4 Monitoring REDD+ Impacts: Cross Scale Coordination And Interdisciplinary Integration

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4.1 Introduction

Results-based compensation for reducing emissions from deforestation and forest degradation and enhancing carbon stocks (REDD+) is one promising way to help mitigate global climate change. Since the climate impact from reduced emissions (and increased removals) is the centerpiece of REDD+, countries are asked to set up systems to monitor changes in forest carbon stocks for reporting at the international level (Herold and Skutsch, 2011; Romijn et al., 2013). Yet, REDD+ monitoring goes beyond carbon for at least three reasons. First, REDD+ activities can promote a host of social and environmental co-benefits or entail risks that should be considered in their design and implementation. Second, the United Nations Framework Convention on Climate Change (UNFCCC) Cancun Agreement articulates seven safeguards (Decision 1/CP.16) for REDD+ programs to: 1) complement national forest programs and international conventions and agreements; 2) maintain transparent governance; 3) respect knowledge and rights of indigenous people and local communities; 4) obtain effective participation in REDD+ design and implementation; 5) promote forest conservation and other environmental and social co-benefits; 6) address risks of reversals; and 7) reduce leakage (UNFCCC, 2011a). Countries must set up Safeguard Information Systems to be eligible for results-based payments (UNFCCC, 2014). Also, jurisdictions and projects engaged with multi- and bilateral donors and third-party certifiers may need to consider additional standards and/or guidance for demonstrating high social and environmental performance, such as those of the World Bank Forest Carbon Partnership Fund (FCPF, 2013), the UN-REDD Programme (UN-REDD, 2012), the Climate Community and Biodiversity Alliance (CCBA, 2013) and REDD+ Social and Environmental Standards Initiative (REDD+ SES, 2013). Third, forest monitoring is becoming an important national policy tool for countries to assess and understand drivers of forest change, underpin REDD+ and related climate-friendly land use strategies, track implementation, and form the basis for the distribution of benefits generated through climate finance (De Sy et al., 2012; Kissinger et al., 2012). The multidimensionality of REDD+ poses great challenges to identifying efficient trade-offs between in-depth, fully comprehensive monitoring and increasing complexity and costs, which is a serious problem given the limited funds available for REDD+ monitoring. Monitoring both the carbon and non-carbon impacts of REDD+ requires development of systems that are scientifically sound, yet simple enough to be implemented effectively (Gardner et al., 2012). Resolving this challenge is critical to operationalizing REDD+.

One of the primary challenges for REDD+ monitoring systems is the issue of scale. To date, most monitoring of REDD+ performance has occurred at the subnational level. Since the Bali Road Map of 2007, hundreds of subnational REDD+ initiatives have emerged throughout the tropics, which range from localized projects to broader jurisdictional REDD+ programs (Simonet et al., 2014, Sunderlin et al., 2014). Many of these initiatives include a combination of forest law enforcement and implementation of both conditional and non-conditional incentives to promote more sustainable land use practices (Sunderlin and Sills, 2012). While these initiatives conform to various third-party accounting and verification systems, many have struggled to implement sustained and effective monitoring (Joseph et al., 2013). This difficulty is partly due to limitations in capacity and resources, and because the role of subnational monitoring systems becomes less clear as national REDD+ systems develop. For instance, some subnational REDD+ programs are pilots of the Verified Carbon Standard (VCS) Jurisdictional and Nested REDD+ Framework for carbon accounting and crediting. These rules may eventually differ from those for accounting and reporting of national forest monitoring systems to the UNFCCC using Intergovernmental Panel on Climate Change (IPCC) Good Practice Guidance (GPG). For non-carbon, several subnational REDD+ programs are part of the REDD+ SES Initiative for demonstrating high environmental and social performance, which may or may not dovetail with national Safeguard Information Systems. In addition to the issue of reporting across scales, the issue of scale of measurement is central to monitoring. Coarse- versus fine-scale monitoring of the carbon and non-carbon impacts of REDD+ may lead to different conclusions about its results-based performance, making it key to find the right balance between precision/accuracy and effort (Romijn et al., 2013). This issue surfaced in the reporting of Annex 1 countries for land use, land-use change and forestry (LULUCF) activities under the Kyoto protocol.

A second challenge is the disconnect between carbon and non-carbon monitoring efforts in REDD+, which are often pursued in disciplinary isolation. On the one hand, there are remote sensing and forest carbon scientists focused on improving systems and approaches for carbon monitoring through activity data (i.e. human activity resulting in emissions or removals), emission factors (i.e. emissions or removals of all greenhouse gases in all carbon pools), and assessing impact against robust reference emissions levels (i.e. counterfactual benchmark against which actual emissions and removals can be measured) (Herold et al., 2012; Verchot et al., 2012). On the other, there are social scientists, ecologists and advocates focused on minimizing social and environmental risks associated with REDD+ and enhancing benefits, with further subdivision into social and environmental camps. On the social side, the focus has been on protecting and enhancing local governance and wellbeing (Brown et al., 2008), along with securing local rights to land and resources (Sunderlin et al., 2009), which are often considered key to REDD+ effectiveness (e.g. secure tenure as a pre-requisite for application of regulatory and incentive-based REDD+ mechanisms; Duchelle et al., 2014). On the environmental side, the focus is on conserving the environmental services provided by natural forests to avoid a pure focus on carbon. The fear is that a sole-carbon focus could lead to displaced destruction from high biomass to low biomass forests, replacement of native ecosystems with monoculture tree plantations (Stickler et al., 2009), or silvicultural interventions to increase carbon stocks in forest management areas that negatively affect biodiversity (Putz and Redford, 2009). Calls for biodiversity conservation, as an integral part of REDD+ planning, stem from the perception that biodiversity is instrumental to long-term stable ecosystem service provision (Phelps et al., 2012a). There are also warning calls that too narrow of a focus on carbon could overlook negative feedbacks to human wellbeing through negative impacts on the environment at the landscape scale (Lindenmeyer et al., 2012; Phelps et al., 2012b). Divisions between carbon and non-carbon monitoring are reinforced through international and national reporting frameworks. While there are exceptions to these divisions in practice, we argue that better integration across scales and between disciplines is crucial to long-term cost-effectiveness and performance of REDD+ and its monitoring systems. These same issues of scale and disciplinary divides are pertinent to the design and application of sustainability indicators towards fostering sustainable development more broadly.

The objective of this chapter is to examine possibilities for cross-scale coordination and interdisciplinary integration in monitoring the carbon and non-carbon impacts of REDD+ (Fig. 1). We first present key concepts in monitoring as relate to REDD+. We then review available options for carbon monitoring, social monitoring and environmental monitoring, with particular attention to issues of scale. Finally, we present strategies for moving forward through more integrated REDD+ monitoring across scales and between disciplines, which can go beyond REDD+ to inform approaches for measuring sustainability in landscapes.

4.2 Key Concepts And Objectives In Monitoring

Monitoring is tracking key elements of program performance (inputs, activities, results) on a regular basis. Monitoring differs from impact evaluation, which is the episodic assessment of the change in targeted results that can be attributed to an intervention through understanding the counterfactual (i.e. what would have happened in its absence). Importantly, data gathered through the monitoring process can feed into impact evaluation. Although the discourse for monitoring in REDD+ is largely driven by the need to conform with requirements set up by the UNFCCC, the approaches employed can certainly draw on previous experiences in status assessments and effectiveness measurements, which have been widely used in the fields of conservation and international development for decades (Stem et al., 2005).

There are some generic issues for the way monitoring works in practice. First, clearly defined objectives, users and uses are essential for efficient monitoring,

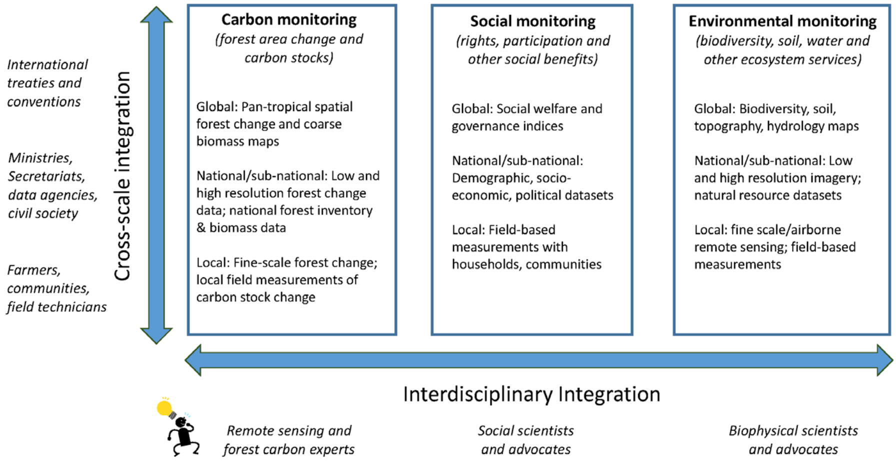

Figure 1: Scalar and disciplinary components of REDD+ monitoring.

particularly if used as basis for improved decision-making and resource management across a variety of sectors. Second, monitoring assumes that phenomena are measured and assessed at multiple points in time to track them. This temporal component requires consistency and stability in data acquisition and has often led to a focus on areas of change that are smaller than the overall area to be monitored. Third, not every phenomenon can be monitored with the same degree of effectiveness. There is a non-linear relationship between increases in monitoring precision and accuracy, and related costs. At a reasonable cost, one may be able to reach a good level of certainty, but going from good to near-perfect can increase such costs exponentially. This is exemplified by the increasing costs for acquiring and processing of satellite data with higher spatial and temporal detail (GOFC-GOLD, 2013), or the growing number of field plots and observations needed to reduce errors in carbon inventories. In related accounting, the focus on getting the big things right is inherent. For instance, in the IPCC GPG, the use of tiers that reflect different levels of certainty and comprehensiveness in estimating carbon stocks, focusing on priority emission sources through key source category analysis and the use of conservative adjustments, is a common approach to dealing with uncertain or incomplete data.

The objectives and reporting rules for countries in measuring and reporting the carbon impacts of REDD+ activities are rather clearly defined in UNFCCC decisions and the IPCC GPG. With these objectives in mind, the technical community has developed dedicated guidelines and training materials to support countries in these efforts (i.e. GOFC-GOLD, 2013). There are two stages of monitoring, which correspond to the REDD+ design and implementation phases, respectively. In the first stage, the goal is to develop a baseline or reference level (i.e. counterfactual) based on existing or new data. In the second stage, the goal is to monitor changes against the baseline. These two stages can also relate to monitoring the social and environmental impacts of REDD+, with *ex ante* impact analysis helping provide the necessary data to develop REDD+ strategies, and *ex post* impact evaluation used to measure the causal effects of REDD+ interventions. Importantly, evaluation of impacts during REDD+ implementation can help inform modifications needed through learning and adaptive management (Lawlor, 2013).

When compared to carbon monitoring, the objectives of social and environmental monitoring in REDD+ are less clearly and less strictly defined internationally. Aside from the international requirement that Safeguard Information Systems should be "transparent, consistent, comprehensive and equitable" and "build upon existing systems, as appropriate" (UNFCCC, 2011b), countries are not given much guidance on the use of appropriate indicators, data collection methods and reporting frameworks. While minimal guidance supports national ownership and provides space for independent experimentation in complex country-specific contexts, it also creates uncertainties and very high transaction costs if each country is "re-inventing the wheel." Additionally, while the notion of the counterfactual is intrinsic to carbon monitoring through reference level setting and additionality requirements (i.e. showing that the intervention results in lower emissions than the baseline scenario), there is little use of counterfactual scenarios for understanding socioeconomic or other environmental outcomes of REDD+ (Caplow et al., 2011).

Beyond the international negotiations, there is a broader set of objectives for national REDD+ monitoring, which present clearer pathways and opportunities for linking carbon, social and environmental monitoring. These objectives are not beholden to the UNFCCC process, but reflect the need for national forest monitoring to evolve to: i) underpin and stimulate strategies and priorities for REDD+ implementation; ii) track REDD+ activities and both carbon and non-carbon impacts; and iii) support the generation and sharing of benefits. For all three objectives, a greater understanding of common concepts between different monitoring approaches can enable more harmonization among them. Increased integration can also help make REDD+ monitoring more cost-effective.

4.3 Options For Monitoring The Carbon And Non-Carbon Impacts Of REDD+

4.3.1 Carbon Monitoring

Robust data and methods for estimating greenhouse gas emissions from and removals by forests are crucial for REDD+ (UNFCCC, 2009; UNFCCC, 2011b). Countries have been encouraged to establish national forest monitoring systems based on the IPCC

Guidelines (IPCC, 2006). These guidelines have been agreed upon internationally and have been used for many years for Kyoto reporting and to generate UNFCCC national communications. Measuring and monitoring forest carbon emissions at the national level involves estimating and monitoring changes for two key variables: i) area of deforestation and degradation (activity data); and ii) terrestrial carbon stock densities per unit area (emission factors; Verchot et al., 2012; GOFC-GOLD, 2013). Many REDD+ countries are starting with large gaps in capacity for carbon monitoring and have concrete plans to improve this capacity as part of REDD+ readiness activities (Romijn et al., 2013).

While the IPCC GPG provides the framework for emissions estimation and reporting, there are several tools and approaches for carbon monitoring, some of which may be more appropriate in different contexts (Table 1). The IPCC methods are particularly suitable for evaluating the impacts of forest clearing for commercial agriculture and infrastructure expansion, which commonly lead to large-scale permanent conversion and can be accurately monitored through a combination of remote sensing and forest inventories. In contrast, monitoring deforestation associated with subsistence agriculture poses a greater challenge, since the disturbances are smaller and the long-term net carbon outcomes less certain (Ziegler et al., 2012). Small-scale deforestation therefore requires investigation at a finer scale, such as through the use of very high resolution imagery, or through other innovative spatial techniques, such as classifying change processes using "landscape mosaics" (Hett et al., 2012). Conversely, forest degradation processes and their specific drivers are more difficult to detect through remote sensing. The changes in carbon stocks vary greatly in space and time, and thus require more frequent ground surveying. Monitoring industrial/commercial extraction of forest products can build upon the combined use of archived satellite data, forestry concession data, and forest inventories. For forest degradation associated with local markets and subsistence, however, proxy data may be needed as historical field data sources are generally rare, and remote sensing approaches have limited ability to provide information based on archived data, which results in the lack of a proper reference level for many small-scale forest degradation processes (Skutsch et al., 2011).

Proponents of every jurisdiction or project planning to estimate the emissions impact of their REDD+ activities should do so based on appropriate data measured within the area of implementation. The IPCC has suggested a concept of different tiers for estimating emission factors, commonly measured through forest field sampling and repeated forest inventories (and reported as MgC ha^{-1} yr^{-1}). Changes in emission factors should be calculated for each of the five forest carbon pools: aboveground biomass, belowground biomass, deadwood, litter, and soil organic matter. The IPCC provides three tiers for estimating emissions with increasing levels of data requirements, analytical complexity and increasing accuracy. Tier 1 uses IPCC default values, Tier 2 uses country-specific data (i.e. collected within the national boundary), and Tier 3

Table 1: Options for monitoring approaches and data sources of the main forest change activities and drivers at the national level beyond the use of default data (adapted from Herold et al., 2011; Kissinger et al., 2012; GOFC-GOLD, 2013; Pratihast et al., 2013).

Activity/driver of deforestation and forest degradation	Indicator for mapping	Common sources for activity data (at national level)	Common data sources for emission factors/estimations (at national level)	Examples of other data on proxies and for assessing underlying causes
Commercial agriculture; clearing for cattle ranching, row crops etc.	Large clearings; post-clearing land use	– Historical satellite data (i.e. Landsat-type data time series) for deforestation area and land use following deforestation	– Traditional national forest inventories/ground measurements	– Commodity prices – Agriculture census, agricultural GDP, exports etc.
Subsistence agriculture; smallholder farming and shifting cultivation	Small clearings, often rotational fallow cycles	– Historical satellite data (i.e. dense Landsat time series and high-resolution data) for determining area and rotation pattern	– Traditional national forest inventories, ground measurements and targeted surveys – Efforts to assess long-term net emissions	– Population growth in rural and urban areas – Agricultural imports/exports – Land use practices (e.g. rotation cycles etc.)
Infrastructure expansion (roads, mines, settlements etc.)	Road networks; new mines; built-up areas	– Historical satellite data (i.e. Landsat time series) to measure deforestation area and land use following deforestation	– Traditional national forest inventories and ground measurements	– Growth in urban/rural population – Infrastructure/development programs – Mining: commodity prices/exports
Industrial/commercial extraction of forest products, such as selective logging	Small-scale canopy damage; Logging roads / infrastructure	– Historical satellite data (i.e. Landsat time series) analyzed with concession areas	– Regular national forest inventories, ground measurements, and harvest estimates from commercial forestry	– Timber prices and demand (nationally, internationally) – Timber import/exports

Continued **Table 1:** Options for monitoring approaches and data sources of the main forest change activities and drivers at the national level beyond the use of default data (adapted from Herold et al., 2011; Kissinger et al., 2012; GOFC-GOLD, 2013; Pratihast et al., 2013).

Extraction of forest products for subsistence and sale in local and regional markets (e.g. fuel wood and charcoal)	Very small-scale canopy damage; understory impacts; footpaths	– Limited historical data – Information from local scale studies or national proxies – Only long-term cumulative changes may be observed from historical satellite data	– Limited historical data – Information from local scale studies – Emission factors can be measured today and applied as consistent factors for historical periods – Important role for community-based monitoring – Besides direct forest carbon stock changes, more indirect methods (such as head loads of fuel wood) may be useful	– Rural/urban population growth – Energy use/fuel sources (% of population) – Consumption patterns and changes
Other disturbances, such as (uncontrolled) wildfires	Burn scars and associated impacts	– Historical satellite-based fire data records (since 2000) to be analyzed with Landsat-type data	– Regular emissions estimates can be applied consistently for historical periods with suitable activity data	– Land use practices (e.g. agricultural fires) – Links to other activity data to attribute fire emissions – Fire prevention – Natural wildfire events

uses actual inventories with repeated measurements to directly measure changes in forest biomass and/or well-parameterized models in combination with plot data.

The concept of tiers emphasizes how different kinds of data can be useful for carbon monitoring in REDD+. Ideally, both activity data and emission factors should be measured with sufficient precision and accuracy (fine-scale monitoring), but this is sometimes not achievable due to a lack of capacity and resources. Thus, questions arise about using available, coarser-scale datasets as supplementary or complementary sources. For example, if a local REDD+ project is able to build on a strong national forest monitoring system, including suitable remote sensing-based activity data and emission factors based on detailed national inventories, the estimates obtained can be robust with only a limited amount of refinement or additional data needed. Alternatively, since many national monitoring systems are still evolving, regional or global datasets can be used. More large-area or pan-tropical datasets on forest change (Hansen et al., 2013) and biomass (Saatchi et al., 2011; Baccini et al., 2012) are becoming available that can provide data on scales that matter for REDD+. These datasets, however, often have an intrinsic requirement of a consistent (global) definition and method to ensure large area consistency, which often implies a trade-off in local precision and accuracy. This trade-off can be exemplified by the use of remote sensing for REDD+ monitoring (De Sy et al., 2012), which is shown here as the operational ability of different forest information products at multiple scales (Table 2). Commonly, remote sensing research starts from the local experimental level to develop and test technologies and methods, and if suitable, moves towards larger demonstration areas or even global level analysis. While monitoring forest area change is operational at all scales, approaches for mapping forest types or biomass are not yet used by many REDD+ countries. Given that the most appropriate and suitable methods for generating forest information products often depend on national and local circumstances (e.g. types of forest changes, data costs and availability, technical capabilities, size of forest area, drivers, etc.), coarser-scale products often show less suitability for use at national and subnational scales without additional calibration or integration. Yet, as more coarse-scale datasets become available with increasing degrees of precision and accuracy, their usefulness for REDD+ monitoring at national and subnational levels also increases and should be evaluated by dedicated research at multiple scales.

Aside from the need to acquire appropriate data, different frameworks are available to estimate and report on the carbon impacts of REDD+. At the national level, the IPCC GPG provides the rules and tools for international reporting. At local and subnational levels, other reporting frameworks, such as VCS, are more commonly used. Importantly, these frameworks are designed for different users and uses; the first is for reporting to the UNFCCC, while the second is to feed into the voluntary carbon market. It is thus not uncommon that reporting to the different frameworks, even when based on similar data (i.e. activity data and emission factors), will lead to different results due to different definitions, time frames, accounting rules, approaches for developing reference levels, activities to include, use of conservative

Table 2: Operational ability of different forest information products in REDD+ context (black = high, dark grey = intermediate, light grey = low and white = limited or no operationality). Adapted from De Sy et al., 2012.

Forest information product	**Local pilot and research sites**	**Large research demonstration areas**	**National level**
- Forest area change monitoring	black	black	black
- Near real-time deforestation detection	dark grey	dark grey	light grey
- Land use change patterns and tracking of human activities	dark grey	dark grey	light grey
- Forest degradation monitoring	dark grey	light grey	light grey
- Monitoring of wildfires and burned areas	black	dark grey	light grey
- Biomass mapping	black	dark grey	white
- Subnational hotspot monitoring	black	light grey	light grey
- Forest type mapping	light grey	white	white

adjustments, etc. Currently, the differences between estimates derived from different accounting methods are often greater than the actual difference in the data, and comparability is often limited. Therefore, cross-scale integration of national and subnational estimations will require agreement on the level of data and fundamental approaches used.

4.3.2 Social Monitoring

It has been widely accepted that REDD+ must minimize social risks and maximize social benefits to be effective and to support countries' rural development goals. Following the logic of social safeguards, social monitoring can focus on three main categories: i) respect for knowledge and rights of indigenous people and local communities; ii) full and effective participation of local stakeholders; and iii) enhancement of other social benefits. For the first, while respect for local rights is a broad concept, much of the REDD+ literature to date has convened on the importance of tenure security, or clear and enforceable local rights to forests and carbon (e.g., Corbera et al., 2011; Larson et al., 2013). For the second, full and effective participation requires high levels of engagement by local stakeholders throughout REDD+ design and implementation. It begins with access to information, which is reflected in the requirement of free, prior, and informed consent (FPIC), as target communities choose whether or not to participate in REDD+. It also links to broader multi-level governance issues with mechanisms needed to promote local engagement in higher-level REDD+ processes (Agrawal et al., 2011). For the third, enhancement of other social benefits can be conceptualized as improving human wellbeing, assuring equitable benefit sharing and increasing the adaptive capacity of local people (Lawlor, 2013). There are important interconnections among these social dimensions; for instance, secure tenure can be considered the basis for improving local livelihoods and increasing local adaptive capacity (Chhatre et al., 2012), while greater local participation in REDD+ decision making may result in more equitable benefit sharing and long term support of the activities (Cromberg et al., 2014).

The issue of scale is quite relevant for social monitoring, since the determined social outcomes of REDD+ will likely differ based on scale and level of aggregation of analysis. For instance, while protected areas may have substantial socioeconomic effects (both positive and negative) on local people, a global study of 136 countries showed that such effects were not discernable at the national scale (Upton et al., 2008). Social outcomes will also vary among and within social groups, and net benefits may be distributed unevenly. In Thailand, while protected areas contributed to economic development and reduced poverty, they may have increased overall local inequality (Sims, 2010). Disaggregation into social groupings (i.e. along gender, age and ethnicity lines) is needed to understand uneven social impacts, and is most critical in places with greater inequality (Daw et al., 2011). Given the complexity of social monitoring, the key challenge is developing simple, yet adequate methods and performance indicators that are appropriate to the scale of analysis.

To select and monitor social performance indicators, countries can draw on existing national socio-economic monitoring programs, and leverage both secondary and primary datasets. A variety of national-level secondary datasets are publicly available, such as the World Bank Living Standards Measurement Study (LSMS, 2014) and USAID Demographic and Health Surveys (DHS, 2014), which have been applied in many REDD+ countries in partnership with national statistical agencies. These secondary datasets can be used in REDD+ monitoring and complemented by primary data collection in the field. For social monitoring at the local level, more expensive primary data collection would include extensive household surveys, whereas a less expensive approach would be based on participatory methods at the village level. The World Bank's Poverty Mapping technique provides an interesting example of combining census and household-level data towards informing policies that are better tailored to local conditions (Bedi et al., 2007). The application of mixed methods at multiple scales in social monitoring can help provide a more accurate understanding of the results-based performance of REDD+, which could be misinterpreted through the use of one dataset or method alone (Jagger et al., 2010). In all REDD+ monitoring, engagement with relevant stakeholders throughout the process can help address issues of legitimacy of data and results. Such engagement is also required to address social safeguards and ensure local participation and ownership of the process.

To be able to attribute social outcomes to specific REDD+ interventions, impact evaluation is needed in addition to monitoring. There have been detailed reviews of specific methods and indicators that can be used in social impact evaluation (e.g. Schreckenberg et al., 2010), along with guidebooks for conservation practitioners (Wongbusarakum et al., 2014), with distinct mixed methods approaches favored depending on the amount of time, funds and capacity available (Lawlor, 2013). The Participatory Theory of Change approach involves broad stakeholder consultation in the REDD+ design stage to provide a road map for expected changes that a given intervention will have, focusing on selection of indicators that can most strongly inform attribution (Richards and Panfil, 2011). Multiple theories of change are created to establish attribution and eliminate rival explanations. The strength of this approach is that it is highly participatory and relatively inexpensive; its main weakness is that its robustness depends on how indicators are selected, measured and analyzed. Participatory approaches can be complemented with rigorous social impact evaluation at the site level, which involve the application of experimental (e.g. randomization) or quasi-experimental methods (e.g. Before-After-Control-Intervention, BACI) to evaluate REDD+ impacts (Jagger et al., 2010). Experimental approaches, such as randomization, can only be used if REDD+ participants are selected randomly (e.g. through a lottery system) allowing for no bias between treatment and control groups. Quasi-experimental approaches that employ matching techniques to create controls and measure conditions before implementation of REDD+, such as BACI, are more rigorous in establishing attribution, but also more time-consuming and difficult to implement. Importantly, these same concepts apply to environmental monitoring. While countries will need to report on the social performance of REDD+ at relatively coarse scales, fine-scale monitoring of local processes can help inform of national-level indicators for respecting local rights, ensuring local participation and enhancing social co-benefits in an iterative process.

4.3.3 Environmental Monitoring

Environmental monitoring in REDD+ focuses on the need to promote forest conservation and other environmental co-benefits, which loosely translates into biodiversity conservation and ecosystem services provision. The Cancun safeguards propose that REDD+ activities should take into account the multiple functions of forests and other ecosystems, be consistent with the conservation of natural forests and biological diversity, and not be used for the conversion of natural forests but instead to incentivize their protection.

The biodiversity component of environmental monitoring in REDD+ has foreseeably received the most international attention. Biodiversity monitoring at national or global scales has been a concern of conservation science pre-dating REDD+ (Stoms and Estes, 1993; Innes and Koch, 1998). In recent years, the UN Convention on Biological Diversity has recognized the potential opportunities and risks of REDD+, including leveraging REDD+ as a tool for biodiversity conservation in their post-2020 targets (CBD, 2012). There has been a growing policy focus on the environmental co-benefits of REDD+, along with practical information on biodiversity monitoring for REDD+ (Latham et al. 2014). Several unresolved issues, however, stand in the way of a faster uptake of environmental safeguarding in subnational and national REDD+ designs.

Monitoring of biodiversity and other ecosystem services in the tropics is historically hindered by a shortage of data (Martinez et al., 2011) deriving from chronic underfunding of conservation science, in general, and more evidently so for taxonomic work in biodiversity-rich tropical rainforests (Balmford and Whitten, 2003). This situation is compounded by the high cost of multi-taxa field studies (Margules et al., 1994; Lawton et al., 1998). Moreover, biodiversity and ecosystem services are distributed unevenly within forests and between forests and other ecosystems, and the lack of a common measure, such as metric tons of CO_2 in carbon monitoring, poses a challenge in how to compare results both between habitats within a country or landscape, and between countries and landscapes (Dickson and Kapos, 2012).

The issue of scale therefore becomes a centerpiece of the debate on environmental monitoring in REDD+. Fine-scale field measurements provide important but spatially limited information at high costs (as an exception, see Bassett et al., 2004), and efficient pathways for scaling-up to national and international monitoring systems are largely lacking. On the other hand, at higher geographic scales, biodiversity (or specifically gamma diversity; Hunter, 2002) is usually measured through remote sensing and expressed as changes in land cover type. Although this approach is key to carbon accounting in REDD+, it is still unable to translate into actual changes in species and populations, and importantly, the related consequences of these changes on ecosystem functioning. Without this information, our understanding of the environmental risks and benefits of REDD+ will remain largely inadequate to effectively inform its design.

Environmental monitoring in REDD+ is reinvigorating a long-standing challenge in ecology and conservation. Some authors are calling for the development of effective, flexible biodiversity indicators to maximize field-monitoring efficiency (Gardner et al., 2008), while others argue that ecological indicators must reflect the health of a landscape or water catchment (Stickler et al., 2009). Although the relationships between potential indicator species and total biodiversity are not well established (Lindenmeyer and Franklin, 2002), it has been proposed that ecological indicators should be easily measured, sensitive to change and respond to stress in a predictable manner, anticipatory, and have a known response to disturbances with low variability (Dale and Beyeler, 2001). In tropical settings, bats (Waldon et al., 2011) dung beetles (Rodriguez et al., 1998), butterflies (Beccaloni and Gaston, 1995), and several arthropod groups (Kremen et al., 1993) represent taxa that are common, diverse and sensitive to change. Focusing on such taxa relies on evidence that many taxonomic groups respond similarly to habitat modification (Schulze et al., 2004). Nevertheless, there are concerns about depending on a small number of species without considering the full complexity of the ecological system (Carignan and Villard, 2002). There are also concerns with choosing ecological indicators that are not clearly informed by long-term goals and implementing monitoring programs that lack scientific rigor in identifying suitable target organisms (Dale and Bayeler, 2001). Alternative models have been proposed that place more emphasis on community assembly metrics, such as (relative) abundance, richness, composition and (a-) symmetry (Dufrene and Legendre, 1997). Diversity indices rather than species count are widely used in ecology, as they provide a common-standard, comparable measure as well as capturing ecological complexity beyond species richness (Scholes and Biggs, 2005). Such aggregated indices have been developed and widely used in plant community composition and structure. It is also recognized that animal diversity is often closely linked and predicted by vegetation diversity; therefore, vegetation surveys are and remain one of the most efficient tools for biodiversity monitoring (Noss, 1990; Noss, 1999). On the other hand, the use of novel tools such as camera traps to inexpensively obtain distributional and abundance data over time (Ahumada et al., 2013; Rendall et al., 2014), are emerging as additional tools that can prove especially useful where large-territory species (which may not reflect local vegetation trends) are integral part of the conservation effort. This wealth of knowledge indicates that rigorous biodiversity monitoring is possible, albeit not necessarily technically easy or inexpensive. Thus, further advances such as the identification of "high performance indicators" as part of a framework that includes assessing the costs of monitoring different taxa (Gardner et al., 2008; see also chapter 3), are needed, but monitoring in REDD+ can rely on a solid scientific base that can be tailored for its purposes.

Ecosystem-level monitoring is also faced with challenges as to what should be measured. Despite a clear interdependence between biodiversity and ecosystem function (Loreau et al., 2001; Hooper et al., 2005), this relationship cannot be used a priori to serve as a proxy for monitoring purposes. Ecosystem services can derive from biodiversity-independent processes and factors (e.g. a single or few plant species can provide soil erosion control on a riparian bank) or can operate at a landscape scale (i.e. encompassing multiple habitats with distinct biodiversity values). On the other hand, there are also clear opportunities for maximizing monitoring efficiency wherever biodiversity and a target ecosystem service are in spatial, functional and temporal synchrony. A recent assessment, however, has noted how "the relationship between biodiversity and the rapidly expanding research and policy field of ecosystem services is confused and is damaging efforts to create coherent policy" and calls for caution in oversimplifying a complex relationship (Mace et al., 2012).

The above challenges make it difficult to devise a clear pathway for environmental monitoring without further research, which likely contributes to the lack of explicit environmental co-benefits in the national strategies of most REDD+ countries. While social safeguards are seen as strictly necessary to obtain stakeholder support, even before considering any humanitarian and development benefits, environmental co-benefits beyond the “do no harm” principle are less central to the success of a market-driven mitigation scheme such as REDD+ (Phelps et al., 2012b). While environmental safeguards are well anchored in the discourse, the extent to which REDD+ should achieve additional co-benefits is less clear. Ecosystem services, watershed and species protection all have the potential to harness consumer support and willingness-to-pay or, in some cases, even be the primary motive for establishment of a REDD+ project (Cerbu et al., 2011), yet can also increase design and implementation costs making their inclusion in REDD+ less appealing to investors with a primary focus on carbon (Phelps et al., 2012b). Although extreme scenarios of a REDD+ scheme devoid of environmental co-benefits versus a scheme that prioritizes environmental co-benefits over carbon are unlikely, a satisfactory middle ground is yet to be reached (Dickson and Kapos, 2012).

4.3.4 Possibilities For Integrated Monitoring?

REDD+ countries currently follow entirely separate reporting frameworks for carbon Measurement, Reporting and Verification (MRV) and for Safeguard Information Systems. Yet, there can be no holistic understanding of the impacts of REDD+ without integrated monitoring of its carbon and non-carbon impacts, or at least integrated analysis of observation data from different sources. While overall integrated monitoring would likely be difficult to achieve, coherence between data sources can help in understanding and balancing the trade-offs and synergies between reducing emissions, enhancing local rights, participation and wellbeing, and conserving biodiversity and other ecosystem services. Given limited funding for REDD+ monitoring, it is also a potential way to make it more cost-effective. The key is to identify pathways for integration, through complementary data collection methods at multiple scales, and to generate empirical evidence that demonstrates the relationships between the carbon and non-carbon impacts of REDD+.

Clear opportunities exist for integrating carbon and environmental monitoring (Fig. 2). As highlighted in the previous section, and in a recently-proposed framework for biodiversity monitoring integration in REDD+ (Gardner et al., 2012), there is considerable existing knowledge from ecology and conservation that could be integrated into the strategic planning of REDD+. Combined carbon and biodiversity analysis can be conducted at various scales to identify either carbon neutral solutions that offer varying benefits for biodiversity, or opportunities where minor sacrifices of carbon effectiveness can deliver disproportionate environmental co-benefits (Venter et al., 2009; Thomas et al., 2013). Similar datasets can be leveraged to

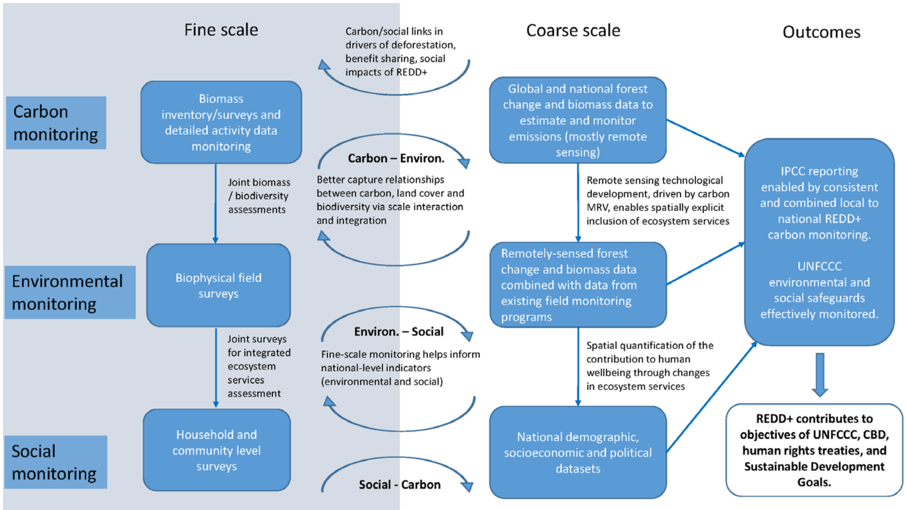

Figure 2: Possibilities for integrated carbon monitoring, environmental monitoring and social monitoring in REDD+.

measure the carbon and environmental impacts of REDD+ at multiple scales. Remote sensing, widely used to estimate forest cover and area change, can deliver a great deal of ecological information, including percent forest cover of water catchments, fragmentation of terrestrial and aquatic habitats, stream continuity, fire incidence, and soil erosion susceptibility (Stickler et al., 2009). Rapidly increasing imagery resolution and analytical processing capabilities are now being combined with terrestrial and aerial biomass measurements, which could be further developed to capture and integrate biologically relevant indicators in a spatially explicit way. For instance, adding data on the distribution of species and threats, along with known responses of ecosystem-level variables to change in forest cover and forest management strategies can be included in REDD+ prioritization processes (Gardner et al., 2012; Thomas et al., 2013). Biologically meaningful monitoring of ecosystem function at a coarse scale (Stickler et al., 2009) can help overcome the funding barrier to global biodiversity monitoring and associated ecosystem services. REDD+ presents an enormous opportunity for scaling up environmental monitoring to a global level from its current local and regional focus. It is only very recently that remote sensing science, ecology and conservation have started to coordinate efforts (Pettorelli et al., 2014), providing the first steps in informing current and long-term trends in carbon, biodiversity and other ecosystem services. Such improvements, however, will only be harnessed when plans for monitoring the environmental impacts of REDD+ (and ensuring the necessary institutional coordination) are incorporated early on in REDD+ design, and environmental co-benefits are considered as a centerpiece of REDD+ beyond "do no harm" requirements (Thomas et al., 2013).

There are also opportunities for integrated monitoring of the carbon and social impacts of REDD+ (Fig. 2). Both are mediated by human behaviors, and the viability of REDD+ depends on understanding and managing the relationship between emissions reductions and improvements in human wellbeing. While the data sources for social monitoring are quite different from those for carbon monitoring, the conceptual links become clearer when drivers of deforestation, benefit sharing systems and measurement of the social impacts of REDD+ are considered. For instance, understanding the socioeconomic drivers of deforestation and forest degradation is fundamental to the creation of effective REDD+ strategies, including the justification and prioritization of REDD+ interventions that address key drivers (Hosonuma et al., 2012; Salvini et al., 2014). There are instances when REDD+ strategies to address the drivers of deforestation and forest degradation could adversely impact local livelihoods (e.g. strategies to curb swidden agriculture) if no alternatives are provided. Closely linked carbon and social monitoring systems are needed to highlight such tradeoffs to be able to inform policy in an iterative way. Additionally, while carbon monitoring will help determine the flow of benefits, more integrated monitoring could help provide the foundation for benefit sharing systems that focus on activities and changes in land use practices that go beyond forested areas (Salvini et al., 2014). Finally, social monitoring is needed to understand the equitability of benefit sharing mechanisms and can guide the adaptation of REDD+ interventions, since the social impact of any intervention (e.g. support for land tenure regularization, fuel-efficient cooking stoves, agricultural intensification to reduce pressure on forests etc.) will ultimately determine its cost-effectiveness.

Finally, the concept of ecosystem services provides a platform for linking social and environmental monitoring, since these services are the benefits that people derive from ecosystems (Millennium Assessment, 2005). Aside from the global public goods of carbon sequestration and biodiversity, the value of ecosystem services depends on the location of forests in relation to beneficiaries (i.e. whose values are counted). For example, forests up-stream of drinking water supply systems generate more valuable watershed services than remote forests. Many studies have explicitly attempted to account for ecosystem services through in-depth analysis of their contribution to human wellbeing, using monetary valuation of ecosystem services as a tangible measure (Ferraro et al., 2012; Ninan and Inoue, 2013). That said, moving from a research intensive, one-point-in-time valuation to long-term monitoring remains a considerable challenge, suggesting an urgent need to advance the interdisciplinary science that investigates the full ensemble of processes and feedbacks. Synergies and trade-offs between human welfare and ecosystem services (including carbon sequestration) as related to REDD+ will be best understood through the application of monitoring and evaluation methods that use similar approaches to constructing the counterfactual (Caplow et al., 2011) and flexible systems that best reflect the context.

4.4 Lessons Learned And Way Forward

Given the lack of capacity and funds for REDD+ monitoring in many countries, greater integration of carbon, social and environmental monitoring – both across scales and between disciplines – could help make the process more cost-effective. To promote such integration, advancements are needed in three key areas.

First, there is a need for cross-scale coordination in measuring, reporting and verifying the carbon and non-carbon impacts of REDD+. The challenge of applying international guidelines at the national level can be seen in countries' responses to the sustainable forest management criteria and indicators, which stem from the Forest Principles defined at the UN Conference for Environment and Development (UNCED) in Rio de Janeiro in 1992. These criteria and indicators consider social, economic, environmental, and cultural dimensions, are to be applied at regional, national and local (i.e. forest management unit) levels, and are commonly accepted as appropriate tools for defining, assessing and monitoring progress toward sustainable forest management (Castañeda, 2000). A recent assessment of the Montreal Process, which includes 12 temperate and boreal countries that in 1995 agreed to report on a common set of criteria and indicators, showed a lack of harmonization in reporting. The majority of countries had not reported on the agreed upon criteria and indicators, likely due to data collection difficulties or lack of commitment to the agreements, and the assessment highlighted clear areas for improvement in communication and consultation with stakeholders (Chandran and Innes, 2014). For REDD+ monitoring to work, it is critical to understand how monitoring systems can be elaborated from existing national policies, indicators and data so that monitoring requirements are a source of support and not a burden. REDD+ country experiences in establishing Safeguard Information Systems and advancing with monitoring efforts should be widely disseminated and contribute to the international policy process in a "bottom up" fashion. Additionally, as national REDD+ frameworks develop, countries can learn from and incorporate advances already made at subnational levels, so that the hard lessons learned by subnational jurisdictions and projects are not lost as national carbon monitoring systems and Safeguard Information Systems are consolidated. In this context, there is the opportunity to think beyond forests and forest monitoring towards the engagement of multiple sectors and stakeholders in measuring sustainability more broadly. Considerable needs for research and action lie in this area.

Second, there is a need to resolve the issue of coarse- versus fine-scale monitoring methods and datasets to facilitate the choice of appropriate performance indicators for REDD+ monitoring. Performance indicators should be: i) easy to understand; ii) applicable at multiple scales; iii) applicable to any location; iv) efficient to measure and monitor; v) sustainable in providing data; and vi) able to be improved over time. There is a disconnect between the widely-available coarse-scale data on forest cover change derived from remote sensing, and the fine-scale data needed to monitor forest degradation processes and changes in social and environmental conditions. Fine-scale data are much more limited, are costly to obtain and generally lack historical measures. The constraints associated with fine-scale monitoring highlight the need for higher levels of aggregation, especially since monitoring efforts ultimately need to align with broader UNFCCC reporting guidelines. Yet, such aggregation threatens the loss of important information on local processes. Consequently, there is a need to establish clear pathways through which local-level information can inform and update any attempts at aggregation. This represents the rationale behind the call for establishment of robust sustainability indicators to evaluate the impacts of conservation and development projects, which can inform efforts to measure sustainability more broadly (Agol et al., 2014). That said, the robustness of indicators is ultimately dependent on the amount and quality of field sampling for development and testing. Since effective monitoring is hampered in many tropical forest countries by lack of capacity and funds for even the simplest monitoring efforts, creative ways to reduce the high costs associated with local-level data collection should be explored. For instance, collection could be partly (but not exclusively, to avoid sampling bias) directed towards sampling potentially more vulnerable populations to create a baseline against which future data collected could be measured (Lawlor, 2013). Although not without its own set of challenges, there are also important opportunities to involve local people in community-based monitoring to address some of the smaller-scale processes, and make links to higher-level monitoring efforts in both environmental and social fields (Bassett et al., 2004; Pratihast et al., 2013).

Further technical work can help understand the differences between the results of coarse- versus fine-scale monitoring of both carbon and non-carbon impacts. Information on the early impacts of pilot subnational REDD+ initiatives is beginning to be consolidated with clear opportunities to compare methods used for assessing performance. For instance, there are opportunities for the Center for International Forestry Research (CIFOR) and The Nature Conservancy (TNC) to compare REDD+ monitoring and evaluation efforts at two subnational sites in Brazil (São Félix do Xingu) and Indonesia (Berau). At these sites, CIFOR's REDD+ impact evaluation is based on a quasi-experimental BACI approach using village, women and household surveys, along with fine-scale spatial and biomass data. While this approach is considered very rigorous for measuring impacts, data collection is limited to relatively small areas within the larger sites and is expensive and time-consuming to implement. In contrast, TNC is using focus group discussion, key informant interviews and secondary data to monitor a larger set of indicators of human wellbeing, an approach that allows for a broader coverage at lower costs, but may sacrifice data quality and depth. Empirical, multidisciplinary analysis of the results-based performance associated with these different monitoring systems can help in the development of coarse-scale indicators that can capture typical outcomes from aggregated fine-scale mechanisms to be used in future REDD+ monitoring efforts.

Finally, there is an important opportunity to promote more interdisciplinary integration in monitoring systems to reduce costs and advance our understanding of synergies and trade-offs between carbon and non-carbon benefits. As discussed earlier, many of the same remotely sensed and field-based datasets that are being leveraged to measure changes in forest carbon emissions can be used to assess changes in biodiversity, hydrology and water resources, and soil resources. There are also key linkages to social benefits. Although most countries report carbon and non-carbon benefits separately, there are interesting examples of bridging this divide. For instance, the Food and Agriculture Organization of the UN and the government of Finland jointly support the Peruvian National Forest Inventory, which is making steps to integrate biophysical and socioeconomic monitoring across the country. In addition to learning from such initiatives, there is an opportunity to promote more interdisciplinary research at the local level. Results can be scaled up to inform the creation of national and global indicators, test their robustness and iteratively update the current set of indicators towards achieving coarse scale, relatively inexpensive monitoring that does not miss the implications of critical local processes. To achieve this, scientific disciplines that remain largely isolated will need to increasingly work together and develop common protocols and frameworks to achieve true interdisciplinarity. Integrated monitoring of REDD+ performance is not only important for assessing adherence to safeguards, but can go well beyond REDD+ to inform indicators of sustainability towards promoting benefits for both people and the environment.

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