmers access to chemical fertilizers, and reduced the demand for manure from domestic animals, which in turn led to less demand on the areas for grazing, fodder and leaf litters from forests.[10]

In sum, over the two decades following the first inventory, rural HHs in the Middle Hills became less dependent on local forests, and consequently less interested in the management of forest areas. Considering these changes, our main finding, that 'Greens Has Made a Bold Comeback!' might not be due to, for instance, successful community forestry programs and active DFOs, but simply due to the less dependence over forest

10 Less cultivation intensity is also due to the lack of labor (Fox 2018).

resources. In fact, other case studies, e.g. Baral *et al.* (2019), do not attribute the forest resource recovery to community management.

Our inventories also suggest that the less use of forests was the major driving force of the recovery of green in the Middle Hills. Table 6 presents the changes in human impacts on the measured plots between our first and second inventories. These indices were made from the subjective evaluations by the several enumerators and we did not complete this evaluation on all the 3,839 plots in the first inventory. Nonetheless, from Table 6, we can infer major changes in forest use over the two decades. Forest fire instances in forest areas significantly decreased over the two decades: "fire almost every year" became a mere 1.1 per cent of the sampled plots in the second inventory from 9.3 per cent in the first inventory. This can be due to effective patrolling of forest areas by the CFUGs, but also can be due to the disappearance of slash-and-burn cultivation in the forest areas.

Table 6: Intensities of Human Activities on the Plots

	First Inventory	Second Inventory
Fire Intensity		
Number of Plots Evaluated	2448	3764
Not in the last 5 years	56.6%	67.8%
Occasional	34.1%	31.1%
Every year	9.3%	1.1%
Grazing Intensity		
Number of Plots Evaluated	2449	3764
Low	37.6%	50.6%
Moderate	44.0%	42.3%
High	18.3%	7.1%
Lopping Intensity		
Number of Plots Evaluated	2447	3764
Low	55.0%	43.1%
Moderate	39.4%	48.9%
High	5.6%	8.0%
Leaflitter Collection Intensity		
Number of Plots Evaluated	2446	3764
Low	58.7%	16.2%
Moderate	33.6%	59.0%
High	7.6%	24.8%

Grazing in the forest areas significantly decreased as well. The ratio of intensively grazed plots decreased to 7.1 per cent in the second inventory from 18.3 per cent in the first inventory. The plots with little grazing activities increased from 37.6 per cent to 50.6 per cent in the same period. Again, this can be due to a strict implementation of community-forestry regulations, but also can be simply due to the smaller number of domestic animals at the time of the second inventory.

Fewer fires and less grazing in the forests surely helped saplings and seedlings grow to trees. Contrary to our expectation, however, Table 6 also shows that there were more lopping and leaf-litter collection activities at the time of second inventory compared to that of the first inventory. The ratio of the plots with intensive leaf-litter collection, for example, increased to 24.8 per cent in the second inventory from 7.6 per cent in the first inventory. We suspect that this increase indicated the forest-floor cleaning activities by the CFUGs, not leaf-litter collections by the farmers. We, however, have no information supporting this suspicion.

Stainton (1972, p.60) suggested that severe lopping of stands for fodder made pure *Shorea robusta* colonies in the Middle Hills. Initially, we inferred that the recovery in the richness of tree species as shown in Table 5 was mainly due to less lopping in the *Sal* (*Shorea robusta*) forests. Table 6, however, proved that our initial guess was too naïve.[11]

11 More intensive lopping observations in the second inventory might be partly due to the *de facto* border closure by India in 2015. Half of our sample forests were measured during or after this border closure. At that time, in addition to shortage in the supply, the price of LP gas, mainly imported from India, skyrocketed and many rural HHs who had LP gas facilities switched to firewood for household purpose.

Limitations

A possibly significant limitation to this study was that for some tree species, there were difficulties to identify the corresponding scientific names. An example, among many, is a tree identified as *Kali Kath* in the field. In the first inventory, we had identified this species as *Myrsine semiserrata*. Based on Manandhar (2002, p.446), in the second inventory, we changed our *Kali Kath* identification to *Symplocos pyrifolia*. Manandhar (2002, p.446), however, also shows that the corresponding local names of *Symplocos pyrifolia* are not only *Kali Kath* but also *Kholme*, *Seti Kath*, etc.

Note that the alpha diversity in Table 5 is largely free from this identification problem of scientific names. The alpha diversity was calculated based on local tree names. Without knowing the scientific names, the local guides hired in the fields had little difficulties to distinguish different tree species and gave their local names to the enumerators.

CONCLUSION

Repeated forest-resource inventories in an area provide indispensable information to evaluate the stand growth and changes in tree-species composition. This paper presented a summary of such longitudinal forest inventory data in the Middle Hills of Nepal over the two decades. We found that both the number of trees ha^{-1} and tree-species richness improved from the period of 1997-1999 to that of 2014-2016. An important future work will be to decompose the causes of these improvements into community management, depopulation, and access to roads.

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