Linking community-based and national REDD+ monitoring: a review of the potential

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Countries participating in REDD+ schemes are required to establish a national monitoring system that keeps track of forest carbon changes over time. Community-based monitoring (CBM) can be useful for tracking locally driven forest change activities and their impacts. In this paper, we review some of the key issues regarding CBM and options to link CBM and national forest monitoring systems. More specifically, we highlight the importance of local drivers of deforestation and degradation and, thus, the relevance of community involvement in REDD+ implementation and monitoring; we review the scientific literature to better define the role and technical conditions under which CBM can contribute to national level monitoring; we develop a conceptual framework for linking local and national monitoring; and we analyze and synthesize 28 REDD+ country approaches to CBM. Finally, we provide recommendations for integrating CBM data into national monitoring systems.

The IPCC has demonstrated that tropical deforestation and **forest degradation** (D&FD) generate a significant contribution to the increase of GHGs in the atmosphere [1]. In response to this, the UNFCCC is negotiating the details of a mechanism for REDD and enhancing forest **carbon stocks** in developing countries (REDD+) [2]. Currently, REDD+ includes five key activities, namely: reducing deforestation, reducing degradation, enhancing forest carbon stocks, sustainable management of forests and their conservation [3,4]. In addition to being an important step towards reducing emissions of GHGs, the UNFCCC REDD+ policy proposals include the issues of co-benefits and safeguards for biodiversity protection, sustainable livelihoods for local communities and the potential role of communities in monitoring efforts [3,4].

Countries wishing to participate in the international REDD+ mechanism will be required to establish a reliable, transparent and credible system of measuring, reporting and verification (MRV) of changes in forest areas and forest carbon stocks by REDD+ activities [5]. The key to MRV is a consistent monitoring system, which keeps track of these changes over time. Countries are further asked to identify the drivers of D&FD that cause the forest carbon changes, and they should establish reference levels, building upon available data while taking into account national circumstances and the anticipated impact of REDD+ implementation activities [6]. Involving communities, local expert groups and civil society in REDD+-related forest monitoring is important, not only in providing additional local data, but also in establishing a mechanism by which the broader public may be engaged in the REDD+ implementation process, particularly given the prospect of compensations and credits for carbon and other environmental services, and the need for benefit sharing [3,7,8].

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Key terms

Forest degradation: As further adopted by IPCC Good Practice Guidance, forest degradation is *"a direct human-induced long-term loss (persisting for X years or more) of at least Y% of forest carbon stocks [and forest values] since time T and not qualifying as deforestation or an elected activity under Article 3.4 of the Kyoto Protocol"*.

Carbon stock: As further adopted by IPCC Good Practice Guidance, carbon stock is the quantity of carbon in a 'pool', meaning a reservoir or system that has the capacity to accumulate or release carbon. Examples of carbon pools are living biomass (including above- and below-ground biomass), dead organic matter (including dead wood and litter) and soils (soils organic matter). The units of measurements are mass.

Community-based monitoring : The gathering systematic measurement of variables and processes by local people over a period of time. It is also referred as participatory monitoring or local-based monitoring.

A variety of practical experiences from countries such as Nepal, Tanzania, Cameroon, India and Mexico have demonstrated that local communities can play a vital role in forest monitoring and management programs [4,9,10]. **Community-based monitoring** (CBM) is of particular relevance in tracking locally driven change activities and causes of small-scale forest degradation; for example, subsistence fuelwood collection, charcoal extraction and grazing in the forest. The impacts of these activities are rarely captured accurately in national inventory databases of developing countries or in commonly available remote sensing data sources [11–14]. In these cases, data acquired by local people can include incidences of change events as well as their drivers, targeted ground measurements on forest carbon stock changes, and for tracking and reporting on local REDD+ implementation activities in the long term [4,15,16]. Several analogous cases of community environmental monitoring have been reported in Canada [17,18], the USA [19] and in other areas across the globe, indicating that CBM efforts are making an impact [20,21].

Despite the potential, CBM for REDD+ still faces challenges. First, rules for REDD+ implementation (under the UNFCCC) speak of national-level estimation and reporting requirements, while the CBM experiences so far have been of local scope. The link between national and local efforts remains largely unknown and unstudied; for example, the use of locally collected data is still challenged by the lack of suitable and agreed data collection protocols [16]. Second, practical approaches to stimulating and integrating community-acquired data in national REDD+ monitoring will likely work best if targeted and optimized for specific country and regional circumstances, taking into account the existing monitoring capacities, the drivers and types of ongoing D&FD processes, the existing roles and experiences of communities in forest management and conservation, and (national) priorities for REDD+ implementation activities. However, very little is known about these variables yet, and the long-term success of local monitoring programs will depend in part on sociocultural conditions as well as the sustained technical capabilities of the community members. Third, CBM-acquired data streams are sometimes challenged on the grounds that they do not have the quality, consistency and credibility of centrally generated data, although CBM data has rarely been formally assessed against data from professional forest inventories or remote sensing data at national level, despite the increasing number of local case studies. A few studies have shown that CBM data at project level is not significantly different from 'expert' data at this level but in a national REDD+ program there is also a need for consistency of CBM data between different parts of the country [22,23].

In this paper, we review some of the key issues and options available to better link CBM and national REDD+ monitoring, starting from the national perspective. More specifically, we:

- Describe the importance of local drivers of D&FD from a REDD+ implementation perspective, to highlight the importance and relevance of community involvement in REDD+ implementation and monitoring;
- Review the scientific literature to better define the role and technical conditions under which CBM can contribute a dedicated and independent stream of measuring and monitoring data to national level monitoring efforts;
- Develop a conceptual framework and discuss the key technical issues involved in linking local and national monitoring efforts;
- Analyze and synthesize the status of REDD+ country approaches in regards to CBM, based on a review of 28 readiness preparation proposals (R-PP) to the World Bank Forest Carbon Partnership Facility (FCPF). Based on this assessment, we draw conclusions and recommendations for enhancing REDD+ monitoring with the formal integration of community-acquired data into national MRV systems.

The review and assessments provided in these four sections are made from the broad perspective of likely requirements for MRV under international REDD+ policy, taking into account technical issues related to data integration and management, and we include a 'reality check' on how individual countries are advancing on these issues within their national REDD+ efforts. For the literature review, electronic databases such as Scopus, Web of Science, Google Scholar, national and international REDD+ reports and the FCPF webpage were searched. Search terms included 'CBM', 'locally based monitoring', 'participatory monitoring', 'capacity building' and 'community capacity', combined with 'REDD+' or 'MRV REDD+'. Literature from 2005 onwards (the year REDD was first proposed) was taken into consideration.

Based on this assessment, we present conclusions and recommendations that will help in the evolution

of REDD+ monitoring and enhance the integration of community-acquired data into REDD+ program planning under different national circumstances and priorities.

Importance of local D&FD drivers from a national REDD+ perspective

D&FD are caused by a variety of proximate and underlying driving forces at local, national and global levels [24]. Proximate drivers are human activities that directly affect forest change, such as agricultural expansion, wood extraction, charcoal production and livestock grazing. In the case of subsistence land use and wood extraction, local communities act as direct actors of change. Thus, their direct involvement in REDD+ activities is essential to plan, implement and monitor forest change successfully. For these kinds of D&FD processes, directly addressing local actors and drivers within REDD+ is even more critical and relevant than for other drivers such as urban expansion, mining and other commercial activities.

A recent study by Hosunuma *et al.* considered the relative importance of different D&FD drivers in developing countries based on a synthesis of national data [25]. **Figure 1** shows the contribution (relative importance) of local drivers to D&FD. We consider subsistence agriculture a local driver of deforestation, and charcoal and fuelwood extraction a local driver of forest degradation. Recently, it has been argued that commercial actors play an increasingly larger role in the expansion of agriculture into the forest, but locally driven D&FD is still a widespread phenomenon, especially in Africa and parts of Asia [24]. Countries that have a large proportion of locally driven forest change must give priority to these drivers in their national strategies and, as a consequence, must particularly consider the role of local communities. It is important that the differences between drivers of D&FD are understood, for they are in many cases quite distinct, as are the appropriate strategies to deal with them [26].

Importance of local communities in a national MRV system

The specific and different drivers, actors and processes behind D&FD need to be known, not only to determine what strategies should be included in the national REDD+ program to combat them, but also to develop effective approaches and methods to monitor them. Our concern here is with the potential role of CBM within a national monitoring system, and **Table 1** summarizes the niche for this by looking at broad forest change processes and comparing the potential of CBM with other approaches such as national inventories and remote sensing, for each of these change processes. **Table 2** evaluates the role of community-acquired data compared with other monitoring data sources.

▪ Community-based data in assessment of deforestation & reforestation

As shown in **Table 1**, forest area change and associated carbon stock changes from reforestation and deforestation are commonly monitored by remote sensing and forest inventory data sets at national level [27]. However, even in these cases there could be important contributions from data locally sourced by communities:

- REDD+ requires tracking forest changes resulting from human activities: local people can help to track these changes by signaling change events when they happen and can especially provide information on why they happen [28]. This information can be particularly useful when provided on a near real-time basis;
- REDD+ requires information about long-term performance: the capacity of communities to regularly revisit sites over long time periods means that implementation activities can be checked and verified;
- REDD+ MRV requires consistency, accuracy, comparability and transparency: the data and information coming from communities provides an additional independent data source that can serve as reference and validation for national datasets such as those originating from satellite-borne sensors [29].

Thus, while remote sensing techniques are certainly the main tools to be used at the national level to detect deforestation, community-generated data could be an important input to the analysis of deforestation and commercial degradation events [16]. CBM can help to verify remote sensing estimates and to signal new changes in near real-time (even before the remote sensing data have been made available or analyzed). Important information could include location, time, area and type of the change events, and in particular could specify the driver of change, since this cannot easily be identified by other means [28]. In this way, information acquired by communities and local experts can complement data derived independently at the national level using more established methods such as remote sensing.

▪ Community-based data in the assessment of degradation & forest enhancement

Degradation and forest enhancement assessments in many, if not most, cases require on-the-ground measurement as the changes in stock are often quite small on an annual basis and cannot easily be identified, let alone measured, using remote sensing; here there may be a major role for CBM. Expert or professional

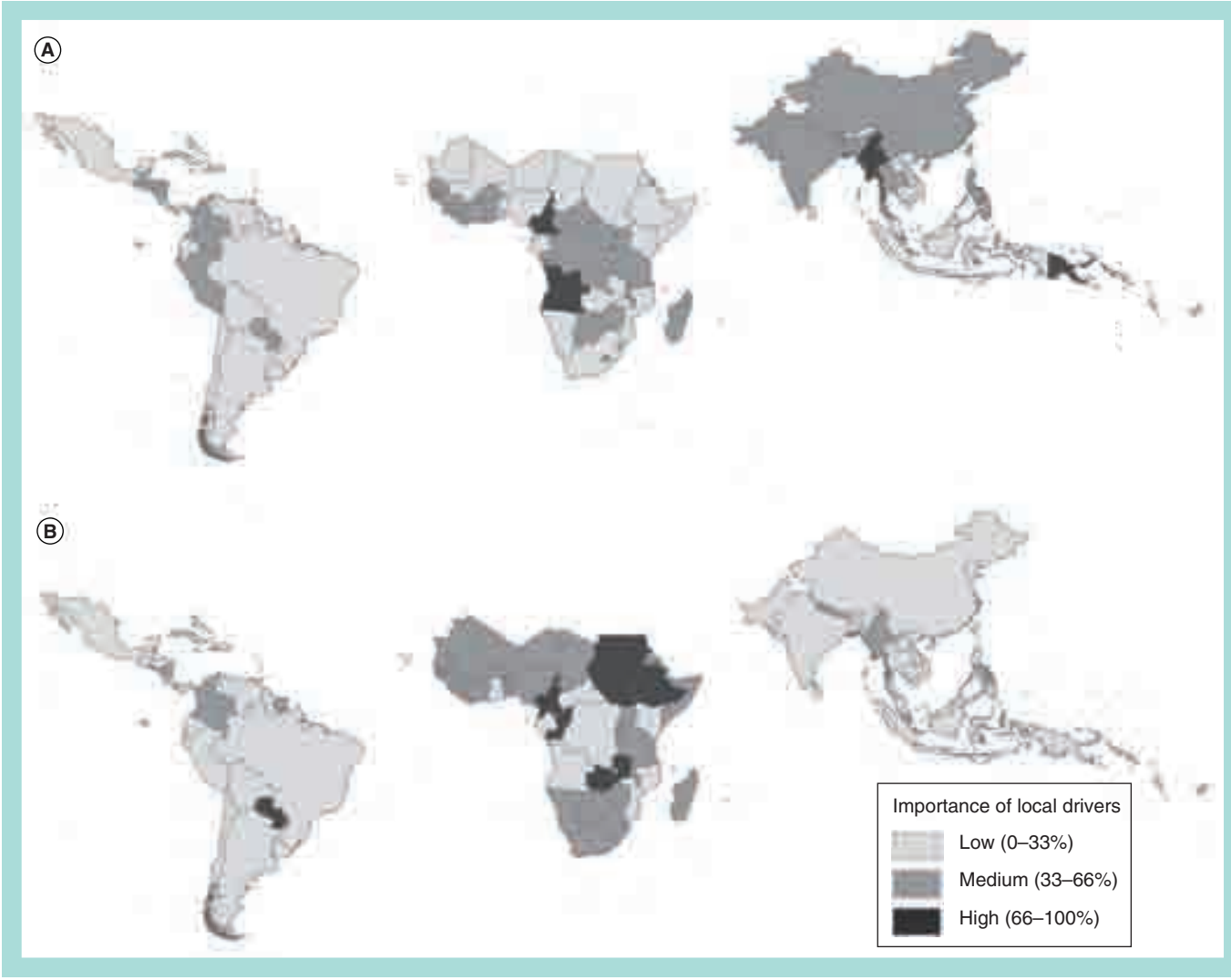

Figure 1. Relative importance of local drivers for deforestation and forest degradation. (A) Relative importance of subsistence agriculture as local driver of deforestation. **(B)** Relative importance of firewood/charcoal extraction as local driver of forest degradation. Low, medium and high importance denote that 0–33, 33–66 and 66–100% of deforestation/degradation is locally driven, respectively. Data taken from [25].

forest inventories collect ground-based measurements (e.g., tree height, diameter at breast height [DBH] and tree species) on plots selected through a sampling design, and use these to estimate forest carbon stocks and changes using allometric relationships, or using a biomass expansion factor [30]. This process is established but requires considerable resources, time and capacity. To date, only a few developing countries have established comprehensive forest inventories that allow for national forest carbon stock estimates [31]. Experience gained from studies conducted in Ghana, Tanzania [4,32] and the Philippines [33] shows that communities themselves can collect some forest inventory data adequately and more cost-efficiently than professional foresters. With proper field measurement equipment, hardware (e.g., GPS, personal digital assistant [PDA] and smart phone), software (user-friendly data forms) and training, it has been shown that local communities can accurately measure and record basic variables such as DBH, height, tree species and tree count. Most importantly, local communities can repeat these measurements on a regular basis. Data collected by local communities have proven to be of a level of accuracy comparable to that produced by professional forest inventory staff [34,35].

This may be particularly useful both to assess changes in rates of degradation within forests and to quantify rates of forest enhancement, particularly in areas that are under community management. Here, it will be essential for performance reporting in the case of local REDD+ implementation activities that are designed

Table 1. Comparison of data sources and observation methods, and the role of community-based monitoring for national REDD+ monitoring for different forest change activities.

Forest change activity		Monitoring options at national level	Potential contribution of community-based monitoring
Reforestation		Remote sensing, national forest inventory, monitoring through forestry companies	Acquiring/signaling the location, time, area and type of change events (in near-real time), ground level measurements for local implementation (i.e., of reforestation plots), independent local reference for national/other data sources
Deforestation		Remote sensing, national forest inventory	
Forest degradation	Commercial activities, including selective logging	National forest inventory, commercial companies (i.e., harvest estimates), remote sensing	
	Wild fire	Remote sensing, national forest inventory	Acquiring/signaling date, area and type of change event (near-real time)
	Subsistence forest use including fuelwood, charcoal, community forest management and so on	Limited historical data, possibly national forest inventory	Regular ground level measurements and reporting of forests and carbon stocks, tracking growth/decrease of local activities (drivers)
Forest enhancement	Increases in carbon due to REDD+ activities at project level		

Data taken from [27,28].

to address forest degradation caused by local fuelwood collection or grazing, and to measure the impacts of improved community forest management. Forest inventory-type measurements for forest enhancement, for example, maybe repeated each year and sites allocated for reforestation or sustainable management can be regularly checked. Even a proof of 'no change' is an important finding to ensure that new activities do not negatively affect the carbon performance of REDD+ implementation activities.

Table 2 further shows that forest change and carbon stock data can be acquired in many ways, from different sources. While there are preferred data sources for different change types (Table 1), the fact that phenomena can be observed independently from different data sources is important, for reasons of transparency, assessment accuracy, studying and estimating uncertainties, and to continuously improve the estimates at the national level.

A conceptual framework to link local & national monitoring

Opportunities to link local and national REDD+ monitoring are best considered in terms of contributions and relative benefits. If both sides contribute and benefit at the same time, a win–win situation can be created that can help to stimulate a suitable level of collaboration. Global Observation for Forest Cover and Land Dynamics provides some general guidance for evolving CBM and for conceptualizing how communities can be linked to national MRV in a mutually beneficial way [11]. In forming this link, it is clear that all monitoring processes need to follow the principle of consistency, transparency, comparability, completeness and accuracy [11,36]. Indeed, if well organized and systematic, CBM could provide a very strong basis for 'nested' systems of REDD+, allowing performance at the local or project level to be assessed within a national system of REDD+ [37,38].

Figure 2 highlights some of the contributions and potential benefits of linking CBM with national REDD+ MRV. Clearly, this relationship is likely to work best in countries where the engagement of communities to address local drivers has been identified as a key component in the national REDD+ strategy. In this case, actors at the national level are expected to provide strategies, incentives and policies that stimulate such community involvement in REDD+ implementation. Existing national data (i.e., maps, remote sensing images and so on) may be utilized (e.g., to identify areas at risk of deforestation/degradation or to identify areas of potential forest enhancement), capacity development (both for forest management and for monitoring) can be provided and potential revenue streams can be identified to support local efforts. In addition, national-level actors would need to provide a data infrastructure system such that locally acquired data could be uploaded, verified, disseminated and shared, thereby continuously improving the national monitoring efforts. Only consistent national-scale monitoring is capable of properly accounting for the displacement of emissions (leakage),

Table 2. Matrix to compare and evaluate the performance of community-acquired data with existing remote sensing and professional monitoring approaches at the national level.

Acquisition type	Forest inventory				Deforestation area			Degradation area				Cost per area
	Diameter at breast height	Height	Tree species	Number of tree per plot	Clearing for commercial purpose, agriculture forestry	Subsistence agriculture	Infrastructure expansion (e.g., road, mines and urban)	Selective logging	Fuel-wood	Forest grazing	Wildfire	
Coarse resolution (250–1000 m) satellite data	-	-	-	-	+	-	+	+	-	-	++	$
Medium resolution (10–60 m) satellite data	-	-	-	-	+++	++	+++	+	-	-	++	$$
Fine resolution (<5 m) satellite data	-	-	-	++	+++	+++	+++	++	+	++	++	$$$
Airborne laser scanning	-	+++	-	++	+++	+++	+++	++	++	++	++	$$$
Community-based monitoring	++	+	++	++	+	+	+	+	+++	+++	++	$
Professional forest inventory	+++	+++	+++	+++	++	++	++	+++	++	+	+	$$

-: Very low performance; +: Low performance; ++: Medium performance; +++: High performance; $: Low performance; $$: Medium performance; $$$: High performance.
Data taken from [4,11,13,27,48,49].

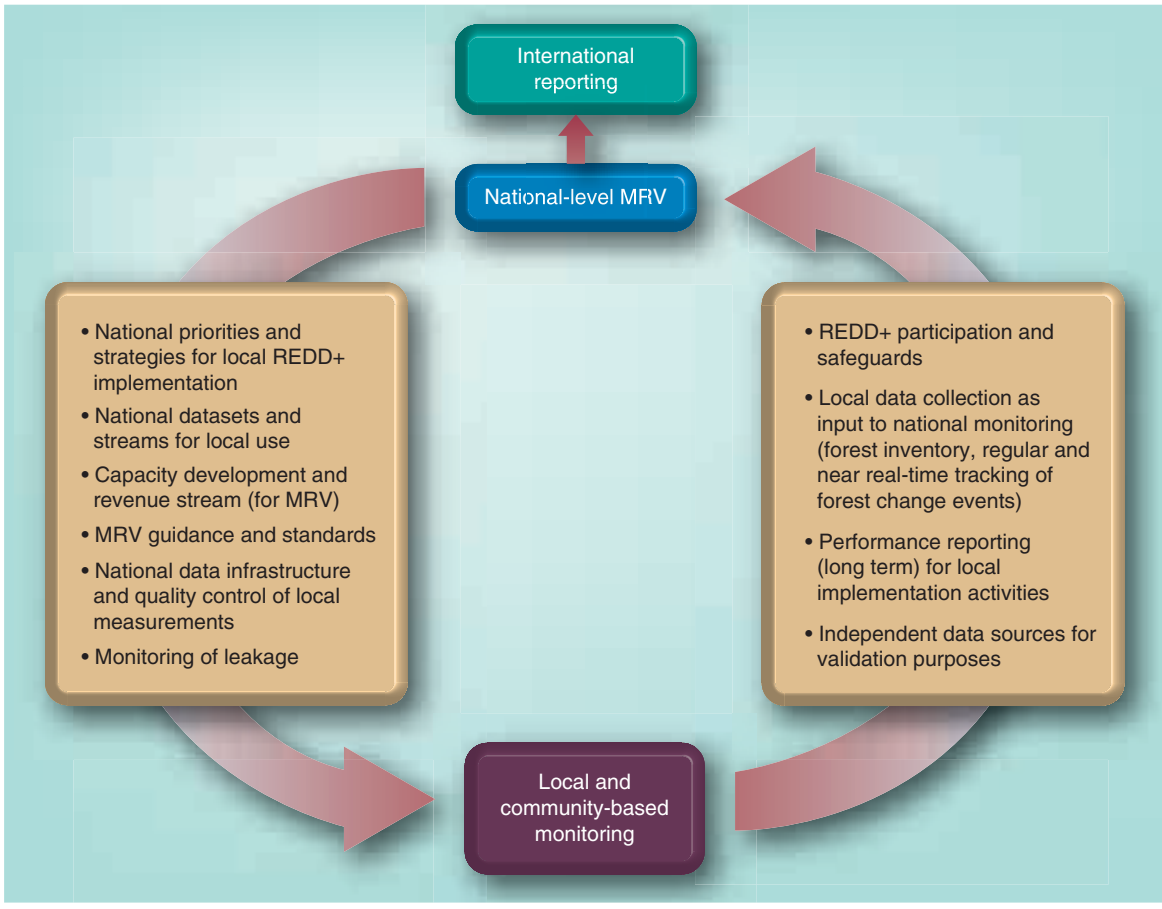

Figure 2. Contributions and benefits of community-based monitoring for national REDD+ measuring, reporting and verification.
MRV: Measuring, reporting and verification.

and a national data infrastructure system can thus provide a service to local-level activities.

In order for CBM to make an important contribution to the national-level emission reporting, a number of issues need to be considered. First, there should be a set protocol with standards and guidelines for data acquisition at community level, since systems used by communities should be consistent across the country. Second, communities should be made aware of the value of monitoring and should be trained in monitoring activities and related issues. Local data such as DBH, height, tree species and small-scale degradation, deforestation and reforestation activities can be acquired using different handheld technologies such as smart phones, tablet personal computers and PDA devices with integration of GPS, cameras and so on, provided these devices have user-friendly interfaces [39,40]. Third, the national implementing agencies would need to develop a robust system to collect and store the locally monitored data. In brief, a national-level strategy to process local data can be summarized as follows:

- Data collection system: the national government should design a system/protocol to collect and report CBM data. The community can easily provide these data to a national data repository if internet access or wireless networks are available;
- Integrating local data into national databases: national authorities should also develop quality standards to evaluate the quality of locally collected data and ensure overall data accuracy and consistency. Local data, if meeting all the national requirements, can then be integrated into the national database. The national database will be used to identify and analyze both areas of forest cover change and carbon stock change within forests;
- Information processing and analysis: the information will be processed, analyzed and translated into estimations of emissions and removals at the national level. The results can be reported according to the IPCC Good Practice Guidance [36] to an international body for carbon crediting.

One of the central elements of data exchange is quality control, which should be applied both to local- and national-level datasets. Table 2 shows that there is often more than one type of observation available for each parameter and, thus, data should be checked and (as far as practical) validated using an independent source. In this sense, light detection and ranging, fine resolution satellite data and professional forest inventories can be used in selected cases to check the monitoring provided by communities, at least on some variables. At the same time, local data on forest change events can be used to assess the quality of national forest area change monitoring using remote sensing. In addition, an open exchange and universal access to data is fundamental and important to ensure the issue of transparency.

A further aspect of CBM relates to the distribution of benefits among the many stakeholders that may have contributed to reduced emissions. At the international level, REDD+ is a performance-based instrument, and many observers believe that local stakeholders within a national REDD+ program should also be rewarded according to their carbon achievements. In practice, it is very difficult to attribute reductions in deforestation to individual communities, not least because this would require individual baselines, and accounting for leakage, but forest enhancement could easily be measured by annual carbon surveys at the local level and rewarded directly [41]. An alternative option might be for communities to be paid, not for their carbon achievements, but simply for carrying out the monitoring; for example, as part of a payment for environmental services scheme, given that this data strengthens the national forest monitoring system and provides a credible basis for the government to make carbon claims internationally.

CBM for REDD+ is new and the national investment needed for developing an institutional framework to provide technical and perhaps financial support to local monitoring activities needs to be explored. However, there is no country comprehensively implementing CBM schemes at the moment. Furthermore, there is a huge capacity difference among the country participating in REDD+, so it is difficult to assess what the national investment would be since it is dependent on country circumstances.

Overview & status of REDD+ country approaches

The FCPF of the World Bank is a global partnership focused on helping developing countries to develop coherent REDD+ national strategies, reference emission levels, MRV systems and implementation plans [101]. The FCPF also strongly emphasizes the role of local communities in the national REDD+ process. To date, 37 developing forest countries (14 in Africa, 15 in Latin America and the Caribbean, and eight in Asia-Pacific regions) are participating in the FCPF. Out of 37, 28 countries (summarized in Supplementary Table 1) have submitted their R-PP. An R-PP is a policy document submitted to the FCPF Committee and to the UN Collaborative Program on REDD. Key elements of the R-PP template include: readiness organization and consultation; REDD+ strategy preparation; reference emission level; and a MRV Systems for forests and safeguards.

A review of the proposed strategies, as outlined in their in R-PPs, of 28 FCPF countries has been performed (Supplementary Table 1) to assess community consultation, community involvement in monitoring, community involvement in forest management, the importance of subsistence agriculture as a driver for deforestation and the importance of fuelwood/charcoal extraction as a driver for degradation. Community consultation, and community involvement in monitoring and management, can take many forms. This assessment only considers whether any type of community consultation, CBM and forest management were mentioned in the R-PPs. Thus, we assess whether countries consider these options but not if and how these activities are actually happening in practice, since it is too early to make such an assessment. Furthermore, there is lack of consistency regarding the status of CBM in all R-PP countries and we need to develop common indicators and a framework for more detailed analysis, which is beyond the scope of this paper.

The analysis of country efforts highlights that these countries have rather different national circumstances and strategies to deal with them (Supplementary Table 1). Looking deeper into the link between the proposed strategies and the importance of local drivers for degradation (Figure 3) shows that all 28 FCPF countries have consulted with communities during the design phase of the R-PP and propose their participation during the implementation of the program. Different information sharing tools such as local newspapers, community radio and national television were used for community consultation during the design phase of R-PP. The relationship between CBM and/or community forest management and the importance of local drivers (e.g., fuelwood collection and charcoal production) for degradation is not clear cut (Figure 3). Countries with low importance of local drivers seem to engage more in CBM and management of forests than countries with high importance of local drivers for degradation (Figure 1) [25]. This could be for several reasons. Figure 3 shows that community-based management is often linked to community forest management, and whether countries involve their communities in forest monitoring might have more to do with a tradition of involving communities in forest management than with the importance of local drivers for degradation. In general, the link between analysis of

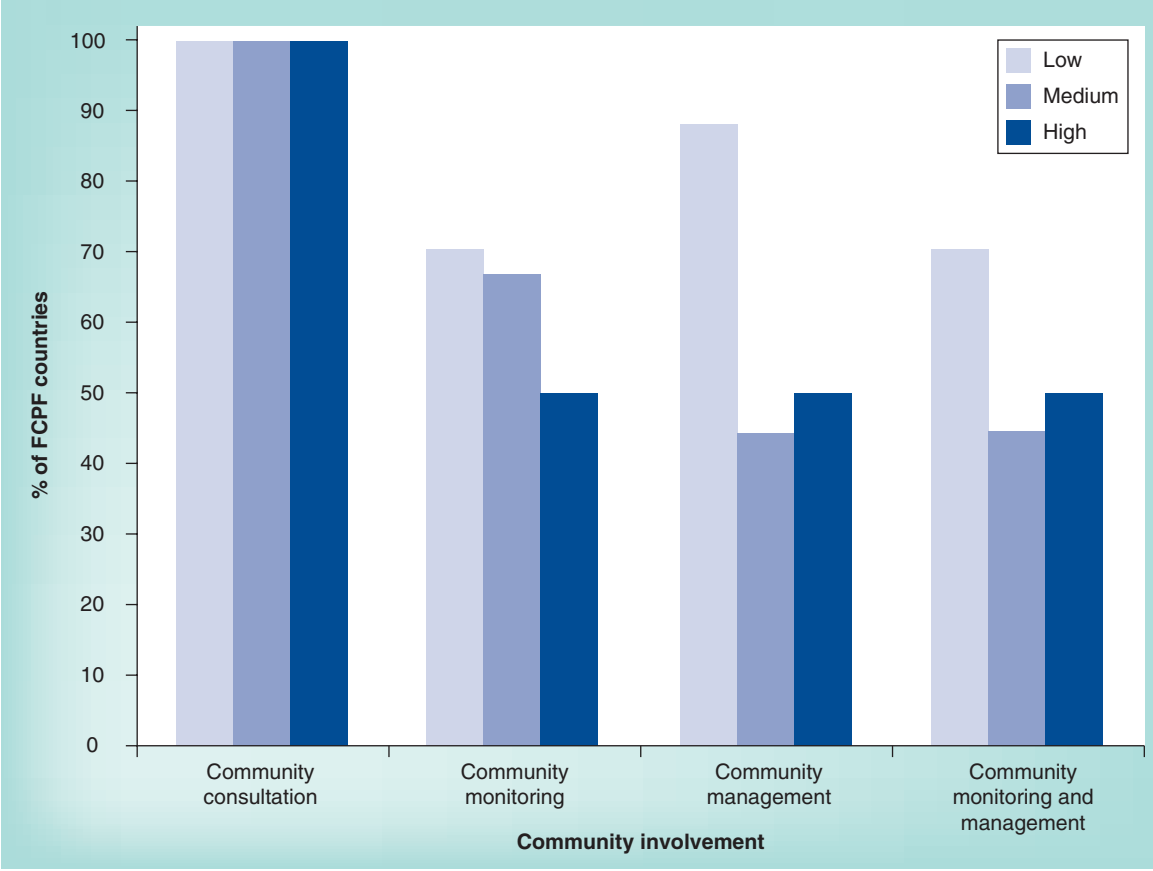

Figure 3. Community involvement as outlined in the readiness preparation proposals of 28 countries, regarding different levels of importance of locally driven degradation.
FCPF: Forest Carbon Partnership Facility.
Data taken from [25].

drivers of D&FD, REDD+ strategy development and MRV design is weak in most R-PPs [41].

In several of the R-PP countries, community involvement is a driving force to improve forest management and its sustainable use [42–44]. Some countries (in particular Mexico, Tanzania, Vietnam and Nepal [4,8,45]) are in advanced stages of developing community-based forest management and monitoring strategies (or systems), and have been able to demonstrate these activities at the project level. These countries have also provided more detail on the plans to involve local communities in monitoring and the results are presented and compared in Table 3. All four countries recommend that local participation should be based on already existing community forest management programs. Capacity building of communities will be done through government institutions, NGOs, academics and/or community leaders, depending on country circumstances. Furthermore, plans to involve local people in measuring forest parameters for aboveground biomass estimation are present. However, only two countries (Vietnam and Mexico) have also mentioned the involvement of local communities in monitoring forest area change per management unit. Case studies are available from Mexico, Nepal and Tanzania regarding forest carbon measurement, whereas only one case study is available from Mexico regarding forest degradation monitoring. All countries propose that national government institutions will provide the overall coordination, protocol development, information management, data evaluation and reporting to international level. Roles for subnational or regional units are foreseen and should focus on planning of forest area to be monitored, training material preparation, equipment lending and distribution of funds to initiate the activities. The local level, such as local governments and communities, is anticipated to contribute to data acquisition and data management. There is quite some congruency in the general plans of these four countries, and all approach the idea with a similar perspective, presenting the CBM concept as a two-way exchange process, outlined in Figure 2.

Table 3. Key elements of different proposals for community-based monitoring.

Activity		Functional elements	Example countries			
			Vietnam	Mexico	Nepal	Tanzania
Participation in monitoring		Forest usage rights allocated to communities	✓	✓	✓	✓
Responsibility for training and orientation		Government institutions	✓	✓	✓	✓
		NGOs		✓	✓	✓
		Academics	✓	✓		
		Community leader	✓			
Parameters of measurements		Forest measurement for aboveground biomass stocks	✓	✓	✓	✓
		Monitoring forest area change per management unit	✓	✓		
Number of case studies		Carbon stocks measurement†	0	2	2	2
		Forest degradation monitoring‡	0	1	0	0
Coordination and data management	National	Overall coordination, protocol development, information management, data evaluation and reporting	✓	✓	✓	✓
	Sub-national/ regional	General coordination planning of forest area to be monitored, training, equipment lending and funds to initiate	✓	✓	✓	✓
	Local level	Public participation, data acquisition, data management	✓	✓	✓	✓

†Carbon stocks measurement consists of the measurement of tree parameters; for example, diameter at breast height, height and species for deriving aboveground biomass.
‡Forest degradation monitoring represents the tracking of the area affected by forest degradation activities that cause the changes in forest carbon stocks.
Data taken from [4,8, 45,50].

Conclusion

The main aim of this paper was to study the prospects for enhancing the linkages between CBM and national REDD+ monitoring. The review and assessments provided here consider this from a national perspective, which is commonly lacking in the literature, since studies on community monitoring mostly consider only the local situation. The review also includes a broader international REDD+ priorities perspective, focusing on technical considerations, data integration and management, and provides a status check on how countries are advancing in considering CBM in their national REDD+ efforts. Several conclusions and recommendations can be made:

- The consideration of locally driven deforestation, and particularly forest degradation in national strategies and REDD+ implementation, as well as the link with the role local communities can play both in forest monitoring and management in many FCPF countries, is not always recognized. Information acquired by communities and local experts constitutes an increasingly justified and independent data stream for national level monitoring, where it may be complementary to the more traditional and established data streams. Local communities can play a useful role in ground monitoring of degradation and forest enhancement by measuring and monitoring forest carbon stocks, but they may also provide useful information on deforestation by signaling its occurrence in near real-time and its drivers (e.g., agriculture and mining). In addition, they can provide other ground-level information on the impact of REDD+ implementations activities on issues such as biodiversity and equal distribution of REDD+ benefits;
- Forest change and carbon stock data can be acquired in various ways and from different sources. There are preferred sources for different forest change types, with community-acquired data being most important for small-scale forest disturbance activities (i.e., degradation) that are more complicated to observe from other

data sources. The fact that the same phenomenon can be monitored independently from different data streams has many advantages as regards reliability, precision and transparency, and thus helps to continuously improve national-level estimations and reporting;

- The linkage between local CBM and national level efforts requires careful consideration of issues such as data transmission, data infrastructures, standards and guidelines, capacity development and flow of resources (e.g., equipment, supervision and incentives). Implementation will be most successful and efficient if both the local and the national level contribute and benefit at the same time, and a win–win situation can be created that can help to stimulate a suitable level of collaboration for integrated monitoring;
- Systematically gathered and reported CBM data could form the backbone of a nested REDD+ structure in which the efforts of different levels (local, subnational and national) are integrated into one MRV system [46]. It could even form the basis for a system of benefit sharing, since it would help determine the performance of different communities or land owners at a local level, which could be used as the basis for allocation of rewards or payments [47].

These results emphasize why and how it is useful for countries to build into their MRV systems an explicit role with specified tasks for CBM. However, it is to be recognized that monitoring capacities in many countries are still rather low and the development of these capacities will take time and resources. So far, dedicated country efforts (i.e., for Vietnam, Mexico, Nepal and Tanzania) have reflected and recognized the importance and the elements of such an integrative monitoring framework, but have not yet moved beyond including these considerations in their general plans. It is expected that these efforts will continue and that they could be enhanced by considering some general principles that have been emphasized in this review:

- The role of communities could be defined for specific REDD+ monitoring efforts, carefully selected to dovetail with and support national monitoring procedures, and this may vary from country to country;
- CBM data could form the basis for a nested system and even for the distribution of rewards within a national REDD+ program;
- There is a need for creating a win–win situation with the local and the national level contributing and benefiting at the same time. Local data streams may be integrated with other national data sources and monitoring efforts;
- Investing in further demonstration activities and research will help to better link the local and national monitoring in practice and for different country circumstances.

Future perspective

Over the next 5–10 years, the involvement of local communities will be a vital data source in REDD+ monitoring and integration with national REDD+ reporting, and implementation could create joint benefits. Advancements in handheld devices such as smart phones and PDA devices will improve local participation within the monitoring program. This will stimulate a near real-time data stream from satellites and the local communities that can serve a new way of monitoring forest carbon and its change.

To make local data useful on the national level, there are a number of key technical issues to be addressed. There will be a need for systematically developed methods, common guidelines and quality control mechanisms for CBM. Dedicated tools such as smartphones and PDA, incorporated with user-friendly applications, are required to facilitate data collection and transmission for local communities.

Furthermore, ongoing nested MRV structures are expected to narrow the gaps of different levels (local, subnational and national) monitoring data for effective REDD+ implementation [47].

Supplementary data

To view the supplementary data that accompany this paper please visit the journal website at: www.future-science.com/doi/suppl/10.4155/CMT.12.75

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Executive summary

Background & objectives

- REDD+ includes reducing deforestation, reducing degradation, enhancing forest carbon stocks, sustainable management of forests and their conservation.
- REDD+ mechanism requires a reliable, transparent and credible system of measuring, reporting and verification system for forest carbon stocks and its changes activities.
- Community-based monitoring (CBM) is being seen as increasingly useful, in particular for tracking locally driven change activities and their impacts.
- The main objective of this paper is to review some of the key issues and options available to better link CBM and national REDD+ monitoring, starting from the national perspective.

Importance of local drivers form a national REDD+ perspective

- Communities can act as direct drivers or local actors of forest carbon change in the case of subsistence agriculture (deforestation) and fuelwood collection/charcoal production (degradation).
- Locally driven deforestation and degradation is still widespread phenomena.
- It is important to consider the role of communities in national strategies for REDD+ monitoring and implementation.

Importance of local communities in national measuring, reporting & verification systems

- Local communities can provide information on forest change events, and their causes, in near real-time and for long time periods (revisits).
- CBM data provides an additional independent data source, useful for validation of national datasets.
- CBM can accurately and efficiently gather ground-based data on forest degradation and enhancement.

A conceptual framework to link local & national monitoring

- By creating a win–win situation (both sides contribute and benefit) a suitable level of collaboration between local and national level can be stimulated.

Overview & status of REDD+ country approaches

- To date, 37 developing forest countries have applied to participate in the Forest Carbon Partnership Facility.
- A total of 16 out of 26 countries with low to medium contribution of local drivers to degradation have proposed community involvement in both monitoring and forest management, whereas the remaining countries suggest engaging in one of these activities.

Conclusion

- Many Forest Carbon Partnership Facility countries recognized that the role of local communities will be important in monitoring locally driven deforestation and forest degradation activities.
- Information acquired by communities and local experts constitutes an independent data stream for national level monitoring.
- Community-acquired data is most important for small-scale forest disturbance activities (i.e., degradation) that are more complicated to observe from other data sources such as remote sensing and professional forest inventory.
- The linkage between local CBM and national-level efforts requires careful consideration of issues such as exchange of data, data infrastructures, standards and guidelines, capacity development and flow of resources.
- Systematically gathered CBM data and reported activities could form the backbone of a nested REDD+ structure.

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