Available online at www.sciencedirect.com

SciVerse ScienceDirect

Current Opinion in Environmental Sustainability

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

Alejandra Larrazábal[1,2], Michael K McCall[1,2], Tuyeni H Mwampamba[3] and Margaret Skutsch[1,4]

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.

**Addresses**
[1] Centro de Investigaciones en Geografía Ambiental, Universidad Nacional Autónoma de México, Campus Morelia, 8701 Antigua Carretera a Patzcuaro old road, Col. Ex-hacienda San José de la Huerta, P.C. 58190 Morelia, Mexico
[2] Faculty of Geo-Information Science and Earth Observation, University of Twente. PO Box 217, 7523 CE Enschede, The Netherlands
[3] Centro de Investigaciones en Ecosistemas, Universidad Nacional Autónoma de México, Campus Morelia, 8701 Antigua Carretera a Patzcuaro old road, Col. Ex-hacienda San José de la Huerta, P.C. 58190 Morelia, Mexico
[4] Centre for Studies in Technology and Sustainable Development, University of Twente, P.O. Box 217, 7500 AE Enschede, The Netherlands

Corresponding author: Larrazábal, Alejandra (larrazabal@ciga.unam.mx)

**Current Opinion in Environmental Sustainability** 2012, **4**:707–716

This review comes from a themed issue on **Climate systems**

Edited by **Ingrid J Visseren-Hamakers, Aarti Gupta, Martin Herold, Marielos Peña-Claros** and **Marjanneke J Vijge**

For a complete overview see the Issue and the Editorial

Received 2 May 2012; Accepted 5 October 2012

Available online 3rd November 2012



http://dx.doi.org/10.1016/j.cosust.2012.10.008

## 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. Temperate conifer. |
| 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. | Shrestha [62] | Nepal | Lower temperate broad-leaved forest. Pine forest. |
| Comparison of carbon stock changes in four villages. | Zahabu and Malimbwi [44] | Tanzania | Woodland. Lowland. Montane forest. |
| Cutting edge technology model for measuring and monitoring forest carbon emissions. | Bey [40] | Nigeria | Lowland. Hill tropical forest. |
| First approach to an experience on carbon stocks measurement using cyber tracker in Michoacán state. | Peters-Guarin and McCall [39] | Mexico | Temperate forest. |
| To study the requirements of a system for planning and administering the production and sale of carbon services from small-scale landowners. | Tipper [63] | Mexico | Moist tropical forest. |
| Measuring carbon loss from forest degradation. | Danielsen *et al.* [50••] | India Madagascar Tanzania | Temperate forest. Dry forest. Miombo woodland. |
| Reforestation activities. | Leimona *et al.* [64] | Indonesia | Grassland Dry farmland. |
| To record the carbon outcomes of typical community forest management regimes. Assess local communities' capability of making carbon stock measurements themselves. | Skutsch and Ba [65] | Guinea Bissau Mali Senegal | 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 devise | Design devise | |
| 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••].

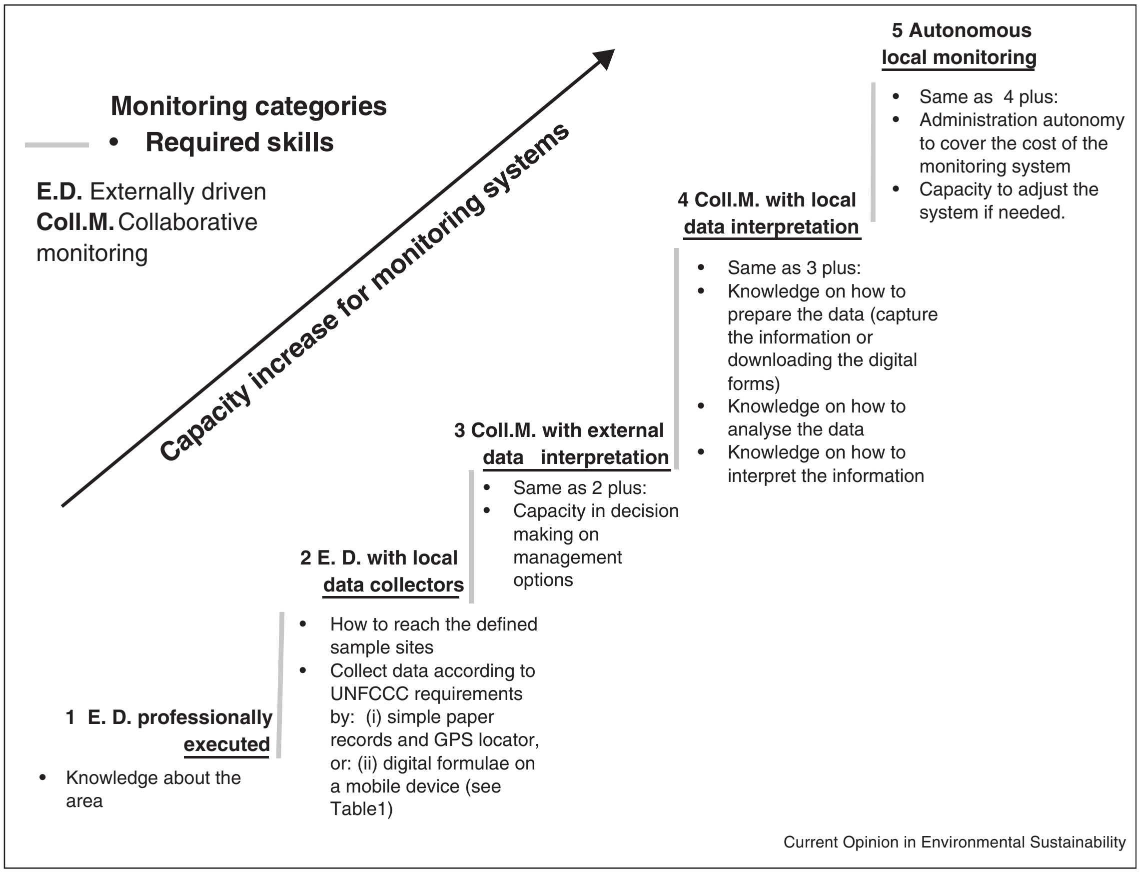
Community carbon monitoring is placed as part of category 2, with some aspects of category 3, because the design, analysis, interpretation, and the purpose of the carbon stock monitoring is primarily for the benefit of outsiders, that is global humanity. This will be particularly true for REDD+ entities. 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.

## References and recommended reading

Papers of particular interest, published within the period of review, have been highlighted as:

- • of special interest
- •• of outstanding interest


1. UNFCCC: **United Nations Framework Convention on Climate Change**. *Copenhagen Accord*. 2009. http://unfccc.int/meetings/copenhagen_dec_2009/items/5262.php.

2. Barker T, Bashmakov I, Bernstein L, Bogner JE, Bosch PR, Dave R, Davidson OR, Fisher BS, Gupta S, Halsnæs K *et al.*: **Technical summary**. In *Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.* Edited by Metz B, Davidson OR, Bosch PR, Dave R, Meyer LA. Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press; 2007.

3. Clements T: **Reduced expectations: the political and institutional challenges of REDD+**. *Oryx* 2010, **44**:309-310.

4. UNFCCC: **Decision 4/CP.15. Methodological guidance for activities relating to reducing emissions from deforestation and forest degradation and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries**. 2010.

5. SBSTA: **Draft text for a decision on methodological guidance for activities relating to reducing emissions from deforestation and forest degradation in developing countries: Approaches to stimulate action**. FCCC/SBSTA/2009/L.9 2009.

6. Van Laake P, Skutsch M, McCall MK: **Community forest monitoring**. In: *Reducing greenhouse gas emissions from deforestation, degradation in developing, countries. A sourcebook of methods, procedures for monitoring measuring, reporting*. Version COP 17 (November 2011). Edited by GOFC-GOLD (Global Observation of Forest Cover and Land Dynamics), ESA and Wageningen University, Land Cover Project Office. 2011.

7. Goldsmith B: *Monitoring for Conservation and Ecology*. London, UK: Chapman & Hall; 1991.

8. Spellerberg IF: *Monitoring Ecological Change*. New York, USA: Cambridge University Press; 2005.

9. Sutherland WJ: *Ecological Census Techniques*. New York, USA: Cambridge University Press; 1996.

10. Sheil D: **Conservation and biodiversity monitoring in the tropics: realities, priorities, and distractions**. *Conserv Biol* 2001, **15**:1179-1182.

11. Garcia CA, Lescuyer G: **Monitoring, indicators and community based forest management in the tropics: pretexts or red herrings?** *Biodivers Conserv* 2008, **17**:1303-1317.

12. Peters-Guarin G, McCall M: **Participatory mapping and monitoring of forest carbon services using freeware: cyber tracker and google earth**. In *Community forest Monitoring for the carbon market, opportunities under REDD.* Edited by Skutsch M. London, Washington DC: Earthscan; 2011:94-104.

13. •• Knowles T, McCall M, Skutsch M, Theron L: **Preparing community forestry for REDD+: Engaging local communities in the mapping and MRV requirements of REDD+**. In *Pathways for Implementing REDD+, Experiences from Carbon Markets and Communities.* Edited by Zhu X, Møller LR, de Lopez T, Zaballa Romero M. Technical University of Denmark; 2010: 156.

Based on fieldwork, this article presents the case for communities being permitted to make their own forest carbon inventories for the purposes of monitoring under national REDD+ programmes.

14. Reed MS: **Stakeholder participation for environmental management: a literature review**. *Biol Conserv* 2008, **141**:2417-2431.

15. •• Danielsen F, Mendoza MM, Tagtag A, Alviola Pa, Balete DS, Jensen AE, Enghoff M, Poulsen MK: **Increasing conservation management action by involving local people in natural resource monitoring**. *Ambio* 2007, **36**:566-570.

The authors compare the cost efficiency of participatory and conventional biodiversity monitoring methods in Philippines parks. The research found that a combined scheme is more cost effective.

16. •• Danielsen F, Burgess ND, Balmford A, Donald PF, Funder M, Jones JPG, Alviola P, Balete DS, Blomley T, Brashares J *et al.*: **Local participation in natural resource monitoring: a characterization of approaches**. *Conserv Biol* 2009, **23**:31-42.

The authors propose a categorization of the community monitoring systems based on the degree of participation and autonomy.

17. Balram S, Dragićević S, Meredith T: **A collaborative GIS method for integrating local and technical knowledge in establishing biodiversity conservation priorities**. *Biodivers Conserv* 2004, **13**:1195-1208.

18. Holck MH: **Participatory forest monitoring: an assessment of the accuracy of simple cost-effective methods**. *Biodivers Conserv* 2007, **17**:2023-2036.

19. Moller H, Berkes F, Lyver POB, Kislalioglu M: **Combining science and traditional ecological knowledge: monitoring populations for co-management**. *Ecol Soc* 2004:9.

20. Aswani S, Hamilton RJ: **Integrating indigenous ecological knowledge and customary sea tenure with marine and social science for conservation of bumphead parrotfish (*Bolbometopon muricatum*) in the Roviana Lagoon, Solomon Islands**. *Environ Conserv* 2004, **31**:69-83.

21. Luzar JB, Silvius KM, Overman H, Giery ST, Read JM, Fragoso JMV: **Large-scale environmental monitoring by indigenous peoples**. *Bioscience* 2011, **61**:771-781.

22. Danielsen F, Burgess ND, Jensen PM, Pirhofer-Walzl K: **Environmental monitoring: the scale and speed of implementation varies according to the degree of peoples' involvement**. *J Appl Ecol* 2010, **47**:1166-1168.

23. Evans K, Guariguata MR: **Participatory monitoring in tropical forest management**. *A Review of Tools, Concepts and Lessons Learned*. Bogor, Indonesia: Center for International Forestry Research (CIFOR); 2008.

24. Berkes F, Colding J, Folke C: **Rediscovery of traditional ecological knowledge as adaptive management**. *Ecol Appl* 2000, **10**:1251-1262.

25. McCall MK: **Seeking good governance in participatory-GIS: a review of processes and governance dimensions in applying GIS to participatory spatial planning**. *Habitat Int* 2003, **27**:549-573.

26. Doswald N, Zimmermann F, Breitenmoser U: **Testing expert groups for a habitat suitability model for the lynx Lynx lynx in the Swiss Alps**. *Wildl Biol* 2007, **13**:430-446.

27. Elbroch M, Mwampamba TH, Santos MJ, Zylberberg M, Liebenberg L, Minye J, Mosser C, Reddy E: **The value, limitations, and challenges of employing local experts in conservation research**. *Conserv Biol* 2011, **25**:1195-1202.

28. Colfer CJP: **The complex forest: communities, uncertainty and adaptive collaborative management**. *Resources for the Future*. Bogor, Indonesia: Center for International Forestry Research (CIFOR); 2005.

29. Skutsch M, Zahabu E, Karky BS, Danielsen F: **The costs and reliability of forest carbon monitoring by communities**. In *Community Forest Monitoring for the Carbon Market: Opportunities under REDD.* Edited by Skutsch M. London, UK: Earthscan; 2011.

30. Coleman EA, Steed BC: **Monitoring and sanctioning in the commons: an application to forestry**. *Ecol Econ* 2009, **68**:2106-2113.

31. McCall MK, Minang PA: **Assessing participatory GIS for community-based natural resource management: claiming community forests in Cameroon**. *Geogr J* 2005, **171**:340-356.

32. IPCC: **Good practice guidance for land use, landuse change and forestry (GPG-LULUCF)**. In *Good practice guidance for land use, land-use change and forestry*. Edited by Penman J, Gytarsky M, Krug T, Kruger D, Pipatti R, Buendia L, Miwa K, Ngara T, Tanabe K, FW, et al. Institute for Global Environmental Strategies (IGES) for the IPCC. Kamiyamaguchi Hayama, Kanagawa Japan. 2003.

33. Dickson B, Kapos V: **Biodiversity monitoring for REDD+**. *Curr Opin Environ Sustain* 2012, **4**:717-725.

34. Visseren-Hamakers IJ *et al.*: **Trade-offs, co-benefits and safeguards: Debating the breadth of REDD+**. *Curr Opin Environ Sustain* 2012, **4**:646-653.

35. Chhatre A *et al.*: **Social safeguards and co-benefits in REDD+: a review of the adjacent possible**. *Curr Opin Environ Sustain* 2012, **4**:654-660.

36. • Angelsen A: *Moving Ahead with REDD. Issues, Options and Implications*. Bogor, Indonesia: Center for International Forestry Research (CIFOR); 2008.

The book is a collection of articles ranging from political economy to technical issues around the development of REDD+ activities in the early stages. The articles adopted common criteria, known as three E's to evaluate the effectiveness, efficiency and equity of REDD+ activities.

37. McCall MK: **Local participation in mapping, measuring and monitoring for community carbon forestry**. In *Community Forest Monitoring for the Carbon Market: Opportunities under REDD.* Edited by Skutsch M. London, UK: Earthscan; 2011.

38. Verplanke JJ, Zahabu E: *A Field Guide for Assessing and Monitoring Reduced Forest Degradation and Carbon Sequestration by Local Communities*. Enschede, The Netherlands: University of Twente, K:TGAL programme; 2009.

39. Peters-Guarin G, McCall M: **Participatory mapping and monitoring of forest carbon services using freeware: Cybertracker and Google Earth**. In *Community Forest Monitoring for the Carbon Market, Opportunities under REDD.* Edited by Skutsch M, Earthscan. 2011:94-104.

40. Bey A: **Using technology to enable community based forest monitoring: from theory to implementation challenges and opportunities**. *Helveta* 2009.

41. Rana EB, Shrestha HL, Silwal R: **Participatory carbon estimation in community forest: methodologies and learnings**. *Initiation* 2010, **2**:91-98.

42. Bhishma PS, Shiva Shankar P, Ajay P, Eak Bahadur R, Sanjeeb B, Tibendra RB, Shambhu C, Rijan T: *Forest Carbon Stock Measurement Guidelines for Measuring Carbon Stocks in Community-managed Forests*. Nepal: Asia Network for Sustainable Agriculture and Bioresources (ANSAB); 2010.

43. Theron L-J: *Carbon Stock Quantification Training and Field Manual*. Stellenbosch, South Africa: Peace Parks Foundation, Climate Change Programme; 2009.

44. Zahabu E, Malimbwi RE: **The potential of community forest management under REDD+ for achieving MDG goals in Tanzania**. In *Community Forest Monitoring for the Carbon Market. Opportunities under REDD.* Edited by Skutsch M. London, UK: Earthscan; 2011:134-147.

45. Wilson JB: **Cover plus: ways of measuring plant canopies and the terms used for them**. *J Vegetation Sci* 2011, **22**:197-206.

46. Hopkinson C, Chasmer L, Young-Pow C, Treitz P: **Assessing forest metrics with a ground-based scanning lidar**. *Can J Forest Res* 2004, **34**:573-583.

47. Skutsch M, Van Laake PE, Zahabu E, Karky BS, Partiyal P: **Community monitoring in REDD+**. In *In Realising REDD+: National Strategy and Policy Options.* Edited by Angelsen A. Bogor, Indonesia: Center for International Forestry Research (CIFOR); 2009:101.

48. Rist J, Milner-Gulland EJ, Cowlishaw G, Rowcliffe M: **Hunter reporting of catch per unit effort as a monitoring tool in a bushmeat-harvesting system**. *Conserv Biol* 2010, **24**:489-499.

49. Topp-Jørgensen E, Poulsen MK, Lund JF, Massao JF: **Community-based monitoring of natural resource use and forest quality in montane forests and miombo woodlands of Tanzania**. *Biodivers Conserv* 2005, **14**:2653-2677.

50. Danielsen F, Skutsch M, Burgess ND, Jensen PM,
•• Andrianandrasana H, Karky B, Lewis R, Lovett JC, Massao J, Ngaga Y *et al.*: **At the heart of REDD+: a role for local people in monitoring forests?** *Conserv Lett* 2011, **4**:158-167.
This paper proposes 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 towards achieving REDD+.

51. Guijt I (Ed): *Negotiated learning: Collaborative monitoring in forest resources management.*. Washington, D.C., USA: Resources For the Future; 2007.

52. Gardner T, Burgess ND, Aguilar-Amuchastegui N, Barlow J, Berenguer E, Clements T, Danielsen F, Ferreira J, Foden W, Kapos V *et al.*: **A framework for integrating biodiversity concerns into national REDD+ programmes**. *Biol Conserv* 2011 http://dx.doi.org/10.1016/j.biocon.2011.11.018.

53. UNFCCC: **FCCC/SBSTA/2009/L.9 10 June 2009, SBSTA, 13th session, Bonn, 1.10 June 2009, Agenda item 5, Reducing emissions from deforestation in developing countries: approaches to stimulate action**. 2009.

54. Romijn E, Herold M, Kooistra L, Murdiyarso D, Verchot L:
•• **Assessing capacities of non-Annex I countries for national forest monitoring in the context of REDD+**. *Environ Sci Policy* 2012, **19**–**20**:33-48.
A desk study to assess the capacity gaps of 99 non-Annex I countries based on their profiles found in the REDD Readiness project documents submitted to the World Bank Forest Carbon Partnership Facility (FCPF). Country reports found in FAO's FRA 2005 and FRA 2010 were also examined.

55. Funder M: *Reducing Emissions from Deforestation and Degradation (REDD). An Overview of Risks and Opportunities for the Poor*. Copenhagen, Denmark: Danish Institute for International Studies (DIIS); 2009.

56. Lyster R: **REDD+, transparency, participation and resource rights: the role of law**. *Environ Sci Policy* 2011, **14**:118-126.

57. Corbera E, Estrada M, May P, Navarro G, Pacheco P: **Rights to land, forests and carbon in REDD+: insights from Mexico, Brazil and Costa Rica**. *Forest* 2011, **2**:301-342.

58. Corbera E, Schroeder H: **Governing and implementing REDD+**. *Environ Sci Policy* 2011, **14**:89-99.

59. Palmer Fry B: **Community forest monitoring in REDD+: the "M"**
•• **in MRV?** *Environ Sci Policy* 2011, **14**:181-187.
A desk study providing an up to date review of the relatively limited literature on locally based natural resource monitoring, looking at the inherent advantages it has over professional monitoring.

60. Karky BS, Skutsch M: **The cost of carbon abatement through community forest management in Nepal Himalaya**. *Ecol Econ* 2010, **69**:666-672.

61. MacDicken KG: *A Guide to Monitoring Carbon Storage in Forestry and Agroforestry Projects*. Arlington, VA: Winrock International Institute for Agricultural Development, Forest Carbon Monitoring Program; 1997.

62. Shrestha R: Participatory carbon monitoring: An experience from the Koshi Hills, Nepal. *Livelihoods and Forestry Programme, RECOFTC Newsletter.* 2011.

63. Tipper R: **Helping indigenous farmers to participate in the international market for carbon services: the case of Scolel Té**. In *Selling Forest Environmental Services. Market-based Mechanisms for Conservation and Development.* Edited by Pagiola S, Bishop J, Landell-Mills N. London, UK: Earthscan; 2002222-233.

64. Leimona B, Boer R, Arifin B, Murdiyarso D, Van Noordwijk M: **Singkarak: combining environmental service markets for carbon and watershed functions?** In *Community Forest Management as a Carbon Mitigation Option.* Edited by Murdiyarso D, Skutsch M. Bogor, Indonesia: Center for International Forestry Research (CIFOR); 2006:60-73.

65. Skutsch MM, Ba L: **Crediting carbon in dry forests: the potential for community forest management in West Africa**. *Forest Policy Econ* 2010, **12**:264-270.

66. Gupta A, Lovbrand E, Turnhout E, Vijge M: **In pursuit of carbon accountability: the politics of REDD+ measuring, reporting and verification systems**. *Curr Opin Environ Sustain* 2012, **4**:726-731.