Participatory Measurement, Reporting, and Verification (MRV) for forest carbon credit recognition: collaboration among community forest owners and stakeholders in watershed forests of Vietnam

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1 Introduction

Measurement, Reporting, and Verification (MRV) is a systematic framework used to quantify, document, and independently validate forest carbon stocks and their changes over time for the purpose of recognizing forest carbon credits (Figure 1). MRV ensures that carbon sequestration and emission reductions generated by forest activities are accurately measured, transparently reported, and credibly verified in accordance with recognized standards. Through the integration of field-based forest inventories, biomass allometric equations, remote sensing data, and standardized accounting methodologies, MRV provides a scientifically robust basis for demonstrating additionality, permanence, and avoidance of double counting. As such, MRV is essential for establishing trust, environmental integrity, and market acceptance of forest carbon credits (IPCC, 2003, 2006)

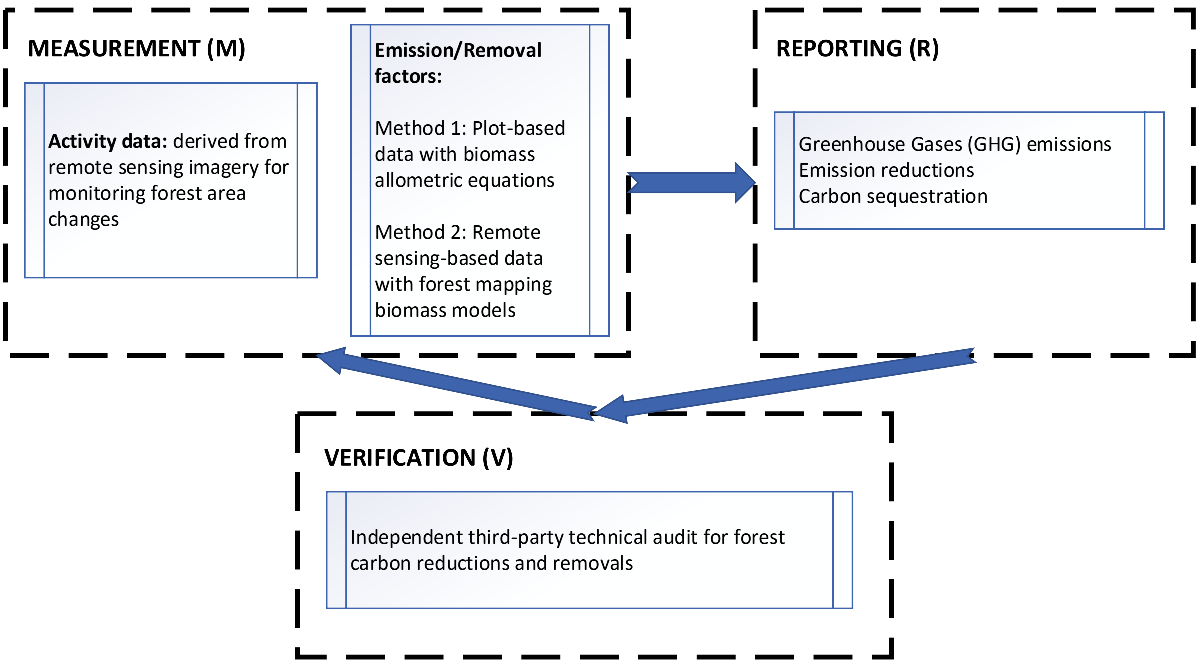

Figure 1. MRV workflow (IPCC, 2006) as the basic for the recognition of forest carbon credits

Forest carbon is defined as the amount of carbon accumulated within forest ecosystems and distributed among the five carbon pools recognized by the IPCC (2003, 2006), including aboveground forest biomass, belowground forest biomass, dead wood, litter, and soil organic carbon (SOC). However, forest carbon credit accounting typically focuses on the aboveground pool, often in combination with the belowground pool. The litter and dead wood pools generally contain relatively small amounts of carbon but are costly to measure, and are therefore often excluded. Although SOC stores a substantial amount of organic carbon, it is relatively stable and is primarily released only when forests are completely cleared, ploughed, or burned. Due to the high costs associated with measurement of SOC, this carbon pool is also commonly excluded from forest carbon credit assessments (Huy, 2013; Huy and Long, 2019).

Watershed forests in Vietnam play a vital role in regulating hydrological processes, conserving biodiversity, preventing soil erosion, and supporting downstream livelihoods. Within these landscapes, community forest owners - inluding village communities, household groups, and community-based forest management entities - hold legally recognized rights to manage and protect forest resources under Vietnam's forestry and land tenure framework. Community forest owners are directly responsible for day-to-day forest management activities such as forest protection, enrichment planting, sustainable harvesting of timber and non-timber forest products, and monitoring forest condition. Their close dependence on forest ecosystem services makes them key actors in maintaining watershed functions and forest carbon stocks.

In addition to community forest owners, a broad range of stakeholders are involved in watershed forest management. These include local authorities, protection forest management boards, forest rangers, research institutions, non-governmental organizations, and private-sector actors. Each stakeholder contributes distinct roles, ranging from policy implementation and technical support to capacity building, monitoring, and financing.

Effective coordination and collaboration among community forest owners and stakeholders are essential for sustainable watershed forest management. Participatory approaches enhance transparency, credibility, accountability, cost-effectivenes, and local ownership, particularly in the context of forest carbon initiatives and MRV systems. By integrating local knowledge with scientific and institutional support, collaborative engagement strengthens both forest conservation outcomes and socio-economic benefits for local communities (Gerrand, 2014).

2 Measurement methods in watershed forests - Stakeholder roles and variables measured by local communities

The scale and scope of MRV for forest carbon credits should be implemented at the watershed level, with collaboration among different forest owners, including local communities, households, protection forest management boards, commune-People's Committees, and private forest owners. Such collaboration enables the sharing of resources and helps reduce costs associated with measurement and verification. Within a single watershed, forests generally share similar ecological conditions, forest types, and primary ecological functions; therefore, a common carbon measurement methodology can be applied across the entire watershed. Aggregating forest areas of multiple owners within the same watershed optimizes stakeholder strengths and mobilizes resources for forest measurement, while reducing the cost of independent verification compared with conducting MRV separately across numerous small and fragmented forest holdings. In addition, knowledge and technical skills among local communities and stakeholders can be shared and mutually supported, leading to more effective and efficient implementation.

In the measurement (M) component, two main approaches are used to quantify forest carbon emission reductions or carbon sequestration: (1) plot-based data with biomass allometric equations, and (2) remote sensing–based data with forest biomass mapping models (Figure 1). Within these two approaches, the variables that indigenous communities and technical staff, experts can measure, calculate and provide information on are presented in Figure 2.

Based on the results of community forest management projects in six countries in Asia and Africa (Skutsch et al., 2009a), as well as studies conducted in Vietnam (Huy, 2012; Huy et al., 2013; Anh, 2017), demonstrated that with appropriate training, local communities are capable of monitoring forest area changes using maps and measuring forest carbon pools. These projects further showed that local people with education levels equivalent to grades 4–7 can be readily trained to conduct forest inventories in accordance with IPCC guidelines (IPCC, 2003, 2006) (Huy et al., 2013; Anh, 2017).

With collaboration among forest owners within a watershed, in addition to the roles and responsibilities of local communities, the participation and cooperation of technical staff and experts are also required. These may come from forest owners with technical capacity, such as protection forest management boards, commune People's Committees, and private forest owners; in some cases, experts from research institutes or universities may need to be engaged.

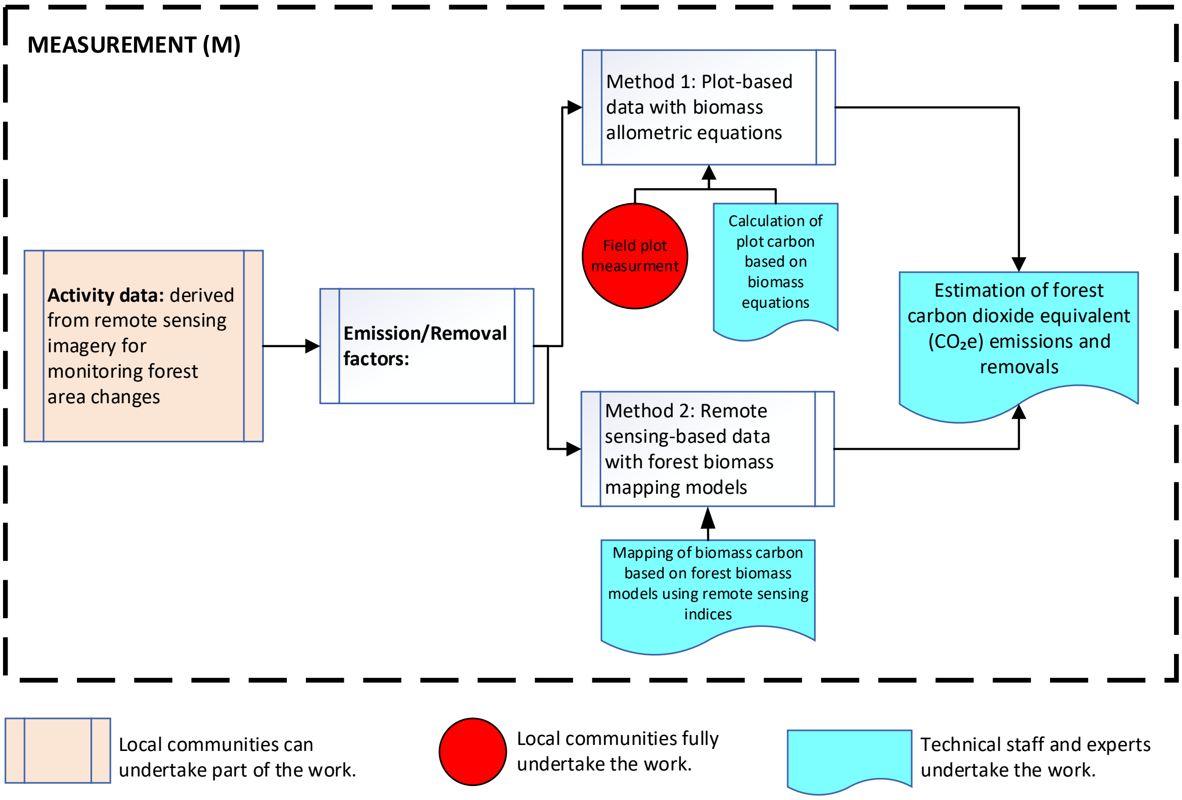

Figure 2. Measurement (M) methods and participation of indigenous communities and other stakeholders

The activity data shown in Figure 2 provide information, data, and maps of forest area changes, including deforestation, afforestation, and forest restoration. These data are primarily derived from remote sensing imagery and are processed by technical staff and remote sensing experts. The resulting maps should be validated by local communities, who possess detailed knowledge of local terrain, geography, and areas where changes in forest extent and quality have occurred, enabling effective verification of these changes. This can be regarded as an effective integration of local ecological knowledge with scientific and technological advances in monitoring forest area changes.

In Measurement Method 1 - plot-based data with biomass allometric equations (Figure 2) – trained indigenous communities can fully carry out field plot measurements (Huy et al. 2013). These activities include using GPS to locate randomly selected sample plots, establishing plots, identifying tree species using local names, and measuring tree diameter at breast height (DBH). Technical staff can estimate tree height (H) by developing height–diameter (H/D) regression models, determine species-specific wood density (WD), and apply pre-established biomass models using one or more predictors (e.g., DBH, H, and WD) to calculate biomass and carbon stocks at the plot level.

In Vietnam, a wide range of biomass allometric equations have already been developed at the tree and stand levels for different forest types, ecological regions, and nationwide. These include models for estimating aboveground biomass (AGB) in evergreen broadleaf forests (EBLF) (Huy et al., 2016a,b) and deciduous dipterocarp forests (DDF) (Huy et al., 2016c); models for the simultaneous estimation of AGB and belowground biomass (BGB) in EBLF and DDF (Kralicek et al., 2017); deep learning models for estimating tree-level AGB in EBLF (Huy et al., 2022); multi-output deep learning models for the simultaneous estimation of tree-level AGB and BGB in EBLF and DDF (Huy et al., 2024); deep learning models for the simultaneous estimation of stand-level AGB and BGB in EBLF and DDF (Huy et al., 2025); and biomass estimation models for bamboo species (Huy and Long, 2019).

In Measurement Method 2 - remote sensing - based data with forest biomass mapping models (Figure 2) - technical staff or remote sensing experts apply established models to map and estimate stand-level AGB and/or BGB over large spatial areas. These models may include conventional regression approaches as well as advanced techniques such as machine learning, deep learning, or ensemble models that combine both. Remote sensing data may consist of optical spectral imagery, radar, LiDAR, or integrated combinations of these data sources. Under this approach, measurements are primarily carried out by remote sensing specialists.

Finally, under both measurement methods, technical staff use activity data and emission/removal factors to calculate carbon dioxide equivalent (CO_2e) emissions and/or removals within the watershed over time. The resulting information should be communicated back to local communities, who are the forest owners.

3 Why local community participation in MRV

FAO (2008, 2010) emphasized that deforestation not only increases greenhouse gas emissions but also adversely affects the livelihoods and cultural values of local communities. Therefore, the Reducing Emissions from Deforestation and Forest Degradation (REDD+)

programme is regarded as an opportunity to compensate forest-dependent communities through their efforts in monitoring, measurement, and management of forests and forest carbon pools (Peskett, 2008; IUCN, 2007; Anh, 2017). Vickers (2014) further noted that, under existing international conventions and agreements, there are no barriers preventing communities from playing a role in the MRV system of the REDD+ programme.

In addition, practical implementation of REDD+ has introduced the concept of monitoring (M: Monitoring) as a key contribution to the MRV system. MRV represents a periodic system for reporting forest carbon emissions and removals within ecoregions or watersheds; however, forest use and human impacts occur on a continuous basis. Therefore, ongoing monitoring activities are necessary. Monitoring is particularly well suited to local communities, as they possess in-depth knowledge of forest conditions, terrain, geography, and the drivers and dynamics of forest change.

A general trend enabling indigenous communities to participate in forest carbon monitoring and measurement processes is the adaptation and simplification of complex methodologies and technical procedures so that they can be applied by communities with limited formal education (Shrestha, 2010). In addition, there is a need to strengthen local institutions and place the roles of communities and local people at the center of natural resource management systems (Anh, 2017).

Community Forest Management (CFM) has been widely implemented in many countries, including Tanzania, India, Senegal, Nepal, and Vietnam, and has demonstrated a strong foundation for further developing participatory forest carbon monitoring and measurement. It is therefore regarded as an effective pathway for reducing forest degradation (Skutsch et al., 2009a). Conversely, REDD+ has been identified as an important opportunity to promote the development of community forest management approaches in the Asia–Pacific region (Sikor et al., 2013; Anh, 2017).

From a conventional technical perspective, forest measurement has typically been carried out by external professional agencies (Goldsmith, 1991; Spellerberg, 2005); however, this approach has proven to be costly to sustain and reliant on specialized skills that could be replaced by trained local communities (Sheil, 2001). The reliability of data collected and provided by local communities has long been a subject of debate, with a prevailing bias that communities with lower levels of formal education produce forest measurements with higher errors, leading to substantial inaccuracies in forest biomass and carbon estimates. However, Skutsch et al. (2009b,c), Huy (2012), Huy et al. (2013), and Anh (2017) reported contrasting findings, based on comparisons of deviations between biomass estimates derived from community-collected data and those produced by professional experts. These comparisons were conducted across oak forests, pine forests, and mixed forests in India, Nepal, and Tanzania, as well as evergreen broadleaf forests in Vietnam. The results showed that the deviation between measurements conducted by local communities and professional experts ranged from only 1% to 7%. This level of deviation is minimal and indicates that data collected by communities are sufficiently reliable for use in forest biomass and carbon estimation. Similarly, Danielsen et al. (2013) reported no significant differences across 289 sample plots in Southeast Asia when estimating carbon based on measurements conducted by local communities compared with those carried out by professional agencies.

In addition, another key concern is the cost of involving local communities in forest carbon monitoring and measurement compared with professional agencies. Skutsch et al. (2008, 2009c) collected cost data over four years across four communities and compared these with the costs incurred by professional agencies for producing the same output, namely biomass estimates per hectare of forest. The results showed that the costs of community-based forest carbon measurement were substantially lower than those of professional agencies. On average, community-based costs amounted to only about 5 - 34% of the costs incurred by professional agencies. This represents an important opportunity to generate greater economic benefits for communities through payments from forest carbon credits.

For the implementation of REDD+ and the establishment of forest carbon credits at both national and international levels, community participation has been recognized as a key solution for enhancing awareness of the role of forests in climate change mitigation, improving data transparency, and creating opportunities to compensate poor and forest-dependent communities through forest carbon credit payment mechanisms (Skutsch et al., 2009a,b; Huy et al., 2013; Anh, 2017). The key issue, therefore, is to recognize communities as important partners and stakeholders in the monitoring and measurement of forest resources and forest carbon, and to integrate indigenous knowledge and community participation in forest monitoring and measurement as an effective approach to sustainable forest management, livelihood security, and compensation for their forest protection efforts (Anh, 2017).

Overall, the review indicates that the participation of local communities and stakeholders in MRV at the watershed-level for the establishment of forest carbon credits provides several important benefits, as follows:

- Participatory MRV enhances data transparency, credibility, and accountability through cross-validation, social oversight, and continuous local presence.
- Integration of local ecological knowledge with advanced technologies improves the reliability of forest condition, area change, and species-specific WD measurements.
- Continuous community-based monitoring enables early detection of forest disturbances and leakage between formal MRV reporting cycles.
- Participatory MRV strengthens REDD+ safeguards by supporting social legitimacy, local oversight, and conflict prevention.
- Participatory MRV strengthens local ownership of forest carbon data and forest management processes while building long-term local technical capacity.
- Collaboration among community and other forest owners within a watershed improves methodological consistency and optimizes knowledge and skills in MRV implementation.
- Participatory MRV reduces long-term dependence on external technical experts and is more cost-effective than MRV conducted solely by professional agencies.
- MRV with multi-stakeholder participation enhances the effectiveness and equity of benefit-sharing from forest carbon credits.

4 Conclusions

Participatory MRV for forest carbon credit recognition, based on collaboration among community forest owners and stakeholders in watershed forests, is essential and beneficial to all stakeholders.

Establishing collaborative participation among stakeholders within a watershed is appropriate from both ecological and institutional perspectives. Forests within the same watershed typically share similar ecological conditions, forest types, and primary ecosystem functions, allowing the application of consistent carbon measurement and monitoring methods. At the same time, watersheds often encompass diverse forest owners with different knowledge bases, skills, and management capacities; collaborative participation therefore enables the integration of these complementary strengths, leading to more effective, efficient, and coherent MRV implementation.

Participatory MRV aims to maximize the use of resources, knowledge, and skills of all stakeholders - particularly local communities - to optimize MRV implementation. Stakeholder participation in MRV is intended to enhance key principles, including transparency, credibility, accountability, local ownership, cost-effectiveness, and the effectiveness and equity of benefit-sharing from forest carbon credits.

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