

Methods for assessing and monitoring change in the ecosystem- derived benefits of afforestation, reforestation and forest restoration

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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

Nathalie Doswald, Matea Osti, Lera Miles

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Summary

Forests provide a number of ecosystem services, which REDD+ activities including afforestation, reforestation and forest restoration have the potential to promote. On the other hand, REDD+ could be detrimental to biodiversity and ecosystem services if locations are poorly chosen or management poorly planned. Whilst some responses to management can be estimated based on ecological principles, to assess actual changes in the delivery of ecosystem services, monitoring is essential.

This report summarises the steps needed to design a system to assess and monitor change in ecosystem services resulting from afforestation, reforestation and forest restoration projects or programmes. Design of a monitoring scheme involves identifying how the results will be used, selecting appropriate indicators, defining a methodology for obtaining data and calculating indicators, and deciding how frequently monitoring will be undertaken.

This report also refers to useful existing guidance on monitoring and indicators that will be of help in deciding what sort of monitoring to undertake and how to do so.

Méthodes d'évaluation et de suivi des changements dans les bénéfices écosystémiques provenant du boisement, reboisement et la restauration des forêts : Résumé

Les forêts fournissent un nombre de services écosystémiques que les activités de REDD+, comme le boisement, le reboisement et la restauration des forêts, pourraient promouvoir. D'un autre côté, REDD+ pourrait être nuisible à la biodiversité et aux services écosystémiques si l'emplacement est mal choisi ou la gestion mal planifiée. Tandis que certaines réactions à la gestion peuvent être estimées en se basant sur les principes écologiques, le monitoring est essentiel pour évaluer les changements réels dans la provision des services écosystémiques.

Ce rapport résume les étapes nécessaires pour la conception d'un système pour évaluer et suivre les changements dans la provision des services écosystémiques provenant des projets ou programmes de boisement, reboisement et de restauration des forêts. La conception d'un système de monitoring consiste à identifier comment les résultats seront utilisés, à sélectionner des indicateurs appropriés, à définir une méthodologie pour recueillir des données et calculer les indicateurs et à décider la fréquence du suivi.

Ce rapport fait aussi référence aux directives existantes sur le monitoring et les indicateurs qui seront utiles pour décider quelle sorte de monitoring à entreprendre et comment.

Métodos de evaluación y seguimiento de los cambios en los beneficios ecosistémicos derivados de la aforestación, reforestación y restauración forestal : Resumen

Los bosques proporcionan varios servicios ecosistémicos que las actividades REDD+, incluyendo la aforestación, reforestación y restauración forestal, tienen el potencial de promover. Por otro lado, REDD+ podría resultar perjudicial para la biodiversidad y para los servicios ecosistémicos si los lugares se elijen mal o si la gestión se planifica mal. Aunque ciertas respuestas a la gestión se pueden estimar basándose en principios ecológicos, el monitoreo es esencial para evaluar cambios reales en la provisión de servicios ecosistémicos.

Este informe resume los pasos necesarios para diseñar un sistema para evaluar y seguir cambios en los servicios ecosistémicos resultantes de proyectos o programas de aforestación, reforestación y restauración forestal. El diseño de un esquema de monitoreo consiste en identificar cómo se usarán los resultados, seleccionar indicadores apropiados, definir una metodología para obtener los datos y para calcular indicadores, y decidir la frecuencia de seguimiento.

Este informe también hace referencia a directrices existentes sobre el monitoreo y los indicadores que serán útiles para decidir qué tipo de monitoreo llevar a cabo y cómo hacerlo.

Metode-metode untuk menilai dan mengawasi perubahan pada manfaat-manfaat yang diperoleh dari ekosistem yang disebabkan oleh aforestasi, reforestasi dan restorasi hutan : Ringkasan

Hutan menyediakan banyak sekali jasa-jasa ekosistem, dimana aktifitas-aktifitas REDD+ yang mencakup aforestasi, reforestasi dan restorasi hutan berpotensi untuk meningkatkannya. Namun di sisi yang lain, REDD+ juga dapat merugikan keanekaragaman hayati dan jasa-jasa ekosistem jika pemilihan lokasi-lokasi nya tidak dilakukan dengan baik dan pengelolaannya tidak direncanakan dengan seksama. Meskipun sejumlah respon terhadap aspek pengelolaan dapat diperkirakan dengan menggunakan prinsip-prinsip ekologi, tetapi monitoring masih merupakan hal yang sangat penting untuk menilai perubahan aktual pada perolehan jasa-jasa ekosistem.

Laporan ini menyimpulkan tahapan-tahapan yang diperlukan di dalam mendesain sebuah sistem untuk menilai dan mengawasi perubahan pada jasa-jasa ekosistem yang disebabkan oleh proyek atau program aforestasi, reforestasi dan restorasi hutan. Desain dari suatu skema monitoring mencakup: identifikasi tentang bagaimana hasil-hasilnya nanti akan digunakan, menyeleksi indikator-indikator yang tepat, mendefinisikan metodologi untuk pengumpulan data dan perhitungan indikator, serta memutuskan seberapa sering monitoring tersebut akan dilakukan.

Laporan ini juga merujuk pada pedoman tentang monitoring dan indikator-indikator yang ada saat ini, yang mana dapat membantu untuk memutuskan jenis monitoring seperti apa yang akan dilakukan dan bagaimana akan melakukannya.

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1 Introduction

Forests provide a number of ecosystem services including biodiversity, water regulation and carbon sequestration and storage. Forest management practices can impact on these services in either a positive or negative manner. In general, deforestation and forest degradation diminish these services, whilst practices such as afforestation, reforestation or forest restoration are likely to have a positive influence on ecosystem services. This influence is more mixed if monoculture plantations and non-native species are used (Sajwaj *et al.*, 2008, Miles *et al.*, 2010b).

Afforestation, reforestation and forest restoration are activities that could be undertaken as part of a REDD+ strategy to enhance forest carbon stocks. Whilst carbon is the primary concern for REDD+, the protection and enhancement of other ecosystem-derived benefits is of interest to many stakeholders, including the UN-REDD Programme.

It has been argued that if these multiple benefits are not measured, there is no way to ensure that REDD+ activities, such as forest restoration, are leading to their delivery (Palmer & Filoso, 2009). Monitoring is therefore essential to assess the changes in the delivery of ecosystem services. Monitoring also can contribute to adaptive management strategies to ensure that the ecosystem services valued most are maintained or enhanced.

A monitoring system for ecosystem services would thus be most useful where its results are assessed against clear goals for the delivery of ecosystem services, and REDD+ activities adapted if these goals are not being met. Ideally, there would be a continuous interaction between project design, monitoring and management, ensuring that ecosystem services are maintained and enhanced, and changing the REDD+ approach if not (Miles *et al.*, 2010a).

Appropriate indicators need to be identified before a monitoring (and reporting) system is put in place (Teobaldelli *et al.*, 2010). In a REDD+ context, carbon monitoring can sometimes provide data useful for other ecosystem services monitoring. Indeed the monitoring methods required for carbon monitoring (remote sensing and forest inventories) are also useful for monitoring additional ecosystem services. Additional fieldwork or analysis during carbon monitoring can yield some information relevant for other ecosystem services with a relatively small additional effort. However, monitoring some ecosystem services requires a different approach and data.

This report details the steps needed to design a system to assess and monitor change in ecosystem services resulting from afforestation, reforestation and forest restoration projects or programmes. It discusses the methods required and refers to useful existing guidance on monitoring and indicators that will be of help in deciding what sort of monitoring to undertake and how to do so.

2 What are monitoring systems?

A monitoring system measures change in or the condition of the resource of interest and is driven by objectives. The objectives of monitoring can be (1) to support effective management, (2) to report change in the status of the resource, for example to the Convention on Biological Diversity (CBD), (3) to demonstrate compliance with environmental standards and/or (4) to provide an early warning system for new or emerging threats. In this paper we focus on (1), and specifically the objective of ensuring that benefit or no harm results to the ecosystem service of interest following afforestation/reforestation.

A monitoring system can be part of an adaptive management cycle (Fig.1; Elzinga *et al.*, 2001) in which objectives are developed to describe the desired condition of resources (e.g. maintains or increases numbers of a threatened species). Management is designed to meet these objectives. The response of the resource is monitored to determine if the objective has been met; if objectives are not reached an alternative management practice could be implemented. If monitoring produces inconclusive data then a rethink of the monitoring system design may be needed (Elzinga *et al.*, 2001). Monitoring efforts should be directed toward objectives for which management solutions are available. Implementation of this type of monitoring system is justified only if opportunities for management change exist (Sheil, 2002).

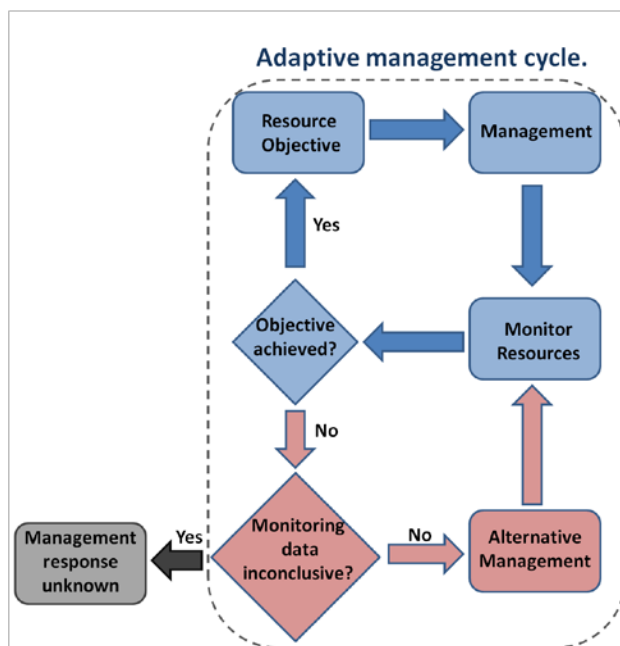


Figure 1: Adaptive management cycle where a monitoring system provides the critical link between objectives and adaptive (alternative) management. If the monitoring system is inconclusive, the appropriate management response is unknown and the cycle is unsuccessful (Elzinga et al. 2001).

There are three main phases involved in building a monitoring system: 1) scoping, 2) design and 3) implementation and reporting (Green *et al.*, 2005). During the first phase it is useful to identify interested stakeholders (because they might have particular interest in the conservation of the ecosystem services, or be able to offer relevant data), identify valued attributes and objectives (including through stakeholder consultation) and assess existing information. These objectives and the resources available will underpin the monitoring plan, determining the appropriate indicators, scale (e.g. national or site), sampling effort and frequency.

3 Selecting indicators: conceptual frameworks for monitoring ecosystem-derived benefits

There is a wide choice of potential indicators, and selection should take account of what aspects of the ecosystem-derived benefits of REDD+ are most valued. Ecosystem services and biodiversity are multi-dimensional concepts and hence have no single measure. Their value may vary with context (Fischer *et al.*, 2009) and scale. For instance, water regulation is a service rendered over a large scale, whereas provisioning services are more localized. It may be helpful to consider the value and attributes of different services in respect to the distinct groups of people that they benefit.

Identification of services to different people could be achieved through stakeholder consultations, questionnaires, as well as from the scientific literature (e.g. on valuation or ecosystem functioning). Multi-criteria decision tables may be useful for rating services important to different stakeholders.

Measuring and monitoring ecosystem-derived benefits requires the use of indicators. Indicators summarise information into standardised numbers, graphs or even maps and can be used to infer change in a complex system where there is no single 'best' measurable parameter. Indicators are purpose-dependent. For example, data on net change in forest area could contribute to an indicator of change in timber availability, in forest carbon sequestration, or in soil cover and erosion.

Box 1: DPSIR framework for multiple benefits in REDD+

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, deforestation and forest degradation indicators such as population density, household income inequality, and infrastructure could be used.
- 2) **Pressures:** these indicate 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.
- 4) **Impacts:** these indicators track the negative effects of REDD+ such as change in invasive species typical of plantation forest.
- 5) **Response:** these indicators track the efforts made with regards to the desired objective, such as conserving biodiversity

The Driving force-Pressure-State-Impact-Response (DPSIR) framework is useful for constructing a set of indicators for assessing and monitoring ecosystem services (Box 1; EEA, 2007). This framework differentiates between monitoring the condition of the ecosystem (state indicators), the harms faced by ecosystems (driving force, pressure and impact indicators) and the measures put in place to achieve the objective of the monitoring (response indicators). Monitoring state indicators will give an indication of the condition of the benefit (e.g. increase or decrease in species numbers), whilst monitoring pressures such as the fragmentation of forest will warn of future likely declines in species numbers. The most effective set of indicators would cover states, pressures and responses. However, if resources are limited, state indicators are the bare minimum.

More attention has been given to devising appropriate indicators for biodiversity than for many other ecosystem services, partly as a result of the Convention on Biological Diversity (CBD)'s 2010 biodiversity target. The *Guidance for National Biodiversity Indicator Development and Use*, developed for Parties to the CBD, enumerates the steps required and useful questions to consider. It can be found at <http://nbip.notlong.com/>.

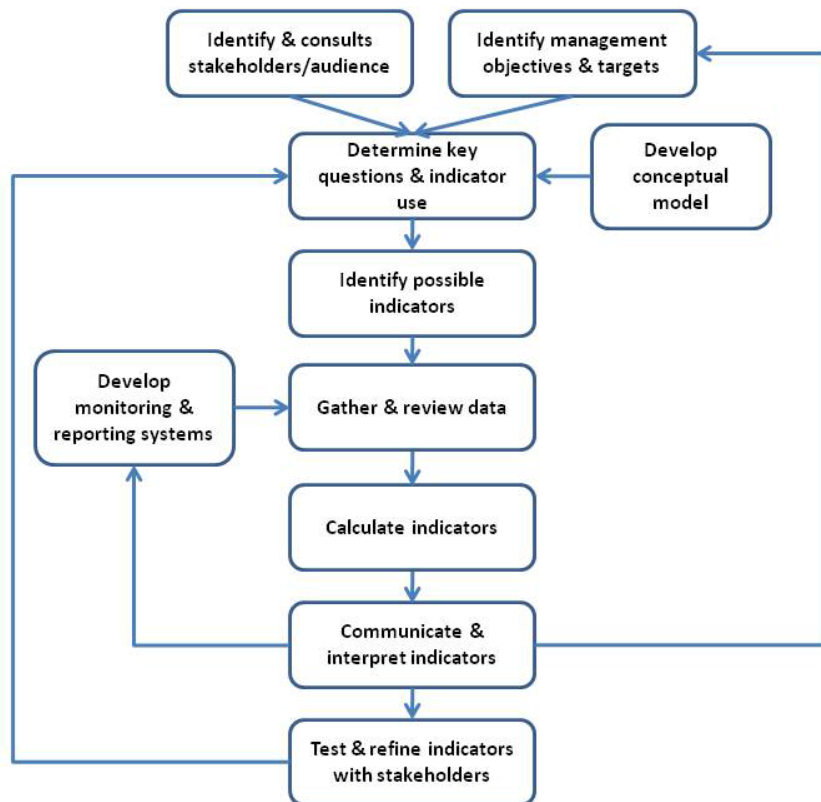


Figure 2: Indicator development framework (from Bubb *et al.*, 2010)

This guidance shows that developing a framework for assessing and monitoring change in ecosystem services is a step process, in which indicators are central (Figure 2):

- 1) Consultation with stakeholders along with the development of objectives and targets.
- 2) Determine a set of key questions: e.g. Does the REDD+ activity protect or enhance biodiversity? Does the REDD activity improve water quality?
- 3) Identify indicators. Example indicators for the above questions could be number of species of conservation concern, or sediment load in downstream water. Consider using a framework for analyzing indicators (e.g. DPSIR) and/or building a conceptual model to identify the relationship between the indicators and objectives. Table 1 provides some examples of indicators that could be used in assessing and monitoring change in ecosystem services.
- 4) Develop and/or make use of a monitoring and reporting scheme.
- 5) Calculate and analyze indicators.
- 6) Interpretation and communication.
- 7) Test and refine indicators with stakeholders to ensure that they are fit for purpose.

Indicator selection will depend on the objectives, the ecosystem service of interest and is dependent on scale of the project (e.g. site or national programme) and of the delivery of the service (e.g. water regulation is delivered at a large scale, non-timber forest product provision at a smaller scale). State indicators for water regulation could include forest extent or pH downstream of the watershed whilst a pressure indicator could be the number of flooding events (Table 1). These would have to be assessed over scales broader than a forest site. In contrast, non-timber forest products are tied to the forest and most indicators thereof, such as quantity or quality (Table 1), would be assessed at the site scale.

Table 1: Example indicators for four ecosystem services associated with afforestation, reforestation and forest restoration

Benefits	State Indicators (e.g.)	Pressure Indicators (e.g.)	Response Indicators (e.g.)
Water regulation	-Sediment load -pH -Forest cover	-Overgrazing -Number of gullies -Flooding events	-Riparian revegetation
Non-timber products	-Quantity -Quality -Number of pollinators Availability of products at local market	-Extraction rate -Proportion of planted trees non-native -Pesticides	-Area of agroforestry -Sustainable management -Community involvement
Biodiversity	-Number of species -Abundance of species -Extent of ecosystem -Forest deadwood	-Invasive species -Nitrogen deposition -Fragmentation -Deforestation	-Conservation efforts -Awareness raising events
Soil conservation	-pH -Soil organic content -Depth top soil -Total nitrogen -Bulk density	-Fires -Logging -High rainfall events -Overgrazing	-Assisted natural regeneration -Grazing control -Management strategies

4 Designing a monitoring system

Choice of indicators is crucial to effective monitoring (Figure 3). Ecosystem services can be assessed through a range of indicators which in turn may sometimes be tailored for specific objectives. For example, for biodiversity, there could be a decision to monitor particular species.

In selecting indicators relevant for monitoring the ecosystem-derived benefits of REDD+, it is first useful to review existing national data and monitoring schemes. For example, environmental information collected by different governmental or non-governmental agencies can sometimes be used to assess multiple benefits, either directly (data is collected at a scale compatible with multiple benefit needs) or indirectly (information provides additional data for baselines, modeling, or context). Resources and cost will also determine which indicators can be monitored.

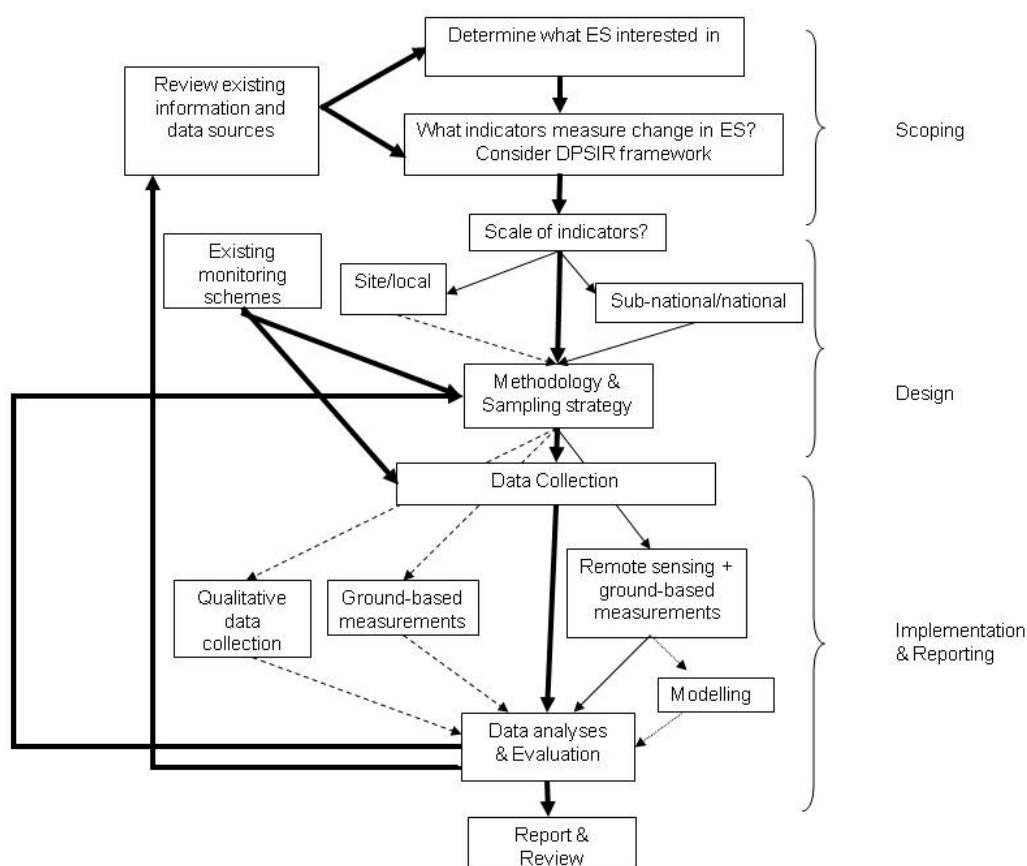


Figure 3: Steps to designing a monitoring system. There are three steps in such a system 1) scoping where the objectives and ecosystem services (ES) are determined and indicators are selected; 2) design where the scale, methodology and data collection methods are determined; 3) implementation and reporting. The collection of data is undertaken through a) remote sensing with ground truthing and optional modelling b) ground-based measurements and/or c) qualitative methods. The data are then analysed and evaluated. Finally data are reported and reviewed.

Bold arrows indicate essential steps. Data collection options are dependent on the scale of the indicators with dashed lines representing local scale and fine lines representing sub-national/national scale.

The existing resources that could contribute to the development of ecosystem benefit indicators include data gathered to assess national progress towards the goals of international conventions and agreements. Similarly, new data gathered for the purposes of monitoring ecosystem-derived benefits could feed into national reporting under UN Conventions and other forest-related international agreements. For example, as part of its commitments to the 2010 biodiversity targets under the CBD, Viet Nam is monitoring national progress towards the global goal of effective conservation of 10% of each of the world's ecological regions. The national extent of forest cover has been chosen as an indicator of forest conservation. The underlying data could contribute to indicators for ecosystem-derived benefits such as water regulation and biodiversity, which are affected by the presence and extent of forest cover, and improvements in the dataset resulting from REDD+ monitoring could be used to update the CBD indicator.

Figure 3 shows the steps required in designing and implementing a monitoring system. There are three steps in such a system: (1) scoping, where the objectives and ecosystem services are determined and indicators are selected; (2) design, where the scale, methodology and data collection methods are determined; (3) implementation, where the data are collected, analysed, evaluated and reported.

Approaches to monitoring include top-down methods (remote sensing) and bottom-up methods (ground-based) as well as a combination of the two. The precise methods selected to collect and analyze data are dependent on scale, the indicators chosen, and cost and resources. If the indicators pertain to local features then ground-based measurements may be necessary, or if they relate to socioeconomic matters then qualitative methods (e.g. consultation or questionnaires) are appropriate. If the indicators are national or subnational, such as forest extent, then remote sensing with ground-truthing and optional modeling may be the best approach.

4.1 Remote sensing

Any method that collects information about the Earth's surface from a distance is classed as remote sensing. Two broad sensor types are available:

a) passive sensors: these capture images from reflected light, from the vantage-point of a satellite or sometimes aircraft. Resolution varies as does spectral band, and these determine what kind of information can usefully be obtained. For example, the MODIS satellite views the entire surface of the Earth every one to two days, at three spatial resolutions: 250m, 500m, and 1000m, and its outputs can be interpreted to provide ecosystem and land cover data. In contrast, Landsat ETM+ image data have fewer spectral bands, but a spatial resolution of up to 30m. http://eros.usgs.gov/#/Find_Data/Products_and_Data_Available offers information on freely available data collated by the US Geological Survey. Data from other satellites are also readily available (though often not free).

b) active sensors: these sensors emit an energy pulse to capture images and include radar and lidar. These provide detailed information that can be very useful in mapping forest structural characteristics. However, such data is expensive to collect and do not have the breadth of cover (geographic and time-series) that passive sensors have. There are some commercial sensors which provide such information. Radarstat-2 and Envisat for example provide radar data.

Use of remote sensing provides greater scope at greater speed to assess and monitor the environment (Strand *et al.* 2007). Remote sensing information usually requires additional information to interpret the data, relating it to reality on the ground. Technical expertise is also required to process the data. Strand *et al.* (2007) give a good overview of the type of ecosystem and biodiversity information that can be acquired through interpreting remotely sensed imagery.

4.2 Ground-based measurements

Ground-based measurements are the most common forms of monitoring. The location and methodology as well as the technical expertise required for these vary depending on what is being measured. Field methodology options include surveys, transects, point sampling, quadrats, interviews, questionnaires and workshops. Examples of indicators and associated monitoring methodologies are provided in the annex of the *Guidelines for monitoring and evaluation for biodiversity projects* (World Bank, 1998). There exist also a number of publications on field techniques, such as the *Handbook for biodiversity methods: survey, evaluation and monitoring* (Hill *et al.*, 2005). Information and handbooks also exist for other environmental (e.g. Artiola *et al.*, 2004) and socio-economic survey techniques.

There are costs and trade-offs in using either top-down or bottom-up methods. To assess which method to use to collect data, two factors need to be evaluated. First is the fitness for the purpose, which is determined by the relevance of what is being measured and the precision & accuracy of the method. The second is the available resources, which is expertise, equipment and money. Although indicators chosen will to some extent determine the data collection, the reverse may also occur.

Using remote sensing is the fastest and easiest way to derive environmental data. However, technical capacity is required to interpret and derive the necessary data from the remote sensing to construct meaningful indicators. Furthermore, some ground truthing is required for analysis of remote sensing data.

Setting up and regularly implementing field surveys can be costly in terms of time and costs. These costs could be reduced first by making use ongoing monitoring schemes if possible and second by using community monitoring. Communities in forest areas can be trained to collect relevant data, which also has the benefit of involving communities in REDD+ and typically provides them with a direct financial incentive (Skutsch *et al.*, 2009).

To avoid duplication of effort, it is worth considering the relationships and synergies between monitoring for carbon stock change and monitoring for ecosystem services. Monitoring carbon stock change requires information on forest area and change within the forest area, which can be obtained through remote sensing and on the ground measurements to calibrate the remote sensing and obtain tree-specific information. Where these techniques can also provide information on ecosystem services, using the monitoring scheme for carbon to at the same time monitor ecosystem services may prove cost-effective (Teobaldelli *et al.*, 2010).

5 Implementation and reporting

Before full implementation of the monitoring system, the indicators chosen and the data collection, analyses and indicator calculation should be tested. The testing phase is crucial to identify:

- 1) whether the indicator gives an accurate message about changes in the ecosystem service it measures. This will indicate whether the indicator is fit for purpose.
- 2) whether the data can be feasibly collected repeatedly, given levels of cost, expertise, and access to field sites. At this point, it can be determined whether any (further) training is required, whether other resources are necessary and whether the monitoring system needs to be redesigned.
- 3) whether the indicator is understood by the audience.

In order to determine the effect of a REDD+ activity on the ecosystem services of interest, baselines for the indicators may need to be established so as to give meaning to the current value of the indicator. For this purpose, the baseline could be reference to some historical level (average or value of a predetermined time period), or can be calculated as a historical rate of change. This latter type of baseline is that most used for some of the CBD indicators (Butchart *et al.* 2010) since their purpose was to indicate whether the rate of loss of biodiversity had been reduced (Decision VI/26). Baselines can also be set with the use of scenarios, which project what would happen without actions, i.e. a business-as-usual (BAU) baseline (Angelsen, 2008). If no information is available to determine a baseline prior to the set up of a monitoring system then the first measurements may need to serve as baseline. Depending on the indicator and on what question it aims to answer (e.g. rate of change versus state), measurements may be required prior to the set REDD+ activity to determine the effect of REDD+.

Implementing the full scale monitoring system involves gathering and reviewing data, analyzing data and calculating indicators. The results can then be drawn up in a reporting system. Considerations at this stage involve data storage, analytical capacities, training and how the indicators will be reported.

Reporting formats vary. The ideal reporting principles for carbon stock change are that the estimates of greenhouse gas removals and emissions be transparent, consistent, comparable, complete and accurate (GOFC-GOLD, 2009). In terms of reporting ecosystem service indicators some of these principles are useful, whilst the principles of comparability (across countries) and completeness (across carbon pools, etc.) are less relevant. Transparency in reporting on ecosystem service indicators would entail clearly documenting and explaining the methodologies used and the assumptions made. This is particularly important for ecosystem service indicators since some of the indicators may be proxy measures. Consistency would ensure that indicators used, methods and data used to calculate them were always the same between sites and through time. Accuracy refers to avoiding any systematic bias in the data, and providing a measure of confidence where possible.

Some form of verification would add credibility to the results. Verification could be either an internal process, which implements a quality assurance and quality control plan, and/or could be achieved through third party (external) verification using a set of defined criteria (Brown, 2002). Verification may be a challenging and costly process. Costs could be reduced through the use of simple criteria and confidence intervals (Penman *et al.*, 2003) or through local verification if community-based monitoring is undertaken.

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