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Review

Participatory monitoring to connect local and global priorities for forest restoration

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Abstract: *New global initiatives to restore forest landscapes present an unparalleled opportunity to reverse deforestation and forest degradation. Participatory monitoring could play a crucial role in providing accountability, generating local buy in, and catalyzing learning in monitoring systems that need scalability and adaptability to a range of local sites. We synthesized current knowledge from literature searches and interviews to provide lessons for the development of a scalable, multisite participatory monitoring system. Studies show that local people can collect accurate data on forest change, drivers of change, threats to reforestation, and biophysical and socioeconomic impacts that remote sensing cannot. They can do this at one-third the cost of professionals. Successful participatory monitoring systems collect information on a few simple indicators, respond to local priorities, provide appropriate incentives for participation, and catalyze learning and decision making based on frequent analyses and multilevel interactions with other stakeholders. Participatory monitoring could provide a framework for linking global, national, and local needs, aspirations, and capacities for forest restoration.*

Keywords: adaptive management, forest change, large-scale restoration, local monitoring, monitoring protocols, reforestation, restoration accountability, restoration assessment, restoration success

Monitoreo Participativo para Conectar las Prioridades Locales y Mundiales de la Restauración de Bosques

Resumen: *Las nuevas iniciativas mundiales para restaurar los paisajes boscosos presentan una oportunidad incomparable para revertir la deforestación y la degradación de los bosques. El monitoreo participativo podría jugar un papel muy importante al proporcionar rendición de cuentas, generar compras locales al por mayor, y catalizar el aprendizaje en el monitoreo de sistemas que necesiten adaptabilidad a una gama de sitios locales. Sintetizamos el conocimiento actual a partir de búsquedas en la literatura y entrevistas para proporcionar lecciones para el desarrollo de un sistema de monitoreo participativo y adaptable. Los estudios mostraron que la gente local puede recolectar datos precisos sobre el cambio en el bosque, conductores del cambio, amenazas para la reforestación, e impactos biofísicos y socioeconómicos que la telemetría no puede detectar. Esto se puede hacer a un tercio del costo de los profesionales. Los sistemas exitosos de monitoreo participativo recolectan información con unos cuantos indicadores simples, responden a las prioridades locales, proporcionan incentivos apropiados para la participación, catalizan el aprendizaje y la toma de decisiones basada en análisis frecuentes e interacciones en múltiples niveles con otros accionistas. El monitoreo participativo podría proporcionar un marco de trabajo para conectar las necesidades, aspiraciones y capacidades locales, nacionales y globales para la restauración de los bosques.*

Palabras Clave: cambio en el bosque, evaluación de la restauración, éxito de restauración, manejo adaptativo, monitoreo local, protocolos de monitoreo, reforestación, restauración a gran escala, rendición de cuentas de la restauración

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摘要: *为恢复森林景观开展的新一轮全球行动是逆转森林采伐和森林退化空前的机会。参与性监控在提供责任制、创造当地市场, 以及促进需要扩展性且能适应当地研究位点的监控系统中的学习有重要作用。我们从文献搜索和访谈中梳理了现有的知识, 为可扩展的多位点参与性监控系统的发展提供了经验指导。研究表明, 当地人可以收集森林变化、变化的驱动力、再造林所受威胁和生物物理及社会经济影响因素的精确数据, 而这些数据是遥感不能获得的。由他们完成这些数据收集所需开支是专家的三分之一。一个成功的参与性监控系统可以收集一些简单指标的数据, 对当地保护优先地做出响应, 为参与者提供恰当的激励机制, 并促进在频繁分析和与其他利益相关者多水平互动的基础上的学习和决策。参与性监控可以作为一个框架, 来连接全球、国家和当地对森林恢复的需求、愿望和能力。* **【翻译: 胡怡思; 审校: 魏辅文】**

关键词: 适应性管理, 森林变化, 大尺度恢复, 本地监控, 监控协议, 再造林, 恢复责任制, 恢复评估, 恢复成功

Introduction

Globally, degradation and removal of millions of hectares of forest have contributed to depleted water supplies, soil erosion, food insecurity, and loss of wildlife habitat. Through a planned, multifunctional, and multistakeholder approach, forest-landscape restoration (FLR) aims to restore forests and create awareness at national and subnational levels to recover the many goods and services forests provide to society (Chazdon et al. 2017). To restore degraded lands via country-based targets (e.g., The Bonn Challenge 2017), national restoration plans need to link local realities and national restoration objectives (Murcia et al. 2016; Holl 2017). Local and national objectives also need to be connected to the goals of international stakeholders such as the Global Partnership for Forest Landscape Restoration, the Forest and Landscape Restoration Mechanism of the United Nations Food and Agriculture Organization, and the Convention on Biological Diversity. Yet such connections are often overlooked (Mansourian et al. 2017). Flexible approaches and governance mechanisms built on social learning are crucial (van Oosten et al. 2014) as is actively linking restoration science with local aspirations and practices so that national targets and plans and relevant legal mandates achieve their social and environmental goals (Viani et al. 2017). Given the long-term nature of FLR, monitoring is an essential component of tracking progress and taking corrective measures (Holl & Cairns 2002).

Monitoring is also crucial for determining whether desired endpoints have been reached (Dey & Schweitzer 2014), providing social learning (DellaSala et al. 2003) and securing long-term sustainability. For example, in addition to quantifying the number of hectares reforested, monitoring may reveal why forest cover is increasing (e.g., Le et al. 2014) or whether a restored area is providing expected environmental and social benefits (Cáceres et al. 2015; Mansourian et al. 2017). As FLR grows in international importance, participatory monitoring (Laake et al. 2013; Boissière et al. 2014; Pratihast et al. 2014; Bellfield et al. 2015) may play a critical role in providing a 2-way link between local aspirations and large-scale national and global goals. Nevertheless, monitoring often receives insufficient attention in ecological restoration projects and initiatives in both developing (e.g., Murcia & Guariguata 2014) and developed (e.g., Bernhardt et al. 2005) countries. Murcia et al. (2016) analyzed 119 ecological restoration projects in Colombia and found that most monitored only short-term goals, and local involvement was marginal. In their study across the drylands of Latin America, Newton et al. (2012) found that the biggest obstacle to the success of ecological restoration initiatives was the lack of government policies that consider public participation in decision making. Galabuzi et al. (2014) reported that when local people in Uganda were not involved in forest-restoration decision making, degradation worsened. Conversely, when including local people, particularly during monitoring, personal interest and commitment increased. Even occasional monitoring by local people improves reforestation outcomes in Nepal (Nagendra 2007).

We define "participatory monitoring" as a system that involves stakeholders from multiple levels in project design and the collection and analysis of data gathered from a given management activity that leads to improved collaborative decision making (Danielsen et al. 2009). Participatory processes that engage multiple stakeholders are more likely to lead to success than top-down approaches (Reed et al. 2016), provide a sense of ownership for those who benefit the most, and help local stakeholders maintain interest and commitment in the medium and long term (DellaSala et al. 2003). Researchers find that participatory monitoring catalyzes learning processes that lead to faster decision making at the local level (Danielsen et al. 2009), encourages knowledge sharing (Saipothong et al. 2006; Fernandez-Gimenez et al. 2008), and strengthens stakeholder capacity and empowerment (Constantino et al. 2012). If properly designed, participatory monitoring may facilitate reporting by governments to intergovernmental bodies (Viani et al. 2017). To gauge progress toward global goals and national commitments and improve outcomes, it is necessary to synthesize and share FLR successes and failures. However, participatory monitoring, thus far, has not been much applied in large-scale restoration projects. Exceptions include a multisite and multi-stakeholder participatory monitoring system in

Brazil to measure the success of Atlantic Forest restoration (Viani et al. 2017) and the U.S. Forest Service's national, multisite forest landscape restoration program that includes participatory monitoring (Demeo et al. 2015). Although some generic frameworks for prioritizing FLR are being developed internationally (e.g., IUCN & WRI 2014), existing national initiatives (responding to global restoration targets) have developed somewhat independently without a transnational view on how to plan, implement, and monitor FLR (e.g., Meli et al. 2017).

Methods

We conducted a global survey of current knowledge and practice to broaden understanding of participatory monitoring to improve the outcomes of international FLR initiatives. We surveyed existing knowledge and recent experiences in participatory monitoring, including pitfalls and failures, to compile a set of key messages to inform FLR. In 2016 we searched 59 research databases, including Science Citation Index Expanded, Social Sciences Citation Index, Environment Complete, AGRIS, GreenFILE, ScienceDirect, OAIster, MEDLINE, Networked Digital Library of Theses & Dissertations, JSTOR Journals, GEORef, BioOne, and SciTech. We used the following 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. Out of 21,300 hits, 71 articles provided insights into and positive or negative experiences with participatory monitoring in restoration-related activities. From the citations in these articles, gray literature, and suggestions from authors of some of the pertinent papers, we identified 136 relevant articles and resources (Supporting Information). Semistructured, open-ended interviews were also conducted with international experts (Supporting Information) to explore emerging issues. We followed CIFOR's Principles for Ethical Research, adapted from the Professional and Ethical Codes for Socio-economic Research in the Information Society (www.respectproject.org).

We are not the first to emphasize the importance of monitoring restoration activities (Holl & Cairns 2002). Other authors have addressed how restoration success has been gauged on the ground (Ruiz-Jaen & Aide 2005; Wortley et al. 2013) and have described the application of local monitoring protocols (Chaves et al. 2015; Viani et al. 2017). But operationalizing local restoration monitoring into national FLR programs that respond to the goals at both ends, seems, in our view, nascent. Furthermore, a better understanding of the issues surrounding the connection of local and national levels of actions is needed, including institutional structures and processes. We distilled key lessons and considered a path forward for developing and testing a multiscale, multisite participatory monitoring framework.

We examined participatory monitoring's role in accountability and social learning, elements necessary for FLR success. We compiled lessons learned that can be applied in the design of a multiscale, multisite participatory FLR monitoring and considered pitfalls and limitations of participatory monitoring in the context of FLR. Finally, we devised a generic approach for testing and implementing participatory monitoring at multiple scales.

Key Messages

Cost-Effective Mechanism for Accountability and Learning

Relevant data that complement remote sensing can be collected reliably and economically by local people. Bellfield et al. (2015) developed and tested a community-based monitoring framework in indigenous villages in Guyana. They used offline Android smartphones to map areas by land use, measured aboveground biomass in plots, ground-truthed satellite data, and collected well-being data through household surveys. They found that local monitoring more effectively distinguished between agricultural areas and forested areas than remote sensing, demonstrating that communities are well positioned to monitor drivers of deforestation, natural forest regeneration, and reforestation. When testing a participatory monitoring system in the Kafa Biosphere Reserve in Ethiopia, Pratihast et al. (2014) found that local experts accurately provided spatial, temporal, and thematic details of the forest-change process that complemented and enhanced high-resolution remote sensing. Vergara-Asenjo et al. (2015) found that local knowledge was crucial to differentiating between forest transformed by human intervention and undisturbed primary forest. Using handheld computers for capturing data, local people have accurately measured aboveground biomass of trees in forests and woodlands with a simplified structure (Danielsen et al. 2011; Bellfield et al. 2015) and used low-tech field approaches to measure aboveground biomass of trees in structurally complex forests (Danielsen et al. 2013; Hawthorne et al. 2016). They have recorded the status and trends of forest resources through patrols (Danielsen et al. 2014*a*) and used focus-group discussions to accurately estimate the status of forest resources (Danielsen et al. 2014*b*) and tree species identification (Zhao et al. 2016). With sufficient training and support, local people have successfully used bioindicator species, among other methods, to monitor stream flow and water quality (Saipothong et al. 2006). Local forest users can outperform professional foresters at monitoring some aspects of forest change, such as tree density (Nagendra & Ostrom 2011).

We found that participatory monitoring can be a cost-effective way to implement a multiscale, multisite monitoring system because it can lead to lower labor and transportation costs relative to professionally trained monitors (Danielsen et al. 2011; Pratihast et al. 2014). Community-based identification of tree diversity can be done at a quality comparable to trained botanists at about one-third of the cost (Zhao et al. 2016). Costs vary depending on the monitoring approach, location, investments in training, and staff time needed. Laake et al. (2013) found that the cost of professional analysis of aboveground biomass is 2–3 times higher than when local people analyze data. Costs are higher in the first year due to training and follow-up (Brofeldt et al. 2014) but decline thereafter. A study in Tanzania comparing 4 different approaches to tree surveys showed that the costs were US$0.04–0.12/ha for local people to carry out plot-free, tree-counting methods twice a year or US$1.88/ha for local people to survey permanent sample plots once per year (Holck 2007).

Investments in training, capacity building, and follow-up should be considered. For instance, Holck (2007) found 1 full day per year was needed to train local participants. There are limitations to the data-collection capacity of communities. Laake et al. (2013) found data are not always of consistently high quality and vary among individuals and communities. To ensure reliability and accuracy of data, a parallel process of cross-checking is necessary. They found that data collection was most successful when it focused on basic properties: boundaries, forest use, types of species, tree count, and tree diameter. Experts need to set up initial sampling plots and processes and supply ongoing training and support. Furthermore, local communities should take annual measurements to keep up their interest and to generate enough data points to smooth out anomalous years.

Building trust among stakeholders is cited as one of the benefits of participatory monitoring. Fernandez-Gimenez et al. (2008) explored the role of collaborative monitoring in 5 community-based forestry organizations in the United States and looked for evidence of social learning as an outcome. The authors found that trust, community cohesiveness, and relationships were stronger when local people were involved in the design and planning. They also found that repeated interactions among diverse stakeholders allowed participants to get to know each other, move beyond stereotypes and assumptions, and build respect for different viewpoints. Farmers and development practitioners in Niger who were involved in farmer-managed natural regeneration created learning networks at multiple levels (e.g., peer to peer and through the forestry service), which helped catalyze the transformation of 5 million ha of treeless land into wooded plots (Tougiani et al. 2009). Participatory monitoring can also be the only way to achieve large-scale monitoring of restoration interventions carried out as means of legal compliance. For instance, in São Paulo, Brazil, a monitoring protocol is in place, based on 3 ecological indicators, to gather information on vegetation development in areas where restoration is mandatory according to the Native Vegetation Protection Law (Chaves et al. 2015). Farmers have to collect field data and insert information into a self-reporting, web-based system developed to register monitoring information, which can be further checked by government officials. Engaging farmers in restoration monitoring would be the only cost-effective way to operationalize this activity in the more than 300,000 landholdings spread across about 17 million ha where mandatory restoration projects are planned in the state for the next 20 years.

The global FLR dialogue is beginning to address how to link the need for accountability in ambitious, country-level FLR plans with local priorities and decision making (Holl 2017).

When to Plan Monitoring

Ongoing, national restoration initiatives such as the U.S. Forest Service Collaborative Forest Landscape Restoration Program (Demeo et al. 2015) emphasize the importance of planning the monitoring strategy at the outset (Moote et al. 2010). This ensures tight linkages to project objectives and encourages prompt commencement of monitoring (Holl & Cairns 2002; Vallauri et al. 2005; McDonald et al. 2016). Planning monitoring at the early stages is essential for securing funds for its implementation and for establishing a reliable accountability system to attract investments from the private sector (Gutierrez & Keijzer 2015). What constitutes restoration success must be agreed on by all parties, and the goals should be simple. Determining the goals of any restoration project requires, in addition to biophysical goals, responding to social values (Stanturf et al. 2014). For most projects, this involves negotiation and collaboration. The next step is to translate what might be vague goals into feasible objectives and measurable targets that at some point will show success. Success, however, is as much a socially determined value as a biophysical one (Stanturf et al. 2014), both of which may change over time within an inherently 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 desired endpoints (Holl & Brancalion 2017).

The What and Who of Monitoring

Successful participatory monitoring systems emphasize responding quickly with information that is sufficient to answer the questions and needs of local, national, and global stakeholders and are not focused only on generating scientifically rigorous data. This is called the continuum-of-evidence approach; the method selected is sufficiently rigorous to answer a question in a timely way rather than the most scientifically rigorous (Demeo et al. 2015).

The process of selecting indicators is not straightforward (Dey & Schweitzer 2014), but it is an invaluable opportunity to collaborate with local people and include local priorities in monitoring. When approached in a structured way and when given enough time (Demeo et al. 2015), it elicits what is important to stakeholders. Instead of focusing on the technicalities of defining indicators at the outset, it can be more useful for local stakeholders to conceptualize indicators as questions that ask what information is needed for decision making to support restoration objectives (Lawrence et al. 2006; Demeo et al. 2015).

A scalable, multisite participatory monitoring system for upscaling FLR may need 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. Developing protocols and tools for integrating and analyzing data sets across multiple locations is a necessary part of this process, as is creating opportunities and events for stakeholders to reflect on the results, learn from them, and adapt their activities as needed (Metzger et al. 2017). Databases could be created to store monitoring information so as to allow its integration at multiple spatial scales and follow up on progress. For instance, the Atlantic Forest Restoration Pact in Brazil created a database to register restoration projects and their monitoring data (https://pactoma.esalq.usp.br/pacto/). This information has been used by this coalition to track the advance of the restored area and to assess the effectiveness of different restoration approaches across the biome (Brancalion & van Melis 2017). Such protocols and tools could also provide a mechanism for oversight and quality control (i.e., monitoring the monitors to ensure compliance with standards of data collection). This approach has been applied in the United States (Demeo et al. 2015) and Brazil (Viani et al. 2017). Once the relevant indicators are determined, defining milestones or thresholds on the path to each objective can also be important; if data show a particular outcome, corrective actions are triggered (Holl & Cairns 2002; Dey & Schweitzer 2014). These actions rely on a comprehensive overview of the local barriers limiting restoration success, which can be much better identified if local communities participate in the monitoring process and in the decisions regarding subsequent restoration interventions or adjustments.

Role of Women in the Process

Men and women can have different objectives in FLR and different motivations to participate in monitoring. For instance, Ugandan men are mostly interested in on-farm tree planting, whereas women prioritize controlling soil erosion; monitoring needed to take both views into consideration (Galabuzi et al. 2014). Mwangi et al. (2011) explored monitoring and sanctioning of activities related to FLR and management in East Africa and Latin America and found that mixed gender groups tend to do more monitoring than male-dominated groups; female-dominated groups are unlikely to conduct any monitoring; and mixed gender groups have the least conflict. Strategies to involve women may include organizing mixed-gender monitoring groups, special outreach efforts to ensure that technical resources and training reach women (Mwangi et al. 2011), and specifically prioritizing women's participation in some monitoring protocols (Constantino et al. 2012).

Selecting Monitoring Methods

Defining the monitoring methods should also be a collaborative process, and individual elements should not be monitored in isolation. The tendency is to drift toward research-focused methods, instead of answering the monitoring questions established by stakeholders (Demeo et al. 2015). Monitoring methods should be easy to use, be participatory in their conceptualization and implementation, be verifiable, and generate the appropriate level of accuracy (Holl & Cairns 2002; Danielsen et al. 2011; Laake et al. 2013; Skutsch et al. 2014). Evans and Guariguata (2016) supply details of participatory monitoring topics and methods.

Monitoring methods should emphasize rapid collection and analysis to encourage timely discussion and decision making. Mills et al. (2015) describe the hazards of delaying data processing and analysis. Scientifically rigorous monitoring information was collected regularly but was not evaluated until the end of the project, when the project had already failed. These authors argue that failure would have been averted if monitoring data had been analyzed frequently; if small rapid experiments had been conducted, as well as the large long-term ones; and if a strong ethos of debate had been encouraged among all stakeholders to spur innovation.

We found several studies in which digital tools (e.g., smartphones and handheld global positioning systems) were used to collect data. Advantages of these tools over pen and paper include fewer errors, improved accuracy, shorter processing time, and more useful data for analysis and decision making. Digital tools may also help bridge the gap between participatory and scientific monitoring when the technical aspects of sampling and data analyses are automated (Laake et al. 2013; Pratihast et al. 2014; Bellfield et al. 2015; Brammer et al. 2016). There are disadvantages too, such as the cost of training and technical support, and thus dependence on outside resources, and alienation of groups who may be less familiar with digital tools (Brammer et al. 2016). Photo point monitoring at the plot level or at the landscape scale is considered a simple yet effective way for local people to collect information that can be discussed and analyzed collaboratively (Danielsen et al. 2000).

Social learning and Learning Networks

Scalable, multisite FLR monitoring systems may help link results across projects so that different projects can share information and learn from each other. This connects stakeholders at multiple levels for accountability and decision making. These connections can be made through organizations, web sites, meetings, workshops, and conferences that encourage people to interact regularly to learn how to do things better (van Oosten 2013). Collaborative research and coordinated knowledge exchanges across countries may also prove valuable (Liu et al. 2017).

Effort and resources may be invested to create interactions among local stakeholders to share monitoring information and make decisions; repeated interactions are more likely to generate trust, learning, adaptive management, and appropriation (Fernandez-Gimenez et al. 2008). Monitoring will generate local decision making and adaptive management only if data-collection activities are followed by communications and discussions for processing and using the data. Focus groups have been used successfully to estimate species abundance of birds, mammals, and plants (Danielsen et al. 2014*b*). Fieldtrips have been organized to provide opportunities for people who might not be collecting monitoring data themselves to visit the restoration sites, informally monitor change, and discuss and analyze data collaboratively (Metzger et al. 2017). Visual tools have been used, such as a traffic-light coding of progress (green, yellow, red) (Doren et al. 2009) and progress wheels (McDonald et al. 2016). Local radio broadcasts have been used to share monitoring results more widely where long distances or limited internet access present a challenge, and instant messaging has been used to alert stakeholders about problems and changes (Stankovich et al. 2013).

A fundamental lesson is that the monitoring system itself must have a built-in capacity to learn and adapt. Some experts advocate for the designation or establishment of an organization that is specifically responsible for overseeing the monitoring of restoration efforts (Cheng & Sturtevant 2012). One of the challenges for that organization would be to balance local needs with national and global needs to achieve the right mix of broadness and specificity while keeping local people motivated (Reed et al. 2016). This could be facilitated by establishing a small number of global indicators and a selection of local ones (Viani et al. 2017). Monitoring is more than setting up a protocol and selecting indicators. There needs to be a monitoring system that supports data collection, aggregation, and analysis, and the system must generate accurate reporting and catalyze social learning at multiple levels.

Funds for Monitoring and Provision of Local Incentives

Given the long-time frames for FLR to achieve its environmental and social goals and the uncertainties and pressures facing newly forested and historically forested areas (Wiens & Hobbs 2015), a scalable, multisite monitoring system will need dedicated funding for at least the length of the project, including costs of implementation and costs of knowledge transfer to guide decision making, action, and adaptive management (Chazdon et al. 2017). Successfully planning and implementing a monitoring system, whether participatory or otherwise, requires a concerted, long-term commitment by stakeholders from inception to completion (Fernandez-Gimenez et al. 2008). In the U.S. Forest Service Collaborative Forest Landscape Restoration Program, 10% of project funding is dedicated to monitoring. In Peru 20% of transaction costs associated with REDD+ work were related to monitoring (Rendón Thompson et al. 2013).

Investment in training local people may translate into a demonstrable difference in the quality of data, while sufficient incentives and support can motivate individuals to participate in monitoring for the long term. These include orienting the FLR activities to meet local goals and priorities, guaranteeing appropriate compensation and incentives (Saipothong et al. 2006; Le Tellier et al. 2009; Danielsen et al. 2011), capacity building (Constantino et al. 2012), encouraging participation in reporting and analyzing results (Fernandez-Gimenez et al. 2008), and linking with and learning from other initiatives with frequent analysis and multilevel interactions with other stakeholders (Tougiani et al. 2009). In a participatory mapping of forest-change in Panama, accuracy was high because local communities received training in carbon-related projects over the past 10 years (Vergara-Asenjo et al. 2015).

Pitfalls and Limitations

Participatory monitoring as a multiscale, multisite system will likely involve a centralized (possibly government or internationally led) component to gather and process national-level data emerging from subnational and local data collection. There will be challenges at all levels, some related to power imbalances and competition among the interests of international organizations as well as those of national governments. We considered those specific to the local level. Care must be taken not to offload costs onto local people (Holck 2007; Danielsen et al. 2011), and modest compensation may be necessary (Saipothong et al. 2006) even though it may compromise the ability to sustain the scheme over time, unless there is dedicated funding (Danielsen et al. 2000). Fernandez-Gimenez et al. (2008), in their studies of collaborative monitoring in 5 community-based forestry organizations in the United States, determined that gaining and keeping the participation of key local stakeholders was the biggest challenge. Furthermore, FLR projects need to pay for the opportunity costs borne by local stakeholders, such as loss of cattle grazing sites or curtailment of traditional

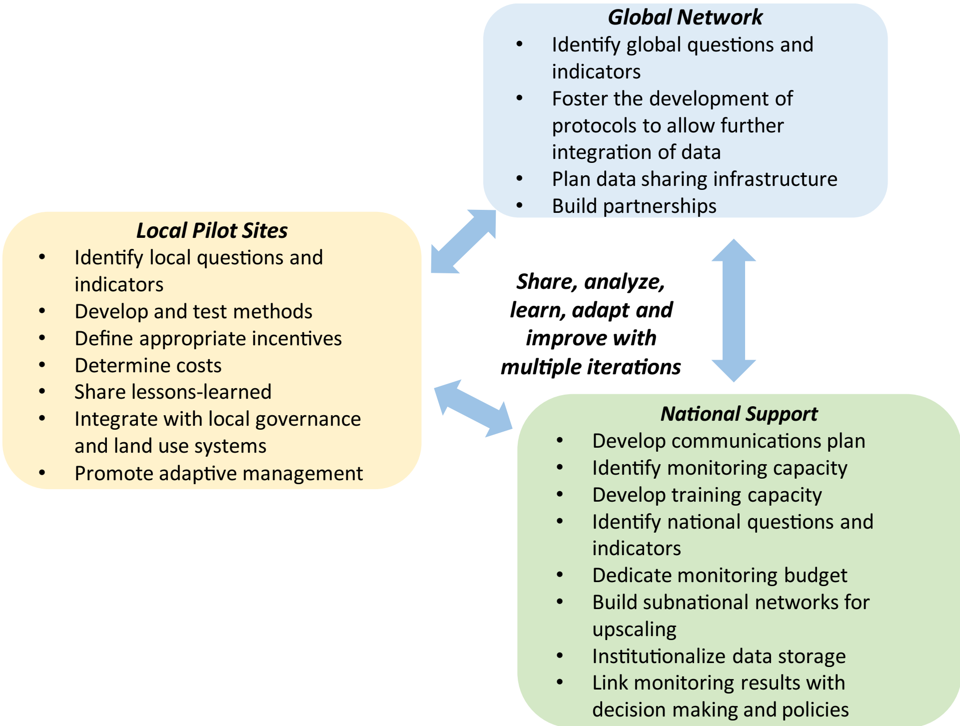

Figure 1. A proposed multilevel approach for researching, planning, and testing a participatory monitoring system for large-scale forest restoration.

forest use (Newton et al. 2012). Participation can also be derailed by competing livelihood pressures. In their work to develop a multistakeholder system for monitoring nontimber forest product harvesting in rural Laos, Boissière et al. (2014) found that people stopped monitoring when a gold mine opened nearby, demonstrating that their priorities about land and resources can easily shift.

It may also be difficult to harmonize locally collected data with centralized national programs. Local people often struggle with understanding indicators that were identified by outsiders (Sabai & Sisitka 2013). Because the information needs and goals of local stakeholders must be considered (Saipothong et al. 2006), cross-checking to ensure data integrity may be needed (Le Tellier et al. 2009; Nielsen & Lund 2012; Laake et al. 2013; Skutsch et al. 2014). Furthermore, agreement is not always to be expected between data collected through local monitoring and scientifically collected data (Nielsen & Lund 2012; Boissière et al. 2014). For instance, as community benefits through monetary compensation payments grow so do the incentives to manipulate or fabricate data (Danielsen et al. 2011; Nielsen & Lund 2012). In Bolivia, Le Tellier et al. (2009) hired local farmers to collect data on stream depth in a forest-based environmental services initiative and suspected that data fabrication took place (rendering it useless for decision making). Solutions to these problems may include a system for spot-checking or cross-checking data (Danielsen et al. 2014*a*) or uncoupling payments for monitoring from performance to avoid the stigma of reporting failures (Skutsch et al. 2014).

Conclusions and a Way Forward

We have highlighted key issues and lessons learned for developing a scalable, multisite participatory monitoring system in the context of the international agenda for FLR. If properly planned, participatory monitoring can play a key role in meeting the accountability needs of intergovernmental and governmental agreements while meeting the local needs for decision making and generating local buy-in. The design of a participatory monitoring system in the context of natural resource use is implied in several global agreements that require or advocate the participation of local people in order to meet commitments which, eventually, are to be reported to multilateral fora. Local monitoring is linked to the Convention on Biological Diversity Aichi Targets 1, 2, 4, 15, 17, and 18 (Convention on Biological Diversity 2010; Reed et al. 2016). The Manaus Letter (PMMP 2015) called attention to the potential of participatory monitoring by aggregating best practices of participatory monitoring of biodiversity, many of which apply to FLR. The UN Framework Convention on Climate Change mandated the participation of indigenous peoples and local communities in carbon measuring and monitoring (Vergara-Asenjo et al. 2015). The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services explicitly advocates for the inclusion of indigenous and local knowledge systems in Western scientific systems within global, regional, and local assessments (Danielsen et al. 2014*b*). A participatory monitoring prototype in the context of the global FLR agenda is lacking.

Although progress has been made in linking locally measured deforestation with national-level, remote-sensing quantification of forest loss (Pratihast et al. 2014), quantifying forest recovery is more complex than detecting forest versus nonforest cover (Chazdon et al. 2016). Ecosystem service provision, food security, biodiversity recovery, and human well-being are just a few of the many objectives that an (often inherently slow) increase in forest cover can help address (Stanturf et al. 2014). Measuring changes in forest cover exclusively through satellite images is problematic because, for example, the replacement of native forests by commercial tree plantations, the ongoing loss of biodiversity, and distinguishing residual from new carbon stocks are often masked by increased tree cover (Brancalion & Chazdon 2017). Although recent technological advances, such as LiDAR, may improve the way forest changes are assessed remotely, involving the major local actors responsible for forest change in monitoring will more meaningfully identify the drivers of restoration success and failures and provide paths to adaptive management and improved outcomes. It is time for international organizations to recognize the value of participatory monitoring and to work collaboratively with countries to integrate local monitoring outcomes with national and global assessments. It may be the only opportunity for cost-effective, reliable, and meaningful accountability for FLR.

In spite of the growing body of experience in participatory monitoring and potential for application in FLR, there are knowledge gaps. Information is needed on (top-down and bottom-up) monitoring costs and on the conditions that provide and sustain motivation and support for local participation. There is also the need to better understand the constraints on local stakeholders that can limit success, such as when monitors have vested interests or disadvantageous economic conditions, and how to overcome those constraints through training, support, or joint monitoring with other partners. Also, more pilot testing of data-collection methods and how to use the data for national and local decision making is needed. We suggest authors publish their original data sets so others can use meta-analysis to potentially provide greater insights.

To the best of our knowledge, there is no proven way to operationalize a multiscale, multisite participatory monitoring project, although there are lessons to be learned from various contexts and projects. Therefore, we suggest a learning-based approach to develop and test a system that emphasizes local input in the process (Fig. 1). This approach embraces the concept that a participatory monitoring system must be developed as an adaptive process through which methods themselves are both tested and adjusted through iterations that integrate learning and encourage rapid, local experimentation involving a range of actors at the local, national, and global levels.

We argue that not everything needs to be measured. The challenge is to agree on a small, common set of indicators that inform both national and global objectives, that apply to local situations and to which new components can be added as needed. Global attempts to monitor progress on FLR are accessible (e.g., the Bonn Barometer [https://www.iucn.org/sites/dev/files/content/documents/2016/bonn_challenge_barometer_of_progress.pdf]). Issues that merit discussion in international fora include what questions need to be answered; how will monitoring data be aggregated, integrated, and analyzed across multiple sites and how will data quality be gauged; how is the monitoring data going to be used and by whom; who will do the monitoring and manage and interpret the data; and who is responsible for getting the monitoring done, building the system, and paying for it? Without due attention to these questions, long lists of indicators may be re-created that only a few can monitor, often due to technical and financial constraints. Although indicators are important, and a minimum set of national and global indicators should be decided upon in the early stages, discussions about indicators should be embedded within a framework focused on critically answering at least some of the above questions.

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Conflicts of Interest

M.R.G. conceived the research. K.E. carried out the survey with contributions by M.R.G. K.E., M.R.G., and P.H.S.B. wrote the manuscript.

Supporting Information

Complete lists of sources identified (Appendix S1), experts interviewed (Appendix S2), and questions (Appendix S3) are available online. The authors are solely responsible for the content and functionality of these materials. Queries (other than absence of the material) should be directed to the corresponding author.

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