OCCASIONAL PAPER

Success from the ground up

Participatory monitoring and forest restoration

Kristen A Evans

Manuel R Guariguata

OCCASIONAL PAPER 159

Success from the ground up

Participatory monitoring and forest restoration

Kristen A Evans

Manuel R Guariguata

Center for International Forestry Research (CIFOR)

Occasional Paper 159

ISBN 978-602-387-039-4
DOI: 10.17528/cifor/006284

Evans KA and Guariguata MR. 2016. *Success from the ground up: Participatory monitoring and forest restoration.* Occasional Paper 159. Bogor, Indonesia: CIFOR.

Photo by Kristen A Evans/CIFOR
Guarayos, Bolivia

CIFOR
Jl. CIFOR, Situ Gede
Bogor Barat 16115
Indonesia

T +62 (251) 8622-622
F +62 (251) 8622-100
E cifor@cgiar.org

cifor.org

We would like to thank all funding partners who supported this research through their contributions to the CGIAR Fund. For a full list of CGIAR Fund Donors please see: http://www.cgiar.org/about-us/our-funders/

Contents

List of figures and tables

Figures

Tables

Boxes

Abbreviations

AFRP	Atlantic Forest Restoration Pact
CFLR	Collaborative Forest Landscape Restoration
CFUG	Community forest user group
FLR	Forest landscape restoration
FMNR	Farmer-managed natural regeneration
GPS	Global positioning system
REDD+	Reducing emissions from deforestation and forest degradation, and enhancing forest carbon stocks in developing countries
UNFCCC	United Nations Framework Convention on Climate Change

Acknowledgements

Many local people, researchers and field practitioners around the world contributed the knowledge that was aggregated in this review, and to them we express our sincere thanks. We also thank the experts interviewed for their perspectives and feedback: James Aronson, Manuel Boissière, Pedro Brancalion, Lindsay Buchanon, Tom DeMeo, Nigel Dudley and Karen Holl. We thank Pedro Brancalion, Finn Danielsen and Carolina Murcia for reviewing earlier drafts of this paper. We also thank Chetan Kumar and Miguel Calmon for supporting this initiative. We are grateful to the United Kingdom Department for International Development (DFID) for financial support, through the KNOWFOR project, and to the CGIAR Research Program on Forests, Trees and Agroforestry.

Executive summary

New global forest restoration initiatives present an unparalleled opportunity to reverse the trend of deforestation and forest degradation in the coming years. This effort will require the collaboration of stakeholders at all levels, and most importantly the participation and support of local people. These ambitious restoration initiatives will also require monitoring systems that allow for scalability and adaptability to a range of local sites in order to understand how a given restoration effort is progressing, to determine why or why not it is succeeding, and to learn from both its successes and failures. A scalable monitoring system would have the potential to aggregate participatory monitoring information from multiple sites within a country or globally.

Participatory monitoring – defined as a multilevel collaborative system for collecting and analyzing data, learning, and decision making, that involves local people in a meaningful way – could play a crucial role in meeting international monitoring needs. This review presents a series of lessons learned, synthesized from reviews of over 100 articles and interviews with global experts. Key findings include:

- A scalable, multisite forest restoration monitoring initiative should have a small number of indicators shared by all sites, with the flexibility to determine other indicators to respond to local needs.
- A scalable, multisite forest restoration monitoring system should emphasize the creation of learning networks to facilitate the connection of stakeholders at multiple levels with information that they need for decision making, while connecting stakeholders with each other to catalyze learning.
- Given the relatively long timeframes for forest restoration to achieve its biodiversity goals, and the uncertainties and pressures facing both newly forested and historically forested areas, a scalable, multisite monitoring system will need dedicated funding for the length of the project and probably indefinitely, to be able to claim success and identify forest change, drivers and threats.
- Successful participatory monitoring systems follow basic principles of forest restoration monitoring, but with an emphasis on responding quickly with information that is adequate to answer the questions and needs of local stakeholders – and not necessarily focused only on generating scientifically rigorous data.
- Local people – with appropriate training and crosschecking – can reliably collect accurate data on forest change, drivers and threats, as well as the biophysical and socioeconomic impacts that remote sensing sometimes cannot, thus complementing it.
- Local monitoring can cost up to one-third of professional monitoring. However, more research is needed to understand the full range of costs of participatory monitoring, including support staff, technical resources, data management infrastructure, training, workshops and meetings.
- Sufficient incentives and support can motivate local people to participate in monitoring for the long term. These include orienting the restoration activities to meet local goals and priorities, guaranteeing appropriate compensation, providing training, encouraging participation in reporting and analyzing results, and linking with and learning from other initiatives.
- Effort and resources must be invested to create interactions among local stakeholders to share monitoring information and make decisions; repeated interactions are more likely to generate learning, adaptive management and appropriation.
- Digital devices can facilitate data collection and speed up analysis at multiple levels, including local discussion, interpretation and decision making. However – like any technology – they have drawbacks, and they are only successful if they are used within a robust structure of collaboration, along with locally defined and locally relevant monitoring goals.

1 Introduction

Participatory monitoring is a system that involves stakeholders from multiple levels – especially local people – in a meaningful way, in the design, collection and analysis of monitoring data about the progress and success of a given management activity. In multiple studies, participatory monitoring has involved local people in a variety of contexts in collecting data, analyzing information collaboratively, learning together and making decisions to encourage better natural resource management with various goals. These include non-timber forest product management, wildlife management, poaching control, timber harvesting, fisheries management, fire control and many other applications (Danielsen et al. 2005; Guijt 2007; Evans and Guariguata 2008; Fernandez-Gimenez et al. 2008). Participatory monitoring has also demonstrated that it can help meet the monitoring needs of large-scale restoration initiatives, if appropriately planned and supported: it is cost effective in terms of collecting data (Holck 2007; Pratihast et al. 2014) and decision making (Danielsen et al. 2007), it produces reliable results (Saipothong et al. 2006; Danielsen et al. 2013; Brofeldt et al. 2014; Zhao et al. 2016), encourages learning and adaptation, promotes local buy-in, and, along with the application of appropriate indicators, can provide critical information necessary for decision making at the local and global levels (Fernandez-Gimenez et al. 2008; Galabuzi et al. 2014; Pinto et al. 2014; Schultz et al. 2014).

The potential of participatory monitoring in forest restoration and related forest management activities is outlined in multiple case studies, experiences, field tests and conceptual discussions. However, this knowledge is not always easily accessible to practitioners, or else has not yet been aggregated and thematically systematized. This review seeks to deepen and broaden the understanding of the potentials for participatory monitoring to improve the outcomes of forest restoration initiatives at multiple levels by teasing out the lessons learned from existing knowledge and mapping a possible path forward. More specifically, the objectives of this review are to:

- explore and discuss lessons learned and ways forward to make use of participatory monitoring cases and experiences with forest restoration to connect and strengthen regional, national and global restoration efforts; and
- identify current tools and methods for designing participatory monitoring systems for forest restoration and propose a monitoring framework.

1.1 The context

Need for forest restoration. Globally over a billion hectares of forestlands have been degraded or deforested, contributing to environmental crises on multiple levels; climate change and species extinction are among the calamities on a global scale (Aronson and Alexander 2013; Hanson et al. 2015). Forest degradation and loss can generate severe local effects: depleted watersheds, soil erosion, food insecurity, local climate change and loss of habitat for wildlife (Dewees 2013; Kumar et al. 2015).

New global initiatives. Forest restoration initiatives around the world have demonstrated that forests can be recovered and the many services that they provide can be restored – at least partially (Hanson et al. 2015). New international initiatives aimed at increasing restored forest cover by millions of hectares (the Bonn Challenge, Initiative 20x20, AFR100, the Convention on Biological Diversity Aichi Targets), offer the opportunity to reverse the trajectory of forest degradation and loss by investing in forest restoration at a global scale (The Bonn Challenge 2016).

Need for effective monitoring. Those who work in forest restoration in developing countries have countless stories of failed tree-planting projects (Tougiani et al. 2009; Le et al. 2012). How can we minimize these failures, learn from other restoration initiatives and build success from the ground up? Restoration experts agree: monitoring is essential to restoration success (SER 2004; Lamb et al. 2005; Mansourian et al. 2005). However, in light of these major global initiatives, not enough attention is being given to monitoring progress and success, and as a whole, the global dialogue is just starting to address monitoring in a holistic, multisectorial and transdisciplinary fashion (Chazdon et al. 2015; Reed et al. 2016). To date, the global discourse is largely focused on planning where to restore (Berrahmouni et al. 2015; Hanson et al. 2015; Maginnis et al. 2015). While remote sensing should be a key element of any monitoring strategy, quantifying the number of hectares covered by trees provides only part of the picture, as it cannot directly discern why or why not forest cover is increasing (i.e. the drivers of change) (Boissière et al. 2014a,b; Pratihast et al. 2014). In addition, remote sensing cannot always tell us what is in the forest, whether local people are supportive of a given restoration initiative and what problems need to be addressed to head off potential failures (Pratihast et al. 2014). Remote sensing also provides a coarse grain along the time scale, in that it only detects major changes in vegetation biomass over multiyear periods. Participatory monitoring can provide this crucial information, which is needed to understand whether a restoration is moving along the right trajectory (Laake et al. 2013; Boissière et al. 2014a,b; Pratihast et al. 2014; Bellfield et al. 2015).

Need for local buy-in. If ambitious global restoration targets are to be met, local buy-in will be important, and involving a wide range of stakeholders and landholders in a meaningful way will be necessary. Participatory, inclusive processes that engage multiple stakeholders are more likely to lead to restoration success (Reed et al. 2016) as they provide a crucial sense of ownership for local people, and they help convince local people that they will benefit from restoration (DellaSala et al. 2003; Sayer et al. 2013). In their study across the drylands of Latin America, Newton et al. (2012) found that the biggest obstacle to the success of restoration initiatives was the lack of government policies that consider public participation in decision making.

Need for accountability. Restoration projects need accountability (Murcia et al. 2015) and investors, governments, international organizations and intergovernmental bodies need to know if targets are being met. The biggest challenge for investors is to find restoration projects that meet their standards of accountability and social safeguards (Global Landscapes Forum 2015). Monitoring will play a key role in cultivating the confidence of these investors that forest restoration initiatives can deliver on their promises. To this end, local participation in forest restoration monitoring is key (DellaSala et al. 2003; Sayer et al. 2013; Dey and Schweitzer 2014; Maginnis et al. 2015).

Link global and local. Forest restoration starts on the ground. "Restoration becomes a linking pin between global interests and local needs; between production and conservation goals" (Oosten 2013a, 123). As global forest restoration initiatives ramp up, participatory monitoring has a crucial role to play in providing that two-way link between the local reality and global goals and objectives.

1.2 Methods

The first step of this analysis was a search of peer-reviewed literature for relevant keyword combinations: *forest landscape restoration*, *forest restoration*, *reforestation*, *rehabilitation*, *ecosystem restoration*, *participatory monitoring*, *community-based monitoring*, *local monitoring*, *community monitoring*, *farmer-managed natural regeneration*, *agroforestry*, *forest*, *watershed*, *soil erosion*, *ecosystem services*. Fifty-nine databases were searched, the most important being Science Citation Index Expanded, Social Sciences Citation Index, Environment Complete, AGRIS, GreenFILE, ScienceDirect, OAIster, MEDLINE, Networked Digital Library of Theses and Dissertations, JSTOR Journals, GEORef, BioOne and SciTech. From these, 71 relevant articles were identified and reviewed. Their bibliographies, searches of grey literature and author suggestions produced an additional 43 relevant articles and resources. In addition, seven experts were interviewed (in a semi-structured format) about the role of participatory monitoring in forest restoration, lessons learned, indicators and related themes. After reviewing and thematically organizing the identified resources, a total of 101 articles and resources were included in this review, in addition to the personal reflections of the experts.

Section 2 of this paper defines and discusses key concepts related to forest restoration, participation and monitoring. Section 3 presents cases of participatory monitoring in forest restoration (or related activities), organized thematically as concepts and considerations, and lessons learned. Section 4 is a distillation of lessons learned into a series of essential steps that may be needed for designing a participatory monitoring system in forest restoration. Finally, Section 5 presents a proposed framework for development and testing of a participatory monitoring system.

2 Concepts

2.1 What is forest restoration?

Definitions are important, although it is equally important not to get bogged down trying to come up with the perfect definition. The ecological restoration literature features much discussion about terminology and definitions, and much of the debate centers on the degree to which 'naturalness' – or some other objective, such as the restoration of selected ecosystem services without a full complement of species – is the goal or among the goals (Stanturf 2015). The Society for Ecological Restoration defines ecological restoration as "the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed" (SER 2004, 3) and this definition is widely used. Stanturf's (2015) definition of forest restoration embraces a broad range of approaches to restoring the structure and function of a forest. How, why and what is to be restored comes down to social and environmental decisions, values and priorities, as well as the level of site degradation – which in turn determines what can be achieved in practical terms (Stanturf et al. 2014). Furthermore, the goals of a restoration activity or initiative should be seen as adjustable endpoints on a continuum, and may change as societal values or the environment changes (Stanturf et al. 2014).

Forest restoration treatments can include a wide range of activities: tree planting, weeding, fencing areas off to eliminate grazing, invasive species removal, trimming or tree removal, controlled burning, regeneration of trees from stumps, reintroduction of native plant and animal species, reintroduction of soil microbes, earthworks to minimize soil erosion, and other treatments. Forest restoration may also include passive restoration, where the only intervention may be removing the source of the disturbance, thus allowing forest succession to proceed (Mansourian et al. 2005; Stanturf et al. 2014; Stanturf 2015). See Table 1 for examples of objectives and activities from a hypothetical restoration project.

In not all cases is it possible, necessary or feasible to restore a forest to a natural, pre-human disturbance state. Furthermore, given the shifts in environmental conditions that climate change is bringing, it may not even be desirable or sustainable to 'turn back the clock' (Stanturf et al. 2015). It is more appropriate to consider how to restore the historical trajectory of the forest ecosystem. Stanturf et al. (2014) advocate for considering an array of approaches under the umbrella of forest restoration. To achieve the goals of the existing global restoration initiatives, a wide range of restoration approaches are possible (Table 1). Thus, this paper presents a range of participatory monitoring cases that could be relevant to an equally diverse set of forest restoration objectives.

Many organizations and initiatives are embracing the forest landscape restoration (FLR) approach. FLR is "a process that aims to regain ecological integrity and enhance human well-being in a deforested or degraded forest landscape" (Maginnis and Jackson 2007, 10). FLR explicitly broadens the scope to include human activities and needs. Increasing tree cover, either passively or actively, is part of FLR, but achieving a completely forested landscape is not the main goal. FLR is particularly relevant in places where forest restoration must be balanced with the needs of using land for food production, conservation or other activities to improve social and environmental outcomes. In this paper, the term 'forest restoration' is used to refer broadly to the various approaches that increase forest cover, among them FLR. In the context of the existing global restoration initiatives, it is likely that most if not all types of restoration approaches have a role to play, in some form or another. Thus, determining how to monitor – and monitor in a participatory way – is relevant to all of these approaches.

Table 1. A hypothetical restoration project with specific objectives.

Communicating progress and promoting a hypothetical FLR project in a medium-sized landscape				
	Objective	**Mechanism**	**Restoration Activity**	**Implementation Level**
Mitigation	Sequester carbon	Increase forest area	Afforestation	🟢
		Increase biomass/unit area	Increase productivity	🟢
			Longer-lived species	🟢
		Increase soil carbon	Increase rooting depth	🟢
	Reduce emissions	Bioenergy	Bioenergy plantations	🟢
Adaptation	Maintain forest area	Reduce deforestation drivers	Policy reform – wetlands drainage regulations	🟢
			Conservation easements	🟢
			Improve silviculture	🟡
	Maintain carbon stocks	Reduce degradation	Sustainable forest management (improve regeneration)	🟡
	Maintain other forest stocks	Improve biodiversity	Afforest with mixed species	🟡
			Recover endangered species	🟡
			Manage for species of concern (migratory birds)	🟡
		Improve hydrology	Restore microsites	🔴
			Plant stream buffers	🔴
	Manage for resistance	Reduce vulnerability to stressors	Integrated pest management of key species	🟡
		Overcome regeneration barriers	Secure advance regeneration of key species	🟡
		Reduce vulnerability by breeding, introduce new provenances, genetic modification		🔴
	Manage for resilience	Expand population (with range)	Emphasize key species in afforestation	🟡
		Expand range		🔴
		Create refugia		🔴
Transformation	Novel ecosystems	Manage spontaneous ecosystems	Management of mixed plantings	🔴
		Create ecosystems	Translocate species	🔴
			Replace species within assemblages with desired functional traits	🔴
			Introduce exotics (non-native) with desired functional traits	🔴

FLR = forest landscape restoration.

Note: The far right column depicts a visualization tool based on a traffic light – with simple markers of green, yellow and red – to show whether certain activities have reached success, are moving in the right direction or need to be addressed.

Source: Adapted from Stanturf et al. (2015)

2.2 Why is monitoring important?

There is broad agreement that monitoring is fundamental to successful forest restoration (SER 2004; Clewell and Aronson 2013; Sayer et al. 2013; Dey and Schweitzer 2014). There are several core reasons why this is so.

Evaluating success and avoiding failure. Without monitoring progress and change, it is impossible to gauge whether restoration efforts are successful, are on the path to success or are shifting away from the original management objectives (Holl and Cairns 2002). Thus, monitoring is the best tool to avoid failure and to identify alternative management actions, by detecting problems early on and during specific implementation phases. Inspecting the restoration site is the most direct and critical form of monitoring in order to identify whether the restoration treatments are working or need to be modified before problems become entrenched (McDonald et al. 2016).

Learning and adapting. Every restoration site is different, and every restoration effort will encounter unique challenges, uncertainties and changes. Learning and adapting along the way is crucial for success. Not least because goals may change as a restoration project advances (Le et al. 2012). Monitoring generates the data that is needed for learning and adaptive management (Reed et al. 2016) and provides a mechanism for social learning[1] through the process of timely, deliberate, collaborative analysis of the monitoring results (Evans et al. 2014). Figure 1 shows that monitoring is a core function of social learning and adaptive management through learning cycles, as represented by 'the worm'. Failing to monitor represents a lost opportunity to learn from a project (DellaSala et al. 2003).

Monitoring for accountability and transparency. Restoration projects need accountability and investors, governments, international organizations and intergovernmental bodies need to know if targets are being met. Monitoring serves to gauge whether the system is likely to yield the expected results; and to show evidence of good practices that are likely to succeed.

1 "Social learning" is a cognitive process that takes place in a social context either through observation or direct instruction, or both.

> The International Union for Conservation of Nature (IUCN) ROAM tool describes adaptive management and monitoring as one of the principles of successful restoration practice: "Adaptively manage. Be prepared to adjust the restoration strategy over time as environmental conditions, human knowledge and societal values change. Leverage continuous monitoring and learning and make adjustments as the restoration process progresses" (Maginnis et al. 2015, 16).

Monitoring for compliance and enforcement. Monitoring can also help determine whether local stakeholders are complying with agreed-upon rules and can encourage compliance with a system of sanctions and rewards. For instance, in the Ecuadorian Amazon, communities participating in the conservation program Programa Socio Bosque receive payments for complying with requirements, such as refraining from logging, burning, land-use change or commercial hunting. They must submit legal statements that they are complying. While the communities do not have to monitor, several have instituted their own monitoring programs, including a system of sanctions for violations of the rules (Krause and Zambonino 2013).

More attention needs to be paid to monitoring. It is widely recognized that more work and emphasis on monitoring is needed (Reed et al. 2016). While restoration projects might intend to monitor at the outset, it is common for the monitoring activities to fall well short of the necessary duration to establish whether the project has been successful or is on the right track during its implementation. Restoration projects often do not pay for themselves and so monitoring and evaluation is often under-budgeted or not included (DellaSala et al. 2003). For example, in Colombia, Murcia et al. (2015) surveyed restoration projects and found that while 96% of projects monitored short-term variables, such as early survival of tree seedlings, only 5% monitored long-term variables associated with the goals of the project, such as landscape change or improvements in water availability. Ruiz-Jaen and Aide (2005) found that only 15% of 468 restoration projects, reviewed over 11 years, monitored success. In spite of its broad importance, monitoring is often the last thing planned and the first thing cut.

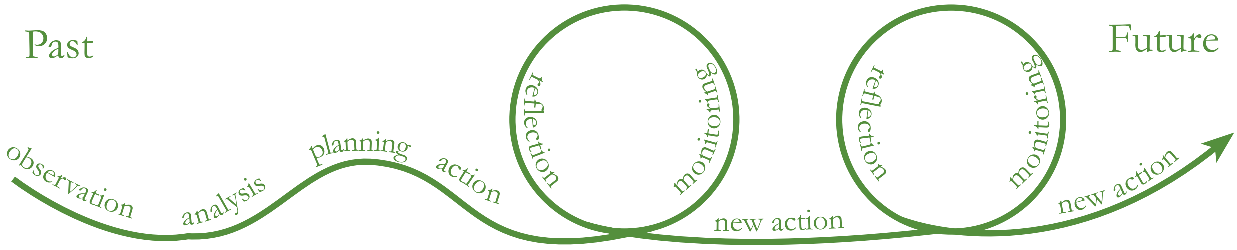

Figure 1. Monitoring helps to learn and adapt
Source: Colfer (2005)

2.3 What does forest restoration monitoring include?

Many resources present principles and guidelines for monitoring (Holl and Cairns 2002; Dey and Schweitzer 2014; Stanturf et al. 2014). It is not the purpose of this paper to review this broad topic, but it may be useful to present the basic tenets of forest restoration monitoring in the context of participatory approaches and the ways that stakeholders at many levels can participate. The succinct guidelines presented by Holl and Cairns (2002) and McDonald et al. (2016) provide starting points from which to build the discussion about participatory monitoring (see Box 1), although they do not directly address roles and participation – that is, by whom and at what level (national, subnational, local) activities are carried out, and to what degree local people are involved.

Box 1. Basic guidelines for restoration monitoring

- Set specific targets and measurable goals and objectives at the outset. The importance of this cannot be overemphasized. What constitutes restoration success must be agreed upon by all parties, and the goals must be simple.
- Make a monitoring plan during the planning stage, not as an afterthought.
- Allocate a specific portion of the restoration budget for monitoring.
- Establish an appropriate reference system that serves as a point of comparison, and ensure that any reference site is representative of the varied stages of succession and restoration.
- Decide the spatial scale and the temporal scale (length and frequency) for monitoring:
  a. Length – ideally until the system is self-regulating
  b. Frequency – more frequent early on.
- Establish action thresholds – an early warning system in case things are not working.
- Set milestones or trigger points to judge progress.
- Collect data at the beginning and then at regular intervals.
- Collect data about the process: work sessions, treatments and costs.
- Decide on the appropriate methodology. The minimum standard for small projects is photo monitoring at photo points, with species lists and a description of conditions. Ideally this will also be done at the reference site, and at an untreated site as a control.
- Monitor performance of the recovery process using the pre-identified indicators consistent with objectives.
- Represent the information on progress and desired endpoints in a way that is visually understandable to stakeholders.

Source: Adapted from Holl and Cairns (2002) and McDonald et al. (2016)

2.4 The need for participation in monitoring

Multiple authors argue that the participation of a range of stakeholders in monitoring leads to more successful outcomes in restoration projects, and in forest management more generally (DellaSala et al. 2003; Sayer et al. 2013; Le et al. 2014; Reed et al. 2016). "Communities that monitor, manage better" (Skutsch et al. 2014, 234). DellaSala et al. (2003) further mention that participatory monitoring is necessary to support the long-term viability of forest restoration for both communities and forests: "Acceptable restoration projects must include a transparent public process that provides for assessment, implementation, monitoring, evaluation, and adaptive criteria" (DellaSala et al. 2003, 18). Monitoring can motivate local stakeholders to maintain interest in and commitment to forest restoration (Galabuzi et al. 2014; Hanson et al. 2015). Sayer et al. (2013) call for participatory and user-friendly monitoring: "All stakeholders should be able to generate, gather, and integrate the information they require to interpret activities, progress, and threats" (Sayer et al. 2013, 8352). Reed et al. (2016) argue that participatory approaches, when well applied, can be cost-effective ways to generate necessary data and empower local people.

Several global agreements require or advocate for the participation of local people in monitoring and decision making in order to meet targets or commitments. Participatory, user-friendly monitoring is linked to the Aichi Biodiversity Targets 1, 2, 4, 15, 17 and 18 (Convention on Biological Diversity 2010; Reed et al. 2016). The International Indigenous Peoples' Forum on Climate Change (IIPFCC) has repeatedly called for the United Nations Framework Convention on Climate Change (UNFCCC) to include "respect for and recognition of the monitoring and information systems of Indigenous Peoples based on their traditional knowledge and practices, and customary law, and forest governance" (IIPFCC 2013). The UNFCCC has mandated the full and effective participation of indigenous peoples and local communities in carbon measuring and monitoring (Vergara-Asenjo et al. 2015). The Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES), explicitly states its intentions to include indigenous and local knowledge systems together with 'western scientific' systems within global, regional and local assessments (Danielsen et al. 2014c).

The globally significant top-down demand on forest restoration over the last few years runs the risk, at the country level, of overlooking local participation during design and implementation. For example, Murcia et al. (2015) analyzed 119 ecological restoration projects in Colombia, and assessed aspects of their planning, governance and monitoring. Although the practice of ecological restoration in Colombia is decades old, it has been mostly driven by the government and carried out at small spatial scales. Local participation seemed marginal at best during project design and implementation (mostly provision of local resources, knowledge or labor). The authors found that almost all projects had monitoring plans but little monitoring in action, and almost no participatory monitoring. Only a very small fraction (5%) monitored social outcomes.

Perhaps most important is the recognition of the fundamental and catalytic role of monitoring in convincing people of all levels of the value of forest restoration: "People don't value what they don't own. That is a fundamental flaw with a lot of monitoring... a few [technical experts] are going out and doing it on their own. We tried to build [the Collaborative Forest Landscape Restoration Program] so that people own it" (T DeMeo, personal communication, 2016).

3 Participatory monitoring

3.1 Concepts and considerations

Participatory monitoring is a system that involves stakeholders from multiple levels – especially local people – in the design, collection and analysis of data. When stakeholders from the local to the global levels engage, participatory monitoring provides a crucial and unique opportunity to link their goals through a network of learning and information exchange. Figure 2 shows how global and local needs, aspirations and capacities can be connected through a network of participatory monitoring in the context of forest restoration. Danielsen et al. (2009) provide a characterization of the different approaches to local monitoring in Table 2. The table describes the roles of professionals and local people across varying levels of collaboration.

While Table 2 presents what appears to be a continuum, it is important to note that the function and the nature of the monitoring varies when local stakeholders are involved. The priorities organically shift from only collecting data to serve rigorous scientific purposes to answering the questions of stakeholders and responding to their specific needs. Furthermore, the desire for collecting data of the utmost scientific rigor becomes contextualized within the larger questions of meeting the priorities of local stakeholders, learning together and improving restoration practices. In the words of a regional manager of the Collaborative Forest Landscape Restoration (CFLR) program, a large-scale national forest restoration initiative in the United States: "I'd rather collect adequate data on two or three indicators in a collaborative way with local stakeholders than ten indicators scientifically."

Villaseñor et al. (2016) reviewed 111 cases of participatory monitoring and classified them in two categories: collaborative learning and evidence-based monitoring. Collaborative learning was focused on creating situations for social learning to enhance adaptive management and self-reflection. Collaborative learning was generally focused on the evaluation of long-term management goals (e.g. reducing soil erosion). Evidence-based monitoring is conservation or management oriented (e.g. biodiversity assessments) and generally focused on short-term implementation goals (e.g. achieving the planting of thousands of tree seedlings).

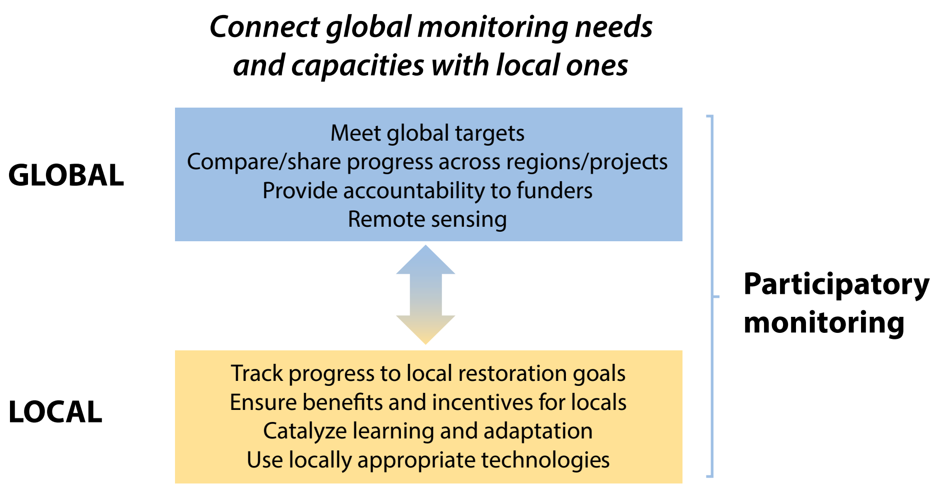

Figure 2. The potentials of a participatory monitoring system

Table 2. A characterization of approaches to local monitoring.

Category of monitoring	Primary data gatherers	Primary users of data
Externally driven, professionally executed	Professional researchers	Professional researchers
Externally driven with local data collectors	Professional researchers, local people	Professional researchers
Collaborative monitoring with external data interpretation	Local people with professional researcher advice	Local people and professional researchers
Collaborative monitoring with local data interpretation	Local people with professional researcher advice	Local people
Autonomous local monitoring	Local people	Local people

Source: Adapted from Danielsen et al. (2009)

They found that monitoring that is focused on collaborative learning was more likely to be used in management decision making.

The distinctions noted above highlight the dual roles of monitoring in the context of existing global restoration initiatives. Ideally, monitoring systems must successfully fulfill the needs of learning, adapting and responding to local aspirations, while also providing information for accountability and surveillance at a higher level – in other words, participatory monitoring that is both collaborative learning and evidence based.

Throughout this review, we use the terms 'participatory monitoring', 'collaborative monitoring' and 'multiparty monitoring' interchangeably, referring to a system of monitoring that involves stakeholders at multiple levels, but with meaningful local involvement. When we refer to 'local monitoring', we are discussing activities at the local level, which may (or may not) be part of a multilevel participatory monitoring system.

3.1.1 Who participates?

A wide range of stakeholders with diverse cultures, educational backgrounds, literacy levels and motivations have been involved in participatory monitoring in forest restoration. Among them are herders in the Nigerien Sahel, large agriculture enterprises in Brazil, high school students in the United States, smallholder farmers in Nepal, conservation organizations and forest service officers (Tougiani et al. 2009; Brancalion et al. 2013; Schultz et al. 2014; Staddon et al. 2015; USDA Forest Service 2015). Furthermore, the nature of the participatory monitoring – what people are doing and why – is equally diverse. The monitoring activities depend on the local goals and context, and people's participation in turn shapes the nature of the monitoring activities and goals.

For instance, in farmer-managed natural regeneration (FMNR) efforts in the African Sahel in Niger, the efforts are led by international nongovernmental organizations (NGOs), forest service technicians and local smallholder farmers. Monitoring focuses on learning from the experiences of local farmers as they experiment with various silvicultural treatments to encourage the recruitment of native species from tree stumps. Local herders play a key role in the effort because of the importance of controlling grazing; however, because herders are migratory and socially marginalized, including them in monitoring to encourage enforcement of grazing rules has required special efforts (Tougiani et al. 2009). National policy makers have become increasingly involved as efforts to replicate the small-scale successes into bigger ones have flourished (Smale 2009; Tougiani et al. 2009). Nonetheless, in spite of the current scale – over 5 million hectares have been reforested – FMNR remains a farmer-centered, local, grassroots effort.

For the Ngati Hine people in New Zealand, young people are nominated to become community monitors of restoration activities. After the community monitors receive training, they are responsible for their assigned areas, including monitoring, controlling invasive species and coordinating enhancement work. The monitors discuss findings at monthly meetings with the community elders, and upload data to a traditional knowledge database and a geographic information system (GIS). Monitors make recommendations and further action is decided at the meetings. The outcomes are also reported via radio (Stankovich et al. 2013).

Brazil's Atlantic Forest Restoration Pact (AFRP) (see Appendix A) has a different context from these community-based monitoring activities. The restoration effort in the Atlantic forest is motivated by a new forest law that requires conservation easements on all agriculture lands of a certain minimum size; no smallholders or communities are involved. Those lands are generally owned by large landholders or agro-industrial enterprises, and the restoration and monitoring is performed by contracted technicians or NGOs who have partnered to assist. Universities also play a key role in the monitoring. Nonetheless, AFRP staff consider it participatory because the relevant local stakeholders are core participants in the monitoring efforts (Brancalion et al. 2013; Pinto et al. 2014; P Brancalion, personal communication, 2016).

In the CFLR program (see Appendix A) in the United States, local groups, called 'collaboratives' are formed up by timber companies, environmental NGOs, universities, local landowners and other local stakeholders (Schultz et al. 2014; L Buchanan, personal communication, 2016). To date, 23 collaboratives have been formed in order to achieve a range of goals, defined by each collaborative. These include fire suppression, creating wildlife habitat, controlling soil erosion and job creation, among others. Membership of a collaborative is completely open to anyone interested and this is thought to be one of its strengths; the exception is one collaborative which has limited participation to timber companies and tribal members and is thought to have had difficulties and conflicts as a result. Local monitoring is performed by student groups, birders and senior groups, as well as professional consultants.

All of these projects or initiatives have successfully embraced participatory monitoring in varying forms to the benefit of the environment and the multiple stakeholders involved.

3.1.2 Women and participatory monitoring

Gender affects the success and outcomes of monitoring. Men and women can have different objectives in forest restoration and different motivations to participate in monitoring. For instance, Galabuzi et al. (2014) found in restoration projects in Uganda that men are mostly interested in on-farm tree planting to generate timber, while women want to control soil erosion. A successful participatory monitoring system would need to respond to both goals.

Women also bring their own skills and strengths, and challenges, to monitoring efforts. Mwangi et al. (2011) explored monitoring and sanctioning in activities related to forest restoration and management, such as tree planting and clearing undergrowth, in four sites in East Africa and Latin America. They found that mixed gender groups tend to do more monitoring than male dominated ones, and female dominated ones are unlikely to conduct any monitoring at all. All-women groups are less likely to adopt new technologies; this is thought to be because they are less likely to be visited by extension agents or to have the money to buy equipment. Women dominated groups may not participate in monitoring and sanctioning because of the distances to be covered for patrols and the potential damage to social networks, upon which they are more dependent. As a whole, mixed groups are less likely to have conflict, because women are more likely to have stronger norms of solidarity, due to their tendency to cooperate in other spheres. Women bring distinct knowledge and skills, such as the ability to construct alliances and resolve conflicts, which are key to group restoration efforts. Thus, constructing strategies to include women is necessary for restoration success (Mwangi et al. 2011).

3.1.3 Power and participation

Involving marginalized people in monitoring – and valuing their knowledge systems – can be key to restoration success. In a forest restoration monitoring effort in communities in Nepal, Staddon et al. (2015) explored the role of power and knowledge in interactions among local smallholders, Dalits, NGO technicians and forestry officials. They looked at the choice of the methods, decision making and control using the critical theory of 'tyranny of participation' (Cooke and Kothari 2001). They found that the process of participation constructed and enforced unequal power relationships from the outset. For instance, when the NGO selected the participants, young, literate men were favored. Participants also experienced an uneasy relationship with outside organizations who were thought to possess superior knowledge. This reinforced the perception of technical and knowledge deficits and differences by local people, further exacerbating unequal power relations and engraining feelings of inferiority and lack of authority among the communities. In addition, the monitoring information – although collected by local people – was rarely shared with them. In response, local people went around the barriers of the scientific monitoring to do their own local monitoring (i.e. informally comparing control plots with treated plots). The authors suggest that participatory monitoring projects should approach their work with honesty and self-critique with regard to power and knowledge. For instance, they should define what they mean by 'community' – who are the participants and why would they do the work? How will non-data benefits (like empowerment) be assessed? The authors conclude that projects should pay attention to local systems of monitoring – they may be more effective, and adopting them will counter feelings of inferiority.

3.2 Lessons learned

3.2.1 Local knowledge can complement remote sensing with crucial information

Remote sensing is a valuable tool in gauging progress on forest restoration; however, remote sensing primarily provides surveillance data – whether or not there is forest cover at the time of imaging (Pratihast et al. 2014). Remote sensing alone cannot directly tell why forest cover is increasing or decreasing (i.e. the drivers of change) (Pratihast et al. 2014; K Holl, personal communication, 2016), what is in the forest or what type of forest it is, whether local people are supportive (or not) of the restoration, and what problems or threats may need to be addressed to head off failures. Remote sensing also does not indicate whether the forests are missing key functional elements that grant resiliency to the ecosystem (i.e. if they are defaunated forests), if forests are being overtaken by invasive species or if they are providing the goods and services that are expected at their given state of development. Decision makers at the national and global levels need information on these local drivers and the effectiveness of restoration measures; communities can supply these (Laake et al. 2013). For example, several studies connected to REDD+[2] monitoring efforts explore the roles of local people in collecting forest data that could integrate with national monitoring regimes. They found that local people can reliably monitor forest changes, forest quality, deforestation drivers and social impact information that remote sensing cannot (Danielsen et al. 2011; Brofeldt et al. 2014; Pratihast et al. 2014; Bellfield et al. 2015; Vergara-Asenjo et al. 2015; Zhao et al. 2016).

Communities can uniquely monitor drivers of deforestation, and being involved improves their buy-in. Bellfield et al. (2015) developed and tested a community-based monitoring framework in indigenous villages in Guyana. The aim was to explore the potentials for local people to gather data, analyze local drivers of deforestation and forest degradation, conduct participatory mapping, ground-truth satellite imagery, measure carbon stocks and monitor local co-benefits for REDD+. The study site included 16 Makushi communities in a forested area covering 311,531 ha. Thirty-two community members and five local project management staff were trained as monitors. Data collection forms and protocols were designed together with researchers, government staff and community monitors. Natural resource use and well-being indicators were defined by the community in workshops. Community members used applications on offline Android smartphones to map geo-referenced polygons designating land use types, measured above-ground biomass in plots, ground-truthed satellite data and collected well-being data through household surveys. Data was then uploaded for analysis by project management staff and project facilitators, who used various tools for storing and analyzing the data and comparing it to remote sensing data. All data was owned by the communities, and a data sharing protocol designed so that communities could decide what data to share. Discrepancies between remote sensing and local monitoring highlighted that local monitoring more effectively distinguished between agricultural areas and forested areas. Furthermore, when surveyed, 85% of participants felt that their needs were considered

2 REDD+ = reducing emissions from deforestation and forest degradation, and enhancing forest carbon stocks in developing countries.

in the monitoring system. The authors conclude that communities are well positioned to monitor drivers of deforestation, natural forest regeneration and reforestation.

Local people who are trained appropriately can generate forest change data that is equivalent to data collected by remote sensing data. Pratihast et al. (2014) tested a participatory monitoring system to see if communities could successfully monitor forest activity change and to explore the perception that data credibility and trustworthiness are major obstacles to community-based monitoring of forest stocks. They trained 30 local community members in the Kafa Biosphere Reserve in Ethiopia on how to monitor forest activity change. All had secondary education, some forest management understanding, and were responsible for various elements of project activities related to the biosphere reserve (e.g. tourism, reforestation and community plantations, among others). The monitors collected information on forest changes, identifying the location, the type of change and taking photographs. Two methods of data acquisition were employed: paper forms with global positioning system (GPS), and mobile devices with integrated GPS and camera function, with a decision-based collection form. They found that mobile devices had a clear advantage over the paper system because fewer data entry errors occurred. The authors spot checked 65% of the sites to verify local expert data acquisition and location, drivers and forest change polygons with high-resolution SPOT and RapidEye remote sensing images. Some issues with spatial and temporal accuracy occurred, which the authors think could be corrected through training and providing better maps. They felt the most critical issues were that most data were collected near roads (53% of local data were collected within 1 kilometer of roads) and frequency of monitoring varied depending on the weather and people's motivation. The authors conclude that compared to field-based observations and high-resolution remote sensing, local experts are accurate in providing the spatial, temporal and thematic details of the forest change process in a way that complements and enhances remote sensing-based, forest change analysis.

There are some types of data that communities can collect well, but other types that require the support or assistance of professionals. Laake et al. (2013) present the experiences of several community carbon accounting (CCA) projects implemented in Cambodia, Indonesia, Laos, Papua New Guinea and Vietnam. They conclude that community teams can take accurate forest surveys, retain the skills they have learned and can do more than is often assumed. The authors present a table outlining the tasks and steps to get community forest monitoring going, defining what steps require an intermediary and which steps communities can take autonomously. They found some limitations to the data collection capacity of communities. Data collection is best restricted to a set of basic forest properties, such as boundaries, types of species, tree count and tree diameter. Measurements might not always be of consistently high quality, thus professionals need to analyze data jointly with communities. Communities must also be assisted in setting up plots. The authors conclude that in order to ensure reliability and accuracy of data, a parallel process of cross-checking is necessary. Furthermore, communities should take annual measurements to keep up their interest and to generate enough data points to smooth out anomalous years.

Local knowledge can provide the information needed to correctly classify forests and forest use. Vergara-Ansenjo et al. (2015) compared the accuracy of remote sensing imagery processed from RapidEye satellite images with a map of land cover created by indigenous communities in eastern Panama. Both maps were evaluated against field data collected by scientists to check their accuracy. They found that the participatory map had 83.7% accuracy compared to the remote sensing map at 79.9%. In the digital image processing, forest transformed by human intervention is often confused with undisturbed primary forest. Local knowledge proved to be crucial to differentiating between these different forest types (Vergara-Asenjo et al. 2015). "We have demonstrated for the first time that local knowledge can improve land cover classification and facilitate the identification of forest degradation. The plea of the [UNFCCC] for the full and effective participation of local and indigenous people could indeed improve the accuracy of monitoring" (Vergara-Asenjo et al. 2015, 437).

While it has been proven that community members can assess carbon stocks and drivers of deforestation just as well as professional foresters, one of the challenges is in harmonizing monitoring practices and protocols between projects. Torres et al. (2014) analyzed 11 early action REDD+

projects in Mexico and considered the potential for the use of community-based monitoring information in national monitoring systems. The authors determined that community-based monitoring can become the backbone for a nested data collection structure for REDD+ monitoring if (i) national monitoring systems have the infrastructure for data registrations, storage and processing; (ii) standard procedures exist for monitoring processes to be consistent and transparent; and (iii) communities and the public benefit.

3.2.2 Local monitors can provide reliable, accurate monitoring data with training, motivation and cross-checking

Several studies – directly related or relevant to forest restoration activities – have demonstrated that local monitors can collect data of equivalent quality to scientist-collected data under certain conditions (Saipothong et al. 2006; Danielsen et al. 2011; Danielsen et al. 2014a; Bellfield et al. 2015). Successful methods include measuring above-ground biomass of trees in simple forests and woodlands with the use of handheld computers for capturing data (Danielsen et al. 2011), measuring above-ground biomass of trees in structurally complex forests with low-tech field approaches (Danielsen et al. 2013), recording the status and trends in forest resources through patrols (Danielsen et al. 2014a), focus group discussions on the status of forest resources (Danielsen et al. 2014b) and tree species identification (Zhao et al. 2016). Furthermore, in interviews conducted for this study, experts expressed their opinion that this may no longer be a debate: local people can provide reliable monitoring data given appropriate training and motivation and if the monitoring activity is relevant to them. However, there are some limitations: local people often struggle with monitoring or understanding indicators decided elsewhere (Sabai and Sisitka 2013), the data needs and goals of local stakeholders must be considered (Saipothong et al. 2006), and experts must conduct cross-checking to ensure data integrity (Le Tellier et al. 2009; Nielsen and Lund 2012; Laake et al. 2013; Skutsch et al. 2014). These themes are explored below.

Locally-based natural resource monitoring is suitable for monitoring resources or phenomena that are meaningful for community members – such as those connected to their livelihoods – but may not be suitable for monitoring attributes that are not relevant from the local perspective. Danielsen et al. (2014a) compared local systems to professional monitoring in five types of natural resource use at 34 sites across four countries in order to evaluate the competence of local monitoring. They looked at resource abundance, and status of and trends in resource abundance indices, and they compared data from patrols by community members with that of line transects conducted by trained scientists along the same or adjacent survey routes and in the same forest areas. They found that "in tropical forest habitats in developing countries, community members with little or no formal scientific education, who have decided which natural resources should be monitored, can generate records of abundance estimates, relative trends, and the variation over time of natural resources and resource uses that are very similar to those of trained scientists" (Danielsen et al. 2014a, 246). They believe the reason that results were so good was because community members know their forest intimately. "Here, we have shown that local people and trained scientists can be equally good at collecting data and, therefore, that local communities can play this role in monitoring if schemes are organized to facilitate their engagement" (Danielsen et al. 2014a, 250). However, if monetary benefits are tied to the results, local people may have an incentive to provide false reports, so triangulation will be necessary. Triangulation could be random spot checks or combined with statistical analysis to identify anomalies or trends.

Local people have also successfully monitored watershed restoration with sufficient training and support. Saipothong et al. (2006) tested simple locally-managed science-based methods for monitoring watershed services in an area of montane Thailand that is shifting to opium production from swidden agriculture. The monitoring objectives were to provide feedback on the impacts of local land-use management on watershed services, help manage tensions and conflicts, and facilitate communication and negotiations between upstream and downstream communities. They tested a set of tools in 12 study sites over a 30-month period. To measure climate, they set up simple structures near the villages that recorded data on rainfall, temperature and relative humidity. To measure stream flow, they measured stream depth, using a staff gauge; and surface flow velocity, using a leaf or foam float with a stop watch to time its travel over 5–10 m. The data collected by the community monitors was comparable to expert collected data for both climate and stream flow. To monitor water quality, they used bioindicators: specific species were identified and given scores. At first, villagers were apprehensive about identifying bioindicators, but this became one of the most popular and highly regarded activities. To assess local environmental knowledge, the authors compared villager predictions with the data. When assessing the quality of the monitoring, scientists developed basic criteria for evaluating the completeness and consistency of records. They found that data quality was high and comparable to data collected using more sophisticated techniques, and villagers could explain the reasons for gaps and inconsistencies. The following suggestions about the use of data were proposed by the villagers: schedule regular meetings among monitors to exchange information and data; involve village headmen so that they appreciate the data; match the data needs of villagers with scientists and watershed managers early on to avoid conflict (because the needs may be different); and plan for appropriate training in data collection, interpretation and use, so that villagers can build understanding and answer questions. Villagers were confused about the use and interpretation of data from science-based tools, and they suggest that future trainings need to emphasize tool use and data interpretation, and support information exchange.

Not all local monitoring experiences have successfully generated reliable data. Le Tellier et al. (2009) hired local farmers to collect data on stream depth in a payment for environmental services initiative in Bolivia. For each location, they hired two monitors to take readings on different days to avoid people fabricating data. However, they suspected that data fabrication still took place. As a result, the data was not of sufficiently high quality to be used, although the authors think that with further refinement of the methods it could be. The authors also concluded that the methods were too complicated. They recommend the monitoring of only what is locally relevant, rather than fulfilling scientifically complete criteria – in their case, switching to just monitoring dry season hydrologic flow. Furthermore, they suggest that locally-based monitoring needs to be socially acceptable.

Furthermore, some authors caution that agreement is not always to be expected between data collected through local monitoring and scientifically collected data (Nielsen and Lund 2012; Boissière et al. 2014a,b). While much of the literature supports local monitoring as acceptable in the context of forest restoration or REDD+ for example, this resonates poorly with the body of literature that documents local power struggles over benefits and resources (Nielsen and Lund 2012), which is characterized by contestation as much as cooperation. For instance, as community benefits through monetary compensation payments grow, so may the incentives to manipulate or fabricate data (Danielsen et al. 2011; Nielsen and Lund 2012). Nielsen and Lund (2012) evaluated the local monitoring of forest conditions and the financial transactions of a showcase community-conservation project in Tanzania and compared the results against transect data and audits of the taxes and fines collected. They also interviewed key informants and made observations of the power struggles. They found that monitoring data collected by community members contradicted trends in wildlife densities and human disturbance that came from the transect studies and from reviewing their own reports. Community monitoring data also underrepresented financial flows. They found that income based on receipts and vouchers was higher than income presented in monthly reports. There was no indication of a lack of understanding and ability; in fact, there was a high level of capacity in performing the monitoring tasks, although less so in the maintenance of records and in the use of the data for reflection. Instead, the discrepancies were evidence of instances of embezzlement, taking shortcuts, turning a blind eye to infractions, extorting offenders, re-using receipts, and of leadership or patrol guards accessing the resources themselves. The local monitors adjusted reports to avoid audits by the district-level authorities, and also because a 5% tax on their receipts is leveled by the district. So many instances of discrepancy were found that it is unclear from the patrols what the ecological conditions are. The authors also found that no village compared the data from year to year to identify or reflect upon trends. Interviews and observations found that this information is communicated in a context of ongoing power struggles over access to benefits. “It seems relevant to pose the question whether the locally-based monitoring setup in this case has not failed on both its stated objectives of 1) providing an information basis for discussion and informed management decision making in the communities and 2) generating accurate information to higher authorities about the performance of collaborative forest management” (Nielsen and Lund 2012, 10).

Solutions to these problems suggested by other authors include having a system for spot-checking or cross-checking data (Danielsen et al. 2014a) or uncoupling payments for monitoring from performance (Skutsch et al. 2014).

3.2.3 Participatory monitoring enhances learning and decision making at local and global levels

Participatory monitoring can lead to faster decision making (Danielsen et al. 2010), encourage learning and sharing (Saipothong et al. 2006; Fernandez-Gimenez et al. 2008; Pinto et al. 2014) and strengthen stakeholder capacity and empowerment (Constantino et al. 2012; Funder et al. 2013). This section explores these themes to understand the connections between participatory monitoring, learning and decision making at different levels and suggests how to better link local and global perspectives.

Including local people in monitoring enhances management decision making and responses at the local level and increases the speed of response to issues or problems that emerge. Danielsen et al. (2010) reviewed 104 cases of monitoring schemes to assess whether participation in data collection and analysis influences the speed and scale of decision making and action. They found that scientist-executed monitoring informs decisions within regions, nations and international conventions and takes 3–9 years to be implemented. At the village level, monitoring that involves local people and is related to resource utilization is much more effective at influencing decisions and takes up to 1 year to implement. In contrast, scientist-executed monitoring has little impact at the village scale, where most natural resource use decision making occurs.

Community involvement in monitoring can facilitate social learning, build trust, increase resilience, enhance appreciation for monitoring and reconnect people with landscapes. Fernandez-Gimenez et al. (2008) explored the role of collaborative monitoring in five community-based forestry organizations in the United States and looked for evidence of social learning as an outcome. The local community participants were diverse: most were multiethnic and impoverished because of loss of jobs from timber harvesting. Community members were involved in a wide range of monitoring activities: ecological assessments, inventories, compliance monitoring and management effectiveness monitoring. The authors found evidence of social learning in those cases where there were self-reflection, public meetings to discuss lessons learned, and learning workshops. In slightly less than half of the projects, the monitoring results were used to complete the adaptive management cycle (Figure 1); that is, catalyze changes in response to reflection on management activities. The monitoring results were also used to inform other projects, either to include monitoring or actually to change the management approaches. Clear objectives and design were key. Fewer social learning outcomes were detected in projects where the objective was to validate existing knowledge. The authors found more evidence of trust, community building, stronger relationships and social learning when community members were involved in the design and planning. Repeated interactions between diverse stakeholders allowed participants to get to know each other as individuals and move beyond stereotypes and assumptions; they also allowed individuals to demonstrate qualities like reliability, consistency, transparency and respect for others' viewpoints. Projects designed by agencies or researchers alone resulted in fewer social learning outcomes, and less community building and trust. Collaborative monitoring built trust between community groups, environmental groups and government, even if that was not a goal at the outset. The two biggest challenges were obtaining broad-based and sustained participation and determining and securing the necessary levels of technical assistance and capacity to assure the scientific validity and credibility of the monitoring. In conclusion, community involvement in monitoring advanced the overall goals of transforming relationships between ecosystems, communities and local economies.

Encouraging social learning and decision making requires the establishment of flexible governance mechanisms, as Oosten et al. (2014) concluded when they evaluated the governance dimensions of three cases of forest restoration in Indonesia. Governance mechanisms must support local landscape stakeholders in planning and design, and link locally-designed plans to state-designed plans. Most importantly, forest landscape restoration cannot be based on professional plans alone, but depends on gradual changes in governance, local creativity and public-private partnerships at the landscape level. Oosten et al. (2013a) argue that if global initiatives like the Bonn Challenge are able to pick up local initiatives and scale them up by creating learning networks both within and between landscapes, they may be able to reconcile global needs and processes with local ones. They emphasize the need to create learning networks, or 'glocalized' networks that use events, workshops and the Internet to connect local stakeholders at global levels. Social learning is integral to landscape restoration, and how people learn and connect with each other is a function of the landscape governance structures. "Landscape restoration requires a flexible approach of social learning rather than a strongly institutionalized approach based on design criteria" (Oosten et al. 2014, 1158).

Community participation in monitoring enhances local empowerment by catalyzing learning and skills development. Constantino et al. (2012) explored the empowerment outcomes of participatory monitoring in four cases in Brazil and Namibia. The authors define empowerment as gaining control over one's future, either as an individual or as a community. Three of the cases were programs in Brazil that focused on hunting to evaluate sustainability. They were characterized by substantial training, feedback opportunities and capacity building. Some activities prioritized the participation of women. The authors also examined the Namibia Event Book System, where local people monitor wildlife, rainfall and craft making. Monthly and yearly reports are presented, and the information is used by local managers to help mitigate human-wildlife conflict, develop craft-making skills and sustainably manage craft resources. The information is reported back to communities through village representatives and annual meetings. The authors found that individuals in all four systems were psychologically empowered, "feeling proud to engage in a program with external researchers, learn new techniques, and promote resource stewardship" (Constantino et al. 2012, 22) and that monitors viewed themselves as respected community members. Participation in data analysis was particularly important to social empowerment because members used the data for decision making. Monitors learned from each other and improved their skills over time. They also found that dissemination of results was very important: it enhanced transparency, highlighted monitors' work and improved management.

Not all approaches to participatory monitoring enhance learning and decision making equally. In their comparative study of two approaches to participatory monitoring – 'evidence-based' and 'collaborative' learning, as described in Section 3a – Villaseñor et al. (2016) sought to determine which was most effective at influencing conservation and management decisions. The authors conclude that it was more likely for monitoring information collected in the collaborative learning cases to be used in decision making. This is because collaborative learning focuses more on evaluating processes rather than results, and greater local empowerment leads to greater use of monitoring information. The authors suggest creating monitoring schemes that generate information local people can use in their own productive activities, such as agriculture and hunting, while discussing the monitoring results in ways that local people can both interpret and apply. Certain activities can make it more likely that information will be used, such as environmental education campaigns and regular reporting of the results to communities.

3.2.4 Participatory monitoring can be cost-effective but requires investment at the outset

Participatory monitoring can be a cost-effective way to implement scalable, multisite monitoring because of the lower costs of labor and transportation versus professionally trained monitors (Danielsen et al. 2011; Pratihast et al. 2014). However, care must be taken not to offload costs onto local people (Holck 2007; Danielsen et al. 2011). Costs will vary depending on the monitoring approach, location, investments in training and staff time needed. A study carried out in Cambodia, Indonesia, Laos, Papua New Guinea and Vietnam found that the costs for analyzing above-ground biomass are usually USD 1–4 per hectare/per year, and professional costs are 2–3 times higher to collect equivalent data. Costs are always higher in the first year; they decrease as less training and follow-up is required. Communities should be paid annually at least, not at the end of a multiyear phase (Laake et al. 2013). Another study in Tanzania compared four different approaches to tree surveys carried out, and found that the costs were USD 0.04–0.12 per hectare for local people to carry out plot-free, tree-counting methods twice a year, or USD 1.88 per hectare for surveying permanent sample plots once per year

(Holck 2007). Investments in training, capacity building and follow-up should be considered in the costs of participatory monitoring. For instance, one full day of training per year was needed to train the local participants in the methods (Holck 2007).

Community-based identification of tree diversity can be done at a quality comparable to trained botanists at one-third of the cost, as Zhao et al. (2016) found in a comparison of data from community members and trained scientists in montane forest in Yunnan, China. Community members could provide the ethnotaxonomical names for 95% of 1071 trees in 60 vegetation plots, without accessing herbaria, identification guides or the Internet. The community-led survey also spent most of the expenses at the village level (89%), compared to the botanists who spent only 23% of monitoring funds at the village level.

More information is needed to fully understand the costs of local monitoring. The studies encountered in this review primarily compared day labor rates of local people with those of professionals, plus transportation costs. The picture is more complex, however, as local monitoring may require a more robust infrastructure of training, resources and paid staff to support the monitoring efforts. Furthermore, the appropriate incentives must be in place to motivate local people to participate, as they may have to balance the opportunity cost of the monitoring with other livelihood demands; that is, the day labor rate may not be the appropriate incentive. Finally, participatory monitoring involves much more than data collection; resources must be dedicated to data analysis and social learning activities – meetings, workshops, training, fieldtrips – that support decision making and adaptive management cycles. Furthermore, the costs related to quality control, data management and data storage must also be considered.

3.2.5 Planning and implementing a monitoring system is a slow process

Successfully planning and implementing a monitoring system – participatory or otherwise – requires a concerted, long-term commitment by stakeholders to get it off the ground and see it all the way through (Fernandez-Gimenez et al. 2008; Boissière et al. 2014b). Unless the learning loop is closed, (i.e. monitoring data is collected, analyzed and used to inform decisions, see Figure 1), there is little point in monitoring. This section presents several cases where projects struggled at various phases of the process, in order to understand why and how those pitfalls can be avoided.

Monitoring plans are often the easiest components to drop from a project. Dudley et al. (2003) spearheaded the development of a multilevel participatory monitoring and evaluation plan for forest landscape restoration in Vietnam in collaboration with the World Wide Fund for Nature and the local government. Over 60 meetings were held at different levels to define indicators on various issues: forest condition and biodiversity, forest ecosystem services, livelihoods and capacity for good management of natural resources, among others. Some indicator data was to come from existing government sources. They planned to use local data collectors to monitor forest cover or quality, forest management, biodiversity and governance capacity. The plan included a list of over 30 indicators; the framework, objectives and principles of the monitoring and evaluation system; and sample questionnaires. A follow-up interview revealed that the plan was never implemented (N Dudley, personal communication, 2016). According to the interviewee, big monitoring systems get dropped as soon as there is a cash flow crisis: "Monitoring is one of the easiest things to drop, even though it is key." One solution is to "keep pushing the message that if you don't have a monitoring system you will fail." Another approach is to have a full monitoring system that is really simple, can be applied by projects, and is written into their work plans so it does not fall apart if there is a staff change. Another solution is for monitoring programs to use as much data that is already being collected as possible. For instance, many types of social data are already being collected by the government, and they can be used for monitoring some aspects of the social impacts of forest restoration.

It is recommended that monitoring data be analyzed frequently; small rapid experiments are conducted, as well as large long-term ones; and a strong ethos of debate is encouraged among all stakeholders to spur innovation. Mills et al. (2015) describe a large-scale effort in South Africa to restore subtropical thicket, where the project waited too long to reflect on the monitoring data. The project started in 2004, with an investment of over USD 8 million. While the project did monitor, the monitoring results only emerged a decade after the project was initiated, and monitoring information was not evaluated until the end of the project. By then, it was too late to avoid many of the pitfalls. The project failed to restore thickets significantly because of a flawed seedling planting methodology and because the methods were not adapted to the landscape position. By neglecting to analyze the monitoring data in a timely manner, they were not able to adopt an adaptive management approach, they did not analyze the effect of landscape position on survivorship and they did not carry out cost-benefit analyses. As a result, they did not understand the degree to which the effort was failing until it was too late. Based on this experience, the authors advocate for building in an experimental approach: “Intelligent tinkering needs to be prescribed, not assumed” (Mills et al. 2015, 4342). The authors also recommend ensuring a mixture of experiences: involving ecologists, agronomists and local people experienced in planting, cultivation and soils in that location. Furthermore, they recommend connecting payments to survival outcomes, since consultants were just interested in planting, not in plant survivorship.

Local people will often seek the opportunity to learn in spite of barriers, and they may learn better using their own systems. In a forest restoration monitoring effort in communities in Nepal, Staddon et al. (2015) explored the role of power and knowledge in interactions among local smallholders, low-caste individuals, NGO technicians and forestry officials. The goals of the restoration effort were to convert pine forest to broadleaf and improve the yields of several native income-generating species. The restoration treatments included fencing off areas from grazing and thinning and pruning pines to encourage broadleaf tree growth. Members of the community forest user group (CFUG) measured trees, pruned and thinned, supervised, affixed ribbons, provided snacks, counted plants, and recorded results. In the monitoring phase, they measured girth and height of trees when established and each subsequent year, observed annual grass growth in plots, and cut grass. The monitoring activities stopped short of analyzing and reflecting on the data to formally encourage social learning: 95–100% of participants said that they were learning, but not exchanging information. One of the CFUGs never received an official report, even though they took all of the measurements. Of those who did receive the reports, few people understood them. Nonetheless, they had their own conclusions and impressions based on the experience and using their own criteria. For instance, in the control plots where there was no treatment, they saw no change. But in the plots where they cut, they saw improvement in the growth of the remaining trees, density of vegetation, presence of new species and the growth of seedlings. Some were surprised by the results: where they cut, 50% did not expect the forest to do well, but it flourished. Even people who did not participate in the project had their own observations and conclusions. People saw the results were positive and wanted to scale them up. However, members of one CFUG felt that they did not have the authority, and in the other did not have the capacity to control the grazing over the entire village.

3.2.6 Participatory selection of indicators can build common ground and catalyze social learning

Selecting indicators in forest restoration “is inherently a human process and therefore hard to manage” (Dey and Schweitzer 2014, S53). Monitoring activities need a set of indicators closely aligned with management objectives in the short, medium and long term, even though selecting indicators can be a “messy and time-consuming process” (Dey and Schweitzer 2014, S53) in any restoration effort. Participatory monitoring adds complexity and input that – while enriching and strengthening the monitoring activities and the restoration outcomes – requires recognizing that time, negotiation, experimentation and training are part of the process (Izurieta et al. 2011; Sabai and Sisitka 2013; Schultz et al. 2014). Nonetheless, forest management and restoration efforts have successfully developed indicators in a participatory way (Dudley et al. 2003; Fernandez-Gimenez et al. 2008; Sabai and Sisitka 2013; Schultz et al. 2014; Bellfield et al. 2015) and found that locally developed indicators can be more relevant to the success of the restoration effort (Fernandez-Gimenez et al. 2008). Several studies discuss the difficulties of identifying appropriate indicators in participatory monitoring, and the pitfalls of selecting too many indicators (Fernandez-Gimenez et al. 2008; Sabai and Sisitka 2013), indicators that are too technical (Sabai and Sisitka 2013), too time-consuming to monitor or simply wrong. The examples below illustrate these points.

Sabai and Sisitka (2013) came to the conclusion that it is advisable to avoid indicators that are too numerous or technical, based on their experience in Tanzanian coastal-community mangrove restoration projects. In the 1990s, scientific institutions developed indicators to guide community-based monitoring practices. However, the authors observed in 2005 that it had been a challenge for communities to understand, identify or apply the indicator framework. They found that low formal education made it difficult for people to understand indicators or their relevance; the indicators were too technical or involved a lot of mathematical knowledge. Their study sought to identify the challenges that enable or constrain adapting or using scientific indicators, and to test a new approach to develop indicators that are more relevant and more likely to facilitate social learning. The authors used the Experiential Learning Intervention Workshop as a methodology to test the existing framework, analyze its relevance, and add local input to improve it and make it more user-friendly. As a part of the methodology they conducted questionnaires, interviews and focus group discussions held with fishers, mangrove restorers and elders. Four themes emerged addressing the concerns of participants: the physical condition of mangroves, threats to the mangrove ecosystem, changes and trends in the mangroves, and fisheries species. Next, the groups identified indicators and field tested them through monitoring.

The process of identifying indicators can create common ground and open communication among stakeholders. Izurieta et al. (2011) present the process of selecting indicators for a participatory monitoring and evaluation system for joint management of traditional lands, involving Aboriginal peoples (the Wardaman) and national park staff in the Northern Territories of Australia. The authors focused on the process of developing a participatory monitoring and evaluation system to see if the participants were meeting joint management goals and agreed-upon outcomes. During 2007–2008, they used several methods to develop a participatory monitoring system (e.g. focus groups, small group meetings, oral and visual tools) and utilized several environments for meetings (e.g. formal meetings in offices, outdoor meetings with larger groups of diverse stakeholders). To help identify the indicators, they used the five capitals approach (Bebbington 1999) and the management effectiveness framework (Hockings 2003). Izurieta and colleagues present the list of indicators, which focus on building social capital, communication and learning. They found that outside facilitation by experienced experts from Charles Darwin University was key to building a closer relationship between partners. These experts also provided extra capacity to run the workshops and minimized the bias towards the park's interests, which would have tended to dominate. Participatory monitoring and evaluation was seen as way for participants to learn from each other. The process created common ground and opened communication, in contrast to prior experiences the Wardaman have had with the park management. Informal moments where Wardaman and park staff spent time outside of the meetings, such as fishing together, were important. While at first participation seemed to be constrained, the authors realized that those who spoke tended to be elder women, who may have been nominated to be spokespeople by the participants.

3.2.7 Generating and maintaining local participation can be challenging

Generating and maintaining participation by local stakeholders is a common challenge. Fernandez-Gimenez et al. (2008), in their studies of collaborative monitoring in five community-based forestry organizations in the United States, determined that gaining and keeping the participation of key local stakeholders was the biggest issue. Long-term participation can be difficult to sustain, particularly when it means mobilizing and maintaining long-term volunteer commitment. A related pitfall – all too common in development projects – is over-reliance on specific individuals at the expense of building broad-based participation. The authors suggest keeping all members up to date and regularly distributing monitoring results through the community to help maintain motivation (Fernandez-Gimenez et al. 2008). Other authors suggest that asking local people to volunteer their time without getting paid is an inappropriate way of offloading costs (Danielsen et al. 2011) and provides inadequate incentive. Modest compensation is necessary (Saipothong et al. 2006) even though it may compromise the ability to sustain the scheme over time (Danielsen et al. 2000). Newton et al. (2012) document difficulties engaging stakeholders to participate in monitoring in their study of restoration projects in drylands of Latin America. The authors noted 'stakeholder fatigue' caused by the frequent promises of benefits from development projects that failed to deliver. They recommend that stakeholders be strongly engaged in order to improve motivation, and noted that stakeholders must perceive benefits to their participation. Furthermore, the restoration projects need to pay for the opportunity costs borne by local stakeholders, such as loss of cattle grazing sites.

Participation can also be derailed by competing livelihood pressures as Boissière et al. (2014a) found in a study to develop a multistakeholder system for monitoring non-timber forest products in six villages in rural Laos. The authors used community meetings, participatory mapping, scoring exercises, focus group discussions, village-level interviews and household surveys to identify key resources to be monitored. Then households used logbooks to record what they collected. Villagers hoped to use the monitoring as a negotiating tool with local authorities to gain more control over natural resources, but they also saw it as a distraction that provided no income. The project was significantly disrupted when a gold mine opened nearby: in three villages people stopped monitoring because they wanted to participate in the gold mining, and the other villages were negatively impacted by the mining activities. As a result, the authors were not able to follow the project all the way through the monitoring phase. This outcome shows how people's concerns about land and resources can be a lower priority compared to issues like livelihoods and income. The authors recommend including adaptive approaches to be able to adjust to unforeseen events.

Participatory monitoring has been found to help motivate participation in restoration projects "to sustain the hope of local people achieving the intended benefits of restoration" (Galabuzi et al. 2014, 729). This is particularly important, given that restoration projects see results slowly and over long timeframes. Galabuzi et al. (2014) explored the conditions for participation in forest restoration in 12 communities surrounding a forest reserve in Uganda. They conducted interviews and focus group discussions to understand what motivates people to be involved in various aspects of restoration, not just monitoring. They found that the main conditions for local participation in forest restoration are access rights and benefit sharing. Another condition is the promotion of locally important species, especially indigenous species. To maintain participation, regular sensitization is needed, including building skills like tree nursery establishment and tree planting, as well as monitoring. Furthermore, the authors found that community to community exchange visits help facilitate learning, demonstrate new ideas and generate interest in restoration. They found that local people need to be involved because restricting resource use simply does not work and can worsen forest degradation.

4 Proposed elements for designing a participatory monitoring system

This section presents a series of essential elements for the development of a participatory monitoring system for forest restoration, based on this review. This is not intended to be a step-by-step process but rather an aggregation of principles and considerations for setting up monitoring systems for large-scale forest restoration initiatives.

4.1 Set up a monitoring system and include a mechanism to oversee it

It is not enough to set up a monitoring protocol: there needs to be a monitoring system that supports data collection, aggregation, analysis and learning. This is the conclusion of one of the experts who has worked on the AFRP in Brazil. The AFRP set up a monitoring protocol in 2011 (and then a revised version in 2013) to bridge gaps between members of the pact, to facilitate the exchange of information between the many restoration projects and to encourage learning. After several years of working with the protocol, they found that few members were collecting the data: it was too complicated and had too many indicators. "We realized that we had to deliver a good monitoring system, not just a protocol" (P Brancalion, personal communication, 2016). They reduced the number of indicators and focused on creating the infrastructure for collecting and analyzing the data, including an online database and a mobile application for data entry. The new system is slated to be launched by the end of 2016. A fundamental lesson learned from this process is that the monitoring system itself must have a built-in capacity to learn and adapt.

Several experts advocate for the designation or establishment of an organization that is specifically responsible for organizing and overseeing the monitoring of restoration efforts (Cheng and Sturtevant 2012; K Holl, personal communication, 2016). One of the challenges for that organization would be to balance local needs with national and global needs – achieving the right mix of breadth and specificity and keeping local people motivated (Reed et al. 2016). The staff of the CFLR program agree that maintaining this balance is the biggest challenge across its 23 projects (L Buchanan, personal communication, 2016). Their solution is to have a small number of national indicators (five categories) and a pool of local ones to choose from. Likewise, the AFRP in Brazil decided to go with only a few 'high-level' indicators, and let locals choose more if they want (Brancalion et al. 2013). This balancing act between local and global needs could be facilitated by the establishment of national frameworks, as was suggested in the context of Latin America: "Latin American countries responding to international restoration calls should balance bottom-up initiatives and approaches with explicit policy frameworks and national-level planning to provide the necessary large-scale context" (Murcia et al. 2015, 6).

4.2 Dedicate funds for participatory monitoring

It is crucial to establish a dedicated budget for monitoring covering the length of the restoration initiative (Cheng and Sturtevant 2012). "Restoration financing should include not only the costs of the implementation on the ground but also the transfer of knowledge needed to guide effective action and adaptive management" (Chazdon et al. 2015, 7). Monitoring can actually save money in the long run; if problems are discovered early on, corrective action can be taken. This has been demonstrated repeatedly in restoration projects (Holl and Cairns 2002). In the CFLR program, 10% of project funding is dedicated to collaborative monitoring (L Buchanan, personal communication, 2016).

Given the long timeframes of forest restoration and the uncertainties and pressures facing forested areas, a large-scale forest restoration monitoring system will need dedicated funding for decades – ideally indefinitely – to be able to claim success and identify forest change, drivers and threats. This might necessitate securing the funding for monitoring in a savings mechanism (e.g. a trust fund or endowment) to ensure that funding is available beyond budgetary cycles.

4.3 Prepare to monitor: readiness, training and capacity building

When is local monitoring feasible? Several studies present frameworks for assessing local monitoring capacity. Boissière et al. (2014b) present a multidisciplinary approach to understanding local readiness for participatory monitoring in the context of REDD+, which might be applicable to forest restoration. They studied three sites in Indonesia and worked with an interdisciplinary team to develop three research models to explore local readiness. The social science model explores the enabling conditions for local participation, the governance analysis identifies existing monitoring systems in forestry and health, and the remote sensing model compares local and remote sensing assessments of forest cover change. The process can be used to identify stakeholders and the governance levels that should be involved in monitoring, and to answer the question as to how to make participation feasible and sustainable. Cheng and Sturtevant (2012) present a framework for assessing the collaborative capacity of community-based forest management in the United States, including restoration projects. It focuses on six areas of collaboration: organizing, learning, deciding, acting, evaluating and legitimatizing. The framework provides groups with a tool to assess what capacities they have or lack, and it can provide organizations with a way to identify where they need to invest in building and sustaining collaborative capacities. It could serve as a diagnostic for emerging or newly formed collaboratives to identify what they need to strengthen in order to prepare themselves for participatory monitoring. Danielsen et al. (2011) present a protocol for identifying where local REDD+ monitoring is appropriate, looking at key conditions that should be in place in the community, the forest, the government and the partner organization. They also outline a three-step process to establishing a local monitoring team.

Training and capacity building in preparation for the participatory monitoring activities are crucial. Torres et al. (2014) stress the need to build local capacities for participatory monitoring, including technical and organizational skills, and invest in technical resources, including computers, software, satellite imagery and an Internet connection. The investment in training local people makes a demonstrable difference. In a participatory mapping of forest change project in Panama, accuracy was high in one village because people had received a lot training in carbon projects over the past 10 years. "The preparation and training of local dwellers in interpreting basic aspects of aerial or satellite images becomes a fundamental step before any participatory mapping exercise takes place... the trainers should avoid complex aspects and terminologies of conventional scientific methods, and keep the training stage as simple as possible" (Vergara-Asenjo et al. 2015, 437).

Local people value and appreciate training, as was demonstrated in a community-based watershed monitoring project in Thailand. Villagers recommended that extension support staff ensure that enough time is spent on training in monitoring, including collecting, interpreting and using data, as well as building understanding about the importance of the data (Saipothong et al. 2006). A skilled, well-compensated regional staff is necessary to support local monitoring, and the restoration efforts must commit to maintaining local and regional training capacity (DellaSala et al. 2003). Understanding what conditions promote successful participatory monitoring requires further research. Saipathong et al. (2006) recommend a study of factors that help support monitoring activities, since volunteers must manage their time carefully.

4.4 Make the monitoring plans at the very beginning

Some experts argue that monitoring should be the very first activity: "[Community-based forest management monitoring] is in fact the first cycle of action research that builds community institutions and generates data for exploring the feasibility of alternative forest management options as well as data to improve existing forest management planning" (Scheyvens et al. 2014, 10). Monitoring plans should be closely linked with restoration goals and involve a range of stakeholders. The ultimate motivation for monitoring is, after all, (i) to ascertain whether the restoration effort is proceeding well and is yielding the expected outcomes and benefits for society and the environment, and (ii) to take the necessary measures in case the system is not behaving as expected and failure is a risk if no timely action is taken.

Several papers provide guidance in this process. Laake et al. (2013) present a table outlining the task and steps necessary to get community forest monitoring going, defining which steps require an intermediary and which ones communities can take autonomously. The CFLR program emphasizes the importance of planning the monitoring strategy at the outset of the initial project planning phases. The sequential steps of their multiparty monitoring process are outlined below in Figure 3 (Moote et al. 2010).

4.5 Set clear goals, objectives and targets collaboratively

Holl and Cairns (2002) emphasize the importance of setting clear goals at the outset for any forest restoration project. What constitutes restoration success must be agreed upon by all parties – and the goals should be simple. For most projects, this will be a process of negotiation, conversation and collaboration. Determining the goals of any restoration project requires responding to social questions and determining social values (Stanturf et al. 2014). According to Maginnis et al. (2015), stakeholder involvement should be a guiding principle of the process: "Actively engage local stakeholders in decisions regarding restoration goals, implementation methods and trade-offs… A well-designed process will benefit from the active voluntary involvement of local stakeholders." Forest restoration will almost always have multiple goals, ranging from improving the provision of ecosystem goods and services, and realizing positive social impacts, to biodiversity-related goals. Examples may

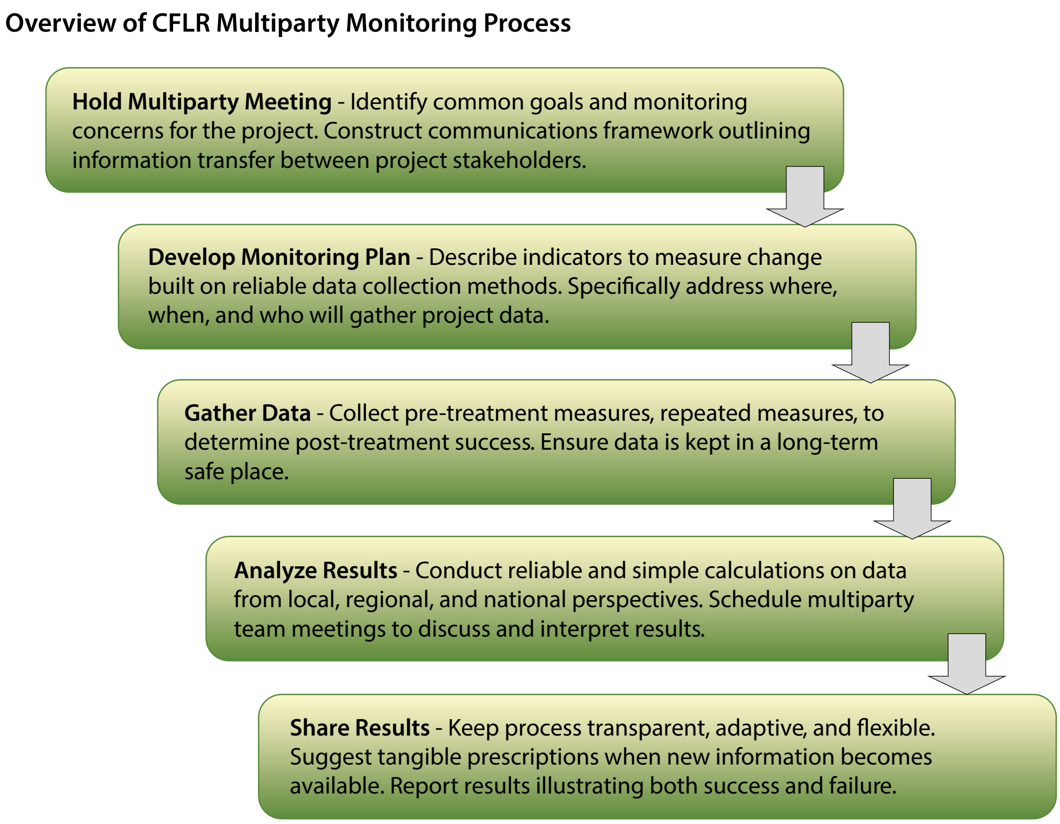

Figure 3. Steps in a multiparty monitoring process

CFLR = Collaborative Forest Landscape Restoration

Source: Moote et al. (2010)

include habitat creation, forest cover increase, water provision, job creation, fire control, erosion control and improving food security. Clearly, each one of the goals might have one or more indicators that can help determine if the project is moving toward that goal.

The next step is to translate what might be vague goals into feasible objectives and measurable targets that represent success. Success is a socially determined value (Stanturf et al. 2014) that may change over time, and forest restoration can be a long-term endeavor. Measures of success may also vary widely at different stages. Thus, it may be necessary to revisit targets and objectives based on changing notions of success. Box 2 outlines attempts to define success.

Box 2. Defining restoration success

Experts agree that establishing clear objectives or targets is crucial (Holl and Cairns 2002; SER 2004; Vallauri et al. 2005; Clewell and Aronson 2013; McDonald et al. 2016). However, there is no consensus on how to do so.

Many restoration experts advocate for identifying a reference site, a model ecological site that resembles the structure and function of a fully restored site (Clewell and Aronson 2013; McDonald et al. 2016). It can be an actual physical location that closely resembles what the restored site is hoped to look like in composition, structure and function after a certain number of years, or it can be a theoretical model based on attributes that are aggregated from various sites (SER 2004; McDonald et al. 2016). According to Clewell and Aronson (2013), a description of a reference site should include the following information: species composition, community structure, physical conditions of the abiotic environment, exchanges of organisms and materials that occur with the surrounding landscape, and anthropogenic influences on the ecosystem. When choosing an actual site as a reference, some criteria can help guide the selection: same ecological zone, close by and subject to similar natural disturbances (Ruiz-Jaen and Aide 2005). Sometimes, because a site may go through various phases of recovery, multiple reference sites may be necessary to determine how that site should look at those distinct phases of recovery (SER 2004; McDonald et al. 2016).

In practice, many restoration projects do not use a reference site, and some practitioners argue against it. In a literature review of monitoring in ecosystem restoration, Wortley et al. (2013) identified 301 papers over 28 years where ecosystem restoration was monitored beyond survival of plantings. The vast majority were in North America. Less than half of the projects used a reference site. Staff of the United States Collaborative Forest Landscape Restoration Project see reference sites as problematic because baselines shift as the restoration process advances, deciding what is an ideal site is inherently subjective and setting up appropriate random sampling methods between sites is not feasible (T DeMeo, personal communication, 2016).

No examples of participatory monitoring where a reference site was explicitly specified were found in this review. This may be because in restoration efforts with participation by local stakeholders, the targets are framed in terms of socioeconomic outcomes instead of ecological goals. For instance, in the case of farmer-managed natural regeneration in the Nigerien Sahel, the goal was not to recreate a forest ecosystem, but rather to increase tree cover to halt desertification and to provide firewood and other forest products using native trees. Farmers experimented with treatments that created the best possible outcomes for their individual needs (Tougiani et al. 2009). The Atlantic Forest Restoration Pact in Brazil intends to use its new monitoring protocol as a way of aggregating results to establish regional reference values for ecosystem types without using reference sites, per se. The reference values will be evaluated and adjusted in an iterative process as the restoration projects proceed. The only reference indicator is forest structure establishment at 70% canopy cover.

Ultimately, what is most important is that stakeholders at multiple levels are in agreement on the goals of the restoration initiative, regardless of whether a reference site is used.

4.6 Decide what to monitor: questions and indicators

Defining indicators is never easy. Selecting indicators "should be a collaborative interdisciplinary result of cooperative and diverse partnerships"(Dey and Schweitzer 2014, S53). When approached in a structured way and when given enough time and patience, it can be an invaluable process that also builds trust (Demeo et al. 2015) and elicits what is important to stakeholders (N Dudley, personal communication, 2016).

Le et al. (2012) witnessed many failed reforestation projects and abandoned nurseries in developing countries. They conclude that indicators that represent the drivers of reforestation success are ignored in the majority of assessments. They identified that what is needed is a monitoring framework that integrates both the indicators and the drivers of success. They reviewed the success indicators (performance measures) that have been applied in the tropics and internationally, and then related them to the key biophysical, environmental and socioeconomic drivers that affect success. In follow-on research, Le et al. (2014) tested this framework by surveying 43 restoration projects in the Philippines. They investigated 98 potential success drivers and measured 12 success indicators. They found the key drivers of reforestation success to be: revegetation method, funding source, education and awareness campaigns, the dependence of local people on forests, reforestation incentives, project objectives, forest protection mechanisms, and the condition of road infrastructure. They also found that the most important drivers of tree survival were grazing management (20x greater impact), weed control (18x greater impact) and whether road conditions were good (12x greater impact), because poor road conditions make it difficult to reforest sites or maintain them.

Practitioners of participatory monitoring have found that, instead of focusing on indicators at the outset, it can be more useful for local stakeholders to construct questions that ask what information is needed for decision making to support restoration objectives (Lawrence et al. 2006; Kusumanto 2007; Demeo et al. 2015). Box 3 presents a list of guiding questions to support the formulation of monitoring questions. Demeo et al. (2015) describe their question development process with one collaborative group in the Pacific Northwest of the United States. They presented an initial 65 questions in a workshop and then narrowed them down to 9 questions later on. A predetermined set of criteria for each question was related to a specific restoration goal, and then the indicator that answers those questions was determined. They emphasize the collaborative nature of the question development process: "The process should facilitate an environment of mutual learning and successive refinement rather than one of opposition or blame. In this way, the group owns failures as well as successes" (Demeo et al. 2015, 10). The process takes time, and it can take multiple iterations: "Go slow to go fast" is the guiding phrase of the CFLR program. Investing time at the outset in developing the questions and the monitoring approaches sets the restoration projects up for more efficient, smoother and more effective monitoring, with less conflict among stakeholders. The workshops to identify local indicators can take the course of a year. Often a large number of indicators come out of first meetings, and so there must be a plan to pare them down, such as identifying a subcommittee charged with that task. They learned that having fewer indicators is better.

Box 3. What monitoring questions should be used?

Does the question:

- meet a core objective of the project?
- meet other specified and agreed upon collaborative goals?
- facilitate learning (adaptive management)?
- facilitate the decision-making process?
- address something new, and if not, what results are currently available?
- address the appropriate spatial scale?

Is the question:

- cost effective and practical to implement?
- outcome focused?
- adequately representative of social, economic and ecological issues?
- agreed upon by the collaborative (i.e. everyone has access to the process, has offered input and is committed to seeing the question through)?

Source: (Demeo et al. 2015)

Table 3. Shared indicators in two participatory large-scale restoration monitoring efforts.

	Collaborative Forest Landscape Restoration program (United States)	Atlantic Forest Restoration Pact (Brazil)
National indicators	– Economic impacts – Fire risk and costs – Ecological condition – Collaboration – Leveraged funds (Note: These are categories of indicators, with multiple indicators per category)	Ecological indicators: canopy cover; density and richness of regenerating plant community Socioeconomic indicators: number of jobs and daily income; how these jobs are distributed (male/female); restoration investments (total costs and costs distribution – materials, taxes, profit from restoration companies, labor, etc.); and economic benefits (payment for environmental services, timber exploitation, tourism, tax reduction)

A scalable, multisite participatory monitoring system for forest restoration may well find it useful to have a small set of national or global indicators, and then individual restoration projects can select additional indicators specific to each site's needs. This is the case for the two examples of such multilevel systems found for this review, the CFLR program and the AFRP. The CFLR program identified five shared national indicators, and locals can pick more specific ones. The most recent version of the monitoring protocol for AFRP has only seven shared indicators, and local projects can decide to add other indicators if they choose. Table 3 outlines the shared indicators in these two systems.

Once the indicators are determined, some experts recommend defining milestones along the path to each objective. These milestones help gauge if the rate of progress is on track. In addition to milestones, 'trigger points' along that path can be helpful – if the data reaches a trigger, then certain corrective actions should be taken (Holl and Cairns 2002; Dey and Schweitzer 2014).

4.7 Pick appropriate monitoring methodologies and technologies

Once the monitoring questions and indicators have been determined, the methods used to collect, analyze and share the data must be decided. This section shares one approach to making those decisions, and presents several technology tools that have been used in the field for data collection and information sharing. Many methods can be applied in monitoring forest restoration in a participatory way. Instead of presenting all of the possibilities here, a selection of them are organized into a table in Appendix B to make it easier to locate information on specific methods.

Experts recommend methods that are easy to use, participatory and verifiable, and that generate the appropriate level of accuracy (Holl and Cairns 2002; Danielsen et al. 2011; Laake et al. 2013; Skutsch et al. 2014). The CFLR program relies on the 'continuum of evidence' approach, where only the level of rigor needed to answer a question adequately is used, not the most scientifically rigorous approach: "the approximate answer arrived at quickly is often more valuable than the precise answer a year from now" (Demeo et al. 2015, 6). The authors advise against developing individual monitoring elements in isolation; these tend to drift toward research-focused monitoring methods, instead of focusing on answering the monitoring questions established by stakeholders. Defining the methods needs to be a collaborative process (Demeo et al. 2015).

4.7.1 Digital data collection

Several studies found that using digital tools, (e.g. smartphones, GPS, personal digital assistants, etc.) for data collection can have advantages over pen and paper under certain conditions (Laake et al. 2013; Pratihast et al. 2014; Bellfield et al. 2015; Brammer et al. 2016). Brammer et al. (2016) reviewed 107 cases of participatory monitoring to understand the degree to which using digital tools in the field benefits or detracts from participatory monitoring. Two out of three participatory monitoring projects use pen and paper instead of digital devices. However, they found advantages to digital devices for those projects that did use them: reducing errors, improving accuracy, reducing processing time and making data more useful for analysis and decision making. There are disadvantages too, such as the cost of ongoing training and technical support and alienation of groups who may be less familiar with digital tools, such as women, older people and marginalized groups. Some groups may be suspicious of the technology, and some concerns about data ownership and the control of sensitive information are legitimate. On the other hand, engaging youth is an advantage, and technology sometimes connects younger people and older members of a community. The authors conclude that participatory monitoring benefits from digital devices only if there is already a strong foundation in place of collaboratively defined questions, objectives and approaches. Digital data entry increases the capacity of the monitoring program to share information with other stakeholders at multiple levels and integrate with remote sensing, but it also makes a program more dependent on outside expertise and support. Pratihast et al. (2014) compared the forest activity data collected by two groups of local community members in Ethiopia. One group used pen and paper, and the other group used smartphones with GPS, cameras and a data-entry application. The group with the smartphones said that the devices made data entry simpler and made it easier to communicate results to other community members. Data was also immediately accessible for analysis and could be integrated with top-down monitoring programs and remote sensing.

An online monitoring data collection application is being developed for AFRP by the Nature Conservancy (P Brancalion, personal communication, 2016). It will be used to collect field data and send it to a web-based registry and assessment tool (Brancalion et al. 2014; Pinto et al. 2014). An open-source application called Open Data Kit has been used to create customized forms, such as FormHub, for entering participatory monitoring data into a shared database through Android smartphones. These can be used offline when in the field and then connected to the database when cell service is available (Laake et al. 2013; Ferrari et al. 2015). Cybertracker was developed in Southern Africa and has been used widely by indigenous groups in Australia (Brammer et al. 2016) as well as in experimental REDD+ monitoring, reporting and verification projects in Mexico (Peters-Guarin and McCall 2010). Its icon-based interface for identifying wildlife is easy to use by people with varying levels of education, even those who are not literate, and minimal exposure to technology.

Some of these applications and digital tools may also help to bridge the gap between participatory and scientific monitoring, because some of the more technical aspects of sampling and data analysis procedures can be automated and put into the hands of local monitors. This can further empower local monitors to collect data, get results in real time, associate results with reference values to judge whether results are good or not and, eventually, to make a decision while on-site as to what kind of corrective intervention is needed. Social media also has the potential to be used in participatory monitoring, to link local people with external supporters of restoration – for example by making monthly videos of the site, or posting photos of animals.

4.7.2 Imaging technologies and tools

Imaging and remote sensing technologies are becoming more accessible and affordable for use at the local level. For instance, Landsat images are now downloadable for free (Burton 2014) and drones are being used for imagery (Burton 2014; Zahawi et al. 2015); however, there are questions as to how participatory the process can be because significant technical knowledge is required to process and interpret the images (K Holl, personal communication, 2016).

Photo point monitoring is considered a simple yet effective way for local people to collect information that can be discussed and analyzed collaboratively (Danielsen et al. 2000). In a participatory monitoring research project with the indigenous Pueblo of Zuni, in New Mexico, United States, local monitors used photos taken at the same point over the course of two years. These images were used together with data collected on tree density, basal area, species, tree diameter, canopy cover and ground cover to respond to their questions about whether restoration treatments (e.g. thinning) were improving resilience to fire and wildlife habitat. The paired pre- and post-treatment photographs provided an effective visual representation of change to aid in discussion and analysis of the effectiveness of the interventions (Schumann and Waikaniwa 2004).

4.7.3 Collaboration and decision-support tools and approaches

Monitoring methods can promote local discussion and interpretation of the findings during the monitoring process, often leading to decisions that are locally meaningful. Danielsen et al. (2014b) found that focus group discussions of forest resources in indigenous communities in Nicaragua led not only to accurate assessments of biodiversity, but also contributed to empowerment and learning. Fieldtrips can provide opportunities for people who might not be collecting monitoring data themselves to visit the restoration sites, informally monitor change, and discuss and analyze collaboratively. The CFLR program found that fieldtrips to restoration sites provide catalytic opportunities for local stakeholders – who may have had disagreements – to see the restoration activities and impacts, learn together, build trust and overcome differences (T DeMeo, personal communication, 2016). Evans et al. (2014) discuss the value of organizing short monitoring fieldtrips with community members to see reforested areas in indigenous communities in Nicaragua. Community members quickly learned how to take tree growth measurements and reflected on the results on the spot: they saw for themselves if the trees were growing and recognized that weeding was needed if the trees were to survive.

Presenting the monitoring results to stakeholders in a meaningful way is just as important as collecting the data. Some restoration projects have adopted a visualization tool based on a traffic light – with simple markers of green, yellow and red – to show whether certain activities have reached success, are moving in the right direction or if they need to be addressed (Doren et al. 2009; Stanturf et al. 2015) (See Table 1). Another tool used to present monitoring results is a 'progress wheel' (McDonald et al. 2016) (See Figure 4). The progress wheel illustrates the degree to which a restoration initiative is achieving the goals agreed during project design over a specific time period. Six attributes are represented, with various subattributes. Indicators of progress are assessed and shaded in as they are achieved, on a scale of 1 (low) to 5 (full achievement).

Several technologies have been used to share monitoring results more widely, especially where obstacles like long distances or poor Internet access present challenges. These include local radio broadcasts (Stankovich et al. 2013) and instant messaging to alert stakeholders about problems and/or changes (Stankovich et al. 2013; Ferrari et al. 2015).

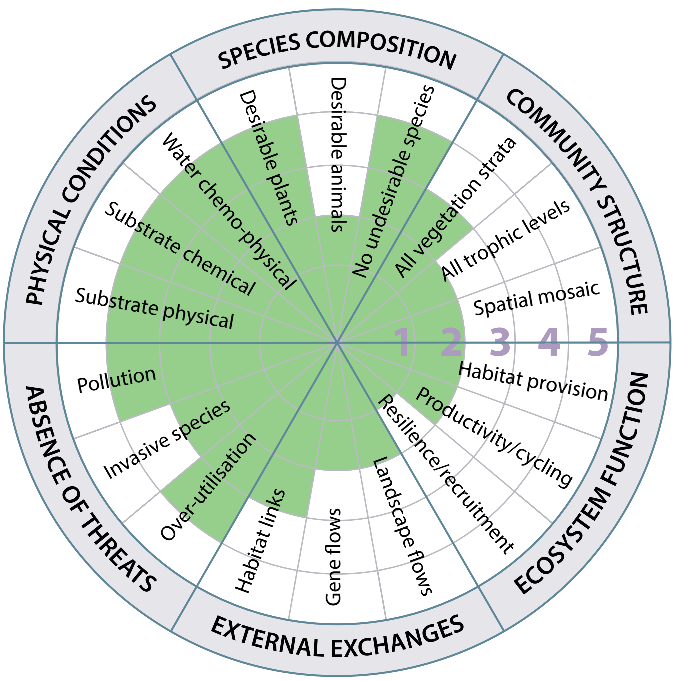

Figure 4. The progress wheel
Source: McDonald et al. (2016)

Several existing monitoring and decision-support tools may be useful to forest restoration projects (Ouya 2014). The Land Degradation Surveillance Framework provides systematic and comparable assessments of ecosystem health (Landscape Portal 2016). The Toolkit for Ecosystem Service Site-based Assessment (TESSA) allows users to evaluate and decide on appropriate interventions for forest restoration before, during and after implementation. TESSA tracks progress in achieving targets related to five ecosystem services: climate, harvested wild goods, water, nature-based recreation and cultivated goods (TESSA Tools 2016). The Biodiversity Indicators Partnership (BIP) indicator toolkit guides practitioners in the design of appropriate indicators for measuring the state of biodiversity and ecosystem health at various points in forest restoration programs (BIP 2016).

4.8 Involve women and marginalized groups

It may take special strategies to involve women (Mwangi et al. 2011; Evans et al. 2014), depending on the sociocultural context. These may include organizing mixed-gender monitoring groups or special outreach efforts to ensure that technical resources and training reach women (Mwangi et al. 2011). Community-based resource monitoring in Brazil specifically prioritized women's participation in some monitoring protocols (Constantino et al. 2012). Evans et al. (2014) found that collaborative monitoring of the participation of women in activities (e.g. keeping a tally of how often women spoke at meetings, and then presenting and discussing the results at the end of the meeting) opened up spaces for reflecting on the barriers and opportunities to women taking a greater role in activities related to natural resource management, including reforestation monitoring.

4.9 Encourage social learning and learning networks

Multiple cases demonstrate that participatory monitoring catalyzes learning cycles and adaptive management among the stakeholders in a project (Guijt 2007; Fernandez-Gimenez et al. 2008). However, scalable, multisite forest restoration monitoring systems have the potential to link monitoring results so that restoration projects can share information and learn from each other. In order to operationalize learning in the context of restoration, Oosten (2013b) finds it useful to define 'communities of practice' as the group of people who are concerned about a local issue or problem. A social learning system thus networks these communities of practice into a constellation-like system. This can be done through the creation of organizations, websites, meetings, workshops and conferences that encourage people to interact regularly to learn how to do things better.

In the case of Nigerien farmer-managed natural regeneration, initially people worked in isolation. They then created learning networks at multiple levels (peer-to-peer, through the forestry service and a website etc.) which catalyzed the transformation of 5 million hectares of degraded land into wooded plots (Smale 2009; Tougiani et al. 2009).

Creating similar cross-scale linkages to learn, share and improve restoration projects is the primary motivation for Brazil's AFRP to develop its monitoring system (Pinto et al. 2014). The new monitoring system will provide the opportunity for members to compare progress with other projects via the monitoring website.

5 A proposed framework

This review has examined a range of considerations related to participatory monitoring in forest restoration. Hopefully it has provided insights that can contribute to discussions about how to link forest restoration monitoring efforts through a framework that responds to both the global need to track compliance and a local need for meaningful information for decision making.

Scalable, multisite, participatory monitoring systems for forest restoration have a clear role to play in efforts to track progress, provide accountability and create a framework for learning and adaptation. Existing models, cases and lessons learned can be built upon: the United States' CFLR program, Brazil's AFRP, FMNR in the Sahel and others. What needs to be monitored is increasingly well understood: not just tree planting, but drivers of success, local concerns and forest change.

There are, however, knowledge gaps: information on monitoring costs is still incomplete, as is our understanding of the conditions that provide motivation and support for local participation. Also, more testing is needed of data collection methods specifically geared to forest restoration monitoring approaches for local and global decision making. There seems to be no published evidence of a multilevel participatory monitoring system where information and learning link local and global stakeholders, although it may be useful to look to at public health systems for models (J Aronson, personal communication, 2016).

Forest restoration planning is underway at the global level; now is the ideal time to begin developing and testing a participatory monitoring framework. Figure 5 represents a proposed learning-oriented adaptive approach that emphasizes local input in the process, to define success from the ground up.

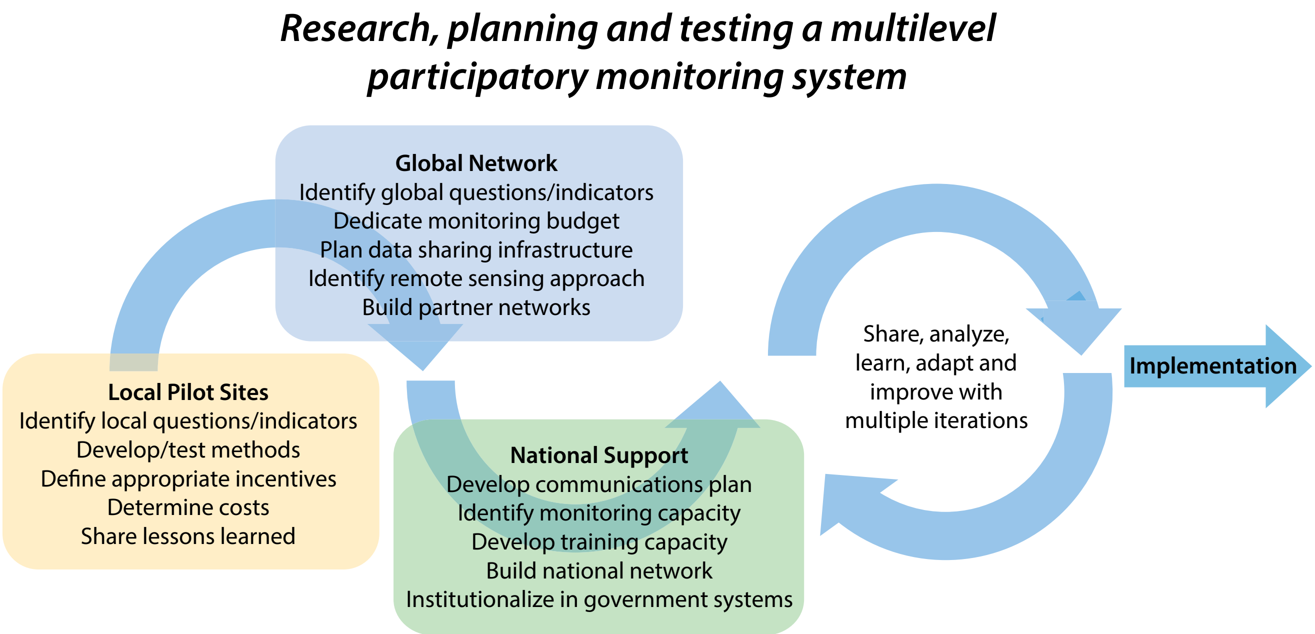

Figure 5. A proposed multilevel participatory monitoring system

References

[AFRP] Atlantic Forest Restoration Pact. 2013. *Monitoring Protocol for Forest Restoration Programs & Projects*. Brazil: AFRP.

Aronson J and Alexander S. 2013. Ecosystem restoration is now a global priority: Time to roll up our sleeves. *Restoration Ecology* 21(3):293–96. doi:10.1111/rec.12011

Bebbington A. 1999. Capitals and capabilities: A framework for analyzing peasant viability, rural livelihoods and poverty. *World Development* 27(12):2021–44. doi:10.1016/S0305-750X(99)00104-7

Bellfield H, Sabogal D, Goodman L and Leggett M. 2015. Case study report: Community-based monitoring systems for REDD+ in Guyana. *Forests* 6(1):133–56. doi:10.3390/f6010133

Berrahmouni N, Regato P and Parfondry M. 2015. *Global Guidelines for the Restoration of Degraded Forests and Landscapes in Drylands: Building Resilience and Benefiting Livelihoods*. Forestry Paper No. 175. Rome: Food and Agriculture Organization of the United Nations.

[BIP] Biological Indicators Partnership. Accessed 7 September 2016. http://www.bipindicators.net/

Blay D, Appiah M, Damnyag L, Dwomoh F, Luukkanen O and Pappinen A. 2008. Involving local farmers in rehabilitation of degraded tropical forests: Some lessons from Ghana. *Environment, Development & Sustainability* 10(4):503–18. doi:10.1007/s10668-006-9077-9

Boissière M, Bastide F, Basuki I, Pfund J and Boucard A. 2014a. Can we make participatory NTFP monitoring work? Lessons learnt from the development of a multi-stakeholder system in northern Laos. *Biodiversity & Conservation* 23(1):149–70. doi:10.1007/s10531-013-0589-y

Boissière M, Beaudoin G, Hofstee C and Rafanoharana S. 2014b. Participating in REDD+ measurement, reporting, and verification (PMRV): Opportunities for local people? *Forests* 5(8):1855–78. doi:10.3390/f5081855

Brammer JR, Brunet ND, Burton AC, Cuerrier A, Danielsen F, Dewan K, Herrmann TM, Jackson MV, Kennett R, Larocque G, et al. 2016. The role of digital data entry in participatory environmental monitoring. *Conservation Biology* 30(6):1277–87. doi:10.1111/cobi.12727

Brancalion PHS, Cardozo IV, Camatta A, Aronson J and Rodrigues RR. 2014. Cultural ecosystem services and popular perceptions of the benefits of an ecological restoration project in the Brazilian Atlantic forest. *Restoration Ecology* 22(1): 65–71. doi:10.1111/rec.12025

Brancalion PHS, Viani RAG, Calmon M, Carrascosa H and Rodrigues RR. 2013. How to organize a large-scale ecological restoration program? The framework developed by the Atlantic Forest Restoration Pact in Brazil. *Journal of Sustainable Forestry* 32(7):728–44. doi:10.1080/10549811.2013.817339

Brofeldt S, Theilade I, Burgess ND, Danielsen F, Poulsen MK, Adrian T, Bang TN, Budiman A, Jensen J, Jensen AE, et al. 2014. Community monitoring of carbon stocks for REDD+: Does accuracy and cost change over time? *Forests* 5(8):1834–54. doi:10.3390/f5081834

Burton PJ. 2014. Considerations for monitoring and evaluating forest restoration. *Journal of Sustainable Forestry* 33(sup1):S149–60. doi:10.1080/10549811.2014.884001

Chazdon RL, Brancalion PHS, Lamb D, Laestadius L, Calmon M and Kumar C. 2015. A policy-driven knowledge agenda for global forest and landscape restoration. *Conservation Letters*. doi:10.1111/conl.12220

Cheng AS and Sturtevant V. 2012. A framework for assessing collaborative capacity in community-based public forest management. *Environmental Management* 49(3):675–89. doi:10.1007/s00267-011-9801-6

Clewell AF and Aronson J. 2013. Ecological references. *Ecological Restoration*: *Principles, Values, and Structure of an Emerging Profession*. Washington, DC, USA: Island Press and Center for Resource Economics. 137–53. http://link.springer.com/chapter/10.5822/978-1-59726-323-8_7

Colfer CJP. 2005. *The Complex Forest: Communities, Uncertainty, and Adaptive Collaborative Management*. Washington DC, USA and Bogor, Indonesia: Resources for the Future and Center for International Forestry Research.

Constantino PAL, Carlos HAS, Ramalho EE, Rostant L, Marinelli CE, Teles D, Fonseca SF, Fernandes RB, and Valsecchi J. 2012. Empowering local people through community-based resource monitoring: A comparison of Brazil and Namibia. *Ecology and Society* 17(4):22. http://www.ecologyandsociety.org/vol17/iss4/art22/

Convention on Biological Diversity. 2010. *Aichi Biodiversity Targets*. Montreal, Canada: Convention on Biological Diversity. Accessed 18 November 2016. https://www.cbd.int/sp/targets/

Cooke B and Kothari U. 2001. *Participation: The New Tyranny?* London; New York: Zed Books.

Danielsen F, Adrian T, Brofeldt S, van Noordwijk M, Poulsen MK, Rahayu S, Rutishauser E, Theilade I, Widayati A and The An A, et al. 2013. Community monitoring for REDD+: International promises and field realities. *Ecology and Society* 18(3):41. doi:10.5751/ES-05464-180341

Danielsen F, Balete DS, Poulsen MK, Enghoff M, Nozawa CM and Jensen AE. 2000. A simple system for monitoring biodiversity in protected areas of a developing country. *Biodiversity & Conservation* 9(12):1671–705. doi:10.1023/A:1026505324342

Danielsen F, Burgess ND and Balmford A. 2005. Monitoring matters: Examining the potential of locally-based approaches. *Biodiversity & Conservation* 14(11):2507–42. doi:10.1007/s10531-005-8375-0

Danielsen F, Mendoza MM, Tagtag A, Alviola PA, Balete DS, Jensen AE, Enghoff M and Poulsen MK. 2007. Increasing conservation management action by involving local people in natural resource monitoring. *AMBIO: A Journal of the Human Environment* 36(7):566–70. doi:10.1579/0044-7447(2007)36[566:ICMABI]2.0.CO;2

Danielsen F, Burgess ND, Balmford A, Donald PF, Funder M, Jones JPG, Alviola P, Balete DS, Blomley T, Brashares J, et al. 2009. Local participation in natural resource monitoring: A characterization of approaches. *Conservation Biology* 23(1):31–42. doi:10.1111/j.1523-1739.2008.01063.x

Danielsen F, Burgess ND, Jensen PM and Pirhofer-Walzl K. 2010. Environmental monitoring: The scale and speed of implementation varies according to the degree of peoples involvement. *Journal of Applied Ecology* 47(6):1166–68. doi:10.1111/j.1365-2664.2010.01874.x

Danielsen F, Skutsch M, Burgess ND, Jensen PM, Andrianandrasana H, Karky B, Lewis R, Lovett JC, Massao J and Ngaga Y. 2011. At the heart of REDD+: A role for local people in monitoring forests? *Conservation Letters* 4(2):158–67.

Danielsen F, Jensen PM, Burgess ND, Altamirano R, Alviola PA, Andrianandrasana H, Brashares JS, Burton AC, Coronado I, Corpuz N, et al. 2014a. A multicountry assessment of tropical resource monitoring by local communities. *BioScience* 64(3): 236–51. doi:10.1093/biosci/biu001

Danielsen F, Jensen PM, Burgess ND, Coronado I, Holt S, Poulsen MK, Rueda RM, Skielbo T, Enghoff M, Hemmingsen M, et al. 2014b. Testing focus groups as a tool for connecting indigenous and local knowledge on abundance of natural resources with science-based land management systems. *Conservation Letters* 7(4):380–89. doi:10.1111/conl.12100

Danielsen F, Pirhofer-Walzl K, Adrian TP, Kapijimpanga DR, Burgess ND, Jensen PM, Bonney R, Funder M, Landa A, Levermann N, et al. 2014c. Linking public participation in scientific research to the indicators and needs of international environmental agreements. *Conservation Letters* 7(1):12– 24. doi:10.1111/conl.12024

DellaSala DA, Martin A, Spivak R, Schulke T, Bird B, Criley M, van Daalen C, Kreilick J, Brown R and Aplet G. 2003. A citizen's call for ecological forest restoration: Forest restoration principles and criteria. *Ecological Restoration* 21(1):15. http://www.wildwestinstitute.org/pdf/Restoration%20Principles.pdf

Demeo T, Markus A, Bormann B and Leingang J. 2015. *Tracking progress: The Monitoring Process Used in Collaborative Forest Landscape Restoration Projects in the Pacific Northwest*

Region. Working Paper Number 54. Ecosystem Workforce Program. Eugene, Oregon: University of Oregon.

Dewees P. 2013. *Bouncing Back: Forests, Trees, and Resilient Households.* Working Paper prepared for the International Conference on Forests for Food Security and Nutrition, Rome, 13–15 May 2013. Washington, DC, USA: Program on Forests.

Dey DC and Schweitzer CJ. 2014. Restoration for the future: Endpoints, targets, and indicators of progress and success. *Journal of Sustainable Forestry* 33(sup1):S43–65. doi:10.1080/10549811.2014.883999

Doren RF, Trexler JC, Gottlieb AD and Harwell MC. 2009. Ecological indicators for system-wide assessment of the Greater Everglades Ecosystem Restoration Program. *Ecological Indicators*, Indicators for Everglades Restoration 9(6sup):S2–16. doi:10.1016/j.ecolind.2008.08.009

Dudley N, Cu N and Manh VT. 2003. *A Monitoring and Evaluation System for Forest Landscape Restoration in the Central Truong Son Landscape, Vietnam*. Hanoi, Vietnam: WWF Indochina Programme and Government of Vietnam.

[ELTI] Environmental Leadership and Training Initiative. 2015. *National Greening Program Monitoring Workshop*. Workshop Report. 23–27 January 2015. Cebu, Philippines: ELTI.

Enda Dominicana. 2015. *Levantamiento Y Medición de Parcela de Regeneración En Seboruco*. Enda Dominicana. Accessed 18 November 2016. http://www.endadom.org.do/2015/09/levantamiento-y-medicion-de-parcela-de-regeneracion-seboruco/

Evans K and Guariguata MR. 2008. *Participatory Monitoring in Tropical Forest Management: A Review of Tools, Concepts and Lessons Learned*. Bogor, Indonesia: Center for International Forestry Research. http://www.cifor.org/publications/pdf_files/Books/BGuariguata0801.pdf

Evans K, Larson AM, Mwangi E, Cronkleton P, Maravanyika T, Hernandez X, Müller P, Pikitle A, Marchena R, Mukasa C, et al. 2014. *Field Guide to Adaptive Collaborative Management and Improving Women's Participation*. Bogor, Indonesia: Center for International Forestry Research.

Fernandez-Gimenez ME, Ballard HL and Sturtevant VE. 2008. Adaptive management and social learning in collaborative and community-based monitoring: A study of five community-based forestry organizations in the western USA. *Ecology and Society* 13(2):4.

Ferrari MF, de Jong C and Belohrad VS. 2015. Community-based monitoring and information systems (CBMIS) in the context of the Convention on Biological Diversity (CBD). *Biodiversity* 16(2–3):57–67. doi:10.1080/14888386.2015.1074111

Funder M, Danielsen F, Ngaga Y, Nielsen MR and Poulsen MK. 2013. Reshaping conservation: The social dynamics of participatory monitoring in Tanzania's community-managed forests. *Conservation & Society* 11(3):218–32. doi:10.4103/0972-4923.121011

Galabuzi C, Eilu G, Mulugo L, Kakudidi E, Tabuti J and Sibelet N. 2014. Strategies for empowering the local people to participate in forest restoration. *Agroforestry Systems* 88(4):719–34. doi:10.1007/s10457-014-9713-6

Global Landscapes Forum. 2015. *Putting Restoration Pledges into Practice*. Presentation at the Global Landscapes Forum, COP21, Paris, 5–6 December 2015. https://youtu.be/u_hTTr5mAGE

Green Belt Movement. 2016. *Participatory GIS Mapping in Kirisia Forest, Samburu County.* Nairobi, Kenya: Green Belt Movement. Accessed 19 November 2016. http://www.greenbeltmovement.org/node/455

Guijt I, ed. 2007. *Negotiated Learning: Collaborative Monitoring in Forest Resource Management*. Washington, DC, USA: Resources for the Future.

Hanson C, Buckingham K, DeWitt S and Laestadius L. 2015. *The Restoration Diagnostic: A Method for Developing Forest Landscape Restoration Strategies by Rapidly Assessing the Status of Key Success Factors*. Washington, DC, USA: World Resources Institute. http://www.wri.org/publication/restoration-diagnostic.

Hockings M. 2003. Systems for assessing the effectiveness of management in protected areas. *BioScience* 53(9):823–32. doi:10.1641/0006-3568(2003)053[0823:SFATEO]2.0.CO;2

Holck MH. 2007. Participatory forest monitoring: An assessment of the accuracy of simple cost–effective methods. *Biodiversity and Conservation* 17(8):2023–36. doi:10.1007/s10531-007-9273-4

Holl KD and Cairns J. 2002. Monitoring and appraisal. *Handbook of Ecological Restoration*. Cambridge, United Kingdom: Cambridge University Press. 1:411–32.

[IIPFCC] International Indigenous Peoples' Forum on Climate Change. 2013. *International Indigenous Peoples' Forum on Climate Change (IIFPCC)*. Statements at the 38th Sessions of the Subsidiary Bodies to the UNFCCC, Bonn, Germany. 6–14 June 2013. Moreton-in-Marsh, United Kingdom: Forest Peoples Programme. Accessed 19 November 2016 http://www.forestpeoples.org/topics/redd-and-related-initiatives/news/2013/06/international-indigenous-peoples-forum-climate-chan.

Izurieta A, Sithole B, Stacey N, Hunter-Xenie H, Campbell B, Donohoe P, Brown J and Wilson L. 2011. Developing indicators for monitoring and evaluating joint management effectiveness in protected areas in the Northern Territory, Australia. *Ecology and Society* 16(3). doi:10.5751/ES-04274-160309

Krause T and Zambonino H. 2013. More than just trees – Animal species diversity and participatory forest monitoring in the Ecuadorian Amazon. *International Journal of Biodiversity Science, Ecosystem Services & Management* 9(3):225–38. doi:10.1080/21513732.2013.822930

Kumar C, Begeladze S, Calmon M and Saint-Laurent C, eds. 2015. *Enhancing Food Security through Forest Landscape Restoration: Lessons from Burkina Faso, Brazil, Guatemala, Viet Nam, Ghana, Ethiopia and Philippines*. Gland, Switzerland: International Union for Conservation of Nature.

Kusumanto T. 2007. Learning to monitor political processes for fairness in Jambi, Indonesia. *In* Guijt I ed. *Negotiated Learning: Collaborative Monitoring in Forest Resource Management.* Washington DC, USA: Resources for the Future.

Laake P van, Skutsch M and McCall MK. 2013. Community forest monitoring. *In* Achard F et al., eds. *Reducing Greenhouse Gas Emissions from Deforestation and Degradation in Developing Countries: A Sourcebook of Methods and Procedures for Monitoring Measuring and Reporting*. Wageningen, Netherlands: Global Observation of Forest Cover and Land Dynamics (GOFC-Gold). 187–202. http://www.gofcgold.wur.nl/redd/index.php

Lamb D, Erskine PD and Parrotta JA. 2005. Restoration of degraded tropical forest landscapes. *Science* 310(5754):1628–32. doi:10.1126/science.1111773

Landscape Portal. 2016. *The Land Degradation Surveillance Framework (LDSF)*. Accessed 19 November 2016. http://landscapeportal.org/ldsf/

Lawrence A, Paudel K, Barnes R and Malla Y. 2006. Adaptive value of participatory biodiversity monitoring in community forestry. *Environmental Conservation* 33(4):325. doi:10.1017/S0376892906003432

Le HD, Smith C, Herbohn J and Harrison S. 2012. More than just trees: Assessing reforestation success in tropical developing countries. *Journal of Rural Studies* 28(1):5–19. doi:10.1016/j.jrurstud.2011.07.006

Le HD, Smith C and Herbohn J. 2014. What drives the success of reforestation projects in tropical developing countries? The case of the Philippines. *Global Environmental Change* 24:334–48. doi:10.1016/j.gloenvcha.2013.09.010.

Le Tellier V, Carrasco A and Asquith N. 2009. Attempts to determine the effects of forest cover on stream flow by direct hydrological measurements in Los Negros, Bolivia. *Forest Ecology and Management* 258(9):1881–88. doi:10.1016/j.foreco.2009.04.031

Maginnis S and Jackson W. 2007. What is FLR and how does it differ from current approaches? *In* Rietbergen-McCracken J, Magginis S and Sarre A, eds. *The Forest Landscape Restoration Handbook*. London, United Kingdom: Earthscan.

Maginnis S, Laestadius L, Verdone M, DeWitt S, Saint-Laurent C, Rietbergen-McCracken J and Shaw DMP. 2015. *A Guide to the Restoration Opportunities Assessment Methodology (ROAM): Assessing Forest Landscape Restoration Opportunities at the National or Sub-National Level*. Gland, Switzerland: International Union for Conservation of Nature. https://portals.iucn.org/library/node/44852

Mansourian S, Vallauri D and Dudley N. 2005. *Forest Restoration in Landscapes: Beyond Planting Trees*. Springer Science & Business Media. https://books.google.com/books?id=V-noMq-iPsMC&lpg=PR21&ots=4viI89Ke52&dq=forest%20restoration%20participatory%20monitoring&lr&pg=PA7#v=onepage&q=forest%20restoration%20participatory%20monitoring&f=false

McDonald T, Jonson J and Dixon KW. 2016. National standards for the practice of ecological restoration in Australia. *Restoration Ecology* 24(S1):S1–S3. doi:10.1111/rec.12359

Mills AJ, van der Vyver M, Gordon IJ, Patwardhan A, Marais C, Blignaut J, Sigwela A and Kgope B. 2015. Prescribing innovation within a large-scale restoration programme in degraded subtropical thicket in South Africa. *Forests* 6(11):4328–48. doi:10.3390/f6114328

Mogoi J, Obonyo E, Ongugo P, Oeba V and Mwangi E. 2012. Communities, property rights and forest decentralisation in Kenya: Early lessons from participatory forestry management. *Conservation and Society* 10(2):182–94.

Moote A, Savage M, Abrams J, Derr T, Krasilovsky E and Schumann M. 2010. *Multiparty Monitoring and Assessment of Collaborative Forest Restoration Projects – Short Guide for Grant Recipients*. Las Vegas, New Mexico: Ecological Restoration Institute and New Mexico Forest and Watershed Restoration Institute. http://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5274477.pdf.

Murcia C, Guariguata MR, Andrade A, Andrade GI, Aronson J, Escobar EM, Etter A, Moreno FH, Ramírez W and Montes E. 2015. Challenges and prospects for scaling-up ecological restoration to meet international commitments: Colombia as a case study. *Conservation Letters* 9(3):213–220. doi:10.1111/conl.12199

Mwangi E, Meinzen-Dick R and Sun Y. 2011. Gender and sustainable forest management in East Africa and Latin America. *Ecology and Society* 16(1)17. http://www.ecologyandsociety.org/vol16/iss1/art17/

Newton AC, del Castillo RF, Echeverría C, Geneletti D, González-Espinosa M, Malizia LR, Premoli AC, Rey Benayas JM, Smith-Ramírez C and Williams-Linera G. 2012. Forest landscape restoration in the drylands of Latin America. *Ecology & Society* 17(1):268–94.

Nielsen MR and Lund JF. 2012. Seeing white elephants? The production and communication of information in a locally-based monitoring system in Tanzania. *Conservation and Society* 10(1):1–14. doi:10.4103/0972-4923.92188

Oosten C van. 2013a. Forest landscape restoration: Who decides? A governance approach to forest landscape restoration. *Brazilian Journal of Nature Conservation* 11(2):119–26.

Oosten C van. 2013b. Restoring landscapes—governing place: A learning approach to forest landscape restoration. *Journal of Sustainable Forestry* 32(7):659–76. doi:10.1080/10549811.2013.818551

Oosten C van, Gunarso P, Koesoetjahjo I and Wiersum F. 2014. Governing forest landscape restoration: Cases from Indonesia. *Forests* 5(6):1143–62. doi:10.3390/f5061143

Ouya D. 2014. *Taking the Pulse on Biodiversity and Environmental Health: Decision Support Tools, Metrics and Indicators.* Agroforestry World blog. 22 October2014. Accessed 19 November 2016 http://blog.worldagroforestry.org/index.php/2014/10/22/taking-the-pulse-on-biodiversity-and-environmental-health-decision-support-tools-metrics-and-indicators/

Peters-Guarin G and McCall MK. 2010. *Community Carbon Forestry (CCF) for REDD: Using CyberTracker for Mapping and Visualising of Community Forest Management in the Context of REDD*. Enschede, Netherlands: Kyoto: Think Global, Act Local. http://www.communitycarbonforestry.org

Pinto SR, Melo F, Tabarelli M, Padovesi A, Mesquita CA, de Mattos Scaramuzza CA, Castro P, Carrascosa H, Calmon M, Rodrigues R, et al. 2014. Governing and delivering a biome-wide restoration initiative: The case of Atlantic Forest Restoration Pact in Brazil. *Forests* 5(9):2212–29. doi:10.3390/f5092212

Pratihast AK, DeVries B, Avitabile V, de Bruin S, Kooistra L, Tekle M and Herold M. 2014. Combining satellite data and community-based observations for forest monitoring. *Forests* 5(10):2464–89. doi:10.3390/f5102464

Pratihast AK, Souza CM Jr, Herold M and Ribbe L. 2012. *Application of Mobile Devices for Community Based Forest Monitoring*. Sensing a Changing World Workshop II. Wageningen, Netherlands, May 2012. Accessed 19 November 2016. https://www.wur.nl/upload_mm/e/f/9/9e2756ae-1eb5-4d8a-8275-6cd8373190ee_Pratihastetal.pdf

Reed J, Van Vianen J, Deakin EL, Barlow J and Sunderland T. 2016. Integrated landscape approaches to managing social and environmental issues in the tropics: Learning from the past to guide the future. *Global Change Biology* 22:2540–54 doi:10.1111/gcb.13284

Ruiz-Jaen MC and Aide TM. 2005. Restoration success: How is it being measured? *Restoration Ecology* 13(3):569–77. doi:10.1111/j.1526-100X.2005.00072.x

Sabai D and Sisitka H. 2013. Analysing learning at the interface of scientific and traditional ecological knowledge in a mangrove ecosystem restoration scenario in the eastern coast of Tanzania. *Transylvanian Review of Systematical and Ecological Research* 15(2):185–210. doi:10.2478/trser-2013-0027

Saipothong P, Preechapanya P, Promduang T, Kaewpoka N and Thomas DE. 2006. Community-based watershed monitoring and management in northern Thailand. *Mountain Research and Development* 26(3):289–91.

Sayer J, Sunderland T, Ghazoul J, Pfund J, Sheil D, Meijaard E, Venter M, Boedhihartono AK, Day M, Garcia C, et al. 2013. Ten principles for a landscape approach to reconciling agriculture, conservation, and other competing land uses. *Proceedings of the National Academy of Sciences* 110(21):8349–56. doi:10.1073/pnas.1210595110

Scheyvens H, Yamanoshita M, Fujisaki T, Avtar R, Bun Y, Winai M, Poruschi L, Evans T, Thannarak C, Mesa H, et al. 2014. Community-based forest biomass monitoring: Action research in PNG, Cambodia, Indonesia, Lao PDR and Vietnam. Kamiyamaguchi, Japan: Institute for Global Environmental Strategies. http://pub.iges.or.jp/modules/envirolib/view.php%3Fdocid=4992

Schultz CA, Coelho DL and Beam RD. 2014. Design and governance of multiparty monitoring under the USDA Forest Service's Collaborative Forest Landscape Restoration Program. *Journal of Forestry* 112(2):198–206. doi:10.5849/jof.13-070

Schumann M and Waikaniwa C. 2004. *Monitoring a Fuel Reduction Treatment: Analysis of Pre and Post-Treatment Data. A Participatory Research Project with the Pueblo of Zuni*. Working Paper 17. Forest Guild Research Center.

[SER] Society for Ecological Restoration. 2004. *The SER International Primer on Ecological Restoration*. Tucson: SER International. http://nau.edu/uploadedFiles/Centers-Institutes/ERI/_Forms/Resources/ser-primer.pdf

Shrestha S, Karky SB and Karki S. 2014. Case study report: REDD+ pilot project in community forests in three watersheds of Nepal. *Forests* 5(10):2425–39. doi:10.3390/f5102425

Skutsch M, McCall M and Larrazabal A. 2014. Balancing views on community monitoring: The case of REDD+. *Biodiversity & Conservation* 23(1):233–36. doi:10.1007/s10531-013-0594-1

Smale CR, Tappan G and Smale M. 2009. *Agroenvironmental Transformation in the Sahel: Another Kind of "Green Revolution"*. Washington, DC, USA: International Food Policy Research Institute.

Staddon SC, Nightingale A and Shrestha SK. 2015. Exploring participation in ecological monitoring in Nepal's community forests. *Environmental Conservation* 42(3):268–77. doi:10.1017/S037689291500003X

Stankovich M, Cariño C, Regpala ME, Guillao JA and Balawag G. 2013. *Developing and Implementing Community-Based Monitoring and Information Systems: The Global Workshop and the Philippine Workshop Reports*. Baguio City, Philippines: Tebtebba Foundation.

Stanturf JA. 2015. What Is Forest Restoration? *In* Stanturf JA, ed. *Restoration of Boreal and Temperate Forests, Second Edition*. London and New York: CRC Press. 1–16. http://www.crcnetbase.com/doi/abs/10.1201/b18809-2.

Stanturf JA, Kant P, Lillesø JPB, Mansourian S, Kleine M, Graudal L and Madsen P. 2015. *Forest Landscape Restoration as a Key Component of Climate Change Mitigation and Adaptation*. Volume 34. IUFRO World Series. Vienna, Austria: International Union of Forest Research Organizations. http://www.iufro.org/publications/series/world-series/article/2015/12/01/world-series-vol-34-forest-landscape-restoration-as-a-key-component-of-climate-change-mitigation/

Stanturf JA, Palik BJ and Dumroese RK. 2014. Contemporary forest restoration: A review emphasizing function. *Forest Ecology and Management* 331:292–323. doi:10.1016/j.foreco.2014.07.029

TESSA Tools. 2016. *Toolkit for Ecosystem Service Site-Based Assessment*. Accessed 19 November 2016. http://tessa.tools/

The Bonn Challenge. 2016. *The Challenge*. Bonn Challenge. Accessed 19 November 2016. http://www.bonnchallenge.org/content/challenge.

Torres AB, Acuña LAS and Vergara JMC. 2014. Integrating CBM into land-use based mitigation actions implemented by local communities. *Forests* 5(12):3295–326. doi:10.3390/f5123295

Tougiani A, Guero C and Rinaudo T. 2009. Community Mobilisation for Improved Livelihoods through Tree Crop Management in Niger. *GeoJournal* 74(5):377–89.

USDA Forest Service. 2015. *Collaborative Forest Restoration Program 5-Year Report*. Washington, DC, USA: United States Department of Agriculture.

Vallauri D, Aronson J, Dudley N and Vallejo R. 2005. Monitoring and evaluating forest restoration success. *Forest Restoration in Landscapes*. New York, USA: Springer. 150–58. http://link.springer.com/chapter/10.1007/0-387-29112-1_21

Vergara-Asenjo G, Sharma D and Potvin C. 2015. Engaging stakeholders: Assessing accuracy of participatory mapping of land cover in Panama. *Conservation Letters* 8(6):432–39. doi:10.1111/conl.12161.

Villaseñor E, Porter-Bolland L, Escobar F, Guariguata MR and Moreno-Casasola P. 2016. Characteristics of participatory monitoring projects and their relationship to decision-making in biological resource management: A review. *Biodiversity and Conservation* 25: 2001. doi:10.1007/s10531-016-1184-9.

Whaley OQ, Beresford-Jones D, Milliken W, Orellana A, Smyk A and Leguia J. 2011. An ecosystem approach to restoration and sustainable management of dry forest in southern Peru. *Kew Bulletin* 65(4):613–41. doi:10.1007/s12225-010-9235

Wortley L, Hero J and Howes M. 2013. Evaluating ecological restoration success: A review of the literature. *Restoration Ecology* 21(5):537–43. doi:10.1111/rec.12028

Zahawi RA, Dandois JP, Holl KD, Nadwodny D, Reid JL and Ellis EC. 2015. Using lightweight unmanned aerial vehicles to monitor tropical forest recovery. *Biological Conservation* 186:287–95. doi:10.1016/j.biocon.2015.03.031.

Zhao M, Brofeldt S, Li Q, Xu J, Danielsen F, Læssøe SBL, Poulsen MK, Gottlieb A, Maxwell JF and Theilade I. 2016. Can community members identify tropical tree species for REDD+ carbon and biodiversity measurements? *PLOS ONE* 11(11):e0152061. doi:10.1371/journal.pone.0152061

Appendices

Appendix 1. Cases and examples

This appendix presents in detail two case studies mentioned in the paper that represent scalable, multisite participatory monitoring systems.

a. Atlantic Forest Restoration Pact

Context. Over the past century, Brazil's Atlantic coastal forest, a biodiversity hotspot, has suffered devastating deforestation. Now, a strengthened forest code requires private property owners to set up conservation easements to restore the forest. Of Brazil's remaining Atlantic coastal forest, 90% is privately owned – mostly by large landholders, and agriculture, mining and paper companies. This means that many local stakeholders are now involved in restoration. However, forest restoration initiatives face many constraints: technological constraints, high costs, lack of economic incentives, low ecological effectiveness and weakness in decision-making processes. Projects driven by nongovernmental organizations (NGOs) were too scattered. What was needed was an overall, inclusive strategy with a diverse coalition. The Atlantic Forest Restoration Pact (AFRP) was formed to address this need and now includes over 200 members, including NGOs, universities and landholders.

Goals. The main goal of the AFRP is ecological restoration. The main goal of the monitoring system is to assess the success of restoration projects, to allow comparison of successes and setbacks among them. The hope is that results will transform the coalition into a large-scale experiment. The monitoring results will also help establish reference points – instead of a target reference system.

Monitoring approach. The participatory monitoring protocol has been developed by more than 50 partner institutions. In the first iterations, too many indicators were identified and projects had difficulty collecting the results because of high time and cost investments. In the newest iteration, only a handful of indicators will be used; individual projects can add more as they choose. These include 3 ecological indicators (forest canopy cover, density and richness of regenerating native plant community), 2 socioeconomic indicators (number of jobs and daily income, and how these jobs are distributed across genders) and 2 management indicators. Canopy cover is measured by setting up random $100m^2$ rectangular or circular plots in the forest and recording the percentage of shade versus no-shade on the outside tape line. A web-based registry and monitoring system is being developed with a mobile app for data collection, slated for launch by the end of 2016. Everyone will have tools to access data and compare progress, but the names of all projects will be coded.

Lessons learned

- Pact members were not just lacking a protocol; they needed a monitoring system with tools to collect and analyze data, and then to adapt to future management actions.
- The main problem is that people still see monitoring as a waste of time and money, not as a strategy to get the most out of their projects. They are more concerned about implementing and not necessarily succeeding. Laws and policies need to have targets that require success.
- It is better to have few indicators that are simple and not time-consuming or expensive to monitor.

(AFRP 2013; Brancalion et al. 2013; Pinto et al. 2014; P Brancalion, personal communication, 2016)

b. Collaborative Forest Landscape Restoration Program

Context. The United States Forest Service Collaborative Forest Landscape Restoration (CFLR) program is a 15-year initiative to develop and test successful forest restoration approaches on public lands, with an emphasis on collaboration by local stakeholders and applying monitoring and adaptive management strategies. Twenty-three collaboratives have been formed by environmental groups, loggers, universities, citizen groups, tribes and private landholders to plan and monitor restoration approaches collaboratively.

Goals. The monitoring objectives vary widely among the collaboratives:

- job creation and economic growth in rural communities
- strengthening the local timber industry
- making progress in restoration treatments
- utilizing citizen science to increase trust and communication among stakeholders
- building a scientific and sociopolitical case for restoration in an area with a history of litigation
- refining desired conditions and restoration treatments to create desired spatial heterogeneity at multiple scales
- supporting adaptive management
- supporting larger-scale and more flexible project decisions
- understanding landscape interactions
- coordinating data across broad scales
- understanding ecological impacts to at-risk species
- collecting socioeconomic data.

Maintaining stakeholder support to carry out restoration was also an important objective. Monitoring is important to support larger planning documents and to adjust actions within these large-scale projects. It is also important to produce monitoring results that can inform projects in other areas; data must be consistent enough for cross-site comparison. Some projects are focusing on socioeconomic monitoring to demonstrate where the money is going and why restoration is a good investment. Others emphasize engaging stakeholders; they have found that engagement of stakeholders in monitoring has contributed to a high level of trust and shared understanding of desired conditions.

Monitoring approach. The monitoring approach included five categories: fire and fuel dynamics, biodiversity, soil and water effects, economic impacts, and social implications. Progress is evaluated as good, fair or poor based on a scoring system that identifies the proportion of the landscape that is moving toward the desired conditions. Each project can determine what the desired conditions are for its landscape. There are formal roles for participants in designing monitoring programs, but less formal roles for implementing the monitoring and interpreting the data. Some groups have professionals collecting monitoring data, others have school groups, senior groups and universities. For instance, the Dinkey project has a monitoring coordinator and a monitoring working group. The coordinator is in charge of collecting data and presenting semi-annually to working groups. One group, LongLeaf, contracted out the monitoring to the Tall Timbers Research Station (Florida), which developed the monitoring plan and then the collaborative approved it. In general, 10% of restoration funds are going to monitoring. The monitoring groups apply the 'continuum of evidence' approach, where only the level of rigor needed to generate adequate information is used, not the most scientifically rigorous approach. No formal process is in place for incorporating monitoring information into future projects.

Lessons learned

- People have to own something to feel committed to it. Collaborative monitoring provides that: "We all own this. We are all in this together and we are going to learn. We are validating what we learn and we are going to change it. We own the successes and the failures"(L Buchanan, personal communication, 2016).
- The program has largely failed to have frequent reporting. The CFLR have occasional workshops and fieldtrips, but the monitoring data will not be available on the Internet until after the end of the project.
- One significant pitfall is that the governance mechanisms do not include formal processes for using the monitoring data to inform future planning. They have not yet seen adaptive management cycles, although there has been learning and changes of approach. Those take time to build.
- Fieldtrips are successful for building trust and resolving conflicts.
- "Collaboration is slow and clunky…We're just learning how to operate collaboratively together, and it's painful"(Schultz et al. 2014, 205).
- Integrating national-level indicators can be a challenge if the local ones have already been developed.
- Capacity is a challenge, in terms of time and expertise. Developing monitoring plans has

proceeded slowly. Most people are volunteers. The Forest Service staff sometimes do not know if they are trained to collect data with enough statistical certainty.

(Schultz et al. 2014; Demeo et al. 2015; USDA Forest Service 2015)

c. Other cases

Below is a list of additional forest restoration initiatives that have implemented participatory monitoring to varying degrees. Readers can access the references provided for further information.

- Philippines – National Greening Program (ELTI 2015)
- Tanzania – Mangrove restoration (Sabai and Sisitka 2013)
- Nepal – Exploring participation in ecological monitoring in Nepal's community forests (Staddon et al. 2015)
- Nepal – Case study report: REDD+ pilot project in community forests in three watersheds of Nepal (includes enrichment planting) (Shrestha et al. 2014)
- Niger – Farmer-managed natural regeneration (FMNR) in the Sahel (Smale 2009; Tougiani et al. 2009)
- Colombia – Community-led watershed conservation (Global Landscapes Forum 2015)
- Kenya – Participatory GIS mapping in Kirisia Forest (Green Belt Movement 2016)
- Uganda – Conditions for local participation in forest restoration (Galabuzi et al. 2014)
- New Zealand – Ngati Hine, community-based monitoring and information systems (Stankovich et al. 2013)
- Ghana – Involving local farmers in rehabilitation of degraded tropical forests: Some lessons from Ghana (Blay et al. 2008)
- USA – Community-based forest organizations (Fernandez-Gimenez et al. 2008; Cheng and Sturtevant 2012)
- Peru – Dry forest restoration in Ica (Whaley et al. 2011)
- South Africa – Restoration of degraded thickets (Mills et al. 2015)
- Dominican Republic – Natural regeneration of *Acacia mangium* (Enda Dominicana 2015; Global Landscapes Forum 2015)

Appendix 2. Monitoring topics, approaches and methods

The table below presents the various monitoring topics, approaches and methods that have been represented in this paper – in addition to others not referred to in the paper, for additional information.

Table Appendix 2

Monitoring topic	Approaches/methods	Citation/resource
Above-ground biomass	Mapping boundaries, identifying types of species, tree count, tree diameter measurement, comparing with satellite data	Community forest monitoring (Laake et al. 2013)
Biomass, forest cover, forest use change, resource use, well-being	Biomass plots, mapping, household surveys, ground-truthing, workshops	Community-based monitoring systems for REDD+ in Guyana (Bellfield et al. 2015)
Biomass, forest utilization (cut trees)	Biomass: set up plots and measured number of trees, diameter at breast height, height, species Utilization: walked routes on patrols and counted number of cut trees	At the heart of REDD+: A role for local people in monitoring forests? (Danielsen et al. 2011)
Biomass, land use	Permanent sample plots with low cost/ simple methods to measure trees, 3D photogrammetric techniques, tree rings	Community-based forest biomass monitoring: Action research in PNG, Cambodia, Indonesia, Lao PDR and Vietnam (Scheyvens et al. 2014)
Canopy structure, ecological trajectory, project management, socioeconomic impact	Sample plots, semi-structured interviews, document review, participant observation	Monitoring protocol for forest restoration programs and projects (AFRP 2013)
Climate, stream flow, water quality, soil erosion, stream sediment, local environmental knowledge	Weather stations, soil bridges, bioindicators, village discussions	Community-based watershed monitoring and management in Northern Thailand (Saipothong et al. 2006)
Economic impact and livelihoods	Job monitoring	Collaborative Forest Restoration Program 5-year report (USDA Forest Service 2015)
Forest activity	Types and size of forest change	Combining satellite data and community-based observations for forest monitoring (Pratihast et al. 2014)
Forest change	Above-ground biomass, below- ground biomass, leaf litter biomass and soil carbon	Case study report: REDD+ pilot project in community forests in three watersheds of Nepal (Shrestha et al. 2014)
Forest condition and biodiversity, forest ecosystem services, livelihoods, capacity for good management of natural resources, threats	Questionnaires, review of government data sources, local monitors to collect field data	A monitoring and evaluation system for forest landscape restoration in the Central Truong Son landscape, Vietnam (Dudley et al. 2003)
Forest condition, rule compliance, sanctions	Not clear from article	Communities, property rights and forest decentralisation in Kenya: early lessons from participatory forestry management (Mogoi et al. 2012)
Forest inventory, forest activity change	Forest inventory information (tree diameter, location, height, species, photo, date-time); activities signaling forest change (geo-location, date-time, change activity, photo, description)	Application of mobile devices for community-based forest monitoring (Pratihast et al. 2012)

continued on next page

Table Appendix 2. Continued

Monitoring topic	Approaches/methods	Citation/resource
Non-timber forest products	Logbooks	Can we make participatory NTFP monitoring work? Lessons learnt from the development of a multi-stakeholder system in Northern Laos (Boissière et al. 2014a)
Physical condition of mangroves, threats to the mangrove ecosystem, changes and trends in the mangroves and fisheries species	Physical observations of various characteristics, setting up plots to count mangroves, counting stumps, taking stride/meter measurements, observing canopy at a distance	Analysing learning at the interface of scientific and traditional ecological knowledge in a mangrove ecosystem restoration scenario on the eastern coast of Tanzania (Sabai and Sisitka 2013)
Resource abundance	Focus groups	Testing focus groups as a tool for connecting indigenous and local knowledge on abundance of natural resources with science-based land management systems (Danielsen et al. 2014b)
Resource abundance, trends in resource abundance	Community patrols	A multicountry assessment of tropical resource monitoring by local communities (Danielsen et al. 2014a)
Resource use, project implementation, restoration impacts	Ecological assessments, inventories, compliance monitoring, effectiveness monitoring (effectiveness of management)	Adaptive management and social learning in collaborative and community-based monitoring: A study of five community-based forestry organizations in the western USA (Fernandez-Gimenez et al. 2008)
Restoration project implementation	Document validation, such as signed contracts and disbursement reports; key informant interviews about the planning and implementation process, and whether policies and guidelines were clear, and funds and resources sufficient; key informant interviews to follow up on certain issues; visits to nurseries to review stock, logbooks and financial reports, and conduct key informant interviews; field assessments of the reforestation area	National Greening Program Monitoring Workshop (ELTI 2015)
Tree species	Community-led surveys of tree species without outside guides	Can community members identify tropical tree species for REDD+ carbon and biodiversity measurements? (Zhao et al. 2016)
Watersheds, water quality	Stream depth	Attempts to determine the effects of forest cover on stream flow by direct hydrological measurements in Los Negros, Bolivia (Le Tellier et al. 2009)
Women's participation	Workshops, adaptive collaborative management techniques	Field guide to adaptive collaborative management and improving women's participation (Evans et al. 2014)

ISBN 978-602-387-039-4
DOI: 10.17528/cifor/006284

CIFOR Occasional Papers contain research results that are significant to tropical forest issues. This content has been peer reviewed internally and externally.

New global forest restoration initiatives present an unparalleled opportunity to reverse the trend of deforestation and forest degradation in the coming years. This effort will require the collaboration of stakeholders at all levels, and most importantly, the participation and support of local people. These ambitious restoration initiatives will also require monitoring systems that allow for scalability and adaptability to a range of local sites. This will be essential in understanding how a given restoration effort is progressing, determining why or why not it is succeeding and learning from both its successes and failures. Participatory monitoring could play a crucial role in meeting international monitoring needs. The potential of participatory monitoring in forest restoration and related forest management activities is explored in this review through multiple case studies, experiences, field tests and conceptual discussions. The review seeks to deepen and broaden our understanding of participatory monitoring by teasing out the lessons learned from existing knowledge and mapping a possible path forward, with the aim of improving the outcomes of forest restoration initiatives.

RESEARCH PROGRAM ON Forests, Trees and Agroforestry

This research was carried out by CIFOR as part of the CGIAR Research Program on Forests, Trees and Agroforestry (CRP-FTA). This collaborative program aims to enhance the management and use of forests, agroforestry and tree genetic resources across the landscape from forests to farms. CIFOR leads CRP-FTA in partnership with Bioversity International, CATIE, CIRAD, the International Center for Tropical Agriculture and the World Agroforestry Centre.

cifor.org blog.cifor.org

Fund

UKaid from the British people

Center for International Forestry Research (CIFOR)
CIFOR advances human well-being, environmental conservation and equity by conducting research to help shape policies and practices that affect forests in developing countries. CIFOR is a CGIAR Research Center. Our headquarters are in Bogor, Indonesia, with offices in Asia, Africa and Latin America.