UN-REDD
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Monitoring for REDD+: carbon stock change and multiple benefits

UN-REDD PROGRAMME

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Multiple Benefits Series **3**

The UN-REDD Programme, a collaborative partnership between FAO, UNDP and UNEP, was created in response to, and in support of, the UNFCCC decision on REDD at COP 13 and the Bali Action Plan. The Programme supports countries to develop capacity to reduce emissions from deforestation and forest degradation and to implement a future REDD mechanism in a post-2012 climate regime. It builds on the convening power of its participating UN agencies, their diverse expertise and vast networks, and "delivers as One UN".

The United Nations Environment Programme World Conservation Monitoring Centre (UNEP-WCMC) is the biodiversity assessment and policy implementation arm of the United Nations Environment Programme (UNEP), the world's foremost intergovernmental environmental organization. The centre has been in operation since 1989, combining scientific research with practical policy advice.

The United Nations has proclaimed 2010 to be the International Year of Biodiversity. People all over the world are working to safeguard this irreplaceable natural wealth and reduce biodiversity loss. This is vital for current and future human wellbeing. We need to do more. Now is the time to act.

Prepared by

Maurizio Teobaldelli, Nathalie Doswald, Barney Dickson

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Abstract

Forests provide a number of ecosystem services including biodiversity, which could be added multiple benefits to the climate change mitigation potential arising from implementing REDD+. However, there have also been concerns that harms to ecosystems could ensue from its implementation. Monitoring would be one way to support and promote benefits and avoid harms to the ecosystem. However, monitoring changes in carbon stocks for anthropogenic forest-related greenhouse gas emissions and removals estimation will impose considerable demands on REDD+ countries, and additional monitoring would increase the cost and burden on countries. This paper investigates the relationship and potential synergies between monitoring systems for carbon stock changes and multiple benefits from REDD+. Monitoring multiple benefits, such as biodiversity and ecosystem services, has usually been undertaken by selecting a set of indicators. A good framework of indicators provides more robust way to preserve benefits. However, identifying measurable indicators, setting baselines and determining the frequency of measurements for other benefits of REDD+ is challenging and these do not necessarily match those required for carbon.

Taking advantage of current biodiversity or environmental monitoring schemes would be beneficial not only for monitoring these aspects for REDD+ but also for monitoring carbon. Indeed some information collected for biodiversity monitoring purposes could be used to increase the accuracy of carbon monitoring. Moreover, the methods used and the data collected for carbon monitoring can be used to monitor some aspects of ecosystem services. For instance, remote sensing can provide information on different ecosystem indicators either directly or indirectly; whilst ground-based measurements provide opportunities to gather information pertinent to both carbon stocks and multiple benefits.

There are clear synergies and relationships between monitoring systems for carbon stock change and multiple benefits. However, gaps in current monitoring schemes exist and it may be necessary to collect extra information so as to get an adequate picture for the multiple benefits and harms from REDD+. Nevertheless, with careful planning and use of existing monitoring schemes and carbon monitoring data could provide a cost-effective solution.

Le monitorage pour REDD+: changement en stock de carbone et bénéfices multiples : Résumé

Les forêts fournissent un nombre de services écosystémiques y compris la biodiversité, qui pourraient être considérés comme les multiples bénéfices additionnels au potentiel d'atténuation des changements climatiques survenant de la mise en œuvre de la REDD+. Cependant, il y a aussi des craintes que certains dégâts soient causés aux écosystèmes (forestiers) lors de sa mise en œuvre. Le monitorage serait une façon de pour soutenir et promouvoir les bénéfices et éviter les impacts négatifs. Par contre, le monitorage des changements en stock de carbone pour estimer les émissions et l'absorption de gaz à effet de serre résultant des activités forestiers, imposera des demandes considérables aux pays, et donc imposer un monitorage additionnel accroîtrait le coût et le fardeau aux pays. Ce document examine les rapports et les synergies potentielles entre les systèmes de monitorage des stocks de carbone forestiers et des bénéfices multiples de REDD+. Le monitorage des bénéfices multiples, comme la biodiversité et les services écosystémiques, est normalement fait avec l'aide d'indicateurs. Un bon cadre d'indicateurs fourni une manière solide de conserver les bénéfices. Par contre, identifier des indicateurs mesurable, déterminer les bases (scénarios de référence) ou la fréquence des mesures pour les bénéfices multiples de REDD+ est un challenge et ceux-ci ne sont pas toujours comparable à ceux nécessaires pour le carbone.

Tirant parti des systèmes de monitorages actuels de la biodiversité ou de l'environnement serait bénéfique non seulement pour le monitorage de ces aspects pour la REDD+ mais aussi pour le monitorage du carbone forestier. En effet, les données recueillies par le monitorage de la biodiversité pourraient être utilisés pour augmenter la précision du monitorage du carbone forestier. De plus, les méthodes utilisées et les données recueillies pour le monitorage du carbone forestier peuvent être utilisées pour le monitorage de certains aspects des services écosystémiques. Par exemple, la télédétection peut donner de l'information pertinente à divers services écosystémiques d'une manière directe ou indirecte ; et les mesures au sol donnent l'opportunité de recueillir des données pertinentes à la fois aux stocks de carbone et aux bénéfices multiples.

Il y a donc des synergies et des rapports nets entre les systèmes de monitorage du changement des stocks de carbone et des bénéfices multiples. Cependant, des lacunes existent dans les systèmes actuels de monitorage et il sera donc nécessaire de recueillir des nouvelles données pour obtenir une idée adéquate des avantages et des impacts négatifs de REDD+. Néanmoins, une solution rentable pourrait être trouvée avec une planification minutieuse et l'utilisation des systèmes actuels de monitorage ainsi que celui du carbone forestier.

Monitoreo para REDD+: cambios en las reservas de carbono y beneficios múltiples : Resumen

Los bosques proporcionan varios servicios ecosistémicos incluyendo la biodiversidad, que podrían ser considerados como los beneficios múltiples adicionales al potencial de mitigación del cambio climático derivado de la implementación de REDD+. Sin embargo, también se ha expresado preocupación por los daños a los ecosistemas que podrían resultar de su implementación. El monitoreo sería una forma de apoyar y promover los beneficios y evitar los daños a los ecosistemas. Sin embargo, monitorear los cambios en las reservas de carbono para estimar las emisiones y la absorción de gases de efecto invernadero resultantes de las actividades forestales, impondrá demandas considerables en los países REDD+, y el monitoreo adicional aumentaría el costo y la carga para los países. Este documento investiga las relaciones y las posibles sinergias entre los sistemas de monitoreo de cambios en las reservas de carbono y los beneficios múltiples de REDD+. El monitoreo de beneficios múltiples, tales como la biodiversidad y los servicios ecosistémicos, normalmente se ha llevado a cabo mediante la selección de un conjunto de indicadores. Un buen marco de indicadores representa una manera más sólida de preservar los beneficios. Sin embargo, identificar indicadores medibles, fijar líneas base y determinar la frecuencia de las mediciones para otros beneficios de REDD+ supone un desafío y éstos no se ajustan necesariamente a los requeridos para el carbono.

Sacarle partido a los sistemas actuales de monitoreo de la biodiversidad o del medio ambiente sería beneficioso no sólo para monitorear estos aspectos para REDD+ sino también para monitorear el carbono. De hecho, parte de la información recogida por razones de monitoreo de la biodiversidad podría usarse para aumentar la precisión del monitoreo del carbono. Además, los métodos usados y los datos recogidos para monitorear el carbono pueden usarse para monitorear ciertos aspectos de los servicios ecosistémicos. Por ejemplo, la detección remota puede proporcionar información sobre distintos indicadores de ecosistemas, bien directa o indirectamente; a su vez, medidas tomadas a nivel de suelo brindan oportunidades para recopilar información pertinente tanto a las reservas de carbono como a los beneficios múltiples.

Existen claras sinergias y relaciones entre los sistemas de monitoreo de cambios en las reservas de carbono y los beneficios múltiples. Sin embargo, existen lagunas en los sistemas actuales de monitoreo y podría ser necesario recoger información extra para conseguir una visión adecuada de los beneficios múltiples y de los daños causados por REDD+. No obstante, una planificación minuciosa y la utilización de sistemas y datos de monitoreo existentes sobre el carbono podrían proporcionar una solución rentable.

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1 Introduction

Forests provide a number of ecosystem services, such as climate and water regulation and the provision of timber and non-timber forest products. REDD+ [1] aims to harness forests' climate regulation services (carbon storage and sequestration) to mitigate climate change by reducing emissions from deforestation and forest degradation and by the conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries.

Many stakeholders have shown distinct interests in promoting, in the implementation of REDD+, the ecosystem services, including biodiversity, other than carbon sequestration, which have become known as potential 'multiple benefits' from REDD+. Reasons for interest in multiple benefits are varied but include the importance of some of these benefits in ensuring the permanence of forest cover and carbon stocks including under climate change, the well-being of the environment and people, the obligations to other conventions and national polices, as well as the potential to link these benefits to markets similarly to the carbon market.

On the other hand, there is concern that some activities undertaken during the implementation of REDD+ may be detrimental to ecosystem services and people. Indeed, the current United Nations Framework Convention on Climate Change (UNFCCC) negotiations surrounding REDD+ have included draft text on "safeguards", which covers avoiding the potential harms to ecosystems and people that could result from certain forms of implementation of REDD+, such as "conversion of natural forest" to plantations or failure to "respect [] the knowledge and rights of indigenous peoples and members of local communities", potentially depriving local communities of access to forests (FCCC/AWGLCA/2010/6). These "safeguards" also include provision to "incentivise the protection and conservation of natural forests and their ecosystem services, and to enhance other social and environmental benefits" (FCCC/AWGLCA/2010/6).

If safeguards in REDD+ are to be "promoted and supported", there needs to be some way of estimating whether multiple benefits have been enhanced or harms have been avoided. Monitoring of these two issues would indicate whether safeguards were met. This paper sets out to establish what would be needed for monitoring multiple benefits, as well as harms, from REDD+ and how these relates to the monitoring requirements in REDD+.

Monitoring requirements in REDD+ relate to anthropogenic greenhouse gas (GHG) emission reductions and removals and more specifically to carbon stock and forest area changes. Although there are challenges in monitoring carbon stock changes and estimating emissions (Teobaldelli et al. 2010; Anglesen 2008), established methodology and guidance exist (IPCC 2003; GOFC-GOLD 2009). The investment and capacity needed to set up such a monitoring system, especially if it is required to follow rigorous MRV (measurement, reporting and verification) modalities used under the Kyoto protocol (UNFCCC 2006), is potentially large. Despite the interest from different stakeholders, it is unclear whether monitoring requirements for the safeguards alluded to in the UNFCCC text will be established

[1] REDD+ or Reducing Emissions from Deforestation and forest Degradation; including the conservation of forest carbon stocks, sustainable management of forests and enhancement of forest carbon stock is a potential future finance mechanism under the UNFCCC which provides incentives for undertaking these activities.

by the UNFCCC. The current negotiating text includes reference to the development of a monitoring system for safeguards though the text is bracketed (FCCC/AWGLCA/2010/6). Several UN REDD pilot countries are making provisions to monitor these benefits. Nevertheless, monitoring multiple benefits is essential if these are integral to REDD+ but may impose substantial extra costs, which some countries may not be able to support. This paper therefore, sets out to investigate the relationship and synergies between monitoring systems for carbon stock changes and for multiple benefits from REDD+. The aim is to understand whether, and how, monitoring for one of these can provide information that is relevant for the other. In this paper, we focus our attention on monitoring the ecosystem services other than carbon sequestration provided by forests, but also discuss the relationship to monitoring non-ecosystem derived benefits.

2 Monitoring for REDD+

Monitoring requires explicit goals, as well as understanding of appropriate indicators[2] for their achievement (Elzinga et al. 2001; Tucker et al. 2005). The use of appropriate indicators provides an efficient way of monitoring and communicating environmental conditions, results of policy decisions and management activities (Niemeijer 2002). In terms of the climate change mitigation goal of REDD+, the appropriate indicator is change in carbon stocks, which is fairly straightforward to monitor. In contrast, where goals relate to ecosystem services including biodiversity, which are multi-dimensional concepts containing ideas of provision, flow and beneficiaries, there is no single obvious measure and identifying which indicators are appropriate is complicated by the fact that these may be dependent on the context (Fischer et al. 2009).

Identifying appropriate indicators is achieved by determining key questions, which are formed by the objectives (Bubb et al. 2010). For example, if the objective is to protect biodiversity, key questions could be 'is biodiversity increasing or decreasing in the forest?' or 'what are the main threats to biodiversity?'. Making use of a framework for indicators enables broad coverage of issues and monitoring needs as it helps identify and structure key questions. A commonly used approach is the driving force-pressure-state-impact response (DPSIR) framework (Box 1). This framework differentiates between monitoring the condition of the ecosystem (state indicators), the risks faced by ecosystems (driving force, pressure and impact indicators) and the measures put in place to achieve the objectives (response indicators).

Indicators in themselves are not monitoring and reporting systems, but are a prerequisite in designing monitoring systems. Monitoring carbon stock changes in REDD+ (section 2.1) makes use of state and driving force/pressure indicators and collects measurements regarding land use and land-use change and carbon stocks (GOFC-GOLD 2009; Teobaldelli et al. 2010). By contrast, monitoring multiple benefits and harms from REDD+ first require identification of relevant indicators before establishing what measurements to collect (section 2.3).

Box 1: DPSIR framework in REDD+ context

The **driving force-pressure-state-impact response** (DPSIR) framework aims to describe interactions between society and the natural environment. It classifies indicators into five categories:

1) **Driving forces**: in a REDD+ context, the factors that drive deforestation and forest degradation; indicators, such as population density, household income inequality, and infrastructure could be used.

2) **Pressures:** These measure factors causing harm, such as fires or fragmentation.

3) **State**: These measures relate to the condition of the object of interest, such as number of species or total forest carbon stock.

4) **Impacts**: these indicators track the negative effects of REDD+, such as proportion of non-native species planted or change in invasive species.

5) **Response**: these indicators track the efforts made with regards to the desired objective; for an objective to conserve biodiversity, indicators might track protected areas established or investments made in them.

2.1 Monitoring carbon stock changes

The IPCC provides standards for carbon accounting as well as an established monitoring system (IPCC, 2003). Monitoring needs for carbon stock and carbon stock changes requires measuring carbon stocks, ideally from all five carbon pools (aboveground biomass, belowground biomass, dead wood, litter, and soil organic carbon; IPCC 2003), for different land-use categories and conversion between land use categories (e.g. non-forest land converted to forest land and forest land converted to non-forest land). In particular, monitoring carbon stock change in REDD+ requires assessing:

(1) *Location*: land unit (ha), land-use categories, carbon pools;

(2) *Quantification*: carbon density (carbon ha^{-1}) and carbon stock (stratified[3] by eco-regions, forest type, carbon pools);

(3) *Changes*: spatial, temporal, quantitatively variation of carbon stocks over time.

These three aspects are assessed by collecting (1) “activity data”, information representing existing land-use categories (e.g. forest area), changes within the land use (e.g. degradation or sustainable management of forest) and land-use changes (e.g. deforestation or afforestation) and is presented in hectares, and (2) “emission factor”, a carbon stock coefficient generally collected through repeated (e.g. every 5 years) national forest inventories. Activity data is multiplied by the emission factor to estimate the anthropogenic forest-related GHG emissions by sources and removals by sinks. Multiple assessments of these two over time provide change in anthropogenic forest-related GHG emissions by sources and removals by sinks (3).

Remote sensing (RS) is the easiest and quickest way to determining location (1) and changes (3) in land use area and, as such, RS is one of the main tools for national deforestation monitoring (DeFries et al. 2006). Moreover, it offers different levels of resolution, the highest of which can be used to monitor forest degradation or enhancement of forest carbon stocks if these result in distinguishing landscape features (GOFC-GOLD 2009). Ground-based measurements, usually in the form of forest inventories, are needed to calibrate remote sensing data, monitor some forest changes (especially degradation or enhancement of stocks which can be difficult to monitor through remote sensing) and provide information for calculating carbon stocks (Brown 2002).

Quantification of carbon stocks (2) are estimated by combining land use area with biomass density, which can be estimated using IPCC default values, but greater accuracy is achieved using country-specific information, preferably derived from detailed national forest inventories. These different levels of accuracy are characterised by the IPCC as three different *tiers*, which show a progression from least to greatest levels of accuracy. Tier 1 uses the basic method and default emission factors provided in the IPCC Guidelines in combination with activity data that are spatially coarse, such as nationally or globally available estimates of deforestation rates, agricultural production statistics, and global land cover maps. Tier 2 uses the same methodological approach as tier 1 but applies emission factors and activity data, which are defined by the country for the main land uses/activities. Finally, tier 3 uses higher-order methods including models and inventory measurement systems customized to address national

[3] Stratification refers to the division of any heterogeneous landscape into distinct sub-sections (or strata) based on some common grouping factor (GOFC-GOLD 2009).

circumstances, repeated over time, and driven by high-resolution activity data and disaggregated at sub-national to fine grid scales.

Setting reference levels or baselines against which to monitor carbon stock changes, is a challenging but necessary process in implementing a REDD+ programme (Herold & Skutsh 2009). There are three different types of baseline. A historical reference level sets the baseline at some predetermined level. This can be either an average of a predetermined time period or a rolling average spanning a predetermined time frame. Alternatively, a crediting baseline is a reference level agreed by negotiation, and determines the level at which rewards should be made, i.e. similar to a quota. Finally, baselines can be set with the use of scenarios to give a prediction about what would happen without actions, i.e. a business-as-usual (BAU) baseline (Angelsen 2008). Measuring the effect of a REDD+ project requires a BAU baseline, which gives a prediction about what would happen without the action (Herold & Skutsh 2009), and information on leakage.

2.2 Monitoring multiple benefits from REDD+

Multiple benefits from REDD+ include the ecosystem services and biodiversity provided by forests (Table 1) whilst harms to ecosystems from REDD+ include plantation of non-native species or non sustainable management, all of which results in a multitude of aspects that could be monitored. Further, different benefits from REDD+ may be only perceived depending on which scale is selected. For instance, water regulation is of large-scale benefit whilst fuel-wood supply can be thought of as primarily of local concern.

Given this breadth, it will be necessary to define the scope and boundaries of the monitoring as these potentially can be very wide (e.g. where benefits accrue internationally) and consider the interests or needs of different stakeholders. For instance monitoring (and reporting) needs may be different for globally decided safeguards than monitoring of water supplies for an ecosystem service market. The first step in a monitoring system for multiple benefits from REDD+ will therefore involve determining what is of interest and selecting appropriate indicators (Figure 1). Guidance on how to develop and use national (biodiversity) indicators, providing a useful set of steps and questions to consider during indicator development, has been compiled by UNEP-WCMC in light of experience from the CBD’s indicators (Bubb et al. 2010). The UN Commission on Sustainable Development (CSD) also provides some guidelines on adapting its indicators for national needs (CSD 2001).

Table 1: Forest ecosystem services (based on Millennium Ecosystem Assessment 2005); excluding global climate regulation, and adding biodiversity, these are the potential ecosystem co-benefits of REDD-plus.

Ecosystem services	**Examples for forest ecosystems**
Provisioning	**The goods or products obtained from ecosystems**
Food	Edible non–timber forest products (NTFPs) such as fruits, berries, and bush meat;
Fresh water	Around 4.6 billion people depend on forests for all or some of their water supplies;
Wood & fibre	Timber, and non-timber forest products such as silk, rubber, bamboo;
Fuel	Fuel wood;
Genetic resources	Wild species and genes used for animal and plant breeding and biotechnology;
Biochemical & natural medicines	Many commercial and traditional medicines are derived from forest species;
Regulating	**The benefits obtained from an ecosystem's control of natural processes**
Climate regulation	The regulation of the global carbon cycle through carbon storage and sequestration, in addition to local and regional climate regulation (albedo effects, regional rainfall etc);
Flood regulation	The reduction and slow down of surface water run–off;
Disease regulation	Intact forests reduce the occurrence of standing water, reducing the breeding area for some disease vectors and transmission of diseases such as malaria;
Water regulation	Forest systems are associated with the regulation of 57% of total water runoff, and play a large role in the hydrological cycle;
Pollination	Crops, such as coffee, that are close to forests receive more visits from pollinators;
Cultural	**The non-material benefits obtained from ecosystems**
Aesthetic & inspirational	The scenery and landscapes provided by forest, both for their own beauty and as an inspiration for art;
Spiritual & religious	Indigenous peoples and others attach spiritual significance to forests;
Educational	Research, education and training in forests;
Recreational	Ecotourism in forest areas;
Cultural heritage & sense of place	Some cultures place high value on particular landscapes or species;
Supporting	**The natural processes that maintain the other ecosystem services**
Nutrient cycling	Forests are extremely efficient at maintaining nutrient flows through atmosphere, plants and soils;
Soil formation	Forests on slopes hold soil in place and can prevent degradation;
Primary production	The total organic matter produced as a result of photosynthesis and nutrient uptake from the soil;

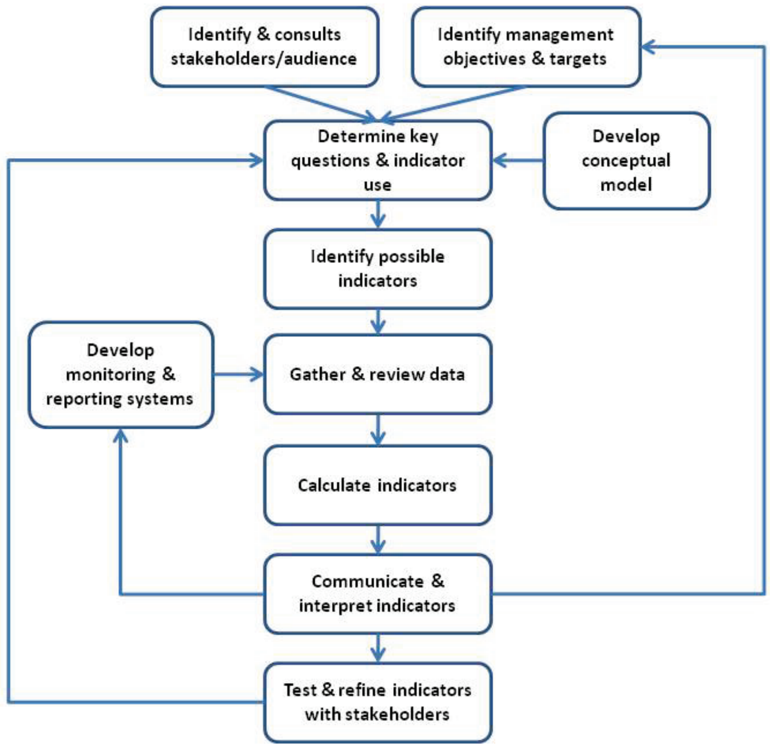


Figure 1: Indicator development framework (from Bubb et al. 2010)

Indicator selection should therefore involve selecting indicators that will reveal information on the benefits of most interest, rather than try to measure in detail all the services and biodiversity that forests delivers (Failing and Gregory 2003; Tucker et al. 2005). The choice of the precise indicators and means of monitoring them will also depend on feasibility of gathering data and ability to convey the appropriate information (Layke 2009). Further, knowledge and understanding of some services is still rudimentary (Kremen & Ostfeld 2005) making their characterisation, let alone their monitoring, difficult. As biodiversity includes variation in genes, species and ecosystems, no single agreed measure exists (or can exist) to monitor it (The Royal Society 2003).

Nonetheless, ecological and environmental monitoring has a long history, allowing the development of a framework of indicators that will give a reasonable understanding of the state and trends. For instance, repeated bird surveys have been undertaken worldwide over long time periods. The Convention on Biological Diversity[4] (CBD) global wild bird indicator consists of data from 1965 to the present[5], whilst the Red list index for the worlds' birds consists of data from 1988 to present[4].

Whilst monitoring state indicators will give an indication of the condition of the benefit (e.g. increase or decrease in species numbers), making use of other indicator types will provide useful information

[4] http://www.twentyten.net/indicators
[5] This indicator is currently formed mainly from data from Europe and Northern America but it is hoped to add monitoring data from other continents.

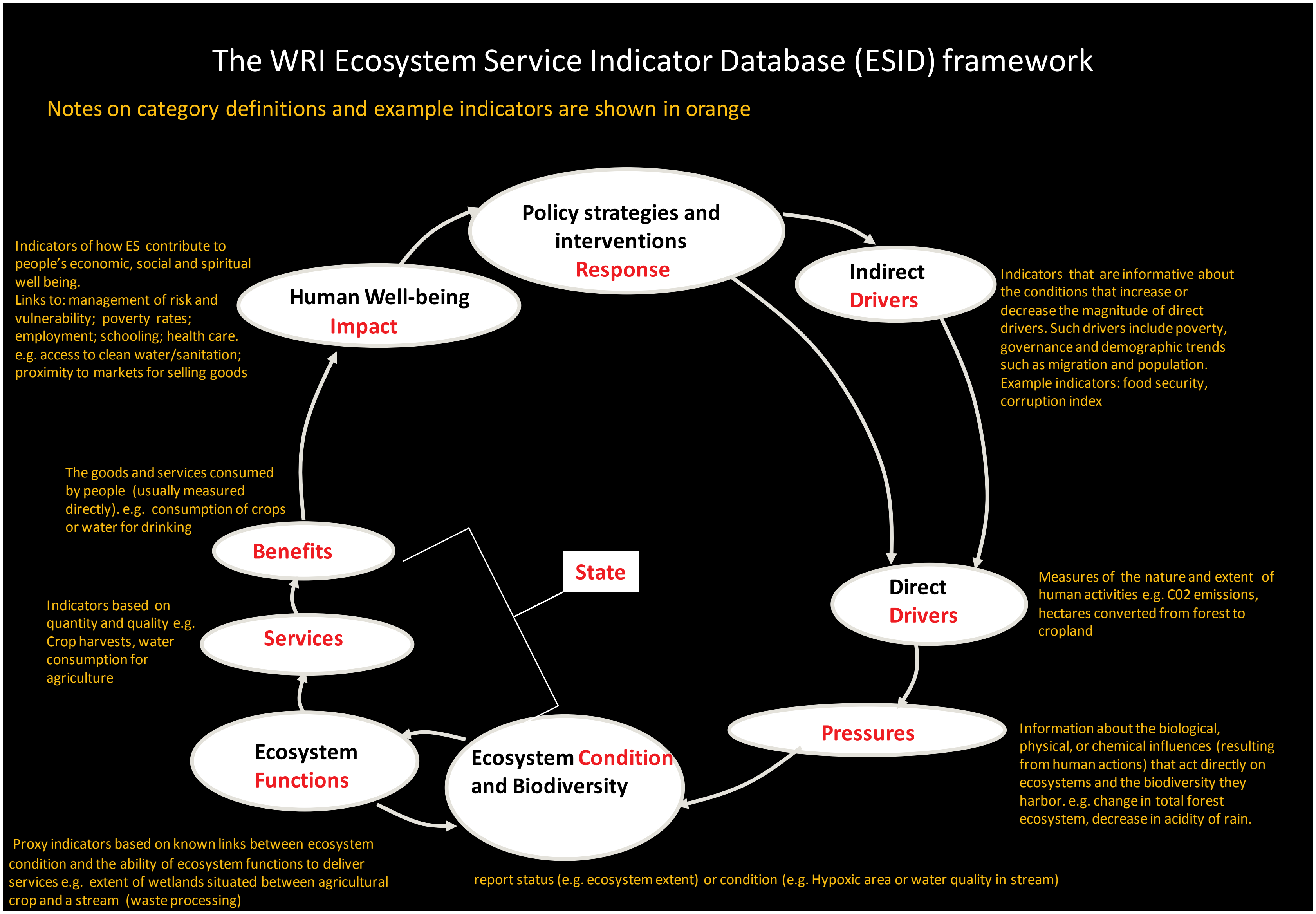
pertaining to the benefit; for example, monitoring the fragmentation of forest will give an idea on pressure on species numbers, offering an early warning of future declines in state. Indeed, the biodiversity indicators compiled for the CBD include state, pressure and response type indicators (POST 2008). Ecosystem service indicators have recently been compiled by the World Resource Institute with help from UNEP-WCMC[6] (Layke 2009) and follow the full DSPIR framework (Box 1; Fig. 2). However, coverage of ecosystem services are limited in terms of existing indicators: there are strong indicators relating to provisioning services, but existing indicators assessing regulating or cultural services are weak (Layke 2009).

Many ecosystem benefits and possible indicators for these benefits lack data, possible metrics and standards. Further, not all benefits are measurable. In the past, there has been a tendency to use indicators for which there is an understanding of the process, ease of measurement, or data available which may not cover the attributes that are important in a management sense (Failing and Gregory 2003). Research would be needed to identify and if necessary construct measurable indicators and useful metrics. Experience on how challenging this is can be drawn from the development of the CBD 2010 target indicators. The framework of indicators and indicator development took about 5 years to finalise and was to a large extent based on existing indicators, though a few new indicators were developed. However, there are still many gaps and heterogeneity in the coverage of these indicators and much uncertainty over their representativeness and the inter-linkages between them (Butchart et al. 2010). The CSD Indicators of Sustainable Development uses a different indicator framework, which aims to address the inter-linkages between indicators and provide useful basis for adapting these in a national context (CSD 2001).

Lack of data is dealt with in carbon stock change monitoring by the use of different "*tier*" levels. It may be possible to use such a system for multiple benefits. The use of simple measures as surrogates of biodiversity and other ecosystem services may be cost-effective and might at the same time permit testing the monitoring system ahead of more detailed metric availability/development (O'Connor 2008). The use of proxy measures and extrapolations from available information is also feasible to address data availability issues. Information relating to one indicator can also sometimes be used to infer information for another. Many socio-economic indicators (which can serve as state or driving-force indicators of REDD+ depending on the focus) such as population density, governance and corruption correlate with environmental indicators; for example countries with high population density, greater wealth, and poor governance have greater total environmental impact than countries with opposing trends (Bradshaw et al. 2010). However, relationships between indicators are not necessarily linear, and it is necessary to understand whether a correlation is likely to be causal, or whether each indicator is responding to a third factor in the same way. Relationships between indicators are useful to establish as these can provide additional information. However, if possible it is more transparent to have a limited number of indicators, which have accessible data and can be relatively easily collected (Niemeijer 2002).

[6] http://www.esindicators.org/

Figure 2: The Ecosystem Service Indicator Framework of the World Resources Institute (WRI) (adapted from http://www.esindicators.org/files/esid/Framework%20discussion%20for%20download.pdf)



Unlike for carbon stock change monitoring (e.g. GOFC-GOLD 2009), there exists no tailored multiple benefit monitoring handbook, although there exists plenty of guidance when it comes to monitoring specific benefits, such as biodiversity (e.g. World Bank 1998). A monitoring system for the chosen indicators will require the collection of information regarding:

(1) *Location*: land unit (ha); eco-region; ecosystem; forest type; niche, etc.
(2) *Evaluation*: quantity/quality (information may be stratified by grouping variables such as land use, forest types, eco-regions, etc.)
(3) *Changes:* spatial, temporal, quantitatively or qualitatively variation

These three information categories are similar to those needed for carbon monitoring. Further, the most common methods of data collection are through remote sensing, ground-based measurement (transect or point sampling), which are also required for carbon stock estimation, and through community/individual/expert consultations (questionnaires, interviews, workshops). These similarities will be further explored in section 3.2. However, the necessary frequency of measurements for different multiple benefits may be different to those required for carbon. The timescale to observe or capture changes in some of the benefits may be vastly different. Some changes, such as soil formation, may only be measurable over long time periods whilst others may have greater fluctuations such as some of the socio-economic changes. The ability to detect true trends in multiple benefits is a further challenge. Indeed conclusive and generalisable cause-effect results in ecology are rare. For instance, there are many studies with conflicting results as to the effects of forest cover on stream flow (Ingversen 1985; Brown et al. 1996; Ataroff & Rada 2000; Le Tellier et al. 2009).

It will also be necessary to set a baseline for multiple benefits, which is likely to be even more challenging than for carbon. Firstly, for many benefits, current knowledge is limited, and any measurement of these may be a first. Second, appropriate baselines depend on the scale and focus of the benefit. For instance a crediting baseline may make no sense with regards to species richness indicators or population abundance indicators. For the former, what constitutes enough biodiversity is unknown and for the latter, populations fluctuate naturally and following long-term trends therefore makes more sense. Finally, with regards to BAU, trends in some of the benefits, for example biodiversity, are not linear and depend on the indicator and type of indicator chosen. If enough is known about the form of the relationship between the indicator and the REDD+ activity, then a BAU prediction may be made. However, for many ecosystem services change depends on multiple factors, which make BAU predictions more difficult. For instance, protecting forest habitat may not retain amphibian diversity if disease is also a driver of change. Furthermore, for some services it is very difficult to measure avoided changes that arise by protecting a service (Layke 2009) if the extent of the service is unknown.

3 Relationship and synergies between monitoring systems for carbon and multiple benefits

Monitoring relevant to some ecosystem services, indicators thereof or aspects from the abiotic environment is currently being done by a number of institutions at international, regional and national level, though not necessarily in the most useful forms for the REDD+ context. Section 3.1 explores some of these initiatives and considers the relationships and especially the synergies between these and monitoring carbon stock changes. Monitoring gaps and challenges with regards to multiple benefits are also outlined. Then in section 3.2, the links between monitoring systems for carbon and multiple benefits are explored. Indeed, some of the methods used to collect activity data and emission factors and the data collected itself may be of use for monitoring multiple benefits.

3.1 Using existing monitoring schemes

3.1.1 Environmental & ecosystem monitoring

Environmental data, such as water quality, are likely to be collected on a regular basis by appropriate government agencies in many countries because this information is pertinent to human health. Some of the data collected could also be used to monitor multiple benefits from REDD+. For example, enhanced water quality from protection of a forest in a watershed area could be demonstrated by such data. However, the necessary linkages between departments (forestry department and water department for example) are not always very effective. Creating linkages or ensuring better communication and data access between government departments could therefore be a way of making use of existing monitoring schemes for REDD+ and vice-versa.

Meteorological data, which are usually gathered on a regular basis in most countries, are also useful for formulating indicators relating to water regulation services (e.g. high rainfall events in relation to flooding) and soil stabilisation (run-off and erosion). Moreover, because carbon sequestration and storage are affected by climate such monitoring would contribute to assessing the permanence of carbon stocks secured by REDD+ efforts.

National forest inventories (NFIs) are also undertaken in many countries and play a key role in informing international agencies interested in monitoring the state of forests worldwide and fulfill international agreements (e.g. FAO's Global Forest Resource Assessment)[7]. Information originally gained through forest inventories, such as the standing crop or the economic value of the forest, is often complemented by other ecological information within the NFI, which makes possible a more comprehensive view of the forest ecosystems. NFIs were originally intended to provide stock assessment of marketable timber and thus not designed to provide parameters necessary for carbon stock and carbon stock changes over time in a carbon-accounting scheme. However, NFIs may be adapted to better fulfill requirements of reporting sources and sinks of carbon and multiple benefits in the context of REDD+ (IPCC 2010). Current practice is often inadequate to estimate forest biodiversity (Kapos & Jenkins 2002), but NFI's modified to include a few key parameters could provide information on biodiversity (Newton & Kapos 2002).

The FAO's Global Forest Resource Assessment (FRA) has been collecting information on forest related indicators since 1946. The FRA is based on data that countries provide to FAO at 5 to 10 year

[7] http://www.fao.org/forestry/fra/fra2010/en/

intervals using a common questionnaire. Data are compiled and analyzed by FAO to inform different stakeholders (e.g. policy-makers in individual countries, the scientific communities, etc.) about the current status of the world's forest resources and their changes over time. Biodiversity indicators have been included in the FRA since 2000. The 2010 assessment includes indicators covering seven broad topics representing the thematic elements of sustainable forest management: 1) extent of forest resources and their contribution to the global carbon cycle; 2) forest health and vitality; 3) forest biological diversity; 4) productive functions of forests; 5) protective functions of forests; 6) socio-economic functions of forests; 7) legal, policy and institutional framework related to forests (FAO 2010). As part of the FRA 2010, FAO and its member countries and partners are also undertaking a global remote sensing survey of forests aimed at substantially improving the knowledge on land use change dynamics over time, including deforestation, afforestation and natural expansion of forests (FAO 2010).

There are a number of issues concerning the FRA country reporting process, which need to be considered in relation to its potential usefulness for tracking both carbon and other benefits from REDD+. The FRA 2010 consists of 17 national reporting tables covering forest characteristics, such as extent, management, carbon, impacts, such as fires and other disturbances, and socio-economic aspects, such as forest products and value, employment, and education (FAO 2008). The guidelines make it clear that lack of data is likely to be a problem. Some of the ways suggested to overcome lack of data (instead of filling in "not available") are to base results on forecasts from previous data, use expert estimates and default values (FAO 2008). This indicates that putting in place an appropriate monitoring scheme in REDD+ countries could provide benefits both for reporting to the FRA and for REDD+ implementation. The main biodiversity indicator used in the FRA is proportion of forest in protected areas, which may not be useful for REDD+ as the sole biodiversity indicator since it ignores many of the aspects of biodiversity and is a "response indicator" according to the CBD indicator framework. However, many of the reporting tables such as those on disturbances or timber and non-timber products, and more specifically the information collected for them, could be very useful in helping to track multiple benefits from REDD+.

In some developing countries, forest resources are monitored not only by national agencies but also through Independent Forest Monitoring, which is a system implemented mainly by non-governmental organizations to monitor logging, legal compliance and forest law enforcement (Ottke et al. 2000; Global Witness 2009). This could provide information pertinent to some of the harm indicators or socio-economic indicators such as governance.

3.1.2 Biodiversity monitoring

Global level commitments have created the need to monitor changes in biodiversity. In 2002, the 6th Conference of the Parties to the Convention on Biological Diversity (CBD) adopted in its strategic plan a target "to achieve by 2010 a significant reduction of the current rate of biodiversity loss at the global, regional, and national level" (Decision VI/26). The CBD also proposed a framework of indicators for measuring progress towards this goal; these have been used at global scale (Butchart et al 2010; GBO) and some have also been adapted for use at national scale. Further at a national scale, under the CBD most countries have established National Biodiversity Strategy and Action Plans (NBSAPs), and may have associated ongoing biodiversity monitoring. In some cases, the monitoring schemes established to generate these indicators may provide data relevant to monitoring biodiversity benefits from REDD+. Similarly, the data gathered in national forest inventories to address criteria and indicators of sustainable forest management (set up in response to the "Forest Principles" of Agenda 21; FAO 2001a) also have great relevance to biodiversity (Newton & Kapos 2002) and other benefits. Despite this diverse range of monitoring mandates, existing monitoring may not be of precisely the right type and scale to meet the needs for monitoring multiple benefits from REDD+ or may fail to fulfil their mandate.

At the national level, the 4th National Reports to the CBD reveal that countries are at different stages in terms of national biodiversity indicator development, with 21% not (yet) in the process of developing national biodiversity indicators. The main challenges faced especially by developing countries were lack of capacity, lack of institutional responsibility and accountability for biodiversity monitoring, data management and ownership issues, lack of consistent trend data, absence of ecological baselines and insufficient knowledge of ecosystem processes (UNEP-WCMC 2009).

Other relevant biodiversity data may be generated by regional or national scale monitoring programmes, organised by non-governmental conservation organisations or academic/research institutions that measure a broad range of components of biodiversity. For instance some Birdlife International Partners regularly monitor important bird areas or key biodiversity areas (e.g. Nature Kenya and Nature Iraq). Information gathered by forest certification schemes may also provide useful data, though usually at very local scales. These sources vary in the extent and scale of their coverage and, especially in the case of research organisations, ease of access to the information. For some regions or topics, networks exist to bring together monitoring information such as the ILTER network[8], GBIF[9] and IABIN[10].

Making use of current monitoring systems and refining them could provide information pertinent to both REDD+ and other initiatives. Much biodiversity information or monitoring of biodiversity exists in a fragmented fashion, which would benefit from better co-ordination and common standards (Green et al. 2005). Duplication of efforts may also be a problem, which a more coordinated approach could solve. Monitoring multiple benefits for REDD+, if joined to such other initiatives, could therefore result in a clear synergy by provide a better and more coordinated approach to biodiversity monitoring as well as providing better information on carbon stocks. Indeed, gathering data on tree species would provide an indication of species richness in countries relevant and could provide better carbon density information by providing country specific tree parameters for the allometric equations used to calculate biomass (Brown 2002; GOFC-GOLD 2009). Similarly, gathering information on dead wood would provide information on an extra carbon pool (GOFC-GOLD 2009) and give an indication of ecosystem maturity and diversity (Humprey et al. 2004).

Depending on the objectives, existing information or monitoring schemes may not be sufficient. Indeed, synergies between the needs from current biodiversity priorities, for example, and multiple benefits from REDD+ may be limited if the objectives are not similar. Moreover, combining data from different monitoring schemes could be difficult if data are not collected in the same way, if the distribution of the data does not match, or resolutions are different. This may be most problematic in exploring relationships between indicators, such as links between drivers or pressures and the state or condition of the ecosystem. Moreover, there are gaps in the current monitoring schemes

[8] http://ilternet.edu/
[9] http://www.gbif.org/
[10] http://www.iabin.net/

and it may be necessary to collect extra information so as to get an adequate picture for the multiple benefits and harms from REDD+.

3.2 Using carbon monitoring systems to monitor multiple benefits

Implementing REDD+ will require a monitoring scheme set up to provide information on change in carbon stock (see section 2.1). Monitoring carbon stock change requires information on forest area and change within the forest area, which can be obtained through Remote Sensing (RS) and on the ground measurements to calibrate the RS and obtain tree-specific information (Table 2). Information collected via these methods could also provide information on multiple benefits.

Table 2: Examples of how methods used to gather information for carbon stock monitoring can be used to monitor multiple benefits

Methodology			Carbon stock information	Multiple benefits information
REMOTE SENSING	**PASSIVE SENSORS**	**Coarse to medium resolution**	Land use categories, forest cover, deforestation, etc.	Topography, forest cover and location and boundaries of different forest or ecosystem types, etc.
		High resolution	Forest degradation, conservation and enhancement of forest carbon stock, etc.	Forest fragmentation, continuity of streams, etc.
		Multispectral Imagery	Forest type or species differentiation, Indicator of growth rate, vegetation cover and density, NDVI, soil types, etc.	Composition and thermal properties of ground, turbidity, temperature or pollution of lake and/or river, etc.
	ACTIVE SENSORS	**RADAR/ LiDAR**	Biomass; tree height	Degree of vulnerability of land to floods, landslide, erosion or subsidence, etc.
GROUND-BASED MEASUREMENTS			Calibration of RS, additional information (DBH, carbon pools, allometric equations, BECF), etc.	Timber, non-timber forest products; biodiversity, soil, water and air quality, etc.

Remotely sensed data can also provide very useful information for multiple benefit indicators. The CBD Secretariat released a sourcebook on remote sensing and biodiversity indicators (Strand et al. 2007) that helped to demonstrate the potential role of RS in biodiversity monitoring. In the context of REDD+, RS can provide useful information for the following indicators: extent of ecosystems, forest change, rate of deforestation/reforestation, forest intactness, area and number of large forest blocks, forest fragmentation, carbon storage, area and location of old growth forests/plantations, forest degradation, alien species, fire occurrence, productivity and extent to watersheds (see Strand et al. 2007). RS can also provide indirect data for indicators, for instance an estimate of change in forest area provided by RS, especially if the type of forest is known, will give an indication of change in biodiversity, even though the relationship between area and biodiversity is not linear. Data on land use change can also be used in conjunction with modelling to provide estimates of change in the hydrological regime (Strand et al. 2007).

The information collected by RS will depend upon its resolution and type of sensor (Table 2). Optical mid-resolution (10-60 m) data (panchromatic or multispectral) are considered as the primary tool for monitoring deforestation. These data can also be used to estimate many of the indicators mentioned above, such as extent of ecosystem data or forest fragmentation. High resolution RS offers finer scale information pertinent to pressure indices such as degree of fragmentation, or area cleared for plantations (Figures 3 & 4), or to forest characteristics, such as area of old-growth forest. By making use of the different spectral bands in multispectral imagery, information on a wide range of indicators can be collected, such as human-induced physiological stress in ecosystems, air pollution (e.g. smoke due to fires), composition and thermal properties of ground, turbidity of water, groundwater availability, temperature or pollution of lake and/or river (Table 3).

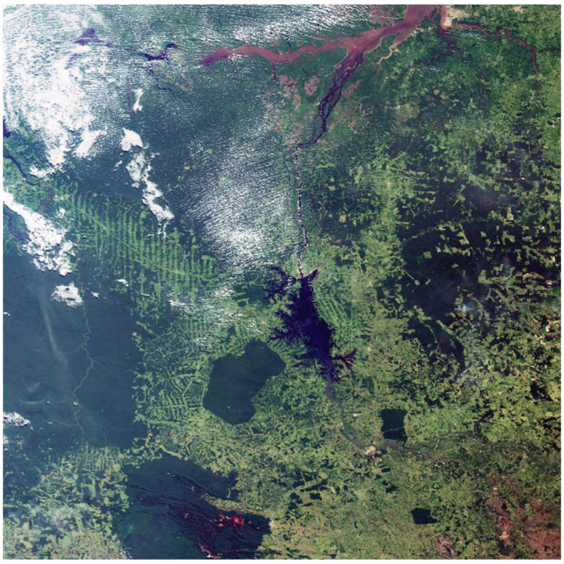


Figure 3: The image shows the eastern part of Brazil's Amazon Basin and rainforests, located in the state of Pará. Rainforest (dark green areas), sprawling land cultivation (the fishbone-like patterns) and agricultural areas (light green colours).The large dark area visible in the image centre is the reservoir that was formed by the Tucurui dam on the Tocantins River. The image was acquired by Envisat's Medium Resolution Imaging Spectrometer (MERIS) on 23 June 2008.

Credits ESA http://www.esa.int/esaEO/SEMWY3SHKHF_index_0.html

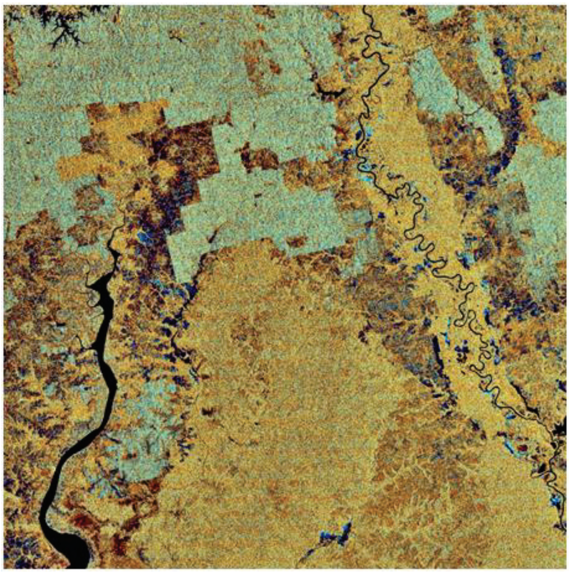


Figure 4: The northern part of the Tanjung Puting Biosphere Reserve is visible in the lower centre half of the image between Kumai Bay (left) and the Seruyan River (right). The reserve boasts a large diversity of forest ecosystems and a wealth of biodiversity, including the world's most endangered species of orangutans. Areas cleared for palm plantations are visible in the image as square green patches. The image was acquired on 23 April 2009 by Envisat's Advanced Synthetic Aperture Radar (ASAR) instrument.

Credit ESA **http://www.esa.int/esaEO/SEM0461P0WF_index_0.html**

Table 3: Bands and Applications of the Landsat Thematic Mapper (Meaden & Kapetsky 1991)

Band	Spectral Range (micrometers)	Resolution	Features/Applications
TM 1	0.45–0.52 visible blue- green	30 m	Bathymetry in less turbid waters, soil/vegetation differences, deciduous/coniferous differentiation, soil types.
TM 2	0.52–0.60 visible green	30 m	Indicator of growth rate/vegetation vigor, sedimentation concentration estimates, turbid water bathymetry.
TM3	0.63–0.69 visible red	30 m	Chlorophyll absorption/species differentiation, crop classification, vegetation cover and density, geological applications.
TM 4	0.76–0.90 solar near infrared	30 m	Water body delineation, biomass and stress variations.
TM 5	1.55–1.75 solar mid infrared	30 m	Vegetation moisture/stress, minerals.
TM 6	10.4–12.5 emitted thermal	120 m	Surface apparent temperatures, urban versus land use separation, distinguishing burned areas from water bodies.
TM 7	2.08–2.35 solar mid infrared	30 m	Hydrothermally altered zones, mineral exploration, soil type discrimination.

Optical satellite data is the most easily and cost effective RS data that can be acquired for monitoring purposes. However, the integration of optical satellite imagery, especially in multi-temporal analyses, acquired by different satellite platforms can be challenging and not always accurate. For instance, the utilization of optical data in tropical areas could be limited by the presence of clouds.

Another form of RS comes from "active" sensors (the satellite sensors discussed above are called "passive" as they work by capturing reflected light), sensors that emit energy pulses in order to capture data, the most common of which are radar and LiDAR (Strand et al. 2007). These sensors are most useful in terms of providing more detailed data on forest characteristics to be used for more accurate carbon stock estimations or forest related indicators and could also be used to construct digital vegetation and elevation models to assess vulnerability to floods, landslide, erosion or subsidence. However, the cost of generating and analyzing data from these sources is relatively large, making it unlikely to be of widespread use for monitoring.

For some ecosystem service indicators, it may be necessary to have RS data from a number of years prior to implementing REDD+ so as to discriminate between natural variation and real change. This is in contrast to carbon stock changes, for which annual measurements are unnecessary, although yearly fluctuations in carbon sequestration occur depending on climate, disturbance and succession (Gough et al. 2008).

Ground-based measurements for monitoring carbon stock change for REDD+, could potentially be useful in the context of monitoring multiple benefits. These are needed to calibrate remote sensing estimates, which are also directly relevant for calibrating RS for benefits, although aerial surveys with digital photography can also be made (Stand et al. 2007). However, locations of these measurements/surveys may not necessarily match those required for calibrating RS imagery for the other benefits. Indeed, the selection of ground truthing sites is usually made so that features of interest can be correctly interpreted during RS data processing. It may be useful therefore when selecting sampling points to consider locations pertinent for both.

Ground-based measurements are also sometimes required to collect extra information for REDD+, such as extra carbon pools, measurements for allometric equations, or to discriminate between direct drivers of change in REDD+, such as forest degradation. Some of this extra information may be used to construct relevant environmental (e.g. amount deadwood or tree species) and socio-economic (e.g. timber and non-timber products) indicators, such as those used in FRA (FAO 2010). The scope of carbon monitoring will therefore have implications for multiple benefits monitoring as well as implications for the valuation and management of different ecosystems (Miles et al. 2010). For instance, if soil carbon is included within the carbon stock monitoring, it could provide information for multiple benefits, such as erosion or nutrient cycling.

In many cases, extra information would need to be collected purposefully for multiple benefits (e.g. many of the biodiversity indicators) during the field visits, as information required for carbon estimation is limited. Further, whilst some ecosystem services, including some aspects of biodiversity, can be monitored as a by-product of carbon monitoring, others require extra information to be collected that is not compatible to carbon-relevant data collection requiring very different field techniques such as transects for bird surveys or undertaking community consultations for the development of socio-economic indicators.

4 Conclusion

In order to get an idea as to the state of multiple benefits that arise from REDD+ or as to any harms that may ensue from REDD+ implementation and potentially ensure that these "safeguards" are "promoted and supported" (FCCC/AWGLCA/2010/6), it will be necessary to monitor their application as it is not possible to manage something effectively without measuring it (EC 2008). The logistics and the limited requirement for stringent multiple benefit monitoring under the UNFCCC make it unlikely that a system comparable to MRV for carbon will be constructed for multiple benefits. Nonetheless, monitoring multiple benefits from REDD+ is of interest for multiple stakeholders and some UN REDD pilot countries are making provision to monitor some of these.

The forest carbon partnership facility (FCPF)[11] currently assists developing countries in their efforts to implement REDD+ by building capacity (readiness mechanism) and by testing a program of performance-based incentive payments in some pilot countries (carbon fund mechanism). The readiness preparation proposal (R-PP) template includes a section requiring countries to propose a monitoring system for a) carbon and b) other benefits and impacts and suggests that these systems can be either integrated or separate. Further it asks countries to consider synergies and conflicts between REDD+ strategy options and other national development priorities.

The readiness plan idea note (R-PIN) from Vietnam reveals that the country considers that "REDD will directly contribute to Vietnam's obligations under the UNFCCC, CBD, UNCCD and to the economic development of remote, upland and ethnic minority areas prioritised in national and provincial SEDPs (Socio-economic development plans)" (Manh Cuong et al. 2008). Forest cover and land use change is currently monitored in Vietnam through remote sensing and through detailed forest inventories carried out in 4200 permanent sample plots where a large number of indicators are collected. However, there are major operational problems such as "poor integration and coordination between different sectors and mapping institutions, lack of systematic approach to update the information within Forest Inventory and Planning Institute, poor harmonisation with ongoing regional and international processes, inadequate staff capacity for mapping programme and no clear data management and data sharing policy among information providers and users". Further biodiversity monitoring is not undertaken at a national level (Manh Cuong et al. 2008).

This example shows that although some countries want to include multiple benefits monitoring in a REDD+ strategy and recognise that synergies between REDD+ and other commitments potentially exist, there is a need to formulate how such monitoring can be undertaken to create these synergies.

Monitoring multiple benefits from REDD+ requires a different approach and data than that needed for carbon monitoring. Indeed, clear objectives, key questions and multiple indicators need to be identified before a monitoring (and reporting) system is put in place. Nevertheless, this paper demonstrated that many of the necessary data can be generated or synthesised from existing initiatives or by minor adjustments to the design of carbon MRV. Moreover, multiple benefits monitoring for REDD+ could result in clear synergies between carbon monitoring and efforts currently underway to monitor biodiversity and ecosystems (section 3.1). This indicates that it is worth coordinating efforts from the different monitoring schemes. The potential relationships

[11] http://www.forestcarbonpartnership.org/fcp/node/12

between monitoring systems (section 3.2) further indicate that it is worth exploring the potential for monitoring both in an integrated way at the national level.

However, differences between carbon and ecosystem service monitoring amplify the challenges in monitoring multiple benefits from REDD+ that stem from the different types of safeguards (benefits and harms) of interest and the diversity of monitoring needs from different stakeholders. Monitoring for biodiversity conservation has slightly different requirements than monitoring for PES or for ensuring equity; compromises may need to be made to allow a workable and cost-effective national scheme. Under the compliance and voluntary carbon markets, numerous small or large-scale projects already include mandatory monitoring, reporting and verification of ecosystem-derived benefits (Kolmuss *et al*. 2008). This suggests that on a small scale at least, integrating multiple benefits within a carbon monitoring system can be feasible.

Developing a clear set of indicators following the DPSIR framework would enable targeted monitoring of harms, state and response. However, experience (e.g. from CBD, ITTO) suggests that indicators are often chosen for ease and feasibility rather than need and that much effort goes into designing (and classifying) indicators in comparison to that expended on field monitoring. Nevertheless, the use of indicators may help harmonise and standardise monitoring schemes.

Lack of knowledge around many of the processes, function and relationships in and between ecosystem services, including effects on carbon sequestration, is limited (Kremen & Ostfeld 2005; Lakye 2009). Moreover, ecosystem services cover a range of processes (Fisher et al. 2009) making their assessment complex if many different aspects are to be taken into account. This is likely to be one of the major challenges facing countries wishing to monitor multiple benefits.

Cost and sustainability of monitoring of multiple benefits within REDD+ are another consideration. It is likely that the extent to which monitoring multiple benefits adds extra costs to the process will depend on the choice of indicators, data needs and capacity to analyze them. The most cost-effective (and therefore more sustainable in the long term) solution would be to incorporate monitoring that is compatible with carbon stock monitoring, including those that can be monitored at little extra cost (e.g. adding one to a number of existing ground-based measurements). However, this may not necessarily result in the most important attributes being monitored (Miles et al. 2010). Another possibility, which could also help ensure the sustainability of monitoring, is to consider the use of locally-based or community monitoring (Sheil et al. 2003; Le Tellier et al. 2009). Community-based monitoring can also be useful for carbon monitoring (Skutsh et al. 2009), and may be more cost-effective than a process involving agency staff.

In conclusion, with sufficient planning, integration of some aspects of multiple benefits within a carbon monitoring system, i.e. making use of monitoring data and opportunities, along with utilisation of existing resources will result in cost effective information that could enhance other monitoring schemes and contribute to national/international commitments.

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