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Using leading and lagging indicators for forest restoration

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Abstract

1. Forest restoration targets are often planned, implemented, measured, and reported based on few short-term lagging indicators (i.e. indicators of realised outcomes), such as the number of seedlings and area planted.

2. We propose the use of leading indicators, which denote likelihood of a certain outcome (e.g. odds that seedlings are of quality and properly planted) to complement lagging indicators and describe how this construct differs from the current practice and how they can be used in conjunction with available frameworks for forest restoration.

3. Leading indicators have great promise to complement lagging indicators because they address the near-term factors more likely to influence the progress and performance of restoration efforts. For example, secure land tenure (leading indicator) can increase the likelihood of long-term maintenance and protection (lagging indicator), and the use of best practices in quality seedling production (leading indicator) can increase survival rate (lagging indicator).

4. By observing near-term leading indicators, management can be adapted towards a goal. Long-term impacts cannot be verified in the early stages of forest restoration, hence claiming success within the length of project cycles is often unrealistic. Reporting on leading indicators can inform the likelihood that forest restoration goals will be achieved in the longer term.

5. Synthesis and applications: Leading indicators complement lagging indicators and can be used in forest restoration beyond monitoring and evaluation. Indicators can also be used in the design, adaptive management and reporting of restoration interventions. Leading indicators can be used to identify issues that might prevent success in a timely manner so they can be addressed.

Portuguese abstract - Resumo

1. Os objetivos da restauração florestal são frequentemente planejados, implementados, medidos e relatados baseados em poucos indicadores defasados de curto prazo (i.e. indicadores de resultados observados), como o número de mudas e área plantada.

2. Propomos o uso de indicadores antecedentes, os quais denotam a probabilidade de um certo resultado (e.g. chances de que as mudas são de qualidade e propriamente plantadas) para complementar indicadores defasados e descrever como esse construto difere das práticas atuais e como eles podem ser utilizados conjuntamente com abordagens de enquadramento de restauração florestal disponíveis.

3. Indicadores antecetentes são promissores para complementar indicadores defasados porque eles se referem a fatores de curto prazo que mais provavelmente influenciarão o progresso e a performance de esforços relacionados a restauração. Por exemplo, seguridade de posse de terra (indicador antecedente) pode aumentar as chances de manutenção e proteção a longo prazo (indicador defasado), e o uso de boas

práticas em producao de mudas de qualidade (indicador antecedente) podem aumentar a taxa de sobrevivência de mudas (indicador defasado).
4. Observando-se indicadores antecedentes, o manejo pode ser adaptado em direção aos objetivos. Impactos de longo prazo não podem ser verificados nos estágios iniciais de restauração, portanto alegar sucesso durante o ciclo do projeto e comumente irrealista. O relato de indicadores antecedentes pode informar a probabilidade de que os objetivos da restauração florestal serão alcancados no longo prazo.
5. Síntese e aplicações: Indicadores antecedentes complementam indicadores defasados e podem ser utilizados em restauração florestal alem do monitoramento e avaliação. Indicadores tambem podem ser usados no planejamento, manejo adaptativo e relatório de intervenções de restauração. Indicadores antecedentes podem ser usados para a identificação de questões que podem impedir o sucesso da restauração em tempo hábil para que eles possam ser abordados.

Keywords: adaptive management, community forestry, Bonn Challenge, FLR, landscape approach, monitoring and evaluation, reforestation, UN Decade in Ecosystem Restoration

1. Introduction

"What we measure affects what we do", stated the Nobel Prize-winning economist Joseph Stiglitz (2009). The quote referred to the way economic activity in the world has been guided to inflate countries' gross domestic product (GDP), and how inappropriate GDP is as an indicator of economic performance and social wellbeing. GDP is an indicator focused on production in the country, leaving behind many economic and wellbeing aspects, including human health, population income earnings, environmental integrity and economic sustainability (Stiglitz 2011). The United States of America and Argentina, for example, showed high GDPs that were based on unsustainable debts used for consumption boosts and not for investments (Stiglitz 2011). This example demonstrates that what we report, and hence strive for, may not be sufficient to achieve the broader goals of improved economic performance and wellbeing (Kubiszewski *et al.* 2013).

An analogous situation often emerges in the context of forest restoration around the world. Forest restoration is being promoted by major initiatives globally, including the Bonn Challenge launched in 2011, the New York Declaration on Forests (launched in 2014), and, more recently, the United Nations Decade on Ecosystem Restoration (2021-2030). Many restoration targets are based on a forest and landscape restoration (FLR) approach. FLR focuses on re-establishing ecosystem functions at the landscape level balancing restoration of ecosystem services, such as land productivity and biodiversity (Sayer *et al.* 2013). It also aims to harmonise global and local, public and private interests (Roderick & Chavez-Tafur 2014). Landscape approaches are concerned with enhancing landscape sustainability and multifunctionality, often under polycentric governance structures (Wilson & Cagalanan 2016; Reed *et al.* 2017; Long *et al.* 2018). Given FLR's multiple goals and multi-governance structure and management, reporting on progress should encompass multidimensional concepts. Also, performance achievement visions vary according to stakeholders' needs and aspirations across time and space (Wilson & Cagalanan 2016; Chazdon *et al.* 2017; Reed *et al.* 2017). Nevertheless, FLR projects are not often planned and implemented with a long-term landscape perspective, and results are commonly measured and reported based on more immediate outcomes such as number of seedlings planted, or area reforested. Similar to GDP, these indicators often fail to document progress towards major goals (e.g., a functional forested landscape) nor do they indicate long-term sustainability of the restoration process (Chazdon *et al.* 2020).

Most frequently forest restoration uses only lagging indicators, while leading indicators are rarely considered. Lagging indicators represent realised outcomes of a process. Leading indicators represent likelihood of a particular outcome and are often predictors of lagging indicators. Leading indicators are widely used within business and economic sectors. They were first developed in economics following the 1929 recession in the USA to detect a recurring event, to measure its impacts, and to guide reactive actions (Moore 1983). The use of leading indicators has been more recently applied in the occupational health and safety literature and practice. In the investment sector, an example of a leading indicator is the Dow-Jones index of industrial common stock prices (Moore 1983) and in the health and safety sector are compliance on jobsite safety audits and pre-task planning meeting attendance at construction sites (Hinze, Thurman & Wehle 2013). Examples of lagging indicators from business, and health and safety sectors are sales levels (Moore 1983) and injury rates (Hinze, Thurman & Wehle 2013), respectively.

Typically, lagging indicators used in forest restoration inform on short-term outcomes rather than on long-term achievements (e.g. increased water infiltration, stable income from forest goods and services). Simple, short-term lagging indicators are convenient because they can be used and understood by a variety of stakeholders, are resource-effective, and their documentation needs low levels of capital and training (Ruckelshaus *et al.* 2015; Mansourian, Dudley & Vallauri 2017). They reflect the short-term perspective with which forest restoration projects are often defined and provide a good documentation of effort. Metrics associated with forest restoration are often developed to match short policy cycles and funding timelines, and in many cases they reflect the scale of effort rather than the magnitude of impact achieved (Mansourian *et al.* 2017). The short period in which outcomes are expected from forest restoration is a serious concern (Chazdon *et al.* 2020). This short-term view has resulted in significant failures in tree planting, given the haste with which actions are implemented that leads to use of inappropriate planting materials, site selection, and overall practices (Holl & Brancalion 2020). Short-term lagging indicators provide little indication of the likelihood of the sustainability of restoration efforts and of the outcomes and impacts at later points in time. They are insufficient under the complex adaptive systems settings underlying restoration interventions, with their focus on multiple objectives that operate at different scales and involve several groups of stakeholders.

Many restoration outcomes are often not observable in the short term, such as the realisation of financial benefits from timber marketing attributable to a forest restoration intervention. Other lagging indicators can complement those simple, short-term lagging indicators. This broader set of indicators is pertinent to monitor and evaluate systems at different scales. For instance, employment generation may be measured on the short-term at the regional scale, while changes in water quality and quantity and availability of forest products may be medium- to long-term indicators of change, at regional and landscape scales, respectively.

Because FLR encompasses long-term processes based on adaptive management, broad objectives need to be articulated into more context-based short-term goals (Mansourian *et al.* 2017). This can be achieved through the use of leading indicators associated with lagging indicators. Secure land tenure is an example of a leading indicator at the onset of the project lifecycle, as it contributes to future impacts. Without secure tenure, communities may have little motivation to protect and tend seedlings. In some cases, indicators can be both leading and lagging, depending when changes are assessed. Seedling survival rate, for example, is an early lagging indicator and also a leading indicator of future tree growth performance.

By predicting longer-term lagging indicators using leading indicators in the near term, stakeholders committed to restore forests and landscapes can assess the likelihood of achieving a desirable long-term outcome. For example, the presence of fleshy-fruited, fast-growing trees that attract a wide range of frugivores may be a leading indicator for the species richness of trees in the future (Viani *et al.* 2015). Furthermore, their early definition, identification, and measurement may guide project implementers to adapt management decisions for that long-term view. If the leading indicator points to suboptimal or negative performance, the issue related to the leading indicator can be recognised and addressed in a timely manner. The stop-light (red, yellow, or green) indicators of the Restoration Diagnostic, for example, provides an assessment of leading indicators that are key success factors for initiating planning and implementation of FLR at national or subnational scales (Hanson *et al.*, 2015).

Leading indicators can also be used in the design of restoration projects. For example, leading indicators can be used to select communities most likely to successfully implement projects based on how ‘prepared’ they (Ota *et al.* 2020). Leading indicators can also be used to assess the status of enabling factors that are closely associated with the core principles of FLR (Chazdon et al., 2020b), and of key success and enabling factors for restoration, such as market conditions, policy alignment, stakeholder engagement, or institutional readiness (Hanson *et al.*, 2015). In addition, connections between leading and lagging indicators can guide reporting, which is often a short-term requirement by governments and donor agencies. Within a project cycle, observed long-term values for lagging indicators are not available.

Besides presenting the current state of the forest restoration process, short-term reporting could shed light on the likelihood of achieving future targets based on leading indicators that inform on the actions being taken.

Because FLR embraces both ecological and human wellbeing principles, where outcomes are measured as both short- and long-term changes and processes, we propose the complementation of lagging indicators with leading indicators in the design, planning, implementation, assessment, and adaptive management of forest restoration. We also argue for diverse leading and lagging indicators across time and space. In forest restoration, as in other natural resource management contexts, leading and lagging indicators will comprise a mix of biophysical, socio-economic and institutional indicators. These domains are very interdependent, although narrow sectoral and disciplinary approaches for their assessment are still common (Mansourian *et al.* 2020). We further layout and illustrate the use of these indicators using a case study from the Philippines. We purposefully avoid the use of the term *indicators of success*, given its vague and controversial nature that often requires specification of thresholds (Dudley *et al.* 2018) – a discussion beyond the scope of this paper.

2. Defining leading and lagging indicators for forest restoration

Lagging indicators are defined based on the objectives of the restoration initiative – which may differ among stakeholders. To define leading indicators, an extensive understanding of a restoration system might be required. A single set of indicators is unlikely to suit a broad range of contexts, although some leading indicators are likely to be relevant in most forest restoration contexts (e.g., secure land tenure, community engagement, use of high-quality seedlings). Leading indicators might relate to direct or indirect factors that affect forest restoration, or proximate and distal drivers, as these are often referred to in the literature on land use change (Rueda *et al.* 2019). Understanding factors and drivers that affect land use and cover change is important in the restoration process, and there are indications in the literature of potentially important drivers that could be used as the basis for identifying leading indicators.

Our initial thoughts on leading indicators were influenced by a comprehensive assessment of the factors affecting the success of reforestation projects in the Philippines (see Le, Smith & Herbohn 2014). That assessment identified multiple biophysical, socioeconomic and institutional drivers of reforestation success, including incentives, forest protection mechanisms, road infrastructure, revegetation method and forest dependence among local people – each of which could be used to develop leading indicators for reforestation success. Success of community groups also depends on various factors, from land productivity and property rights through community group governance and bridging social capital (Baynes *et al.* 2015). Apart from scientific evidence, local knowledge is required for the identification of leading indicators and their connections. Factors that are likely to lead to success are often well-understood by those with experience implementing projects. The process of developing leading indicators, if done in an appropriate manner, can help to capture local experience and knowledge and incorporate them into the project design and implementation. The participation of representatives of different groups of stakeholders might ensure that hidden underlying processes are incorporated in a framework of indicators.

3. Examples of leading and lagging indicators and their connections

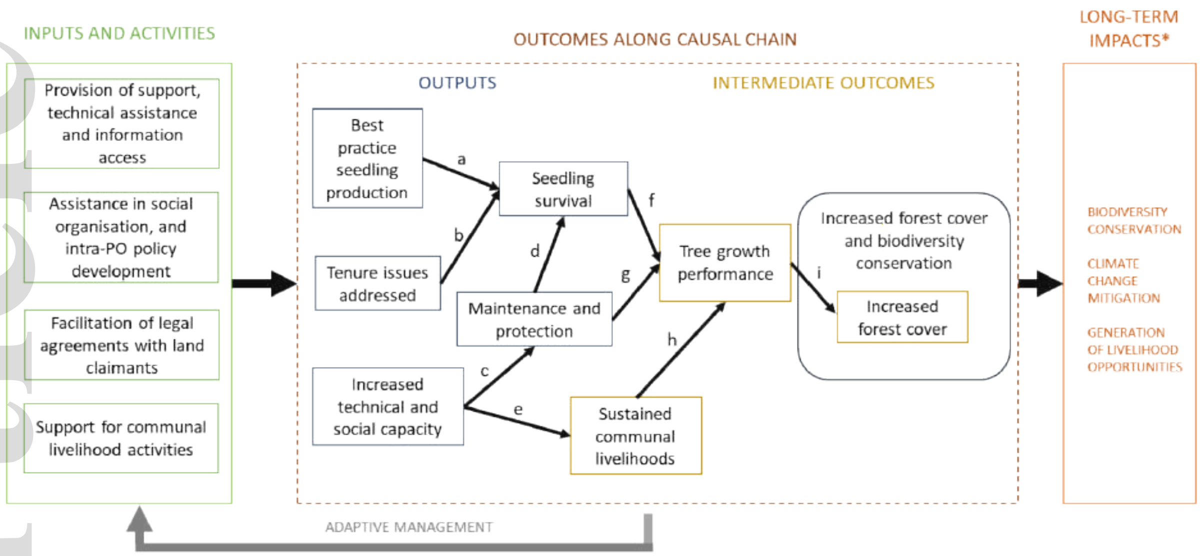
Leading and lagging indicators can be used in combination with several globally-recognised frameworks to explain relationships between components of forest restoration systems such as the IPBES Conceptual Framework (Díaz *et al.* 2015), the Socio-Ecological Systems framework (Ostrom 2007; McGinnis & Ostrom 2014), and Theories of Change (ToC) (Putz & Romero 2012; Sayer *et al.* 2017). Frameworks in use in forest restoration are frequently outlined under principles aligned with the use of leading and lagging indicators and aim to involve stakeholders to define goals. These frameworks are useful to track performance along the causal chain and when needed, guide identification of alternative pathways to change. They also facilitate identification of connections to intermediate outputs and outcomes and can help demonstrating these causal relationships.

This section presents an example of applying leading indicators to complement lagging indicators in forest restoration using ToC. ToC explain how activities will lead to a desired impact through specification of causal relationships and pathways based on evidence and knowledge as assumptions underlying the change process (James 2011; Brooks *et al.* 2014; Rogers 2014). These conceptual models provide implementation feedback throughout the monitoring process and have been largely used in development projects and programs to address complex issues (James 2011; Brooks *et al.* 2014; Valters 2015; Romero & Putz 2018). ToC promote an iterative process through learning and assists decision making as part of adaptive management (Margoluis *et al.* 2009; Vogel 2012). Complexity of adaptive management can be simplified through multiple ToC subsystems that help understanding the system components and the context in which they operate (Gillson *et al.* 2019).

The Philippines Government National Greening Program (NGP) is an initiative aimed to restore over 7 million hectares of forests between 2011 and 2028 and realise biodiversity conservation, climate change mitigation and generation of livelihood opportunities (Department of Environment and Natural Resources 2018). It is largely being implemented through community forestry, with the NGP providing funding as well as rights for communities to access and manage public lands for forest restoration. Communities must achieve 85% seedling survival rates during annual assessments to safeguard support from the government, which irrespective of successful performance, finishes after three years. Other metrics to assess the status of NGP operation are the number of seedlings and area planted, although employment generation is also reported (Gregorio *et al.* 2017; Commission on Audit 2019).

The NGP seedling survival rate metric (i.e. number of live seedlings at time of assessment) requires no sophisticated technology and is easy to communicate to rural people in the Philippines (UNESCO 2015). This metric also conveys a clear idea of what communities are expected to achieve including acting as a straightforward goal to monitor progress. However, this simplistic threshold has resulted in perverse behaviours alongside the forest restoration process. Some communities, for example, have replaced dead seedlings with wildlings or other seedlings without first addressing survival threats immediately before validation assessments by the Department of Environment and Natural Resources. The implication is that, even though the number of seedlings on the ground at the time of the assessment is over 85% of the number of seedlings planted, the NGP objectives (i.e. biodiversity conservation, climate change mitigation and generation of livelihood opportunities) and the long-term success of the program are unlikely to be achieved, as the seedlings planted for the sole purpose of meeting the threshold are unlikely to survive. In this case, the communities themselves cannot be blamed for striving to achieve this metric—it highlights the need for leading indicators as well that will assist with focusing on longer term goals. In this example, seedling survival would be enhanced by the use of high-quality planting stock produced through accredited nurseries – and thus the implementation of a seedling quality accreditation process could be a relevant 'leading indicator' of high seedling survival.

To illustrate potential indicators in the articulation of a ToC with specific outcomes in the context of NGP forest restoration, Figure 1 focuses on a single intermediate outcome, namely *Increased forest cover*. In this ToC, leading and lagging indicators on the biophysical (e.g. tree growth rates), institutional (e.g. land tenure status) and socioeconomic (e.g. technical capacity) spheres are interconnected. Level of community capacity is a leading indicator for the intermediate outcome on *Sustained communal livelihoods*, which in turn affects tree growth performance. One of the potential lagging indicators related to tree growth performance is mean annual increment, which is also a leading indicator for change in tree cover.



Causal Pathway ID	Assumption	Assumption robustness	Output or Outcome	Potential Indicators ► leading ● lagging
a	Chance of seedling survival increases as best-practices are used in seedling production	High	Best practice seedling production	% farmers using best practices/time► % quality seedlings produced/time► survival rate of seedlings planted●
b	There is higher risk of purposeful or non-purposeful burning or killing of seedlings when there are no land or tree tenure disputes	High	Tenure issues addressed	% area with no tenurial disputes► survival rate of seedlings planted●
c	Maintenance and protection are more likely when knowledge on tree growth and social organisation and cooperation increase and when social conflicts are minimised and/or effectively resolved	Fair	Increased technical & social capacities	% farmers who received training successfully implementing practices► # social conflicts reported► % area under regular maintenance and protection after end of support●
d	Patrolling and maintenance increase the chance of seedling survival	High	Seedling survival	# hours invested in patrolling/time► # hours invested in maintenance/time► change in seedling survival rates/time●
e	Communal livelihood activities are more likely to be sustained beyond duration of support when level of local capacity is higher	Fair	Sustained communal livelihoods	level of community capacity*► % income changes from alternative livelihoods/time●
f	Trees will only have the chance to grow if they survive the initial years	High	Tree growth performance	survival rate of seedlings planted► tree growth rates●
g	Maintenance and protection increase the likelihood of better performance of tree growth	Fair	Maintenance & protection	% area under regular maintenance and protection after end of support► Δ tree growth rates and basal area/ time●
h	If communal activities are sustainable, the more likely the community is to apply appropriate silvicultural management for improved tree growth performance	Fair	Tree growth performance	level of community cohesion*► tree growth rates●
i	Improved tree growth favours increase in forest cover	Fair	Increased forest cover	tree growth rate► % change in forest cover●

* These indicators can be documented through qualitative methods

Figure 1. Example of the use of leading (►) and lagging (●) indicators in a Theory of Change for a single mid-term outcome (*Increased forest cover*) for a Forest and Landscape Restoration project with communities in the Philippines under the National Greening Program with support from an international agency. Letters on causal pathways from outputs to intermediate outcomes indicate assumptions as specified in the Assumptions table.

Adaptive management principles are realised when examination of site and cross-site outcomes are the basis for monitoring and evaluation. both through time and space (i.e. local to landscape). As needed, management can be adapted through improved practices to secure progress towards project goals and facilitate learning. For instance, if level of community capacity is low, it is likely that communal livelihood activities will fail, potentially leading to reduced tree growth performance or complete failure of reforested areas. If the issue is detected in a timely manner, the community capacity failure can be addressed through a range of mechanisms (e.g. training, community organising, establishment of benefit sharing arrangements and conflict resolution) to increase the likelihood of a positive outcome on the longer term. However, the robustness of this assumption is fair and there is a risk that other factors (i.e., market price oscillations, competing livelihood opportunities) might compromise the sustainability of livelihood activities even if community capacity is increased.

A program like NGP could add to their reporting framework key leading indicators that relate to the long-term success of reforestation activities. The use of appropriate leading indicators could provide greater confidence that the current measures will produce the desired outcomes or alternatively allow early identification of issues that could jeopardise the success of reforestation. For instance, short-term reporting could include the number of projects with profit-sharing arrangements. At very early stages, the level of application of grazing management and weed control could be assessed as leading indicators, as well as road conditions. In a study on drivers of reforestation success in the Philippines, Le, Smith and Herbohn (2014) found that profit-sharing arrangements had a significant and positive effect on long-term maintenance of planted areas and that grazing management, weed control and good road conditions increased the odds of a project achieving seedling survival rates over 80% by about 20, 18 and 12.5 times respectively. Further, the odds of a project improving food security (lagging indicator) increased by 61 times if the project increased cash income (leading indicator) and by eight times if the project included an agroforestry component (leading indicator) (Le, Smith & Herbohn 2014).

4. The way forward

Because what is measured affects what is achieved, we argue for forest restoration to explicitly include leading indicators. The system presented is framed within an evidence-based agenda and focuses on enhancing the chances of optimal outcomes based on assessments at different scales for adaptive management towards forest restoration goals. Mapping leading and lagging indicators for forest restoration is both a tool and a set of processes that assist in defining desired changes with due attention to how activities' implementation is conducive to change and the nature of constraints and opportunities surrounding implementation on different contexts. We recommend this approach for forest restoration and firmly believe that leading and lagging indicators may also have an application in the management and restoration of other ecosystems and types of natural resources (e.g. community-based conservation, sustainable tourism, mangrove restoration). A recent study by Stevenson *et al.* (2021) discusses the application of this concept in global species extinction and also defends that the concept can be applied to different systems and scales.

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References

Baynes, J., Herbohn, J., Smith, C., Fisher, R. & Bray, D. (2015) Key factors which influence the success of community forestry in developing countries. *Global Environmental Change,* **35,** 226-238.

Brooks, N., Fisher, S., Rai, N., Anderson, S., Karani, I., Levine, T. & Steinbach, D. (2014) *Tracking Adaptation and Measuring Development: a step-by-step guide*. IIED, London.

Chazdon, R.L., Brancalion, P.H.S., Lamb, D., Laestadius, L., Calmon, M. & Kumar, C. (2017) A Policy-Driven Knowledge Agenda for Global Forest and Landscape Restoration. *Conservation Letters,* **10,** 125-132.

Chazdon, R.L., Guttierez, V., Brancalion, P.H.S., Laestadius, L. & Guariguata, M.R. (2020) Co-creating Conceptual and Working Frameworks for Forest and Landscape Restoration Based on Core Principles. *Forests,* **11, 706**.

Commission on Audit (2019) National Greening Program: Reforestation remains an urgent concern but fast-tracking its process without adequate preparation and support by and among stakeholders led to waste of resources. *PAO-2019-01*. Republic of the Philippines, Quezon City, Philippines. https://www.coa.gov.ph/index.php/national-greening-program [access 28 Oct 2020].

Department of Environment and Natural Resources (2018) National Greening Program. Quezon City, Philippines. http://www.denr.gov.ph/priority-programs/national-greening-program.html [access 20 Feb 2018].

Díaz, S., Demissew, S., Carabias, J., Joly, C., Lonsdale, M., Ash, N., . . . Zlatanova, D. (2015) The IPBES Conceptual Framework — connecting nature and people. *Current Opinion in Environmental Sustainability,* **14,** 1-16.

Dudley, N., Bhagwat, S.A., Harris, J., Maginnis, S., Moreno, J.G., Mueller, G.M., . . . Walters, G. (2018) Measuring progress in status of land under forest landscape restoration using abiotic and biotic indicators. *Restoration Ecology,* **26,** 5-12.

Gillson, L., Biggs, H., Smit, I.P.J., Virah-Sawmy, M. & Rogers, K. (2019) Finding Common Ground between Adaptive Management and Evidence-Based Approaches to Biodiversity Conservation. *Trends in Ecology & Evolution,* **34,** 31-44.

Gregorio, N., Herbohn, J., Harrison, S., Pasa, A. & Ferraren, A. (2017) Regulating the quality of seedlings for Forest Restoration: Lessons from the National Greening Program in the Philippines. *Small-scale Forestry,* **16,** 83-102.

Hinze, J., Thurman, S. & Wehle, A. (2013) Leading indicators of construction safety performance. *Safety Science,* **51,** 23-28.

Holl, K.D. & Brancalion, P.H.S. (2020) Tree planting is not a simple solution. *Science,* **368,** 580-581.

James, C. (2011) Theory of change review. Comic Relief, https://www.actknowledge.org/resources/documents/James_ToC.pdf [access 20 Feb 2020].

Kubiszewski, I., Costanza, R., Franco, C., Lawn, P., Talberth, J., Jackson, T. & Aylmer, C. (2013) Beyond GDP: Measuring and achieving global genuine progress. *Ecological Economics,* **93,** 57-68.

Le, H.D., Smith, C. & Herbohn, J. (2014) What drives the success of reforestation projects in tropical developing countries? The case of the Philippines. *Global Environmental Change,* **24,** 334-348.

Long, H., Liu, J., Tu, C. & Fu, Y. (2018) From State-controlled to Polycentric Governance in Forest Landscape Restoration: The Case of the Ecological Forest Purchase Program in Yong'an Municipality of China. *Journal of Environmental Management,* **62,** 58-69.

Mansourian, S., Dudley, N. & Vallauri, D. (2017) Forest landscape restoration: progress in the last decade and remaining challenges. *Ecological Restoration,* **35,** 281-288.

Mansourian, S., Parrotta, J., Balaji, P., Bellwood-Howard, I., Bhasme, S., Bixler, R.P., . . . Yang, A. (2020) Putting the pieces together: Integration for forest landscape restoration implementation. **31,** 419-429.

Mansourian, S., Stanturf, J.A., Derkyi, M.A.A. & Engel, V.L. (2017) Forest Landscape Restoration: increasing the positive impacts of forest restoration or simply the area under tree cover? *Restoration Ecology,* **25,** 178-183.

Margoluis, R., Stem, C., Salafsky, N. & Brown, M. (2009) Using conceptual models as a planning and evaluation tool in conservation. *Evaluation and Program Planning,* **32,** 138-147.

McGinnis, M.D. & Ostrom, E. (2014) Social-ecological system framework initial changes and continuing challenges. *Ecology and Society,* **19**.

Moore, G.H. (1983) The forty-second anniversary of the leading indicators. *Business Cycles, Inflation, and Forecasting, 2nd edition*, pp. 369-400. Ballinger.

Ostrom, E. (2007) A diagnostic approach for going beyond panaceas. *Proceedings of the National Academy of Sciences,* **104,** 15181-15187.

Ota, L., Herbohn, J., Gregorio, N. & Harrison, S. (2020) Reforestation and smallholder livelihoods in the humid tropics. *Land Use Policy,* **92,** 104455.

Putz, F.E. & Romero, C. (2012) Helping curb tropical forest degradation by linking REDD+ with other conservation interventions: a view from the forest. *Current Opinion in Environmental Sustainability,* **4,** 670-677.

Reed, J., van Vianen, J., Barlow, J. & Sunderland, T. (2017) Have integrated landscape approaches reconciled societal and environmental issues in the tropics? *Land Use Policy,* **63,** 481-492.

Roderick, J.Z. & Chavez-Tafur, J. (2014) Towards productive landscapes—a synthesis. *Towards productive landscapes* (eds J.Z. Roderick & J. Chavez-Tafur), pp. VI-XIX. Tropenbos International, Wageningen, the Netherlands.

Rogers, P. (2014) Theory of change. *Methodological briefs: impact evaluation*, pp. 16. UNICEF Office of Research, Florence, Italy.

Romero, C. & Putz, F.E. (2018) Theory-of-Change Development for the Evaluation of Forest Stewardship Council Certification of Sustained Timber Yields from Natural Forests in Indonesia. *Forests,* **9,** 547.

Ruckelshaus, M., McKenzie, E., Tallis, H., Guerry, A., Daily, G., Kareiva, P., . . . Bernhardt, J. (2015) Notes from the field: Lessons learned from using ecosystem service approaches to inform real-world decisions. *Ecological Economics,* **115,** 11-21.

Rueda, X., Velez, M.A., Moros, L. & Rodriguez, L.A. (2019) Beyond proximate and distal causes of land-use change: linking Individual motivations to deforestation in rural contexts. *Ecology and Society,* **24**.

Sayer, J., Sunderland, T., Ghazoul, J., Pfund, J.-L., Sheil, D., Meijaard, E., . . . Buck, L.E. (2013) Ten principles for a landscape approach to reconciling agriculture, conservation, and other competing land uses. *Proceedings of the National Academy of Sciences,* **110,** 8349-8356.

Sayer, J.A., Margules, C., Boedhihartono, A.K., Sunderland, T., Langston, J.D., Reed, J., . . . Kusters, K. (2017) Measuring the effectiveness of landscape approaches to conservation and development. *Sustainability Science,* **12,** 465-476.

Stevenson, S.L., Watermeyer, K., Caggiano, G., Fulton, E.A., Ferrier, S. & Nicholson, E. (2021) Matching biodiversity indicators to policy needs. **35,** 522-532.

Stiglitz, J.E. (2009) GDP fetishism. *The Economists' Voice,* **6**.

Stiglitz, J.E. (2011) Rethinking Development Economics. *The World Bank Research Observer,* **26,** 230-236.

UNESCO (2015) Education for All 2015 Review Report: Philippines.

Valters, C. (2015) *Theories of change: Time for a radical approach to learning in development*. Overseas Development Institute, London.

Viani, R.A.G., Vidas, N.B., Pardi, M.M., Castro, D.C.V., Gusson, E. & Brancalion, P.H.S. (2015) Animal-dispersed pioneer trees enhance the early regeneration in Atlantic Forest restoration plantations. *Natureza & Conservação,* **13,** 41-46.

Vogel, I. (2012) *ESPA guide to working with Theory of Change for research projects*. ESPA Directorate, Edinburgh.

Wilson, S.J. & Cagalanan, D. (2016) Governing restoration: Strategies, adaptations and innovations for tomorrow's forest landscapes. *World Development Perspectives,* **4,** 11-15.