

The role of community carbon monitoring for REDD+: a review of experiences

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This paper reviews research which has investigated community skills for carbon (and other natural resource) monitoring. The assessment focuses on the reliability of the data, the cost of community monitoring (CM) versus expert surveys, and the broader benefits and challenges of involving communities in the process. We identify the tasks considered necessary for carbon monitoring inventories. The review finds that CM is useful and cost-effective for REDD+ carbon monitoring. In particular, forest inventories communities can provide forest enhancement data unobtainable by other means at the scale required. CM is particularly helpful in assessing rates of forest degradation, and would densify a national forest inventory in community management areas. We conclude that communities can assess above ground biomass, monitor social and environmental variables, and store and transmit the data.

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Introduction

The goal of the Copenhagen Accord [1] can only be achieved if rates of deforestation and forest degradation in tropical developing countries are reduced, since forest destruction contributes approximately 17% of global

greenhouse gas emissions annually [2]. Economic instruments to provide positive incentives for reducing emissions form the basis of the United Nations Framework Convention on Climate Change (UNFCCC) policy ‘Reduced Emissions from Deforestation and Forest Degradation in Developing Countries (REDD+)’ [3,4]. Incentives will be proportional to achievements in reducing carbon emissions or increasing sequestration rates, relative to a ‘reference emissions level’; therefore the quantitative monitoring of changes in forest area and carbon stocks is central to REDD+.

A number of countries have already selected community forest management (CFM) as a central part of their national REDD+ plans. A textual survey of the 26 Readiness-Preparation Proposals (R-PPs) currently under the World Bank Forest Carbon Partnership Facility (FCPF) REDD Readiness programme shows that all 26 mention some form of community forest management or community conservation, even those (e.g., Argentina) where there is very little forest in community hands. In most countries, communities are seen as central to the whole enterprise and in at least 10 cases (Madagascar, Tanzania, Nepal, Ethiopia, Guatemala, Ghana, Kenya, Liberia, Panama, Peru) community monitoring (hereafter CM) of carbon is specifically mentioned as a viable option which may be taken up.

Moreover text in the Subsidiary Body for Scientific and Technological Advice (SBSTA) [5] on REDD+ methodology supports full and effective engagement of indigenous peoples and local communities, and the contribution of their knowledge to, monitoring and reporting activities, and this is recommended in the GOFC-GOLD sourcebook [6].

The underlying value to national REDD+ programmes of CM is that it could provide data about increases or decreases of carbon stocks at a level of detail not possible through remote sensing or national forest inventories.

This paper first outlines the rationale for community forest monitoring, it then discusses the specific carbon data requirements of REDD+, and through reviewing experiences with CM of other natural resources, it highlights the challenges and risks of community monitoring.

The rationale for community forest monitoring

Natural resource monitoring is usually externally driven whereby professional researchers set up, run or analyse the

Box 1 Examples of locally based monitoring in REDD+

CM assessment has taken place in many locations around the world [1–3], and from the cases it has been possible to extract those that made specific reference to REDD+ goals and requirements. The experiences range from just carrying out the measurement of different biophysical parameters to comparing the outputs and costs with those of expert-based monitoring.

The studies cover the use of different tools under dissimilar management schemes and a diversity of forest types.

The experiences help us to recognize the benefits of this participatory and capacity building process, but also to foresee the likely obstacles and risks.

Monitoring activities carried out	Case study	Country	Forest type
Biomass survey for assessing carbon stock following the IPCC (2003) Good Practice Guidelines.	Karky and Skutsch [60]	Nepal	Sub-tropical broad leaved. Lower temperate broad leaved.
An overview of participatory biomass and carbon estimation. Application of methodologies of national inventory, IPCC, MacDicken [61] and literature to execute inventory and calculate the biomass and carbon density. Comparison of carbon stock changes in four villages.	Shrestha [62]	Nepal	Temperate conifer. Lower temperate broad-leaved forest. Pine forest.
Cutting edge technology model for measuring and monitoring forest carbon emissions.	Zahabu and Malimbwi [44]	Tanzania	Woodland. Lowland. Montane forest.
First approach to an experience on carbon stocks measurement using cyber tracker in Michoacán state. To study the requirements of a system for planning and administering the production and sale of carbon services from small-scale landowners.	Bey [40]	Nigeria	Lowland. Hill tropical forest.
Measuring carbon loss from forest degradation.	Peters-Guarin and McCall [39]	Mexico	Temperate forest.
	Tipper [63]	Mexico	Moist tropical forest.
Reforestation activities. To record the carbon outcomes of typical community forest management regimes. Assess local communities' capability of making carbon stock measurements themselves.	Danielsen <i>et al.</i> [50**]	India Madagascar Tanzania Indonesia Guinea Bissau Mali Senegal	Temperate forest. Dry forest. Miombo woodland. Grassland Dry farmland. Dry Forest.

results using financing from a remote agency [7–9]. This approach has been criticized however, for being expensive to sustain over time and reliant on non-local skills [10]. The multiple benefits of involving local people in monitoring of forest conditions and forest products have been identified and demonstrated in many studies [11,12,13**,14–20], though very few are specifically aimed at biomass carbon.

Local CM schemes for forest resources and other environmental services exist in many countries, including specifically with indigenous peoples (e.g. [20,21]). A bibliographic search on community natural resources monitoring finds more than 200 articles (note especially the review articles [15**,16**,22,23] (several cases are summarized in Box 1). Experiences specifically on monitoring for carbon are very scarce. In this review paper our concern is carbon and we base our findings and conclusions on the nine sources in which carbon monitoring is a central focus. These refer to a number of different countries and forest types (Box 1).

According to those studies the strengths and comparative advantages of community participation in forest monitoring result from:

- data quality advantages of recognising and employing local knowledge;
- efficiency and cost reductions;
- more sustainable social development through improved governance and empowerment.

For the case of forest carbon monitoring, these advantages are as follows.

Data quality benefits

Local people complement scientists' information with skills and knowledge that scientists may lack [24,25], and they provide important ecological data in areas where studies have not been conducted [20,26,27]. Groups within the local community (forest users, herdsmen, hunters, women gatherers) are more likely to quickly identify areas of their forest which are subject to biomass losses or gains - and from which specific drivers, and local people have detailed knowledge of tree species and their characteristics. CM can also result in more rapid management interventions through early warning of how forests are responding to management practices, i.e. adaptive management.

Monitoring not only records community forest management, but creates a culture of critical questioning. 'Recent thinking has concluded that monitoring is more than a way of generating information; it is a catalyst for learning processes at the core of adaptive forest management' [23,28].

Cost efficiency

Carbon monitoring is one of the major costs of REDD+ programmes. Forest carbon measurement by community members can reduce the transaction costs of the monitoring so that it is economically viable for smaller communities to become involved in carbon finance projects. Their operational costs are much lower than the costs of hiring external professionals. The monitoring may be partly voluntary and therefore monitoring costs will be lower [13[•],18,19]. If costs are funded from outside, there would also be local employment generation. But if the community itself has to cover the costs of monitoring, (upfront, or from eventual carbon payments), there is then no additional benefit. In the sites of the 'Kyoto: Think Global Act Local' (KTGAL) project case, the costs of CM were almost half of the costs required for professionals [29]; and communities may be able to collect data more intensely (both in space and in time), which would result in more consistent estimates and narrower confidence levels. CM in areas which are under community management could result in high quality Tier 3 data,¹ and provide higher density coverage of forest carbon information within a national forest inventory approach. By themselves, national inventories are unlikely to generate better than Tier 2 data.

Strengthen sustainability

Participatory approaches should satisfy the majority of the community and other relevant actors; they should not cause unwarranted harm, and they should create and support more autonomous initiatives within the community. They must also deliver concrete results, in this case, a sufficiently accurate assessment of changes in carbon stocks over time [37].

Participation should lead to improved governance, empowerment and sustainability potential, and community involvement in monitoring and in MRV in general is capacity-enhancing [13[•],30,31]. Communities and groups can be empowered by involvement in the processes – this means developing their social and political

capital and building self-confidence. Participation provides an entry into and control over handling the technology which further builds capacity and confidence. It can build more equitable and respectful relations between local people and the authorities, which is important for issues of permanence. Moreover, 'ownership' of the information on carbon stocks may be crucial in establishing the communities' rights to REDD+ rewards.

Monitoring for carbon in REDD+: the information requirements

The two primary variables required for MRV under REDD+ are: forest area and carbon stock. Whereas there is plenty of expertise and experience in identifying and quantifying changes in forest cover using remote sensing, changes in carbon stock are much more elusive to assess remotely and require at least some ground level monitoring. Procedures for measuring and monitoring forest area and carbon stock are outlined in the IPCC Good Practice Guidance [32] which provides strict scientific principles for sampling. Monitoring at ground level is also essential in addressing the other REDD+ components such as sustainable forest management, forest conservation, biodiversity, and safeguards, (see other articles in this issue [33–35]).

The tasks necessary for carbon monitoring are:

- mapping and geo-referencing the boundaries of the forest and its strata;
- establishing a system of sample plots and regular measurement of the standing biomass stock parameters in the sample plots, for example diameter at breast height (dbh);
- assessing leakage – because leakage extends outside the community, it has to be monitored at a higher geographical scale although data are still provided by the local monitoring scheme. [36[•]];
- monitoring of social and environmental variables, such as changes in biodiversity.

For all these tasks, some degree of training is needed, not only for community members but also for NGOs and government staff, to ensure that the strict procedures approved by the IPCC are followed. Therefore supervision will be necessary in early stages, and third party independent verification will be required.

Mapping

The first step in forest carbon mapping is delineation of the forest boundaries and, if necessary, the strata within the forest which represent different ecological or management conditions; the next step would be the location of the sample plots.

Mapping by community members may be facilitated by the use of Participatory Geographical Information

¹ The IPCC [32] provides three tiers for estimating emissions, with increasing levels of data requirements and analytical complexity and therefore increasing accuracy: Tier 1 uses default emission factors (indirect estimation of the emissions based on canopy cover reduction) for forest activities ('activity data') that are collected nationally or globally. Tier 2 applies emission factors and activity data from country-specific data. Tier 3 uses methods, models and inventory measurement systems that are repeated over time, driven by high-resolution activity data and disaggregated sub-nationally at a finer scale.

Table 1

Mapping tools available for carbon monitoring

Tool name	Description	Licence type	Skills required	Origin	Operating system		Data storage
					Mobile device	Design device	
Cybertracker (http://cybertracker.org/)	Software originally created for tracking animals and birds and slowly developed to become a monitoring tool.	Freeware	Computer skills are needed and basic knowledge on databases.	Began as a tool to reach conservation goals and potentialize the local indigenous knowledge.	Windows mobile. Now migrating to Android.	Windows xp, 7	A regular desktop
Google Open Data Kit (http://opendatakit.org/)	Set of tools designed to facilitate mobile data collection	Freeware	Currently computer skills are needed but there are several groups developing simplified alternatives.	Began as a complete tool for monitoring activities.	Android 2.2 or higher	Windows xp, 7	A regular desktop and a server.
PoiMapper (http://poimapper.com/)	Application for mobile phones developed to collect point of interest data	Copyright	Direct support from the developing team is needed	Client oriented product.	Android 2.2 or higher	Windows xp, 7	A server
Helveta's Control Intelligence (CI) world	Platform that provides a set of modular software. CI World makes real time end-to-end tracking of assets.	Copyright	Forms are customized for the client.	Interactive cartography application for 'bottom-up' monitoring	Windows mobile	Windows xp, 7	Online server

Systems (PGIS) [37]. The KTGAL project made use of handheld computers (PDAs) with GPS attachments, together with ArcPad software [38]. Smartphones have also been used with icon-based freeware (thus avoiding illiteracy issues), such as CyberTracker [39]. Helveta developed an icon-driven data capture application for creating maps of forest inventory in an online environment which can be accessed over the internet by authorized users [40]. The application works through modules which enable the end-user to carry out different activities. Google has an open source package of tools know as Open Data Kit, and PoiMapper (Finland) offers possibilities for CM as well as an online storage space. Details of these tools are displayed in Table 1.

In these approaches, communities are trained to use GPS for mapping. GPS geo-referencing is less time consuming than using chain and compass for boundary mapping [41,42]. The use of such applications however, usually requires some technical backup or expertise rarely present in communities, particularly for when electronic equipment malfunctions, and during the initial programming of the digital forms on the devices.

Establishing plots and measuring biomass

Establishment of permanent plots requires a pilot survey to estimate standard error which enables calculation of the number of sample points needed. The plots need to be laid out over the forest area, using a systematic pattern with a random starting point. This is a technical exercise which needs skills unlikely to be found within the community, implying external support from a suitable agency.

Within the plots, measurements need to be taken to estimate above-ground biomass, using dbh and tree height. A number of field guides describing procedures have been written with communities especially in mind [38,42,43]. These data may be entered directly into a database on a handheld computer or collected on paper. In general, the less frequent that data have to be transcribed, the fewer opportunities for error, therefore a computerized database is preferable [44], with data entered directly. Still, any small errors in measurement of dbh and heights can result in large errors in biomass estimates. Alternative methods which could be used by communities are small laser rangefinders such as Laser-Ace [45].

New laser technology has recently been released which will make a complete 3-dimensional scan of a whole sampling plot in a matter of minutes, with complex software to translate this into biomass estimates [46], and dbh and height are translated into biomass estimates through the use of allometric equations which can be integrated into the database. This technology however, (a) is not yet ready for addressing the real conditions of forests, (b) is too expensive, and, (c) requires highly complex

post-fieldwork analysis. Therefore its most probable use would be as a verification tool.

Measurement of soil carbon presents problems since samples would have to be analysed in a laboratory. Moreover it is currently unlikely that carbon gains in the soil will be credited under REDD+. More likely, communities will have to provide evidence that their forest management activities are not resulting in losses of soil carbon. This could be done in a qualitative way and might be subject to verification by an outside organisation. The carbon stocks in other pools (litter or dead wood) are likely to be small and the effort of measuring them may outweigh the returns in terms of carbon accounting.

Estimating and monitoring leakage

Leakage refers to emissions that occur in other places due to the displacement of activities in the project area. Leakage is estimatable by monitoring deforestation, forest degradation rates, and aspects of forest resource consumption. For example, a REDD+ project that prohibits timber harvesting may result in a shift of timber harvesting activities to another location in the vicinity of the project, thus increasing emissions in the new area and

resulting in an overall net zero carbon gain. In stand-alone projects leakage is sometimes physically measured in adjacent areas, but not usually by the communities themselves. In a national REDD+ programme, measuring leakage would have to be carried out at national level [13^{••}]. However, local knowledge of the drivers of deforestation and degradation, and of the specific locations of these, would be essential to develop an efficient and effective leakage monitoring plan.

Challenges and risks of community monitoring

In most of the literature the significant challenges and risks are recognized as those affecting the data supply and quality management – in other words issues from the REDD+ data user's side, but we consider also the risks from the community's perspective. The advantages and disadvantages of a community-based approach compared to a professional approach are summarized in Box 2.

The major risks to be addressed are ensuring data sufficiency for REDD+ reporting and the accuracy and reliability of the information, the costs and sustainability of CM, the degree of participation and involvement, and the distribution of burdens versus gains for local people.

Box 2 Advantages and disadvantages of community-based and expert-based monitoring [13^{••}].

Monitoring component	External consultants	Local community residents
Cost	High professional fees, travel and accommodation costs	High initial set-up and training costs followed by substantially lower salary, travel, accommodation costs over time
Local knowledge	Usually poor. Local guides and translators usually needed	Good. Residents typically know the area well in terms of access, logistics, local authorities, laws, and species names
Data quality	Good	Good, but dependent on appropriate training and data verification
Consistency	Potentially low if same consultants cannot continue with monitoring over lifespan of project	Potentially high if same team members or at least the same coordinators can be maintained
Intensity	Usually low. Too costly to spend long periods in field.	Good. Even if sampling is done part-time, substantial travel and set-up time is saved
Value addition	Low. Usually limited to technical input and PDD (Project Design Document) compilation	High. Project success depends on local resource users. Monitoring by locals creates ownership.
Spin-offs	Maybe for consultants' business, not for community.	Participation adds to the skills levels and capacity of local residents. Possible spin-offs to other community Payment for Environmental Services activities.
Management	Expected to be good	Potential area of concern in many communities.
Logistics	Consultants' flights, vehicles and accommodation costs are high. In remote areas, costs escalate when vehicles are needed.	If locally organised cheaper and more appropriate, for example working by foot or animal can be effective because field surveys are spread over time.
Initial inputs, for example time	Low. Assumption is that professional teams need relatively little preparation time	High. Takes more time to identify, train and equip teams
Collection of other important data, for example socio-economic information	Generally poor. Very challenging to understand local socio-economy and culture, time-consuming to collect the data	Good. In-built knowledge of local economy and culture; easy to collect initial information and monitor changes

Accuracy and reliability

Accuracy and reliability in carbon accounting are paramount for REDD+ and it will be important to establish that communities are capable of generating data which can meet the standards of the IPCC methodology.

For the case of carbon stock measurement, the procedures used follow standard scientific formats. In the KTGAL project, a study of community measurement of carbon stock was made in 39 sites across seven countries, over periods from three to six years [29,47]. In three cases, experts (professional foresters and scientists) were contracted to carry out stock measurement in forests which the communities had already measured. In all three cases, there were no significant differences in the estimate of mean stock or in the confidence level between the experts' measurements and the communities'. Variability of locally produced data is usually a consequence of different communities employing slightly different techniques, rather than lack of skill within the community [47]. Hence the variability of locally-based data can be reduced by standardising the techniques used. Reliability can be increased by increasing the sampling frequency – something that is more easily done by local communities living close to the forest resources.

There remains the proposition that community responsibility for monitoring may tempt the local leadership to exaggerate the carbon stock increases if they are rewarded on the basis of these. The use of permanent plots is also a concern, because permanent plots tend to be treated differently from the rest of the forest, by receiving extra care and attention to degradation drivers, especially when carbon finance payments to the community are tied to biomass data.

Costs and sustainability

Locally-based monitoring tends to have higher start-up costs associated with training and supervision [13^{••},48,49,50^{••}], but professional monitoring is more costly in the long run because of much higher expenditures associated with travel, field allowances, and salaries of experts [13^{••}]. Clearly, the lower the monitoring costs, the more financially sustainable a REDD+ project might be. Sustainability of monitoring is probably to be the bigger problem. A solution could be to make monitoring a condition for participation in REDD+, or to pay communities for the monitoring work itself.

Degree of participation

An extensive review of experiences and tools in community forestry monitoring [23] sets up a typology of community forestry monitoring in which the monitoring of carbon for REDD+ would hardly be considered 'participatory monitoring' at all: 'Participatory monitoring shifts the emphasis away from externally defined and

driven programs... It means involving...creating conditions so that they [communities] can dictate the focus, means and rhythm of the learning process' [51,23]. Nor can current procedures for carbon monitoring be considered as 'collaborative monitoring', which is seen as 'a process of conscious information seeking followed by shared critical analysis to inform collective decisions that affect resource management' [23,51].

In Figure 1 below, we locate the skills, capacities and activities needed by a community to become involved in CM, in terms of another categorization of monitoring schemes, that of Danielsen *et al.* [15^{••},16^{••}].

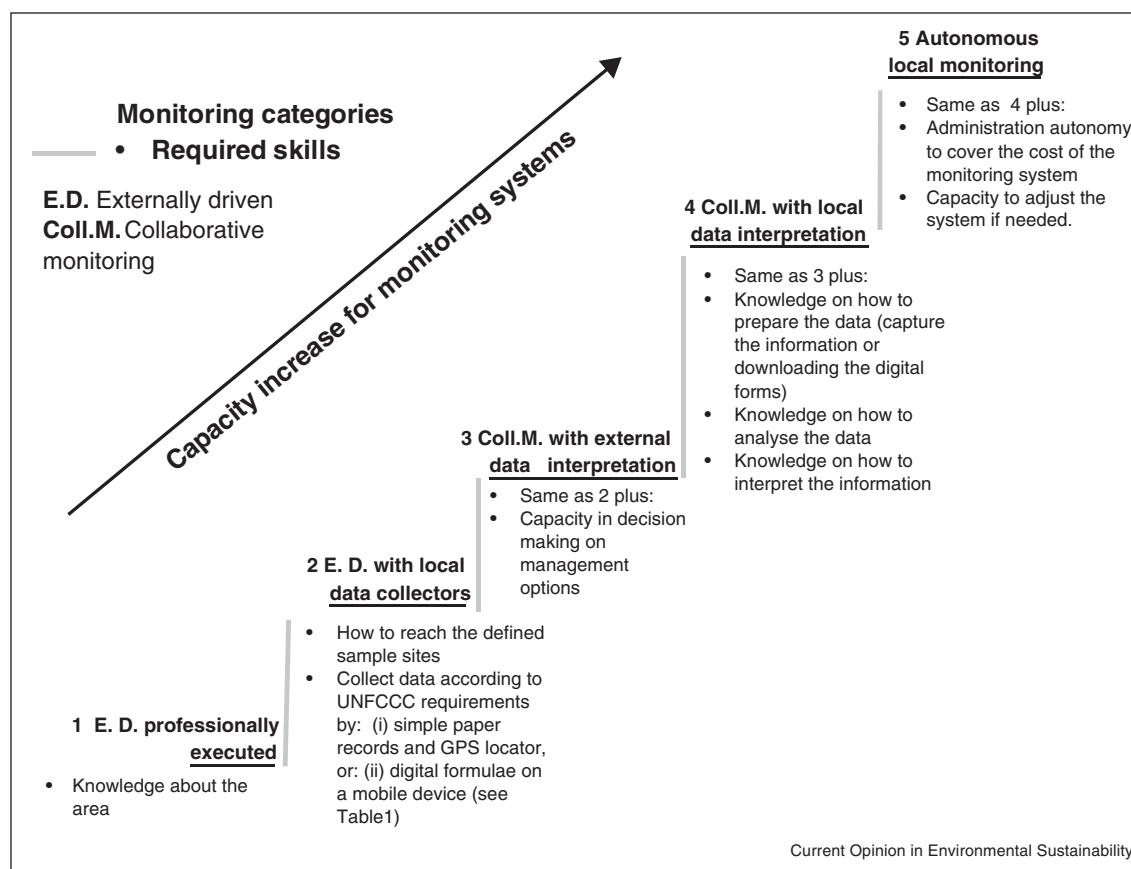
Community carbon monitoring is placed as part of category 2, with some aspects of category 3, because the design, analysis, interpretation, and the purpose of the carbon stock monitoring is primarily for the benefit of outsiders, that is global humanity. This will be particularly true for REDD+ entities. However, category 3 type participation could and should become more prominent for the non-carbon aspects of monitoring – for example, monitoring of community forest management methods, of deforestation and degradation drivers, and of safeguards [33,34].

The need for data across all REDD+ activities in a country to be consistent limits the degree of participation, since it implies that communities will not be able to design their own carbon monitoring protocols. Even if carbon credits are issued to local communities, so as to reflect their achievements in reducing forest emissions and enhancing forest stock, these carbon credits will be calculated on the basis of overall achievements at national level. Data from the community will have to conform to standard formats and protocols.

A clear distinction needs to be made between the tighter imperatives of the biomass/carbon monitoring data requirements of REDD+, and the broader, more flexible needs to monitor social issues such as, the community natural resources management (NRM) systems, the changes and drivers of degradation and deforestation, leakage, resource rights, social welfare and equity [34]. The design and operation of monitoring these latter elements should be a collaboration between the outside demands for 'hard facts' and the internal understanding and recognition of local conditions and local priorities.

The case for CM of biodiversity falls between these two [33]. Although the definitions and data requirements of biodiversity measurements and mapping are largely external, the perceptions and the interpretations of the local value of biodiversity and of its drivers are highly significant. It was recently suggested that the assessments of changes in biodiversity following REDD+ implementation could be greatly facilitated by paralleling

Figure 1



Typology of monitoring schemes and the community capacities and activities needed (utilising Danielsen *et al.*'s categories [16^{**}]).

the existing IPCC architecture for assessing carbon emissions [52]. This approach is not only a social–political position, the SBSTA text [53] states that there must be a management plan for carbon, social issues and biodiversity, before monitoring can even be considered, and, that communities must participate in developing these plans.

In most cases communities will not conduct monitoring wholly on their own, but with considerable support from external technical experts. Therefore an important option at the subnational level is for communities to share their capacities and help each other; similar to the call for networking of capacities between regional non-Annex I countries [54^{**}].

Burdens versus gains for local people

It could be argued that engaging local communities in monitoring for REDD+ sets up the transfer of the burden of monitoring and reporting requirements and their costs onto poorer local people. This is a risk if the process is not designed for equity, particularly if the community is not the direct recipient of the carbon credits. However, a bigger risk would be that of 'exclusion' if the national

authorities may apply for international credits using very rough (but cheaply derived) estimates of carbon savings based on satellite imagery. This would bypass completely the communities that actually manage the forests in terms of their inputs into the reporting process [50^{**}].

A monitoring system based on local people carrying out the required tasks is unlikely to be sustainable unless the benefits, financial and otherwise, of forest resources use are perceived and experienced locally. Monitoring is therefore most appropriate where local people have other significant interests in natural resource use or other environmental services. For the case of REDD+, there must be some return to the community, whether in the form of carbon credits or other.

Furthermore the case studies show that community members are more likely to be interested in long-term monitoring when they are actively participating in other natural resource management to which the monitoring is related. This is strengthened when they also participate in developing locally relevant indicators of changes and their drivers.

There is a strong parallel in that a community's participation in a REDD+ programme (independent of involvement in carbon monitoring *per se*) is much more probable if the community is already actively involved in the management of other environmental services and natural resources and aptly rewarded for it.

Conclusions and reflections

In many circumstances CM has advantages over conventional monitoring: it can provide otherwise-unavailable or irretrievable information, build local capacity and more equitable relations between local people and the authorities, it can be economically more efficient, and it can result in more rapid management interventions [11,16^{••}]. In the case of REDD+, CM can have additional advantages in empowering communities within the carbon crediting system.

From the community viewpoint there are nevertheless questions to ask about financial benefits, resources rights and entitlements. There are possible adverse effects on communities, such as the risk of funds not reaching the people who carry out the work as a result of mismanagement, corruption or elite capture [55]. There is also much concern raised regarding community rights over forest under REDD+ if credits are claimed only at a higher national or regional level [56,57].

When monitoring of carbon stock changes associated with CFM activities for REDD+ is devolved to the communities, their position within the whole REDD+ system is strengthened. Their 'worldview' can go through a scale expansion, and people can better understand the impacts of their forest management activities on carbon stocks. Also when knowledge of all-important data on stock change is in the hands of the community, they will be in a better position to negotiate for the rewards under REDD+. Ownership of, or at least full access to, these data could be the key to protecting their rights to such rewards [58,59^{••},60–66].

Communities need expert support, especially at early stages. These experts should be (a) locally sourced, (b) associated with a local NGO or cooperative that facilitates other environmental service-related knowledge transfer, including negotiations and marketing of carbon credits, (c) trained and willing to pass on their responsibilities to local communities, and (d) low cost. Their costs could be subsidized by forest user licences and fees, or as part of overall community capacity-building, or more appositely, be subsumed (in part) by the national state as part of the costs of national data collection.

CM has been shown to be as feasible and reliable as, and cheaper than, expert monitoring in a variety of natural resource monitoring situations; and the few studies on community carbon stock monitoring *per se* are generally in

accordance with this. However, if locally-based forest monitoring is to become a key element of the MRV of REDD+ schemes, further assessments are needed of the relative strengths and weaknesses of the different approaches and tools.

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