POLICY PERSPECTIVE

A Policy-Driven Knowledge Agenda for Global Forest and Landscape Restoration

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Abstract

The global restoration movement is gaining momentum. International and national leaders are demonstrating unparalleled political will for achieving ambitious targets. However, the knowledge base for implementing large-scale forest and landscape restoration (FLR) needs further development. Besides application of scientific and local knowledge, a broad understanding of the social, economic, and environmental context in which this knowledge is being applied is also needed. To address knowledge gaps and guide implementation of FLR at local to global scales we propose a knowledge creation agenda that we derive from emerging policy goals. We present a holistic approach that addresses food security, ecosystem services, and livelihoods, and that supports implementation by a wide array of actors from farmers and municipalities to corporations and state agencies. Our knowledge creation agenda is based on six broad policy goals, with several associated knowledge gaps for each goal. We recognize that this agenda is simply a starting point and will surely evolve and become more locally focused as the concept of FLR gains ground and as multiple groups of stakeholders engage in the long-term process of restoring functionality and value to ecosystems and landscapes around the world.

Introduction

We face an unprecedented opportunity to transform degraded and unproductive lands into functional landscapes and restored ecosystems that offer multiple benefits to society and future generations. The Millennium Ecosystem Assessment documented deterioration of 60% of ecosystem services (ES) globally. Global land-use changes between 1997 and 2011 resulted in an estimated loss of $4.3 to 20.2 billion per year (Constanza *et al.* 2014; Suding *et al.* 2015). Taking no action is more costly than taking action. The massive scale of this opportunity creates an enormous implementation challenge that requires engagement, mobilization, and commitment of all sectors of society across all regions of the planet.

The global restoration movement is rapidly gaining momentum. International and national leaders are demonstrating unparalleled political will for achieving ambitious restoration targets such as the Aichi Targets, Bonn Challenge, and New York Declaration on Forests (Suding *et al.* 2015). Multiple efforts by multilateral organizations, nongovernmental organizations, and the private sector have been launched with the goal of achieving large-scale restoration targets (Table 1). Over 20 countries and regional initiatives have already committed to restore close to 60 million ha of degraded and deforested land to productive, functional and biodiversity-friendly landscapes (Bonn Challenge 2015). Many developing countries are including forest-based mitigation and adaptation measures as part of their commitments to reduce

Table 1 International organizations, multilateral conventions, and networks with active forest and landscape-scale restoration programs

Organization/network	Program
Global Partnership on Forest and Landscape Restoration (GPFLR)	Learning Network/Discussion Platform on Forest Landscape Restoration
International Union for the Conservation of Nature (IUCN) (Global Forest and Climate Change Program)	Forest Landscape Restoration Initiative
World Resources Institute (WRI)	Global Restoration Initiative, 20×20 initiative (Latin America), AFR100 initiative (Africa)
United Nations Food and Agriculture Organization (FAO)	Forest and Landscape Restoration Mechanism
United Nations Convention on Biological Diversity (CBD)	Forest Ecosystem Restoration Initiative
Collaborative Group on International Agricultural Research (CGIAR)	Research Program on Forests, Trees, and Agroforestry, Research Program on Water, Land, and Ecosystems
People and Reforestation in the Tropics, a Network for Education, Research, and Synthesis (PARTNERS)	Synthetic research, policy outreach, educational outreach
Iberoamerican Model Forest Network	Model Forest Network Forest and Landscape Restoration Initiative contributing to 20×20 initiative and Bonn Challenge
African Union	The Great Green Wall for the Sahara and the Sahel Initiative
United Nations Environment Program (UNEP)	One Billion Tree Program
The Nature Conservancy (TNC)	Plant a Billion Trees
World Wildlife Fund (WWF)	Landscape restoration in 10 ecoregions
Ecological Restoration Alliance of Botanical Gardens	100 restoration projects on several continents over next 20 years
EcoAgriculture Partners	Landscapes for Food, People, and Nature
	Model Forest Network

carbon emissions. Moreover, many countries are developing national and subnational restoration plans, strategies, and policies and are seeking ways to integrate restoration strategies into sustainable development and conservation agendas (Pinto *et al.* 2014, Aguilar *et al.* 2015, Murcia *et al.* 2015). But the path towards achieving these goals remains uncharted due to the challenges of navigating around poorly understood biophysical, socioeconomic, and governance impediments and the complexity of integrating multiple benefits.

Restoration of ecosystems and landscapes

Ecological restoration assists the recovery of an ecosystem that has been damaged or destroyed (SER 2004). At the landscape level, the goal of forest and landscape restoration is to regain ecological functionality and enhance human well-being across degraded landscapes (Lamb 2014). Successful FLR reverses environmental degradation, strengthens the resilience of landscapes, secures forest-based livelihoods, and optimizes ecosystem goods and services to meet the changing needs of society (IUCN and WRI 2014). A key feature of FLR is that a combination of forest and nonforest ecosystems, land uses, and restoration approaches can be accommodated within a landscape to achieve sustainable food production, ES provisioning, and biodiversity conservation. These approaches include ecological restoration of environmen-

tally important areas, increasing agricultural productivity to create space for natural regeneration in marginal areas, and increasing tree cover through the implementation of farm forestry and agroforestry systems (Lü *et al.* 2012; Latawiec *et al.* 2015). In regions where forests are not components of the natural vegetation, FLR approaches can be applied to landscape-scale restoration of nonforest ecosystems.

Research focused on ecological restoration approaches, natural regeneration processes, landscape ecology, and recovery of ecosystem services has grown dramatically over the past 10 years (Chazdon 2014, Perring *et al.* 2015). Yet, we still lack much of the knowledge needed to operationalize and implement restoration successfully at different scales while also addressing the needs and aspirations of landholders. Restoration ecologists have called for more effective information transfer from scientists to policy makers (Menz *et al.* 2013; Jørgensen *et al.* 2014). They emphasize the need to identify knowledge gaps and prioritize research that will help build capacity and the business case for restoration. Yet they do not specify what these gaps are or what research is most urgently needed.

We focus here on addressing key knowledge gaps. Apart from the development and implementation of appropriate scientific techniques, implementation of FLR also requires a broad understanding of the social, economic, political, and environmental context of restoration activities and their trade-offs and synergies. In contrast to the call by Suding *et al.* (2015) for policy

makers to adopt science-based restoration principles, here we propose a knowledge creation agenda driven by emerging policy goals. This agenda recognizes major knowledge gaps that hinder the wide and successful implementation of forest and landscape restoration initiatives and includes ideas and concerns of colleagues who are not authors.

The road to restoration needs to be built on solid ground with access for all travelers. Multiple actors—farmers, villagers, communities, municipality leaders, forestry agencies, business leaders, environment ministers, and heads of state—are becoming motivated to work towards landscape-scale restoration. They need knowledge, tools, financial support, access to robust and locally relevant information, and answers to questions that will help them to set appropriate restoration goals for specific areas and to build institutional arrangements to prioritize areas for restoration, develop and implement restoration plans that maximize multiple societal and environmental benefits, minimize costs, track and evaluate implementation efforts, and procure stable, long-term financial and logistical support (Figure 1).

Whose degraded land is it?

Restoration activities are commonly focused on land that has been deforested or degraded. Degraded land can be owned or managed by households, communities/villages, companies/industries, or the state; a landscape can encompass multiple types of landholders, which differ in their perception of degradation, their relationship with the land, their expectations of benefits from restoration, and their motives for restoration (Figure 1). The type of restoration undertaken at particular locations within a landscape will therefore depend on the biophysical environment at that place as well as on the socio-economic circumstances of the landholder. For households and communities with land tenure, restoration may be an attractive option if it ensures food, water, and energy security, improves their economic and social circumstances, and provides locally needed ecosystem goods and services. For companies, restoration may help offset or compensate environmental impact caused by their activities or comply with legal and certification requirements. Much state-held land is degraded because it has been seen as an open-access resource and because scientific knowledge is lacking or has not been disseminated through extension agents and technicians to guide decision-making regarding sustainable land use. But restoration is now becoming attractive to state actors because expanding degraded areas are negatively affecting publicly valued ecosystem services, agricultural production, and economic development. Increasing the functionality and productivity of degraded lands has now

become a global priority (Aronson and Alexander 2013). At the same time, lack of secure land tenure creates disincentives for restoration, as farmers have no assurance of reaping future benefits. Policies need to be developed to encourage each of these groups of landholders to implement restoration on some or all of their land and to coordinate these various activities within landscapes in ways that maximize overall benefits to the broader community.

Policy and knowledge gaps for forest and landscape restoration

The Aichi Target 15 calls for "restoration of at least 15 per cent of degraded ecosystems by 2020" (Jørgensen 2013). The target, however, does not specify what is meant by "restoration" nor which approaches and criteria are most appropriate (Lamb 2014, Stanturf *et al.* 2014, Rappaport *et al.* 2015). It is likely that some flexibility will be needed to accommodate the circumstances of various landholders within a landscape. It is also likely that these approaches may need to evolve over time. For example, the Republic of Korea's National Reforestation Programme, when originally implemented in the 1960s, used approaches that generated new forest cover but did not fulfill today's more holistic objectives of FLR. But reforestation methodologies and approaches evolved over time from being mainly concerned with producing fuelwood and building timbers to largely one of generating ecosystem services (Bae *et al.* 2012).

General policies to facilitate forest restoration on private lands include removing barriers to farmers wishing to undertake restoration as well as providing incentives to landholders to embark on what—for many—is a new, long-term land use. Incentives can also include access to technical advice and extension services, providing financial and nonfinancial support and facilitating access to markets for ecosystem services and other value chains. In some cases, policies may be needed that legally oblige landholders to initiate and track restoration on private lands (Aronson *et al.* 2011, Calmon *et al.* 2011, Chaves *et al.* 2015, Hanson *et al.* 2015).

But FLR is more than simply scaling-up these ecosystem- or farm-based activities. It also involves planning and coordinating of restoration across the landscape to ensure that the large-scale ecological processes needed to generate ecosystem services are indeed able to develop while, at the same time, the livelihoods of people living in the landscape improve. FLR provides a framework for integrating agricultural and environmental policies, beyond the conservation/production dualistic perspective that has predominated in the past. The know-how for implementing FLR at scale is developing, but is far from mature.

Table 2 A knowledge agenda for forest and landscape restoration (FLR) based on a set of six integrated policy goals and key impediments to implementation of these goals. Relevance of knowledge gaps for three principal knowledge clients is indicated

| Policy goals	Key impediments	Research questions	Relevance to knowledge client		
			State	Muni-cipality	Farmer / land-holder
1. A widespread, long-lasting FLR process that reverses effects of degradation	Lack of public and institutional understanding of the multiple beneficial outcomes of FLR on degraded lands	What key policies are needed to facilitate restoration at large scales? Will markets suffice or are other incentives also needed? What incentives will have long-lasting impacts?			■
		What are the institutional frameworks and collaborative arrangements needed to develop and implement these policies? How can different sectors of society become agents of change and mobilize actions to initiate and sustain restoration activities in the long term?			
		Under what circumstances have smallholders and communities derived economic returns and overcome opportunity costs through restoring degraded ecosystems?			■
2. The lands most in need of restoration are given priority	Lack of clarity and agreement on criteria for assessing and selecting the most urgent areas for forest restoration within particular landscapes	What definition of degradation and which expected benefits could be used to identify and map priority areas for restoration?	■		
		Where are the intersections between areas where the need for ecosystem services is greatest and where restoration could significantly increase the supply of these ecosystem services?			
		What tools and local knowledge are needed to configure landscapes that combine ecosystem restoration, productive land uses, food-water-energy security, biodiversity conservation, and poverty alleviation under different land tenure regimes? How can these tools be used to facilitate multi-stakeholder restoration planning?			■
3. Appropriate interventions are developed to suit different types of ecological and economic circumstances	The environmental and economic outcomes of different interventions are poorly quantified	Under what conditions is natural regeneration a viable restoration approach compared to tree planting? Under what ecological or economic conditions are more active and costly restoration interventions needed?			
		What are the effects of different restoration interventions on the rates at which ecosystem services recover and on the tradeoffs and synergies among them, at different spatial scales?			

Continued

Table 2 Continued

Policy goals	Key impediments	Research questions	State	Municipality	Farmer / land-holder
4. The collective benefits of FLR are known and widely understood in the community	Benefits of FLR at the landscape scale are rarely monitored and quantified	How do the spatial configuration and extent of restored ecosystems influence biodiversity and overall provision of ecosystem services within a landscape matrix?	Green	Green	Yellow
		What are the effectiveness, cost, and limitations of different methods for monitoring and assessment of the effect of restoration, e.g., the delivery of ecosystem services, at different spatial scales?	Green	Green	Yellow
		What indicators of human wellbeing can be easily and consistently monitored to evaluate FLR outcomes at different scales? How are costs and benefits distributed among stakeholders?	Green	Green	Yellow
		How might the effectiveness of FLR be demonstrated in practice in ways that would be persuasive to landholders and communities?	Green	Green	Yellow
5. The FLR planning process achieves equitable balance between collective benefits and individual landholder costs	Methods to spatially prioritize restoration approaches and outcomes for landholders are poorly developed and collective action among landholders can be difficult to achieve	What landscape-scale models and tools can be used to maximize the delivery of ecosystem services and minimize costs under different combinations of ecosystem restoration and productive land uses?	Green	Green	White
		What is the cost-effectiveness of different restoration methods for delivering benefits across different types of landscapes, climate zones, and spatial scales?	Green	Green	White
		What methods increase the attractiveness of restoration to different types of landholders (small and large landholders, communities, companies, and governments)?	Green	Green	Yellow
6. Sufficient financial resources are mobilized to sustain the implementation of FLR	Long-term and stable sources of financial support are not currently available for FLR at the scales required	How might private enterprise and financial institutions work with (local) governments and landowners to finance restoration and generate new revenues?	Yellow	Green	Green
		How can landholders benefit from restoration, including from payments from the collective generation of ecosystem services, exploiting timber and nontimber forest products in restoration sites, as well as from the added value of certification of products from restoration value chains?	Green	Green	Green
		How can funding from diverse bi-lateral and multi-lateral development assistance sources be coordinated, distributed, and managed to maximize overall benefits and cost effectiveness?	Green	Green	Yellow

Relevance to knowledge client

Green = high relevance; Yellow = moderate relevance; White = low relevance.
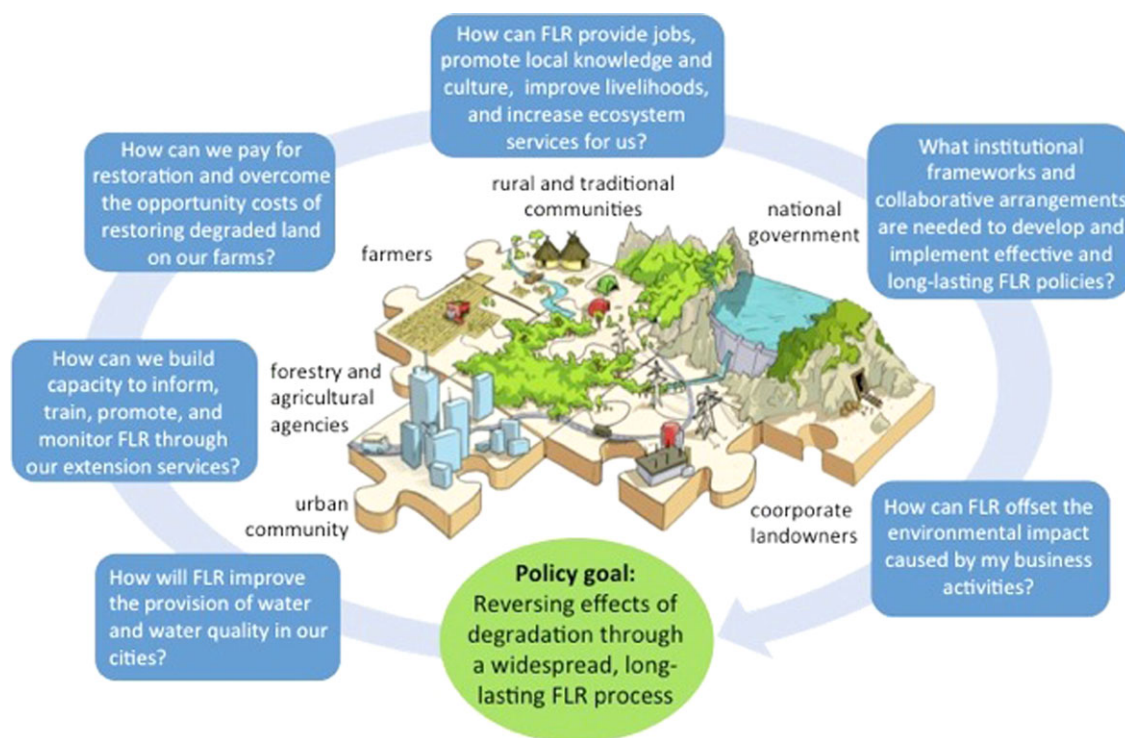
Figure 1 Stakeholders and knowledge clients living and working within a landscape mosaic need different knowledge to support implementation of Forest and Landscape Restoration (FLR). We illustrate here one policy goal with research questions that address knowledge gaps from the perspective of multiple knowledge clients. To achieve broad policy goals, such as those listed in Table 2, knowledge generation requires multidisciplinary research teams working in collaboration with landowners, local research institutions, and agriculture/forestry extension services familiar with the social and environmental context in focal landscapes. Landscape graphic courtesy of Cora van Oosten, the Wageningen UR Centre for Development Innovation.

Here we sketch a broad and far-reaching agenda for addressing major knowledge gaps that impede the successful and long-term implementation of FLR (Table 2). Realizing the holistic vision of FLR requires addressing economic, cultural, and political concerns in addition to the need to restore ecological functions and ecosystem services. Moreover, planning and implementation of FLR must be adapted to work within the unique context of individual regions and countries. We focus on six interdependent policy goals that represent a set of desired outcomes (Table 2). Key knowledge-related constraints prevent these goals being realized. The knowledge clients are diverse and include community water boards, villages, municipalities, state, and national governments, small holders, agricultural cooperatives, private companies, and multi-stakeholder initiatives. Three major classes of knowledge clients—the state, municipality, and farmer/land manager—share many, but not all, knowledge needs (Table 2).

How to fill the knowledge gaps?

The knowledge gaps broadly sketched in Table 2 suggest a multidisciplinary research agenda for teams of social and natural scientists working in collaboration with landowners, local research institutions, and agriculture/forestry extension services familiar with the social and environmental context in focal landscapes (Figure 1). Some knowledge gaps can be addressed as hypothesis-testing research projects that focus on social or ecological costs and benefits of restoration interventions or local and landscape factors that influence growth and survival of native species and performance of species mixtures. The entire range of knowledge clients will benefit from long-term studies of the rates at which ecosystem services recover following different restoration interventions. Such studies will produce fundamental knowledge of ecosystem functioning and should be strongly supported by state research agencies that can provide financial and logistical support for long-term field research.

Research–policy partnerships

Policy agendas are often the outcome of a political process and develop with little input from researchers and experienced practitioners who generate potentially relevant knowledge. At the same time, research agendas are often developed without the participation of policy makers and are therefore irrelevant to key policy issues (Jørgensen *et al.* 2014; Suding *et al.* 2015). Knowledge generation projects, regardless of their funding sources and origins of investigators, need to ensure that information and knowledge be transferred to multiple stakeholders. In some cases, capacity building and local empowerment will be needed to promote successful long-term implementation of FLR, whereas in other cases existing knowledge on effective restoration practices and their multiple benefits needs to be recognized, rewarded, and encouraged more widely (Reij and Winterbottom 2015). Local stakeholders will need to actively plan, govern, and track the process. Finally, restoration initiatives at local scales need to be supported by larger-scale state-based programs, nongovernmental organizations, and public-private partnerships.

We reinforce the need for a tighter linkage between researchers and FLR implementers, or knowledge producers and knowledge clients. 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. Stopping and reversing the tide of environmental degradation requires a novel approach to integrating knowledge creation with policy goals. In the future, such an approach may evolve to more closely resemble the research–policy interface that is now well developed globally within the public health arena.

Inevitably, implementation of FLR needs to move forward using the best available knowledge. Moreover, adaptive management may not be feasible when attempting to transform landscapes at large spatial scales, where biophysical and socio-economic uncertainties abound and where there may not be strong local constituencies favoring changes to the *status quo* that restoration would generate. A process sometimes referred to as "muddling through" may be the best pragmatic response under these circumstances (Sayer *et al.* 2008). Instead of more traditional planning processes that seek to optimize outcomes, muddling through involves "long term engagement in the messy processes of influencing decisions and activities on the ground" (Sayer *et al.* 2008, 321).

Ultimately, new institutions and governance models need to be developed to hold responsibility for implementing, reporting, tracking, and adaptively managing FLR programs at local, national, and international scales.

These institutions will need to build social capital through facilitating cross-level environmental governance (Brondizio *et al.* 2009). Such institutions will often be the best vehicle for identifying obstacles to progress and for linking researchers and policy makers. The proposed research and knowledge agenda will surely evolve and become more locally focused as multiple groups of stakeholders adaptively guide the long-term process of restoring functionality and value to ecosystems and landscapes around the world.

Acknowledgments

References

Aguilar, M., Sierra, J., Ramirez, W., *et al.* (2015). Toward a post-conflict Colombia: restoring to the future. *Restor. Ecol.*, **23**, 4-6.

Aronson, J. & Alexander, S. (2013). Ecosystem restoration is now a global priority: time to roll up our sleeves. *Restor. Ecol.*, **21**, 293-296.

Aronson J., Brancalion P.H.S., Durigan G. *et al.* (2011). What role should government regulation play in ecological restoration? Ongoing debate in São Paulo State, Brazil. *Restor. Ecol.*, **19**, 690-695.

Bae, J.S., Joo, R.W. & Kim, Y.-S. (2012). Forest transition in South Korea: reality, path and drivers. *Land Use Policy*, **29**, 198-207.

Bonn Challenge. Available from http://www.bonnchallenge.org/. Accessed 6 July, 2015.

Brondizio, E.S., Ostrom, E. & Young, O.R. (2009). Connectivity and the governance of multilevel social-ecological systems: the role of social capital. *Annu. Rev. Environ. Res.*, **34**, 253-278.

Calmon, M., Brancalion, P. H. S., Paese, A., Aronson, J., Castro, P., da Silva, S. C. & Rodrigues, R. R. (2011) Emerging threats and opportunities for large-scale ecological restoration in the Atlantic Forest of Brazil. *Restor. Ecol.*, **19**, 154-158.

Chaves R.B., Durigan G., Brancalion P.H.S., Aronson J. (2015) On the need of legal frameworks for assessing restoration projects success: new perspectives from São Paulo state (Brazil). *Restor. Ecol.* **23**, 754-759.

Chazdon, R.L. (2014). *Second growth: The promise of tropical forest regeneration in an age of deforestation*. University of Chicago Press, Chicago.

Costanza, R., de Groot, R., Sutton, P., *et al.* (2014). Changes in the global value of ecosystem services. *Global Environ. Chang.*, **26**, 152-158.

Hanson, C., Buckingham, K., DeWitt, S. & Laestadius, L. (2015). *The restoration diagnostic*. Washington, DC: WRI.

IUCN and WRI (2014). A guide to the Restoration Opportunities Assessment Methodology (ROAM): Assessing forest landscape restoration opportunities at the national or sub-national level. Working Paper (Road-test edition). Gland, Switzerland: IUCN. 125pp.

Jørgensen, D. (2013). Ecological restoration in the Convention on Biological Diversity targets. *Biodivers. Conserv.*, **22**, 2977-2982.

Jørgensen, D., Nilsson, C., Hof, A.R., *et al.* (2014). Policy language in restoration ecology. *Restor. Ecol.*, **22**, 1-4.

Lamb, D. (2014). *Large-scale forest restoration*. Routledge, London.

Latawiec, A.E., Strassburg, B.B., Brancalion, P.H., Rodrigues, R.R. & Gardner, T. (2015). Creating space for large-scale restoration in tropical agricultural landscapes. *Front. Ecol. Environ.*, **13**, 211-218.

Lü, Y., Fu, B., Feng, X., *et al.* (2012). Policy-driven large scale ecological restoration: quantifying ecosystem services changes in the Loess Plateau of China. *PloS One*, **7**, e31782.

Menz, M.H.M., Dixon, K.W. & Hobbs, R.J. (2013). Hurdles and opportunities for landscape-scale restoration. *Science*, **339**, 526-527.

Murcia C., Guariguata M.R., Andrade Á. *et al.* (2015). Challenges and prospects for scaling-up ecological restoration to meet international commitments: Colombia as a case study. *Conserv. Lett.* DOI: 10.1111/conl.12199.

Perring M.P., Standish R.J., Price J.N. *et al.* (2015). Advances in restoration ecology: rising to the challenges of the coming decades. *Ecosphere*, **6**, art131. http://dx.doi.org/10.1890/ES15-00121.1.

Pinto S.R., Melo F., Tabarelli M. *et al.* (2014) Governing and delivering a biome-wide restoration initiative: the case of Atlantic Forest Restoration Pact in Brazil. *Forests*, **5**, 2212-2229.

Rappaport D.I., Tambosi L.R., Metzger J.P. (2015) A landscape triage approach: combining spatial and temporal dynamics to prioritize restoration and conservation. *J. Appl. Ecol.*, **52**, 590-601.

Reij C. & Winterbottom R. (2015) *Scaling up regreening: Six steps to success. A practical approach to forest and landscape restoration*. World Resources Institute, Washington, D.C.

Sayer, J., Bullb, G. & Elliott, C. (2008). Mediating forest transitions: 'Grand design' or 'Muddling through'. *Conserv. Soc.*, **6**, 320.

SER Society for Ecological Restoration International Science & Policy Working Group. (2004). SER international primer on ecological restoration. Society for Ecological Restoration. Available from http://www.ser.org/resources/resources-detail-view/ser-international-primer-on-ecological-restoration. Accessed 6 July, 2015.

Stanturf, J., Palik, B. & Dumroese, R.K 2014. Contemporary forest restoration: a review emphasizing function. *Forest Ecol. Manag.*, **331**, 292-323

Suding, K., Higgs, E., Palmer, M., *et al.* (2015). Committing to ecological restoration. *Science*, **348**, 638-640.