Alianza MéxicoREDD+
Con la gente por sus bosques

White Paper: Opportunities and challenges for integrating CBM into MRV systems for REDD+ in Mexico
Final Report

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Executive Summary

Community based monitoring (CBM) can offer good options to engage local communities in the management of natural resources and to help generating the information necessary for REDD+. New technologies are being used to create flexible and innovative on-line systems to monitor natural resources. It is necessary to create flexible 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 in REDD+.

This work reviews different elements of the design and implementation of national REDD+ programmes in order to identify the opportunities and challenges for CBM as means for generation of information at the local level, particularly to fulfil requirements of monitoring, verification and reporting (MRV) and as part of National Forest Monitoring Systems (NFMS). The implementation of REDD+ in Mexico through the national strategy is used as a practical example. The document presents a review of the use of CBM followed by a description of REDD+ at the international level. Then methods and technologies available for CBM are compared. This is followed by the narration of the main developments for REDD+ implementation in Mexico to identify possible strategies to integrate locally produce data into national MRV system. Finally, conclusions and opportunities and challenges for CBM are presented.

Section 1 makes a literature review on CBM for natural resource monitoring and management describing different types of monitoring schemes depending on the degree of involvement of communities and external experts in different stages of the process based on the typology by Danielsen *et al.* (2009). When monitoring is driven by local interests it is more plausible these activities will be maintained in the long term, conversely when monitoring is driven by external interests only, it can be expected that when external incentives end, monitoring activities will also stop (Danielsen *et al.* 2005). It can also be expected that if information is gathered, processed, interpreted and reported locally, this might be more helpful for prompt decision-making in natural resource management (Danielsen *et al.* 2009). Previous experiences have shown communities can produce field data for the estimation of carbon stocks and stock changes in forests; although it is more difficult, it is also possible to create the capacities and provide the infrastructure required to analyse and process data locally.

Section 2 initiates with the revision of the design of REDD+ under the UNFCCC. Decisions adopted at the COP have identified the need to engage local communities and indigenous groups in MRV for REDD+ (UNFCCC, 2010). Based on the general architecture expected for REDD+, four different processes by which local information could be integrated into national systems are identified: firstly, CBM can be used to increase the density of existing forest inventories through *ad hoc* schemes or as part of existing public programs (CBM 1); secondly, national systems could integrate information produced locally as part of forest management activities motivated by the direct benefits communities receive from improved management (CBM 2); thirdly, refers to the information generated in projects participating in carbon markets and other certification schemes (CBM 3); and finally, the fourth group of data would be that which can become part of the system to monitor safeguards and data produced to describe other local environmental services.

Section 2 continues by describing the general methods for carbon accounting and the representation of lands according to the IPCC methodologies. The text discusses the potential to

use Stock-Difference and Gain-and-Loss methods to evaluate the levels and changes of specific carbon reservoirs and the way in which they could be used to characterize specific managed areas and be integrated in the NFMS; when these two methods are based on compatible statistical designs, they can provide comparable information of the different carbon stocks. This means that if communities generate information for a specific management unit area only of one or two carbon reservoirs through particular methods, these still can be integrated into NFMS. Stock- Difference methods are more suitable to monitor deforestation while Gain-and-Loss can help understanding better the processes of degradation and enhancement. Additionally, Gain-and-Loss methods can produce information more frequently for a given geographical area in comparison to Stock-Difference methods considering these require many years to produce estimates. Since there are no specific guidelines for the implementation of different REDD+ activities, the recommendations for LULUCF projects made in the IPCC (2003) are presented to offer an operative benchmark for REDD+ interventions. The way forward for implementation based on this approach would be to produce protocols at project (regional or national) level for measurement, analysis and reporting and a set of indicators to be monitored at parcel level for different management practices to be implemented. The final part of this section describes how CBM can contribute to produce de information for each REDD+ activity and to set baselines, understand drivers of emissions and implement safeguards.

Section 3 provides a review of different techniques and methods that can be used in the field to monitor the different carbon reservoirs and to produce geographical information through participatory approaches. The comparison is made according to the equipment required, the accuracy and reliability that can be obtained, the specific requirements and costs of each option and the potential to meld local data with other data sources. There are different technologies and methods that can reduce the time to gather data in the field (e.g. relascopic methods), or even eliminate it by using remote sensing technologies (e.g. LiDAR using small planes); these technologies can also provide and update information in real time. However in some cases the cost of these new technologies is still high to be implemented on small areas through CBM. Furthermore, it will be necessary that national MRV systems and NFMS specify the requirements for the generation and integration of local information gathered possibly different methods and technologies. Communities can still use the cheapest and simplest methods to monitor their natural resources, however it is necessary to define if it is desired that this information should be compatible with national systems in REDD+.

The next sections present the details to produce geographical information locally and identify the achievable geographical scales, associated uncertainty, uncertainty management and potential to combine field carbon data with remotely sensed data. The inclusion of information produced through CBM requires the use of higher geographical scales in the systems to represent forest areas and map carbon and emissions (e.g. higher than 1:50,000). Otherwise, considering the relatively small size of most forest polygons or units managed at local level, it might not be possible to represent areas in the maps or the percentage uncertainty associated will be high. This is because of the uncertainty introduced by expected errors of field measurements, and the limits imposed by the larger minimum mappable areas when working at small geographical work scales (e.g. 1:250,000). Section 3 concludes by describes the risks for the manipulation and the integrity of data to discuss the role that verification should play in MRV systems. Finally, the section mentions the different capacities for CBM required at the local level and the general costs of CBM.

Section 4 describes the different steps undertaken in the preparation of REDD+ activities in Mexico as preamble to discuss the potential future inclusion of CBM into MRV systems. First the Vision on REDD+ (CONAFOR, 2010) and the preparation of the national REDD+ strategy (ENAREDD+; CONAFOR, 2012) are described. This is followed by the description of three REDD+ related activities in development in Mexico: the Mexico-Norway Project, where the relationship between the NFMS with the NGHGI, the potential use of Tier 3 approaches, the generation of information of carbon stock change factors and geographical information are described; the second initiative corresponds to the first steps undertaken for the development of a system for the implementation of safeguards; and the third initiative corresponds to the LAIF project that explores the potential to produce local capacities for CBM.

Mexico has advanced in the definition of the ENAREDD+ and CBM is mentioned in both the Vision and the national strategy in the context of MRV systems; however there are still practical steps that need to be undertaken. One of these, is for instance the formal adoption of a definition of forests for REDD+, this will allow identifying clearly which mitigation activities could be implemented (and monitored) in forestland and in other land uses; mitigation activities off-forest can be coordinated with SAGARPA in an appropriate NAMA based on a landscape approach. The focus of the ENAREDD+ is on Sustainable Rural Development with the critical participation of inter- municipal associations as new governance structures. In the preparedness stage for REDD+, care has been taken of not focusing on carbon and creating expectations on carbon performance based incentives, at a moment when financing and benefit sharing mechanisms have not been defined at international and national levels. There is work being done to up-date periodically the system for the representation of lands and increase the geographical scale, to harmonise the systems for preparing the NGHGI and the NFMS and to prepare methods, models and protocols to produce information at Tier 3 level. In this context it will be necessary to define how local information can be integrated and aggregated into regional and national systems, and prepare the corresponding protocols for data gathering, analysis, revision, storage and reporting. This can help also to prepare a transparent system for benefit sharing. Mexico should have defined its MRV system within the next two years. The system for monitoring the implementation of safeguards is on its first steps of development; there are examples in the existing legal framework that are aligned to the system to implement safeguards. There is a pilot project in Jalisco for the development of a system to monitor safeguards based on REDD+ SES, however it is still to define specific principles, criteria and indicators for implementation.

The LAIF project has been working in four communities in Jalisco to explore the requirements to create local capacities for CBM. The approach adopted by this project is that monitoring practices should be locally relevant and respond to local interests; this is online with the description of more autonomous monitoring systems as described in Section 1. Findings indicate communities can learn the techniques to monitor their forests, however there are also certain organisational requirements that might not be present in all communities; more advanced skills for analysis and reporting can also be generated locally but this will require more initial resources. When monitoring is driven by local interests it is important to evaluate the impact on carbon in the long term; if communities recognize the need to mitigate climate change as a legitimate local interest this might help implementing activities with positive impacts on carbon. However it is necessary to maintain effective communication with communities regarding carbon monitoring and reporting requirements once local monitoring capacities have been developed. A pending activity is the engagement with private forest landowners for the development of CBM

The final parts of section 4 describe different scenarios in which both carbon and geographical local information could be merged into regional and national accounting systems in Mexico. Given the small scale of the information used to estimate forest carbon emissions and removals in Mexico (e.g. 1:250,000), these estimates do not represent properly carbon dynamics at the local or management unit level, moreover it will be difficult for existing systems alone to pick up the impact of mitigation activities to be implemented as part of REDD+ at the management level. Currently information reported in the most recent NGHGI does not include all carbon reservoirs and is based on international Tier 1 default values; the information used for NFMS to produce Tier 2 data does not include yet information on all carbon reservoirs. In this context CBM data can help to replace lower tier data and fill in data of missing carbon reservoirs for specific management units, however the scale at which information is represented should increase. The integration of CBM data would require the definition of specific geographical areas or management units where data is gathered, which will require a dynamic system for the representation of lands. Then the information of existing inventories within these polygons and/or the information of carbon stocks and stock changes gathered through CBM can be used to obtain the estimates in these managed areas. In this context a new criteria for stratification will be the management practices present in a given forest polygon which can help to explore the variances in canopy cover and carbon stocks within vegetation types (e.g. community forest management, forest management plans, PES, natural protected area, etc.). Once geographical areas under specific local management/monitoring are defined in the system for representation of lands, specific information on carbon content, emissions and/or removals and their associated uncertainties can be updated. After this, estimates of carbon stocks, emissions and/or removals can be recalculated for an area of interest or the whole inventory. The final part of Section 4 presents a description of how information that can be produced through the four different CBM schemes identified in Section 1 can be integrated into the different stages of collaborative systems for the management of natural resources (i.e. data gathering, data communication and storage, analysis/modelling and validation, and publication and use).

Currently, in Mexico governmental offices aided with external consultants centralise the generation, analysis and use of information from forest inventories and the system for the representation of lands. On-going efforts have been careful in not creating yet expectations for carbon based results financing. However if the objective is to access to international results based financing it would be necessary to communicate clearly to the different stakeholders that there will be a baseline and that certain national, regional and local objectives will need to be achieved. In this context it will be necessary to define specifically how CBM will be integrated into MRV for REDD+; this will require defining protocols, roles and responsibilities of different actors and stakeholders and technical specifications for equipment and models to be used. Protocols required include those to define variables to be monitored, fieldwork methods, specifications for the design of monitoring schemes, and for the analysis, reporting and validation of information. Information produced locally would feed the systems to determine carbon stock change factors and the system for the representation of lands. It will be necessary to prepare flexible interphases to allow the integration of local information into these systems. The Activity Reporting System could make use of information generated already available as part of local land use plans, and other programs to refine the stratification of the territory (e.g. PES, NPAs, community forestry, forest management plans, etc.).

If the objective is to create long standing monitoring systems useful for communities, then technical and organisational capacities need to be created and initial training and infrastructure needs to be provided. These type of schemes will correspond to the type of model promoted by the project LAIF and the CBM 2 type of schemes. However when direct use of forest resources is not allowed and the local valuation of other environmental is not high, it might be necessary to provide external incentives to gather the information (this will correspond to CBM 1 type of schemes); for schemes of CBM 1, information will continue to be managed centrally. In the cases when local actors own information that can be integrated into the systems (CBM 2 and CBM 3) it will be necessary to generate the appropriate agreements to validate and share this information. It will also be necessary to harmonise the baseline of projects participating in carbon markets to that of REDD+.

Section 5 presents a summary of the opportunities and challenges identified for the inclusion of CBM into MRV systems for REDD+ in Mexico (Table ES1).

Table ES1.Summary of the most relevant opportunities and challenges identified in this document.

Opportunities	Challenges

• There is a need to integrate CBM into MRV systems as expressed in decisions adopted at the COP. • Communities and local actors can produce field measurements as accurate as professional brigades. Unlike INFYS, CBM can cover both forest and non-forestland. • Participation of private landowners in monitoring schemes has potential benefits that need to be explored (e.g. expedite decision-making, lower transaction costs, economies of scale and access to capital). • Communities can create and update geographical data of mitigation activities implemented through CBM to create cartography with high scales (e.g. land use plans, transects with GPS, PGIS). • Local monitoring is less costly; when local interests drive CBM, activities might be implemented without the need of external incentives. • Management activities locally driven with the potential to protect natural forests while producing other services can contribute in the implementation and monitoring of environmental safeguards. • New technologies allow CBM applying different and innovative techniques in on-line collaborative ways. • Different activities can be grouped together under CBM schemes for MRV (i.e. public programs, local initiatives and carbon markets and certification schemes). • Local monitoring can update, complement and replace Tier 1 or Tier 2 data in NFMS by Tier 3 values for specific management areas and for specific carbon reservoirs and it can also be used to evaluate the impact and benefits of different mitigation activities. Local and national level information can be merged. • It is possible to design flexible methodologies including Gain-and-Loss and Stock Difference methods, to generate control indicators, to follow-up implementation and verify performance more frequently. • Local information can help to design mechanisms for benefit sharing of REDD+. • Local generation and analysis of data enables prompt practical decision-making over the management of natural resources.	• The inclusion of CBM in REDD+ is described in the Vision and ENAREDD+ consider CBM, but it has not been implemented yet; the deadline for the creation of the MRV system is 2015. • Local capacities and basic infrastructure is needed for setting up CBM (i.e. electricity, internet, hardware, software). Additionally to data gathering, other skills needed relate to preparing inventories/sample schemes, store and maintain data, data analysis, interpretation and reporting. Not all communities have the conditions to start CBM schemes. Currently private landowners have not been engaged in this process. • The definition of forests for REDD+ is needed to identify clearly forest/management strata and identify and plan mitigation activities in forests and other lands. • The system for the Activity Data/Representation of Lands still does not include data for different management practices as criteria for stratification and analysis. • There is not an Activity Reporting System that allows receiving local data to define management areas. • Current work scale in NGHGI (1:250,000) does not allow incorporating local geographical data for small management units <2,000 ha at low levels of uncertainty (Table 10). • When CBM is only based on external incentives/drivers, once external *stimuli* end, the activity may be suspended. • Usually initial costs of training and infrastructure need to be covered to start CBM systems; however exhaustive monitoring for REDD+ and other environmental services benefits from economies of scale to reduce costs. • When only local interests drive monitoring, data produced may not be compatible in scope and 'quality' with external reporting needs for REDD+. Information is owned locally and not directly available for NFMS/MRV. • Compatible and harmonised protocols for sampling schemes, data gathering, validation, storage, processing and reporting are needed to realise the potential of CBM for NFMS/MRV. • The process to elaborate and up-date NGHGI is not yet institutionalised and does not offer collaborative options to integrate local data. • It is necessary to harmonise baselines. • Results/Reports based on current monitoring schemes (e.g. INFYS) usually do not reach back local communities to contribute to local decision-making. • It is not clear if climate change related issues (mitigation and adaptation) are part of the local interests for the management of natural resources. If they are not, positive results in carbon terms of locally led initiatives cannot be granted *a priori*. • It is necessary to show direct cause-effect between management practices and the provision of specific environmental services and other benefits to prevent the creation of false expectations.

The natural path in which many of the activities and recommendations made in this document could be implemented, consistently with the ENAREDD+, will be through the inter-municipal associations. The inter-municipal region will be the appropriate level to create economies of scale for different processes. The associations could work as regional umbrella organisations. They could help to create local capacities, to coordinate local monitoring efforts, to consolidate local information to be nested at the state and national levels and to contribute in the integration of information for NGHGI. The role of the associations and other local actors in the Early Action Areas will be critical to create the necessary capacities or provide specific services for data analysis and reporting (e.g. consultants, academia, NGOs).

1. Introduction and Background

1.1 Objective

The aim of this work is to review different elements of the design and implementation of national REDD+ programmes in order to identify the opportunities and challenges for community based monitoring (CBM) as a means for generation of information at the local level, particularly to fulfil requirements of monitoring, verification and reporting (MRV). These opportunities and challenges are identified by considering the range of technologies and methods that are available for CBM for the estimation of carbon content and forest area (stocks/areas levels and changes) and their potential to contribute through a bottom-up approach. 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 which is used to assess the implementation and results of REDD+. In order to show a practical example of the prospects for implementation of a REDD+ approach including CBM, this work refers to the implementation of REDD+ in Mexico through the national strategy, with emphasis on the early actions that are being carried on by the Alliance Mexico REDD+ under the MREDD+ project in five early action areas (EAA).

1.2 Outline of the Document

This is one of two documents that part of a consultancy for The Nature Conservancy to explore the opportunities and challenges to integrate CBM into MRV for REDD+ in Mexico. This document presents a review of the use of CBM for natural resources and for climate change mitigation in the forestry sector. This is followed by the description of the different characteristics of REDD+ from which the main opportunities for including CBM are identified; the general methods for carbon accounting and information requirements for each REDD+ activity are also presented. Thirdly, the document includes a description and comparison of the methods and technologies available for CBM for measuring carbon stocks and stock changes and to produce geographical information through geographic information systems (GIS); the description also includes a review of the capacities required for CBM and associated basic costs. This is followed by the narration of the main developments for REDD+ implementation in Mexico to identify possible strategies to integrate locally produce data into national MRV system. Finally, conclusions and the main opportunities and challenges for CBM are presented. The second document of the consultancy uses the approaches discussed here to identify specific strategies to include CBM into the projects financed by the Alliance.

1.3 Literature Review

1.3.1 Community Based Monitoring

Environmental monitoring, the systematic measurement of variables over time, is a precondition for environmental management and sustainable development (Spellerberg, 2005). It describes changes in ecosystems or particular environmental attributes of interest. Depending on the type of information gathered four types of environmental monitoring can be defined according to Vaughan *et al*. (2001): *simple monitoring*, this is when values of single variables at specific points are collected over time; *survey monitoring*, this includes sampling in affected and unaffected areas or controls when historical data is not available; *proxy monitoring* refers to the case when is necessary to compensate for the lack of previous monitoring or by using surrogate information to infer changes; and *integrated modelling* that might include multi-disciplinary approaches to generate detailed sets of ecological info which may serve different purposes.

Here, participatory or locally based monitoring approaches are grouped under the term Community Based Monitoring (CBM), which can be described as the process that involves local people directly in data collection and/or interpretation using relatively simple methods (Danielsen *et al.* 2005, 2008; Van Laake *et al.* 2009, Burgess *et al.* 2010). CBM schemes have been implemented in developed and developing countries to monitor different environmental attributes such as biodiversity and wildlife (e.g. Danielsen *et al.* 2005), hydrological services (e.g. Becker *et al.* 2005) or carbon in forests (e.g. Skutsch, 2011; Partihast *et al.* 2013). In fact there are more than 1,300 applications of participatory approaches for development and environmental issues reported in the literature (McCall, 2012).

In general the implementation of monitoring schemes presupposes there are specific reasons to collect the data and standards that should be met (Spellerberg, 2005). This is the case of international environmental agreements that require countries to monitor the state of their natural resources. In developed countries, volunteers undertake part of monitoring activities through citizen-scientist programs (Greenwood, 2007; Danielsen *et al.* 2009). However developing countries often lack systems and trained personnel to enable local participation and thus most of the efforts rely on researchers/professionals funded by remote agencies, external to study areas (e.g. Spellerberg 2005); these schemes are often expensive, based on non-endemic know-how and may be non-sustainable in the long-term once external funding ends (Sheil, 2001, Danielsen *et al.* 2009). Nevertheless there are various types of initiatives to produce information through monitoring schemes with varying level of involvement of 'external' actors and local communities (Table 1).

Table 1. Typology of monitoring schemes depending of the participation of local people. Adapted from Danielsen *et al.* (2009).

Variable	1 Externally driven.	2 Externally driven, local data collection.	3 Collaborative with external interpretation.	4 Collaborative with local interpretation.	5 Autonomous
Characterisation					
Primary data gathers	Professional researchers.	Professional researchers, Local people.	Local people with professional advice.	Local people with professional advice.	Local People.
Primary users of data.	Professional researchers.	Professional researchers.	Local People and professional researchers.	Local People.	Local People.
Cost to locals.	+	++	++	+++	+++
Cost to outsiders.	+++	++	++	++++	+
Local expertise required.	+	++	++	+++	+++
External expertise required.	+++	+++	+++	++++	+
Accuracy and precision.	+++	+++	+++	++	+
Promptness of decision-making.	+	+	+	+++	+++
Potential to enhance local capacities.	+	+	++	+++	+++
Capacity to inform external schemes.	+++	+++	+++	++	+
Evaluation of Suitability					
Highly accurate data is required.	+++	+++	++	++	+
Public/NGO budget available.	+++	+++	+++	++	
Professionals available.	+++	+++	+++	++	
Volunteers available.		+++	++	++	++
Government staff available locally.		+	++	++	

Variable	1 Externally driven.	2 Externally driven, local data collection.	3 Collaborative with external interpretation.	4 Collaborative with local interpretation.	5 Autonomous
Area remote difficult external access.		++	+++	+++	+++
Natural resources important for livelihoods.		+	+++	+++	+++
Management regimes allow involvement of locals.			++	+++	+++
Supportive policy and legal environment.		++	++	+++	+++
It is important to empower local decision-making.			++	+++	+++

The typology presented in Table 1 shows a spectrum ranging from externally to locally driven monitoring schemes that might respond differentially to the interests of external and local users (type 1 to 5). It describes the different options in terms of the participants and users of the information the characteristics of the schemes (e.g. costs, capacities, accuracy), and the suitability of the approach for different conditions. Following Danielsen *et al.* 2009 the share of costs between external and local actors will be mutually compensated when going from type 1 to 5 in the spectrum; while local monitoring is cheaper in operative activities (due to lower wages and transport costs), it will require relatively high initial costs (i.e. equipment and capacity building) (Danielsen *et al.* 2005, 2009). If monitoring is locally relevant it may be more sustainable since valuation of local benefits will promote participation (type 3-5) (Danielsen *et al.* 2005); nevertheless monitoring programs should not rely on this 'low cost' monitoring, since if real local benefits are not enough to cover the participation costs, monitoring will not occur (Danielsen *et al.* 2009; Hockley *et al.* 2005; Topp-Jorgenesen *et al.* 2005). In the opinion of scientists, local schemes will be more prone to biases and the generation of inaccurate/imprecise results. Nevertheless recent research in the context of climate change mitigation and REDD+ have shown that local brigades with few years of formal education can gather ground data via forest inventories for measuring carbon stocks with results comparable to those produced by professional brigades (e.g. Skutsch, 2011; Danielsen *et al.* 2011). These results indicate the potential to develop monitoring schemes of types 2-3 which will work better if they are institutionalised in official organizational schemes to enable the provision of support/feedback by officials and other technical experts (e.g. Bennun *et al.* 2005; Danielsen *et al.* 2009). External support is needed for REDD+ since institutions, skills and infrastructure might not be in place yet for the interpretation of field data to produce more elaborate estimates of carbon stocks, baselines and leakage at statistical levels expected for national and international schemes.

An important aspect for the design of a monitoring scheme is who is the final user of the information and what will be it used for. Here emerges a contrasting situation, in the context of REDD+ information is required to produce inventories and reports for national and international reports with high levels of accuracy and precision (type 1 scheme in Table 1). However the final objective of REDD+ is to implement actions on the ground, responding to local needs without compromising local livelihoods and biodiversity (schemes of types 4 and 5). Schemes with higher involvement of communities can help to build social capital, and facilitate a prompt response for forest management decision-making, when the schemes are developed within a supportive legal framework (Danielsen *et al.* 2009) and communities have rights to manage and use forest resources (Topp-Jorgensen *et al.* 2005; Hobley *et al.* 1995; Davies and Richards, 1999). Participatory monitoring creates institution or fora where discussion, negotiation and decisions can be made; it also creates opportunities to collaborate with governmental staff while translating local knowledge onto official/scientific languages (Danielsen *et al.* 2005). While a local based approach is important for practical implementation, it should be dismissed that top-down approaches usually have stronger influence at national and international policy levels and can help to release funding flows; CBM could contribute also in this process if it is embedded within national or international schemes (Danielsen *et al.* 2005).

CBM will be sustainable overtime if it is built on existing institutions, helps to prevent conflicts between government and traditional authorities and if data is stored and analysed locally (Danielsen *et al.* 2005); this might need that the process of implementation should be simple, appropriate to local needs and developed at a slow pace despite the pressures from external actors (e.g. funding bodies) (Danielsen *et al.* 2005; Rodriguez *et al.* 2003). One possible disadvantage of CBM would be the trend to report only positive results in the presence of incentives; this could be reduced by periodic third party verification (Danielsen *et al.* 2011). If the data is also relevant for local decision-making this risk may be reduced since it will be also in the interest of the local community to generate accurate data.

1.3.2 Community Mapping and Participatory Geographic Information Systems (PGIS).

The action of gathering, storing and then processing data about an issue and converting it into maps is known as "mapping" (Forrester and Cinderby, 2011). Participatory mapping allows a group of people related to a certain issue to communicate their knowledge, such as pointing out problems or recording specific locations or resources, as part of the mapping process. In this context, "Community Mapping" is a form of participatory mapping, which is carried out with members of a community either a geographic community or a group of people sharing common characteristics or interests, to represent the views of some or all its members (Forrester and Cinderby, 2011).

The digitalization of paper maps marked with pens and general knowledge recorded from participatory activities (e.g. meetings, focus groups, fieldwork) into databases makes a Participatory Geographic Information System (PGIS). Therefore, as Forrester and Cinderby point out "the key difference between community mapping and a PGIS is what happens to the data *after* it is gathered" (pp. 4). In contrast to community mapping, PGIS gives the opportunity to combine or compare different groups of maps and allows performing analyses that would be otherwise impossible or very time-consuming. Participatory monitoring and mapping has proven to be crucial in projects to quantify and monitor biodiversity to plan and implement conservation and management strategies for protected areas and indigenous territories (Herlihy and Knapp, 2003).

In the context of the monitoring of carbon sequestration and REDD+, geographical data, such as GPS data of forest's boundaries and measurement plots need to be combined with carbon data, such as estimates based on forest inventories for biomass, soil and litter. Then, a re-mapping process is required to produce "carbon maps". Experts outside the community will often perform this step. After the mapping production process is completed, maps would be used to recognize and understand the implications associated to carbon sequestration and climate change mitigation and will help in planning and decision-making. In this context according to Kolagani *et al.* (2012), PGIS can be divided into two categories in order to empower a community as well as obtaining benefits at a broader level:

1. Map production: as its name indicates, this category makes possible to produce maps based on GIS without much technical assistance or expertise brought from outside the community. In addition, data collection is also needed either by using a global positioning system (GPS) or general knowledge from the villagers.
2. Map utilization: this category involves not only the mapmakers but also the entire community which must be able to understand and analyse the maps and participate in decision making and monitoring their implementation with little or no assistance from outsiders.

The use and diffusion of geographic information technologies, including GIS increased since the 1990s. Additionally, the use of low-cost GPS and satellite imagery became popular. All of the above are more user-friendly than ever. As a result, their use in community initiatives to record, organize, visualize and geo-reference indigenous spatial knowledge to produce PGIS has enormously grown (CTA, 2005). In this light, PGIS empowers rural and indigenous communities to enhance their capabilities to generate, manage and use spatial information (CTA, 2005).

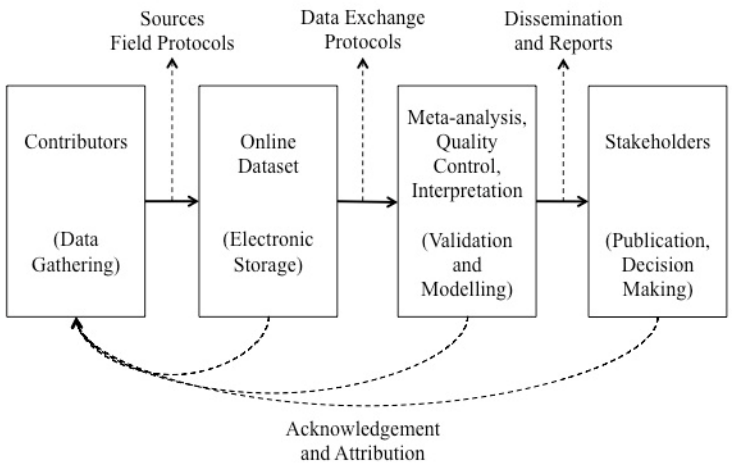
1.3.2.1 Mobile GIS.

Mobile GIS technology represents an alternative to process spatial data outside the community or having purpose-built infrastructure. The term "mobile GIS" refers to mobile devices that can be used to view, collect and update geographic information in the field. These devices include mobile handhelds, tablets, in-vehicle mounted systems, iPods, iPaqs and smartphones. Most commonly, mobile devices integrate Global Navigation Satellite Systems (GNSS), rugged handheld computers and GIS software. Put simple, these GIS appliances process and export collected data to applications of GIS platforms. The GIS market leaders, have developed the "ArcPad" which is a software package for mobile GIS and field mapping applications (ESRI, Mobile GIS Software for Field Mapping Applications 2006). It includes advanced GIS and GPS platforms for capturing, editing, and displaying geographic information in the field. Likewise, a company specialized in software and hardware for forestry and related fields, has launched a low cost iPad application named iCMTGIS. This GIS mobile application software allows data collection and mapping tasks, wherever signal is available, and it is intended for the forestry, land management, utilities and natural resources professionals (GeoConnexion, 2011).

1.3.3 On-Line Collaborative Schemes.

Emerging technologies influence citizen-based or participatory scientific research processes by streamlining data collection, improving data management, automating quality control and expediting communication (Newman *et al.* 2012). Smart phones and tablets are no longer only portable electronic devices to register information but are becoming online measurement instruments (Wobbrock 2006; Paulos *et al.* 2008), specific applications can make the process for data gathering more interactive (Kim *et al.* 2009); moreover sensors could be plugged to devices to collect specific measurement automatically (Kuo *et al.* 2010) though they will require calibration and validation and monitors would deserve proper attribution (Newman *et al.* 2012). In this context it will be required to improve the capabilities for the statistical modelling and management of large volumes of data (Newman *et al.* 2012; Kelling *et al.* 2009). Typically participative on-line monitoring schemes include the following stages: definition of research questions and formats, assemblage –and training- of gathering teams, collection and management of data, analysis and interpretation, dissemination of results and evaluation of the program success and participant outcomes (Bonney *et al.* 2009; Newman *et al.* 2012). Figure 1 presents the expected elements of an online collaborative monitoring scheme.

Figure 1. Process for on-line participatory monitoring scheme (modified from Newman *et al.* 2012).



1.3.4 CBM and Climate Change Mitigation

Rural communities can gather forest-related data in the context of climate change mitigation instruments such as REDD+ (e.g. Skutsch, 2011). 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+ (Danielsen *et al.* 2011). One important challenge is the integration of CBM into national systems and to ensure that there is no leakage (Burgess *et al.* 2010).

The design and selection of the monitoring scheme in REDD+ will depend on specific management objectives selected in national programmes, the resources available and other factors as accessibility to the sites; one of the challenges will be to satisfy international/national and local needs. With an appropriate design and planning, local monitoring schemes can reduce costs, increase accuracy and precision and facilitate the use of local data for national and international monitoring schemes (Danielsen *et al.* 2009). It will be critical that the communities trust external actors and that collaboration is not associated with collusion, corruption or coercion of any kind. Danielsen *et al.* 2011 present a protocol to help identifying when CBM will be more appropriate according to the attributes of different actors in the context of REDD+:

Community.

- Previous experience managing natural resources.
- Evidence of trusted community organization/leadership.
- Residents show interest in Sustainable Forest Management (SFM).
- Residents utilize forest resources.
- Clear rights over forest resources are present in practice.

Government

- Policy is in place for shared management of forest resources with communities.
- Community Forest Management has been adopted within national REDD+.

- National databases of carbon stocks will accept local data via CBM.

Intermediate Organizations

- Presence of suitable and interested intermediate organization (local).

Forest Area

- Area >100 ha to break-even for costs (economies of scale).
- Evidence that CFM ensure tree growth.
- No recent story of conflicts, violence or threats reported by forest managers or communities.

This preliminary protocol can help to evaluate the pertinence of integrating CBM into the implementation of REDD+ at the local level.

1.3.4.1 Examples of CBM for Climate Change Mitigation in the Forestry Sector

In recent years academic literature has published a growing number of cases from research and implementation studies where CBM has been included in the context of climate change mitigation in the forestry sector. Danielsen *et al.* (2011) compared the performance and costs of CBM and professional brigades in 17 communities from India, Tanzania and Madagascar in monitoring forest biomass and utilization (i.e. methods: forest inventory plots and records of cut trees during regular patrols). They report no significant differences in results.

In Tanzania, a case study was carried out in three villages around Angai Villages Land Forest Reserves to (a) assess local communities' perception and willingness to get involved in REDD+, (b) assess the capability and costs to implement Participatory Forest Carbon Assessment (PFCA) methods, and (c) determine forest carbon stocks in the villages (Mukama *et al.* 2012). The results showed that between 40% and 30% of the participant villagers were able to use a GPS accurately. The time for training was identified as a key issue. Also, the case study revealed that villagers were a lot more willing to participate in the REDD+ program in return for some monetary compensation additionally from carbon credit remuneration. More importantly, although villagers were able to take GPS coordinates, they were not able to use GIS software to produce maps since there were no GIS facilities in the villages or at district level. Therefore, maps were produced at a GIS laboratory facilitated by the Sokoine University of Agriculture. In Nepal, a study concluded that although the use of GPS for CBM requires training of local people, it is less time consuming than using a compass and reduces personal errors in capturing data (Rana *et al.* 2008).

Similarly, in Cameroon in an initiative under the Clean Development Mechanism (CDM) of the Kyoto Protocol in the Bimbia Bonadikomo Community, the project used PGIS as a tool for carbon forestry planning. This project identified local and indigenous knowledge as very significant since “it is a (spatial) information system that develops from the close relationship between local people and their land and natural resources” (Minang and McCall, 2006, pp. 86). Key members of the community were identified as expert knowledge holders of historical land use changes. However, the case study also points out weaknesses in the participation of communities in these schemes such as: difficulties in predicting future stable conditions for the project; lack of facilities for data storage and communication systems; and limited skills for the analysis of information. For the purpose of the project, GPS was used to take coordinates to clarify forest resource ownership, rights and access to use of forestland. Data was analysed externally due to the lack of local GIS facilities and personnel. Afterwards, maps were brought back to the community for validation.

In Brazil, The Amazon Conservation Team (ACT) has done a similar work to create local capacities to create PGIS to monitor carbon stocks and deforestation and forest degradation (Butler, 2010). Local maps were constructed in a collaborative process involving indigenous researchers, cartographers and GIS specialists (e.g. local knowledge was gathered from elders, hunters, women and all relevant members from the community). Finally, the maps helped to plan and carry out expeditions in the area with indigenous cartographers, usually young members of the tribe and elders. Data was analysed externally to produce local maps by GIS specialists and then brought back to the site for validation. "The Suiri ethnographic map has become the key instrument in integrating their traditional knowledge of the forest technologies in carbon measuring and monitoring" (Butler, 2010 pp. 18). Access to satellite imagery also played a key role in PGIS for monitoring deforestation and forest degradation. The Suiri tribe is working in partnership with Google Maps to monitor land use, quantify resources and estimate carbon sequestration (Teague, 2011). In the voice of the local leader: "The Suiri know little about the internet, but Google knows little about the forest, so working together we will be stronger. We are mapping and monitoring our lands to protect our resources from loggers and ranchers" (Butler, 2010, pp. 18).

In order to access results-based incentives Vietnam, as other developing country participating in REDD+, needs to generate accurate and complete estimates of carbon stocks and set a monitoring system. A case study in Vietnam implemented and tested CBM in four districts of the Lam Dong province using the Technical Manual for Participatory Carbon Monitoring UN-REDD Viet Nam Programme 2011 as a guideline (Huy, 2012). The monitoring system was divided in two tasks and work forces. First, a group of GIS analysts processed, interpreted and classified satellite imagery to estimate forest areas and forest area changes. Communities participated in a second group in charge of producing ground-level carbon data through CBM. Local groups would be committed to manage their forests sustainably and after appropriate training will collect data periodically (e.g. mapping forest polygons with GPS and establishing forest inventory of measurement plots).

There are also successful cases when PGIS have been implemented locally. For instance in the Siaya district of Kenya, a PGIS project was established to monitor the impact of brick-making industry on forests (Flynn, 2005); spatial data was processed onsite at the Ugunja Community Resource Center (UCRC). In order to implement the local system a number of issues were addressed first (i.e. unreliable electricity supply and unsuitable computing equipment and technical services and economic resources to run the laboratory). In order to succeed, the project needed predictable funding to pay for the personnel. Another important aspect was related to technical capacities, it was necessary to develop solid skills to accomplish the objectives of the project. Volunteer trainees learned to collect data, develop databases, design maps and use a GPS. Additionally they learned more complex tasks such as downloading and converting GPS data, and planning, design and management of GIS databases. Thanks to this project, now the community has strong evidence to build a case linking brick-making and declining forest areas. In the future, the UCRC plans to expand and cover the entire Siaya district and include participatory 3D modelling in their GIS capacities.

Mobile GIS can be an extremely useful tool to monitor changes in carbon stocks. The University of Twente, has run a project to encourage sustainable forest management using mobile GIS (Verplanke, 2005). The project´s main objective is to provide local communities with knowledge and procedures to carry out their own "carbon accounting". For this purpose, communities in

India, Senegal and Tanzania were tested to assess forest dweller's ability to use a standard GIS interface and evaluate the level of training needed. Firstly, a mobile GIS unit was assembled to on- site data collection. The unit comprised an HP iPAQ pocket PC, a handheld personal digital assistant (PDA) loaded with Windows and GIS software ArcPAD 6.0.2 and a GPS to register locations of data recordings, this is particularly useful if high resolution imagery is displayed, as the mapper may "adjust" the GPS reading based on topographical features observed in the real world. Secondly, a group of community members in each country were invited to a workshop to evaluate and test the mobile GIS unit. In addition, the participants were taught to use the unit and within a few hours were able to use the iPAQ successfully, acquire the ability to locate themselves using the GPS system embedded in the iPAQ, retrieve pre-recorded data points and plot an area. However, they needed assistance to enter the necessary data into a predesigned form to describe the plot. The project concluded that villagers were able to quickly learn forest measurements techniques as well as how to use the iPAQ. Furthermore, they provided feedback about issues with the computer system and about what should be measured in the forest. It was also found that a key point for the villagers to be able to use the unit was an illustrated manual to accompany the system, more than extensive training.

In most of the case studies described in this section locals contribute in CBM by collecting data, but for different reasons information is often processed outside the community. In this context most of CBM schemes corresponds to schemes of type 2 in Table 1. The following section makes a detailed revision of the characteristics of REDD+ programmes to identify specific opportunities for CBM.

2. REDD+ and CBM

2.1 REDD+

2.1.1 REDD+ in the Decisions of the Conference of the Parties of the UNFCCC

REDD+, the international policy to reduce emissions from deforestation and forest degradation and the role of 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 (UNFCCC, 2008) and it aims to provide incentives to developing countries to reduce emissions from deforestation and forest degradation and to enhance carbon stocks and removals.

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 (UNFCCC, 2010). 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 recognised; countries were encouraged to prepare appropriate guidance for it (UNFCCC, 2010), and have since started to design and implement systems to monitor carbon in forests.

REDD+ is a program that will be implemented in three general phases (i.e. preparedness, implementation and full results-based activities) (UNFCCC, 2011). 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), which should be implemented with the full participation of relevant stakeholders, particularly indigenous groups and local communities (UNFCCC, 2012); environmental and social safeguards need to be implemented in all the phases of REDD+ (UNFCCC, 2012).

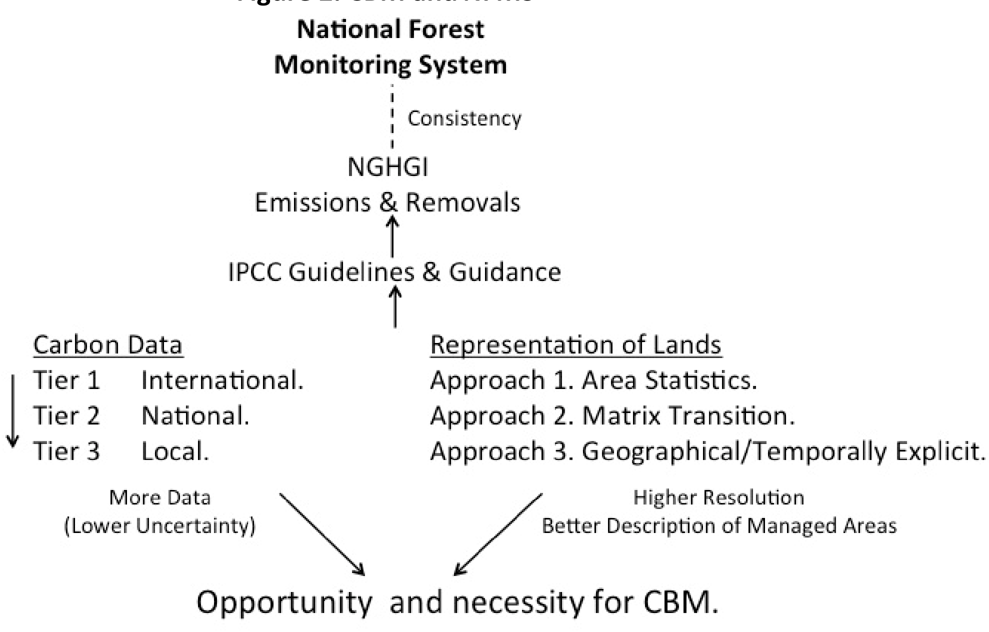
The assessment of results-based actions will require the establishment of reference emissions levels and forests reference levels measured in tCO_2e/yr (REL/RL) (UNFCCC, 2012). The information used to establish these baselines needs to be consistent with the information contained in the National Inventories of Greenhouse Gases Emissions and Removals by Sinks (NGHGI) and can be established following a step-wise approach to allow the incorporation of better data and methods (e.g. to transit from systems based on Tier 1 to Tier 3 approaches) (UNFCCC, 2012).

NGHGI are elaborated following the guidance and guidelines published by the Intergovernmental Panel on Climate Change (IPCC, 1996; IPCC, 2000; IPCC, 2003; IPCC, 2006). 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 (UNFCC, 2008; UNFCCC, 2010). 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 (UNFCCC, 2011); 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 revised guidelines IPCC (1996) where the Land-Use Change and Forestry section is methodologically limited (IPCC, 2003).

In order to access results-based finance, results-based actions need to be fully monitored, reported and verified (UNFCCC, 2012). Mitigation activities implemented by non-Annex I countries seeking international support would be subjected to international monitoring, reporting and verification system (MRV) (UNFCCC, 2010). During 2013 works for the implementation of REDD+ under UNFCCC include the discussions on the possible ways to pay for results-based actions and incentivize non-carbon co-benefits (UNFCCC, 2013); thus co-benefits will 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 for the NFMS to produce detailed data with high level of resolution and low levels of uncertainty based on IPCC guidelines and consistent with NGHGI. Based on a step-wise approach this implies transiting form the use of data of Tiers 1 and 2 (i.e. international and national level data) to Tier 3 (i.e. local level data) for emissions factors and to geographical and temporally explicit information for the representation of land with high levels of resolution and frequent updating. In practice a large effort will be required to produce detailed geographical information and data of the different carbon reservoirs and change in stocks at the local level (Figure 2). CBM offers an opportunity to produce information for the representation of lands and emissions factors at the local level through participatory mapping/GIS and local measurement and monitoring at Tier 3 and Approach 3.

Figure 2. CBM and NFMS

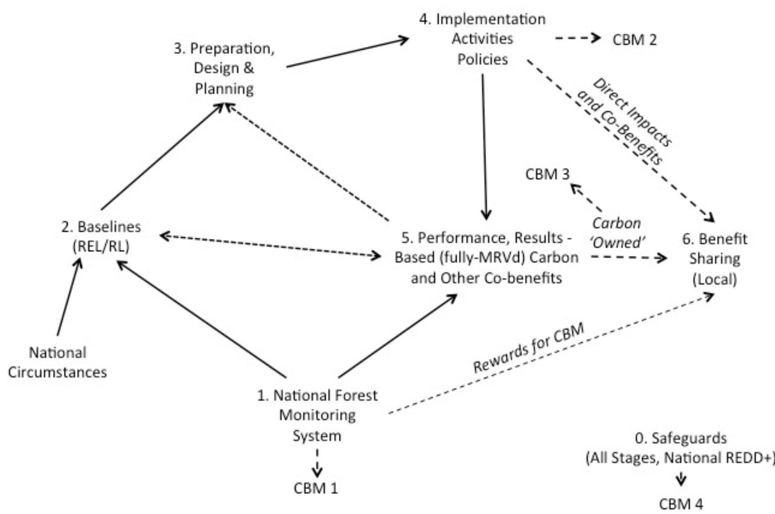


CBM offers an opportunity to advance in the step-wise generation of better and more detailed data for REDD+ by including more measurements and carbon stocks, and also due to the fact that it can allow the mapping of the areas with different forest management practices (units of management), which is essential to understand the effectiveness of these practices in terms of REDD+.

2.1.1.1 *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 3 presents a schematic summary of the different steps for the implementation of REDD+ based on the rules and frameworks that are being built within the UNFCCC and the potential for including information generated through CBM into the NFMS.

Figure 3. General Process for implementing REDD+ and Opportunities for CBMs.



International REDD+ is based on the notion of results-based finance and the assessment of results requires a strong and reliable NFMS that meets international standards as regards data requirements. The process described in Figure 3 starts from the NFMS that is one of the first requirements for countries interested in REDD+(1). The NFMS, based on IPCC guidelines and consistent with NGHGI, is one of the inputs needed for the establishment of baselines (REL/RL) (2), which will be based on historical trends of deforestation and degradation, and national circumstances; the baselines need to consider also 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 evaluated, as part of the MRV system of the NFMS (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 benefit sharing. In Figure 3 it is expected the implementation or REDD+ could produce at least three different types of benefits: direct benefits from the implementation of activities; benefits from the participation in carbon based market mechanisms; and compensation for collaboration for producing information for NFMS (e.g. wages for being part of forest inventory brigades). The evaluation of performance can serve to update the baselines and to revise the REDD+ policies and strategies based on the observed effectiveness for the next period of implementation (from 5 to

2). In all the stages safeguards need to be implemented. The process will be iterative and would repeat, to transit from the preparedness and implementation stage until activities are fully implemented and MRVd. It is within this simplified framework that this work aims to identify the potential for CBM and the challenges it might face. As mentioned above, the case of the REDD+ strategy in Mexico and specifically the projects financed by the Alliance in the EAA are used as an example/case for analysis.

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 that still need to be defined. Figure 3 identifies four different ways in which data from CBM could be integrated into the MRV systems. CBM can potentially provide (1) information to feed the NFMS which contributes in setting the REL/RL, (2) information on activities implemented and monitored at the local level driven by local interest on specific benefits (e.g. timber, water, biodiversity), (3) information produced by projects participating in carbon markets and other certification schemes and (4) feedback on the local implementation of safeguards. Table 2 presents a brief description of the potential challenges associated with these four functions by which CBM may contribute to national REDD+. A common challenge in the four cases will be the creation of the system within the NFMS to collect, analyse and share the information to be produced through CBM. The table also relates these four functions with the five types of community participation which were identified by Danielsen *et al.* (2009), which were presented in Table 1.

Table 2. Description of general opportunities for CBM in REDD+ and main challenges

	Description of function and relation to typology of participation.	**Main Challenges.**
CBM 1	Data gathering to increase sample size of national inventories usually made by professionals and information collected as part of other public programs (Type 2).	Consistent protocols for fieldwork, data transmission and quality assurance. Training and capacity building. Data management and analysis of information with heterogeneous geographical sampling intensity since not all communities will participate.
CBM 2	Monitoring of activities producing specific local benefits highly valued by communities (Type 3-4).	Different information generated depending on local context: activities implemented and co-benefits of interest. This can include a variety of local protocols, qualitative variables and measurement of proxy variables that may not be compatible with official forest inventories. Monitoring may be incomplete and focused only in one carbon pool or process. Information owned by communities, it is necessary to explore potential to integration onto NFMS.
CBM 3	Information produced as part of participation in carbon markets and possibly other certification schemes (e.g. FSC) (Type 2 to 4).	Training and capacity building for advanced methods (Tier 3 level in which many standards for carbon markets are based). Some activities in carbon markets take place in non-forest lands (i.e. afforestation/reforestation, pastureland management). Low risk of possible incompatibility between standard chosen and methods of NFMS (e.g. field protocols, allometric equations, statistical management). Possible incompatibility in methods to set local baselines. Information ownership issues as in CBM 2 and possible double counting. Implementation constrained by level of carbon prices; monitoring is a large part of transaction costs. Sustainable as long as the markets/schemes operate.

CBM 4	Monitoring of safeguards (Type 3-4).	Still it is not clear how safeguards will be implemented in all stages of REDD+. It is necessary to harmonise protocols and processes to monitor social and environmental (biodiversity) if they are to be integrated into the NFMS.

* **Typology refers to the five cases described in Table 1.**

One important difference among these four schemes identified is the degree of participation between local and external actors. Based on the typology presented in Table 1 national centralised inventories (such as INFyS) would correspond to type 1 of monitoring (externally driven); CBM 1 would correspond to a type 2 where communities will participate as data gatherers within an externally designed monitoring system. CBM 2 could be fulfilled by types 3 or 4, since the main motivation for participation would be the generation of local benefits and co-benefits. CBM 3 could involve participation of types 1 to 4, depending on the resources provided by carbon markets and/or requirements that are established as regards benefit sharing, which may or may not involve hiring external brigades to monitor results. However depending on how capacity building is included in the programme, the information could be gathered starting as type 3 scheme and could evolve into a type 4. The monitoring of safeguards (CBM 4) will be externally driven (in the sense that the safeguards will be selected at national level, and a standard protocol will be applied), but considering the interests that local actors may have on these issues (e.g. to ensure respect to their rights, and the value of other environmental services), it could involve a mixed approach of types 3 and 4. It is important to point out that CBM can be in place also as part of the activities to follow-up REDD+ implementation without being included formally in estimates for NMFS or NGHGI; however if local data is used to obtain carbon estimates this can help to define in a more transparent way schemes for benefit sharing.

Regarding the costs of local monitoring, for CBM 1 it is clear that if the main purpose is 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 option is to include these practices as part of existing forest management public programs. Conversely, for CBM 2 once capacities are developed and a local system is designed, it is possible that in many cases it may not be necessary to pay communities directly for the monitoring since it will be in their own interest s to monitor (provided the benefits are valued highly enough to cover costs). Still, not all the communities may have capacities to organise and commit to these practices, the challenge is to create the appropriate levels of social capital. For CBM 3, it is expected that the cost of CBM will be covered by the payments received in the markets or from a national benefit distribution system. Thus carbon prices should to cover the transaction costs (e.g. monitoring, validation, certification), in order to provide net incentives for participation. It will be necessary to create the appropriate agreements for information and benefit sharing related to CBM 2 and 3 since the information will be owned by the communities. 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 costs involved. In all cases it is necessary to evaluate labour availability since agricultural practices have different demand for labour throughout the year.

The implementation of these four types of monitoring schemes could also serve to identify specific ways in which implementation of REDD+ activities will distribute certain benefits at the local level. For CBM 1 local benefits will be associated mostly to wages and capacities developed, especially if the information is processed and used externally. For CBM 2 benefits include the strengthening of local capacities and access/enhancement of specific valued resources or services enjoyed locally.

In CBM 3 local compensation will be linked to carbon performance and channelized locally through market mechanisms. 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.

2.1.1.2 REDD+ in Mexico

Prior to COP 16 in Cancun, Mexico prepared a document to define its Vision on REDD+(CONAFOR, 2010); two years later in November 2012, CONAFOR published a draft version of its national REDD+ strategy (ENAREDD+ to use its initials in Spanish) (CONAFOR, 2012), and a revised draft is currently (July-August 2013) being circulated around a Consulting Technical Committee (CTC) for comments. There are various activities and initiatives under development as part of REDD+ in México that are being implemented jointly with other parties. These include actions for the preparation and implementation of the national strategy, the preparation of the institutional arrangements and early actions.

In 2010 the Ministries of Environment of Mexico and Norway signed an agreement of understanding to develop cooperation activities related to REDD+ including the design of a MRV system (at least to a Tier 2 level), promoting South-South capacity building and the design of local incentives (PMN, 2013); the official name of the project is *"Fortalecimiento del proceso de preparación para REDD+ en México y el fomento de la Cooperación Sur-Sur"* and is usually known as the Mexico-Norway project (MNP). CONAFOR is also implementing a project in collaboration with the French Development Agency (AFD) and the Spanish Agency for International Cooperation and Development (AECID) funded by the Latin American Investment Facility (LAIF) of the European Union, to replicate the creation of local governance systems for REDD+ (CONAFOR, 2013). The objective of the *LAIF project* is to replicate the inter-municipal association scheme adopted in the Ayuquila River Basin in other watersheds of high priority and early actions areas in order to build local capacities to link activities for rural development and sustainable forest management in REDD+ (CONAFOR, 2013). The United States Agency for International Development (USAID) is funding the Alliance to contribute in the implementation and achievement of the objectives of the ENAREDD+. The work of the Alliance, which is led by The Nature Conservancy (TNC), is being carried out by different organizations in collaboration with SEMARNAT and CONAFOR (Alliance, 2013), including the Rainforest Alliance, Woods Hole Research Centre, and the Carnegie Institute. The Alliance is initially financing the implementation of 3-year projects to create local capacities based using a territorial approach in six early action areas (Alliance, 2012). Section 4 presents a thorough description of the implementation process of REDD+ in Mexico and the implications for CBM. The next section presents a revision of the general methods for carbon accounting to discuss the potential contribution of CBM and the basic requirements that can be considered to include it in REDD+ projects and activities.

2.2 Approach for Carbon Accounting and the Representation of Lands.

NGHGI and the NFMS estimate carbon emissions and removals by sinks based on the guidance and methodologies published by IPCC (IPCC, 1996; IPCC, 2003; IPCC, 2006). The general approach focuses on the estimation of the carbon emissions or removals that occur in a certain territory over a period of time. From this, there are two important factors to consider: first, the area of study (A); and secondly, the emission (or removal) factor, this is a Carbon Stock Change Factor (CSCF).

Equation 1. General equation to estimate carbon emissions.

$$C = A * CSCF$$

Where:
C is the carbon annual emissions in the territory (tCO_2e/yr).
A is the area of study (ha).
CSCF is the carbon stock change factor to represent carbon emissions or removals for a specific ecosystem or management area (tCO_2e/ha-yr, the sign will be negative for emissions and positive for absorptions).

2.2.1 Representation of Lands

Carbon emissions and removals are estimated in 'managed areas' receiving the impact of anthropogenic actions (IPCC, 2006); in order to facilitate the analysis, managed areas are stratified into different land cover classes or vegetation types. Land and land-use change dynamics can be represented following one of the three general approaches described in IPCC (2006): first, based only on general area estimates for each land use class/category/stratum; second, based on a land- use transition matrix over the period of analysis; and thirdly, through the geographical and temporally explicit representation of land cover and land use change based on cartography and remotely sensed data. The territory is classified as forestland, cropland, grassland, wetlands, settlements and other covers (IPCC, 2006). Countries can identify specific classes or strata within each category to represent more homogeneous vegetation types and management practices. For inventories, emissions and removals are estimated in areas that remain under the same land category during a period of analysis, and for those changing from one category to other (IPCC, 2006).

2.2.2 Carbon Reservoirs

The completeness of the carbon estimates depends on which carbon reservoirs are included and the source of the information used. In forests, and more formally in the AFOLU/LULUCF sector, carbon reservoirs include: above and belowground living biomass (trees, shrubs, herbs), soil, dead organic matter (deadwood and litter) and harvested wood products. Additionally IPCC provides methods to estimate emissions from disturbances (i.e. fires, pests and those following meteorological events) and emission of non-CO_2 GHG. The sources of data include default data derived from international studies presented in the IPCC guidance and guidelines (Tier 1); data derived from national studies (Tier 2); and information obtained at sub-national/local level which can be used in advanced carbon modelling (Tier 3) (IPCC, 2003; IPCC, 1996).

In the Marrakesh Accords (COP-7), the recommendations for mitigation activities in the LULUCF sector in the context of Kyoto Protocol, indicate that a country could choose not to monitor a carbon reservoir or GHG if it could prove it was not source of emissions (IPCC, 2003). Similar guidance has not been issued in REDD+ for developing countries. In this context if a specific reservoir is a source it would make sense to include it on the monitoring scheme if the benefits received for reducing emissions are higher than the extra cost of monitoring and reporting the additional reservoir

2.2.3 Carbon Balance

It is important to point out that the CSCF in Equation 1 refers to the annual change of carbon stocks and not to the absolute level of stocks. Carbon stocks can be estimated by obtaining the carbon content or carbon density in tCO_2e/ha for a certain vegetation type or area under a management practice and then multiplying it by the corresponding area. For a period of time, going from an initial time 1 (t_1) to time 2 (t_2), the final level of carbon stocks in an area can be represented by Equation 2:

Equation 2. General Carbon Balance.

$$C_{t2} = C_{t1} + G_{t1\text{-}2} - L_{t1\text{-}2}$$

C_{t2}: carbon content at time t_2 (tCO_2e)
C_{t1}: carbon content at time t_1 (tCO_2e)
$G_{t1\text{-}2}$: carbon gains or increments from time t_1 to t_2 (tCO_2e)
$L_{t1\text{-}2}$: carbon losses or reductions from time t_1 to t_2 (tCO_2e)

The final level of carbon stocks based on a simple mass balance will be given by the initial stock plus the difference between the gains and losses occurred during the period of analysis. C_{t1} and C_{t2} refer to the stock levels of carbon standing in the different reservoirs at the given times. $G_{t1\text{-}2}$ refers to the carbon absorptions due to vegetation growth and accumulation of carbon in soils and dead organic matter occurring from time 1 to time 2; vegetation growth includes that of existing trees and that of new naturally/planted trees. Conversely $L_{t1\text{-}2}$ refers to the losses of carbon experienced in the reservoirs in the area of interest over the period of analysis. Losses correspond to harvests (timber, fuel-wood and illegal logging) and losses from mortality and disturbances (i.e. fires, pests and meteorological events). It is possible to identify the different processes associated with the gains and losses expressed in the last two factors in Equation 2; Table 3 presents a general list of the processes associated to gains and losses of carbon in the different reservoirs in forests.

Table 3. 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); *Stock 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	Factors that Increase Occurrence:	Factors that Reduce Occurrence/ Severity:

Reservoir	Losses/Reductions	Gains/Increments
Occurrence	Deadwood, dry herbs/shrubs; drought, wind, human presence, agricultural practices, roads, rubbish, limited access.	Brigade and vigilance, firebreaks, black lines, prescribed fires, improved access, fast access for brigades.

2.2.4 Stock-Change and Gain-and-Loss Methods

By inspection of Equation 2 it is clear to see that it can be rearranged into

Equation 3: Equation 3. General Carbon Balance Rearranged.

$$\frac{C_{t2} - C_{t1}}{t} = \frac{G_{t1\text{-}2} - L_{t1\text{-}2}}{t}$$

t: period from t_1 to t_2 (years). This will produce figures in tCO2e/yr in both sides of the equation.

The most recent methodologies IPCC (2003) and IPCC (2006) present two general approaches to estimate emissions and removals. The first is the *Gain-and-Loss* method that makes a balance between absorptions and removals occurring in the AFOLU/LULUCF sector during the period of analysis. It is based not on field measurements but on calculations of estimated off-takes of different products and estimated growth rates of the vegetation during the period under consideration. This corresponds to the right side of Equation 3. The second method is the *Stock- Difference* method, in which carbon stocks are measured in the field at the beginning and end of the period under consideration (time 1 and time 2); then emissions/removals are estimated as the difference between the final and the initial level of the stocks, this is the left side of Equation 3. The two methods are not usually compared in this way, but we present them here in this way because it is evident that they should be equivalent (i.e. they should produce equivalent results). The information for the NGHGI needs to be presented on a yearly basis, for this, the equations is divided by the number of years between t_1 and t_2. For the Gain-and-Loss method usually the information is generated on a yearly basis, otherwise the difference would also need to be divided by the number of years.

Equation 3 has been formulated on the basis that these two IPCC general methods should be equivalent. However, in order to provide comparable results, the systems used to monitor carbon should in both cases provide a full assessment of identical carbon reservoirs, and changes in these over the given period. The Gain-and-Loss method is more suitable for simpler estimates (Tier 1), whereas the Stock-Difference method is usually associated with more advanced methods (Tier 3) (IPCC, 2006). For the Stock-Difference method the sampled areas should be identical at time 1 and 2 in order to use the information in connection with periodical carbon inventories (IPCC, 2006). This means that both the size of the area and the management practice should remain the same over the period of analysis. Hence, when a new management practice is initiated in an area of forest, this should considered in a new stratum and the changes in carbon stocks should be assessed independently from those of forest areas with the same vegetation type but different management practice.

It is important to point out that one advantage of the gain-loss method is that data can be gathered *per* event or on yearly basis depending on the process and reservoir being monitored (i.e. timber extraction). Conversely for the stock-difference method there will be long periods when data will not be generated (>5 years in areas with slow growth rates). In the context of provision of positive incentives based on results-based actions this could create uncertainties since it will take a long time to know whether or not resources could be attributed locally.

Figures presented in both sides of Equation 3 correspond to the aggregation of carbon in the different reservoirs. Then Equation 3 can be expressed as the summation of the changes in the different reservoirs for the two general methods for a specific area of forest (Equation 4).

Equation 4. Identification of specific carbon pools in Stock-Difference and Gain-Loss methods based in Equation 3.

$$\Delta B_{SCHi} + \Delta S_{SCHi} + \Delta D_{SCi} + \cdots = \Delta B_{GLi} + \Delta S_{GLi} + \Delta D_{GLi} + \cdots$$

Where:

ΔB_{SCHi}: Change in carbon in biomass measured through stock-change method in area of forest i (tC/yr)
ΔS_{SCHi}: Change in carbon in soil measured through stock-change method in area of forest i (tC/yr)
ΔD_{SCi}: Change in carbon in dead organic matter measured through stock-change method in area of forest i (tC/yr)
ΔB_{GLi}: Change in carbon in biomass measured through gain-loss method in area of forest i (tC/yr)
ΔS_{GLi}: Change in carbon in soil measured through gain-loss method in area of forest i (tC/yr)
ΔD_{GLi}: Change in carbon in dead organic matter measured through gain-loss method in area of forest i (tC/yr)

From Equation 4 it can be seen that in theory, if data on the different carbon reservoirs for the two methods was complete and comparable, the terms for the different carbon reservoirs in both sides of the equation will be the same. This also implies that when the NFMS or NGHGI includes information on only one carbon reservoir (i.e. tree biomass), carbon estimates could be complemented by incorporating information on other reservoirs or other processes leading to gains and losses. For instance, the grid of a national inventory could be measuring carbon in trees and its growth overtime; it will also include the information on tree mortality and recruitment as observed within the measurement plots. Then, when inventories are set at national level (Tier 2), it will be very likely that measurement plots will not capture the effect in carbon stocks of activities implemented at local level (e.g. restoration through tree planting, re-vegetation, improved management, cattle exclusion, and obviously it will not capture the effect of other practices implemented off-forest e.g. reforestation/afforestation, management of pasturelands). In this case it might be possible to provide complementary information to account for the missing values of gains and losses once the area over which these activities are implemented is identified.

Periodical measurements in national forest inventories can produce information to identify the changes in carbon stocks based on the Stock-Difference method. If a forest inventory were implemented in each forest management unit, these would measure the changes in stock. If however such inventories are not in place, it would be still possible to identify what processes would be modifying the level of different carbon reservoirs overtime in the different management units by measuring the associated carbon gains and losses in each management area. This is by identifying what relevant activities/processes affect increments and reductions present in the area (Table 3).

Both the Stock-Difference and Gain-and-Loss methods rely on statistical methods. In the Stock- Difference method, maps are used to stratify forestlands into homogenous units and then a sampling plan is set for which it is necessary to define the number, size, form of measurement plots and distance between plots. Information is collected on the ground and then verified and statistically analysed to obtain figures on carbon stocks per hectare and per hectare-year when successive measurements are made; the information is then combined with the area of forest. The alternative non-statistical approach would be to make a complete census of carbon in all forests (and in all trees). This 'carbon census' could potentially be done using LiDAR and a calibrated model to transform height (or volume) data directly into carbon; however this would be very expensive and still ground data on of carbon reservoirs other than biomass would be required.

Conversely for Gain-and-Loss methods, the data usually refers to the registries on timber or fuel- wood production especially at Tier 1 or 2 levels. This may be information reported by industry or communities and refer to 'total' figures. This information would hardly correspond to a complete 'census' of all extractions occurring in a country within a period of time, making the national estimates incomplete. An alternative approach would be to design an appropriate sampling scheme to obtain data on carbon gains/losses per hectare-year for different forest types and management practices; this information then could be combined with statistics of areas with the same vegetation type/management practice to estimate the impact in carbon stocks.

It is important to understand that although CBM is often presented in the literature in the context of stock change methodology (communities physically measuring their forest density), it could equally well be used in the context of gain-loss methodology. If standard protocols were to be developed to inventory typical off-take (quantity of firewood per family, number of cows/cattle allowed to graze within the forest, timber and pole removals etc) and if standard statistics on the typical growth rates of forests in a given area were provided, in principle communities could estimate changes in forest stock using gain-loss techniques. In the voluntary carbon market gain- loss methods are already in use at project level, and for example, a gain-loss method entitled ´deemed deforestation´ is currently under development by members of TNC for the VCS (Bronson Griscom/Peter Ellis personal information).

2.3 LULUCF Mitigation Projects

Under Kyoto Protocol, developed countries listed in the Annex B that ratified the protocol, could decide to implement mitigation actions in the LULUCF sector to comply with their commitments, in which case they should report information of activities and projects implemented. Chapter 4 of Good Practice Guidance (GPG) for LULUCF offers two options for reporting the information of these projects supplementary to that included in national GHG inventories (IPCC, 2003). The first option is to assume that the existing system to produce NGHGI will be able to capture the effect of the projects developed; the second option is to generate the information of the project and use it as primary data for the inventory, for instance as new strata, in which case double counting should be avoided (IPCC, 2003, pp 4.19). An important difference when handling project-level data is that carbon results should report performance in reference to a baseline, while the inventories only report the observed levels of stocks or changes over time (IPCC, 2003).

The implementation of projects in the LULUCF sector imposes the challenge that many participants in small parcels could implement activities. The IPCC's recommendation in this case is to prepare monitoring protocols at the project level and develop monitoring indicators at parcel level (IPCC, 2003)[1](Table 4).

Table 4. Recommendations at project and parcel level (based on IPCC, 2003; Box 4.3.6)

Level	Recommendation
Project	Develop a technical description of the project (e.g. describe management objectives, describe the site –soil, climate, vegetation, species-, suitable activities, expected inputs –material, labour…-, expected outputs –survival, growth, yield, products…-). Produce technical descriptions for specific management activities; identify indicators at parcel level to estimate carbon stocks (e.g. species, density, height, DBH). Identify parameters needed to establish local baselines Establish measurement plots to calibrate the technical descriptions with local conditions. Frequency of measurements will depend on the expected growth/change in stocks/emissions (e.g. for tropical rapid growth areas it could be <3 years; for temperate areas around 5 years, or longer depending on growth/assimilation rates). Implement quality assurance/quality control procedures: this can include re-measurement or independent checks.
Parcel	Measure the variables/indicators selected and verify if the results lie within the ranges given in the technical description; measure baseline indicators.

Following IPCC (2003) actions at project level can select which carbon reservoirs and GHGs to monitor depending on the impact expected, the magnitude of the reservoir and the expected rate of change (including emissions of non-CO2e GHG[2]), the availability of methods, cost restrictions and expected accuracy and precision. The inability to detect changes in carbon stocks when periodic inventories are used, could be related to the limits of the methods/equipment used, the slow rate of the biological process being measured or due to the compensation/feedback between different carbon reservoirs. In the last case, it will be easier to monitor the effect of specific management practices if the analysis is made for each carbon reservoir separately. Considering the expected long-term nature of projects, it is necessary to store and maintain adequately the data and analyses made (physical and electronic, it is important to up-date versions of software and electronic files) (IPCC, 2003). For projects practical steps for LULUCF projects suggested in IPCC (2003) include:

- To develop a baseline (use historical data, preferably local, if necessary use models and establish control areas).
- To stratify the project area into homogenous units.
- To identify the relevant carbon pools and non-CO_2 GHG.
- To design a sampling framework (protocols, size/form/number of permanent/temporary plots, identify field methods and models[3]).
- To develop a monitoring plan including quality assurance/control.

[1] This is also similar to the way in which regional projects are developed for the voluntary carbon market (e.g. the Scolel te project in Mexico also required the generation of a regional plan over 1.9 million ha in Chiapas, and the design of different technical specifications for management practices which once implemented are monitored at the parcel level with specific indicators; details can be found in de Jong et al. 2004).
[2] i.e. biomass burning; synthetic and organic fertilizer application; cultivation of n-fixing trees, crops and forages; soil re-flooding, drainage or disturbance; changes in grazing land management (Table 4.3.2, IPCC, 2003).
[3] Methods to estimate biomass in trees can be based on a direct approach, for instance by measuring trees and using allometric equations; or the indirect approach by using biomass expansion factors (IPCC, 2003).

IPCC (2003) was the document used to prepare the guidelines for reforestation/afforestation projects that were the only activities eligible for developing countries under CDM. However the guidelines and methods can also be applied for the implementation and design of monitoring schemes of other activities in the LULUCF sector that now are expected to be included in REDD+ (i.e. control of deforestation, forest management, revegetation, cropland management and grazing land management)[4]; IPCC (2003) provides specific guidelines for the measurement and monitoring of these activities.

2.4 CBM and the Different Elements within REDD+

It is important to recall that the objective of REDD+ is to reduce the rate at which emissions are generated and increase the rate at which carbon is removed from the atmosphere. Thus the determination of the levels of carbon stocks standing in a forest is only the initial part of the process; the next steps would be to construct a historical baseline and scenarios that include emissions associated with the local situation. Incentives for results-based actions will be evaluated against these baselines, in terms of the reduced emissions or increased removals observed over time. Thus both determining the current level carbon stocks and determining the prospects for further improvements are of interest. This second element is often neglected in discussions on monitoring (and CBM). But 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 make a review of the information that is required to characterize the different activities of REDD+, including for this kind of diagnostic process, and how this information could be generated through CBM.

2.4.1 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 (UNFCCC, 2002); each country should define the appropriate parameters to define their forests. Deforestation is the process by which forest cover is completely and permanently removed 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. According to IPCC's guidelines, when a change of land category takes place, for instance a land use change from forest to grasslands due to a fire, the change will be permanent if after 20 years the area has not recovered beyond the threshold for forests (IPCC, 2003). An historical analysis of deforestation can be done to some extent by analysing a series of satellite images and other remotely sensed data to get the trend in land use change; forest inventories and IPCC default data can provide information of the typical forest carbon content in tCO_2e/ha which can be used to make a first assessment of emissions from deforestation. 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); data on carbon stocks based on large inventories can also provide information with relatively low level of uncertainty for carbon stocks; however these sources of information may not capture differences related to local conditions and management practices when the intention is to use information at the local level.

[4] Specific methods and guidance for these activities can be found in Chapter 4 IPCC (2003)

It is clear that remote sensing to map changes in forest area will be beyond the capacities of most communities and that historical analyses which rely on this technology cannot usually be carried out at this level; and although IPCC default data could be made available to communities for their use in calculating stocks, this is probably not the best way to involve them. The strengths of CBM lie elsewhere. For example, CBM could produce information that defines local management units (e.g. forest stands, areas under cyclical timber management, or under shifting cultivation, the boundaries of which cannot be identified directly from remote sensing), which assists in defining the polygons of changing land uses and the different activities undertaken within the territory of the community. But it may also be crucial in explaining the reasons why the land-use change took place (drivers) – for example, identifying where illegal logging is taking place. In NFMS the emission factors are based usually on the information on carbon stocks from default data (Tier 1) or the national forest inventory (Tier 2). A strength of CBM is that it could be used to update the data at a Tier 3 level, or generate information of other carbon reservoirs (i.e. soil, dead organic matter) if they have not been included in the NFMS; for this, local inventories or other forms of fieldwork should have to be undertaken.

The variables of interest for carbon monitoring as regards deforestation are: forest area (distinguishing between different strata), 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 estimating emissions of non-CO_2 GHG, and the fraction of harvested timber that may have end up as durable wood products.

In terms of community diagnostics, the process of actively identifying areas which are subject to land use change (deforestation) and the drivers behind this change may stimulate the community to consider what REDD+ activities they could engage in. As mentioned above, this will probably not be done by using remote sensing (at least, not by the community itself). Rather, the community may identify deforested areas through sketch mapping or through its carbon inventory at ground level. This monitoring goes further than simply located areas that earlier was forest and is now under other use. The monitoring may also help them identify and map areas within their boundaries that are most likely to be under threat of deforestation and to consider how (and indeed whether) they could counteract these processes. This would involve a discussion of the opportunity costs of deforestation, and balancing the benefits (including financial benefits) of adopting a REDD+ strategy against the financial value of the change in land use. But it will also involve a discussion of the feasibility of implementing a REDD+ strategy from the point of view of public policy. Under current conditions in Mexico, many communities have essentially privatised their land holdings, even including what were earlier common property forests, and the level of control that the *Asamblea* and the community leaders have over land use choices by members is limited. The CBM and analysis exercise would be a very useful start to this kind of profound discussion at the community level.

2.4.2 Reduced Degradation and Carbon Enhancements

Deforestation describes the changes in carbon stocks when there are changes in land use, however there can also be changes in carbon stocks in areas of forest that remain as forest during the period of analysis; these changes are defined as forest degradation and carbon enhancement.

Forest degradation refers to the losses of carbon in areas that remain classified as forests under the definition of forest adopted by a country (in the case a Mexico a decision still has to be made regarding the definition to be used under REDD+[5]. The general national definition of forest uses a canopy cover threshold of 10%, but for the purposes of the Kyoto Protocol, Mexico was using 30% as the canopy threshold. 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 a level of 30%. Beyond this point, deforestation would be said to have occurred (provided the change is permanent and not part of a cyclical management practice – which highlight the importance of making judgements about degradation and deforestation in the context of real management units, not simply on the basis of changes observed through remote sensing.) 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. An area of forest could lose most of the stocks in shrubs, herbs, soil, dead organic matter and trees, and still be considered to be forest. Degradation can also relate to the reduction in the rates of carbon uptake that in the long term would degrade the forest. For instance, grazing might reduce the recruitment of new trees, thus after old trees die they would not be replaced by young ones. Although FAO´s definition of degradation is broad, for purposes of REDD+ degradation should usually be measured in terms of reduced carbon stocks in all pools.

The opposite of forest degradation is carbon enhancement. In this case, a forest that has not reached equilibrium (i.e. its carbon stocks are currently below the level they would be at this location, if they were in ´intact´ state) may, under improved management, be able to accumulate carbon and possibly even augment its canopy cover. Carbon enhancements could occur due to the natural growth of existing vegetation under an improved management regime, and also by the natural and induced recruitment of young trees and other plants, and 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 enhance the establishment of vegetation and the control of activities degrading the forest (i.e. cattle exclusion, limits on extraction of firewood and poles etc.).

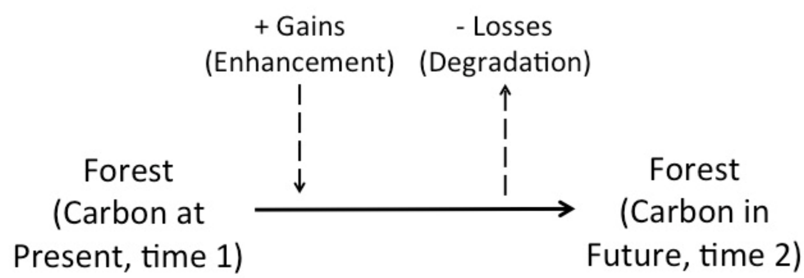
Under forest management activities to reduce degradation, it is quite possible that degradation is brought to a halt and that after some time, net growth and enhancements are measured on the ground. In this scenario it can be assumed that carbon gains include those from the enhancements measured plus the reduced degradation in comparison with a baseline. 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 (i.e. processes listed in Table 3). These processes are identified *per* carbon pool. Depending on the rate and magnitude of these processes, measurements might have to be carried out at frequencies higher than those of regular forest inventories, and Gain-Loss methodology could be appropriate for this (Figure 4). Stock-Difference methodology could be used to confirm the results by comparing stocks at time 1 and 2. Stock measurements would also

[5] The Vision of REDD+ (CONAFOR, 2010) defines forests using 10% canopy cover, 1 ha and 2 m height; however this has not been officially communicated to the UNFCCC.

be needed to establish strata within the forest. Both Gain-Loss and stock measurements could be included in CBM, which would entail also construction of a map of the different forest strata present, using ground level observations.

Figure 4. Approach to use Gain-and-Loss methods to monitor carbon enhancement and forest degradation.



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.). Gain-and-Loss methods can be used to monitor the implementation of specific activities; 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.

A well-known issue is that when the location of permanent measurement plots is known, users may behave strategically and manage the forest differently in those specific areas, producing misleading results. In these cases the monitoring scheme could include a number of permanent measurement plots, and a sample of temporary plots that would be established in sites un-known to the community. The size of the samples should be large enough to generate information statistically comparable and assess if there are meaningful differences.

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) (see recommendations for LULUCF projects in IPCC (2003)); this will depend on the activities selected for implementation and the local arrangements agreed.

In terms of diagnostics, reducing degradation and encouraging enhancement of stocks is likely to be an easier and more feasible strategy for most communities than reducing deforestation, as opportunity costs are likely to be lower. Inventories of stocks at the beginning of the period will reveal to the community where there are particular pressures that result in loss of stock density, and provide information to help target measures to reduce this. This information would be spatial (which parts of the forest) but would also help to identify the causes/drivers. If a community has been involved in earlier forest management programmes such as PSA or timber management, the impact of these of stocks can be assessed by comparing with areas that were not included, enabling the community to consider the value of these kinds of strategies when they come to select their REDD+ activities, and promoting a better informed decision to be made.

2.4.1 Sustainable Management of Forests and of other Lands

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, IPCC, 2003). 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., at stand level), as well as to activities carried out at a regional level (e.g. fire prevention/combating system) (IPCC, 2003). If countries decided to implement activities of Forest Management in the context of Kyoto Protocol, they were instructed to use gross-net accounting system which do not require to know the initial level of carbon stocks; accounting and reporting required only net yearly changes in carbon stocks and non-CO_2 GHG in each commitment period (IPCC, 2003).

Activities included as part of forest management will modify periodically carbon stocks and the gain and loss rates, and ideally should be considered in conjunction with reduction of degradation and enhancement of stocks, since this tends to be their end result. It is necessary to make a description of the different cycles and activities included in the management practices and the geographical and temporal limits. As we have noted above, ideally forest management should be assessed at the level of the entire management unit. An area under forest management may include several sub-units of implementation that would be at different stages of development at a given time (e.g. preparation, planting, thinning, harvest). If carbon estimates are made per hectare or for sub-units of management there would appear to be deforestation in some parts and degradation in others, reflecting what in fact are cycles of growth/harvest. If the analysis is made for the whole area the changes would be averaged out, and the assessment would be more meaningful. Management practices would be considered sustainable if the overall performance of the area shows that carbon stocks are not decreasing; for this, the programmed harvests (and emissions) should be smaller than forest growth(carbon gains/removals). If harvests were much smaller than growth, it would be possible to account for net carbon enhancements. Hence, one possible outcome of SMF would be measured either as carbon enhancements or reduced emissions from degradation. IPCC (2006) provides specific guidance to account for carbon stored in durable harvested wood products, which can be identified as additional benefits of SFM.

In the context of Kyoto Protocol there are other land-based mitigation activities that could be included either as *forest management* or as *cropland* and *grazing*/pasture *land management*. These are management systems where woody vegetation is produced in combination with crops or cattle (e.g. agroforestry –coffee, fruit trees-, enhanced grazing); or when there are different management activities established in cycles of agriculture-grazing-fallow-agriculture, which involve trees, crops and cattle (rotational agriculture). If the area complies with the definition of forests (i.e. area, height, canopy cover), the country could decide whether the area should be considered as managed forests combined with other inter-harvest productive activities, or if the main activities were agriculture/grazing and then should be considered as managed cropland/pasturelands. The same area could not be accounted for under both categories. This selection has implications for the methods to be used. For crop/pasture land management carbon accounting is based on net-net rules where it is necessary to know the initial level of stocks; the main focus is the monitoring of carbon in the soil (i.e. organic, inorganic and emissions from liming activities) which may require a historical modelling (IPCC, 2003); the monitoring of carbon in biomass is optional. If a project decides not to report carbon in biomass it should prove that current stocks would not decrease. However in agroforestry projects, it would make sense to include biomass in the management and monitoring plans since it is an important carbon reservoir that can be increased directly through direct management practices (i.e. tree planting).

Other management practices in KP are re-vegetation, afforestation and reforestation. Re-vegetation relates to activities that increase vegetative cover but have no potential to comply with the definition of forests (IPCC, 2003). These practices can be developed in all land types except forests. Afforestation refers to the planting of trees in non-forested areas and implies a long-term land use change to forests (i.e. considering land use history in the last 50 years), indicating that the area will comply with the definition of forests. On the other hand, reforestation implies a restitution of forest cover in area that had been previously forest, but not since 1990 (IPCC, 2003). Formally afforestation/reforestation are a particular case of forest management, however countries were required to report separately information of these activities (IPCC, 2003). While all these activities contribute to mitigate climate change they might not be included formally in REDD+ since these activities are developed in non-forest lands.

The context for developing countries interested in REDD+ is different from that of the KP. If a country decides to classify areas as managed crop/grazing land, even if they complied with the definition of forests, it would be not included in REDD+. An eventual change in land cover in the area would not be formally acknowledged as deforestation although NGHGI may identify and report the emissions if methods are based on IPCC (2003) or IPCC (2006). As mentioned above, in NGHGI the changes in land use will be permanent, thus the area will be considered as forest (new land use category) if there are no changes after 20 years (IPCC, 2003); for instance a land use change from non-forest to forest through a reforestation/afforestation project could be identified as 'forest', and included in REDD+, after 20 years.

In the context of the COP influential non-governmental organizations (i.e. CGIAR/CIFOR) are starting to move forward from a forest-based mitigation approach in the land sector to a landscape-based approach. However this has not been included in the text of decisions made under the UNFCCC for REDD+. It would be possible for developing countries to prepare comprehensive inter-sectorial strategies to align REDD+ and mitigation actions in the agricultural and other land-use sectors; for this, different specific National Appropriate Mitigation Actions (NAMAs), which could be domestically or internationally financed, could be developed.

In terms of the information needed for monitoring the performance of SMF and mitigation actions in other land uses IPCC (2003) provides specific guidance for projects. In the case of afforestation/reforestation projects the Clean Development Mechanism of Kyoto Protocol has prepared specific methodologies, monitoring and verification/certification standards describing the steps to estimate and monitor carbon sequestration, as part of compliance carbon markets. Since afforestation and reforestation were the only practices eligible for developing countries under CDM, similar methodologies for forest management, crop/grazing land management, (reduced) deforestation and re-vegetation were not developed. However there are methodologies developed in voluntary carbon markets that can provide benchmarks to establish monitoring schemes for projects targeting these activities.

The information to be gathered as part of a monitoring system for SMF includes the geographical boundaries of the areas under different management, and stage of management, the description of the management practices, statistics on the inputs and outputs from forest management (e.g. fertiliser, number of plants, survival; harvests, thinning, accumulation in DOM and soil), information from growth models, and information from forest inventories.

The value of CBM to the community in terms of diagnostics as regards sustainable management of forests is simply that SMF is one of the possible strategies that the community might use to tackle degradation or to encourage enhancement of stocks. Hence the comments made at the end of section 2.4.3 would apply equally to SMF (use of Gain-Loss as well as Stock Change methods, in a mapped approach which includes the different forest strata).

2.4.2 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+. It is evident that it must at minimum mean that the net carbon emissions and removals over a given time period is zero (in contradistinction to reduction of deforestation and degradation, in which the aim is to reduce emissions, and forest enhancement, which it to increase removals). However it is not entirely clear whether this means that the forest in question may be one that is under some kind of productive management or whether it is intended to apply to forests which have essentially never (or within a historical period) been directly used by human beings. Furthermore, when looking in the long term it will be very difficult not to measure changes in carbon stocks particularly if other reservoirs such as soil are included. Interpretations about this vary; some observers clearly see it as a means to prevent pristine intact forest from ever coming into human use, while others see it as a possible outcome of the sustainable management of forest, i.e. when overall harvests in temperate forests are equal to growth. The confusion results from the fact that term was initially introduced in the context of nation-wide carbon balances, to enable countries (such as India, which has had a zero deforestation rate for some years) to participate; it is not at all clear whether, and how, it can be applied at the sub-national level and used as a component within a national REDD+ programme.

Although no decisions or definitions have been adopted at the COP, it could be expected that if a neutral balance in carbon stocks is the product of direct human activity including intensive market- oriented timber extraction, this would be characterised as SMF. 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. declaration of the area as a strict protection zone in which extraction of all sorts is prohibited, and uses are limited to e.g. scientific activity and ecotourism), then the activity could be identified as an area for the conservation of forest carbon stocks. 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 analysing 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.

2.4.3 Other Aspects

2.4.3.1 Construction of Baselines

A critical difference between individual projects developed for carbon markets, and projects aiming to implement similar management activities but in the context of a national REDD+ programme, is how the baselines are set. In markets, individual projects measure performance against an individual project baseline that covers the territory of the project itself and usually a buffer zone of 20- 50 km all around it. In a national REDD+ programme, performance needs to be assessed at the national level (by the third stage of implementation), but obviously the activities contributing to this at the sub-national level will have to be assessed against baselines too. One option is to create nested baselines in REDD+ and aggregate baselines them from the local to regional and national levels (Cattaneo, 2010). 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 (Skutsch *et al*. 2013); however a mixed approach based on local and geographical data can be used to develop baselines for all management units. Rather there are likely to be State level baselines and possibly sub-State baselines (it has been suggested that these could be developed at the level of intermunicipal associations or at the level of UMAFORs, for example). Local communities through CBM could contribute to construction of this lowest level of baselines by providing historical information on land management and drivers, and expectations and future developmental needs. Local land-use management plans at community and municipality level could also be used as sources of information. The local baselines would be helpful in planning and assessing REDD+ opportunities at the subnational level, if not at the community level itself. It will be critical that local baselines are consistent and coherent with the system for the creation of nested baselines at regional and national levels.

2.4.3.2 Understanding Drivers

In order to design adequate strategies it is necessary to understand the drivers of emissions and barriers for favouring carbon enhancements, conservation and SMF. The implementation of REDD+ will require specific activities, policies and programs. A large amount of information on the implementation, 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. However, although this information may be included as part of the MRV system, and it would provide critical information for decision making, overall performance of REDD+ will be strictly measured on a carbon basis. On other words, two types of indicators to be monitored, management related variables for planning and decision-making, and information on carbon stocks that will also be useful as inputs for planning but crucially would be the criteria for the evaluation of performance in terms of tons carbon per hectare per year.

2.4.3.3 Safeguards

Social and environmental safeguards were included in REDD+ to ensure that this programme will not harm the interest of local communities and developing countries and will be 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. 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, reduce reversals and leakage (UNFCCC, 2011).

The monitoring of social safeguards will follow different processes than 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.

The situation is somehow different for environmental safeguards. While they are also need to be considered into the design of REDD+ strategies, for instance to forbid conversion of natural forests to plantations that could receive incentives under REDD+, they can be included also in the system to monitor forest area and carbon. Performance based mitigation activities in carbon markets (e.g. CDM) need to consider these to issues into their design, monitoring and accounting. In this respect, the issue of leakage, the displacement of activities producing emissions as a result of a mitigation action, is a concern at the project level because it will result in the overestimation of the benefits of the project. However since REDD+ is to become a national program, it is expected that the MRV system and NFMS will be able to detect and include theses displacements and thus national performance might not overestimated. The risk will be that of international leakage. In the case of permanence the situation is similar. It is expected that similarly to Kyoto Protocol, REDD+ will establish certain 'commitment periods' over which performance will be assessed. Carbon benefits can be measured and compensated in a first stage, if emissions are reversed in a future stage, that will be in detriment of incentives for the next period; this is also considering that the MRV/NFMS will detect these changes. Since carbon benefits will be estimated *ex-post* this will help to reduce risk of any potential overestimation. It is in the best interest of REDD+ countries to address these issues in the context of performance based finance. The assessment of leakage and permanence will be particularly important of preparation activities, since these could be considered as sub-national 'projects' there are real risks to overestimate carbon benefits of activities implemented.

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 (Table 1) will produce this information in a more transparent way. For environmental safeguards, it will be important to show that relevant criteria has 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.

3. CBM on the Ground

3.1 Measurement Options for CBM in the Context of REDD+

As noted in section 1, since geographical and carbon local data is required for much REDD+ monitoring, the involvement of communities could be a valuable means of obtaining this information, and this would also be in keeping with UNFCCC requirements. This section presents a comparison of the methods available for the monitoring carbon stocks through CBM and characteristics of PGIS for collecting geographical information; this is followed by the description of the general capacities required for CBM and costs associated.

3.1.1 Initial Planning and Sampling

It has been shown by a number of authors that community monitoring of forest characteristics, including carbon, can be as accurate monitoring by professionals, and it is usually considerably cheaper. There are various steps that need to be taken before going to the field. The basic variables or materials that would be needed before monitoring starts include (McCall, 2013):

- Boundaries of the community land (geo-referenced/mapped).
- Any claims on other land that the community is making or conflicts with neighbouring communities concerning land.
- Any land use plans/forest plans which the community has made or which have been made in the past.
- Location of activities that might cause deforestation or degradation, such as areas that are subject to illegal logging, or to shifting cultivation.
- Location of areas potentially affected by hazards (e.g. fires, landfalls, flooding).

Ideally these should be available at least in the form of sketch maps. The next step is to prepare the sampling scheme, this is a critical step for producing statistically reliable results. For study most of the carbon reservoirs it is necessary to generate statistically valid results for different forest strata (for the Stock-difference Method, or for activities/processes for the Gain-and-Loss method). The preparation of a sampling scheme usually requires technical expertise. The size, form and number of plots will be based on the local characteristics and the standard error of mean biomass in each stratum, calculated on the basis of a pilot survey of 3-5 samples in each stratum (these pilot samples may be the ones used in training exercises in which community members learn the basic techniques of tree measurement). Once the number of plots needed is known, their locations need to be set out on a map in a grid pattern, usually using a random starting point. This is a quite complicated exercise. Whether the community can do this themselves depends on their general arithmetic/geometric skills. Secondary school students could probably do the job, under the guidance of a technician. The distances between the points should be standard (e.g. 500m).

Community members using tapes and compasses and a GPS can usually carry out transferring the locations of the sample plots from the map to the forest under guidance of a technician. Handling a GPS is usually within the capacity of at least some community members, after training. Handheld computers and Smartphones can alternatively be used. The geo-reference of the location of each sample point needs to be recorded.

At the location of each sample plot, the sampling area is defined using a pole at the central point and tapes of a standard length to create a circle. The diameter of the circle will be standard, corrected by slope and will have been defined at the time the pilot samples for specific vegetation types were taken (and will depend on the density of the vegetation; technical knowledge is required to make this decision). Circles are to be preferred over square plots as they are easier to lay out. This is a reliable method although sometimes it is difficult to find the plot for successive measurements. One option is to bury a metal bar in the centre of the plot, the brigade can get close to the site using the GPS and aided with a cheap metal detector the bar could be located. Data collected through CBM could be easily mended with information from NFMS, since techniques are easily taught, there are training materials available and it has been proved that community brigades can have similar levels of performance as professional brigades. Once the brigades are in the field most of the costs are proportional to the time required for making the measurements but more importantly to move from one plot to the next one.

3.1.2 Gathering data to Evaluate Carbon Stocks and Stock Changes

For carrying out the above ground biomass inventories, at a minimum the following would be needed (McCall, 2013):

- Delimitation of forest strata, representing different ecotypes, management practices and possibly different levels of degradation, within each of which sampling will take place.
- Location and geo-referencing of the sampling plots to be used.
- Field measurement of the carbon reservoirs to be measured according to specific methods. Information gathered then can be processed to estimate carbon emissions and removals.

As regards the delimitation of forest strata, the community may need technical assistance in identifying important strata. Although the differences between ecotypes (coniferous, tropical dry forest) are generally clear to local people, who tend to use different local terminology to describe these ecological differences, the idea of stratification within one type, for example to reflect the impacts of past management (heavily degraded, lightly degraded) is often not. This does not mean to say however that the job of stratification has to be left to the professionals. In practice, discussion sessions with a sketch map or with Google earth images can be very productive, with a technical person helping the community members to reach a consensus. Such discussions can be very revealing also of the drivers of loss of forest stock.

Once the sample plots have been located in the different forest strata, the task is to make specific measurements associated to each carbon stock or stock change process. Table 5 and Table 6 present a comparison of different methods for monitoring forest carbon through of CBM, and assess the advantages, potential problems, characteristics and potential for local adoption of the available methods. The tables also present general information of methods to evaluate water and biodiversity services.

Table 5. Comparison of different methods available for CBM. Adapted from Skutsch *et al*. in preparation.

Variable/ Method	Description and equipment	Likelihood of measurement error by CBM	Scientific reliability	Capacities needed	Availability training materials	Potential local data processing	Risks (local power relations)	Melding with other data sources
Geographical Data								
1.Area (Polygons)	Relevant geographic information is gathered in the field and fed into the PGIS. Polygon boundaries of areas of forest and specific strata. Specific information can also be recorded (location of measurement plots, waters springs, etc.). Equipment: GPS, smartphone with GPS function, Computer, GIS software. Printing devices (Plotter, printer)	Small, studies have proved use of GPS and GIS by local communities after capacities have been developed.	High, limited by accuracy of equipment and topographical characteristics of sites to receive satellite signal.	Easy to record in field.	Many manuals and examples available.	It would need technical skills/assistance, GIS.	Yes. Small team who have skills	Possible and necessary to locate measurement plots and define polygons. Still cannot be integrated to NFMS through a Participatory Activity Reporting System, but can be included in local land use plans.
2.Canopy Cover (Drones and photography)	Canopy cover is an important instrumental variable in REDD+ and can be particularly useful to understand enhancement and degradation processes and to stratify forest areas to obtain more precise results. There are also methods to model in GIS biomass in trees as function of canopy cover that can work in degraded areas when high resolution imagery is available; however for closed forests there is not a good correlation between these variables. Hence the evaluation of canopy cover is described here as means to enhance stratification of forest areas. ´Drones´ (unmanned very light aircraft, UVA) fitted with relatively simple cameras to take continuous series photos of canopy. Images can be analysed in GIS to determine canopy cover. Equipment: Drones, camera, digital camera, GIS.	Small, but only measures canopy	Getting local values of canopy cover can help to stratify forests and evaluate forest degradation. The relationship of canopy cover to carbon is not linear or simple. This method allows gathering data over large areas of forests.	Easy to operate. But may be perceived as threat locally	Not available yet	It would need technical skills/assistance, GIS.	No. UAV hardly useful for other productive tasks	Melding not easy Data more useful locally; frequency of measurements can be adjusted.
3.Canopy Cover (Ocular or 'tube' based methods, e.g. Korhonen *et al.* 2006).	In a measurement plot a grid or transect is defined, canopy cover is measured at specified points, directly (ocular), or by looking into a concave mirror to percentage covered by the sky or the vegetation (densiometer); or looking into a periscope-like instrument (Cajanus tube) to read if the area is covered by vegetation or not. Canopy cover is estimated based on repeated measurements (more than 50 for Cajanus tube). Equipment: Cajanus tube, densiometers.	There have not been applications for CBM, but it is easy to teach.	Lower bias for Cajanus tube with large samples. Data is produced only for the measurement plot.	Easy to learn how to make measurements. Need to set a sample plan and analyse data.	Available, most are for forestry sector.	Analyses techniques need to be taught first, but it would be possible to be done locally.	Yes. Small team who have skills.	
4.Canopy Cover (Stem and crown mapping e.g. Gill *et al.* 2000)	A square-form measurement plot is defined with graduated ropes, the location of trees and form and size of crowns are drawn in a graduated paper representing the plot. The fraction area covered by vegetation can be counted in paper. Equipment: Same as for inventory plots.		Possible personal bias in measurements. Data is produces only for the measurement plot.		Unknown. Procedures are described in academic literature.	It is possible.		
Stock Difference-Methods								
5.Biomass in trees	DBH measurements using tape or caliper in plots. Height of trees may be also required depending on allometric equations. Diameter of shrubs at the base can be measured provided allometric equations are available (to estimate above and belowground biomass). For biomass in trees, diametric tapes, calipers (DBH), clinometer (height), graduated tape (crown).	Medium; Accuracy of measurements is not always good, but does not seem to be worse than when carried out by professionals.	Generally considered most reliable method available, but availability of allometric equations may be a problem.	Skills can be taught easily.	Many manuals available	With ready programmed database and software it is possible	Yes. Small team who have skills	Good opportunities to collect data on a par with national or state inventories
6.Biomass in shrubs, herbs and litter	The percentage of area covered by shrubs, herbs or litter is determined visually or from photographs taken on-site. A sample of material collected in a given area (e.g. 1m^2) is sent to laboratory to be weighted and determine carbon content. Once the content per m^2 is known carbon estimates can be made for the area. Equipment: identified plastic bags, cooler/box-ice; for laboratory analysis, furnace, scale definition of milligrams, burner other laboratory materials depending on specific standard methods.	Medium, provided protocols for establishing measurement sites and collect samples are in place. Trained/ qualified analysts make laboratory works.	Generally considered most reliable method available, but specific external services are required.	Skills for sample collection can be taught easily.	Procedures exist for research and technical works.	External services are required, mail-post laboratory; technical skills for interpretation and integration into GIS are needed. Soil requires a historical modelling.	Yes. Small team who have skills	Good opportunities to collect data on a par with national or state inventories and to estimate emissions of disturbances.
7.Soil Sample	Soil type, density and depth are determined on site. Samples are collected and sent to the lab to determine density, and		Generally considered most reliable method available, but	Skills for sample collection can be	Procedures exist for research and		Yes. Small team who	

Variable/ Method	Description and equipment	Likelihood of measurement error by CBM	Scientific reliability	Capacities needed	Availability training materials	Potential local data processing	Risks (local power relations)	Melding with other data sources
	organic/inorganic carbon content. Equipment: Soil, cylinder for bulk density, bar for soil depth, equipment to collect samples and laboratory analysis as described above.		specific external services are required; it is also necessary to develop cartography for soil types in order to use the information (strata).	taught easily.	technical works.		have skills	
8.Dead-wood (Transect)	In a plot a series of transects are made to register the frequency of fuel-wood according to the size of the trunks and branches found on the ground. Basic equipment for brigades.	Medium, provided protocols are in place.	Generally considered most reliable method available.	Skills can be taught easily.	There are manuals.	With ready programmed database and software it is possible	Yes. Small team who have skills	
9.Basal Area, Biomass (trees) (Relascopic methods)	A relascope is used to estimate basal area visually, by counting all trunks greater than a selected minimum size, final counts are multiplied by a specific basal area factor. For multispecies site it is necessary to account differentially the basal area per specie. Modified allometric equations can be used to estimate carbon, measuring DBH of few trees would be required to adjust the allometric model (Balderas Torres and Lovett, 2012). Equipment: basic equipment, relascope. There are free relascopic applications for smartphones.	Small for data gathering.	Most useful and reliable where limited range of species are present.	Skills can be taught easily	Manuals not yet adapted for communities	Should be possible	Yes. Small team who have skills	Not so easy to meld as limited to basal area; if figures are converted to biomass/carbon can be melded into state or national systems (only for biomass in trees).
10.Degradation from Photos from fixed points	A set of vantage points is established and marked e.g. with poles. Photos are taken in N,S, E & W directions. Visual comparisons are made with subsequent photos. Equipment: Camera; possibly specialized software can be used to evaluate differences.	Markers get lost, so photos not always in same place	Not tested.	Easily taught	None are needed	Yes, it is in any case subjective; but can be done e.g. in open community meetings with a lot of participation	Probably very small	Difficult, not compatible with formal forest inventories
11.Aboveground Biomass (Ground LiDAR)	A portable LiDAR is placed in centre of permanent plots; then data is processed in a GIS. Equipment: LiDAR.	Measurement error nil. But have to define the plots.	Potentially High. Gives accurate volumetric measures to estimate biomass in vegetation (mostly trees). But need to match tree species to apply allometry. Specific algorithms to transform LiDAR data into biomass ar needed.	Machine does the work, it requires labour to carry equipment to the plot	None are needed	No. Complicated software	Unlikely as data will not be processed locally	Should be possible. Not clear how carbon characteristics of different species are factored in.
12.Aboveground Biomass (Aerial LiDAR)	Using a small plane to carry an Aerial LiDAR.	Small, scan penetrates canopy to get volume data		Needs specialized skills, not available at community level.	Scientific only	No.	Would be carried out by external team.	
Gain and Loss Methods								
13.Gain and Loss Methods (General)	General. Gain loss methods involves estimates of growth rates of trees combined with estimates of off-take rates e.g. for firewood, for impacts of shifting cultivation and for grazing. Reliability of estimates depends whether methods are based on censuses or statistical samples.	Generally is high, as sources of data and methods are usually unknown	Many uncertainties but may help to monitor and understand enhancement and degradation processes.	Would require a protocol for specific activities and reservoirs.	Not available in form community could use.	Would need supervision	Unlikely	Although it could be highly uncertain it is included in IPCC guidelines for lower Tiers. They can be used as implementation control indicators to be confirmed by performance results based on stock-difference methods.
14.Recruitment and Mortality (Biomass)	Gains and Losses can be inferred from information of forest inventories if the same plots and trees are measured. In consecutive forest inventories the register of saplings and young trees with small DBH and of dead trees are registered to account for biomass gains and losses. It is necessary to consider the transfers from one reservoir to another (e.g. biomass to deadwood). It is based on methods and equipment used in forest inventories and stock-difference methods. The objective is to differentiate these processes in the information of the inventories which can be time consuming, however it can help to set local baselines of the rates of mortality and recruitment to be consider in the evaluation of management practices.	The same as for methods based on inventories.						Good opportunities to collect data on a par with national or state inventories

Variable/ Method	Description and equipment	Likelihood of measurement error by CBM	Scientific reliability	Capacities needed	Availability training materials	Potential local data processing	Risks (local power relations)	Melding with other data sources
15.Timber and fuel-wood (Losses)	Registries from harvests included in forest management plans, or registries of reports of illegal logging can be used to produce figures of carbon losses in biomass. Volume or DBH of harvested trees can be transformed into biomass/carbon (allometric models, biomass expansion factors). It is important to define if data will produce censuses or statistical estimates to prepare accordingly data collection. Additional Equipment: None; Registries of harvest and extractions of timber and fuel-wood (a scale).	Censuses are often incomplete thus producing unreliable results, unless it can be ensured there is no missing data. Potentially statistical sampling for specific practices or areas can be implemented and verified periodically via forest inventories	Many uncertainties	Governance over forest resources and discipline in data gathering.	There are existing procedures for projects monitoring fuel-wood use and forest management plans.	The processing of information would be similar to that for estimating biomass in trees.	In the case of illegal activities there could be conflicts with loggers.	Although it could be highly uncertain it is included in IPCC guidelines for lower Tiers.
16.Harvested Wood Products	Depending on the use of timber harvested it is possible to estimate the time stored in different products (e.g. paper, goods, buildings) before it is burned or decomposed and thus estimate carbon stocks at a given moment. The basic input to be recorded is the use given to the harvested wood and by-products.	Low when communities have a forest management plan, if roundwood is sold and not processed locally it could be difficult to assess destination/use.	Medium, estimates rely on assumption on mean life lengths and decay rates in landfills; it is usually not included in NGHGI.	Easy to be acquired, and it is related to the traceability and monitoring of timber production and inventories.	Unknown, besides IPCC guidelines, there may be standards in voluntary market or certification schemes.	It would require external assistance.	Yes. Small team who have skills.	It is possible to be included into NGHGI in the future and for participation in carbon/certified-timber markets.
17.Biomass Growth (Age)	Measuring periodically diameters of the same trees can generate growth rate data s; difference with inventory plots is that here the objective are individual trees and not plots. Alternatively increment borers can be used to extract samples of the core of tree's trunks for species producing growth rings. This information can be used to produce age-size graphs to model tree growth and forest enhancement. Equipment: same as for inventory plots, increment borer (Pressler).	High, errors can be made during the extraction of fragile cores, counting of rings and analysis of data. Brigades participating in community forest management could perform it.	High, the method is accurate; usually this information is used for forest management plans and tier 3 models. Increment borers cannot be used on species with no ring growths or uneven trunk forms (not cylindrical).	For tape and caliper the same as mentioned above. For increment borer specialized training is needed.	Procedures are available for forest technicians.	It could be possible, quantitative and statistical analyses are required.	Yes. Small team who have skills	Information can be used to produce tier 3 level models.
18.Litter (Deposition nets)	Deposition nets of a known area (1m^2) are located below the canopy to capture falling leaves and small branches. The content of the nets is collected periodically and sent to the laboratory for analysis. Equipment: Deposition net; lab services.	Medium (Same as with 6 and 7)	High.	Capacities to set a sample, locate the nets and collect sample.	Available as part of academic works.	With ready programmed database and software it is possible	No.	Good opportunities to collect data on a par with national or state inventories
19.Disturbances (Fires, pests, meteorological)	After a disturbance occurs it is necessary to map the area affected and determine the percentage of losses in the different reservoirs in comparison the levels prior the event. Specific inventory measurements usually are made (Stock-Change Method).	It depends on the techniques used to evaluate each reservoir; external assistance can be required to map large areas affected by fires via recent satellite imagery and GIS.	It depends on the techniques used to evaluate each reservoir	It depends on the techniques used to evaluate each reservoir	There are lesser materials targeted to these events though general manuals can be useful.	It depends on the techniques used to evaluate each reservoir. Additional external assistance needed to estimate emissions of non-CO_2 GHG.	Yes. Small team who have skills.	Good opportunities to collect data on a par with national or state inventories and to estimate emissions of fires.
20.Other: Water Services.	There are various methods to monitor water services provided by forests: Infiltration rates and run-off, requires the establishment of infiltration parcels Study of sediments in bodies of water, requires water quality tool kits or collection of samples and laboratory analysis. Monitoring of water table depth in wells, flows in rivers and levels in reservoirs, based on historical data Monitoring of rainfall and cloud forest moisture capture (pluviometers).	There are examples in the literature of CBM schemes for water services helped by external experts.	It would depend on whether objectives, methods and sampling schemes are appropriate to each case to measure intended impacts.	Similar capacities for taking measurements on the field to those of forestry.	Procedures available as part of academic works.	Estimates need to be made in a GIS with external help to make a thorough water balance.	Yes. Small team who have skills	Possibly it can be integrated into PES programs and watershed management plans.
21.Other: Biodiversity	The monitoring of biodiversity can focus on the verification of environmental safeguards (e.g. use of local species according to plans, not converting natural forests to plantations), and on the monitoring	Low, experience of CBM and monitoring wildlife is well documented.	It is critical to define appropriate objectives and indicators for biodiversity and	To register data in the field and report it; local	Available.	Ecosystem modelling of wildlife corridors	Yes. Small team who have skills	Possibly it can be integrated into PES programs and natural

Variable/ Method	Description and equipment	Likelihood of measurement error by CBM	Scientific reliability	Capacities needed	Availability training materials	Potential local data processing	Risks (local power relations)	Melding with other data sources
	of specific species and populations. The following tools can be used: Species checklists and inventories; Indices of abundance and dominance; Hunting/fishing registers; Direct/indirect registries including photographs (camera traps, focus groups); Capture and release (mist nets for birds).		wildlife management as part of local REDD+ plans.	knowledge is very important. Specific species need to be identified with the assistance of scientists.		and population distributions are made in GIS and require specific skills.		protected area management plans.

Table 6. Comparison of different techniques available for CBM; prospects for local adoption and general requirements.

Variable/ Method	CBM for REDD+	Prospects for local adoption (As opposed to monitoring externally driven) Usefulness of skills to community			Time needed (field work)	General Comments on Overall Costs*
		Local	Ext.	Comments		
Geographical Data						
1.Area (Polygons)	1,2,3,4	X		Yes, locally relevant for land use and forest management; it can help to increase knowledge of territory and management skills.	Rapid, contingent to size of forest area, access and topography.	Data gathering can be cheaply done with GPS and smartphones; cost increase if a local PGIS is to be established.
2.Canopy Cover (Drones and photography)	1,3		X	Some information can be useful for communities (photographs to feed a GIS, data on degradation to stratify forests and monitor degradation) however, quantification of canopy cover is a technical instrumental parameter for REDD+ and not for local management, monitoring might have to be motivated by external incentives.	Rapid, does not require ground movement and can cover a large area.	Much cheaper than LiDAR and high resolution imagery.
3.Canopy Cover (Ocular or 'tube' based methods, e.g. Korhonen *et al*. 2006).	1,3		X		To obtain unbiased results can require from 30 min per plot (Cajanus tube); faster measures can be made with densiometers (from 5 min) or ocular estimates, but there could be biases (Korhonen *et al*. 2006).	Costs depend mostly on transportation to sites and time to take measurements.
4.Canopy Cover (Stem and crown mapping e.g. Gill *et al*. 2000)	1,3		X		It depends on the closeness of vegetation, form of canopy. Once the plot is set, for sites of 900 m2, it takes from 5 min (for areas with very low canopy cover <10%) to 20 or 30 mins (based on Balderas Torres, 2012).	
Stock Difference-Methods						
5.Biomass in trees (Stock Difference)	1,2,3	X		Yes, locally relevant for land use and forest management and if they are interested e.g. in timber volume assessment.	Once in the plot, it depends on tree density and topography; three plots per day per brigade is maximum that can be expected.	Equipment is relatively cheap (tapes, calipers, GPS), but time factor to be considered
6.Biomass in shrubs, herbs and litter.	1,2,3	X		Yes when fodder production or prevention of fires are of local concern.	Once in the inventory plot a sample of 1 m^2 it can take around 15 min.	Equipment for sample collection is relatively cheap; additional costs to transport samples to laboratory and analysis.
7.Soil Sample	1,3		X	It might be motivated by external incentives unless community is interested enough in fertility of soils to cover cost of lab analyses.	Once in the inventory plot a sample 5 min (various samples might be required per site).	
8.Dead-wood (Transect)	1,2,3	X		Yes, if fuel-wood is used locally or fires are a local concern. It can help to determine the impact of mitigation activities (e.g. cook-stoves).	Depends on the amount of deadwood and size of plot (10 to 30 min).	It can be done with the same basic equipment for brigades.
9.Basal Area, Biomass (trees) (Relascopic methods)	1,2,3	X		Yes, locally relevant for land use and forest management and if they are interested e.g. in timber volume assessment	Much quicker than individual DBH measures; transport time needs to be considered. Very low marginal cost of increasing sample size once in the field.	Equipment is cheap and can be own-made; there are free applications for smartphones.
10.Degradation from Photos from fixed points	1,3		X	It is a very visible form of data that can be easily understood and used in meetings but possibly it would require external incentives unless there is a local concern	Quick. It may be distributed to reflect likelihood of degradation in different zones. Walking time is the key factor	Cheap (camera, poles) much quicker than physical measurements.

Variable/ Method	CBM for REDD+	Prospects for local adoption (As opposed to monitoring externally driven) Usefulness of skills to community			Time needed (field work)	General Comments on Overall Costs*
		Local	Ext.	Comments		
				to halt degradation.		
11. Aboveground Biomass (Ground LiDAR)	1,3		X	Communities might be involved only in data gathering, information processed only as carbon may offer little local value unless there are external incentives.	Two or three scans per plot, each of about half an hour. Walking time is the constraint	The equipment is expensive.
12.Aboveground Biomass (Aerial LiDAR)	1,3		X		Rapid, does not require ground movement.	
Gain and Loss Methods						
13.Gain and Loss Methods (General)	1,2,3	X		Yes, when resource use is included and there are clear means to identify violations to local rules, documenting these can contribute to local governance (accountability). Discussion could be useful to community in identifying problems. Skills are useful for forest management plans.	Much quicker than stock change methods; frequency can be adjusted and information can be generated continuously conversely to stock-difference methods.	Very cheap, usually no special equipment is required; possible a scale (accuracy of kg or 100 gr).
14.Recruitment and Mortality (Biomass)	1,3		X	Since it refers to natural forests, possibly without management plans, it might have to be motivated by external incentives (conservation of carbon stocks or PES). It provides information on prospects of forest growth or recovery and on mortality and conservation of stocks.	The same as for forest inventories and stock-difference methods.	Included in forest inventories, but detailed accounting will increase time.
15.Timber and fuel-wood (Losses)	1,2,3	X			Extra time required might be low in areas with forest management plans. Registers are made per event. Time requirements can increase if method is based on statistical sampling. Registries of illegal logging can be taken as part of patrolling routines.	
16.Harvested Wood Products (HWP).	1,2,3,		X	It can enhance analysis skills and forest management but accounting of carbon on HWP might require external incentives.	It should be possible to be done as part of the activities and registries of community/local forestry facilities and forest management plans.	
17.Biomass Growth (Age)	1,2,3	X		Yes, locally relevant for land use and forest management. Skills are useful for forest management plans.	For techniques based on tape and caliper, the same as in inventory plots. For increment borers, it depends on tree size could go from a few minutes to up to one or two hours (per tree).	Increment borers and analysis is required; large part of cost would be time.
18.Litter (Deposition nets)	1,3		X	It would require external incentives in general there would be low applicability. Exceptions would be where litter/soil is extracted for instance for gardening, 'black' oak soil.	It is necessary to leave the equipment on the field and re-visit the site various times per year.	Equipment might not be too expensive, larger share of costs from recurrent field visits and lab and statistical or GIS analyses if included.
19.Disturbances (Fires, pests, meteorological)	1,2,3	X		Yes, particularly when there have been fires in the past and use of forest resources is allowed in management schemes. It can help to get a deeper knowledge on the impact of disturbances on natural resources and importance of possible preventive actions.	It depends on the techniques used to evaluate each reservoir	
20.Other: Water Services.	2	X		Yes, water might be a more visible outcome than climate change mitigation specially if there is local scarcity. Skills are useful for management of natural resources and land use planning. However it is necessary to establish or monitor clear linkages between management actions and impacts on the resource.	In some cases (e.g. pluviometers) it is necessary to leave the equipment on the field and re-visit the site various times per year or even per week.	
21.Other: Biodiversity	2	X		It can be locally driven especially if local use is allowed (hunting) or is associated to other services (ecotourism). Skills are useful for management of natural resources, and to provide external services (training guides for ecotourism)	Time requirements depend of the objective of the study but it can require permanent monitoring (with weekly or monthly collection of data with permanent equipment on the field, e.g. camera traps).	

*For estimates of cost of equipment refer to Table 15.

Table 5 presents a description of different methods available to measure the variables of interest for REDD+. It compares the methods for each variable in terms of the suitability to obtain reliable estimates through CBM, the scientific reliability of the method, the capacities needed and availability of training material, potential for local data processing, risks and melding with other data sources. Methods are presented first for setting up inventories, geographical data and then to produce information for Stock-Difference and Gain-and-Loss methods, and to evaluate water and biodiversity services. Table 6 continues the comparison to define under which form of CBM monitoring the different methods could be more easily adopted (according to the options described in Table 2), it also evaluates whether monitoring practices could be implemented locally by the initiative of communities or if external incentives would be required. Finally it presents the comparison in terms of time and overall costs required. Those variables that contribute to local knowledge to make a better use of local resources as timber, fuel-wood, water, biodiversity have higher potential to be adopted locally. Likewise, methods with the potential to reduce the damage from fires and other disturbances could generate a strong local interest. Conversely, technical aspects totally oriented to external needs (e.g. exhaustive analysis of different reservoirs or assessment of canopy cover) would work better if external incentives were offered. The information contained in these tables can help to evaluate which one would be the best options for specific CBM schemes according to specific objectives, context and management practices. In general, equipment will need to be adapted for the use of local communities, for instance by ensuring instructions are easily understandable in Spanish or the local language.

Most methods of monitoring tree carbon require extensive sampling plots in which many trees need to be measured individually. However there are two methods which do not require this: the measurement of basal area based on relascopic methods (Bitterlich method), which is for ground level measurements; and the course aerial LiDAR and UAVs. The visual determination of basal area has the advantage that once the brigades are on the field, it is very easy and fast to collect a relatively large amount of data at very low cost. On the other hand airborne LiDAR can help to produce carbon estimates over large and inaccessible areas without the need of actually going to the field; but the cost of this technology is still very high and data still needs to be calibrated with local carbon figures (see section 3.1.4).

3.1.2.1 Monitoring of Safeguards

As mentioned in section 2.4.3.3 the implementation of safeguards needs to be included initially in the design of REDD+ and the specific mitigation strategies and actions. Once REDD+ activities are implemented it will be necessary to continue monitoring relevant indicators to ensure the compliance with social and environmental safeguards. Indicators can include the number of denounces claims made by local indigenous groups or disputes arising from the implementation of REDD+ or the degree of participation of different local groups (e.g. women, youth, elders). Socioeconomic impacts will relate to the changes in the level and distribution of local income and the diversification of productive activities. All these are socioeconomic data that could be gathered in the communities and settlements. It could be possible to create a catalogue of cases or situations related to the compliance of safeguards that could be reported by communities. One very important indicator that can reveal if REDD+ activities and its monitoring can be implemented locally relates to the local social stability and land tenure. It is expected that in areas where land rights are not clear or with unstable social conditions (e.g. crime) it will be harder and sometimes impossible to implement mitigation activities.

The monitoring of environmental safeguards will be linked to the design of specific mitigation strategies/actions to address the different REDD+ activities and it will be linked to the national system to monitor safeguards that will be implemented at different scales. It will be very important to indicate which activities will be implemented specifically to conserve and protect natural forests, what species will be planted, what will be the cycles for forest management (and thus consider expected increases and reductions in stocks, different from reversals), and how practices will interlink with other environmental services. Table 5 and Table 6 present basic information on methods for monitoring of biodiversity and water services.

3.1.2.2 Choice of Carbon Pools to Monitor

UNFCCC documents indicate that all carbon pools should be included in the analysis if they are likely to change significantly with or without the implementation REDD+ activities. However, the contribution of some pools to emission levels and to sequestration is very small, and the time and costs involved in measuring them needs to be taken into account when deciding whether or not they should be included. Table 7 presents different attributes that should be considered when deciding which carbon reservoirs, in addition to AGB, should be included in a CBM exercise. Table 7 presents different variables that can be considered when deciding with carbon reservoirs could be included in CBM.

Table 7. Variables for evaluating the inclusion of carbon reservoirs additional to aboveground biomass (ABG) in CBM. Adapted from Skutsch *et al*. in preparation.

Carbon Pools (Additional to AGB)	Typical pool size (vs AGB)	Typical change in pool as a result of management	Methods available for measurement	Complexity of measuring (for communities)	Likelihood of measurement errors	Further analysis required	Overall costs
Roots	Generally one quarter to one half	Does not change significantly Roots remain after felling and after fires in some communities.	Dig out and weigh	Hugely time consuming	Very high - missing roots	Drying weighing	High in terms of time
			The alternative is to use a standard root factor	Easy	Natural variability will introduce error	None	Cheap
Litter layer	1 to 3 %	Will change. If AGB decreases leaf fall will decrease	Bagging samples	Collection is not difficult	Some. Need to define collection quadrants	Drying, weighing	Low
Herb/shrub layer	1-10%	Will change	Bagging samples	Collection is not difficult	Some. Need to define collection quadrants	Drying, weighing	Low
Soil	Depending on ecosystem, from 70% to 300%	Will change but not fast and proportionately much less than AGB (e.g. periods longer than 5 or 10 years).	Digging soil pits to 10cm and bagging samples	Collection is not difficult	Some. Need to define collection quadrants	Laboratory analysis of carbon content	High (professional analysis)

3.1.2.3 Other Considerations

The question of whether leakage (displaced emissions) should be assessed also needs to be addressed. Generally this is difficult for communities to do since it would imply making surveys also in the areas to which the activities causing deforestation/degradation have moved (which are often outside their own territory). In general, deforestation and degradation are assessed using a regional baseline, which means that leakage from all activities within the region would be accounted for within the region, rather than at the level of individual communities; the evaluation of leakage will depend on the specific characteristics of activities implemented and local context projects in carbon markets offer a benchmark on how to account for leakage. If the main aim of community biomass measurement is to assess increases in forest stocks as a result of improved management under REDD+, for example with a view to direct carbon crediting, there is unlikely to be associated leakage; leakage comes from displaced deforestation/degradation.

It is important to understand that in general communities are not able to measure or assess changes in rates of deforestation compared to past losses, since in most cases there is no baseline for comparison. What communities can do is measure at any given point in time what the biomass levels are within areas that are considered to be forest. Of course, if carried out on a regular basis (say every year for 10 years), trends can be assessed, by the community itself or by technical assistants.

3.1.3 Producing Geographical Information through CBM

In order to produce estimates of carbon stocks and stock changes over a specific area is necessary to produce geographical; it is also necessary to know the level of certainty of the information collected and the scale at which it can be represented. This will help to identify ways in which local data can be incorporated into NFMS. While it has been proven that communities can collect information on the ground as part of the mapping process, usually the processing of information needs to be assisted by external experts and technicians in GIS. Most of the information presented in this section relates to the processing of ground data to produce local maps, which is a critical step for the appropriate planning, and evaluation of the effectiveness of REDD+ on the ground.

3.1.3.1 Basic Equipment for Data Collection and Quality of Information

There are different options to produce geographical information through CBM. The most fundamental unit of mobile GIS is the Global Positioning System (GPS). A GPS is a mobile device capable of determining the user's spatial position and show it on the unit's electronic map using 24 satellites placed into orbit by the U.S. Department of Defence as a reference (Garmin, 2013).

In order to understand how uncertainty might be introduced due to local mapping and surveying activities, it is necessary to introduce two concepts: map scale and minimum mapping unit (MMU). Firstly, map scale is simply referred to the ratio between a distance on the map and the corresponding to the real world. Secondly, MMU refers to, the size in map units below which a narrow feature can be reasonably represented by a line and an area by a point for a given scale (ESRI, 2011). For the definition of MMU there are several criteria, for example, the one adopted here defines a 2 mm width on the map for linear features (FAO, 1990). Table 8 shows the MMU associated to different map scales.

Table 8. MMU for different map scales

Scale	Minimum Mapping Unit	
	Linear Unit (m)	Areal Unit (ha)
1: 5,000	10	0.01
1: 10,000	20	0.04
1: 20,000	40	0.16
1: 50,000	100	1
1: 100,000	200	4
1: 250,000	500	25

GPS's accuracy depends on many factors such as atmospheric effects and receiver quality. The National Coordination Office (NCO) reports that real-world data shows that some high-quality GPS receivers currently are able to offer better than ±1.5 meter horizontal accuracy (NCO, 2012). However, in practice, the number and geometry of the received signals from the network of satellites affect accuracy significantly, and in daily use, an accuracy of about ±10 m can be expected (Kowoma, 2009). There is not a straightforward conversion from GPS accuracy to an achievable map scale. However, if GPS accuracy is represented as a square shaped feature, in which the side of the square equals to GPS total error and the 2 mm MMU definition for linear unit is employed, a relationship between the accuracy and achievable scale can be established (Table 9). This area represents the region where the true location of the information collected in the field can be found.

Table 9. Approximated relationship between GPS accuracy and map scale.

GPS Accuracy (m)	Map Scale
± 1	1:1,000
± 3	1:3,000
± 5	1;5,000
± 10	1;10,000

3.1.3.2 Map Accuracy

Accuracy in a GIS context can be divided in three major sub-groups: Thematic accuracy, positional accuracy and temporal accuracy (Willrich, 2002). Thematic accuracy is referred to the attribute values set in a database; these attributes can be either qualitative (categorical or ordinal) or quantitative (interval or ratio) data (de By, *et al.* 2004). There are several sources for thematic inaccuracies; they may originate in early stages of the process, for example, be produced from incorrect measurements in the field. Also, the choice of data model type for representing the features (or conversion between them) can bring thematic inaccuracy with it. Moreover, some data manipulation procedures, such as generalization and simplification, can introduce thematic error (Longley *et al.* 2001).

Positional Accuracy can be understood in terms of the distance between the location in the database and the actual location in the field. Positional accuracy can be divided into two components: absolute and relative. "Absolute positional accuracy addresses how closely all positions on a map or data layer match corresponding positions of features they represent on the ground in a desired projection system (i.e., frame of reference). Relative positional accuracy of a map considers how closely all the positions on a map or data layer represent their corresponding geometrical relationships on the ground. In other words, relative positional accuracy reflects the consistency of any position on a map with respect to any other. While absolute positional accuracy of a map may directly influence relative accuracy, limited research has been performed to study this relationship" (Stanislawski *et al.* 1996, pp.429). Temporal accuracy refers to the coincidence between the encoded coordinates or feature boundaries and actual temporal coordinates or boundaries. It is important that PGIS include protocols to verify the information of cartography produced.

3.1.3.3 Map Scale and Uncertainty

For any object represented in a map there would be a level of uncertainty which can be associated to the level of accuracy of field measurements and scale used. For instance consider that a GPS with an accuracy of +- 5 m was used as part of CBM to map the boundary of a parcel of 1 ha (100 x 100 m); considering the possible error, the sides of the polygon could range from 90 to 110 m (0.81 to 1.21 ha). IPCC (2000) defines the percentage uncertainty of information to produce NGHGI (activity data and emission factors) as half of the 95% confidence interval where the true value can be found divided by the mean expressed as percentage. Using this definition then the uncertainty of the measurement in the field could be estimated by considering the possible values of the polygon measured as U(%)=(Area Max-Area Min)*95%*1/(2*Mean Area), in this case the unceratinty would be of 19% (Appendix 7.1 presents a graphic representation of this). The same approach can be extrapolated to the use of different scales, since due to the rounding of the dimensions given by the minimum unit mappable any object would have a buffer area where the 'real' objects could be found; the variation would be -+ half o the minimum linear unit. Hence it is possible to determine how the percentage uncertainty of a polygon varies depending on its size for a given scale use (Figure 5, both axes are in log-scale).

Figure 5. Percentage uncertainty of square polygons at given map scale represented in reference to the minimum mappable unit.

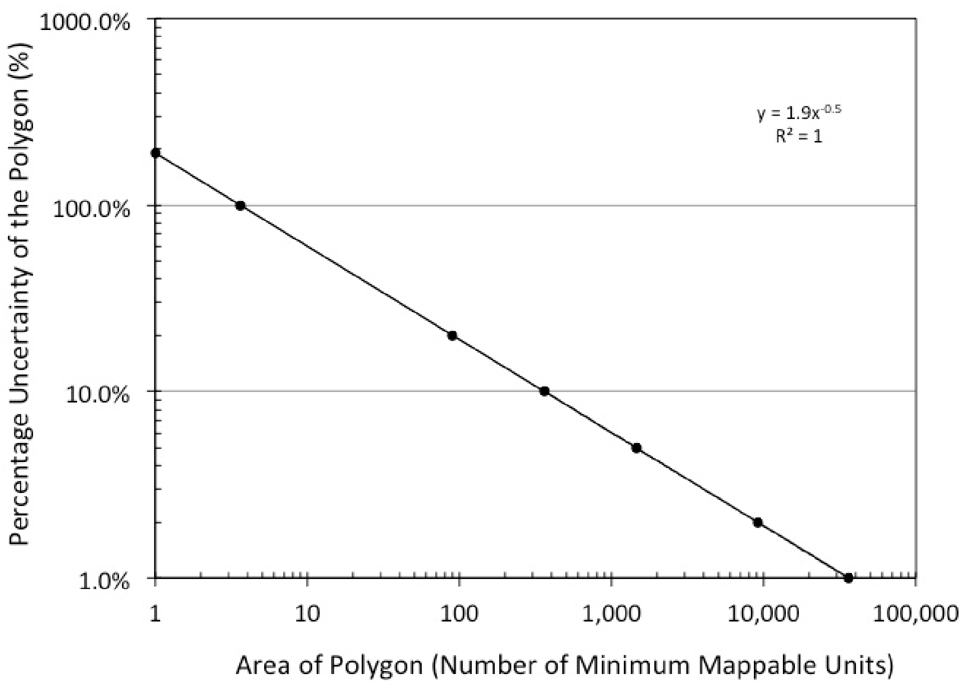


Figure 5 presents that for any given scale the level of uncertainty as function of the polygon size (in MMU). For instance if the objective is to obtain an uncertainty level lower than 5%, then the size of a square polygon should be around 360 MMU or more. For areas larger than 10,000 times the MMU uncertainty will be below 1%. In the context of CBM this means that if relatively small polygons are mapped with high errors, the associated uncertainty of the geographical information will be high.

Table 10 presents for different map scales the size of polygons associated to different levels of uncertainty. For instance if as part of CBM a GPS with an accuracy of +- 5 m is used, the information could be used to produce information up to a scale of 1:5,000; if the goal is to produce

information of polygons with levels of uncertainty below 5%, then polygons should be larger than
14.4 ha. For a work scale of 1:20,000 only polygons of sizes larger than about 231 ha would have uncertainties below 5%. Thus the percentage uncertainty of geographical information gathered through CBM, as defined by IPCC (2000), would depend on the size of the mapped area and the GPS accuracy and can be used to define the attainable map scale.

Table 10. Polygon areas to reach different uncertainty levels for different map scales; values in ha

Map Scale*	Percentage Uncertainty (%)**						
	190% (1)	100% (4)	20% (90)	10% (361)	5.0% (1444)	2.0% (9025)	1.0% (36,100)
1:3,000 (0.004)	0.004	0.01	0.3	1.3	5.2	32.5	130
1:5,000 (0.01)	0.01	0.04	0.9	3.6	14.4	90	361
1:10,000 (0.125)	0.13	0.45	11.3	45.1	58	1,128	4,513
1:20,000 (0.16)	0.16	0.58	14.4	57.8	231	1,444	5,776
1:50,000 (1)	1.0	3.6	90.3	361	1,444	9,025	36,100
1:100,000 (4)	4.0	14.4	361	1,444	5,776	36,100	144,400
1:250,000 (25)	25.0	90.3	2,256	9,025	36,100	225,625	902,500

*For the scale, the number in parenthesis corresponds to the size of the minimum mappable area in ha of a square polygon (included only as reference).
**For the error, the number in parenthesis corresponds to the size of a square polygon, in the number of minimum mappable areas required to reach a specific U% for a given geographical scale (included only as reference).

3.1.3.4 Uncertainty Management

Base data acquired through high quality methods, does not guarantee that results of further processing can be carried out with certainty (de By, *et al.* 2004). Errors and uncertainties can be introduced at any stage of a process, they may arise through the definition of spatial objects, they may be inherent to the source data or they may also occur during data conversion, integration, manipulation and analysis. In general, as the number of processing steps increases, it becomes more challenging to predict the error propagation and uncertainty. In order to manage the errors and uncertainties within a project it is vital to firstly analyse the source of error and uncertainties. The National Center for Geographic Information and Analysis (NCGIA, 2000) in its geographic information science core curriculum recommends a series of actions for effective uncertainty management:

- Developing formal, rigorous models of uncertainty,
- Understanding how uncertainty propagates through spatial processing and decision making,
- Communicating uncertainty to different levels of users in more meaningful ways,
- Designing techniques to assess the fitness for use of geographic information and reducing uncertainty to manageable levels for any given application, and
- Learning how to make decisions when uncertainty is present in geographic information, i.e. being able to absorb uncertainty and cope with it in our everyday lives.

3.1.4 Linkage of Field Carbon Data with Remotely Sensed Data

The role of remotely sensed data in estimating carbon stocks and changes is in the generation of cartography, maps and identification of forested areas to be combined with carbon stock change factors (Section 2.2). However there are other technologies that can be used to model carbon in ecosystems.

Light Detection And Ranging (LiDAR) is a relatively recent active remote sensing technology which for the first time offers the possibility of remote estimation of biomass levels. The basic principle of a LiDAR measurement is to send a laser pulse towards a target and to measure the timing and amount of energy that is scattered back from the target (Lewis and Hancock, 2007). By providing three-dimensional structural information of forests, LiDAR can be used for various structural and biophysical parameters of forest estimations (Kandel, 2011). Advantages of LiDAR over other remote sensing measurements is the fact that in general, other remote sensing measurements of physical properties have to be inferred from radiometric measurements, while LiDAR measurements are relatively direct measurements of or as a function of height (Lewis and Hancock, 2007). Studies have demonstrated a high correlation between field-measured aboveground biomass and forest carbon density to LiDAR estimates of canopy height and high correlation of LiDAR height metrics; results provide both lower uncertainty and higher accuracy than Quickbird high-resolution data (Gonzalez, *et al.* 2010).

In this light, height data provided by LiDAR can be correlated to field measurements carried out through CBM and desktop image classification. In order to accomplish this, three components must be integrated into a GIS: Firstly, the georreferenced carbon measurements carried out through CBM fieldwork. Secondly, the LiDAR height data. Thirdly, a multispectral/high resolution remotely sensed image previously classified into different classes of vegetation type, CBM samples can be used to train the classification process. Based on these three components, a mathematical function can be obtained in order to transform height data and vegetation type to aboveground biomass and forest carbon biomass. Since the GIS analysis is complex, it must be performed by an expert in the spatial analysis field. There are several GIS packages available in the market (some are free and open source) that meet the requirements to carry out this analysis, but software selection will ultimately depend on the expert's choice.

3.2 Data Management, Reliability, Risks of Manipulation and Integrity of Information

A major consideration as regards CBM is the reliability of data and its integrity, particularly if rewards to the community are to be based on these figures. Various studies (e.g. Danielsen, 2009; Danielsen *et al.* 2011; Skutsch 2011) have shown that physical field measurements (DBH, height, location) are made equally accurately by community teams as by professional surveyors. This is not to say that the accuracy is necessarily high; measurements are often made rather rapidly, and a variety of errors may enter the process, such as measuring DBH at the incorrect height, using the tape too slackly, missing some trees etc. The publications mentioned above simply note that community teams and professional ones commit these kinds of errors equally, so that the results are statistically equal.

On the other hand, use of electronic equipment to record and store the data in the field probably reduces errors, at least, the data is recorded only once in each case, meaning that there is only one opportunity for error in transmission. If data is first recorded on paper in the field, and later entered into a computer database, there are two opportunities for transmission error. Moreover, it is possible to introduce filters into the software, such that if an unlikely figure is entered e.g. for a DBH of a particular tree (let us say 100 cm where 10 is the correct figure), the computer may prompt a query and the error may be correctable at source. This will not prevent all such errors of course but would eliminate the grossest of them. Given the potential loss of electronic data it is always recommended to keep a hard copy of the data; if it has been registered electronically this would correspond to the printed version of the formats.

The greater danger may lie in deliberate manipulation of the data. It is obvious that if rewards are based directly on performance in terms of biomass growth, and the monitors are those that will benefit from the rewards, there will be an incentive to exaggerate the results. Even if benefits are not paid out in proportion to measured increases in biomass, communities may be tempted to tweak the data for other reasons. For example, they may fear that their data may lead to punishment, if it shows for example large losses in tree cover (as a result, perhaps, of illegal logging).

The temptation to manipulate data and present a more favourable picture is however not limited to community monitoring. For that reason, verification (the V in MRV) is an essential element in REDD+ and there will always have to be checks and balances at every level. Clearly it is not feasible to verify every measurement made by every community, but it is a simple matter to run community generated data through a programme which will analyze the probability of its being correct (by establishing likely ranges of values). Moreover, communities should be informed that third party verification could be carried out in a small proportion of randomly selected communities (LiDAR offers strong potential for this task), after which communities shown to have been submitting fraudulent information would be penalised/expelled from the REDD+ programme.

3.3 Local Capacities for CBM.

As was mentioned in Section 1, prospects for different types of CBM depend heavily on local capacities. Table 11 presents a brief description of the capacities required to operate different technologies that could be used in CBM.

Table 11. Local capacities required for using different technologies in CBM (modified from Larrazabal and McCall (forthcoming)).

Methods Options	Capacity Required					
	Planning	Measuring	Registering	Processing	Storing	Reporting and Verifying
Paper + GPS	Knowledge about the area Knowledge about the social capital (skills to organize team members)	Skills to understand the selected method (DBH, Bitterlich, etc.)	Capacity to read and write Understanding of GPS function (assuming there is a technician to set the registering options of the devise)	Computer knowledge to capture the data written on paper. Know how to download the GPS files.	It is easy to store the data and make copies to have backups. This is considering that the stored element is paper.	The information will need to be digitalized It is necessary to download the data from the GPS Computer skills are needed to carry out this task.
Handhelds	Knowledge about the area	Skills to understand the		Computer skills to download data	There is a risk of losing	The transcription error is avoided but a medium

<table>
<tr><th rowspan="2">Methods Options</th><th colspan="6">Capacity Required</th></tr>
<tr><th>Planning</th><th>Measuring</th><th>Registering</th><th>Processing</th><th>Storing</th><th>Reporting and Verifying</th></tr>
<tr><td></td><td>Knowledge about the social capital (skills to organize team members)</td><td>selected method (DBH, Bitterlich, etc.)</td><td></td><td>and export it to software to do the management.</td><td>information but it is easier to make backups in order to preserve the data.
Hard disk space is needed</td><td>level of computer skills is need in order to download the data and process it into a report.</td></tr>
<tr><td>Cyber Tracker</td><td></td><td rowspan="2">Knowledge of the area and trees. The digital formulats can be designed without text</td><td rowspan="3">Practice with the specific device and format
Know how to solve the most common problems (like rebooting the device), how to manage zoom</td><td>There is risk of losing the registered information when downloading</td><td></td><td></td></tr>
<tr><td>Google ODK</td><td></td><td rowspan="2">It is possible to send the data to a shared online account and can be processed almost in real time if internet connection is available.</td><td></td><td></td></tr>
<tr><td>Poimaper (1)</td><td></td><td>Knowledge of the area and trees.
The digital forms are customized for illiterate people</td><td>To store information has a cost</td><td></td></tr>
</table>

(1) Application for mobile phones developed to collect point of interest data (http://www.poimapper.com/)

A crucial question in reference to the table above is whether CBM would benefit from the use of electronic equipment or not. As mentioned throughout this report there is some considerable experience with handheld electronic systems of various kinds using different types of software. There remains another question about what skills community people would require for using the different systems that are available; Table 12 reviews this.

What this indicates is that communities may easily use electronic equipment in the field to register data, provided the machines are programmed in advance. Moreover, even illiteracy is not a barrier to its use in this sense (many of the software programmes use icons, and at most numeracy is required), and it is easier to use the GPS function that it built into handheld computers than to use an independent GPS instrument together with a paper system of recording. However, processing the data (downloading it and entering it into other programmes) requires a relatively high level of computer skills that may not be present in the communities. The design of an electronic protocol of its own choice would also be a task beyond the capacity of most communities. This means that in general, technical supports (e.g. from environmental NGOs, consultants and other intermediary organisations) would be necessary for programming and for data analysis, and this same support would need to be used during training. Table 13 comments on the impacts of the use of the different technologies.

Table 12. Level of skill required for the use of different technologies as part of CBM (modified from Larrazabal and McCall (forthcoming)).

Level of skill required to use the option:		***Options***					
High *Medium* *Low.*	***Skills***	***Paper + GPS***	***Registering data with handheld***	***Use of handhelds plus downloading the data***	***Previous plus processing the information***	***Previous plus reporting***	***Previous plus designing a digital form***
	Programming knowledge	[green]	[green]	[green]	[yellow]	[yellow]	[red]
	Basic software use knowledge	[green]	[green]	[red]	[red]	[red]	[red]
	Computing knowledge	[green]	[green]	[red]	[red]	[red]	[red]
	Knowledge on how to turn on and off a handheld device	[green]	[yellow]	[red]	[red]	[red]	[red]
	Knowledge about the territory and its resources	[yellow]	[yellow]	[yellow]	[yellow]	[yellow]	[yellow]
	Measuring method skills.	[red]	[red]	[red]	[red]	[red]	[red]
	Knowledge on GPS use	[red]	[yellow]	[yellow]	[yellow]	[yellow]	[yellow]
	Literate	[red]	[green]	[red]	[red]	[red]	[red]

Table 13. Comments on the use of different technologies in CBM (adapted from Larrazabal and McCall (forthcoming)).

Options	**Verification Means**	**Comments for Different Veg. Types, or Management Practices**	**Likelihood of errors**	**Usefulness of the tool to the community**	**Power concentration**
Paper + GPS	3rd party evaluation of the consistency of the data and possibly physical checks in the field Check consistency of GPS positions.	To carry out the activities by this means is possible for all the forest types if team members are literate.	Errors could take place if the GPS measurement system is changed and the technicians do not notice this.	All these tools and the knowledge related to their use are likely to be applied to a different management process or objective inside the communities.	The skill level needed to manage these tools is easy to spread among community members thus it is not likely to create conflict or dependency.
Handhelds	Time and location are registered automatically, does not require an independent GPS measurement and thus unlikely to lead to	Communities in temperate forest are more likely to be familiar with biomass measurement, as it is a commonly used method associated with timber extraction. Communities in tropical dry forest may be less familiar with the	If the system collapses and the local technicians set is back badly the data could be damaged. If the data protocols are too complicated there could be misunderstandings about	With the skill to understand them comes a certain level of awareness on information power. Handhelds have been	Digital formulas can be designed for illiterate people. It. When the complexity or the degree of community involvement increases

Options	Verification Means	Comments for Different Veg. Types, or Management Practices	Likelihood of errors	Usefulness of the tool to the community	Power concentration
	errors. Consistency of data on biomass can be assessed statistically.	process and may in addition have high marginalization levels. Presence of computational skills may vary, young people are more likely to possess these.	how to register the information or save it when moving between windows.	used to monitor a variety of natural and social parameters, but no studies have been done to assess the additional benefits to the community of developing these skills.	(towards more autonomous monitoring systems),the related knowledge ource of may gradually become a power
Cyber Tracker Google ODK Poimaper		The level of community involvement in the process of preparing the forms depend on the skills that community have developed. A supporting Ngo which is sensitive to community capacities may be able to involve the community actively in the design.			

The material in Table 13 shows that although there are challenges in CBM, these tend to be general, and do not particularly relate to different technologies.

3.4 Costs of CBM

Danielsen *et al.* 2005 report costs for biodiversity monitoring for various studies (15 studies from Africa, Asia and Latin America) of $US 0.08/ha-yr CBM based and $US 3.6/hr-yr for professional brigades. In a comparison of three methods to monitor carbon stocks and disturbances (i.e. permanent plots, Bitterlich gauges and transects with disturbance checklists); Holck (2008) reports that CBM and professional brigades produce similar results in 15 communities in Tanzania. The cost of CBM is lower partly due to the lower wages (payment per day is approximately 10 times smaller than for professionals; Holck, 2008). Bitterlich gauge and checklists methods were more suitable for CBM than permanent plots since they are simpler and cost-effective after only one day of training; but it is necessary to calibrate the methods locally against more comprehensive procedures to adjust the scale (Holck 2008). Table 14 presents a summary of the comparison of monitoring costs between CBM and monitoring undertaken by professional brigades (Danielsen *et al.* 2011).

Table 14. Monitoring costs of CBM and professional brigades (modified Danielsen *et al*. 2011). Costs reported in $USD*.

	Training	Travel and Accommodation	Per diem and food	Equipment	Salary and Administration	Total Cost	Total cost per ha-yr
CBM	700 (97)	629 (227)	769 (108)	282 (59)	1344 (333)	3724 (651)	1.06 (0.33)
Professional	66 (14)	4355 (1133)	2992 (972)	61 (13)	6507 (1033)	13982 (2713)	3.33 (0.96)
CBM/Prof.	10.6	0.1	0.3	4.6	0.2	0.3	0.3

*Data from case studies in India, Tanzania and Madagascar. Costs in Mexico would be from 2 to 7 times higher if the ratio of minimum wage and GNI (both in $ US PPP) are considered. This is a first reference, costs will depend on local conditions and although absolute values might differ it is expected the ratios CBM/Professional brigades can provide an initial reference (USDS, 2012; SAT, 2013; Wikipedia, 2013; WB, 2013).

Table 14 presents that for CBM it is necessary to make an initial investment in training and equipment, however travel and accommodation costs are only a fraction of those of professional brigades. Overall costs of CBM represent about 30% that of professional brigades. Finally, Table 15 presents the approximate prices for the different equipment listed in Table 5 (methods for CBM). These values can be considered as initial references for equipping brigades and CBM schemes. Considering the investment required to fully conform a brigade, and that the equipment will not be used on a full time basis, it would be interesting to consider regional monitoring programs at least for some of the items listed below.

3.6. Conclusions on the Usefulness of Community Based Inventories

National forest inventories produce precise and robust results (i.e. they produce estimates with narrow confidence interval and are not sensitive to the effect of single points, or outliers); this is not due to low variability of carbon in forests (small standard deviation) but to the large sample size of the inventory. As mentioned earlier these results cannot represent local conditions in forest management units. There is a real need to generate local data.

There would be cases where local inventories can with a relatively small sampling effort produce precise values that are statistically different (better than) from Tier 2 values. Nonetheless, if local inventories are planned and implemented poorly, and the sample size is small, results may have relatively higher levels of uncertainty and wide confidence intervals might be involved, making it difficult to differentiate estimates from Tier 2 data. If the local variability in carbon stocks is high, then a large sampling effort will be required to increase the precision, hence increasing the cost; the risk in this case is that the results may converge to those of the NFMS, making them not statistically different, i.e. with no added value as far as the national inventory is concerned. However it is important to recall that local data is necessary not only to contribute to the NFMS but also to contribute to the construction of local baselines; yet another objective of local data would be to assess the changes in stocks of different management practices to evaluate performance of results-based actions in comparison with the baselines. This highlights the need of generating local capacities, preparing standard compatible protocols and of aligning at least some monitoring activities to local needs and interests. It will be particularly important to incorporate local knowledge over the territory and management practices; this can help producing an efficient system for stratification of lands.

As the analysis above has shown, there are a technologies available which make CBM possible at relatively low costs and provided a system of verification is in place, the data may be considered not more biased that data gathered at local level by professional surveyors.

Table 15. Approximate price of equipment for CBM.

Type	Equipment	$USD*
PGIS	Computer	>$200
	GIS Software (iCMTGIS)	>$100
	GPS/Smartphone	$100
	Printer	$200
	Plotter	$1300
Forestry	Graduated Ropes	$30

Type	Equipment	$USD*
Inventory	Clinometer	$150
	Compass	$20
	Digital Camera	$100
	Drone	$300
	Portable LiDAR	$26000
	Diametric Tape	$45
	Caliper	>$30
	Relascope	$10
	Cajanus Tube	$100
	Densiometer	$150
	Collection of soil (probe)	$50
	Cylinder for bulk density	$10
	Increment Borer (Pressler)	$150
Water	Infiltrometer	$300
	Water Quality Kit	$600
	Pluviometers	$300
Biodiversity	Camera traps	$250
	Throw Nets	$100
	Mist nets (birds)	$100
	Aquatic nets	$50

*Costs estimates were obtained from on-line catalogues of technical equipment and are valid for the U.S., any transport or import cost to Mexico were not included (e.g. http://www.forestry-suppliers.com/index1.asp). These are unitary prices, brigades may have more than one unit of some equipment.

4. MRV for the national REDD+ programme in Mexico and the potential role of CBM

4.1 REDD+ and the potential for CBM

This section describes different elements of the initiation of REDD+ in Mexico related to the creation of institutions and frameworks and the implementation of actions. The aim is to describe the local and evolving context of REDD+ in Mexico and what the implications are for incorporating CBM into MRV systems based on the Vision, the ENAREDD+ and on-going projects, to set the NFMS.

4.1.1 Vision on REDD+[6].

The Vision states that the goal of REDD+ is to eliminate emissions from land use change by 2030 and to enhance the quality of carbon reservoirs while incentivizing ecological restoration and biodiversity conservation, contributing to alimentary security and enhancing life standards. Emissions from degradation should be reduced through sustainable use of resources, natural regeneration, controlled use of fire and incentives for such sustainable practices. The main action lines defined are: the creation of institutional arrangements; baselines and a MRV system; capacity building and mechanisms for communication and participation. The Vision points out the importance of learning from successful experiences, respecting landowners' rights and recognizing that the control of emissions in the forestry sector might include interventions beyond forested areas.

The role of the government would be of a promoter and regulator to ensure the respect of property rights and to foresee the needs for institutional arrangements related to REDD+ given the process in which the framework is being built at the international and national levels. In REDD+, forest-owners (communities, individuals or firms) should receive fair and direct benefits, which should not threaten rights to land or the potential to use land sustainably. The strategies should then consider the drivers of emissions and should correct the distortions in the valuation and management of carbon services. Incentives should be aligned to stimulate the sustainable management of forests and natural regeneration, particularly at the community level.

The governance scheme to promote the coherence of the program from the local and sub-national to national levels includes the creation of inter-municipal associations. These associations bring together municipalities sharing an environmental context (i.e. watershed, wildlife corridor), to create local schemes to manage natural resources sustainably. *Local implementation* refers to actions be carried out at the community and the municipality levels.

The scenarios and reference level or baselines for the period 2020-2030 will be prepared using the information on land use change dynamics, emissions and removals for the period 1990 to 2012. The systems for establishing the baselines and systems for benefit sharing would follow a nested approach. The development of a voluntary carbon market is one of the schemes envisioned to create incentives in REDD+.

[6] This section is written based on CONAFOR (2010).

The Vision recognizes MRV as a central element in REDD+ for the provision of information for policy design, in the evaluation of results-based actions, to claim and distribute benefits/incentives, and to generate the information to be reported as part of different commitments made by the country (e.g. national communications, updates, REDD+ related reports). The system should be permanent, reliable, precise, transparent, cost-effective and compatible with the integration of CBM. It should form an integrated multi-scale and multi- functional system to facilitate the use of data from local to national levels, consolidating the information from different public agencies (e.g. CONAFOR, SAGARPA). The mechanisms for *reporting* data will be in agreement with efforts for the elaboration of inventories in the AFOLU sector. The intention is to negotiate, under the UNFCCC, *verification* schemes similar to those used already for the elaboration of national GHG inventories and in the Clean Development Mechanism (CDM).

The Vision's goals related to the MRV system for 2012 included the adjustments of the roles of key public organisms and importantly, in the context of the current study, the development of a cost- effective, multi-scale/multi-purpose MRV system which incorporates CBM; the creation of protocols for CBM; and development of a local voluntary standard (NMX) for carbon measurement in the AFOLU sector and another one for estimating deforestation. At the moment, the status of these elements is not yet clear as the document represents a ´vision´ rather than an agreed programme as such.

Within the preparation of national inventories in the AFOLU sector, estimates of carbon stocks, emissions and removals would be generated following a Tier 2-Tier 3 mixed approach. For this, it is necessary to undertake the following activities: to standardize land use classes and vegetation types consistently with IPCC guidance and guidelines; to up-date carbon content and emissions factors values and the historical data on production and consumption of timber and other forest- related products and activities; to adapt the IPCC methodologies to the local needs of the country; to create protocols for CBM; and to integrate information of the National Forest and Soils Inventory (INFyS) and land monitoring systems of CONAFOR and SAGARPA (CONAFOR, 2010).

Some of the capacities required for the implementation of REDD+ at the local and regional levels relate to the design, evaluation and monitoring of community based projects; the establishment of forest inventories and estimation of carbon stocks; the definition of standards and methods for MRV and certification; the analysis of deforestation and forest degradation; and the establishment of baselines for the estimation of emissions reductions.

4.1.2 ENAREDD+[7].

The ENAREDD+ establishes that the framework for REDD+ implementation is focused on a model for sustainable rural development, based on a territorial approach aligned to the principles of the strategy and with social and environmental safeguards. In line with the General Climate Change Law (LGCC), the strategy updates the target to reach a zero percent level of carbon losses in original ecosystems by 2020; it also aims to reduce emissions from degradation, increase the areas under sustainable management and those regenerating naturally, as well as to conserve and enhance carbon stocks. The strategy recalls that in Mexico the legal framework establishes that as

[7] This section is written based on CONAFOR (2012).

vegetation and soils in forests capture carbon, the property rights relating to that carbon (i.e. in forest stocks and in enhancements of forest stocks) lie with the legal owners of land (e.g. *ejidos*, communities, indigenous groups, individuals, firms). Conversely, however, rights to benefits arising from reduction of emissions from deforestation and degradation do not lie with the forest owners, since activities that lead to land use change and forest-loss are officially not allowed by law; this is still being discussed in the formulation of the final version of the ENAREDD+. The strategy includes objectives and activities for the following elements: Public Policies, Financing Schemes, Institutional Arrangements and Capacity Building, Reference Levels, MRV, Safeguards, and Communication, Social Participation and Transparency. It also provides an account of the advancement of three early actions implemented in the country.

The ENAREDD+ specifies the principal activities required to align incentives produced by public policies and design economic instruments to mobilize resources for REDD+. The institutional arrangements that will be created as part of REDD+ will include strategies, measures and actions to provide long-term certainty for actions implemented. Strategies include the use of *community land use plans,* the promotion of actions to reduce the effect of disturbances and actions to promote restoration and enhancement of ecosystems. Different economic instruments will be designed and promoted to facilitate the implementation of activities in REDD+. Some of these will include the use of domestic funds to subsidize community sustainable forest management, the financing of sustainable activities based on *best practices*, measures for increasing the *access to credit* for productive activities and the creation of a *voluntary market* for carbon sequestration. It will be important to address the issues of permanence, buffers and leakage, and to create synergies with the private and social sectors. It will also be necessary to finance actions to *create capacities* that might enable local communities to engage in implementation, including those related to monitoring.

Based on a territorial or landscape approach, one of the objectives stated in the strategy is the *integration of monitoring into the institutional arrangements* at different scales. For this, activities to be implemented will be *planned locally* as means to create local governance schemes by promoting the participation of communities and inter-municipal associations.

Reference levels have been under preparation since 2010. Baselines will be established first for reduced emissions and for carbon enhancements at the national level. These will be disaggregated sub-nationally. State level baselines will be created and sub-state level baselines would serve to assess the effectiveness of policies in emissions from deforestation and degradation and to link actions to regional funds for incentive based actions and financing. Alternative responses will be included to allow the development of certain market driven agricultural/grazing activities (e.g. avocado, cattle) by intervening in off-forest land.

The system to set the baselines and the MRV should be unified and the information should allow the verification of results. It is necessary to guarantee the consistency between the reference levels, the evaluation of activities implemented and the information of national inventories. The MRV system and reference levels should also facilitate the access to benefits and compensation for results at the local level. REDD+ will promote community forest management and define the options for local participation into MRV and information systems for the implementation of safeguards. MRV will be also linked to the Environmental, Forestry and Sustainable Rural Development Information System.

In line with the texts adopted at the COP, the MRV system should consider the methods and guidance of IPCC (2003) and IPCC (2006) and the implementation will follow three stages (i.e. preparedness, implementation of actions and policies and full MRV). It has been established in local legislation that the MRV system should be created within a period of three years, starting on 5/6/2012 (LGDFS, 2012). CONAFOR is the focal point for the preparation and instrumentation of REDD+. It will also be necessary to include formally the references to the MRV system in the specific regulations derived from the LGCC. The NFMS should be robust and include a transparent MRV system; it should promote local participation by exploring different approaches to improve community forest management while contributing to national systems.

The NFMS will evaluate changes in emissions from deforestation, degradation, permanence and carbon enhancements, and will identify leakage. The NFIS will use information from the INFyS to assess the changes in carbon stocks; a satellite based system to monitor land use changes; and a national inventory system to report GHG emissions and removals in AFOLUC/LULUCF. The necessity of improving information on activity data (land cover/management) and emissions factors is recognised; it will be necessary to evaluate the different methodologies available. However, there is no explicit mention of the role of CBM in this regard.

Given the inherent differences in the causes and processes of deforestation and degradation, the systems for monitoring these may have to use different methodologies. Cartography and satellite images can be used to assess the changes in area of degraded forests but emission factors cannot be derived in this way; for this reason it is better to assess degradation at the level of management areas. Methodological guidance and protocols will be published to standardize and gradually improve MRV practices from national to local and community levels and to define methods to evaluate the impacts of REDD+. It will be necessary to support the monitoring in early action areas to produce scalable and replicable models. The ENAREDD+ provides little guidance regarding the verification and reporting of information; the strategy states that it will be necessary to certify independent actors to carry out transparent verification activities.

The strategy includes the principles and guidelines for the implementation of social and environmental safeguards as included in the COP decisions adopted at Cancun and Durban. Additionally, the national legislation and the ENAREDD+ itself include additional safeguards (Appendix, Section 7.2). Safeguards should ensure the equitable distribution of benefits, guarantee the certainty over property rights and economic competitiveness. The participation of indigenous groups is a challenge; the ENAREDD+ recognizes 62 indigenous groups with their own languages. The strategies for participation and communication should engage and empower different social actors for REDD+ participation and implementation of safeguards.

The ENAREDD+ concludes with a description of the early actions developed in different regions of Mexico: Jalisco, Yucatan and Chiapas. It mentions that the works for the creation of the MRV system in Jalisco are lead by CIECO, CIGA in UNAM and U. de G. In Yucatan the process is focused on the analysis of drivers of emissions and removals and the integration of state level inventories. In Chiapas, the work is in line with the State Climate Change Action Program, the methodology is multi-scale and includes the participation of communities, the monitoring of the main carbon reservoirs according to IPCC Guidelines and guidance and also includes protocols for the evaluation of other environmental services (biodiversity and hydrological); it states that these methods can be implemented at low costs and produce results with low levels of uncertainty.

4.1.3 Mexico-Norway Project (MNP)

The Mexico-Norway project is collaborating in the design of the NFMS and MRV system and in the definition of baselines and its linkage with the NGHGI for the AFOLU/LULUCF sector. As stated in the ENAREDD+, the NFMS is being articulated by the INFyS to produce the information on carbon content and with the satellite monitoring systems for the representation of lands and activity data through the coordination of different agencies (i.e. CONAFOR, CONABIO, INECC and INEGI).

4.1.3.1 NGHGI

One of the tasks of the MNP was to make a revision and comparison of the first four NGHGI submitted by Mexico to the UNFCCC (PMN, 2012). Mexico has submitted five national communications including NGHGI to the UNFCCC between 1997 and 2012. The NGHGI have included results from the LUCF/LULUCF/AFOLU sectors, however the methodology and input data has changed over the different inventories.

In 1997 the basic 1994 methodologies were used to estimate emissions from land use change in 1990 (135,857 GgCO_2e/yr) (SEMARNAT, 1997). In the second communication in 2001 the IPCC 1996 Revised Methodologies were used to estimate emissions for the year 1996 (157,303 GgCO_2e/yr) (SEMARNAT, 2001). In 2007, the preliminary results for 1993-2002 were reported still using the revised IPCC (1996) methods (89,854 GgCO_2e/yr)(SEMARNAT, 2007). In 2009 the fourth communication used the GPGLULUCF (IPCC, 2003) to estimate emissions for the period 1990- 2006; the information was still considered preliminary (80,162 GgCO_2e/yr) (SEMARNAT, 2009).

In 2012 the fifth communication was submitted, the data reported corresponded to the period 2000-2006, with an extrapolation to 2010 (73,877 GgCO_2e/yr) (SEMARNAT, 2012). The methods went back to the use of IPCC 1996 Revised methods and used only Tier 1 values. However the representation of lands was based on the approach suggested in IPCC (2003) and (2006); the information reported includes data of plantation, fuel-wood and timber harvest, emissions from land use change and absorptions in abandoned areas (SEMARNAT, 2012).

The sections of the NGHGI for the LUCF/LULUCF/AFOLU sector, as presented in the national communications available in the UNFCCC's website[8] , offer few specific comments on the methodological steps take and considerations made (Balderas Torres *et al.* in preparation). In the national communications there is on average a gap of 5 years between the year of the report and the year in which the information is reported. Although in theory, the inventories have been improving over time, in general they are inconsistent since each GHG inventory starts with new methods and data without building up on previous approaches (PMN, 2012); this is noticeable specially in the changes from the fourth to the fifth communication. There have been improvements in terms of the sources for activity data which have shifted from a basic approach based on total areas for different land covers in the first communications, to a geographically explicit approach based on information from INEGI (PMN, 2012). However many of the emissions factors used, particularly in the third and fourth communications, refer to unpublished case studies which were not available for the study made by PMN (2012). This, together with the lack of

[8] http://unfccc.int/national_reports/non-annex_i_natcom/items/2979.php

a continuous process to build on previous efforts, may be the reason why the GHG inventory presented in the fifth communication is based solely on IPCC (1996) and default data.

In terms of the exhaustiveness of the GHG inventories, the IPCC 1996 and IPCC (2003)/IPCC (2006) have different scopes in terms of the reservoirs to be reported. In Mexico, NGHGI have only reported data for above and belowground biomass and in the fourth communication for mineral soils; one recommendation for further inventories is to report all the reservoirs using at least Tier 1 data (PMN, 2012).

4.1.3.2 Potential for Tier 3 Approaches

The MNP has included as one of its tasks the assessment of the potential use of Tier 3 approaches modeling carbon in ecosystems as means to reduce the uncertainty of estimates of carbon emissions, to comply with the reporting obligations under the UNFCCC and as preparation for future claims for financing results-based actions (Olguin *et al.* 2012). The approach being explored is based on forest inventories, growth and yield data to be used as input in simulation processes for carbon accounting at national and sub-national levels (Olguin *et al.* 2012). The activities for this task include the definition of the stratification system at national level to compile the input data and define scenarios; the testing of models for ecosystem modeling at Tier 3 by establishing monitoring plots in strategic landscapes; the characterization of the potential to model soil in carbon; and the simulation of the impact of anthropogenic and natural disturbances on carbon emissions (Olguin *et al.* 2012).

Tier 3 methods based on models describe the fluxes of carbon within ecosystems according to physiological processes and in some cases for different management practices. In the MNP, models will be calibrated using information from study areas which will include an exhaustive assessment of carbon stocks and fluxes through ground surveying and eddy covariance towers in ten sites with different vegetation types and management practices (Olguin *et al.* 2012). Information from INFyS and regional/local studies would also be used in the models, however there are challenges in the use of local information outside the area in which it was generated, as comparability cannot be taken for granted (e.g. Olguin *et al.* 2012; Paz *et al.* 2010). The project acknowledges that it is necessary to generate data on growth rates for different vegetation types, to determine the mass transfer within carbon reservoirs (deposition and decomposition rates) and to produce geographically explicit data regarding forest management practices, land use changes and disturbances (Olguin *et al.* 2012). For the generation of input data, there would be agreements with universities, public bodies, civil society and others to generate the required data: forest inventories, growth rate figures, activity data (location, impact, frequency, recovering) and ecologic parameters (deposition and decomposition rates). The project will define the variables that will be measured on the ground and field protocols (including for CBM). One of the pilot sites for intensive forest monitoring will be established in an area under community forest management. However it is not clear yet how CBM could be included as part of the agreements for the generation of input data or for the future calibration and application of the models at national level.

4.1.3.3 Carbon Stock Change Factors (INFyS)

Carbon content, removals and emission factors in the NFMS will be based on the information obtained from INFyS, which is the national forest and soil inventory undertaken by professional brigades; it includes 18,000 measurement plots (CONAFOR, 2008). Sampling is made systematically on a grid pattern with a random start and depending on the type of vegetation the distance between plots is 5 or 20 km. In forest land INFyS can provide information on activities which have a size of at least 25 km^2; although activities implemented in areas of less than 75 km^2 will be underrepresented in national figures (Fernandez *et al*. 2012). In this grid there could be areas of 2500 ha with no measurement plots, 10,000 ha with one plot, or 200,000 ha with three plots (which would be the minimum number of plots to assess local variability based on INFyS, Fernandez *et al*. 2012).

The plots are revisited and re-measured every five years; this can help to generate growth estimates, using the stock-change method. Nevertheless it has proven difficult to guarantee that brigades revisit the exact sites and measure the same trees; due to a number of different factors, including *social inaccessibility*, nearly 7% of the sites have not been re-visited (Fernandez *et al*. 2012). As there are no guarantees that the same trees are being re-measured, it is difficult to apply the *gain-and loss method* to INFyS data by estimating specific growth rates for individual trees (Fernandez *et al*. 2012). It is expected that by 2014, once the second round of measurements is concluded, the INFyS could be used to produce growth data through the *stock-difference method* (Fernandez *et al*. 2012). If brigades re-visit areas within the same stands where the first measure took place, it may be possible that data could still be used to identify the general trend of growth/degradation.

After analysing the data from 2004-2012, Fernandez *et al*. concluded that for practical uses, INFyS can only provide information on carbon stocks in trees; additional reservoirs can be included in the future when information becomes available through successive measurements. Initially INFyS had included the surveying of soils, but the data is not available for CONAFOR; the plan is to incorporate other carbon reservoirs in the system in a step-wise process by 2015 (Michel Fuentes, p.c.). Fernandez *et al*. recommend the inclusion of other carbon reservoirs and incorporation of the state level inventories (a process is on-going to incorporate state inventory data in the INFyS database) but they do not provide explicit guidelines for to the inclusion of local data that could be gathered through CBM. The inclusion of the data from state level inventories would help to increase the overall sampling density. If CBM is included in the system the intensity of the sampling would be much greater, at least in the areas where CBM is applied, but the approach to data collection will be no longer homogeneous and appropriate considerations for data management will be needed when preparing national reports (Michel Fuentes, p.c.).

The basic information taken from the inventory for the estimation of carbon stocks in trees corresponds to the typical dasometric variables: species identification (by scientific name), diameter at breast height (DBH) and the height of the tree (H). Carbon (tC, tCO_2e) is estimated for each tree, and for measurement plot and conglomerate to produce values *per* hectare; then the values for each forest stratum are obtained. For this, allometric equations are used. CONAFOR has a database of allometric equations and an algorithm and a decision tree for the selection of the best equation for the estimation of aboveground biomass, and carbon, depending on the metadata of the equations reported in the literature (e.g. R^2, standard error, variables included, geographic region), and the correspondence with the information of specific trees and measurement plots (e.g. tree species and geographical location) (Michel Fuentes, p.c.). Statistical information includes mean values, confidence interval and associated uncertainties. The carbon content used is 0.48 which is the typical for many species in Mexico (Michel Fuentes, p.c.).

Belowground biomass is estimated using equations from the literature also based on the inventory data.

Ground data for INFyS is generated by professional, private brigades. Once a contract has been assigned to a brigade, they receive the formats for fieldwork. Data is registered on paper on the field and then captured directly into an electronic database. The consultant has a copy of the database software and an user id for the system. The information is filled in the database and transmitted by post-mail to CONAFOR's headquarters (not online). Then, the information is received and uploaded into the system. A quality check is made to verify if the values have been captured correctly (i.e. spelling and values within typical ranges). Considering the amount of data that needs to be managed, the objective is to make the process as automatic as possible.

There is interest within CONAFOR in exploring how information from CBM could be incorporated into the INFyS. There should be compatibility in terms of the variables, codes, methods and formats used for measuring and reporting. Data could be transmitted to CONAFOR online or via email/Smart-phone/post mail, and it will be necessary to link the information to a specific geographic location, outside the grid of the inventory, and run quality control protocols; the implications of these approaches are being analysed by CONAFOR (Villela-Gaytan, p.c.)

4.1.3.4 Activity Data

Mexico reports activity data and land use changes for the NGHGI based on INEGI land use and cover cartography at a scale of 1:250,000. It is necessary to create an automated system to process large amounts of remotely sensed data and produce information at a bigger (i.e., more detailed) scale (1:50,000 with resolution of 0.125 ha) (Schmidt, 2012). The MNP project aims to operationalize the automatic processing of satellite images (Landsat 5/7, SPOT 5/6 and Rapid Eye) following the system for the classification of lands and vegetation of INEGI based on 14 classes on a yearly basis (Schmidt, 2012; Michel Fuentes, p.c.). Initially Mexico would use Landsat images to process the information on a 5 year period basis from 1990 to 2010 to set the baseline for deforestation (Schmidt, 2012), at a scale 1:100,000 (Michel Fuentes, p.c.). There is information from Spot 5 but it needs to be reprocessed by INEGI to improve its exactitude before it can be used (Schmidt, 2012). A Mexican consortium (CONAFOR, CONABIO) has acquired information from the Rapid Eye constellation for 2011-2013 and is aiming to produce information with minimum mapped areas of 0.125 ha with the potential to upgrade the scale still further to 1:20,000 (Schmidt, 2012; Michel Fuentes, p.c.). This information will be used to produce the necessary reports to the UNFCCC (i.e. NGHGI, biennial inventory updates, and information for REDD+).

4.1.3.5 Implications for CBM

If CBM is to generate information for the NFMS to assess the impacts of REDD+ and contribute to future national communications and inventory updates, it should follow a methodology consistent and comparable with the process used to prepare the inventories of the LULUCF/AFOLU sector. It is expected that Mexico will report information about all the reservoirs, for all vegetation types or forest strata, at least to a Tier 1 level. CBM could contribute in producing the information about different reservoirs to replace default data by data at Tier 2 or 3 levels if methodological consistency is observed.

The creation of a Tier 3 system will need data that could be gathered locally by communities, including the geographical location (polygons) of different management practices and disturbances, information on the management practices and local emissions factors. The selection of sites for intensive monitoring could include areas with different management practices. However there has been little written about how the mapping of those practices could be done throughout the country; this information could be generated through local PGIS or using geographical information from existing projects and national programs (e.g. pilot activities, projects participating in carbon markets, PES, community forestry programs, natural protected areas), where communities and other land owners are willing to participate in monitoring.

Without doubt, there is potential to integrate data generated through CBM to the system of INFyS. It is necessary to create the protocols for CBM with the necessary variables to monitor different carbon reservoirs locally compatible with INFyS's methodology and nomenclature, since it is this data on which will determine the format of information held in the NFMS. It Is important to explore the options for sharing 'raw' field data (i.e. data of inventories) or processed values already offering results on tCO_2e/ha-yr. It will be necessary to verify the correspondence between the scientific and common local names of different tree species. When the information is fed into the NFMS, the analysis of data to produce values of carbon stocks and stock changes would be carried out by the agency that manages the NFMS. It is necessary to consider the incentives required and the trade-offs of including monitoring of carbon reservoirs other than biomass in trees as part of CBM as means to contribute to the NFMS.

IPCC guidelines emphasize that carbon emissions and removals should be estimated in areas subjected to anthropogenic influence. The adoption of a national approach for the representation of lands ensures that all processes affecting terrestrial carbon can be considered; however stratification is still focused on the identification of vegetation types through remotely sensed data and has not as yet incorporated management practices as a variable of analysis. Generating geographical information with higher resolution and at a smaller scale on a periodical basis, might facilitate the incorporation of local geographical data at the management unit level through CBM either to delimit areas with specific management practices or to describe human or natural disturbances and associated emissions factors thoroughly. It is still not clear how geographical data generated locally could be incorporated into the system to stratify and monitor forestlands and activity data as part of the MRV system and the NFMS (given that a participatory Activity Report System is not in place). There is potential to include geographical data from on-going initiatives and programs as a first step (e.g. land ownership regimes, local land use plans, forest management plans, PES, Natural Protected Areas, projects in carbon markets).

4.1.4 System for the Monitoring of Safeguards[9]

CONAFOR is taking the first steps to develop a system to monitor safeguards in collaboration with other agencies of the government and stakeholders. There is also pilot project in development in the intermunicipal associations of Jalisco based on the REDD+ Social and Environmental Standards (REDD+ SES); the experience of this pilot will be used to draw conclusions and plan the implementation at national level. However this effort is still on its early stages.

[9] This section is based on the interviews made to Alejandra Aguilar, Ana Karla Perea and Noe Castellanos.

There is experience in CONAFOR from previous projects financed by the World Bank in addressing legal, social and environmental safeguards. The project on Forests and Climate Change at CONAFOR aims first to define clear policies, then to create synergies within national and international programs and finally to implement the strategies at the local level (intermunicipal associations). There are many public initiatives and programs and examples of the local legal framework that are online with the requirements specified in the safeguards that can be considered in the design of the system for implementation and monitoring.

REDD+ SES is an initiative coordinated at international level by the Climate, Community & Biodiversity Alliance (CCBA) and CARE International (REDD+SES, 2012a); the standards were created in a participatory way with the collaboration of many stakeholders, offer a methodology to implement activities to promote the compliance with safeguards in countries and projects interested in REDD+. The implementation of the standards can be divided in three stages: setting the governance structure for the standards, assessment and adaptation of the safeguards and standards according to local context and evaluation of the process (REDD+SES, 2012a); there are specific steps need to be followed (from REDD+SES, 2012a, pp. 1):

- Rise awareness and build capacities (workshops and meetings)
- Creation of facilitation team and Standards Committee.
- Planning
- Draft of indicators (at country level)
- Public consultations on indicators
- Monitoring plan.
- Data collection and assessment.
- Revision of draft report (stakeholders)
- Publication of report.

The standards define the objectives, guidelines and guidance for each step. The final objective of the report is to evaluate the implementation of REDD+ at national or sub-national level against the standards (REDD+SES, 2012b). Based on the safeguards adopted at the COP, REDD+ SES defines a series of principles with associated criteria and indicators that could be selected for implementation. The selection of the specific indicators needs to be led by local stakeholders according national and specific contexts. The process of the pilot project is not completed yet. Part of the outcomes will be the a monitoring plan specifying the type of information to be collected and processes for monitoring, revision and reporting (REDD+SES, 2012b). The criteria and indicators for the evaluation of safeguards can be of three types: they can focus on the processes how REDD+ is implemented; they can target the policies defined for implementation; and can assess the outcomes of implementation (REDD+ SES, 2012b).

It is important that communities are aware and participate actively these processes. The utilisation of REDD+ SES then requires the implementation of specific policies and management practices. It is in this context that communities could integrate the requirements for the monitoring of indicators for safeguards, that still need to be defined, into local monitoring schemes.

4.1.5 LAIF-Project[10].

The objective of the LAIF project is to help to develop local governance schemes for environmental management including REDD+ through the creation, training and operation of inter-municipal associations in Jalisco and the Yucatan peninsula; there is also interest to replicate the process and create an inter-municipal association in Oaxaca. The project is an initiative implemented jointly by CONAFOR and CONABIO and is scheduled to end by December 2014.

The project supports the inter-municipal associations in technical and institutional aspects that might help them to reduce carbon emissions form deforestation and forest degradation based on a watershed approach. The project includes tasks in the following axes: negotiation of public policies; generation of financing schemes; technical/institutional capacity building; and integration to the national MRV system including CBM.

The LAIF-project recognizes that before carbon could be quantified locally, first some capacities need to be created. The process is therefore focused on the creation of capacities rather than on measuring carbon based results of specific activities. Care has been taken not to create expectations related to carbon incentives at a stage when it is not clear how such incentives could be provided at international, national or local levels. In this sense, the creation of capacities for forest management is online with the principle of ENAREDD+ focused on sustainable rural development.

4.1.5.1 Implementation of Pilot Activities

In order to explore the conditions under which local monitoring could take place it was decided to develop pilot activities in four ejidos from the inter-municipal association (JISOC) in the coastal area of Jalisco. The project team first defined technical and socio-economic criteria to select eligible areas for pilot interventions. These included the degree of local organization (social capital), vegetation types present, location within NPAs, experience in other projects and development of land use plans. At a first stage the work group was assembled and the organization and activities were planned jointly with CONAFOR and the inter-municipal associations.

The implementation process followed the official institutional pathways. First the inter-municipal association was approached to ask them which ejidos would meet the required criteria. Four ejidos were selected: three have forest management practices and harvest timber commercially, in fact, one of the ejidos is the only FSC certified forest in Jalisco; the fourth ejido is developing ecotourism/adventure tourism. All communication with the ejidos is made through the associations, to strengthen them as focal points; this is important considering they are the actors who will provide long-term follow-up.

Once the potential areas for implementation were identified, the team approached the ejidos and invited them to participate in the project. The team followed the local rules of the ejidos and made the invitation through the assembly. The decision was subjected to voting and the invitation was accepted by all four ejidos. The local processes included the formal creation of monitoring

[10]This section is based on the interviews made to personal working in the LAIF project and in Community Forestry Management Office of CONAFOR (Noah Chutz, Sofía García Sánchez and Noe Castellanos).

committees; in the future verification and reporting committees could be also integrated as part of the MRV system.

The project first developed a preliminary protocol with different criteria and variables to identify the needs of the community, to define management objectives and to set a plan (e.g. to reduce risks, increase productivity, control pests outbreaks). The implementation process starts when the community identifies a problem that needs to be solved. LAIF's team serves as technical support for the analysis of solutions, for the definition of possible management options and associated monitoring methods. Potential management options, evaluation criteria and variables are presented to the community, by the local monitoring committee, and then the assembly decides what to do about each problem identified and what sort of monitoring scheme should be put in place. The community decides what to do, what to monitor and how to do it based on local priorities. Then dates, objectives and actors are defined and field activities are planned (e.g. mapping, tree measurement, participatory GIS). A very positive activity for capacity building was a peer-to-peer training made by community monitors from Sierra Gorda in Queretaro. Examples of variables selected by ejidos to monitor their forests are the presence of pests, delimitation of conservation and biodiversity areas and timber standing volume (based on tree diameter and height values). The U.S. Forest Service provided the equipment for the brigades. The brigades analyse, interpret and present the data to the assembly and the work plan is reviewed.

This process delivers valuable and useful information to the community. In more traditional approaches to monitoring, the data is the monopoly of intermediaries, consultants or forest technicians; it is not rare that ejidos possess certain information about their forests (e.g. cartography or forest management plans) but since it has been generated externally, the community members are not able to interpret it (they may not even have read the documents.) Monitoring empowers the community by providing local information that situates them in a different position, making it possible for them to communicate and negotiate with other stakeholders.

4.1.5.2 Incentives for Participation in CBM

Based on the project's experience there could be different reasons why people may participate in monitoring, depending on the ecosystem characteristics and the uses of the forests made by the communities. Where there is forest management for harvesting timber and non-timber forest products (NTFPs), better information on the forests' attributes will help in better decision-making and may be reflected in increased value or output of specific goods. This is particularly the case for temperate forests. However there are other ecosystems, such as tropical dry forests, that might not offer attractive products or developed markets for forestry-based products; in these cases there could be other drivers for participation. In the pilot areas there is an ejido with tropical dry forest, close to the coastal area with no opportunities for timber production. The problem identified by the community relates to water supply; some water springs located in areas that had been recently deforested were being lost. Here, the community was interested in forest management practices and the restoration and conservation of vegetation to increase the supply and quality of water. However additional techniques and tools for monitoring environmental attributes, other than standard forest carbon inventories, are needed to evaluate the impact of activities implemented (e.g. watershed approach, infiltration rates). This highlights the fact that in addition to timber and NFTP, the value of other environmental services can serve as an incentive for local monitoring related to forest management (e.g. biodiversity, ecotourism, cultural values).

In many cases before implementing forest management practices, communities would need to undertake activities to restore and conserve soil. Finally, a driver for participation might be *political*; it would be associated to the need to be 'on the stage where things are happening', as means for building a position for negotiation and benefit sharing, or to spot coming opportunities in public programs (Chutz, p.c.).

So far the project has not offered cash incentives to communities for monitoring since it focused on the 'legitimization of monitoring practices aligned to local interests' (Castellanos, p.c.). Each ejido developed its own monitoring methodology supported by other actors (i.e. technical foresters, the inter-municipal associations, LAIF's project members, trainers for capacity building). A potential exercise to bridge the project results with other institutions involved in developing MRV capabilities is to have CONAFOR and MNP analyze the information generated by the communities participating in the LAIF project in order to estimate its carbon content.

4.1.5.3 Preliminary Conclusions.

There are certain conditions that are needed to engage local communities in monitoring (e.g. local governance mechanisms, local codes and assemblies, land use plans) (Castellanos, p.c.). At the national level local capacities are still very heterogeneous. Initial competences needed relate to planning and communication skills. The project has found that it is relatively easier to acquire the technical skills for forest monitoring, however the social skills at the community level to organize, coordinate, collect and process the data, and to present it to the ejido assembly are far more difficult to develop. There is still a lot be done to create the capacities required at the national level.

At this stage in the LAIF project, the activities related with MRV have served to gather information on the forests to support local decision-making. This has enabled the appropriation of the monitoring practices since they are aligned to local needs and interests. In this context it can be expected that no third party would be required to pay for the information of the monitoring since it will be used to produce data valued locally. As long as the benefits expected by the community are higher than the effort needed to gather the data, the community would have an incentive to do it. If local information is produced only to satisfy a third's party interest needs (e.g. CONAFOR, NFMS or carbon credits buyers), then it would make sense to pay for the monitoring (i.e. in carbon markets the prices should be high enough to cover all participation costs, including monitoring). The inter-municipal associations have trust-funds which could be an interesting option to finance MRV (Chutz, p.c.).

The data produced enables the communities to have a better understanding of their own resources regarding issues such as standing timber volume, forest area, or extent of areas affected by pests (e.g. *muerdago*). In particular, geographical data generated through CBM has been regarded highly by communities as it provides visual information on their forests and other resources. If the objective of a community is to maintain/improve the conditions of local forests, then it is expected that activities might not result in a net loss of carbon stocks. However if the focus shifts for instance to the maximization of timber production, in the absence of specific incentives for carbon conservation or enhancements or effective direct controls, it will be necessary to evaluate on a case by case basis the impact these activities might have on carbon. Since carbon-based results have not been included at the planning stage, the effect on carbon dynamics is not clear *a priori*.

Since each community can design its own unique monitoring plan, the challenge is how to integrate local information into a national MRV system. It will be necessary to establish minimum guidelines to ensure that variables and methods are consistent. If local carbon information is to be incorporated into the MRV system, it should be compatible with the system adopted by the NFMS. At this stage it is not clear how local geographical data could be integrated into NFMS. It would also be necessary to define how communities will participate in the system to monitor the implementation of safeguards.

4.1.5.4 Implications for CBM

Although it has been shown that communities can gather data to monitor carbon stocks (e.g. Skutsch, 2011), this has not been yet the focus of activities related to CBM for MRV in Mexico. Initial activities have been cautious in not creating expectations on carbon incentives. Nevertheless the impact of activities implemented will have to be evaluated in terms of carbon at some point (either by using only external data –satellite images and national inventories-, or with the aid of the information generated locally). Based on these evaluations, some actions to 'correct' or 'promote' certain forest management activities will be implemented as part of the ENAREDD+. It is not clear how potential conflicts in REDD+ would be managed. For instance, if communities need to 'correct' their practices after the first evaluation because of carbon performance externally measured 'bad carbon results', they might state that they should have been told from the beginning that carbon was going to be a parameter for evaluation. Conflicts can arise if carbon is not included as a criterion for 'local planning' because it will certainly be one variable for the international 'external evaluation' of activities implemented in REDD+; likewise, the omission of carbon-based figures in this context can reduce the transparency in systems for benefit sharing.

The LAIF Project operates from the perspective that any local REDD+ MRV activity must first be developed according to the needs and interests of the community without initially contemplating carbon as evaluation criteria. The model being promoted in the REDD+ EAA seeks to install and strengthen local capacities in order to a) address local drivers of deforestation and degradation and b) foster the social and technical conditions needed for a community to participate in a future carbon-based methodology.

In order to avoid this potential conflict between community monitoring priorities and carbon- based evaluations, the LAIF Project recommends that forest carbon monitoring and reporting requirements are presented clearly by the appropriate authority only to communities that have *already developed* the capacities promoted by the LAIF model. Carbon should be seen as an additional forest resource that can be evaluated within a larger monitoring framework that functions primarily to generate local forest resource and rural development benefits (Chutz, p.c.).

In the absence of external incentives, CBM would be a reflection of the local valuation of forests and local organizational capacities provided that the appropriate technical skills for CBM are in place. One critical question here is whether or not communities identify climate change as 'their own' problem and if they would define unilaterally internal objectives to reduce emissions from local deforestation and forest degradation. When communities implement activities to adapt to climate change (e.g. to reduce the effect of droughts or landslides) or to maintain other environmental services (e.g. water), it will be necessary to identify realistic scenarios of the benefits that could be accrued. If there are no local motivations to generate local knowledge for forest management, implementation might have to be driven by external incentives or interventions if data from a specific area is required for external use.

There is a big gap in the way on this approach for the generation of local information for MRV: private non-ejido landowners are not included as part of these activities. Although most of forest land in Mexico is hands of ejidos and communities a relevant percentage (e.g. around 20%), is privately owned. Moreover after the constitutional reform in the nineties land has been withdrawn from the ejido regime. By mandate CONAFOR's public programs of the Community Forestry Office target local monitoring on communities, private landowners willing to participate in MRV could approach CONAFOR and receive guidance, but there is an institutional void that could be filled if an ad hoc mechanism is created. Including private landowners in MRV can also have its own advantages for instance in terms of the speed for decision making, transaction costs, access to investment and economies of scale.

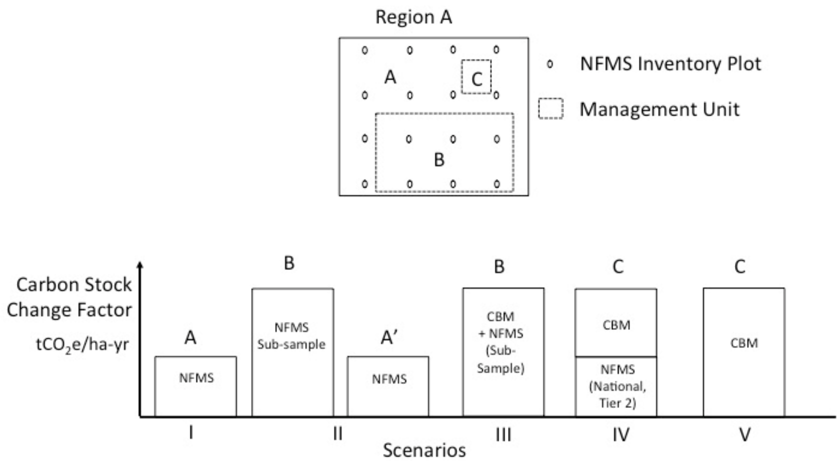
4.2 Dovetailing Data from CBM into MRV Systems (local to national)

According to Schmidt (2012), Mexico reports activity data and LULUCF based on INEGI's information system at scale of 1:250,000. Nevertheless, the MNP targets to operationalize a semi- automatic processing of satellite imagery (Landsat 5/7, SPOT 5/6 and Rapid Eye) aiming to achieve larger scales such as 1:100,000, 1:50,000 and 1:20,000. This information is expected to be used as an input to produce NGHGI. Since IPCC guidelines emphasize that carbon emissions and removals should be estimated in areas subjected to anthropogenic influence and management practices, there is a great potential for future integration of data generated through CBM. This means that Tier 3 level data might be necessary to describe the fluxes of carbon within ecosystems according to physiological processes and different management practices. As mentioned before, there is a need to create replicable and comparable protocols for CBM with the necessary variables to monitor different carbon reservoirs locally, which must be compatible with CONAFOR´s INFYS methodology and nomenclature.

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 the 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 (one site per 5km), 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.

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. The challenge is to identify how the information (and what particular variables) can be integrated into the NFMS in a compatible way. Below different scenarios are explored on how local data can be integrated into NFMS. Figure 6 shows different options to combine local and national level information.

Figure 6. Options to integrate local data produced through CBM with NFMS in REDD+.



The upper part in Figure 6 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 (conglomerates). 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 6 is given by the results of national inventory (Tier 2 data) (Scenario I). It is important to recall that the carbon estimate of A is obtained considering the information of all the inventory plots from the same strata in the country (coniferous forest), not only using the 16 plots within polygon A.

Consider that communities in the region perform different management practices in polygons B and C (e.g. sustainable forest management and forest restoration). Local particularities and the effect of local management in B and C are not captured by the system since the NFMS does not recognise B and C as different management units. The geographical information of polygons of areas B and C could be reported by the community to the NFMS, for instance via an Activity Reporting System (IPCC, 2003). However, as highlighted in section 3.1.3.3, it is necessary to increase the scale at which information is managed to allow the inclusion of smaller polygons corresponding to local management units.

There would be at least four possible ways in which NFMS and CBM could be used to generate carbon estimates. The first option depicted in scenario II shows the case when there are measurement plots of the NFMS within B. 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 statistically 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 (p.e. PES, Reforestation, Community Forestry, Forest Management Plans, Carbon Markets).

Scenario III refers to the situation when there is information of the NFMS in the polygon B but this is not enough to produce results statistically different from A. Data still could be integrated and used in CBM systems (e.g. knowing local variance helps to define the size required of the local inventory). CBM can be used to increase the sample size and to include information of other carbon reservoirs not included in the original sample. In order to combine data from NFMS and CBM it is necessary to verify comparability of the information (i.e. methods, temporal); 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. As shown below in Appendix 7.3 it is important to perform this segregation of data in order to prevent under/overestimation of results.

Scenario IV shows the case when there are no NFMS plots within the management area C and practices to be implemented will affect only one carbon reservoir. 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 reservoir/activity of interest; the Tier 2-3 results would be valid only for area C. In scenario II, local geographical data is used to complement NFMS, while in scenarios III and IV, NFMS could provide input for local CBM. Finally, scenario V shows the case when there are no NFMS plots within the management area of interest C, and/or project managers decide to implement a complete local inventory (e.g. to participate in carbon markets or when various reservoirs will be affected). In this case information of all carbon reservoirs could be generated through CBM producing Tier 3 level data only applicable for area C.

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 emissions. In order to prevent the generation of negative incentives for not included the information, the baselines should be recalculated accordingly.

When the geographic information of a forest unit locally managed is integrated into national systems, the corresponding 'original' polygon in the NFSM could 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 has an associated carbon stock/stock change factor, which could be disaggregated for each carbon reservoir (i.e. biomass, soil, DOM, non-CO2e GHG; the information would include the mean value and the associated uncertainty). If CBM is included into MRV the question becomes how to integrate/up-date the geographical and carbon data into existing systems in a participatory mode. When the information of the 'new' polygon is added, the national inventory and associated uncertainties could be re-estimated. For instance, Table 16 presents an example of how the data can be organized to estimate carbon emissions and removals and how data from CBM for a 'new' polygon could be included.

Table 16. a. Example of a matrix for estimating carbon emissions and removals.

I	II	III	IV	V						VI					VII						VIII	IX
Id.	Stratum	Area (ha)	Uncertainty Area (%U)	Carbon Stock Change Factor (CSCF) (Mean, tCO_2e/ha-yr)						Tier Level (1,2,3)					Uncertainties CSCF (%U)						Carbon Change in stratum (tCO_2e/yr)	%U (Stratum)
				B	S	D	L	…	**EF**	B	S	D	L	…	B	S	D	L	…	**U**		
1	Tropical	5,000	5%	3.0	-	-	-	-	3.0	1	-	-	-	-	ND	-	-	-	-	ND	15,000	ND
2	Oak	12,500	5%	-3.5	-	-	-	-	-3.5	1	-	-	-	-	ND	-	-	-	-	-	-43,750	ND
…																						
T	Totals	Area	%U Area																		Total Carbon	% U

Table 16. b. Example of a matrix for estimating carbon emissions and removals including local data.

I	II	III	IV	V						VI					VII						VIII	IX
Id.	Stratum	Area (ha)	Uncertainty Area (%U)	Carbon Stock Change Factor (CSCF) (Mean, tCO_2e/ha-yr)						Tier Level (1,2,3)					Uncertainties CSCF (%U)						Carbon Change in stratum (tCO_2e/yr)	%U (Stratum)
				B	S	D	L	…	**EF**	B	S	D	L	…	B	S	D	L	…	**U**		
1	Tropical	5,000	5%	3.0	-	-	-	-	3.0	1	-	-	-	-	ND	-	-	-	-	ND	15,000	ND
2	Oak	9,500	5%	-3.5	-	-	-	-	-3.5	1	-	-	-	-	ND	-	-	-	-	-	-33,250	ND
3	Oak (SMF1)	3,000	3%	5.0	0.5	0.3	0.1	-	5.9	3	3	3	3	3	5%	8%	6%	5%	-	4.3%	17,700	5.2%
…																						
T+1	Totals	Area	%U Area’																		Total Carbon’	% U’

%U refers to the percentage uncertainty.
For the group of data V, VI and VII the definitions are: B, biomass; S, Soil; D deadwood; L, Litter; EF Emission Factor (negative sign for emissions, positive for removals).

Table 16a, presents a matrix of variables associated to each forest polygon as described in NFMS: stratum, area, emission/removal factors, source of information and uncertainties. Only the information of two polygons is presented, one of Tropical forest and the second of Oak forests. Table 16a presents the scenario for an inventory where only Tier 1 data for carbon in biomass is included. Table 16b presents the information considering that a community owning forests in the original polygon 2 (Oak forest), reported to be undertaking particular practices for SMF over 3,000 ha; the area of polygon 2 is re-estimated (Table 16b). It could be possible to include specific information of carbon stock change factors for each reservoir and specific uncertainty values. The total inventory, including the new polygon, can be re-estimated and integrated to the NFMS. 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 analyse the propagation of uncertainties.

4.3 Potential for integrating CBM into NFMS/MRV for REDD+ in Mexico

The different stages for a collaborative on-line system for monitoring of natural resources presented in Section 1 (Figure 1), is used here to describe the potential to integrate CBM into NFMS/MRV for REDD+ in Mexico. The stages of such systems are: data gathering, communication and storage, analysis/modelling and validation, and publication and use. Based on the different elements described and analysed throughout this document the potential for creating a collaborative systems for REDD+ is described for the different CBM types and the current scenario. Table 17 presents a summary of the general implications associated to CBM and each stage of collaborative systems for the monitoring of natural resources.

Table 17. Description of the baseline scenario and implications of integrating CBM to NFMS/MRV for REDD+ in Mexico

Case	**Data Gathering (Area, Carbon, Other)**	**Communication, Storage**	**Analysis/Modelling and Validation**	**Publication and Use.**
Baseline (Current Scenario)	Area: Classification and stratification of satellite images to produce cartography at 1:250,000 is made by Federal Government Agencies. There are plans to increase scale. There is geographical information of different environmental programs that has not been included in the system for representation of lands (e.g. PES, ANP, community forest management, community land use plans…). Carbon: Fifth communication NGHGI reported only Tier 1 data; INFYS can produce data only for arboreal biomass. There are plans to include more reservoirs and modelling. Plans to include CBM. Other: system to implement REDD+ safeguards is in preparation; many public programs (social and environmental) are already generating information that could be integrated.	Area. Cartography and satellite images are maintained by Federal Government Offices. Carbon. Data is sent in electronic format (physical) by professional brigades to CONAFOR where the database is updated and information is stored. Other: information is collected as part of each program but not concentred in a systematic way.	Area & Carbon. Data is analysed by Federal Government Officers or consultants and academia. Information and results can be validated according to needs of CONAFOR via consultancy works. Fieldwork as part of INFYS is verified. In REDD+ this information will be externally verified including international auditors. For other information (safeguards), data processing and validation is also made by public offices.	Area & Carbon. Information is used, among other things, to comply with external reporting requirements (e.g. NGHGI, REDD+). Information can be shared with other stakeholders following procedures to access to public information. Information is also used for decision-making at CONAFOR; processed information does not reach communities or inform them on the situation of their lands. Other: publication and use depends on the specific programs' objectives, currently not linked to REDD+.
CBM 1: NFMS and public programs.	Area: Communities can report the location of inventory plots (to increase sample size) and of polygons of managed areas via an Activity Reporting System*. Carbon & Other: Methods could be based on INFYS (Stock-Difference Method) and protocols of other public programs to feed NFMS/MRV.	Mostly external to communities. Paper or electronic files can remain at communities. Information sent to CONAFOR, an online system reduces the cost.	External analysis at CONAFOR. National or international verification REDD+.	Mostly External. Inventories for NFMS/MRV, NGHGI, REDD+, etc. Local Benefits: wage for data gathering; local capacities. Access to processed information could be an input for local decision-making*.

Case	Data Gathering (Area, Carbon, Other)	Communication, Storage	Analysis/Modelling and Validation	Publication and Use.
CBM 2: Local Benefits.	Area: Communities can gather information on polygons of managed areas and location of plots and other sites of interest. Carbon: Information on biomass (carbon), disturbances and other variables of local interest. Other: Information of environmental services or natural resources directly used locally (e.g. water, biodiversity). Methods/scope can be flexible according to local needs. In order to become part of NFMS/MRV ad hoc systems/arrangements are needed*.	Mostly local. Information can be stored in paper and electronic. Communication through local mechanisms (e.g. assemblies). Communication as part of NFMS/MRV needs to be agreed possibly at state level or intermunicipal associations*.	Collaborative systems, external support can be required but this is driven by local interests (e.g. technicians, consultants, academia). Basic PGIS can be built on free GIS software if local capacities are developed. No validation or verification is expected, only when communities participate in certification schemes (see CBM 3). If the information is to become part of NFMS, CONAFOR can set a verification protocol which could be verified at state or local intermunicipal association level*.	Local communication for decision making on management of natural resources. It could be externally used as CBM if it becomes part of NFMS/MRV in a nested system*. Local Benefits: local capacities; input for decision-making locally oriented; more effective management oriented to local needs; benefits for integrating into NFMS/MRV*. If carbon accounting/performance is not a local priority it is necessary to evaluate if activities would result in carbon benefits or not on a case-by-case basis. Options to offer incentives for inputs as long as carbon impacts are not negative*. Methods and management strategies need to be realistic on the results that can be obtained.
CBM 3: Carbon Markets and Certification Schemes.	Communities can gather information on Area and Carbon following standards from carbon markets or other certification schemes (e.g. FSC). Standards can include monitoring of environmental and social indicators (e.g. CCBA for projects). If it becomes part of NFMS ad hoc systems are needed*.	Information is stored locally (paper and electronic) for the time required, according to any requirements set in specific standards. A collaborative agreement can be made with external partners (e.g. NGO, consultants, umbrella organisation) to centralise the information (e.g. to create a regional GIS). Communication and storage as part of NFMS/MRV needs to be agreed; possibly at state level or intermunicipal associations*.	Collaborative systems starting with external analysis later possibly local. External validation is expected depending on the specifications of each scheme (DOE, Verification Units). If it becomes part of NFMS/MRV protocols (or equivalencies) would need to be agreed particularly to harmonise carbon baselines; these could be verified at state or local intermunicipal association level*.	It is assumed that the participation in such schemes is of the interest of local communities, thus use is mixed local-external. It could be externally used to feed national international reporting needs if it becomes part of NFMS/MRV in a nested system*. Local Benefits: carbon finance; monitoring wages*; local capacities; local information for decision-making, carbon benefits and networking with external entities (national & international).

Case	Data Gathering (Area, Carbon, Other)	Communication, Storage	Analysis/Modelling and Validation	Publication and Use.
CBM 4: Safeguards (Environmental and Social) and Other Benefits.	Area: Information can be produced on the areas where safeguards are being implemented; it is necessary to explore the potential to include participatory schemes for data reporting once indicators and systems are defined. Identification of areas for the protection and conservation of national forests. Identification of areas with land rights problems and other conflicts. Carbon: Information on species used and description of management practices. Information from other activities, CBM 1,2, or 3, can be used as input for evaluation of leakage and permanence. Other: Information on biodiversity services. Safeguards: Indicators and monitoring schemes need to be defined (REDD+ SES); they can focus on process, policy or outcome. Socio-economical data can be gathered from surveys, meetings, focus groups, etc.	Mostly external. Still it needs to be defined. Information can be stored in paper and electronically at the community. For information of environmental safeguards (biodiversity, leakage, permanence) information can be treated together with the information in CBM 1, 2, or 3.	Analysis will be mostly external. Specific and sophisticated analysis are needed for evaluating leakage and permanence; there are available methods from existing carbon market mechanisms that can be used as benchmarks.	External to comply with the objectives of public programs and satisfy national requirements for international reporting (e.g. REDD+, UNFCCC, National Communications). Local Benefits: communication with other stakeholders to include local interest in REDD+ agenda; respect to local rights and inclusion in the process. Generation of co-benefits (i.e. biodiversity and other environmental services).

* Shows elements that need to be integrated into existing systems.

Table 17 describes the current scenario and expected changes for NFMS/MRV for REDD+ that is also used to produce the LUCF/LULUCF/AFOLU section for NGHGI; it also describes how information could be (is being) generated through CBM for different types of activities. The main recommendations to include CBM to NFMS/MRV for REDD+ in Mexico from a bottom-up approach will be the following:

It will be necessary to define specifically how CBM will be integrated into MRV for REDD+ this will require defining protocols, roles and responsibilities of different actors and stakeholders and technical specifications for equipment and models used.

It would be necessary to create or adapt existing programs within NFMS to transform them into participatory schemes to report activity data and information on carbon stocks and stock changes. CONAFOR and other public offices (e.g. CONANP, SAGARPA), have geographical information of different programs that in essence are participatory activity reporting systems, however they are not systematised to represent land/activities for REDD+. For instance, it is the communities who report their land use plans with geographical data on management, community forestry management plans and polygons to participate into PES. However the processes are separated and information can only be collected on-demand according to CONAFOR's needs. It could be possible to create an Activity Data Reporting System for REDD+ that could be more flexible to allow communities uploading information directly at any moment. So far the system for the representation of land is focused on the processes for the adequate classification of pixels of satellite imagery, however considerations of the differences in the type of management have not been included yet. It is critical to increase the scale at which geographical information is represented to allow the inclusion of smaller polygons; it will be critical that participatory mapping is able to consolidate information of managed areas in excess of hundreds or a few thousands of hectares to facilitate the incorporation into the system for the representation of lands at low levels of uncertainty.

The second proposal would be to allow hiring community brigades to perform inventory measurements as part of INFYS to increase the sample size in areas that could be of interest to communities (or CONAFOR); the sampling scheme could be planned in a collaborative way to satisfy the needs of both sides. This scheme does not need to be included in the existing system to hire professional brigades through a competitive process; *ad hoc* mechanisms to include forest monitoring compatible with INFYS could be integrated into existing public forest management programs. In this context, processed information from INFYS usually is not reaching back local communities for whom this information could be important for local decision-making (currently information is publicly available upon request). It could be possible to enhance the tools to communicate and make available this information at the local level on an active fashion, for instance to be used in the elaboration or review of land use management plans. NFMS can also design tools and interphases to receive and integrate carbon data (including information already processed, expressed as tCO_2e), from local community forest management or projects participating in carbon markets (CBM 2 and CBM 3). Considering the amount of data that needs to be managed the system could be implemented based on a nested-approach where state level offices or intermunicipal associations could participate in activities for data storage, validation and external reporting for NFMS/MRV.

After local information is integrated into NFMS in a period (a year), it would be necessary to evaluate what considerations need to be made for the next period in order maintain the consistency of the data. For instance establishment of new NFMS plots in 'unmanaged' areas to replace those that are being considered in the 'new' strata; up-dating the strata for the representation of lands to maintain temporal comparability; integrating yearly information for the monitoring of baselines; up-date the technical specification of national inventories to describe methods and the sources of information used (Tier).

It will be important to link monitoring programs to local needs. There are many monitoring requirements for REDD+ some of them are very technical (e.g. canopy cover), and at first sight they may seem detached from local interests. If the system can show the links between improved forest management and local direct an indirect benefits this can trigger the motivation for monitoring and modify management practices. When environmental services other than climate change mitigation are pursued, it is necessary to verify the impacts of implementation however this can help to promote the implementation of locally driven schemes. Still it is necessary to engage more actively with private landowners.

It will be easier to integrate information from activities participating in carbon markets (CBM 3) since most of the methodologies for carbon monitoring are compatible or inspired by IPCC guidelines. Moreover these activities might produce measurable positive carbon impacts but it will be necessary to harmonise the baseline of specific projects with that for REDD+. Conversely for activities locally implemented (CBM 2), it is not clear a priori if having a positive carbon impact is part of their own interests, thus the impact on carbon stocks and emissions cannot be anticipated; these schemes might provide information on environmental services other than carbon. As described in section 4.1.5.4 (LAIF project), this can be potential source of conflict since although activities implemented might respond to local needs it is the evaluation of carbon based performance what will determine the prospects to access to results-based financing in REDD+. From this perspective it would be necessary to state clearly that there will be a baseline and that certain national, regional and local objectives will need to be achieved. Since REDD+ is in a preparation stage there are no specific programs for incentives linked to carbon accounting yet. An initial step to move forward and promote implementation of CBM 2 activities would be not to focus on performance-carbon-based incentives, but to provide incentives and resources to overcome the barriers for sustainable management of forests; access to these incentives could be granted as long as these activities do not impact negatively on carbon performance.

It is clear that if communities were to contribute by producing information for INFYS and other externally driven public programs, these would be compensated accordingly (CBM 1 schemes). However if it were intended to integrate information of CBM 2 and CBM 3 into NFMS/MRV for REDD+, it would be necessary to create the necessary arrangements and protocols to harmonise the information since the information is locally owned. In any of the cases described in Table 17 appropriate training, capacity building and planning of activities will be required.

Finally, the system for monitoring of safeguards can make use of geographical information generated locally through participatory schemes. This can be particularly useful to map social conflicts and special conditions. For the monitoring of environmental safeguards the information of forest management activities implemented can help to identify how these are addressed. Examples of useful information in this context are: the areas and strategies advocated to protect/conserve natural forests; information to estimate leakage and permanence of carbon stocks and removals; and information on biodiversity. For complementary information particularly on the processes, policies and outcomes associated to social safeguards it is necessary follow the pilot process for the implementation of REDD+SES; the evaluation of this experience will produce specific guidance for the integration of safeguards into local monitoring plans.

5. Conclusions

This document has described the background of the use of CBM for the management of natural resources, the description of the institutional framework being created for REDD+ at international level and has analysed options to integrate CBM into MRV system of REDD+ in Mexico. There is potential and there are real necessities to integrate CBM in MRV for REDD+, but there are also challenges associated. Table 18 presents the summary of the main opportunities and challenges identified and discussed throughout this document.

Table 18. Main opportunities and challenges for the inclusion of CBM in the MRV system for REDD+ in Mexico

Opportunities	**Challenges**
There is a need to integrate CBM into MRV systems as expressed in decisions adopted at the COP.	The inclusion of CBM in REDD+ is described in the Vision and ENAREDD+, but it has not been implemented yet; the deadline for the creation of the MRV system is 2015.
Communities and local actors can produce field measurements as accurate as professional brigades. Unlike INFYS, CBM can cover both forest and non-forestland. Participation of private landowners in monitoring schemes has potential benefits that need to be explored (e.g. expedite decision-making, lower transaction costs, economies of scale and access to capital).	Local capacities and basic infrastructure is needed for setting up CBM (i.e. electricity, internet, hardware, software). Additionally to data gathering, other skills needed relate to preparing inventories/sample schemes, store and maintain data, data analysis, interpretation and reporting. Not all communities have the conditions to start CBM schemes. Currently private landowners have not been engaged in this process. The definition of forests for REDD+ is needed to identify clearly forest/management strata and identify and plan mitigation activities in forests and other lands.
Communities can create and update geographical data of mitigation activities implemented through CBM to create cartography with high scales (e.g. land use plans, transects with GPS, PGIS).	The system for the Activity Data/Representation of Lands still does not include data for different management practices as criteria for stratification and analysis. There is not an Activity Reporting System that allows receiving local data to define management areas. Current work scale in NGHGI (1:250,000) does not allow incorporating local geographical data for small management units <2,000 ha at low levels of uncertainty (Table 10).
Local monitoring is less costly; when local interests drive CBM, activities might be implemented without the need of external incentives. Management activities locally driven with the potential to protect natural forests while producing other services can contribute in the implementation and monitoring of environmental safeguards.	When CBM is only based on external incentives/drivers, once external *stimuli* end, the activity may be suspended. Usually initial costs of training and infrastructure need to be covered to start CBM systems; however exhaustive monitoring for REDD+ and other environmental services benefits from economies of scale to reduce costs. When only local interests drive monitoring, data produced may not be compatible in scope and 'quality' with external reporting needs for REDD+. Information is owned locally and not directly available for NFMS/MRV.

Opportunities	**Challenges**
New technologies allow CBM applying different and innovative techniques in on-line collaborative ways. Different activities can be grouped together under CBM schemes for MRV (i.e. public programs, local initiatives and carbon markets and certification schemes). Local monitoring can update, complement and replace Tier 1 or Tier 2 data in NFMS by Tier 3 values for specific management areas and for specific carbon reservoirs and it can also be used to evaluate the impact and benefits of different mitigation activities. Local and national level information can be merged. It is possible to design flexible methodologies including Gain-and-Loss and Stock Difference methods, to generate control indicators, to follow-up implementation and verify performance more frequently. Local information can help to design mechanisms for benefit sharing of REDD+.	Compatible and harmonised protocols for sampling schemes, data gathering, validation, storage, processing and reporting are needed to realise the potential of CBM for NFMS/MRV. The process to elaborate and up-date NGHGI is not yet institutionalised and does not offer collaborative options to integrate local data. It is necessary to harmonise baselines.
Local generation and analysis of data enables prompt practical decision-making over the management of natural resources.	Results/Reports based on current monitoring schemes (e.g. INFYS) usually do not reach back local communities to contribute to local decision-making. It is not clear if climate change related issues (mitigation and adaptation) are part of the local interests for the management of natural resources. If they are not, positive results in carbon terms of locally led initiatives cannot be granted *a priori*. It is necessary to show direct cause-effect between management practices and the provision of specific environmental services and other benefits to prevent the creation of false expectations.

Mexico should create the MRV system for REDD+ in less than two years according to the Federal Forestry Law (LGDFS); important developments are expected in this period. This document aims to identify options for including CBM comprehensively into this process. Table 18 presents a summary of the most relevant opportunities and challenges identified in this document. CBM can offer good options to engage local communities in the management of natural resources and to generate the information necessary for REDD+.

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 to work on the different possible CBM approaches; if systems will made use of public programs or will hire local brigades as part of INFyS appropriate budgeting will be required for this (CBM 1). If activities driven by local interests are to be promoted (e.g. LAIF approach, CBM 2), it is necessary to ensure that the management activities will not compromise carbon performance of the programme; for this, there are alternatives such as providing input- based incentives to activities that prove 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 of the information.

In order to prepare local and regional strategies for REDD+ it is fundamental to adopt an official definition of forests. Once a definition of forests is adopted it will be possible to refine the baselines and identify and plan properly mitigation activities and the associated monitoring schemes. As presented in Section 2 there are different mitigation activities that can be developed in forest and other lands; a collaborative agreement can be made with SAGRAPA (via a NAMA for agricultural areas and grasslands that could be counterpart of REDD+ to adopt a landscape approach).

New technologies are being used to create flexible and innovative on-line 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 (INFyS). 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.).

The natural path in which some of these activities and recommendations could be implemented, consistently with the ENAREDD+, will be through the intermunicipal associations. The intermunicipal region will be the appropriate level to create economies of scale for different processes. The associations could work as regional umbrella organisations. They could help to create local capacities, coordinate local monitoring efforts, to consolidate local information to be nested at the state and national levels and to contribute in the integration of information for NGHGI. The role of the associations and other local actors will be critical to create the necessary capacities or provide specific services for data analysis and reporting (e.g. consultants, academia, NGOs). It is necessary to engage with private forest-owners. An essential element for the implementation of CBM is the formulation of clear protocols defining the essential variables that need to be monitored, with clear procedures for doing this; other required protocols relate to the design of monitoring schemes, analysis, reporting and validation of information. Training in the use of these protocols is usually needed in the first round of monitoring and possibly also later to refresh the ideas imparted initially. It will be very important to observe in all stages ethical principles in regards to benefit sharing and the implementation of safeguards.

It is clear that if communities identify direct benefits associated to monitoring practices they will adopt and continue these practices moving towards more autonomous management of natural resources. One important challenge is the inclusion of climate change within the local agenda, if mitigation and adaptation strategies are appropriated and assumed as genuine and legitimate local interests, this could drive implementation and monitoring of REDD+

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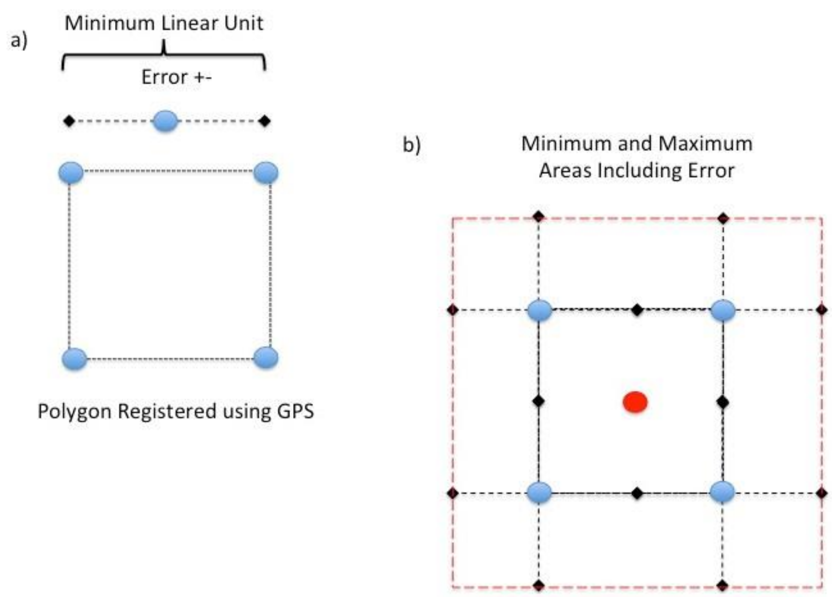
7. Appendices

7.1 GPS, error measurement and uncertainty

Consider that a GPS registers information with a given error, thus the minimum linear unit will be two times the error. Figure 7a, presents the case when four points are registered with a GPS creating a polygon equal to the minimum linear unit; Figure 7b, presents the maximum and minimum areas considering the error given by the equipment. In this case the minimum area would be only a point at the centre of the polygon while the maximum area could be 4 times that given by the measured points representing a percentage uncertainty of 190% (PU=4*0.95/2/1). For larger polygons the relative weight of the error will decrease. Strictly the error around a measured point will be circular; here it is presented as a square polygon to facilitate its representation as a pixel in a SIG.

Figure 7. Representation of areas for polygons based on participatory mapping.



7.2 Safeguards

Additional safeguards included in ENAREDD+ (page 55).
Inclusiveness and equity (territorial, cultural, social and gender). Respect to local organizational and governance processes.
Transparency and legality.
Transversality, integrality, coordination, complementarity among sectors and government levels. Equitable distribution benefits among owners of forest land.
Certainty and respect to land property rights of inhabitants and landowners, and to the sustainable use of natural resources.

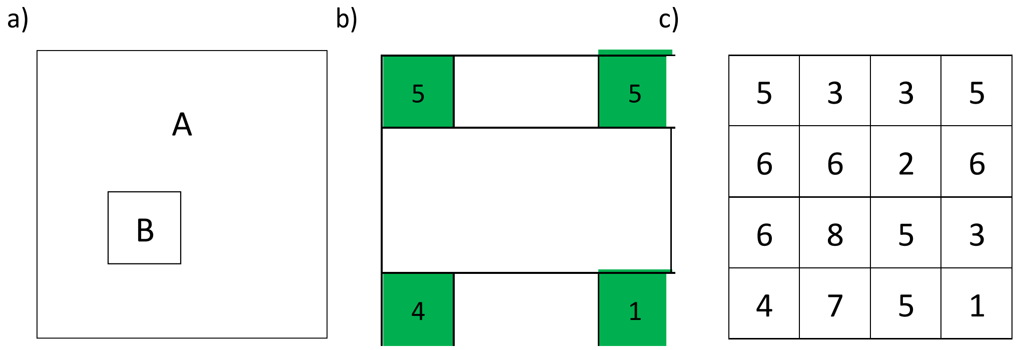
Compliance and free consent, previously informed of the rural communities and indigenous groups in all those elements of the ENAREDD+ that affect or could affect their territories, goods, and individual and collective rights.
Competitiveness of rural economies based on forests, including community forest-based enterprises.

Safeguards included in LGDFS, article 134 bis:
In addition to the safeguards recognized by international law, legal instruments and environmental policies should include:
Free consent, previously informed of ejidos, communities and indigenous groups Equitable distribution of benefits.
Certainty and respect to property rights and legitimate possession and access to natural resources by the legitimate landowners.
Inclusiveness and equity (territorial, cultural, social and gender) Plurality and social participation
Transparency, access to information and accountability
Acknowledgment and respect to internal forms of organization

7.3 Example. Combining national and local data

Let's analyse a hypothetical scenario in which different scale datasets are combined involving local and national samplings. Consider a situation that could be encountered in a real project. There is a forest polygon identified in the NFMS as A, inside A, a community indicates that it is performing specific forest management practices in a polygon B (Figure 8 a). Carbon removal figures from the NFMS for A are built on the data from four measurement plots (Figure 8 b). In order to evaluate the implications of combining the two sources of data let's assume that an inventory could be implemented in the whole area A as shown in Figure 8 c; this could be considered as the benchmark or the 'real' values.

Figure 8. Information for hypothetical forest A showing a) the area B under local management, b) information from national inventories and c) the benchmark 'real' distribution of carbon removals.



The community reports through CBM that they perform SMF in polygon B resulting in removals of 8 tCO2e/ha-yr based on a local inventory of sample size n=30.

Table 19 presents the information of carbon removals per hectare for areas A and B. Based on the national inventory, carbon removals in A would be 60 tCO_2e/yr this would be a conservative result in comparison to the 'unknown' benchmark (75 tCO_2e/yr) (but the opposite scenario could be also possible). Since the value for B is based on a local inventory it is expected that data produced at this level would have lower uncertainty due to a more intensive sampling over a more homogenous area.

Table 19. Carbon removal values for the hypothetical case

	Estimate of A based on National Inventory	Estimate of B based on CBM	Estimate of A based on Regional Inventory (benchmark)
Study Area (ha)	16	1	16
Sample (n)	4	30	16
Carbon Stock Change Factor (tCO2e/ha-yr)	3.75	8.0	4.7
Uncertainty (%)*	80%	8%	21%
Total Removals (tCO2e/yr)*	**60 (12-108)**	**8 (7-9)**	**75 (59-91)**

*Confidence intervals for the mean are built considering a t-distribution; percentage uncertainty is estimated according to IPCC (2000) as half the width of the 95% confidence interval divided by the mean.

Once B has been identified as a new stratum with its own inventory the information of A needs to be re-estimated in order to integrate it to the national accounts (Table 20).

Table 20. Recalculated carbon removal values for A once information of B is removed

	National Inventory (A')	Benchmark' Recalculated
Study Area (ha)	15	15
Sample (n)	4	15
Mean (tCO2e/ha-yr)	**3.7**	**4.5**
%U	**80%**	**21%**
Overall	**56 (11-101)**	**67 (53-81)**

In Table 20, A' represents the value for the polygon once the area of B and its associated carbon value have been removed. In the case of the national inventory only the area has been adjusted (since there were no inventory plots in B); for the 'benchmark' both the area and the Carbon Stock Change Factor are updated since the value of carbon for B is known. Then if the recalculated values in Table 20 are added to those of and B uncertainty is estimated using the formulas for the propagation of uncertainties (IPCC, 2000), total removals in A based on the national inventory would be 64 tCO2e/yr (18-110) with an uncertainty of 70%. This is an increment in removals from the original value of 60 tCO2e/yr and a decrease in uncertainty. In fact if the tendency was to include information of more quadrats with smaller uncertainties, the values would converge to that of the benchmark. In this example the values would converge to the benchmark starting from an initial underestimated value, but the opposite can also occur. If the value of B is combined with the modified benchmark value it can be verified that this does not result in an overestimation of carbon; overall removals are 75 tCO2e/yr (60-90) with an uncertainty of 19%. The central value is the same but the result is more precise (U% reduced from 21% for the benchmark alone to 19% when the local sample in B is included).

The value of 8 in B, has the same magnitude in the local inventory and the plot of the national inventory this could be the case if both sampling schemes were appropriately designed. However the main difference is that in the local inventory in B the value refers to the *mean* of a local sample that provides a more precise result for that specific region whereas in the inventory of the benchmark the value 8 refers to a single value of an inventory plot. Once polygon B is identified as a new area and stratum the information of the inventory associated to B should be removed from the sample for A (in the benchmark); otherwise estimates could be biased. For instance if after separating polygon B, the value in the quadrat had been still considered in the sample for the benchmark, the mean value over the 15 ha would have been still 4.7 tCO2e/ha-yr; when combined with the values from B totals would be 78 (63-94; U 19%); in this example the bias would trend to overestimate carbon removals (from 75 to 78). This means that if new strata based on local management were to be integrated into NFMS (section 4.2), any plots from previous inventories should be removed from the sub-samples of the original polygons (old stratum).

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