Assessing forest change in human impacted forests

Harini Nagendra[1,2] and Elinor Ostrom[3]

[1]Center for the Study of Institutions, Population, and Environmental Change (CIPEC), Indiana University, 408 N. Indiana Avenue, Bloomington Indiana, USA

[2]Ashoka Trust for Research in Ecology and the Environment, Royal Enclave, Srirampura, Jakkur P.O., Bangalore 560064, India

[3] Workshop in Political Theory and Policy Analysis, Indiana University, Bloomington, IN 47408, USA

ABSTRACT

Ecologists and practitioners have conventionally used forest plots or transects for monitoring changes in attributes of forest condition over time. Yet, given the difficulty in collecting such data, conservation practitioners frequently rely on the judgment of foresters and forest users for evaluating changes. These methods are rarely compared. We use a dataset of 53 forests in five countries to compare assessments of forest change from forest plots, and forester and user evaluations of changes in forest density. We find that user assessments of changes in tree density are strongly and significantly related to assessments of change derived from statistical analyses of randomly distributed forest plots. User assessments of change in density at the shrub/sapling level are also related to assessments derived from statistical evaluations of vegetation plots, but this relationship is not as strong, and only weakly significant. Evaluations of change by professional foresters are much more difficult to arrive at, as foresters are not familiar with changes in a number of local areas, and can instead better provide valid single-time comparisons a forest with other areas in a similar ecological zone. We conclude that in forests where local users are present, and capable of accessing the entire forest without restrictions on movement, they can provide reliable assessments of changes in tree density. Forest users are less able to accurately identify spatially variable changes in density at the shrub/sapling layer, and assessments of human disturbance and regeneration at this level may require supplementation by vegetation analysis.

KEYWORDS

Forest monitoring, forest change, biodiversity, peopled forests, community forests

INTRODUCTION

Forests are of immense value to humankind, acting as carbon sinks, protecting biodiversity, providing essential ecosystem services, and enhancing the livelihoods of millions of people. Yet, the same forests that are of such immeasurable value to us are fast shrinking, degrading and transforming. In order to better manage forest change, it is critical to have methods that can provide reliable, inexpensive, and rapid assessments of the manner in which forest condition is changing over time. Unfortunately, despite extensive acknowledgment of the criticality of such information for better management and conservation, there remains a substantial lack of rapid assessment methods that can be used to collect reliable data across a number of forested locations for the purpose of monitoring (Walpole et al. 2009, DeFries et al. 2010). Consequently, despite widespread awareness of the criticality of the issue, the available data on forest change is patchy, and not always consistent or reliable.

Remote sensing has proved to be very useful for global studies of forest-cover change, but forest degradation and regrowth processes often occur at levels undetectable by Earth observation alone (Nagendra and Rocchini 2008, DeFries et al. 2010). Further, remotely sensed data require substantial ground truthing for monitoring applications (Ostrom and Nagendra 2006, Tang et al. 2010). Thus, this approach is best suited for assessing changes in forest cover at broad scales from landscapes to larger bioregions, and less suited for the assessment of fine-scale changes in forest condition at specific locations.

Many conventional approaches to forest monitoring use protocols such as quadrants and transects to assess changes in forest biodiversity, density, biomass, and regeneration (Stohlgren 2007). These tools have been widely used for decades in forests around the world and are generally accepted as reliable approaches for evaluating performance, not only of protected areas but also of other forms of governance in diverse social-ecological settings. Yet, monitoring forest change through field plots alone is expensive, time consuming, and difficult to conduct across large spatial scales.

Consequently, several prominent studies evaluating the effectiveness of forest management approaches have relied on qualitative judgments by park officials (Bruner et al. 2001, Ervin 2003). The continued use of these informal and rapid assessments can be seen from a recent article examining the management of over 1,000 protected areas in Australia, which found that conservation practitioners overwhelmingly tend not to use “evidence-based knowledge” in making judgments. Instead, they rely almost entirely on knowledge acquired from their own prior experience (Cook et al. 2010). Such experiential assessments have not been verified through comparison with evaluations derived from conventional ecological forest monitoring protocols, and their widespread use has been categorized by these authors as “worrying” (Cook et al. 2010).

Forest users and volunteers have also been suggested by a number of recent studies to be able to provide rapid inputs for forest and biodiversity monitoring (Chhatre and Agrawal 2008, Holck 2008, Jones et al. 2008, Danielsen et al. 2009, Schmeller et al. 2009). These studies indicate that user evaluations can be timely, cost effective, and provide reliable data. Yet, they run counter to beliefs widely held by many conservation practitioners and scientists who think that user and volunteer evaluations are biased, noisy, and unreliable. Unfortunately, as with assessments by practitioners and trained professionals, these arguments cannot be resolved by data, as the wider problem remains that forest assessments by local users have not been systematically compared with those derived from conventional, scientific protocols. Such comparisons are necessary if these monitoring mechanisms are to be used more widely as supplements to expensive, time-consuming, and restricted field studies (Jones et al. 2008, Danielsen et al. 2009, Schmeller et al. 2009).

In this paper, we address this issue by using data collected by the International Forestry Resources and Institutions (IFRI) Research Program, a long-term multi-country effort to collect data on forests and users using standardized interdisciplinary data collection protocols across multiple continents (Ostrom and Nagendra 2006, Tucker et al. 2008). From the start of this research program, we have used three methods for evaluating forest change: forest plots, assessments by professional foresters, and assessments by forest users. This dataset thus provides a unique opportunity to compare assessments of forest condition derived from conventional ecological assessments using field plots with assessments of change made by professional foresters and local forest users.

METHODS

For this study, we include 53 forests that have been studied over at least two points in time using the IFRI research protocols. The International Forestry Resources and Institutions Research Program was initiated in 1992, when our research team at Indiana University was asked by the Food and Agricultural Organization of the United Nations to develop a multicountry effort to evaluate how diverse institutions affect forest conditions and forest sustainability. We designed a set of data collection instruments that would enable us to obtain multiple measures of forest conditions (Wollenberg et al. 2007). These instruments were applied in diverse forests located in a range of ecosystems and countries by a network of collaborating centers located in multiple countries around the world (Gibson et al. 2000). At the current time, collaborating research centers exist in Bolivia, Colombia, Guatemala, India, Kenya, Mexico, Nepal, Tanzania, Thailand, Uganda, and the United States. The IFRI program is currently coordinated by Arun Agrawal at the University of Michigan (more details about IFRI are available at www.sitemaker.umich.edu/ifri/).

Our comparative assessment of forest change focused on a subset of IFRI forests for which data were available from at least two visits at different points. We selected five countries—India, Nepal, Kenya, Uganda, and the USA—where a large number of forest revisits were conducted. When forests had data from more than two visits, we selected the most recent visits for which complete information was available. A total of 53 forests were selected for analysis—7 forests in India, 18 in Nepal, 5 in Kenya, 19 in Uganda, and 4 in the USA. Forests were sampled from a diversity of management regimes including government-owned, strictly protected areas, forests managed and used by communities, and private forests managed by small groups such as families or church groups.

From the start of this research program, we used three different methods for evaluating forest change, based on forest plots and assessments by professional foresters and forest users. First, we used randomly located forest plots to obtain rigorous information on the number of trees, saplings, and shrubs, tree size, number of species, etc. At each time point, forest condition was assessed using randomly distributed 10-m circular plots, within which plant species' identity, height, and girth were recorded for all trees greater than 10-cm diameter at breast height (DBH). Within this, a 3-m circular plot was used to collect information on saplings and shrubs below 10-cm DBH. Between 20 and 60 random plots were located in each forest, depending on the size of the forest patch being studied and the biodiversity and variation in the patch. Forest plot data for our study were evaluated for changes in tree and sapling/shrub density. A nonparametric one-tailed Mann-Whitney U test ($p < 0.10$) was used to categorize forests into those with a significant decrease or increase in tree density, or sapling/shrub density, and those where no significant change was observed over time.

Since it is problematic to compare forest condition across different ecological zones using measures of forest condition collected from plots sampled at one point in time (Tucker et al. 2008), our research team adopted two additional approaches for assessing forest condition and change. We asked the opinion of local forest users about changes in tree and shrub density over time. During each IFRI study, forest users were asked whether the densities of trees and the bushy shrub/sapling layer had changed in the previous five years. Answers were recorded on a three-point scale, which indicated whether, in the opinion of the majority of forest users interviewed, the forest had stayed the same, improved, or deteriorated. Information from the recent visit to a forest was used to categorize forests as having deteriorated, improved, or experienced no perceptible change in tree density and shrub/sapling density. We then compared ratings by users based on changes in tree and shrub/sapling density, with evaluations of change based on an analysis of changes in tree and sapling/shrub density from the forest plots, using a Spearman rank correlation.

We were also interested in assessments of forest condition provided by professional foresters, who accompanied each IFRI interdisciplinary research team to supervise collection of forest plot data. The forester who accompanied each team was not necessarily the same forester who had accompanied the team on a previous visit. Thus, this person was not always familiar with the condition of the forest in a previous time period, and could not be asked to directly judge changes in forest condition over time. Therefore, we asked the forester to compare the forest being studied to other forests in the same ecological zone and assess if it was comparable, worse, or better in terms of vegetation density and species richness. This evaluation was done after the team had finished collection of ecological data from forest plot sampling, so that an informed assessment could be made. During forest sampling, professional foresters were asked, "In your best judgment, given the topography and ecological zone in which this forest is located, how would you judge the following attributes of this forest?" Answers with respect to vegetation density were recorded using a five-point scale at each time point, ranging from "very sparse" to "very abundant." We looked for changes in this evaluation across both time periods to characterize forests as having deteriorated, improved, or experiencing no perceptible change in vegetation density over time. While this is not directly comparable with a users' evaluation, this can be compared to the forest plot analysis, where information collected from forest plots at different points in time is similarly compared to provide an evaluation of forest change. This is a challenge faced in other forest contexts, where users are familiar with their local forests and can readily provide evaluations of change, but where it is difficult to find professional foresters with detailed knowledge of specific locations, and who can reliably assess changes in forest condition for a diversity of forests over time. Thus, we compared forester and user evaluations of change in vegetation density, with plot based evaluations of change in tree density over time, using a Spearman rank correlation. We did not conduct direct comparisons of forester and user evaluations, as these were derived using different approaches (necessitated by differences in the familiarity of users and foresters with specific forest locations).

RESULTS

Tree plot data analysis indicates that a large number of forests – 41% - show no significant change in tree density over time, while roughly equal proportions of forests show an increase (32%) and a decrease (27%) in tree density (Figure 1). User assessments provide a more positive picture of changes in tree density, indicating that 51% of forests exhibit an increase, and just 36% exhibit a decrease in tree density between time periods. Forester assessments provide an even more neutral picture of change, indicating that 46% of forests do not show a significant change in tree density, while an almost equal proportion of the dataset records an increase (25%) and a decrease (26%) in vegetation density.

Users indicate a similarly neutral picture of changes at the shrub/sapling level, with just 12% of all forests recording no observed change in density, while equal proportions record an increase and decrease in shrub/sapling density. Plot data however provides a very different story, indicating that a scarce 11% of all forests show a significant increase in density at this strata, compared to 42% of the forests that record a significant decrease (Figure 1).

Pairwise comparisons of the data enable us to further assess the relationship between assessments provided by different methods. There is a strong positive relationship between plot-based assessments and user assessments of changes in tree density. A Spearman rank order correlation between the two variables was strong, with a Spearman r of 0.48, and highly significant, with $p<0.0005$. The assessments were identical for just over half (51%) of the forests (Figure 2). Twenty-three percent (23%) of all forests record an increase in both assessments; 17% do not record a significant change; and 9% record a decrease in both assessments. We categorize disagreements into two types: strong disagreements, where one assessment indicates an increase while the other indicates a decrease, and weak disagreements, where one assessment indicates an increase and the other indicates no perceived or significant change. When looking at the discrepancies between assessments, strong disagreements account for only 10% of the overall forests, while weak disagreements account for the remainder (39%).

Plot-based assessments of change in tree density are not well related to forester assessments of change in vegetation density, however, with agreement taking place in only 34% of the forests (Figure 3). A Spearman rank correlation between the two variables was weak, with a Spearman r of 0.14, and not statistically significant, with $p>0.32$. While these two assessments disagree in two out of every three forests (66%), as indicated by the off-diagonal columns in Figure 3, weak disagreements account for over half of the forests surveyed (56%), with strong disagreement observed in 10% of the cases.

Plot-based assessments of change in sapling/shrub density show a weaker relationship with user assessments at this level, with a Spearman r of 0.26, which is weakly significant at $p<0.1$. These two assessments provide similar responses for 32% of the forests, and conflict strongly in 15% of the forests, while weak disagreements account for over half of the forests surveyed (53%).

DISCUSSION

While plot-based indicators provide widely accepted, time-tested, reliable, and useful assessments of forest change, such data are expensive, time consuming, and difficult to collect for large spatial scales. Thus, in practice, many forest managers appear to rely on a combination of assessments from foresters and users (Bruner et al. 2001, Danielsen et al. 2009, Cook et al. 2010). Therefore, it is important to understand the extent to which these assessments provide similar or contrasting perspectives of forest change. Across 53 forests located in five countries, our results indicate that assessments of change in tree density made by forest users are significantly and strongly related to assessments made based on statistical analysis of forest plot data. Assessments of change in density at the shrub/sapling level appear more difficult for users to gauge accurately, and user assessments paint a fairly neutral picture of overall forest change. In contrast, statistical analysis of forest plot data reveals a more alarming picture of decrease in density at the shrub/sapling level. Nevertheless, these assessments do appear to be somewhat related, albeit at a lower level of significance and strength.

It appears to be far more difficult to use professional foresters to provide reliable assessments of forest change, possibly because of the difficulty in obtaining direct information on change from foresters familiar with different forested locations. Since forest users are expected to be familiar with the forest on which they depend, they could be directly asked for their opinion of how the forest had changed in density during the previous five years. Professional foresters on the IFRI research teams could not be asked similar questions, as it would be difficult to find a professional forester with intimate knowledge of each local forest, and awareness of its change over time. Instead, we asked foresters to compare the condition of a forest patch with similar patches in the same ecological zone, and looked for changes in these assessments over multiple visits. Most foresters on IFRI research teams are familiar with the general condition of forests in the larger region within which the study forests are embedded, and are able to provide reliable assessments for single points of time (Varughese and Ostrom 2001). However, these assessments may be less capable of use to perceive changes in forest condition.

Thus, we found a strong correspondence between plot and user assessments of change in tree density, and a weaker correspondence between plot and user assessments of change in sapling/shrub density. Human disturbance including fire, grazing, and charcoaling has a large impact on the sapling/shrub layer, which is especially responsive to such disturbances (Ostrom and Nagendra 2006). These disturbances on forests are not uniformly distributed, tending to be greater in areas with greater accessibility and lower in areas where there is greater monitoring and enforcement (Schweik 2000). Similarly, forest plantations and protected community-managed or sacred patches are also located in specific parts of the forest. The forest plots are randomly distributed and hence provide information from areas with variable levels of human impact. Our field observations however suggest that forest users tend to focus on change in areas that they visit most frequently, which they know are increasing or decreasing in density. This could explain the greater variation between plot-based and user-derived assessments of change at that level, with users documenting information from specific parts of the forest that are protected and planted, or degrading – while randomly distributed forest plots can provide a more comprehensive, statistically representative picture.

CONCLUSIONS

There is widespread agreement about the importance of maintaining forests for protecting biodiversity, sequestering carbon, and providing ecosystem services to the people of the world. Yet, considerable disagreement exists about how best to govern and manage forests, whether through large-scale, government-owned reserves, relatively small-scale community-owned and -managed forests, or a variety of other approaches. This debate is largely exacerbated by the lack of available, reliable data that measure changes in forest condition across multiple forests and facilitate data-based assessment of how changes in management impact forest condition and conservation. Detailed information on forest change is also essential for forest managers and local users who seek to protect their forests and manage them for sustainable use without impacting forest condition. Yet, monitoring forest change remains a critical challenge for the future (Cook et al. 2010, DeFries et al. 2010). Although quantitative evaluation of change using plots and transects constitutes the most widely accepted approach for monitoring forest condition and change (Stohlgren 2007), it is expensive, logistically challenging and time consuming, and therefore incapable of scaling up for applicability across multiple forests.

Consequently, many forest practitioners and managers have relied on their own qualitative observations of forest change to make management decisions (Bruner et al. 2001, Cook et al. 2010), while a growing number of recent studies seek to also incorporate evaluations by forest users (Chhatre and Agrawal 2008, Holck 2008, Danielsen et al*.* 2009). These evaluations, however, have been largely unverified against conventional ecological monitoring approaches.

Based on a study of 53 forests located in India, Nepal, Uganda, Kenya, and the USA, we find that evaluations of changes in tree density derived from forest plots are largely congruent with assessments made by forest users. There is a greater divergence between plot based assessments of changes in sapling/shrub density and assessments made by forest users. This may indicate the spatially variable nature of changes in density at the shrub/sapling level, due to the patchy nature of forest protection and human disturbance, which is better perceived by randomly distributed forest plots while users are likely to report change from the areas of the forest most visited by them (these are the areas likely to be either protected and actively managed, or the areas most disturbed due to human use and extraction). Even here, there is a weak level of agreement between these two assessments, and perhaps user assessments can be adopted to identify areas at greatest risk, where plot based assessments could then be made.

Naturally, we cannot become fixed on any one method of measuring forest conditions over time. Just as forests are managed in a variety of ways across the world, we will probably need to use a variety of approaches to assess changes in forest condition, depending on practical considerations of time, cost, and logistics, as well as what information is most important to the evaluator. Forest plots cannot be deployed in all forests due to constraints of time and money, challenges of logistics, and availability of human resources. Foresters' evaluations are useful for the quick assessment of forest condition in comparison to nearby forests in the same ecological habitat that have different management regimes, but it is difficult to use these to assess changes in forest density.

Evaluations by forest users of changes in tree density appear to provide reliable indicators of changes in forest density. This may be particularly useful in a world where more forests will be evaluated for their ability to store carbon, and quick assessments of changes in tree density need to be made at frequent intervals. Evaluations made by forest users of changes in shrub/sapling density are less reliable, but still provide an indicator – albeit a weaker one – of forest change. This will of course be related to the level of knowledge that forest users have about their local forests. If the users are self-organizing, their evaluation of how the forest is responding to their efforts and to external disturbances will be very well informed, perhaps as much so as information collected from forest plots. Indeed, participatory monitoring of forest change can lead to greater participation in other forest management activities, with increased collective action acting as a positive force for improved forest management, as has been observed in other instances including in fisheries in the Phillipines (Uychiaco et al.

2005), and of changes in species and resource use in protected areas in the Phillipines (Danielsen et al. 2005). If there are no local users of a forest, or users are restricted from accessing the forest – as is the case in many protected areas - then plots and other quantitative ecological approaches will be essential to accurately measure changes in resource quality and use.

ACKNOWLEDGEMENTS

The IFRI research program has received funding from the FAO of the United Nations, the Ford and MacArthur Foundations, and the US National Science Foundation. We thank Ashwini Chhatre, Arun Agrawal, and Burney Fischer for feedback on earlier versions of this manuscript; the Department of Science and Technology, Government of India, for financial support; Lionel Sujay Vailshery, Madhumitha Jaganmohan, and Suparsh Nagendran for assistance with data analysis; our IFRI colleagues around the world for their collaboration; and the numerous forest users and foresters who assisted us in our enquiries.

LITERATURE CITED

Bruner, A., R. E. Gullison, R. E. Rice and G.A.B. Fonseca. 2001. Effectiveness of parks in protecting tropical biodiversity. *Science* 291: 125–129

Chhatre, A., and A. Agrawal. 2008. Forest commons and local enforcement. *Proceedings of the National Academy of Science USA* 106: 13286–13291.

Cook, C.N., M. Hockings and R.W. Carter. 2010. Conservation in the dark? The information used to support management decisions. *Frontiers in Ecology and the Environment* 8: 181–186.

Danielsen, F., N.D. Burgess, and A. Balmford. 2005. Monitoring matters: examining the potential of locally-based approaches. *Biodiversity and Conservation* 14: 2507-2542.

Danielsen, F., N.D. Burgess, A. Balmford, P.F. Donald, M. Funder, J.P.G. Jones, P. Alviola, D.S. Balete, T. Blomley, J. Brashares, B. Child, M. Enghoff, J. Fjeldså, S. Holt, H. Hübertz, A.E. Jensen, P.M. Jensen, J. Massao, M.M. Mendoza, Y. Ngaga, M.K. Poulsen, R. Rueda, M. Sam, T. Skielboe, G. Stuart-Hill, E. Topp-Jørgensen and D. Yonten. 2009. Local participation in natural resource monitoring: a characterization of approaches. *Conservation Biology* 23: 31–42.

Danielsen, F., N. Burgess, M. Funder, T. Blomley, J. Brashares, A. Akida, A. Jensen, M. Mendoza, G. Stuart-Hill, M.K. Poulsen, H. Ramadhani, M.K. Sam and E. Topp-Jørgensen. 2010. Taking stock of nature in species-rich but economically poor areas: an emerging discipline of locally based monitoring. Pages 89-112 *in* A. Lawrence, editor. *Taking stock of nature: participatory biodiversity assessment for policy, planning and practice*. Cambridge University Press, Cambridge, UK.

DeFries, R., F. Rovero, P. Wright, J. Ahumada, S. Andelman, K. Brandon, J. Dempewolf, A. Hansen, J. Hewson and J. Liu. 2010. From plot to landscape scale: linking tropical biodiversity measurements across spatial scales. *Frontiers in Ecology and the Environment* 8: 153–160.

Ervin, J. 2003. Rapid assessment of protected area management effectiveness in four countries. *Bioscience* 53: 833–841.
Gibson, C., M. McKean and E. Ostrom, editors. 2000. *People and forests: Communities, institutions, and governance.* MIT Press, Cambridge MA, USA.
Holck, M.H. 2008. Participatory forest monitoring: an assessment of the accuracy of simple cost-effective methods. *Biodiversity and Conservation* 17: 2023-2036.
Jones, J.P.G., M. M. Andriamarovololona, N. Hockley, J.M. Gibbons and E.J. Milner-Gulland. 2008. Testing the use of interviews as a tool for monitoring trends in the harvesting of wild species. *Journal of Applied Ecology* 45: 1205–1212.
Ostrom, E., and H. Nagendra. 2006. Insights on linking forests, trees, and people from the air, on the ground, and in the laboratory. *Proceedings of the National Academy of Science USA* 103: 19224–19231.
Schmeller, D.S., P-Y. Henry, R. Julliard, B. Gruber, J. Clobert, F. Dziock, S. Lengyel, P. Nowicki, E. Déri, E. Budrys, T. Kull, K. Tali, B. Bauch, J. Settele, C. Van Swaay, A. Kobler, V. Babij, E. Papastergiadou and K. Henle. 2009. Advantages of volunteer-based biodiversity monitoring in Europe. *Conservation Biology* 23: 307–316.
Schweik, C.M. 2000. Optimal foraging, institutions, and forest change: a case from Nepal. *Environmental Monitoring and Assessment* 62: 231–260.
Stohlgren, T. 2007. Measuring plant diversity: lessons from the field. Oxford University Press, New York, USA.
Tang, L., G. Shao, Z. Piao, L. Dai, M.a. Jenkins, S. Wang, G. Wu, J. Wu and J. Zhao. 2010. Forest degradation deepens around and within protected areas in East Asia. *Biological Conservation* 143: 1295–1298.
Tucker, C.M., J.C. Randolph, T. Evans, K.P. Andersson, L. Persha and G.M. Green. 2008. An approach to assess relative degradation in dissimilar forests: toward a comparative assessment of institutional outcomes. *Ecol Soc* 31: art 4 [online]. URL: http://www.ecologyandsociety.org/vol13/iss1/art4.
Uychiaco, A.J., H.O. Arceo, S.J. Green, M. T. De La Cruz, P. A. Gaite, and P.M. Aliño. 2005. Monitoring and evaluation of reef protected areas by local fishers in the Phillipines: tightening the adaptive management cycle. *Biodiversity and Conservation* 14: 2775-2994.
Varughese, G., and E. Ostrom. 2001. The contested role of heterogeneity in collective action: some evidence from community forestry in Nepal. *World Development* 29: 747–765.
Walpole, M., R.E.A. Almond, C. Besancon, S.H.M. Butchart, D. Campbell-Lendrum, G.M. Carr, B. Collen, L. Collette, N.C. Davidson, E. Dulloo, A.M. Fazel, J.N. Galloway, M. Gill, T. Goverse, M. Hockings, D.J. Leaman, D.H.W. Morganm, C. Revenga, C.J. Rickwood, F. Schutyser, S. Simons, A.J. Stattersfield, T.D. Tyrell, J.-C. Vié and M. Zimsky. 2009. Tracking progress toward the 2010 biodiversity target and beyond. *Science* 325: 1503–1504.
Wollenberg, E., L. Merino, A. Agrawal and E. Ostrom. 2007. Fourteen years of monitoring community-managed forests: learning from IFRI's experience. *International Forestry Review* 9: 670–684.

Table 1

A brief description of the 53 forests studied, providing their location (country), time period between visits, and formal tenure system.

Country	Time between visits (years)	Formal tenure category
India	5	Government forest
India	5	Government forest
India	5	Government forest
India	5	Government forest
India	5	Government forest
India	5	Government forest
India	5	Government forest
Nepal	9	Community forest
Nepal	3	Community forest
Nepal	6	Community forest
Nepal	8	Community forest
Nepal	8	Protected area
Nepal	6	Community forest
Nepal	6	Government forest
Nepal	7	Community forest
Nepal	7	Community forest
Nepal	7	Community forest
Nepal	7	Community forest
Nepal	7	Community forest
Nepal	7	Community forest
Nepal	6	Community forest
Nepal	6	Government forest
Nepal	6	Community forest
Nepal	6	Community forest
Nepal	6	Community forest
Kenya	4	Protected area
Kenya	3	Government forest
Kenya	9	Government forest
Kenya	4	Protected area

Kenya	4	Government forest
Uganda	4	Government forest
Uganda	4	Government forest
Uganda	3	Government forest
Uganda	5	Government forest
Uganda	7	Government forest
Uganda	8	Government forest
Uganda	8	Government forest
Uganda	3	Government forest
Uganda	6	Government forest
Uganda	6	Government forest
Uganda	6	Government forest
Uganda	3	Government forest
Uganda	7	Protected area
Uganda	7	Protected area
Uganda	4	Private forest
Uganda	4	Government forest
Uganda	4	Private forest
Uganda	6	Private forest
Uganda	3	Private forest
USA	6	Intentional community forest[a]
USA	4	Intentional community forest
USA	5	Intentional community forest
USA	5	Intentional community forest

[a] Intentional community forests include a wide diversity of self-organized local forests in the United States. Some are organized as condominiums, some as cooperatives, and some as developments with homes on private land and joint ownership of and responsibility for the surrounding forest.

Figure 1. Assessments of changes in forest vegetation density based on indicators derived from forest plots and assessments by forest users and professional foresters.

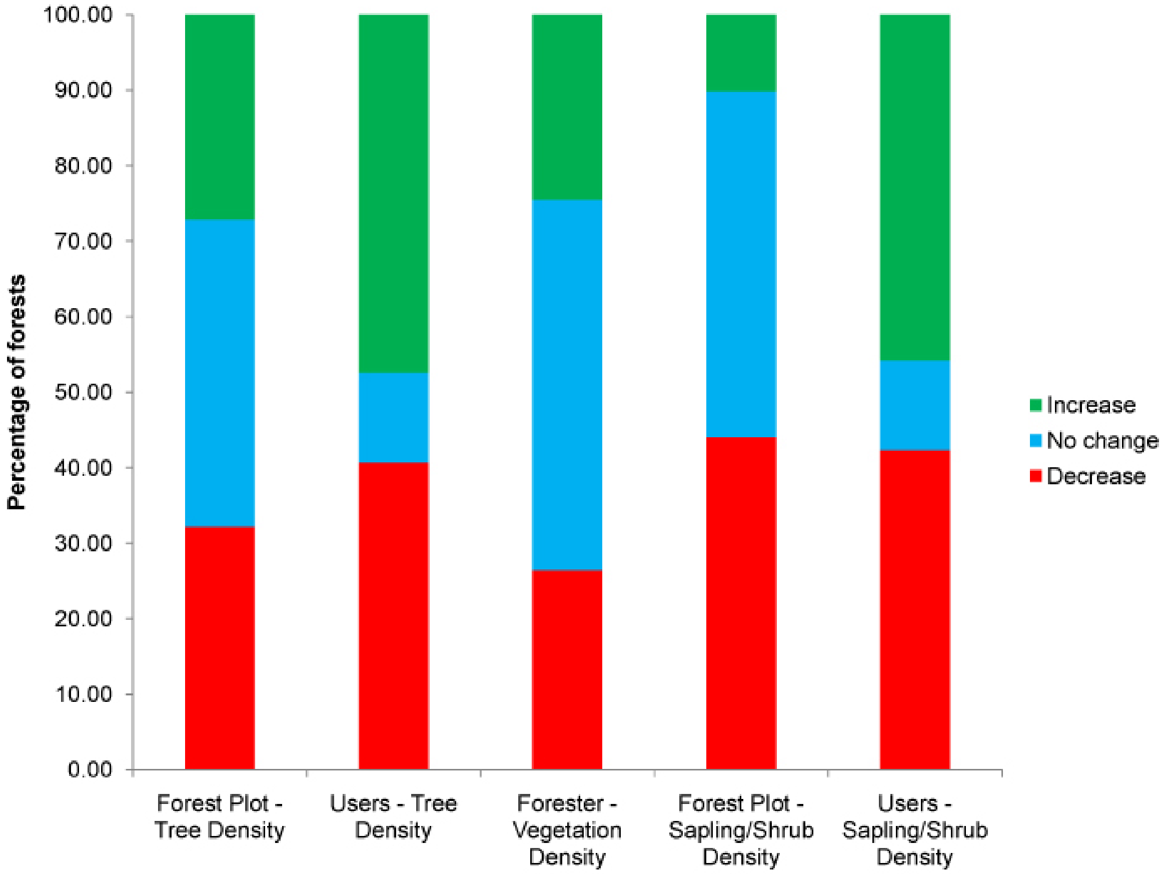

Figure 2. Plot assessment of change in tree density vs. user assessment of change in tree density

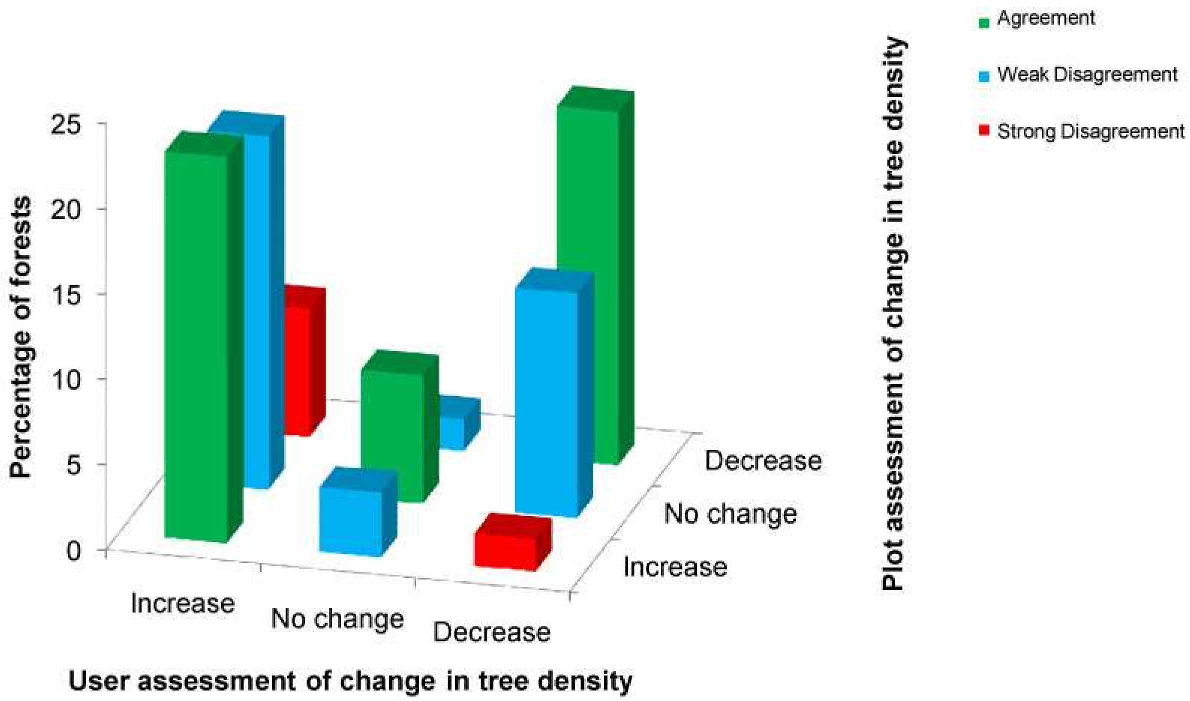

Figure 3. Plot-based assessment of change in tree density vs. forester assessment of change in vegetation density

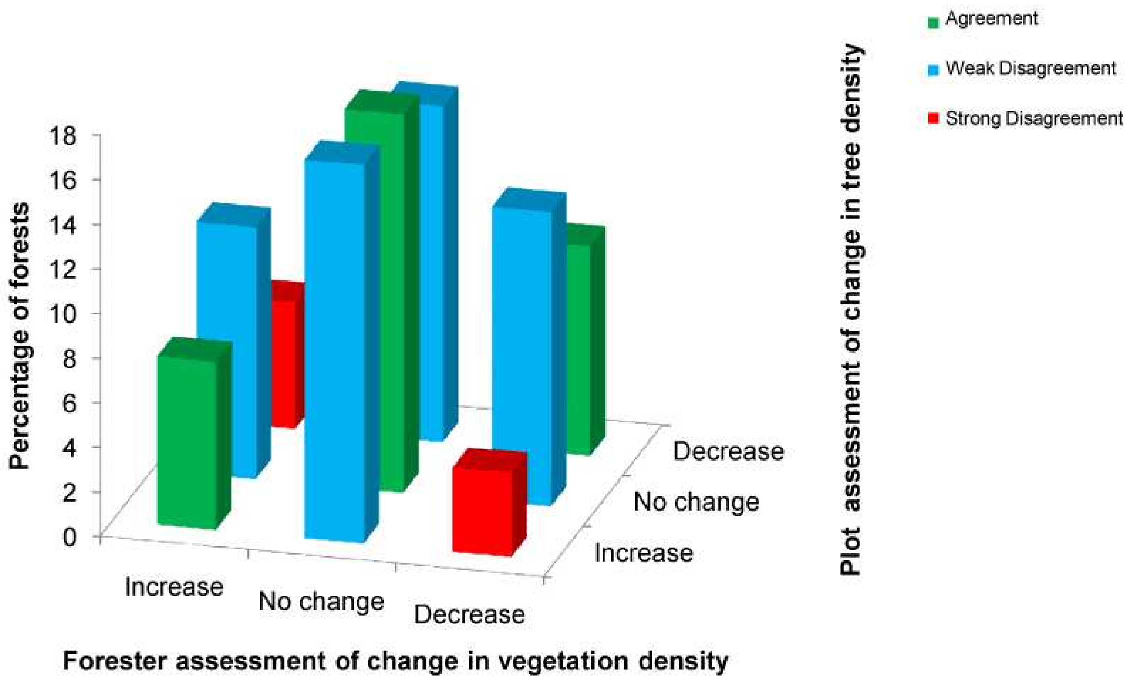

Figure 4. Plot assessment of change in sapling/shrub density vs. user assessment of change in sapling/shrub density