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OPINION PAPER

Implementing forest landscape restoration under the Bonn Challenge: a systematic approach

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Abstract

· ***Key message*** **There is no one-size-fits-all way to successfully implement forest landscape restoration (FLR). Complex socio-ecological systems present challenges and opportunities that can best be met with a systematic framework for designing, planning, steering, and monitoring FLR projects to meet diverse needs. Project cycle management is an iterative, adaptive, hierarchical framework with recurring consultations among stakeholders that can enhance the likelihood of FLR success.**

Keywords Bonn Challenge · Ecological integrity · Livelihoods · Governance · Project cycle management

1 Introduction

Interest in halting and reversing degradation and restoring landscapes is high, particularly forest landscapes; however, the normal issue attention cycle in public opinion and policy (Fig. 1) suggests that the commitment of policy makers will wane as they become aware of costs, complexity, the time needed for outcomes to be realized, and the lessening interest of the public and stakeholders (Downs 1972). The Bonn Challenge and regional initiatives have mobilized political support to commence restoration on 150 million ha of forest landscapes by 2020 and 350 million ha by 2030. Underlying the Bonn Challenge is the forest landscape restoration (FLR) approach that differs from a more eco-centric, ecological restoration in that equal priority is given to human livelihoods and biodiversity conservation (Mansourian 2005; Stanturf et al. 2014a). Although there appears to be general consensus on the broad principles of FLR (Besseau et al. 2018), little guidance exists on how to put these principles into operation (Stanturf 2015). Because FLR is relatively new, examples are lacking of successful long-term implementation that fully satisfy all FLR principles. While there are many practical but isolated examples of specific techniques and projects that illustrate FLR, implementation requires a more general systematic approach to how we manage and govern land, including organization of local, national, and global reward systems (Mansourian 2017; Pistorius and Freiberg 2014).

Resilience is one of the most important aspects of FLR; vigorous trees in ecologically stable ecosystems are a precondition for the delivery of ecosystem services from restored forests in changing environmental conditions (Spathelf et al. 2018). Extreme climatic events, altered climate means, and land use change (Liang et al. 2018; Stanturf 2015) and novel climate and disease scenarios (Aitken et al. 2008) are increasing the need for restoration. Insufficient consideration of future climate means and extremes will negatively affect resilience of restored landscapes (DeRose and Long 2014). While past experience offers hope, we cannot expect that natural

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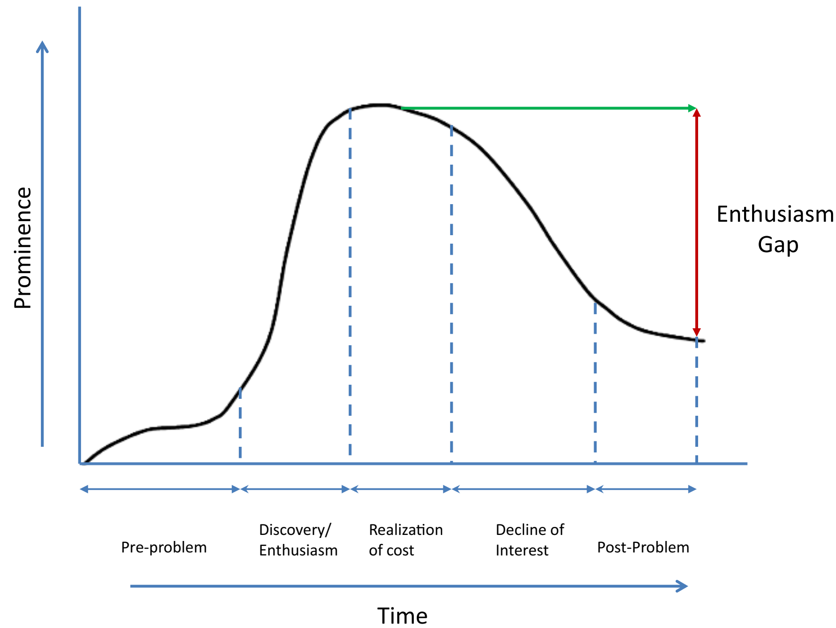

Fig. 1 The policy attention cycle, illustrating the waxing and waning of interest in an issue over time. The beginning of deforestation and forest degradation dates to pre-history, accelerating with the advent of agriculture (pre-problem stage). Recognition of the need for reversing deforestation and degradation probably date to the same time in pre-history but the development of forest landscape restoration (FLR) as a policy issue (stage 2) began with academic attention to ecological restoration in the 1970s and formation of the Society for Ecological Restoration in 1988. Formal definition of FLR dates to 2000. Currently, FLR is in stage 2/3. If the normal cycle prevails and interests decline (stages 3–4), the need for FLR will not decline but a gap in enthusiasm may develop (after Downs 1972)

processes and native species and provenances will provide optimal solutions powerful enough to meet all future needs.

Achieving meaningful success at restoring degraded landscapes will be costly in both financial and social terms. Critics argue that restoration takes too long, costs too much, and produces too few benefits to justify public or private expenditures (Verdone and Seidl 2017). While the costs of investments in restoration may appear to be high—particularly in the near term—these costs are typically very low when compared to the costs of inaction (e.g., IPBES 2018; UNCCD 2017). Embedding restoration objectives in a broader development agenda—such as attainment of the sustainable development goals (SDGs)—may be important for maintaining support and securing the financial resources needed for restoration programs and activities (Mansourian 2018). Restoration can contribute to the attainment of the SDGs, in particular those related to food security, poverty alleviation, water, human health, and biodiversity conservation (Mansourian 2018; Swamy et al. 2018). When international commitments are linked to accepted local goals and aspirations, the chances of achieving restoration targets are enhanced. But, unleashing large-scale restoration may require changes to policy frameworks, tenure systems, and institutional arrangements, in other words challenging business as usual (Mansourian 2017; Reinecke and Blum 2018).

Overcoming the “enthusiasm gap” (Fig. 1) that could develop as the Bonn Challenge matures requires at a minimum, successful FLR implementation following a consistent strategic program, so it is useful to take stock of what tools we already have. Integrated landscape approaches (Freeman et al. 2015; Kusters et al. 2017) such as FLR are prominent in efforts to reverse past socio-ecological damage. Landscapes are multi-functional; they are not defined just by what is found within a geographical space (Oliver et al. 2012; van Oosten 2013). Besides internal dynamics, landscapes are influenced by external factors such as migration, global trade, consumer preferences, international agreements, investors, and climate change (Grau and Aide 2008; Martín-López et al. 2017).

Implementing FLR is challenging because of the need to consider context: political, economic, social, as well as biophysical, in balancing competing interests and differing priorities for livelihoods versus biodiversity (Maron et al. 2012). On the one hand, in contexts such as protected areas, biodiversity conservation may take precedence over immediate human needs and ecological restoration plays a central role (Keenleyside et al. 2012). Nevertheless, people living in and around protected areas often need compensation for loss of livelihoods in order to avoid further encroachment and for restoration to be sustainable over the long term (MacKay and Caruso 2004; Wells and McShane 2004). On the other hand, many landscapes in need of restoration are a mosaic of different land uses and that may tip the scales toward meeting human livelihood needs in restoration decisions, for example by planting non-native species for fuelwood (Kegode et al. 2017; Tesfaye et al. 2015). A strength of FLR as a landscape approach is the opportunity for compromise and sub-optimization of some objectives, for example improving species diversity within a production-oriented landscape, but never quite reaching the diversity of a pure conservation area. Another example of sub-optimization might be planting slower-growing native species that sequester less carbon than faster-growing non-native species but provide better habitat for local wildlife (Lamb et al. 2012).

The objective of this paper is to review topics that need to be considered for successfully implementing FLR at multiple scales, under diverse ecological and socioeconomic conditions, where stakeholders have differing expectations for success. We set the stage with reflections from three well-documented past experiences of large-scale restoration in Puerto Rico, Denmark, and South Korea, followed by an overview of some of the current global challenges to FLR implementation. Then, we suggest that likelihood of successful FLR implementation is enhanced by following the well-established methods of project cycle management (Battisti 2017; Khang and Moe 2008). We conclude by describing some future needs. Our key message is that there is no one-size-fits-all approach to FLR implementation, and the complexity of socio-ecological systems provides not only challenges but also opportunities for meeting diverse needs.

2 Long-term experience of forest restoration

Past restoration approaches based on simple methods have been successful (Stanturf 2016). Much restoration was accomplished by simply abandoning agriculture and allowing undisturbed, natural processes of recolonization. Most active approaches had singular objectives such as reducing soil erosion or restoring productive commercial forest plantations (Mansourian 2018; Stanturf et al. 2014b). While successful, these simple approaches may not be well adapted to today's complexity, including the increased uncertainties associated with climate change and its effects on ecosystems, human communities, and land management practices (Parrott and Meyer 2012; Puettmann 2014). Nevertheless, these examples typify the resilience of forest landscapes.

2.1 Puerto Rico

Puerto Rico provides many examples of passive and active restoration based on 75 years of continuous research in dry, moist, wet, and rain forest environments (Grau et al. 2003; Lugo and Helmer 2004). Research included species trials with over 400 native and non-native tree species. Passive restoration occurred as land was abandoned from active agriculture, either spontaneously or after government intervention. Sometimes, farmers were provided with commercial tree species to intercrop with food plants until canopy closure; farmers were then relocated (Robinson et al. 2014b).

Monitoring of native and plantation forest stands over 60 years provided information on the overstory growth and development of native species in the understory (Lugo 2000; Lugo 2018) and formed the basis for studies of stand dynamics, in particular the effects of hurricane disturbances (Lugo 2000). Continuous island-wide forest inventories conducted since 1982, analysis of land cover changes using air photos from the 1930s to the 1970s, and subsequently high-resolution satellite images have added to the understanding of landscape change (Martinuzzi et al. 2013). In 2017, Hurricanes Irma and Maria significantly damaged the island and reset forest dynamics.

2.2 Denmark

Denmark has a 200-year history of FLR, a story of forest cover losses and gains typical for land in the Northwest European lowland (Madsen et al. 2005). It is also a story of ecological disaster; large areas of degraded, unproductive heathland were created. Attempts at forest restoration in Denmark were similar to events elsewhere including heathland tracts of Northern Germany (Bradshaw 2004). Deforestation from shifting agriculture, grazing, and fire created a highly degraded landscape that needed non-native conifers for restoration; native broadleaves could not establish on the degraded heathlands (Madsen et al. 2005), and people needed wood for construction and fuel. Overgrazing and fire also destroyed the heather, exposing sandy soil to wind erosion. The dunes that formed sometimes covered houses and whole villages.

Because of harsh growing conditions, survival and growth of planted seedlings were low and only non-native conifers such as mountain pine (*Pinus mugo* Turra) could survive. Today, non-native species such as Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco), Norway spruce (*Picea abies* (L.) Karst.), and Scots pine (*Pinus sylvestris* L.) support continuous cover forestry systems. The re-introduction of native broadleaves such as European beech (*Fagus sylvatica* L.) is occurring and managed in mixed, novel forests. Recent research is examining the potential contribution of species from the Caspian Forest in Iran (Stanturf et al. 2018). One lesson to draw from the Danish experience is the importance of citizen support. Although the restoration effort was led by philanthropic elites, there was mass support of the program on the basis of national pride and patriotism (Madsen et al. 2005).

2.3 South Korea

South Korea provides another example of FLR (Lee et al. 2015; Park and Youn 2017). The causes of deforestation in the Korean Peninsula were several: over-exploitation of forest resources for fuel (firewood and charcoal accounted for 62.5% of primary energy into the 1960s); illegal logging that occurred widely, mainly due to increasing poor population; expansion of agricultural lands (19% increase in 1952–1968); and the Korean War (1950–1953) destroyed forests. The restoration example of South Korea is widely praised and relied on three factors, two of which are well known: the positive attitude of the people that favored the government-led reforestation program, which was re-enforced by economic incentives for income generation from community forestry, and overall economic growth of the nation that allowed the government to invest in reforestation (Park and Youn 2017). Critics, however, have also pointed to the largely top-down approach taken to restoration and to the possible displacement of deforestation and forest degradation to other countries.

The third factor in the success of reforesting South Korea, policy integration (Park and Youn 2017), has not received as much attention. Investment in the forestry sector was included in a series of coordinated national economic plans from 1967 to 1987 primarily for erosion control and conservation. Further, governmental agencies collaborated on energy policy to reduce pressure on the forest by substituting wood with coal briquettes, by remodeling house heating systems to use the briquettes, and by establishing fuelwood plantations. Illegal timber harvests were reduced by providing alternatives to local wood for housing construction. The Ministry of Agriculture and Forestry prohibited the use of timber for domestic purposes and limited permits for timber harvesting from private forests. The Ministry of Construction limited construction permits for housing, and the Ministry of Commerce and Industry liberalized timber imports and increased production and distribution of cement as a substitute of timber for construction. Increased enforcement of timber harvesting laws was made possible by moving the Korea Forest Service to the Ministry of Home Affairs in 1973 (until 1987), thereby giving them law enforcement responsibility.

2.4 Lessons learned from these case studies

Some key biological and social lessons can be gleaned from these examples. Restoration interventions, under either anthropogenic or non-anthropogenic control, can be successful. The level of soil degradation determines species composition, and introduced species can colonize without intervention. Protecting and restoring the soil is critical for facilitating restoration, particularly replenishment of soil organic matter. Natural processes, such as seed dispersal, colonization, and self-organization, are restoration assets which humans cannot replace (Lugo 1997; Lugo and Helmer 2004).

Novelty was a component; all species, native or non-native, played a role in restoration (e.g., Lugo and Erickson 2017). Planting monocultures (mahogany on private land in Puerto Rico or mountain pine in Denmark) achieved high levels of diversity over time as native species dispersed into plantations. Canopy closure was a key moment in the restoration trajectory (environmentally and biologically). Monitoring restored systems and allowing time for them to develop were necessary steps to ensure successful restoration.

Local and national support for restoration was critical for success. Popular support in Denmark was cast as a matter of national pride and patriotism. Similarly in South Korea, people approved of the government-driven restoration program backed by incentives and facilitated by overall economic growth. Government ministries reinforced restoration efforts by integrating policies, for example enforcing laws against illegal logging offset by imported wood to meet local needs (Park and Youn 2017). In Puerto Rico, government industrialization policies encouraged land abandonment, thereby reducing pressure on native forests and allowing deforested areas to recover (Grau et al. 2003). In all cases, these were long-term initiatives; today, however, faced with political enthusiasm and climate change, there is pressure to restore vast areas in a much shorter period.

3 Global challenges for FLR

Available evidence strongly suggests that FLR will be successful only when the underlying causes of deforestation and degradation (DeFries et al. 2010) are recognized and addressed (IPBES 2018; Robinson et al. 2014a), particularly unclear land tenure, governance and market failures, and lack of policy coordination (Mansourian 2017). Understanding, influencing, and shaping landscape governance is needed for successful FLR implementation, including notably engaging people at all levels, mechanisms by which people make decisions, tools used to facilitate decision-making, and structures to reach and implement those decisions (Mansourian 2017; Reinecke and Blum 2018).

Landscapes stretch over wide areas, crossing boundaries between administrative jurisdictions, possibly including several municipalities, counties, provinces, or transboundary regions between nations. The socio-ecological processes occurring in landscapes often are asynchronous with the political organization of state and sub-state governance units that may be rooted in historical developments such as colonialism. This asynchrony hampers the process of building strong and coherent institutions within the landscape (Reinecke and Blum 2018), leading to fragmented policies that do not match the multi-functionality of landscapes. Therefore, improving landscape governance means reconnecting the administratively fragmented landscapes and building bridges among actors and sectors operating on either side of a boundary without adding more layers of administration.

Viewpoints differ on some critical issues affecting FLR implementation, including preferences for top-down or bottom-up planning and priority setting (Cordell et al. 2017; Evans et al. 2018), potential of passive versus active restoration (Crouzeilles et al. 2017; Reid et al. 2018), and perceived need for exclusion of non-native species in favor of native species (Davis et al. 2011; Thomas et al. 2014). Too little attention has been given to planning long-term management of restored (or restoring) landscapes that will result in resilience in the face of changing climate, resistance to future degradation, and social benefit from provisioning various goods and services (Reid et al. 2017; Stanturf 2015).

3.1 Meeting expectations

Unmet expectations from FLR could contribute to waning enthusiasm for the Bonn Challenge. For example, because there is no vetting process for Bonn Challenge commitments, it may not be clear in a local context if projects to meet national commitments are really FLR, if the purported benefits will be realized or be realized by the most affected communities. Critics of the Bonn Challenge process have noted its focus on numerical targets (hectares) without sufficient consideration of the effectiveness (quality) of restoration projects (Brancalion and Chazdon 2017; Mansourian et al. 2017). Vague or conflicting ideas of what comprises successful restoration may arise in the absence of clear guidelines on what constitutes FLR. The FLR approach places great emphasis on participatory decision-making (Pistorius and Freiberg 2014; Sayer et al. 2013). As Reinecke and Blum (2018) conclude, however, FLR is unlikely to please everyone and who benefits will depend on who plans and implements FLR.

3.2 Conceptual clarity

Adding to the potential difficulty of unmet expectations is the lack of consensus on key concepts of FLR. Even the definition of forest is contentious with some arguing that a forest must be “natural,” thereby excluding planted forests from such a definition (Chazdon et al. 2016; Putz and Redford 2010). At the other extreme, simply increasing forest cover with non-native species is not realistic either because of the loss of biodiversity and probably lack of livelihood enhancement (e.g., Zhai et al. 2014). Further, a narrow focus on “forests” defined as closed canopy systems will undervalue the contribution of woodlands and trees outside forests (van Noordwijk et al. 2008; Zomer et al. 2016). As well, a lack of trees in the landscape does not always indicate deforestation or degradation; it might indicate the presence of native grassland or savanna (Veldman et al. 2015). Unresolved, these conflicting notions and potentially unmet expectations may render FLR irrelevant over the long term.

Differing definitions of degradation have hampered identifying degraded areas in need of restoration (FAO 2011; IPBES 2018). Determining what is degradation is a subjective matter (Hobbs 2016); what is clear is that FLR is not a simple win-win solution on unoccupied, degraded lands that otherwise would remain unused. Further, land once restored creates new assets, whetting appetites of different actors to acquire or use those assets (Mansourian 2016). For the sake of long-term ecological, economic, and social benefits for many people, FLR inevitably has to deal with conflicts of interest and seeks fair ways to designate losers and minimize resistance. Conflicting interests may be dealt with by fully considering legitimate claims to resources in landscapes through economic incentives, education, or capacity building and especially through transparent implementation (Mansourian 2017; Stanturf et al. 2017).

3.3 Time needed

Restoration requires time for interventions to result in positive change toward defined objectives. The original conception of the Bonn Challenge was 150 million ha of degraded landscape would “be restored” by 2020. Realizing the impossibility of measuring significant positive change in such a short time, the wording was changed to “under restoration.” In addition to the time needed for ecosystems to recover, social processes require time for developing trust among participants (Khadka and Schmidt-Vogt 2008; Metcalf et al. 2015). Partnerships and strong working relations among communities, local and regional governmental organizations, NGOs, and donor organizations are necessary for helping communities to enforce forest use and management rules, provide financial and technical support for restoration and conservation activities, and increase community capacity to sustainably and equitably manage forests and other natural resources (Charnley 2017; Gutierrez-Montes et al. 2009; Gutiérrez-Montes 2017).

The disparity in time scales, between the urgency of restoring degraded land and the longer time needed to address governance issues (Mansourian 2017) and attain positive ecological and livelihood changes, underscores the need for long-term commitment to FLR. Ghana, for example, has committed to restoring 2 million ha of deforested and degraded landscapes by 2030 under the Bonn Challenge and the AFR 100 (http://afr100.org/content/ghana; Foli 2017). Although supportive policy and regulatory frameworks exist, reforms are still required to harmonize customary and statutory laws. Land access and secure tree tenure remain critical elements for policy makers to address (Blay et al. 2008; Damnyag et al. 2012). Successful restoration in Ghana will depend on participatory forest management and monitoring, as well as effective enforcement of forest legislation related to land and tree tenure (Hansen 2011; Wardell and Lund 2006).

4 Applying project cycle management to FLR

Into the constantly evolving socioeconomic, political, and natural environments described above, project cycle management (PCM) is a systematic framework (Fig. 2) that can be useful for designing, planning, steering, and monitoring an FLR project or initiative (Battisti 2017). The PCM framework is not a simple, linear process but rather is iterative, adaptive, and hierarchical with recurring consultations among stakeholders (Stanturf et al. 2017). The implementation process operates at multiple spatial and temporal scales, and there are many useful planning tools available that may be adapted to FLR (e.g., Kusters et al. 2017; Tobón et al. 2017). Well-defined goals and reconciled objectives are indispensable for success. This can only come about from a clear process of engaging local stakeholders (Buckingham et al. 2018; Mansourian and Parrotta 2018). Expectations of the shared vision of the restored landscape must be stated in terms of objectives that can be implemented with an explicit understanding of the mechanisms and trajectory that connects them to the desired endpoint (Hobbs 2007; Hughes et al. 2005).

In FLR, PCM has four phases that progress toward greater specificity with flexible timing (Table 1). Feedback at regular intervals in the cycle allows for opportunities to shuffle priorities, shift implementation activities, and re-align resources in light of changing conditions and new information by continuous learning coupled with adapting to increased knowledge.

Visioning sets out the aspirational goals for FLR, often at a national or regional level, but casting a vision, and getting buy-in, is needed locally as well (Stanturf et al. 2017). Goals may acknowledge international commitments such as biodiversity targets; monitoring, assessments, and research on degradation and/or deforestation drivers may inform the visioning phase by identifying opportunities and obstacles. *Conceptualizing* turns goals into clear and measurable objectives that can be acted upon. This phase determines the most feasible and effective interventions for the target landscape that may be derived from national, regional, or local goals. During the conceptualizing phase, selecting priority regions or landscapes to focus activities may gain the most benefit from limited resources. The *acting* phase plans activities to turn objectives into accomplishments by developing a sequenced list of what will be done, where, when, by whom, and at what cost (Stanturf et al. 2017). *Sustaining* FLR over the long term combines management planning with monitoring and evaluation in order to provide feedback into earlier phases for potential corrective actions. Some examples will illustrate the four phases and the hierarchical nature of PCM, with the greatest emphasis on the conceptualizing and acting phases.

4.1 Visioning

Visioning sets the goals for what comprises a restored environment and the ecological and social benefits flowing from a well-functioning landscape. Often these goals will be identified by what is presently lacking, degraded, or both and should

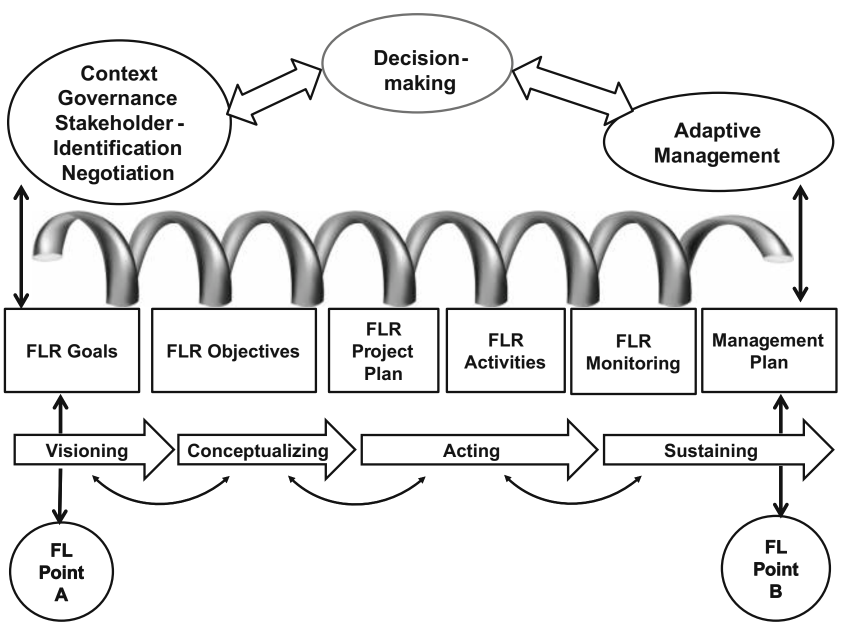

Fig. 2 Project cycle management (PCM) applied to forest landscape restoration (FLR) has four phases: visioning, conceptualizing, acting, and sustaining. PCM is an adaptive, iterative process for moving from broad goals (a vision) for improving the current condition of the forested landscape (FL point A) by conceptualizing tangible, measurable objectives that can be acted upon, resulting in a future restored conditions (FL point B). To ensure the sustainability of FLR, monitoring and long-term management must be integrated into the FLR project and feedback into decision-making (adaptive management). Ample opportunities exist at all phases for feedback and iteration of previous negotiations as new conditions, knowledge, or stakeholders emerge. Preceding PCM initiation and negotiation of goals, environmental and social contexts are recognized (including governance and stakeholder identification)

Table 1 Hierarchical nature of project cycle management illustrated with an example from Rwanda (MINIRENA 2014)

Phase	Visioning	Conceptualizing	Acting	Sustaining
Realization	**Goal**	**Objective**	**Plan**	**Feedback**
Meaning	The purpose toward which an FLR project is directed	Accomplishments or targets of one's efforts or actions	Activities that will result in accomplishments or meet targets	Adaptive management
Measure	Goals may or may not be strictly measurable or tangible	Must be measurable and tangible	Sequenced list of what will be done, where, when, by whom, at what cost	Monitoring, Management Plan
Time frame	Long-term	Mid- to short-term	Mid- to short-term	Long-term
Example	• Increase forest cover and restore degraded land • Provide access to clean water • Improve management of existing woodlots • Reduce soil erosion by introducing agroforestry • Contribute to climate change adaptation	Protect and restore natural forests • 3000 ha new forests • 20,000 ha *Eucalyptus* replaced • 100 m buffers natural forests planted around natural areas • Restore degraded areas within reserves and parks	Plant 100 ha native species in 20 m buffers along rivers in Kigali Province in October by local farmers	• Monitor development Planned interventions • Course corrections • Maintenance

The goal of increasing forest cover and restoring degraded land is realized by the objective of restoring natural forests. One action to implement the objective is to plant riparian buffers of native species in Kigali Province. This also meets the goal of providing access to clean water by protecting the river bank

emanate from multi-stakeholder consultations. A simple exercise can be useful to define goals and structure negotiations on objectives. Two questions (Do we have it? Do we want it?) lead to four possible categories of objectives for preserving or eliminating current conditions or achieving or avoiding certain future conditions (Fig. 3). The "it" may be an ecosystem service (e.g., protection from flooding), an ecological benefit (e.g., protecting endangered species), or an economic benefit (e.g., sustainable fuelwood).

Goals generally describe expected long-term outcomes and may or may not be strictly measurable or tangible, depending upon the scope and level of consideration (Stanturf et al. 2017). Understanding what is needed can be gained through national surveillance monitoring (Hutto and Belote 2013; Petrokofsky et al. 2011), socio-ecosystem assessments (De Vreese et al. 2016; Halofsky et al. 2014), and establishing baselines of current conditions of important functions (Table 2) that feed into stakeholder engagement processes.

Goals may be defined in a landscape hierarchy. For example, FLR in El Salvador is largely a top-down process, using the Restoration Opportunities Assessment Methodology (ROAM) (MARN 2017) to develop goals and objectives. Participatory analysis of landscape degradation identified concerns for surface and groundwater, adaptation to drought, soil conservation and agriculture, floods and storms, biodiversity, climate regulation by urban cities, and rural communities need for firewood. Further participatory processes will define objectives, prioritize the sites to restore, and identify restoration techniques to use. In order to monitor and measure the impact of restoration interventions in the medium and long terms, an

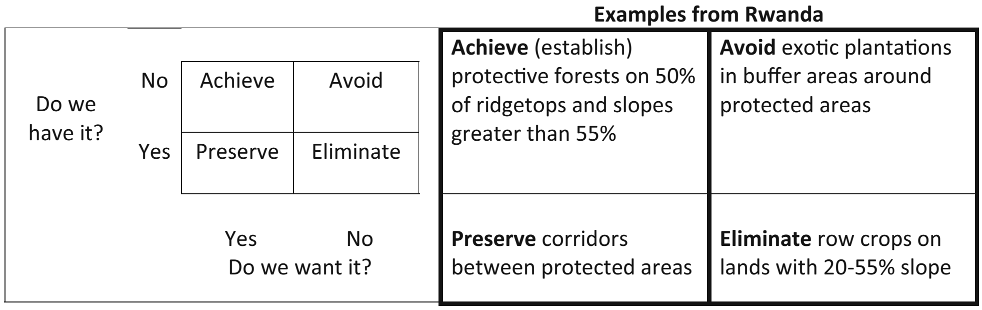

Fig. 3 A schematic for developing objectives and guiding discussion poses two questions: Do we have it? Do we want it? (It can refer to environmental or social condition). Answering these two questions leads to four possible objectives of preserving or eliminating current conditions or achieving or avoiding certain future conditions. This approach applied to Rwanda is illustrated by four objectives

inter-institutional, interdisciplinary national monitoring plan is being defined (MARN 2017). Local restoration and monitoring plans will be developed that need to be implemented by alliances of municipalities, farmer associations, and government agencies.

Identifying goals does not have to be a top-down exercise. In many countries, there is a host of small projects scattered across the landscape. Chile, for example, has committed to restore approximately 500,000 ha by 2030. Since 1990, many small restoration initiatives have been reported but most are isolated examples (< 1 ha) (Vargas 2017). Scaling-up technical knowledge from research studies to operational activity at the landscape scale, however, can be difficult (e.g., Stanturf et al. 2001). Nevertheless, the experience of the Atlantic Forest Restoration Pact shows how over 270 public and private organizations came together to organize small restoration projects into a national movement (Brancalion et al. 2013; Giorgi et al. 2014).

4.2 Conceptualizing

Conceptualizing requires setting tangible and measurable objectives or targets that accomplish the restoration goals and describe the desired future condition of the landscape (Table 1) or units within the landscape (Table 2). The relationship of goals to objectives can be seen in an example from Rwanda (Table 1). The goal of increasing forest cover was linked to the objective of protecting and restoring natural forests, which has five specific sub-objectives. Creating productive, resilient landscapes typically will involve selecting approaches that are feasible and effective in the specific ecological and social context from a variety of possible restoration (Chazdon 2015; Dumroese et al. 2015) and livelihood approaches (Angelsen et al. 2014; Garibaldi et al. 2017).

4.2.1 Social approaches

Meeting the ambitious targets of the Bonn Challenge requires selecting from approaches that provide economic incentives, enabling regulations, or targeted education that modify or replace existing land use systems. Mobilizing and using available scientific, local, and traditional knowledge and technical expertise is critical for achieving successful FLR (Rerkasem et al. 2009; Uprety et al. 2012). While FLR emphasizes participation of local communities, often local people lack the capacity or resources to be fully engaged. Community members need tangible, meaningful, and sustained incentives to support restoration activities so that the benefits of conservation and restoration outweigh the costs. Key challenges are identifying and sustaining appropriate incentive mechanisms that are linked to conservation and equitably distributing the costs and benefits among community members (e.g., Charnley 2017).

4.2.2 Adaptive capacity

Developing adaptive capacity locally can greatly facilitate FLR processes and improve outcomes (Gutiérrez-Montes 2017). Increasing income (nursery work, planting, monitoring), providing alternative livelihoods (non-timber forest products or ecotourism), or improving agricultural yields through sustainable intensification (Rockström et al. 2017) all contribute to local adaptive capacity and buffers against short-term economic or political costs. In densely populated India, for example, linking restoration to employment generation makes it socially relevant and politically attractive (Kant and Burns 2017). The sustainable livelihood approach used in Latin America sees livelihoods as encompassing the full range of resources and assets needed for families to live, as well as community capital and capacities (Gutierrez-Montes et al. 2009).

4.2.3 Economic drivers

A variety of economic drivers can be used to improve overall landscape functioning including timber and fuelwood production, new markets, and payments for ecosystem services such as carbon, water quantity, and quality (Harper et al. 2012;

Table 2 Baseline conditions, from severely degraded mined land to relatively pristine primary forest

Land cover	Vegetation structural complexity	Native vegetation composition	Ecological function	Baseline description (ecological function)	Restoration options
Surface mined land	1	1	1	Generally, all topsoils were removed, possibly stockpiled; hydrology disrupted (1)	Reclamation: restore topography and place topsoil; plant (often exotics)
Row crops	1–2	1–2	1–3	Soil erosion (1); lowered soil organic matter (2); turn rows may be habitat (3); fertility enriched (especially phosphorus) (1–3)	Climate-smart agriculture Agrosylvopastoral systems (integrated trees, animals) ***Taungya*** (woody and agricultural species interplanted during early stages of plantation establishment) Reconstruction: afforestation, cluster, or nucleation planting; natural regeneration
Abandoned pasture	1–3	1–3	1–2		Silvopastoral systems (combined forestry and grazing) Reconstruction: afforestation, cluster, or nucleation planting; natural regeneration; fire management
Trees outside forests	2–3	2–3	2–3	Refers to isolated trees (2); windbreaks, fence or ditch lines (3); early stages of non-forest land such as pasture restored by cluster or nucleation planting may resemble "trees outside forests" (3)	Fire management Grazing protection or management
Alley cropping	2–3	2–4	1–4	May be referred to as trees outside forests; agrisilvicultural systems, a combination of crops and trees (1 to 4, depending on the species and density of woody stems)	Native woody species in hedges, agricultural species in alleys between hedges
Home gardens	2–3	2–4	1–4	May be referred to as trees outside forests; agrisilvicultural systems, a combination of crops and trees (1 to 4, depending on the species and density of woody stems)	Multi-story combination of native trees and crops around homesteads
Industrial tree crops (e.g., rubber, oil palm, nut orchards)	3–4	1–3	1–3	May be referred to as plantations or trees outside forests (1–3, depending on the species and density of any native species in understory)	Integrated multi-story mixture of plantation species; shade trees for plantation crops Intercropping with native trees Clear and plant with native trees
Short-rotation intensive culture -exotic species	3–4	1–2	2–3	Could be an early stage of reconstruction, depending upon soil degradation; could be industrial plantation (2–3, depending	Clear and plant to native species Convert to native species by natural regeneration or underplanting, possibly with overstory thinning to create gaps

Table 2 (continued)

Land cover	Vegetation structural complexity	Native vegetation composition	Ecological function	Baseline description (ecological function)	Restoration options
				on the overstory density and density of any native species in understory)	
Short-rotation intensive culture-native species	3–4	2–3	2–4	Could be an early stage of reconstruction; could be industrial plantation (2–3, depending on the overstory density and density of any native species in understory)	Lengthen rotation, allow self-thinning or thin to create gaps or variable density thinning; underplant with other species
Swidden farming-short fallow	2–3	2–3	2–3	Temporary agricultural plot formed by cutting back and burning off vegetative cover; length of fallow too short for soil fertility to recover (2–3, depending on the density of any native trees in overstory)	Lengthen fallow; native woody species planted and left to grow during fallow Reconstruction: afforestation, cluster, or nucleation planting; framework species planted; assisted natural regeneration
Swidden farming-long fallow	3–4	3–4	3–4	Temporary agricultural plot formed by cutting back and burning off vegetative cover; length of fallow long enough for soil fertility to recover (3–4, depending on the density of any native trees in overstory herbs in understory)	Lengthen fallow; native woody species planted and left to grow during fallow Reconstruction: afforestation, cluster, or nucleation planting; framework species planted; assisted natural regeneration
Degraded forest-scrub	2–3	2–3	3–4	Native forest degraded by frequent wildfire, over grazing, exploitive cutting, possibly for charcoaling (3–4, depending on the presence of any native trees, herbs in understory)	Manage fire (lengthen return interval, burn early in rainy season) with natural regeneration Reconstruction: afforestation, cluster, or nucleation planting; framework species planting
Degraded forest-derived savannah	2–3	2–3	2–4	Native forest degraded by too frequent wildfire, over grazing (2–4, depending on the presence of any native trees, herbs in understory)	Manage fire (lengthen return interval, burn early in rainy season) with natural regeneration Reconstruction: afforestation, cluster, or nucleation planting; framework species planted
Degraded forest-derived woodland	3–4	2–4	3–4	Native forest degraded by frequent wildfire, over grazing, exploitive cutting, (3–4, depending on the density of native trees, herbs in understory)	Manage fire (lengthen return interval, burn early in rainy season) and manage grazing; natural regeneration Reconstruction: clear and afforest, cluster, nucleation or framework species planting Rehabilitation: retain scattered trees, afforest, cluster, nucleation, or framework species planting

Table 2 (continued)

Land cover	Vegetation structural complexity	Native vegetation composition	Ecological function	Baseline description (ecological function)	Restoration options
Degraded forest-regrowth	3–4	3–4	2–4	Native forest degraded by too frequent wildfire, over grazing, Swidden agriculture, exploitive cutting, (2–4, depending on the density of native trees, herbs in understory)	Manage fire (re-introduce if adapted) Rehabilitation: alter structure, underplant, natural regeneration Replace: clear and plant
Managed, artificially regenerated forest plantation	3–4	2–4		Planted forests of exotic (2–3) or native species (3–4) are referred to as plantation forests (with single or few species, even age class, uniform planting density)	Rehabilitate by adding native species and/or thinning to create a complex structure, uneven age stand
Managed, artificially regenerated forest -planted forest	3–5	3–5		Planted forests of indigenous species are increasingly referred to as forms of semi-natural forest or modified natural forest (3–5 depending on the degree of naturalness, rotation length, including mixed species and age classes and variable planting density)	Rehabilitate by adding native species and/or thinning to create a complex structure, uneven age stand
Managed, naturally regenerated forest—few species	3–4	3–5		Naturally regenerated forest of native species, few species may be natural (4–5) or a result of previous high grading or, otherwise, lack of regeneration of some species (3–4)	Manage fire (re-introduce if adapted) Rehabilitation: alter structure, thin and underplant any missing species or natural regeneration Replace: clear and plant
Managed, naturally regenerated forest—many species	3–5	4–5	4–5	Naturally regenerated forest of native species, most native species present (5) or some lacking, a result of previous high grading or otherwise lack of regeneration of some species (4)	Manage fire (re-introduce if adapted) Rehabilitation: transform structure to increase complexity (even age to uneven age)
Primary forest	4–5	4–5	5	Naturally regenerated forest of native species, where there are no clearly visible indications of human activities and the ecological processes are not significantly disturbed. Older life stages may be structurally complex and termed "old-growth" or better, old forest	Protect, add buffer of naturally or artificially regenerated native species stands

Each condition is subjectively scored from 1 to 5 in terms of structural complexity, composition, and ecological function and baseline described relative to ecological function (1 = degraded; 2 = none; 3 = low; 4 = moderate; 5 = high). Different restoration options are listed in a relatively increasing trajectory toward the restored condition. (Based on Figure M3.4 in Stanturf et al. (2017) and Table 1 in Stanturf et al. (2014b))

Wunder et al. 2008). Integrating FLR principles and improved environmental standards into the entire value chain for goods and services can contribute to long-term FLR success. For example in Central Kalimantan (Indonesia), green rural development and financial incentives created through timber production or agroforestry are achieved using fast-growing native species (*Anthocephalus* spp. and *Azadirachta excelsa*) and developing markets for innovative products (Schwegler 2017). Market analyses and product innovation for fast-growing timber species have proven crucial to safeguard high returns over a relatively short time.

Using co-benefits (e.g., carbon, water, ecosystem services) to drive change has been widely touted, but in many cases, payments for co-benefits have not been materialized (Evans 2018; Osborne and Shapiro-Garza 2018). Even in Costa Rica, which has a long history with payments for ecosystem services (Pagiola 2008), Louman (2017) found that both incentives (payment for environmental services) and regulations (land use change prohibition) were insufficient motives for FLR in rural areas and needed to be accompanied by promoting the value of forests and trees, providing technical assistance, and empowering local leadership.

4.2.4 Environmental context

Restoration objectives may be easiest to define but hardest to achieve where severe degradation has occurred, for example mined land or severely eroded agricultural land. Severely degraded sites are difficult to restore because the topsoil has been removed or contaminated, resulting in physical or chemical barriers to plant establishment (Stanturf et al. 2014a). Opencast or surface mining, from large industrial operations to smaller artisanal mining, affects a relatively small area globally but has considerable impact locally and regionally. Reclamation of these areas using forest plantations can restore productivity, biological diversity, and ecological functioning (Macdonald et al. 2015; Parrotta and Knowles 2001). Because of harsh site conditions and loss of ecosystem memory, initially non-native species often are used (Lamb et al. 2005; Parrotta et al. 1997). Severely degraded sites may develop along varied trajectories, depending upon soil depth; over time, native species may establish under the non-native overstory as site improves (Parrotta et al. 1997). The non-native overstory accelerates restoration by moderating understory temperature, humidity, and light, resulting in improved conditions for natural regeneration and suppression of competing grasses or ferns. In Estonia, for example, novel site conditions on reclaimed oil shale mines allowed threatened herbaceous species to colonize spontaneously (Laarmann et al. 2015). This catalyst effect can also be accomplished with fast-growing native species under less-degraded conditions (Stanturf et al. 2014a).

Drylands are somewhat less degraded than mined land, but water-limited dryland forests often prove more difficult to restore than tropical or moist temperate forests. Globally, some 10–20% of drylands are degraded (Hassan et al. 2005) and severe problems arising in drylands include soil salinization. In south-western Australia, deforestation of native *Eucalyptus* forests and conversion to agriculture caused a hydrologic imbalance, salinizing approximately 10,000–20,000 km^2, compromising water sources, and placing more than 500 species at risk (Harper et al. 2017). Rather than simply abandoning the salinized land, economically attractive alternatives included innovative systems of agroforestry strips of short-stature Eucalypts (mallees), biodiversity plantings of multiple native species, species adapted to saline soils (e.g., *Eucalyptus* and *Atriplex*), tax deductions for forestry investment, carbon markets, and bioenergy (Harper et al. 2012; Harper et al. 2014).

The Aral Sea region in Central Asia provides another example of attempting to reverse dryland degradation (Mirzabaev et al. 2016). Two problems exist: water extracted for irrigation exposed sediments of the shrinking Aral Sea to severe erosion (Micklin 2010) and agricultural abandonment after irrigation developed a shallow saline groundwater table. Solutions included planting saxaul (*Haloxylon* spp.) on the exposed sediments (Botman 2009) and conversion of marginal agricultural land to tree plantations before critical levels of salinization develop (Botman 2009; Worbes et al. 2006). These efforts are part of recent Bonn Challenge commitments (http://www.fao.org/europe/news/detail-news/en/c/1142410/).

4.2.5 Landscape structure

Mosaic landscapes provide the greatest opportunity for FLR (Minnemeyer et al. 2011). These are landscapes with moderate human occupancy and generally combine forests or woodlands with agriculture and small settlements, typical of many rural landscapes globally. In mosaic landscapes, there are four paths for already degraded and deforested land: restore to (1) productive agriculture; (2) mixed agroforestry with woody perennials integrated into crop and livestock systems; (3) actively managed, productive forests; or (4) passively managed, protected forests. In Ethiopia, the approach to building productive landscapes and avoiding deforestation has focused on intensifying agricultural production through introduction of high-yielding crops and improved livestock and by improving management of productive forests. Free grazing by large livestock herds remains to be the main challenge to FLR efforts in Ethiopia, and efforts at restricting grazing (e.g., by exclosures) are considered part of its FLR commitment (Hermans-Neumann et al. 2017; Pistorius et al. 2017).

Agroforestry and trees outside forests in mosaic agricultural landscapes can be among the major tools to achieve large-scale restoration. Indeed, ROAM assessments for the Bonn Challenge commitments in Rwanda and Uganda highlight agroforestry potential (MINIRENA 2014; Ministry Water and Environment 2016). Farmers, livestock, trees, and forests interact at multiple scales, influenced by customary tenure and regulations. Many countries committed to the Bonn Challenge are undergoing significant political and cultural transitions that likely will constrain how FLR is implemented. Kyrgyzstan, for example, is an economy in transition, and land use rules and laws are relicts of a centrally planned economy that specified what crops could be planted. Rules regarding agroforestry are unclear, presenting a major obstacle to innovation. Nevertheless, *Populus* spp. (poplars) have been planted by the private sector partly in 250 m × 250 m gridded windbreaks. Extending these linear plantings to all the croplands of Kyrgyzstan would meet the local demand for timber and fuelwood in a country with limited forest resources (Razhapbaev 2017; Thevs and Aliev 2017).

Combining production with conservation objectives can provide biodiversity and multiple ecosystem services (Brockerhoff et al. 2008; Silva et al. 2018). At the landscape level, intermixing sustainably managed production and restored native forests provides landscape diversity (Payn et al. 2015). Planted forest options differ in their potential to deliver benefits to people as well as their potential biodiversity impacts. Depending on restoration goals and objectives, planted forests may include agroforestry to meet food and nutritional security; short- or long-rotation plantations or mixed-species plantings for timber, fuelwood, and livelihood diversification; or silvicultural treatments to restore species and structure to native forests (Keenleyside et al. 2012; Stanturf et al. 2014a).

4.3 Acting

The objective of forest restoration is to change vegetation composition, structure, or both (Meli et al. 2017; Stanturf et al. 2014a) through passive or active means, or some combination of the two. Restoration interventions take place locally, and the combination of these local actions affects the landscape. Restoration decision-making at local levels is comprised of site selection; choice of FLR activities; the pace and the schedule of implementation, costs, and monitoring of work linked to expenditures; and evaluation for feedback to address shortcomings (Stanturf et al. 2017). Before commencing actual implementation activities, several factors should be in place. Stakeholders who will set goals and participate in the project should have already been identified and engaged. Nationally, the regions or landscapes targeted for restoration should have been identified and appropriate collaboration and consultations begun with affected local communities (Stanturf et al. 2017). Importantly, tenure relationships in the project area must be understood and considered in objectives, but not necessarily resolved. Identifying appropriate solutions can be impaired by power relations (Raik et al. 2008). Further, governance challenges exist in such interventions as FLR and need to be acknowledged and addressed in a culturally, socially, and politically sensitive manner (Mansourian 2016). Plans must be acceptable to local stakeholders. By including in the plans specific longer-term land use objectives (what should be produced, how, for whom), FLR can be seen as a pathway to reach these specific objectives. Meeting local needs may require compromises with the national approach on some issues, but compromises should not encourage corruption, or gender and other kinds of discrimination (Kolstad and Søreide 2009; Reinecke and Blum 2018).

The hierarchical nature of project planning is illustrated in Table 1 for Rwanda (MINIRENA 2014). The five goals are similar to those for El Salvador (MARN 2017). Taking one of the goals, "Increase forest cover and restore degraded land," several objectives were developed that included protecting and restoring natural forests, to be accomplished by planting 3000 ha of new forests, replacing 20,000 ha of *Eucalyptus* plantations with native species, planting 100 m forest buffers around natural areas, and restoring degraded areas within reserves and parks. For each of these activities, a plan will address the specific questions listed above; the example given is to plant 100 ha of native species in buffers 20 m wide along rivers in Kigali Province. Planting would be done early in the rainy season by local farmers. Note that this activity also contributes to the goal of providing access to clean water.

4.3.1 Site selection

Because of spatial heterogeneity in physical and ecological characteristics, disaggregating the target landscape into more or less homogeneous units that are expected to respond similarly to important constraints and stressors improves the chances for successful interventions. This can be done efficiently by overlying GIS layers of topographic characteristics, soil, geology, vegetation, climate parameters, and land use. Participatory mapping by local stakeholders can add important social dimensions (Evans et al. 2018; Sacande and Berrahmouni 2016). Rules for combining and weighting layers may rely on expert local knowledge and objectives and are sensitive to the scale being considered (García-Quijano et al. 2008). This step recognizes that the diversity and complexity of landscapes is essential for national- or regional-level FLR and is useful at localized levels where diverse topography, varied community ethnicities, or both make for different priorities or acceptability of some activities.

4.3.2 Restoration strategy

Passive restoration requires ready dispersal and recolonization from nearby sources or in situ regeneration arising from a seed bank or sprouting (Chazdon 2015; Holger et al. 2015). Excessive browsing by wild or domestic animals may preferentially remove desirable species and establish a long-lasting barrier to regeneration (e.g., Kain et al. 2011; Rooney et al. 2015) and requires protection such as fencing to exclude animals. Active restoration by direct seeding or outplanting of desirable species provides many options for covering part or all of an area (Cole et al. 2011; Engel and Parrotta 2001). Assisted natural regeneration, combining active and passive methods, usually involves clearing weeds to reduce competition on desired seedlings or sprouts (Elliott 2016). The extent of soil and vegetation degradation determines whether the starting point is characterized by physical or biological limitations that must be overcome, for example by site preparation such as bedding or mounding (Stanturf et al. 2014a). Good quality seedlings are critical for success for all planting techniques and all restoration objectives (Dumroese et al. 2016). Especially critical in the early stages of restoration development are silvicultural and management practices, including protection from fire and other disturbances. At later stages, further interventions may be needed to increase biodiversity such as thinning to open gaps for additional species to establish (Stanturf et al. 2017).

Silvicultural and management decisions for all types of planted forests can yield "win-win" outcomes for biodiversity conservation and restoration, provision of ecosystem services, and direct livelihood benefits to people (Brockerhoff et al. 2008; Sacande and Berrahmouni 2016). The likely impacts of planted forests on biodiversity depend on what they are replacing—context is critical. Several factors operating at the landscape level mediate the biodiversity impacts of planted forests including land use history and its impact on soils, vegetation, and wildlife. These legacies of previous land use may set the restoration trajectory (Jõgiste et al. 2017; Johnstone et al. 2016). Restoration may also involve removing unwanted vegetation such as invasive exotic grasses or herbaceous plants (Stanturf et al. 2014a), for example *Pteridium* spp., *Lantana camara*, or *Imperata cylindrica*.

Planting trees on degraded sites (Table 3) that are unlikely in the near term to recover through natural regeneration can accelerate restoration (Palma and Laurance 2015; Saha et al. 2016). Several factors affect the rate and extent of biodiversity recovery in planted forests, mainly the context, starting point, and management (Stanturf et al. 2014a). Context refers narrowly to the biological diversity in the surrounding landscape matrix including the proximity to forest remnants for seed sources and dispersal agents (Emer et al. 2018; Wunderle Jr 1997). Broader aspects of context refer to exogenous factors that might affect the sustainability of restoration such as likelihood of land use change driven by changes in government policies or markets. Brazil's Atlantic Forest Restoration Pact recognized the broader context and the potential need of land for agriculture and infrastructure so they concentrated their efforts on marginal land remote from urban centers (Melo et al. 2013).

High-grading and other exploitive uses that remove large trees of commercially valuable species without ensuring adequate regeneration can be corrected by planting the missing species under an existing overstory that may be retained or removed (Dey et al. 2012; Gardiner and Yeiser 2006). Underplanting native species in non-native plantations is a way to convert these plantations to mixed forest (Iwasa et al. 1994; Parker et al. 2001). Underplanting may be preceded by site preparation such as soil scarification with heavy machinery to mimic large-scale and intensive disturbance (Soto et al. 2015). For example, in the Andes Mountains of South America, *Nothofagus dombeyi* and *Nothofagus alpina* have a high survival rate and good (but highly variable) growth when planted under high-graded forests following understory control (Donoso et al. 2015; Donoso et al. 2013). They facilitate natural regeneration, greater diversity, and forest succession.

4.3.3 Species selection

The challenge of restoring resilient, diverse forest landscapes faces a major obstacle of obtaining quality seedlings, beginning with obtaining quality seed (Jalonen et al. 2017; Nyoka et al. 2015). Selecting which species to plant, by what method, and in what density and pattern are decisions based on objectives, the likelihood of successful establishment on the sites available, and the availability of good quality seedlings in the number needed at an affordable cost (Stanturf et al. 2014a). Objectives play a critical role in the choice of species; desirable traits (growth rates, tree form, fruit or nut production, fodder, utility for wildlife, soil improvement potential) dictate the candidate species (Sacande and Berrahmouni 2016). In any case, procuring quality nursery stock is a critical first step (Dumroese et al. 2016; Haase and Davis 2017) and the only opportunity to directly influence the genetics available for climate change adaptation (Doherty et al. 2017; Thomas et al. 2014). High-quality stock, planted correctly at the proper time, maximizes survival and accelerates the forest restoration trajectory (Dumroese et al. 2016; Stanturf et al. 2014a).

Selecting the correct species to plant is not straightforward in former agricultural landscapes lacking examples of relatively undisturbed native forests. Even when forest remnants are available to guide species selection, the remnants may not be representative of the sites to be planted. Proper context involves matching to sites at the species and genetic levels with selections appropriate to today's climate as well as future conditions (Jump and Penuelas 2005; Keenan 2015). Understanding the distribution of natural vegetation provides a good approximation of where wider planting of native tree species will contribute to ecosystem services, and food and nutrition security. For example, the vegetationmap4africa (http://www.vegetationmap4africa.org/Home.html) is an interactive vegetation map designed as a

Table 3 Forest restoration designs, from simple to complex, based on the number of species and cohorts and spacing (terminology from Stanturf et al. 2014a, 2014b)

Number of species	Number of cohorts	Spacing	Variations	Options
Single	Single	Dispersed	Cluster planting	Later infilling by natural regeneration
			Applied nucleation	Later infilling by natural regeneration
		Uniform	Planted into cover crops	Original stand thinned or removed and planted with other species
			Taungya	Trees interplanted with agricultural crops until canopy closure
Multiple	Single	Uniform	Temporary mixture	Interplanting or nurse crop that is removed early
			Permanent, simple mixture	Single-species rows or blocks
		Random	Permanent, intimate mixture	High-density planting, framework species
		Uniform	Permanent, intimate mixture	Designed mixture
		Dispersed	Framework species planting	Complemented by natural regeneration
	Multiple	Dispersed	Permanent, intimate mixture	Cluster with multiple species and natural regeneration between clusters
			Permanent, intimate mixture	Nucleation and natural regeneration to fill-in open spaces
		Uniform or random	Underplanting	With or without partial overstory removal
		Random	Release advance regeneration	With or without partial overstory removal

decision support tool for the selection of suitable indigenous tree species for restoration, forestry, agroforestry, and landscape diversification projects. The map also shows where to obtain planting materials for a particular species (Lillesø et al. 2011).

4.4 Sustaining

Restoration is a long-term process that likely will extend far beyond the initial interest and influx of funding. Maintaining momentum and sustaining interest over the time needed to show results require adaptive management that includes monitoring and effective feedback to make necessary corrections or to undertake needed further interventions such as thinning. The world around the restoring landscape will be changing as well, driven by climate change, globalization, land use, and policy shifts. Effective monitoring is a key to sustaining FLR (Hutto and Belote 2013; Stanturf et al. 2017). To be successful, monitoring should be responsive to key management questions based on criteria of successful restoration. An international effort to identify generic FLR indicators led by FAO (Zoveda 2017) may complement more technical approaches such as carbon monitoring (e.g., Petrokofsky et al. 2011). A critical issue is how intensively to monitor (e.g., Viani et al. 2018) and whether the needed resources are available. In addition to monitoring the restoration project, attention to the external drivers should be included in the overall monitoring system by incorporating data provided by government agencies and NGOs (e.g., Platteau 2004; Vittek et al. 2014).

Participatory monitoring offers local communities opportunities for meaningful participation in FLR (Brancalion et al. 2013; Evans et al. 2018). Collaboratively selecting indicators and local drivers of success to monitor and using locally appropriate technologies to collect data adequate for decision-making can create ownership, get buy-in, and develop trust (Evans et al. 2018; Kusters et al. 2017). Such a system involving women and marginalized groups may increase speed and effectiveness of local decision-making and catalyze social learning. Local monitoring can be cost-effective and reliable, but it requires investment in appropriate training, motivation, and quality control (Evans et al. 2018). Participatory monitoring as a multi-scale, multi-site system may necessitate a dedicated, centralized, possibly government-led platform, but care must be taken to balance national versus local needs and goals (Brancalion et al. 2013; Evans et al. 2018).

5 Future needs

The historic examples of Denmark, South Korea, and Puerto Rico showed that restoration has been successful without today's political enthusiasm, access to funding, and practices supported by broad science-based evidence. Our predecessors managed by simple shared visions to restore forest cover in degraded and previously forested landscapes. Their vision was shared across their society and aided by supportive policies. Only by successfully implementing FLR will we validate the Bonn Challenge and overcome the enthusiasm gap (Fig. 1). Nevertheless, focusing only on success can obscure critical factors unique to social context and historic period. We need to devote more attention to failures, to learning when and why techniques did not work or meet objectives. In addition to analyzing failed attempts, we need to share the results broadly through learning networks, communities of practice, and knowledge platforms.

The complexity of landscapes as socio-ecological systems can be a strength instead of a problem for FLR if approached as incorporating a portfolio of diverse objectives and methods. Trying different objectives and methods may spread the risk of failure across landscapes and stakeholders. Acceptance and even encouragement to attempt and evaluate different methods to address common visions will allow individual entrepreneurship and curiosity. Application of different solutions may strengthen adaptation to the uncertainties of future environmental conditions, markets, and population pressures on restored landscapes. Importantly, will future landscapes become depopulated due to outmigration to cities or will an upcoming bioeconomy and the restored landscapes make them more attractive for settlement? Attractive solutions for the present generation may not be the same for future generations.

Social adaptation to global change generally, and with regard to FLR, will be challenging (Stanturf 2015). Future work on FLR should concentrate on three areas: improving governance related to land tenure and use (Holden et al. 2013; Mansourian 2016), developing capacity (Brooks et al. 2005; Smit and Wandel 2006), and gaining the knowledge needed to address climate change challenges (Gellie et al. 2018; Puettmann 2014). Many countries such as Ghana have made progress in forest governance, spurred by the need to become "REDD Ready" (Hansen et al. 2009; Murdiyarso et al. 2012). Capacity building at different levels is important, but a general need is to develop a cadre of landscape generalists who understand adaptive management and who can work in interdisciplinary and multi-cultural settings. These individuals should value tangible and intangible landscape values, such as economic and ecological benefits and cultural significance. They should be adept at integrating policies and practices and be open to new knowledge, skills, and attitudes. These landscape generalists would facilitate FLR implementation, bringing together technical knowledge with sensitivity to local conditions and stakeholder objectives. Their ranks could be drawn from government agencies, local universities, NGOs, and local communities.

Many native forest tree species already have been extirpated or are severely threatened by introduced pests and pathogens. Re-introduction of threatened tree species offers FLR an opportunity to help meet the targets of the Bonn Challenge and associated policy initiatives, while simultaneously restoring keystone forest species (e.g., Jacobs et al. 2013). Societal and ecological barriers to FLR using non-native species remain but are evolving (Breed et al. 2018; Bucharova et al. 2017); however, resistance to genetically modified organisms remains (Strauss and Bradshaw 2004).

While the challenges are great, so are the opportunities. The landscape approach will be an important vehicle to provide countries with implementation packages tailored to a wide range of landscapes and facilitate scaling-up. It will also help to address the interactions, competition, and trade-offs between different land uses and thereby avoid further degradation of land, ecosystems, and forests. Increasing competition for land for agriculture and other uses (Tscharntke et al. 2012) threatens the sustainability of FLR unless accompanied by attention to meeting local needs for food security. Deep and broad knowledge, practical expertise, innovation, and experience exist within the scientific and professional community and within the countless communities living on the front lines of forest landscape degradation, climate change, and other challenges. Enhanced communication and collaboration are needed across forest science disciplines and between the scientific community and land managers, communities, government agencies, NGOs, the private sector, and other organizations and movements operating at local, national, and global levels (Langston et al. 2019).

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