Forests **2014**, *5*, 1815-1833; doi:10.3390/f5081815

OPEN ACCESS

forests

ISSN 1999-4907

www.mdpi.com/journal/forests

Article

Potential for Integrating Community-Based Monitoring into REDD+

Arturo Balderas Torres [1,2]

[1] Centro de Investigaciones en Geografía Ambiental, Universidad Nacional Autónoma de México (UNAM), Antigua Carretera a Pátzcuaro 8701, Morelia, Michoacán CP 58190, Mexico; E-Mail: abalderastorres@gmail.com

[2] CSTM, Twente Center for Studies in Technology and Sustainable Development, University of Twente, Postbus 217, Enschede 7500 AE, The Netherlands

Received: 10 April 2014; in revised form: 3 July 2014 / Accepted: 10 July 2014 / Published: 28 July 2014

Abstract: Countries at the United Nations Framework on the Convention on Climate Change (UNFCCC) have decided to engage local communities and indigenous groups into the activities for the monitoring, reporting and verification (MRV) of the program to reduce emissions from deforestation and forest degradation and increase carbon removals (REDD+). Previous research and projects have shown that communities can produce reliable data on forest area and carbon estimates through field measurements. The objective of this article is to describe the framework that is being created for REDD+ under the UNFCCC to identify the potential inclusion of local information produced through community-based monitoring (CBM) into monitoring systems for REDD+. National systems could use different sources of information from CBM: first, local information can be produced as part of public programs by increasing sample size of national or regional inventories; second, government can collect information to produce carbon estimates from on-going management practices implemented at local level driven by access to local direct benefits (e.g., forest management plans, watershed conservation); third, national data systems could include information from projects participating in carbon markets and other certification schemes; and finally information will be produced as part of the activities associated to the implementation of social and environmental safeguards. Locally generated data on carbon and areas under different forms of management can be dovetailed into national systems and be used to describe management practices, complement existing information or replace Tier 1/2 values with more detailed local data produced by CBM.

Keywords: benefit sharing; carbon inventories; participatory schemes and mapping

1. Introduction

REDD+, the international policy to reduce emissions from deforestation and forest degradation and to promote the conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries is part of the efforts to mitigate climate change under the United Nations Framework Convention on Climate Change (UNFCCC). It is one of the activities developed in the Bali Action Plan for long-term cooperative action [1] and aims to provide incentives to developing countries to reduce emissions from deforestation and forest degradation and to enhance carbon stocks. In 2009, developing countries aiming to participate in REDD+ were requested to create a robust and transparent National Forest Monitoring System (NFMS) to estimate anthropogenic emissions and removals by sinks, forest carbon stocks and forest area changes [2]; however capacities required for this among many countries still need to be developed [3]. At the Conference of the Parties (COP) in Copenhagen (COP 15) the need to engage indigenous groups and local communities in monitoring and reporting activities in REDD+ was recognized and countries were encouraged to prepare appropriate guidance for it [2]. Ever since, countries have started to design and implement systems to monitor carbon in forests. The objective of this work is to review different elements of the design and implementation of national REDD+ programs in order to identify potential options for integrating community based monitoring (CBM) as means for generation of information at the local level to fulfil requirements of monitoring, reporting and verification (MRV).

The document discusses the potential for up-scaling and dovetailing local information as part of the national forest monitoring system (NFMS) and the associated MRV system of REDD+. The opportunities for CBM are identified by considering the general methods available for the estimation of carbon content and forest area [4]. This document presents first a description of the main decisions adopted by the COP of the UNFCCC related to REDD+; this is followed by the identification of the opportunities for CBM within the framework for national programs stemming from the UNFCCC; later the potential contribution of CBM to the different elements within REDD+ is described; then options for integrating CBM into national MRV and NFMS are discussed.

2. REDD+ and CBM

Rural communities can gather field data in the context of climate change mitigation instruments such as REDD+ via CBM (e.g., [5]). CBM can help to link remote sensing and national forest inventories of carbon stocks to local implementation and measuring carbon from forest degradation in REDD+ [6]. The design of MRV systems for REDD+ will depend on specific management objectives selected in national programs, the resources available and other factors as accessibility to the sites. With appropriate design and planning, local monitoring schemes can help reducing costs, increase accuracy and precision and facilitate the use of local data for national and international monitoring schemes [7].

REDD+ is a program that will be implemented in three general phases (*i.e.*, preparedness, implementation and full monitoring of results-based activities) [8]. It includes five activities to mitigate climate change (*i.e.*, reduced deforestation, reduced forest degradation, conservation of forest carbon stocks, sustainable management of forests and carbon enhancements); these activities should be implemented with the full participation of relevant stakeholders, particularly indigenous groups and local communities [9]; environmental and social safeguards need to be implemented in all the phases of REDD+ [9]. The assessment of results-based actions will require the establishment of national level reference emissions levels and forests reference levels measured in tCO_2e/yr (REL/RL) [9]. The information used to establish these baselines needs to be consistent with the information contained in the National Inventories of Greenhouse Gases Emissions and Removals by Sinks (NGHGI) and can be established following a step-wise approach (*i.e.*, this refers to the incorporation of better data and methods to transit from systems based on international default data -Tier 1- to national level –Tier 2- and locally produced data -Tier 3-) [9].

NGHGI are elaborated following the guidance and guidelines published by the Intergovernmental Panel on Climate Change [4,10–12]. For REDD+, developing countries were asked initially (in 2007) to use the most recent guidelines first for the estimation of emissions from deforestation and two years later to estimate carbon stocks and forest area changes [1,2]. In Cancun (COP 16), non-Annex I countries were instructed to use guidelines presented in IPCC, 2003 to estimate forest related emissions and removals by sinks as part of their NGHGI [8]; this signifies an improvement in the use of more recent methodologies and a more comprehensive approach since the other sections of the inventories of non-Annex I countries are based on the 1996 revised guidelines IPCC [10] where the Land-Use Change and Forestry section is methodologically limited [4].

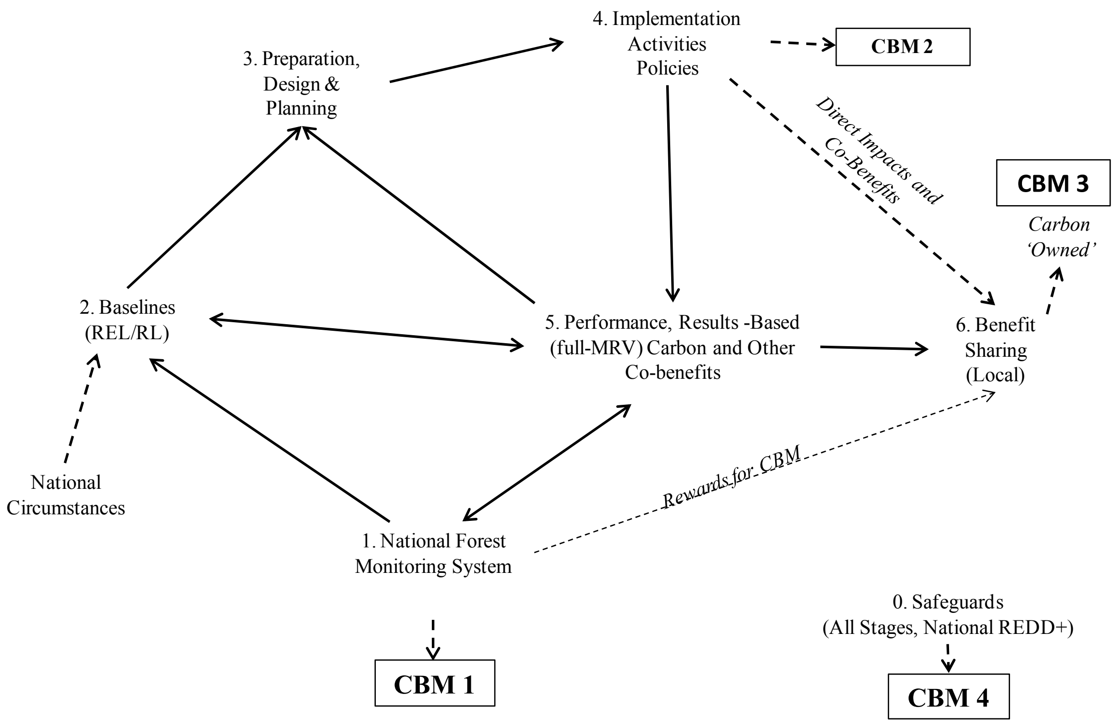
In order to access results-based finance, results-based actions need to be subjected to full MRV [9]. Mitigation activities implemented by non-Annex I countries seeking international support would be subjected to international MRV [2]. During 2013 steps taken towards the implementation of REDD+ under UNFCCC included the discussions on the possible ways to pay for results-based actions and incentivize non-carbon co-benefits [13]; thus co-benefits would need to be quantified and monitored and appropriate baselines may need to be developed.

In REDD+ the aim is to develop a MRV system to evaluate results consistently with the NFMS and NGHGI to produce detailed data with high level of resolution and low levels of uncertainty based on IPCC guidelines. The step-wise implementation requires transiting from the use of data of Tiers 1 and 2 to Tier 3 for emissions factors and from general statistics on forest area (e.g., from FAO), to geographical and temporally explicit information with high levels of resolution and frequent updating for the representation of land. In practice a large effort will be required to produce detailed geographical information and data of the different carbon reservoirs and changes in stocks at local level. CBM offers an opportunity to advance in the step-wise monitoring process for REDD+ by including more measurements and carbon stocks, and also due to the fact that it can allow the mapping of the areas with different forest management practices (Management Units); this is essential to understand the effectiveness of activities implemented in REDD+.

3. Opportunities for CBM in REDD+

The decisions adopted by the COP have highlighted the pertinence of including CBM comprehensively as part of the MRV system of REDD+. However it is necessary to identify the specific opportunities and modalities for the inclusion of CBM into the MRV system for REDD+ considering different types of activities and policies that can be implemented. Figure 1 presents a schematic summary of the different steps for the implementation of REDD+ based on the rules and framework that are being built within the UNFCCC and the potential for including information generated through CBM into the NFMS.

Figure 1. General Process for implementing REDD+ and opportunities for CBM; solid lines indicate the expected implementation process of REDD+; dotted lines refer to expected local benefits and options for community based monitoring (CBM).



In the international arena, REDD+ is based on the notion of results-based finance at country level. The assessment of results requires a strong and reliable NFMS that meets international standards as regards data requirements. The process described in Figure 1 starts from the NFMS, which is one of the first requirements for countries interested in REDD+ (1 in Figure 1). The NFMS, based on IPCC guidelines and consistent with NGHGI, is one of the inputs needed for the establishment of national baselines (REL/RL) (2), which will be based on historical trends of deforestation and degradation, but which may be adapted to take into consideration national circumstances. The REL/RL together with the understanding of the drivers of emissions, and barriers to adoption of sustainable practices, provide an important input for the design and preparation of REDD+ actions and policies (3). Once the activities are implemented (4) then results need to be subjected to MRV (5). Steps 3 to 5 represent roughly the phases for the implementation of REDD+ and might include different processes and activities within each of them. Depending on the evaluation of performance against the baselines it will be possible to evaluate whether or not there would be access to results-based finance; in which case the following step would be to identify mechanisms for benefit sharing (6). Each country should design its own schemes for internal sharing of the financial benefits that flow to the country as a result of its overall performance. The evaluation of performance is made by comparing the results against the reference levels (from 2 to 5); however results serve to update the baselines (from 5 to 2), to revise the REDD+ policies and strategies based on the observed effectiveness for the next period of implementation (from 5 to 3), and to update information in the NFMS (5 to 1). In all the stages safeguards need to be implemented (0); however, in order to keep the diagram simple, arrows are not included to link safeguards to the other stages. The process will be iterative during the transition from the preparedness and implementation stages until activities are fully implemented and subjected to full MRV. REDD+ will be the umbrella that brings together and consolidates different initiatives to manage forests sustainably; some of these are activities already in operation and others still need to be defined.

Figure 1 identifies four different ways in which data from CBM could be integrated into the MRV system: first, CBM can potentially provide information of carbon stocks and forest area to feed the NFMS which contributes in setting the REL/RL (CBM-1 in Figure 1); the second case refers to the information on activities which may be set up by communities primarily for non-carbon purposes (e.g., timber, water, biodiversity, farming improvements *etc.*), this information may not be expressed as carbon figures but could be used to derive these estimates (CBM-2); the third case is the information on changes in carbon stocks produced by independent carbon projects or by stakeholders participating in REDD+ activities promoted by national governments (CBM-3); and finally, CBM can provide feedback on the local implementation of safeguards (CBM-4). Table 1 presents a brief description of the potential challenges associated with these four CBM types that may contribute to national REDD+.

For CBM 1 it is clear that if the main purpose of carbon monitoring is solely to increase the sample size of the national forest inventory, communities would need to be compensated and paid accordingly (e.g., based on the time they invest in the monitoring); one feasible option is to include these practices as an obligatory activity within existing forest management public programs. For CBM 2, the burden of monitoring would be much less, but some incentive might have to be arranged to encourage reporting on these activities from the local level; not all communities may have capacities or the will to organize and commit to this kind of monitoring. The challenge would be first to create the appropriate levels of social capital to facilitate this process. For CBM 3, the monitoring of stock changes would be an integral part of the REDD+ activity on the ground, and the cost of monitoring would be considered a transaction costs to be covered by carbon markets or from a national benefit distribution system. It will be necessary to create the appropriate agreements for information and benefit sharing related to CBM 2 and 3 since the communities will own the information. For CBM 4 it is still not clear what type of activities could be done by communities to monitor the implementation of safeguards and hence it is not possible to assess the kinds of monitoring or costs involved. In all cases it is necessary to evaluate labor availability for CBM activities since agricultural practices have different demand for labor throughout the year.

Table 1. Description of general opportunities for CBM in REDD+ and main challenges.

Type	Description	Main Challenges
CBM 1	(1) Data gathered to increase sample size of national inventories usually made by professionals. (2) Information collected as part of other public programs.	(1) Methodological consistency across communities and quality assurance. (2) Training and capacity building. (3) Analysis and management of data with different geographical sampling intensity since not all communities will participate.
CBM 2	(1) Detailed information on activities implemented (for characterization of management units). (2) Information usually not expressed in terms of carbon (e.g., timber volume) but data could be used to estimate carbon stocks/changes.	(1) Very heterogeneous data generated depending on local context: activities implemented and co-benefits of interest. (2) Need to harmonize methodological approaches, including qualitative variables and proxies and need to integrate them into national MRV system. (3) There might not be information of all carbon reservoirs. (4) Communities own the information; it is necessary to explore potential integration onto national systems.
CBM 3	(1) Information produced as part of: - Participation in independent projects in the carbon markets - Certification schemes (e.g., FSC); or- Decentralized activities/programs promoting REDD+.	(1) Training/capacity building for advanced methods is required (e.g., Tier 3). (2) Some activities take place in non-forest lands (*i.e.*, afforestation/reforestation, pastureland management). (3) Need to harmonize methodologies from carbon markets and that from NFMS/MRV. (4) Challenge to harmonize baselines of project based approaches *versus* regional/national approach. (5) As in CBM 2 communities own the information, need to explore integration onto NFMS. (6) Risk of possible double counting, environmental integrity of estimates. (7) Implementation constrained by level of carbon prices; monitoring is a large part of transaction costs.
CBM 4	(1) Monitoring of safeguards; this will involve non-carbon variables.	(1) Still it is not clear how safeguards will be implemented in all stages of REDD+. (2) It is necessary to harmonize protocols and processes to monitor social and environmental (biodiversity) if they are to be integrated into the NFMS.

Benefit Sharing

In Figure 1 it is shown that the implementation of REDD+ could produce at least three different flows of benefits to local communities in addition to climate change mitigation: compensation for collaboration for producing information for NFMS (e.g., wages for community forest inventory brigades) (CBM 1); benefits from the participation in carbon based market mechanisms (*i.e.*, carbon payments) (CBM 3); finally in CBM 4 benefits will relate to the possibility of maintaining presence and influence in the implementation process of REDD+ and possibly designing an agenda according to local interests. It will be at the third stage of implementation of REDD+ when the trade-offs between carbon and non-carbon benefits will be solidified [14], CBM can provide information in this context for benefit sharing. It is not clear what benefits communities might derive from sharing information produced through CBM 2 activities with the regional or national REDD+ programs; but given that such activities may have an impact on carbon stocks, the data they provide could form a basis for some non-performance related subsidy or incentive. These subsidies or incentives that could be part of the performance-based distribution of benefits will be additional to the strengthening of local capacities and direct benefits from the implementation of activities associated (e.g., timber, NTFP, water and other local environmental services).

It is important to point out that CBM could be part of the activities to follow-up REDD+ implementation without necessarily being included formally in NFMS or NGHGI systems. However if local data is used to obtain carbon estimates this can help to define benefit sharing schemes in a more transparent way. In fact, a more transparent design and planning of REDD+ including participation of communities and other stakeholders might help to avoid conflict during implementation [15]. A common challenge in the four options identified will be the creation of the system within the NFMS to collect, analyze and share the information to be produced through CBM.

In REDD+ both determining the current level of carbon stocks and determining the prospects for further improvements are of interest. This second element is often neglected in discussions on monitoring and CBM. However, for communities, gaining a better understanding of what their opportunities could be under REDD+ is very important, *i.e.*, a kind of diagnostic process that would help them decide on a future management strategy. The following sections review the information required to characterize the different activities of REDD+ and how this could be generated via CBM.

4. CBM and the Different Elements within REDD+

4.1. Reduced Deforestation

In the context of the efforts to mitigate climate change from the Marrakesh Accords, forests are defined as those areas where the canopy of woody vegetation, capable to reach a height of at least 2–5 m at maturity, covers at least 10%–30% of a minimum area of 0.05 to 1 ha [16]; each country should define the appropriate parameters to define their forests. Deforestation is the process by which forest cover is completely and permanently removed beyond the threshold of the definition of forests, for other land uses/covers, typically cropland, grasslands for ranching, housing or the development of infrastructure due to direct human influence. The basic input to assess emissions from deforestation are the area where land-use changes take place and the difference in carbon stocks of the final and initial land uses.

An historical analysis of deforestation can be done to some extent by analyzing a series of satellite images and other remotely sensed data to get the trend in land use change; emission factors can be based initially on the information on carbon stocks from default data (Tier 1) or the national forest inventory (Tier 2). In general, deforestation can be monitored with considerable reliability based on remotely sensed data (contingent to the scale, resolution and frequency of the input data) (e.g., [17]); data on carbon stocks based on large inventories can also provide information with relatively low level of uncertainty. However this information cannot be applied to obtain estimates at local level for local forest management. Satellite imagery can be used to prepare an initial stratification of a study area [18], but it might not be able to identify local management practices and could have classification errors. CBM can help to overcome these issues.

CBM data is not available for earlier periods and therefore cannot be used directly to compare past deforestation rates with current ones. However, it can produce information that defines local management units to define the polygons changing land uses and the different activities undertaken by the community (e.g., forest stands, areas under cyclical timber management, or under shifting cultivation, the boundaries of which cannot be identified directly from remote sensing). Local inventories can also be used to update the data at a Tier 3 level or generate information of other carbon reservoirs if they have not been included in the NFMS (*i.e.*, soil, dead organic matter).

The variables of interest for carbon monitoring as regards deforestation are: forest area (distinguishing between different strata including management practices); estimated average carbon stock per hectare within each stratum; extent of area change (to non-forest) in each stratum between time 1 and time 2; and drivers. If possible it is important to describe the percentage of the area change that was the result of burning, as this allows the emissions of non-CO_2 GHG.

4.2. Reduced Degradation and Carbon Enhancements

Forest degradation and carbon enhancement refer to the changes in carbon stocks in areas of forest that remain as forest during a period of analysis. Forest degradation refers to the losses of carbon in areas that remain classified as forests under the definition of forest adopted by a country. Degradation is said to occur for instance if a forest with an initial canopy cover >90% is subjected to a process of logging which may reduce the canopy cover down to the lower threshold level (*i.e.*, 10% to 30%). It is important also to understand that carbon losses might occur not only in the arboreal stratum of the forest but also below the canopy, "invisible" to most remote sensing technology [19,20]. Degradation can also relate to the reduction in the rates of carbon uptake that in the long term would degrade the forest [19]. For instance, grazing might reduce the recruitment of new trees, thus after old trees die they would not be replaced by young ones.

The opposite of forest degradation is carbon enhancement. In this case, a forest that has been degraded in the past and is recovering, accumulating carbon and possibly even augmenting its canopy cover. Carbon enhancements could occur due to the natural growth of existing vegetation under an improved management regime, also by the natural and induced recruitment of young trees and other plants, and through the deposition of dead organic matter and assimilation into soils. Activities to promote carbon enhancement can include tree planting to restore the forest, soil restoration activities that might favor the establishment of vegetation and the control of activities degrading the forest (*i.e.*, cattle exclusion, limits on extraction of firewood and poles, forest fires, *etc.*).

Under improved forest management it is quite possible that degradation is brought to a halt and that after some time, net growth and enhancements are measured on the ground [19]. In this scenario it can be assumed that carbon gains include those from the enhancements measured plus the reduced degradation in comparison with a baseline (e.g., [21]). It would be necessary to ensure that any activities previously degrading stocks in the area have not been displaced elsewhere (*i.e.*, monitoring leakage).

The information required to monitor reduced degradation and enhancements refers to the rates of change in the loss and accumulation/assimilation of carbon per forest stratum and the management units where these take place (*i.e.*, processes listed in Table 2). Activities to control degradation and or facilitate enhancements could target a specific reservoir, they can be monitored when the activity is started (per event) and then on a periodical basis (e.g., yearly or even monthly once comprehensive protocols are in place to monitor variables such as survival in plantations, operability of protective fences, number of cattle, amount of timber/fuel-wood extracted per community/household, *etc.*). Usually rates of changes are obtained when carbon inventories are made periodically (*i.e.*, Stock Difference Method, IPCC 2003). However Gain-and-Loss methods can also been used to monitor specific degradation/enhancement processes and management activities. These methods rely on estimated off-take and regrowth rates. When Gain-and-Loss methods are used, periodical standard inventories can be put in place to "verify" the impact of the management activities on the forest by considering the initial and final levels of carbon.

Table 2. Processes and activities associated to carbon reductions and increments for different reservoirs.

Reservoir	Losses/Reductions	Gains/Increments
Trees	Timber Harvesting, Illegal Logging, Fuel-wood Collection, Grazing, Mortality and Disturbances (Pests, Fires, Meteorological).	Growth in standing trees, Natural recruitment of trees, Tree Planting, Forest Management Practices (Growth after Thinning, Cattle Exclusion, Fertilization/Watering); Carbon in Durable Wood Products
Shrubs	Harvests and Fuel-wood Collection, Grazing, Mortality, Disturbances, Harvest	Cattle Exclusion, Planting, Natural Growth, Natural Recruitment
Herbs	Grazing, Harvest (e.g., Fodder), Disturbances, Mortality, Erosion.	Cattle Exclusion, Soil Conservation, Planting, Natural Growth, Recruitment
Soil	Erosion, Soil Extraction, Fire, Cattle	Soil Conservation (Barriers-Thinning-Disturbances, Terraces, Dams), Assimilation (from deadwood, litter)
Deadwood	Fuel-wood Collection, Fire, Assimilation Rate (into soil), Erosion	Disturbances, Thinning, Mortality, Deposition Rate. Reduced Extraction (below mortality/ deposition rates)
Litter	Erosion, Fire, Assimilation Rate (into soil)	Disturbances, Thinning, deposition rate
Fire Occurrence	Factors that Increase Occurrence: Deadwood, dry herbs/shrubs; drought, wind, human presence, agricultural practices, roads, rubbish, limited access.	Factors that Reduce Occurrence/ Severity: Brigade and vigilance, firebreaks, black lines, prescribed fires, improved access, fast access for brigades.

CBM can produce information on the underlying strata within the forest as well as the geographical boundaries where activities to control degradation and enhance stocks take place, and on the changes in carbon stocks. In this case it could be possible to include in the CBM a number of metrics which would be additional to standard forest inventories, such as registries on resource use, description of changes in management activities (e.g., improved management) and inputs for or success of, new management practices (e.g., soil conservation, restoration through tree planting, *etc.*); this will depend upon the activities selected for implementation and the local arrangements agreed.

4.3. Sustainable Management of Forests and of Other Lands

Experiences have proven that participatory community forest management is a useful approach to improve forest management [22,23]. In the Marrakech Accords Forest Management was defined as "*practices for stewardship and use of forest land aimed at fulfilling relevant ecological (including biological diversity), economic and social functions of the forest in a sustainable manner*", referring to both natural forests and plantations (Marrakesh Accords, Forest Management, [16]). An equivalent or operative definition of sustainable management of forests (SMF) has not been adopted in the context of REDD+ at the UNFCCC. Forest management practices can refer to practical specific activities on the ground at stand level (e.g., thinning, tree-planting, fertilization, harvests, *etc.*), as well as to activities carried out at a regional level (e.g., fire prevention/combating system) [4]. Activities included as part of forest management will periodically modify carbon stocks and the gain and loss rates, and should be monitored and accounted as reduction of degradation and enhancement of stocks. Hence the comments made at the end of the previous section would apply equally to SMF. IPCC [12] provides specific guidance to account for carbon stored in durable harvested wood products, which can be identified as additional benefits of SMF.

In terms of the information needed for monitoring the performance of SMF and mitigation actions in other land uses IPCC [4] provides specific guidance for projects. The information to be gathered as part of a monitoring system includes the geographical boundaries of the areas under different management, the description of the management practices, statistics on the inputs and outputs from forest management (e.g., fertilizer, number of plants, survival; harvests, thinning, accumulation in dead organic matter and soil), information from growth models, and information from forest inventories. The value of CBM to the community in terms of providing diagnostics for sustainable management of forests is that SMF is one of the possible strategies that the community might use to tackle degradation or to encourage enhancement of stocks.

4.4. Conservation of Forest Carbon Stocks

The UNFCCC have not clearly defined what is implied by "conservation of forests carbon stocks" in the context of REDD+, and neither have they suggested how it could be rewarded in terms of performance; it is the only REDD+ activity that does not involve change in total carbon stock, and it cannot be rewarded on a per ton basis. Several situations could arise in which forests might be said to be "conserved". For example, if a neutral balance in carbon stocks is the product of direct human activity including intensive market-oriented timber extraction, this might be characterized as SMF (*i.e.*, when harvests equal growth) rather than as conservation. When the balance in carbon is the result of the "natural" rates of growth and mortality/decay through the use of total exclusion of activities, or possibly through "soft" management activities (e.g., an area devoted to conservation, scientific activity or ecotourism), then it is clearer that the REDD+ activity could be conservation. This division would enable the identification of different policies and incentives to achieve the different objectives. For instance, SMF could be promoted by providing capacity building for planning and certifying forest management practices, by providing appropriate financing options to buy the required equipment and develop markets for products made with certified timber. On the other hand, incentives for "carbon conservation" activities could be embedded with programs for the management of protected areas, and programs supporting the provision of other environmental services (e.g., water, biodiversity), for instance via programs of Payment for Environmental Services (PES).

Communities themselves could use CBM as a tool for analyzing the processes currently on-going in their forests to determine whether strict conservation is a viable and useful option for all or parts of their forests. CBM can also be used to provide information over management areas and carbon stocks as described in the previous sections.

4.5. Construction of Baselines

A critical difference between individual projects developed for carbon markets, and a national REDD+ program, is how the baselines are set. In markets, individual projects measure performance against a baseline that covers the territory of the project itself and usually a buffer zone around it. In REDD+, performance needs to be assessed at the national level (by the third stage of implementation). However, the activities contributing to this at the sub-national level will have to be assessed against corresponding baselines too. One option is to create nested baselines in REDD+ and aggregate them from the local to regional and national levels [24]. The national REL/RL describes the expected emissions based on national historical trends and national development expectations (expressed as development adjustment factors, DAFs). To some extent, the construction of local baselines could mirror this process. It is highly unlikely that each and every community or forest owner will be required to develop an individual baseline, given the costs and the difficulties involved in this [25]; however an approach including local data can be used to develop baselines for specific management units. Rather there are likely to be regional or provincial level baselines and possibly sub-provincial baselines. Local communities through CBM could contribute to the construction of this lowest level of baselines by providing historical information on land management and drivers, expectations and future developmental needs. Local land-use management plans at community and municipality level could also be used as sources of information; projects supported by international NGOs in the Biosphere Reserve of El Triunfo in Chiapas are developing local land use plans to analyze alternative development scenarios including the carbon dimension [26]. The analysis of alternative development scenarios can be developed in a participatory fashion to set the reference levels and also to determine local opportunity costs of REDD+ (e.g., [27]).

4.6. Understanding Drivers

In order to design adequate strategies it is necessary to understand the drivers of emissions and barriers for favoring carbon enhancements, conservation of carbon stocks and SMF. A large amount of information on the implementation of REDD+, including information related to drivers of emissions and non-carbon impacts of these activities, can be gathered by local actors through CBM. Monitoring schemes could be prepared for specific management practices and policies adapted for different contexts.

4.7. Safeguards

Social and environmental safeguards were included in REDD+ to ensure that this program will not harm the interest of local communities and developing countries and will have no negative effects on biodiversity and other environmental services. As included in the Cancun Agreements, social safeguards indicate REDD+ needs to be consistent with national forest plans and other related international conventions; governance schemes should be transparent, effective, participatory and respect the rights of local and indigenous communities. This might imply the recognition of customary rules (e.g., [28]). For the environmental safeguards, a major concern is the potential conversion of natural forests to plantations with the associated loss of biodiversity; conversely REDD+ should promote the conservation and protection of natural forests and reduce reversals and leakage [8].

Information that can be produced locally for the implementation of safeguards includes the documentation of the processes for the design of REDD+ programs and specific plans for activities to be implemented in the field. In this context, CBM schemes where actions are driven by local interests and have a larger share of local participation will produce this information in a more transparent way [7]. The monitoring of social safeguards will follow different processes from those to monitor carbon stocks, stock changes and forest areas. The later system will focus on monitoring the results of implementation whereas that for social safeguards will focus on ensuring initially that REDD+ and its governance schemes are designed properly. Once REDD+ enters into operative stages it will be necessary to continue monitoring the way in which activities are implemented. For environmental safeguards, it will be important to show that relevant criteria have been included in the design of implementation strategies to protect natural forests. For the implementation stage, considerations of leakage and permanence can be included accordingly into the procedures for data analysis.

Table 3 presents a summary of the information that can be gathered through CBM. There is an extensive body of literature documenting cases of communities producing geographical data through participatory approaches, including climate change mitigation efforts (e.g., [29,30]). It is possible for communities to gather information to characterize management practices and carbon stocks and stock changes. It is important that national systems (NFMS/MRV) are able to integrate this information; in fact it is expected that by simulating local participation communities might participate more effectively into REDD+ implementation [31]. The geographical information could be reported by the communities to the national systems if for instance countries create an Activity Reporting System as described in the IPCC guidelines [4]; this can help in integrating local data into the stratification system for the representation of lands. The next section presents potential options to integrate data on carbon stocks and stock changes into national systems.

Table 3. Key information that can be produced for different REDD+ activities and elements through CBM.

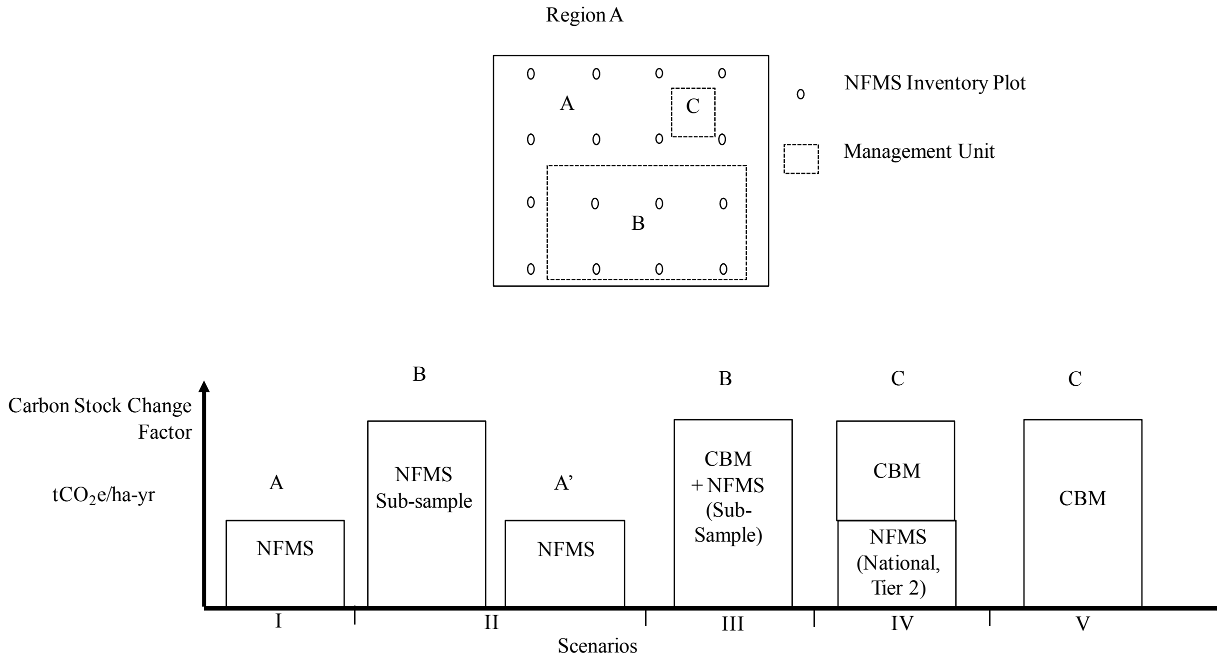
REDD+ Activity/Element	Key Information that can be Produced through CBM
Reduced Deforestation	Forest area and management units; carbon stocks; changes in forest area with high geographical scale and frequency.
Reduced Degradation and Carbon Enhancements	Information of management units; registries for activities implemented for use of gain and loss methods (e.g., harvest, fuel collected, plantings reforestation); rates of change of degradation/enhancement (tCO_2e/ha-yr).
Sustainable Management of Forests	Information of management units; description of practices; information of inputs/outputs of SMF practices; carbon estimates based on information of growth models and local forest inventories
Conservation of Forest Carbon Stocks	Information of management units; information from other conservation programs (e.g., PES, ecotourism, including *ad hoc* forest inventories).
Construction of Baselines	Local land use plans including carbon inventories and local development needs can be used to set local reference levels in a nested system.
Information of Drivers	Historical information on land use and drivers of changes; local information of barriers for implementation of sustainable practices.
Safeguards	Documentation of implementation process of social safeguards; information of non-carbon impacts of REDD+ activities.

5. Dovetailing Data from CBM into MRV Systems

This section presents potential options for the integration of local data into national NFMS. National forest inventories can provide information on the level of carbon stocks and after successive measurements have been taken they would also provide data on the average growth rate of standing trees, mortality and recruitment as observed in the plots. This data is useful to estimate emissions from deforestation once the changes in forest area are assessed via remote sensing. Moreover, since the inventories also collect information on local conditions e.g., on observed degradation and causes of this, the changes in stock may be related to drivers of deforestation and degradation in a generalized sense over large areas. However, given the sampling scale of the national inventory (e.g., one site per 5 km, working at scales of 1:250,000 as in the case of Mexico (e.g., [32]), it will not be possible to pick up changes in carbon stocks in forests at the management unit and parcel levels. For accurate assessment of changes in carbon stocks at the level of the management unit or parcel, there is no real alternative to local generation of data; CBM is one approach that would appear particularly useful in this context.

As mentioned above, the information that can be produced locally through CBM includes the delimitation of polygons of forest under different management, the description of such practices and the changes observed in carbon reservoirs at *ad hoc* frequencies. This information can contribute substantially to the assessment of emissions and removals; this local MRV could provide data for integration in the NFMS. Figure 2 shows different options to combine local and national level information.

Figure 2. Options to integrate local data produced through CBM with NFMS in REDD+.



The upper part in Figure 2 presents a hypothetical case of a forested area (Region A) in a country. Suppose that in the NFMS region A is classified as a coniferous forest and the inventory grid includes 16 plots. Since there are no more details on the management practices the carbon stock change factor for region A, presented in the lower part of Figure 2 is given by the results of the national inventory (Tier 2 data) (Scenario I). It is important to recall that the carbon estimate of A is obtained considering the information from all the inventory plots from the same strata in the country (coniferous forest), not only using the 16 plots within polygon A.

If communities in the region perform different management practices in polygons B and C, (e.g., sustainable forest management and forest restoration) they can map these using CBM (e.g., through participatory mapping). Local particularities and the effect of local management in B and C are not captured by the NFMS system since the NFMS does not recognize B and C as different management units. It would be necessary to increase the scale at which information is managed to allow the inclusion of smaller polygons corresponding to local management units.

Figure 2 shows there would be at least four possible ways in which CBM could feed information to national systems in REDD+ to generate carbon estimates. The first option depicted in scenario II shows the case when there are measurement plots of the NFMS within B (6 in this case). If this sub-sample is large enough, it could be possible to compare information of B to that of A' (*i.e.*, original data in A once the information in B has been removed and treated independently); if statistical differences are detected, then B can be identified as a new stratum within the NFMS. An initial option to consider this approach is to include the geographical information of existing forest management programs (polygons) into the NFMS and check if independent new strata can be identified based on management practices (e.g., PES, Reforestation, Community Forestry, Forest Management Plans, Carbon Markets).

Scenario III in Figure 2 refers to a situation when the information from the NFMS in the polygon B is not sufficient to produce prove of statistical difference in the mean values in B and A'. CBM can be used to increase the sample size within B and to include information of other carbon reservoirs not included in the original sample. The information of the six sites of the NFMS in B can show the local variance and can be used to define the size required of the local inventory. In order to combine data from NFMS and CBM it is necessary to verify comparability of the information (*i.e.*, methodological and temporal consistency); estimates would produce Tier 3 data valid for B. As in the previous scenario it would be necessary to "remove" the subsample of the inventory plots from the original data for A.

Scenario IV shows the case when there are no NFMS plots within the management area C and practices to be implemented will affect specific carbon reservoirs. Carbon estimates for area C can use Tier 2 data from NFMS for carbon stocks not affected by local management. The information can be complemented through CBM for the reservoirs/activity of interest which will generate Tier 3 data; the Tier 2–3 results would be valid only for area C. Alternatively a complete local forest inventory could be implemented in C to produce Tier 3 data for all the carbon reservoirs (Scenario V), hence neglecting the use of previously developed Tier 2 data at national level (e.g., to participate in carbon markets or when various reservoirs will be affected).

It is important to point out that when additional data of new carbon reservoirs or processes is integrated into the NFMS an initial effect could be an increase in the level of estimated emissions; in order to produce consistent estimates of performance, the baselines should be recalculated accordingly.

When the geographic information from a locally managed forest unit is integrated into national systems, the corresponding "original" polygon in the NFMS should be partitioned. Then new carbon data could be associated to the area under specific management (carbon stocks, carbon stock change factors and associated uncertainties). Each forest polygon in each stratum would have an associated carbon stock/stock change factor, which could be disaggregated for each carbon reservoir (*i.e.*, biomass, soil, DOM, non-CO_2e GHG; the information would include the mean value and the associated uncertainty). If CBM is included into MRV then these individual pieces of information for each carbon reservoir and associated uncertainties could be integrated and updated in a participatory mode for each polygon; CBM can replace Tier 1 or Tier 2 values by local data and also complement information for specific reservoirs when these were not included originally. When the information of the "new" polygon is added, the national inventory and associated uncertainties could be re-estimated. It will be necessary to review the technical requirements to make the data compatible in terms of geographical and temporal scales and to consider adequate methods to analyze the propagation of uncertainties.

6. Conclusions

It is essential to include CBM in MRV and NFMS in REDD+ to comply with the decisions adopted under the UNFCCC and favor the transit to systems with data of higher levels of detail (Tier 3 and high geographical scale). Given this, it is critical to define and enable options for integrating local information into national monitoring systems. This article has highlighted the potential contribution of

CBM for producing information on carbon stocks and stock changes and for mapping geographical data for different REDD+ activities.

There are opportunities for integrating different sources of local information into MRV systems; this information can help in the step-wise implementation of the NFMS. Information sources include data produced by communities as part of their management practices motivated by the access to local benefits and environmental services (CBM 2) and information produced for REDD+ projects associated both with carbon markets and with national programs (CBM 3); additionally governments can include specific features in the monitoring of existing public forest management programs to produce information for NFMS or even design schemes based on CBM to increase the sampling intensity of existing inventories (CBM 1). Finally there will be a flow of information that will be generated as part of the implementation of social and environmental safeguards (CBM 4).

In order to create CBM schemes on a national or regional scale an initial investment is needed to build appropriate capacities and to provide the basic operative infrastructure. It is necessary to define the strategies necessary to work on the different possible CBM approaches; if systems need to make use of public programs or to hire local brigades as part of NFMS, appropriate budgets will be required for this (CBM 1). If activities driven by local interests are to be promoted (CBM 2), it is necessary to ensure methodological consistency and that the management activities will not compromise carbon performance of the program; for this, there are alternatives such as providing input-based incentives to activities that prove to have non-negative carbon effects. It will be necessary also to create appropriate linkages with projects participating in carbon markets and other certification schemes that could provide useful information to NFMS/MRV (CBM 3); this will help to define the systems for sharing of benefits while maintaining the environmental integrity.

Participatory options can be created via an *ad hoc* Activity Reporting System that could allow completing or replacing the information of carbon emissions/removals for specific management units. The Activity Reporting System could make use of information generated already available as part of local land use plans, and other programs (e.g., PES, NPAs, community forestry, forest management plans, *etc.*). New technologies are being used to create flexible and innovative systems to monitor natural resources. It will be necessary to create options to make the best use of these tools and include them into basic systems for the representation of lands and the system to generate carbon stock change factors as part of REDD+.

Acknowledgments

This document is based on the report "Balderas Torres, A. 2013. Opportunities and challenges for integrating CBM into MRV systems for REDD+ in Mexico. The Nature Conservancy. Consultancy Report, Mexico, D.F." In reference to this work the author would like to acknowledge the contribution of Margaret Skutsch, Alejandra Larrazabal and Hugo de Alba in different sections of this document and to Tuyeni Mwampamba and Miguel Angel Salinas Melgoza of CIGA-UNAM, Fernando Paz from COLPOS, and Peter Ellis and Jose Manuel Canto of TNC for their comments on early versions of the report. About Balderas Torres (2013) "This publication was possible through the generous support of the people of the United States through the United States Agency for International Development (USAID) under the terms of Cooperative Agreement No. AID-523-A-11-00001 (Project for Reducing

Emissions from Deforestation and Forest Degradation in Mexico) implemented by the prime contractor The Nature Conservancy and its partners (Rainforest Alliance, Woods Hole Research Center and Natural and Espacios Naturales para el Desarrollo Sustentable). The contents and opinions expressed herein are those of the authors and do not reflect the views of Project for Reducing Emissions from Deforestation and Forest Degradation of Mexico and the Agency United States Agency for International Development, the Government of the United States of America".

Conflicts of Interest

The author declares no conflict of interest.

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