Decentralization for cost-effective conservation

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Since 1930, areas of state-managed forest in the central Himalayas of India have increasingly been devolved to management by local communities. This article studies the long-run effects of the devolution on the cost of forest management and on forest conservation. Village council-management costs an order of magnitude less per unit area and does no worse, and possibly better, at conservation than state management. Geographic proximity and historical and ecological information are used to separate the effects of management from those of possible confounding factors.

community management | degradation | forests | impact evaluation

SUSTAINABILITY SCIENCE

Conserving wild areas in developing countries is generally less costly and has higher benefits in terms of biological diversity than doing the same in developed countries (1). However, national governments in developing countries may not find forest conservation economically justifiable, even though it may be so at local and global scales (2). Transfers from developed to developing countries for forest conservation may give rise to perverse incentives and are not easy to negotiate, monitor, and implement (3, 4). In this context, cost-effective conservation of tropical forests assumes importance.

Tropical forests were largely nationalized during and after the colonial era, but over the past 2 decades, many governments, partly motivated by budgetary concerns, have been experimenting with decentralized management (5–8). Case studies suggest that community management of natural resources can be effective for sustainable use (8–10). However, because decentralization is often accompanied by political, economic, and ecological changes, its impact on forest conservation is hard to disentangle from that of confounding factors. A recent review of studies of the impact of decentralized management concluded that none of them identified the impact of decentralization on forest degradation (5).

This article measures the effect of devolution of control of forests to village councils in the Indian central Himalayas on forest conservation and its cost. Forests in the region were nationalized early in the twentieth century. In 1930, approximately a decade after nationalization, and in response to widespread unrest, villages were permitted to carve out council-managed forests both from common lands not nationalized and from nationalized forests. The area under village council management has gradually expanded since then to cover approximately one-third of the forest area in the hill region of what is now the state of Uttarakhand.

We use government data to find the cost per hectare of managing state forests and our survey data to find the cost per hectare of council forest management. We find that state forests cost at least 7 times as much per hectare to administer as do council-managed forests. Second, we compare the extent of degradation in state forests with that in council forests and find that the difference is small and not statistically significant. These findings are the basis for our conclusion that council management is more cost-effective than state management.

Previous studies of the impact of decentralization on forest degradation or deforestation have been criticized for not adequately controlling for potentially confounding factors. In order for our comparison of degradation in state and council-managed forests to be valid, we need to show either that the state and council forests being compared were identical in other respects or that state forests were more naturally suited to dense forest than council forests. We provide evidence in support of the latter statement, thus strengthening the conclusion that council management leads to forest preservation that is at least as great as that produced by state management.

Comparing Costs

Table 1 shows data on management costs of village forest councils and the state forest department in the state of Uttarakhand. Figures for state forests include only expenditure on forests directly administered by the state. Expenditures on research, soil conservation, programs supporting agriculture, etc., are excluded from state forest expenditures in Table 1. The cost of administration in state forests is >7 times as much as in council forests, reflecting the absence of bureaucracy in the councils and their greater flexibility in hiring watchmen. When other costs (of 130 Rs/ha on building and construction, plantation, forest protection, etc.) are included, state forest expenditures are >9 times greater than council forest expenditures. State expenditures on resin extraction are also excluded from these figures, because they bring in revenue. It is likely that councils would also be more cost-effective at resin extraction than the state, but we cannot measure this because we do not have data on council revenues. The savings from council control of state forests would equal ≈70% of the value of the annual firewood output from state forests (see *Methods* below).

Selection of Lands for Inclusion in State Forests

Having established that state administration is far more costly than village council administration, we compare their effectiveness in preventing forest degradation from woodcutting, fires, grazing, and other anthropogenic pressures. We first present evidence that when state forest lands were demarcated early in the 20th century, they were selected to have more tree cover, and then we show that despite this, they are no less degraded than village council-administered forests. Our data come from analysis of a satellite image that covers most of central and eastern Uttarakhand, the area where village council forests are found.

Data were collected on 271 villages and adjoining forests from 10 different areas covered by the Indian remote sensing (IRS) satellite image we used. State and council forest compartments (the smallest units of management with a mean area of 91 ha) were digitized as polygons in a geographic information system. Paired strip polygons with a mean area of 2 ha, 50 m wide and

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Table 1. Expenditure in rupees per hectare on forest administration in 2002–2003

Council forests	Cost	State forests	Cost
Watchmen's wages including imputed cost of time	46.75 (10.20)	General administration including wages	398
Other expenditure	2.06 (0.58)	Other expenditure	130
Government expenditure on council inspectors	6.66		
Total	55.47		528

Sources: Data on expenditure on state forests by forest division and areas of forest divisions, as well as data on government expenditure on councils and the area under council forests in Kumaun were provided by the Government of Uttarakhand and pertain to the Garhwal, Almora, Bageshwar, Pithoragarh, Champawat, and Nainital forest divisions. The data on expenditure per unit area by councils are means from our survey with standard errors in parentheses.

75 m on either side of a state-council forest boundary, were created so as to compare state and council forests as like to each other as possible. See Fig. S1.

Our measure of forest conservation is percentage of crown cover obtained from interpretation of an IRS-1D LISS-3 image from May 31, 1998, covering an area of ≈20,000 square kilometers. Crown cover in these forests is highly correlated with other measures of the forest stock such as bole biomass, total above-ground biomass, and basal cover (11, 12). The broad-leaved and pine areas of each polygon are the final units of observation. Our measure of crown cover is highly accurate when averaged over areas the size of the polygons in the data (see *Methods* below). Other variables were the aspect [varying from 0 (south-facing), to 1 (north-facing)], population density in persons per hectare, round-trip time from the nearest road in hours, and nearby forest stock defined as the area covered by tree crowns within a radius of 2-h round-trip time. Additional details on the data are given in *Methods* below. See also summary statistics in Table S1.

The forest settlement reports (13, 14) written by government officials who demarcated state forests between 1915 and 1920 indicate that lands with more tree cover were preferentially selected for inclusion in state forests. Quotations to this effect from the forest settlement reports are presented in *SI Text*. This historical evidence is supported by the following feature in the cross-border subsample of the survey data. The first 2 rows in Table 2 show that state forests are considerably more north-facing (have higher values of the aspect variable). As seen in Table S2, aspect has a strong and statistically significant ($P < 0.01$) effect on crown cover, suggesting that north-facing slopes were preferentially included in state forests for this reason. Two alternative explanations for the state forests being more north-facing can be ruled out as follows. First, broad-leaved forests are more north-facing and may have been preferred by the settlement officers. In fact, the settlement officers preferred pine (13–15). Second, villages may be largely on south-facing slopes, inducing settlement officers to draw boundaries to leave state forests on the other side of ridges or streams. This, too, is not the case because village common lands in the sample, located close to and in villages, prove to have a value of aspect not significantly ($P > 0.32$) <0.5 (Table S1). We conclude that the boundaries between state and council forests were drawn in a way that the state side of the boundaries started with denser forests.

Table 2. Cross-border sample: summary statistics

Parameter	Mean	SD	Difference (Council − State) Mean	Difference (Council − State) SD	No. of pairs
Aspect (BL)	0.53	0.26	−0.15***	0.02	242
Aspect (pine)	0.47	0.27	−0.10***	0.03	91
Nearby forest stock	4.19	2.32	−0.20***	0.07	276
Population density	0.91	0.95	0.04***	0.01	276
Time to road	2.49	2.52	−0.07***	0.02	276

*** denotes significance at the 1% level.

Crown Cover Compared Along the Boundaries

The small distance between polygons in each pair of the cross-border data ensures that observed variables other than aspect do not differ very much between the polygons in a pair as can be seen from Table 2. Although the differences in nearby forest stock, population density, and round-trip time to the nearest road between council and state polygons in each pair are systematic and statistically significant, they are small. As expected, state forests have larger nearby forest stocks, lower population densities, and are further from roads because of their greater distance from villages. In these and all subsequent comparisons of council and state forests, only forests under council control for at least 15 years in 1998 were used. Because crown cover is a slowly changing variable, younger council forests might not fully reflect the effects of council control.

Table 3 presents our comparison of crown cover in council and state forests from the cross-border data. The estimated regressions (one each for broad-leaved and pine forests) are

$$dy_i = \alpha_0 + \alpha_1.dX_i + d\varepsilon_i, \qquad [1]$$

where dy_i is the difference in percentage crown cover between council and state forest polygons in pair i, α_0, the parameter of principal interest, is the expected difference in crown cover conditional on no difference in other variables, and α_1 is the vector of common coefficients on the control variables in state and council forests.

The coefficients on the constant term are the ones of interest. It is seen from column 1 of Table 3 that in broad-leaved forests, council control does not have a significantly different effect on forest density than state control ($P > 0.67$). In column 2, we exclude the variables that are not statistically significant in this regression, and the difference now turns negative, although it remains small and not significant ($P > 0.77$). Given the small but systematic differences in the variables we have dropped that favor higher density in state forests, this is exactly as we would expect. In pine forests, the results are very similar, with the difference between crown cover in council and state forests being small and not statistically significant ($P > 0.51$ for the regression of column 3 and $P > 0.16$ for column 4). These regressions produce similar results if we distinguish between neighboring forest stocks in state, council, and unmanaged village forests, and so we do not report those separately. Finally, we also examined the difference in the percentage of the area under forest or scrub and find it to be −0.4% points, small and not significant ($P > 0.81$).

We conclude that state forests do not have greater forest density than comparable council forests, at least along the boundaries. However, it is possible that council forests are denser than comparable state forests because of the selection bias discussed above. Although we controlled for the large difference in aspect in our regressions, we cannot control for

Table 3. Estimated regression coefficients from Eq. 1 of differences in percent crown cover between council and state forests

	Dependent variable			
Parameter	Crown cover (broad-leaved), %	Crown cover (broad-leaved), %	Crown cover (pine), %	Crown cover (pine), %
Constant (α_0)	1.2 ($P = 0.677$)	−0.7 ($P = 0.772$)	−2.4 ($P = 0.514$)	−4.0 ($P = 0.161$)
Aspect	32.2 ($P = 0.000$)	30.5 ($P = 0.000$)	12.2 ($P = 0.170$)	12.9 ($P = 0.147$)
Population density	−25.2 ($P = 0.335$)		−112.5 ($P = 0.188$)	
Population density squared	0.71 ($P = 0.805$)		16.5 ($P = 0.116$)	
Time to road	10.3 ($P = 0.107$)		5.7 ($P = 0.631$)	
Nearby forest stock	−0.24 ($P = 0.775$)		−1.7 ($P = 0.424$)	
No. of pairs	242	242	91	91
No. of councils	68	68	44	44

Two-tailed *P* values, in parentheses, were computed by using Huber–White robust standard errors clustered by council forest.

other factors like soil characteristics that may vary at small spatial scales and could have similar effects.

Crown Cover Compared in the Entire Sample by Multiple Regression

Although the cross-border sample offers clear evidence that conservation has been at least as effective in council as in state forests, we need to check that this is true away from the boundaries as well. There could be spatial substitution in forest exploitation so that council forests would be more degraded if there were no state forests near them. We used multiple regression on the whole sample to test for the presence of such spatial substitution. In Table 4, we report coefficients from regressions of broad-leaved and pine crown cover on a dummy variable for council forests, nearby council and state forest stocks, and the interaction of the council forest dummy with the nearby stock variables and with a number of control variables.

Crown cover, as predicted by these regressions at the means of the explanatory variables, is not statistically significantly different between council and state forests ($P > 0.25$ and 0.54 in broad-leaved and pine forests, respectively). This remains true when we do not allow the explanatory variables to have different effects on crown cover in council and state forests (Table S3). The whole sample thus reproduces this result from the cross-border sample.

Note the lack of statistical significance ($P > 0.75$ in pine forests), and in broad-leaved forests, also the negative sign, of the coefficient on D^* (Nearby SF Stock). This means that in council forests, raising the level of nearby state forest stocks does not raise crown cover. Similarly the insignificance of the coefficients on Nearby CF Stock indicates that crown cover in state forests does not fall if their proximity to council forests increases. Table S2 presents regressions with a somewhat different set of control variables that give qualitatively the same results. Thus, it is seen that the finding from the cross-border data that council forests have crown cover no lower than in state forests does not depend on the proximity of the boundary. The proposition that council forests have higher forest density at the expense of nearby state forests finds no support in the data.

Crown Cover Compared in the Entire Sample by Propensity Score Matching

As a further check for the robustness of our results, we match state forest ("treatment group") polygons from the entire dataset with council forest ("control group") polygons with similar propensity scores and then test for a difference in crown cover. The propensity score for a polygon is the probability that it is in the treatment group (in our case, a state forest) conditional on the values of the explanatory variables. Calculating the propensity score reduces the dimensionality of the matching problem by eliminating the need to find matches in every relevant characteristic. If there is no selection bias conditional on the n-dimensional vector of explanatory variables, then there is no selection bias conditional on the 1-dimensional propensity score (16).

The average differences in crown cover are reported in Table 5. The first row reports the mean difference by matching each state forest polygon with the council forest polygon that has the nearest propensity score. Those state forest polygons with a propensity score higher than that of any council forest polygon are excluded so as to avoid comparisons between polygons with propensity scores that are far apart. The third row also excludes

Table 4. Regression coefficients of crown cover in state and council forests, entire sample

Parameter	Broad-leaved crown cover	Pine crown cover
Nearby CF stock	−0.91 ($P = 0.645$)	−0.47 ($P = 0.840$)
$D \times$ nearby CF stock	2.90 ($P = 0.162$)	−0.70 ($P = 0.814$)
Nearby SF stock	2.53 ($P = 0.000$)	−0.56 ($P = 0.605$)
$D \times$ nearby SF stock	−2.18 ($P = 0.164$)	0.68 ($P = 0.752$)
Observations	582	504
Clusters	495	444
R^2	0.50	0.36
Difference in predicted crown cover (Council − State) at state means	−4.35 ($P = 0.255$)	3.00 ($P = 0.548$)

Shown are some of the coefficient estimates from 2-stage least-squares regressions of crown cover on aspect, the first 3 powers of population density, the round-trip time to road and its square, nearby council, state, and unmanaged village forest stocks, their interactions with *D*, a dummy variable for council forests, and dummies for each of the 10 sample areas. CF, council forest; SF, state forest. Two-tailed *P* values in parentheses were computed by using robust (Huber–White) standard errors clustered by council forest. Nearby forest stocks and their interactions with the council dummy (*D*) are instrumented by nearby areas, with first-stage regressions having $R^2 > 0.9$.

Table 5. Mean difference in percentage of crown cover between council and state forests matched by propensity score (entire sample)

Matching method	Broad-leaved	Pine
Nearest neighbor	1.8 (3.0) 75%	14.6 (4.7) 75%
Radius = 0.01	0.5 (2.7) 79%	12.0 (4.0) 74%
Kernel	1.1 (2.2) 75%	9.2 (3.5) 75%
Treated observations	355	318
All observations	582	504

Percentages refer to the percentage of treated observations (state forest polygons) used in the calculation of the mean difference. Figures in parentheses are standard errors estimated from 1,000 bootstrap replications. In broad-leaved forests, the variables used in the estimation of the propensity score functions were the first 3 powers of population density, the neighboring forest stock, broad-leaved aspect, and time to the nearest road. In pine forests, the square of the time to the nearest road was used in addition. The number of treated observations and the percentage of treated observations refer only to the point estimates because the propensity score function is reestimated in each bootstrap sample, and, accordingly, the region of common support changes.

such polygons and matches each state forest polygon with a weighted average of council forest polygons by using the Epanichnikov kernel with a bandwidth of 0.6. The second row matches state forest polygons with an average of council forest polygons with propensity scores within 0.01 of their propensity scores.

Table 5 indicates that council and state forests have virtually the same broad-leaved crown cover because the differences are small and not statistically significant. In fact, the estimates using propensity scores are remarkably close to the point estimate from Table 3, which used the cross-border data controlling for differences in the relevant variables. In pine forests, on the other hand, council forests are seen to have higher crown cover, and the differences are large and statistically significant.

These results pertain only to the state forests that had close enough matches in terms of the propensity score to be used in the comparison. However, it may be remarked that >95% of those excluded have a population density <0.3 persons per hectare with a mean of <0.07 persons per hectare as compared with a mean of 0.67 for all state forests and of 1.41 for all council forests. Therefore, it appears quite unlikely that anthropogenic pressure would result in lower crown cover if these were transferred to council forests.

Results for the sample excluding the Gori valley were similar, except for pine forests. Here, instead of finding a positive and statistically significant effect of council management, we find a positive (4.4% points) but insignificant effect.

Discussion

We find that forests in the Indian central Himalayas have been conserved at least as well and possibly better under decentralized management and at much lower cost. State forests are on average further from villages than council forests, so if they were transferred to council control the costs of managing them may be somewhat higher (because watchmen have to travel further) or lower (because of less anthropogenic pressure) than the current costs of managing council forests. Given the size of the difference in the costs of state and council management, this is unlikely to affect our conclusion that substantial savings could be realized by decentralizing management. More generally, the findings suggest that decentralization deserves wider attention in conservation strategies in developing countries with limited financial resources.

Methods

Comparing the Additional Cost of State over Council Management with the Value of Firewood Production. Multiplying the difference between state and council forest expenditures per hectare by the total area of the State forests in the 4 districts in our data gives total annual savings in rupees. Mean per-capita annual expenditure on firewood (195 in 2002 rupees) in the 4 districts in our data was calculated from the 55th round of the National Sample Survey (done in 1999–2000) and inflated to 2002 rupees by using the Consumer Price Index for agricultural laborers. This is multiplied by the population of the 4 districts to get the total value of firewood consumption. This in turn is multiplied by the proportion of forest area under state forest to get an estimate of total annual firewood production from state forests. Dividing savings by this value gives 0.69, showing that savings would be ≈70% of the value of firewood production.

Data Collection. From the collection of 1:25,000 (≈12 × 14 km each) topographic maps of the Survey of India covering the satellite image we analyzed, a random sample of 9 maps containing villages were taken. These contained 102 villages in all. In addition, after fieldwork commenced, a nongovernment organization, the Foundation for Ecological Security, financed data collection under our supervision in another area covered by our satellite image, the Gori Ganga valley, which contains 169 villages. All results reported in the article that use only the original sample that excludes the Gori Ganga valley are substantially the same.

Information collected on the ground during the course of 2 years of fieldwork from 1997 to 1999 was used as an input to classify each 23.5 × 23.5-m pixel from the IRS-1D LISS-3 image (scene 98/50, 29° to 30.5° N and 79° to 80.75° E, May 31, 1998) into one of the following classes: broad-leaved forest (including scrub), pine forest, and other categories (mainly grasslands and agriculture).

Crown cover was visually measured in a random sample of plots by using a grid placed over an April 24, 2000, 1-m resolution Ikonos satellite image and regression used to predict crown cover for the whole IRS image. Band ratios and the normalized difference vegetation index (NDVI) were computed for each IRS pixel. Regressions of these measures on a logistic transform of crown cover and simulations with split samples revealed that the NDVI and the ratio of bands 2–5 were the best predictors of crown cover in broad-leaved and pine forests, respectively. Accordingly, these were used to predict crown cover for each pixel. Broad-leaved crown cover for each polygon was then defined as the mean over the broad-leaved pixels of the polygon, with an analogous definition for pine crown cover.

Crown cover measurements were obtained for 199 and 183 broad-leaved and pine pixels, respectively. These were randomly split into training (used in the regressions) and assessment (excluded from the regressions) samples with the assessment samples containing 25 pixels, a procedure replicated 1,000 times. The mean error in predicted crown cover for 25 pixels is 0.0% with a standard deviation of 5.7% for broad-leaved forests, whereas in pine forests, the mean error is 3.2% with a standard deviation of 4.8%. Over 90% of the small strip polygons used in the state and council forest cross-border comparisons contain at least 25 pixels of the relevant forest type (broad-leaved or pine). For the much larger polygons that correspond to compartments of the 3 property regimes and contain hundreds of pixels, the prediction errors would be still smaller.

Satellite Images and Other Digital Data Were Overlaid with a Root Mean-Square Error of 1 Pixel (23.5 m). The control variables include aspect, population density, round-trip time to the nearest road, and nearby forest stocks. Aspect is the direction in which a slope faces. North-facing slopes receive less sunlight and so more soil moisture, influencing the vegetation. This results in denser forest. We used elevation data from the topographic maps to create a continuous aspect variable ranging from 0 for south-facing pixels to 1 for north-facing pixels with east-facing and west-facing pixels having values of 0.5. Means over the broad-leaved pixels in a polygon defines aspect for the broad-leaved regressions with a similar definition for pine regressions.

A population-density surface was constructed as a sum of cones centered on habitations, with radii of 4-h round-trip time, and volumes equal to the populations of the habitations. The population of each village was obtained from the latest available (1991) Census of India and distributed over the habitations in each village in proportion to their prominence on the Survey of India maps. The units for population density are persons per hectare. Again, means over polygons were extracted for use in the analysis. The population density of a polygon is thus a measure of its accessibility to local residents.

A round-trip time variable was constructed by converting kilometers to round-trip time in hours (1-h round-trip = 0.845 km) by using a regression coefficient from a survey that we conducted in one of the valleys in the data. This was used to calculate round-trip times of each pixel from the nearest road by using the locations of roads obtained from the topographic maps and updated from the Public Works Department's maps. Means over polygons were extracted for use in the analysis.

For each polygon, nearby state, council, and unmanaged village forest stocks in square kilometers were constructed by summing percentage crown cover multiplied by area for all polygons with centroids within a 2-h round-trip time of the centroid of the given polygon.

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