LETTER

At the heart of REDD+: a role for local people in monitoring forests?

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Abstract

Reduced Emissions from Deforestation and Forest Degradation in Developing Countries (REDD+) is a policy mechanism now agreed under the United Nations Framework Convention on Climate Change (UNFCCC). It aims to reduce carbon dioxide emissions from developing countries through the sustainable management of forests, while providing co-benefits of biodiversity conservation and livelihood support. Implementation challenges include linking remote sensing and national forest inventories of carbon stocks, to local implementation and measuring carbon loss from forest degradation. Community-based forest monitoring can help overcome some of these challenges. We show that local people can collect forest condition data of comparable quality to trained scientists, at half the cost. We draw on our experience to propose how and where local REDD+ monitoring can be established. Empowering communities to own and monitor carbon stocks could provide a rapid and cost-effective way of absorbing carbon dioxide emissions, while potentially contributing to local livelihoods and forest biodiversity conservation.

Introduction

At the 15th Conference of Parties of the United Nations Framework Convention on Climate Change (UNFCCC) in Copenhagen, December 2009, an Accord was drafted proposing to stabilize global greenhouse gas concentrations in the atmosphere at a level that keeps global temperature increase below 2°C in the coming century (UNFCCC 2010a). The goal of the Copenhagen Accord can only be achieved if rates of deforestation and forest degradation in tropical developing countries are reduced as emissions from tropical forest destruction contribute approximately 17% of global greenhouse gas emissions annually (Barker *et al.* 2007). The use of economic instruments to provide positive incentives for reducing emissions forms the basis of the agreed UNFCCC policy "Reduced Emissions from Deforestation and Forest Degradation in Developing Countries (REDD+)" (The Commission on Climate and Tropical Forests 2009; Clements 2010; UNFCCC 2010b). Payments would be linked to reducing emissions from the "reference emissions level"; for example through slowing rates of forest loss, reducing degradation, or enhancing forest carbon stocks (UNFCCC 2010c). REDD+ is an extension of the original REDD policy idea to include forest enhancement, sustainable forest management and conservation, as well as reduced deforestation and forest degradation. Although the REDD+ policy is aimed primarily at reduction of carbon emissions, it may also provide co-benefits (UNFCCC 2010c) in terms of biodiversity and livelihoods.

An operational REDD+ policy will require monitoring of deforestation and forest degradation across nations (Mollicone *et al.* 2007). This is not only to quantify the carbon savings in one area but also to account for potential increased loss of forest biomass ("carbon leakage") elsewhere within the same country. The requirement for forest monitoring has prompted an explosion of potential methodologies. The remote sensing community has proposed several ways to measure *deforestation* accurately and cheaply (e.g., Ramankutty *et al.* 2007; GOFC-GOLD 2009). Measuring forest *degradation* (loss of biomass within a forest) remotely is much more problematic. This presents a major challenge for implementing REDD+, since an important cause of carbon loss from forests in developing countries is a gradual degradation for example from extraction of timber, minerals, firewood, and charcoal by local communities or by people from other areas (The Nature Conservancy 2009; Ahrends *et al.* 2010). This diffuse degradation cannot be measured using traditional remote sensing methods (Achard *et al.* 2006; DeFries *et al.* 2007; Runk *et al.* 2010), although logging and more obvious degradation concentrated in space and time can usually be quantified particularly if measured shortly after the incident occurred (Souza *et al.* 2003, 2005). Alternative methods to measure degradation remotely, such as airborne light detection and ranging (LiDar), are now being developed (GOFC-GOLD 2009; Asner *et al.* 2010). An alternative way to measure standing carbon is ground inventory by professional foresters. This approach requires many trained personnel and is extremely expensive across whole nations (GOFC-GOLD 2009). It has been suggested that the huge technical, financial, and human capacity challenges involved in measuring degradation across whole countries or regions may render carbon credits for reversing degradation financially unviable (Lubowski 2008).

A potentially cheaper alternative monitoring approach at the local implementation scale of REDD+ is to engage local people in monitoring (Burgess *et al.* 2010; Phelps *et al.* 2010; Skutsch 2010). A locally based monitoring system could help make forest condition assessments economical across large areas of forest, and could be an important element in national REDD+ monitoring, reporting, and verification (MRV) systems. Permanence of emission reductions is also more likely if local communities are empowered than if they are alienated from the carbon stocks. Many community members have profound knowledge of the natural resources in their area (Berkes *et al.* 2000; Topp-Jørgensen *et al.* 2005). Results from well designed local monitoring schemes can be as reliable as those derived from professional monitoring (review in Danielsen *et al.* 2005). A locally based forest monitoring approach might therefore hold promise for REDD+. In this article, we assess data collected using monitoring approaches implemented by local people in three tropical developing countries against that collected by scientists. Our aim is to determine if locally collected data might be sufficiently accurate to measure degradation, and consequently carbon flux, for the purpose of REDD+. Comparative cost estimates of professional and locally based measurements of degradation are also provided to assess the relative costs of the two approaches. We also consider whether locally based forest monitoring would be likely to constitute empowerment of the local communities, or simply exploitation of cheap labor for the collection of data for a REDD+ program. Despite the paucity of data available for our analysis, we aim to provide preliminary quantitative assessments with which to inform discussion and stimulate further research.

Methods

To test how well community members can measure forest biomass and utilization, we compared results of community-based and professionally executed monitoring in India, Tanzania, and Madagascar. We chose study sites opportunistically (biomass measurements) and on the basis of existing locally based forest utilization monitoring schemes (forest utilization measurements). Representatives of the local communities in these areas helped us select community participants on the basis of their interest and experience with forest resources. Community members involved in measuring forest condition had only attended primary school, but received training from an intermediary organization, while the professional experts had academic degrees in the natural sciences.

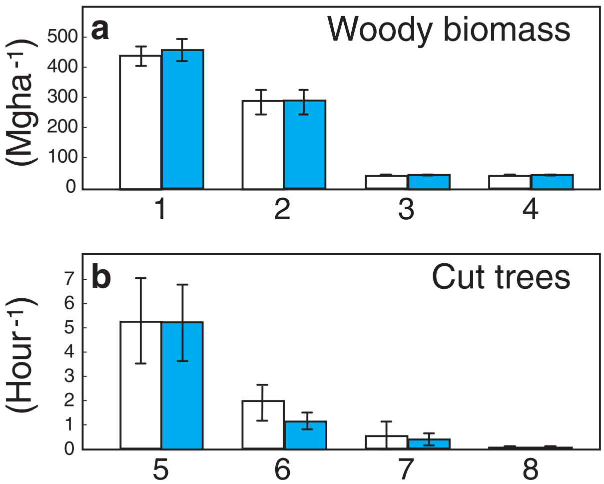

Figure 1 Comparison of forest condition data compiled by local people and trained scientists. Measurements of woody biomass (a, core sites 1–4) and cut trees (b, core sites 5–8) (± S.E.) by community members (white) and professional experts (blue) over a range of forest biomass and resource use intensities in dense oak forest (core site 1), oak forest (core site 2), and degraded forest (core site 3) in India, miombo woodland in Tanzania (core sites 4–6), and dry deciduous forest in Madagascar (core sites 7–8). Data from the other 11 study sites are provided in Table 2.

For forest biomass, we compared above ground biomass from three sites in India and one site in East Tanzania. For forest utilization, we compared five sites in the Eastern Arc Mountains of Tanzania and 10 sites in Madagascar.

From these 19 study sites, we chose a set of eight "core sites" for graphical presentation of the results (Figure 1). The core sites were selected so as to be representative of the full range of forest biomass and forest resource use intensities (Figure 1). For each type of measurement, we selected four core sites. For forest biomass this is all the measured sites. For forest utilization, it is two measured sites from each country. In Tanzania, there are one high-intensity, two medium-intensity, and two low-intensity sites in terms of forest utilization (Table 2b). We selected the high-intensity site (Itagutwa) and the best demarcated forest area among the two medium-intensity sites (Mfyome), where professional and community surveys were made in exactly the same areas (the alternative site, Ny'angoro, is part of a huge forest area where the forest resources are shared between six villages and each village's forest area is not clearly demarcated, see Appendix S3 footnote). In the study area in Madagascar, the intensity of forest utilization is minimal, and hence sites were randomly selected.

In the study sites in India (core sites 1–3), the vegetation is Himalayan temperate mountain forest at around 1,860 meters above sea level (m.a.s.l.), consisting of oak *Quercus* (Fagaceae) and pine *Pinus* (Pinaceae) forests in various states of utilization and degradation. Community members and scientists measured three different forest strata (defined as areas of homogeneous forest), one lightly used with dense oak and pine (40 ha; core site 1), one moderately used with even aged oaks (3 ha; core site 2), and one highly degraded area that had recently started to recover (15 ha; core site 3). In the forest biomass study site in East Tanzania (1,020 ha; core site 4), the vegetation is degraded miombo (*Brachystegia*) woodland at 250–400 m.a.s.l. The forest utilization sites in Tanzania comprised three sites (including core sites 5–6), where the vegetation is miombo woodland at 1,000–1,600 m.a.s.l. and two sites (Kidabaga and Lulanzi), where the vegetation is montane evergreen forest at 1,700–2,100 m.a.s.l. In the 10 forest utilization study sites in Madagascar (including core sites 7–8), the vegetation is dry, deciduous forest at 25–100 m.a.s.l (Appendix S1).

For the measurement of forest biomass (core sites 1–4), community members first identified forest strata with the assistance of an intermediate organization, after which community members and professional foresters independently carried out forest inventory in permanent plots based on methodology recommended by Intergovernmental Panel on Climate Change (IPCC) Good Practice Guidance (Penman *et al.* 2003; Table 1). For the measurement of forest utilization (15 sites including core sites 5–8), community members recorded the number of cut trees during regular patrols and we compared their results with results from scientists (Table 1). We adjusted the counts of cut trees for differences in effort by dividing the counts by the number of hours taken for the surveys in the relevant 3-month period (quarter) at the given site.

We estimated the cost of the community-based and professionally executed measurements on the basis of the actual expenses incurred during the training and fieldwork at each site (Appendix S2). Our cost estimates are conservative because study sites were fairly easy to reach by car. More remote areas would have been more expensive for experts to measure compared to communities.

We used *t*-tests (PROC *t*-tests, SAS 9.1; SAS Institute) for comparing the biomass per ha and the number of cut trees per hour recorded by community members and professional experts across sites. We used the same procedure to compare costs across approaches and sites. For biomass measurements, *n* refers to the number of permanent plots sampled by both types of monitors. For forest utilization measurements, *n* refers to the number of 3-month periods in which measurements were made by both types of monitors. Finally, to assess the ability of our study to detect statistically significant differences, we carried out a power analysis using the Sample Size

Table 1 Description of the methods

Attribute measured	Training provided to the community members	Field survey protocol for community members and scientists	Data processing by community members	Timing and location of the data collection	Equipment	Definitions
Biomass	An intermediary organization trained community members in the use of a handheld computer in the field for: (i) entry of tree measurement data into a database; and (ii) use of the GPS functions to mark the boundaries of the forest strata and to locate the permanent plots. Teams of 3–7 community members were trained for 10 days in the first year. Refresher courses were provided in the 2nd and 3rd year.	The protocol comprised of: (i) Identification of forest strata by community members and the intermediary organization; distribution of sampling plots within each stratum. (ii) Independent inventory of forest vegetation plots by community members and scientists. In each plot, communities and scientists counted the trees, measured their dbh, measured the height of all trees >5cm dbh, and identified the species (MacDicken 1997; Penman *et al.* 2003; see Verplanke & Zahabu 2009).	Calculations were made directly in the computer as soon as measured data were inserted by the community members. The intermediary organization set up the database, uploaded a suitable base map into the computers initially, acquired and entered suitable allometric equations into the computers, and maintained the computers (batteries etc.).	In India, community members collected data every year for 7 years (2003 to 2009). In East Tanzania, community members collected data for 4 years (mid 2004–mid 2008). Scientists collected data only in 2008. We compared the results of the professional survey of forest biomass with community data from the same year. In India, the professional surveys used the same permanent plots as the community. In East Tanzania, the professionals set out new plots and, though they used the same number of plots, they increased the plot size.	Diameter tape, hypsometer, and handheld computer with (i) GPS functions; (ii) database with basemap and allometric equations.	By forest stratum, we mean a "homogenous forest area in terms of tree species composition and level of degradation." By dbh, we mean "diameter at breast height."
Cut trees	An intermediary organization trained community members in the recording of forest resources and resource use during forest patrols. Community members from each village were trained once for 2–3 days.	Community members recorded sightings of cut trees during patrols along regularly used paths through the forest, with patrols taking place 2–3 times every month and lasting 3 to 6 hours. Professional scientists recorded the number of cut trees along 1–2 transect routes of 2,000–2,500 m length located away from regular paths once every 3 months, and the speed of walking was kept constant at around 1km/ hour (250 m/15 minutes; by pacing).	In Tanzania, the community data were used largely unprocessed by the Village Natural Resource Councils for making decisions on natural resource management on a monthly basis (Topp-Jørgensen *et al.* 2005). In Madagascar, the community data were handed over to an intermediary organization who processed the data and who returned the results to the communities.	In Tanzania, communities collected data for 6 years (2002–2008); in Madagascar for 5 years (2004–2009). In Tanzania, scientists collected data from July 2007 to June 2008; and in Madagascar from January 2007 to June 2009. We compared the results of the professional survey of cut trees with community data from the same 3-month period. The community surveys were made along existing trails because the surveys were part of monitoring schemes not set-up for this study.	Notebook, pencil. The scientists also used a GPS receiver.	By cut tree, we mean a "cut tree bole, either the stump that remains or the cut bole itself."

Application, distributed with SAS/STAT software (SAS 9.1, SAS Institute).

Results

We first tested for differences between local people's and scientists' forest biomass data. Over a range of forest biomass intensities from 450 to less than 50 Mgha^{-1} woody biomass—that is, dense oak forest (core site 1), oak forest (core site 2), and degraded forest (core site 3) in India, and miombo woodland in Tanzania (core site 4)—we found no significant differences in the estimates of mean above ground biomass made by community members and by professional foresters (Table 2a; Figure 1a). The local biomass estimates are reliable compared to professional estimates over a range of forest sites from high-carbon to low-carbon forest types. Our power analysis suggested that at least 35 permanent plots sampled by both types of monitors would be needed to obtain a probability of >80% to detect a difference of 20% with statistical significance. Only one site, Kitulangalo, met this criterion, and here there was clearly no significant difference ($P = 0.83$; $n = 89$; Table 2a).

We then compared the number of cut trees as recorded by community members and by scientists, which provides an estimate of rates of forest degradation and impact on carbon stock. Over a range of forest resource use intensities—from more than five to less than 0.1 cut trees per hour of census in heavily used miombo woodland in Tanzania (core site 5–6), montane evergreen forest in Tanzania, and dry deciduous forest in Madagascar (core site 7–8)—we found no significant difference in utilization estimates by community members and by scientists (P-values > 0.05; Table 2b; core sites shown in Figure 1b), although at two sites, the P-values were small ($P < 0.15$, i.e., Nyang'oro and Anketrevo; Table 2b). Our power analysis however suggested that at least 300 three-month periods sampled by both types of monitors would be needed to obtain a probability of >80% to detect a difference of 20% with statistical significance. None of our sites met this criterion (Table 2b). To account for the limited sample size at the site-level, we therefore aggregated the data on forest utilization from individual sites across all the measured sites in each country. Again, we did not find any significant difference between forest utilization measurements by community members and scientists (Tanzania, $P = 0.58$; $n = 19$; Madagascar, $P = 0.82$; $n = 80$). Moreover, the overall pooled mean utilization rates were almost identical (community members: 0.4967 per hour; scientists: 0.4845 per hour; $n = 99$).

Finally, we estimated the costs on a ha^{-1} basis of monitoring forest condition by local people and by experts. From an external perspective, the community measurements of above ground biomass annually cost USD 3.0–5.4 ha^{-1}, whereas expert-executed biomass measurements cost USD 10.3–11.1 ha^{-1} (Appendix S3; and the squares in Figure 2). Similarly, the community measurements of forest utilization annually cost USD 0.04–2.4 ha^{-1} (median USD 0.58 ha^{-1}), whereas expert-executed forest utilization measurements cost USD 0.62–12.37 ha^{-1} (median USD 1.2 ha^{-1}; Appendix S3; and the circles in Figure 2). Community measurements require more funds for training but there are much higher expenditures in expert-based measurements because of travel, field allowances, and salaries (Table 3). Across all 17 sites with financial data community measurements cost significantly less than expert-based measurements ($P = 0.038$; $n = 17$). The per hectare monitoring costs decreased significantly as forest size increased, both for community-based (Spearman Rank; $r_s = -0.91$; $n = 17$; $P < 0.0001$) and professional monitoring of forest condition ($r_s = -0.77$; $n = 17$; $P = 0.0003$; as illustrated in Figure 2).

Discussion

Our results are based on a limited data set but provide cautious support for the idea that in a number of developing country situations, and across a range of forest biomass and resource use intensities, local communities can measure forest biomass and utilization. Biomass data can be converted to estimates of stored carbon and with repeat surveys, the rate of change of stored carbon can be determined. The strongest agreement between community members and experts was for forest biomass, with lower agreement over forest utilization. This might be due to the low number of cut trees in some sites (e.g., Anketrevo; Table 2b) and because the community surveys of cut trees were made along existing trails, whereas scientists surveyed areas away from existing trails. In contrast, all biomass measurements were made in the same vegetation plots. Our results therefore support the idea that data collected by community members can meet the requirements of the highest reporting tier of the IPCC. This implies that community-based forest inventory data could be used for REDD+ applications, particularly for estimating changes in rates of degradation and forest enhancement (increased biomass stocks). Moreover, our findings suggest that community members can collect large volumes of data at relatively low cost.

There are a number of advantages of locally based monitoring for REDD+. One is that those communities, who live close to the forest, will be able to carry out repeated monitoring of data of relevance to REDD+, for

Table 2 Results of the measurements of above ground biomass (a; $n = 125$ permanent plots) and forest utilization (b; $n = 99$ three-month periods) by local community members and professional experts in three countries

(a)

Country	Name of area (Core site number)	*n*	Professional survey of biomass Mean biomass in $Mgha^{-1}$ (S.E.)	Community survey of biomass Mean biomass in $Mgha^{-1}$ (S.E.)	*P*
India	Dhaili (1)	14	453.3 (36.7)	426.4 (36.6)	0.61
India	Dhaili (2)	15	283.4 (40.0)	279.9 (40.5)	0.95
India	Dhaili (3)	7	41.7 (4.6)	38.1 (4.7)	0.55
Tanzania	Kitulangalo (4)	89	43.2 (1.9)	42.2 (4.4)	0.83

(b)

			Professional survey of forest utilization			Community survey of forest utilization			
Country	Name of area (Core site number)	*n*	Hours of survey	Number of cut trees	Cut trees $hour^{-1}$, mean (S.E.)	Hours of survey	Number of cut trees	Cut trees $hour^{-1}$, mean (S.E.)	*P*
Tanzania	Itagutwa Village Forest (5)	4	36	186	5.19 (1.60)	63	255	5.3 (1.76)	0.97
Tanzania	Kidabaga	4	80	11	0.16 (0.09)	53	0	0 (0)	0.19
Tanzania	Lulanzi	4	34	3	0.11 (0.07)	96	0	0 (0)	0.19
Tanzania	Mfyome Village Forest (6)	4	38	47	1.14 (0.40)	112	169	1.95 (0.73)	0.37
Tanzania	Nyang'oro	3	52	62	1.60 (0.68)	93	323	3.63 (0.85)	0.14
Madagascar	Ampataka	7	14	5	0.39 (0.39)	131	0	0 (0)	0.36
Madagascar	Anketrevo	8	15	5	0.34 (0.14)	146	2	0.01 (0.01)	0.06
Madagascar	Ankoraobato	8	15	0	0 (0)	159	0	0 (0)	na
Madagascar	Kiboy	10	19	0	0 (0)	252	5	0.02 (0.02)	0.25
Madagascar	Kirindy Village (7)	6	11	4	0.36 (0.27)	110	55	0.60 (0.58)	0.71
Madagascar	Lambokely (8)	8	15	0	0 (0)	214	15	0.06 (0.05)	0.22
Madagascar	Mandroatsy	7	13	15	1.16 (0.81)	103	21	0.18 (0.09)	0.28
Madagascar	Marofandilia	8	14	1	0.07 (0.07)	169	17	0.09 (0.06)	0.80
Madagascar	Tsianaloky	10	18	0	0 (0)	210	0	0 (0)	na
Madagascar	Tsitakabasia	8	15	1	0.07 (0.07)	85	27	0.36 (0.36)	0.45

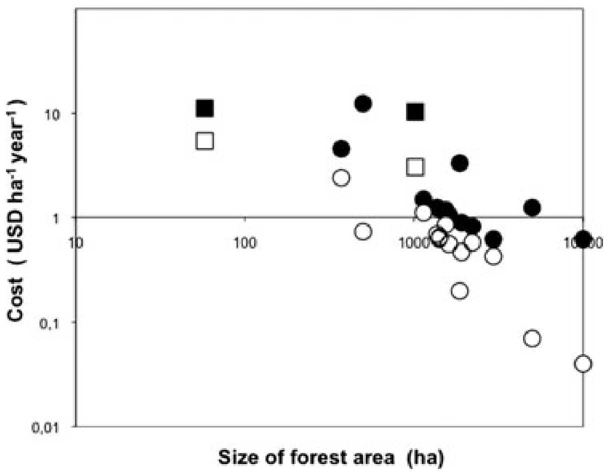

Figure 2 Comparison of the cost of monitoring the condition of forests by local people and trained scientists. Cost of measurements of woody biomass by community members (□) and professional experts (■) and of cut trees by community members (○) and professional experts (●) (log_{10} scales).

example annual measurements of biomass, which would be logistically impossible for professional surveys. Higher frequency of monitoring would greatly improve the statistical and scientific reliability of the results and the level of confidence in the results. Another advantage is that it could provide a fair basis on which communities could be paid for carbon savings, which in turn would provide an incentive for their engagement with REDD+ monitoring and forest management. This could be very good for forests and local livelihoods. Additionally, locally based monitoring provides a way to directly link monitoring to broader concepts of sustainable management of forests, including biodiversity conservation and livelihood support. It has been shown that the involvement of local communities in monitoring correlates with improvements in forest management (Gibson *et al.* 2005). In fact, just the presence of people may have a positive impact and deter illegal loggers. Moreover, involving local stakeholders in monitoring may increase the speed of decisions, and provide information to address environmental problems at operational scales of management (Danielsen *et al.* 2010). It may also enhance the capacity of local people to take care of their own local environment by increasing levels of local awareness and knowledge regarding the current status of the surrounding forest areas (Sheil & Lawrence 2004). A final advantage is that the locally based approach to monitoring may in fact be the best way to address some of the human rights issues that have been raised in connection with the implementation of REDD+ (Robledo *et al.* 2008). In developing countries about 240 million people live in tropical forests (Peskett *et al.* 2008), including some of the world's poorest and most marginalized communities who use the forest as their resource base (Funder 2009). At the UNFCCC negotiations, indigenous peoples' organizations have generally opposed REDD+ (IWGIA 2009; Rights and Resources 2010), mainly because it is expected to operate *via* national governments, and they fear it will undermine local control over forest resources and alienate communities from their resources (Chhatre & Agrawal 2009). In response to this, the current text on technical aspects of REDD+ explicitly allocates indigenous people and local communities a role in monitoring carbon stock change in forests (UNFCCC 2009).

There are also a number of potential disadvantages. One is that local communities will have a strong incentive to report positive trends in the forest cover and condition, so they continue to be paid, even if forests are actually declining. Periodic third party verification of the monitoring results will therefore be required, but this would need to be built into the design and costs of any REDD+ initiative, whether implemented by communities, the State, or the private sector. Independent verification could be based on random spot-checks or the use of high resolution remote sensing images. This would be unaffordable for national inventory, but would be appropriate for verification on

Table 3 Mean cost (over 4 years in USD) of community and expert-executed measurements of biomass and forest utilization across 17 sites with financial data (details in Appendix S3)

Attribute	Data gatherer	Training (S.E.)	Travel and accommodation (S.E.)	*Per* diem and food (S.E.)	Equipment (S.E.)	Salary and administration (S.E.)	Total cost (S.E.)	Total annual cost per ha* (S.E.)
		(USD)	(USD)	(USD)	(USD)	(USD)	(USD)	(USD/ha year)
Mean	Community	700 (97)	629 (227)	769 (108)	282 (59)	1,344 (333)	3,724 (651)	1.06 (0.33)
Mean	Professional	66 (14)	4,355 (1,133)	2992 (972)	61 (13)	6,507 (1,033)	13,982 (2,713)	3.33 (0.96)
P		1.0×10^{-4}	0.005	0.037	0.002	1.0×10^{-4}	0.002	0.038
n		17	17	17	17	17	17	17

* The total cost over 4 years divided with the size of the area and divided with 4 years.

Table 4 Preliminary protocol to help decide where local REDD+ monitoring is appropriate (see also Ostrom 2009)

Who	Positive attributes
The local community	– Experience in communal management of natural resources – Evidence of trusted community organization and leadership – Residents show interest in sustainable forest management – Residents utilize forest resources – Clear rights over forest resources are present in practice
The government	– Government policy is in place for shared management of forest resources with communities – Community forest management has been adopted as a strategy within the national REDD+ program, and attendant procedures and rules are clear (e.g., on benefit distribution to directly affected communities, and verification) – National database for carbon stock accounts will accept data generated by communities at the local level
The intermediate organization	– Presence of suitable and interested intermediate organizations with experience of working with communities, within reasonable distance of the forests concerned
The forest area	– Minimum forest unit size of around 100 ha needed to break even on transaction costs of measurement – Evidence that community management will ensure tree growth and continued presence of the forest – No recent history of major conflicts, violence, or threats reported by forest managers or communities

the basis of sampling. It could be combined with statistical analysis of the community-based data to search for anomalies and growth rates that are beyond the normal or expected range.

Another disadvantage is that by engaging local communities in monitoring for REDD+ the State could be accused of offloading monitoring and reporting requirements, and their costs, onto poor local people. This indeed is a risk, although in reality a greater risk is that the State will apply for credits on the basis of improved management of the forests (as carried out now by the communities), bypassing them completely in terms of providing benefits. However, because remotely gathered data would be Tier 1 or at best Tier 2, the quantity of credits that the state could claim would be less than if local-level data (Tier 3) were available. It is thus in the interests of the State that greater accuracy is attained.

Table 5 Three proposed steps in establishing a viable local REDD+ monitoring team

Step 1. Meet the leader of the community that is interested in carbon crediting. Explain the objectives and activities of local REDD+ monitoring. Stress the common interest of the government and local people in sustainable forest management.
Step 2. Assisted by the village leader, identify 10–15 community members among households utilizing the forest resources and persons involved in natural resource management (forest guards, community forestry committee members, etc.). Include the most experienced all-round forest product gatherers as well as some persons with literacy/numeracy. The persons should be permanent residents to ensure continuity as annual or bi-annual surveys are required (Verplanke & Zahabu 2009). Make sure that both men and women from different age groups are represented.
Step 3. From among these, a group of monitors of 5–8 people should be established based on a selection of the most willing and interested. This group should preferably remain the same over a long period of time. Together with the group and on the basis of a manual (e.g., Verplanke & Zahabu 2009), agree on what should be monitored, where and how.

The risk that local people might be intimidated by the State to exaggerate the carbon stock increases will be controlled by the requirement for third party independent verification.

To help address these challenges, we have developed a preliminary protocol to help decide whether the key conditions are in place for applying and sustaining local REDD+ monitoring (Table 4). This includes screening the potential risk posed to the locals from being involved in REDD+ monitoring. The protocol is intended for the preliminary planning and implementation of local REDD+ monitoring schemes and further work would be needed at the local level to verify and substantiate these variables on the ground.

Finally, it is clear that locally based monitoring is not a silver bullet. Not all local monitors are equally effective, and some are not able to tackle the task. A strong local REDD+ monitoring team requires a committed and competent group of community members, and the selection process to choose these people is critical. To aid this process, we propose three steps as described in Table 5. The competence of the community members also depends on the presence of an intermediary organization that would assist at the beginning in assessing the sample size required, laying out the permanent plots, as well as training.

In conclusion, REDD+ strategies that involve local community members in monitoring carbon stocks may significantly improve the capacity of many developing countries to deliver large cuts in emissions at a low cost within a short time frame. It may be the only economic way for countries to gather data on changing rates of forest degradation, which would be needed if credits are going to be claimed for reduced degradation as well as for deforestation. Additionally, although REDD+ policy is primarily intended to reduce carbon emissions, a community-level approach will certainly involve holistic forest management, which would have the additional advantages of contributing toward conserving biodiversity within globally important forest types (Venter *et al.* 2009) and assisting in the support of local livelihoods (Chhatre & Agrawal 2009). If locally based forest monitoring is to become a key element of the MRV of REDD+ schemes, further quantitative assessments of the ability of locally based forest monitoring methods to detect changes in forest condition are needed. It should also be explored to what extent community members can monitor other aspects of central importance to REDD+ implementation like governance, livelihoods, and biodiversity.

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Supporting Information

Additional Supporting Information may be found in the online version of this article:

Appendix S1: Study areas.

Appendix S2: Details of how the costs of community and scientist-collected forest condition data were calculated.

Appendix S3: Cost (over 4 years in USD) of community and expert-executed measurements of biomass and forest utilization.

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