ECOLOGY

Hurdles and Opportunities for Landscape-Scale Restoration

Gaps in knowledge must be identified, capacities developed, and research translated into policy and practice.

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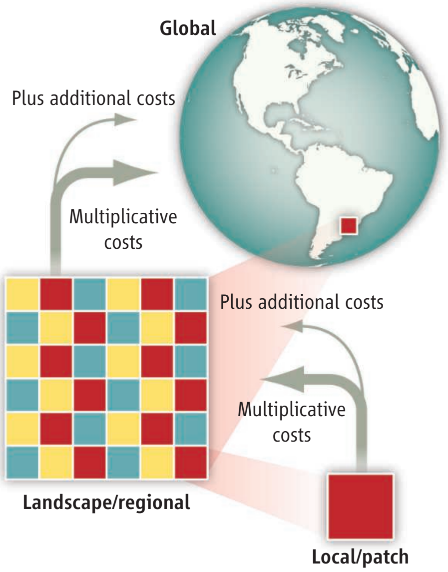
A priority outcome from the 2012 United Nations Rio+20 Conference on Sustainable Development (*1*) was the target to restore, by 2020, 150 million ha of disturbed and degraded land globally (*2*). An initiative of this scale is estimated to cost U.S. $18 billion per year and to provide U.S. $84 billion per year to the global economy (*2*). Although such initiatives have transformative potential because of their scope and backing, they require technology and knowledge capacity to deliver proven, scalable restoration (*3*). Restoration processes must achieve the greatest value for money, as far as socioeconomic and biodiversity conservation outcomes, while avoiding costly and simplistic plantings (*4*).

Although we recognize that preventing loss and damage in the first place is a far better investment than restoration after damage has occurred, we propose a four-point plan to ensure that restoration sustains and enhances ecological values: (i) identify focal regions with high restoration demands, (ii) identify knowledge gaps and prioritize research needs to focus resources on building capacity, (iii) create restoration knowledge hubs to aggregate and disseminate knowledge at the science-practice interface, and (iv) ensure political viability by establishing economic and social values of functioning restored ecosystems. These points are interrelated and may occur in parallel.

Ecological restoration, not just a matter of planting trees (*5*), involves assisting the recovery of a damaged or destroyed ecosystem (*6*). Landscape-scale restoration includes large, contiguous, or fragmented areas (equal to or greater than several km^2). Restoration often takes place in an unpredictable socio-ecological context, involving multiple stakeholders and interests, where local actions aggregate into a broader context that considers landscape flows and connectivity (see the figure). A realistic assessment of prior knowledge, technological capacity, financial viability, and social license is needed for understanding scientific and practical constraints to achieving global restoration targets. Recent examples, such as China's Great Green Wall and Grain for Green programs, although politically viable, could threaten ecosystem services through ill-placed restoration (*7*). In such situations, the scientific support behind less-popular options may have been ignored or simply may not be available. A key limitation is the lack of information on successes and failures in landscape-scale restoration projects (*8*) to guide more effective practice. Early engagement with science will be critical, such as Future Earth: Research for Sustainability, launched at Rio+20, which proposes coordination and facilitation of global science (*9*).

Identification of Focal Regions

Success of landscape-scale restoration projects will be more likely in some ecosystems and regions than others (*10*). We should set realistic goals (*11*–*13*) and identify ecosystems where resources are best positioned to achieve the most cost-effective results to maximize ecosystem services and biodiversity gains. Professional societies, governments, the private sector, and nongovernmental organizations must collaborate through umbrella organizations such as the International Union for Conservation of Nature (IUCN) to set standards and prioritize ecosystems and regions for resource allocation. Such an approach has identified 2 billion ha globally that provide forest restoration opportunities (*14*) where ecosystem services could be delivered through cost-effective natural and assisted regeneration.



Scaling up restoration. Costs multiply as local patches are added, each requiring site treatment, seed or plant input, management, and so on. Additional costs and knowledge are necessitated by landscape and regional structures and processes (e.g., hydrological management or transaction costs among different land uses). Economies of scale may be possible. Scaling up to the global level requires multiplicative and additional costs relating to social and political requirements.

Drylands also provide landscape-scale restoration opportunities. Drylands, extensive in many parts of the world, have been identified as ecosystems that will suffer greatly from climate change, with desertification likely to affect 30% of the world's population (*15*). Many drylands are major resource hubs that provide financial capacity to fund and implement research and restoration (*15*).

Prioritization of Research Needs

Once areas have been prioritized and funding has been secured, key knowledge gaps for achieving landscape-scale restoration should be identified. There are few ecosystems for which we have sufficient knowledge to achieve restoration success beyond the local scale. A range of scalable, proven, and cost-effective capacities will be needed, e.g., the scaling-up of resources such as seed banks, to facilitate landscape-scale restoration (*3*). Approaches are being developed to prioritize actions depending on landscape conditions and likely effectiveness (*16*, *17*).

Although long-term cost-effectiveness of most interventions remains unclear and may be potentially costly, some regional-scale projects may be relatively inexpensive. Linking restoration initiatives with evolving knowledge will allow for targeted, cost-effective interventions (*12*), while avoiding actions that may make things worse in the longer term [e.g., (*18*)]. For example, wetland systems where altered water flows have caused system decline can

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be restarted by reinstating prior conditions, such as in the Mesopotamian Marshes (*19*). Dryland restoration can be kick-started by providing simple physical barriers to water movement (*20*).

There is growing awareness of the interdisciplinary science packages required for restoration (*16*) [e.g., microbiology (*21*), seed science (*3*), and pollination ecology (*22*, *23*)], integrated with socioeconomic expertise (*24*). There needs to be a balance between generally applicable approaches and solutions tailored to region- or ecosystem-specific requirements. Interdisciplinary actions—facilitated by umbrella organizations such as the Society for Ecological Restoration, IUCN, and Conservation International—would provide project carriage beyond the typical 3- to 5-year funding cycles. Although funding agencies and universities need to play a key role in supporting these programs, lobbying by umbrella organizations would be an important step in establishing the process. Successful collaborative initiatives [e.g., (*25*)] provide solid footing for future programs.

Restoration Knowledge Hubs

Effective information transfer is paramount to the success of landscape-scale restoration projects and to avoid repeating costly mistakes while closing the science-practice gap (*13*). Attempts to bridge this gap are often local in focus. Restoration ecologists need to take responsibility for translating their science into on-the-ground actions (*13*, *26*). Successful science-practice communication must be two-way to achieve the greatest benefit, as practitioners are valuable for identifying knowledge gaps and guiding research. Evidence-based literature and information repositories should be developed for the restoration sciences (*27*).

Few restoration initiatives provide for dialogue with the restoration sciences. The Australian government is spending A$1billion (U.S. $1 billion) to restore 18 million ha of degraded land, yet, is silent on links to science or provision of investment in research (*28*). This is despite the acknowledgment of the southwest Australian biodiversity hot spot as a region where restoration need far outstrips scientific knowledge (*3*).

Professional scientific associations can compile scientific knowledge and restoration practice and act as information clearinghouses (*13*). The Global Restoration Network (*29*) provides a Web-based hub for information on restoration projects. Initiatives such as Future Earth provide hope for linking technology, innovation, and science (*30*). Governments and funders of ecological restoration must develop practice-based templates for global capacity-building and measures for streamlining knowledge dissemination.

Political Viability of Restoration

Landscape-scale restoration projects are likely to work best when initiators are motivated by both environmental and social issues or either one [e.g., (*31*)]. Good science is required to ensure that the programs are a success, although achieving long-term, dual ecological and social goals remains challenging [e.g., (*32*, *33*)]. Restoration will provide economic benefits worldwide (*34*), particularly if ecosystem services are matched with biodiversity conservation, including nonmarket services (*35*, *36*). Creating rigorous economic valuation and efficient markets for the wide range of ecosystem services is a critical step, with much still to be done.

Net benefits of sustainable, ecologically resilient restoration (*13*, *37*) must be communicated in a compelling way to policymakers and practitioners if longer-term funding opportunities are to be realized, particularly support for science programs to fill knowledge gaps. Scientists need to shift from a focus on journal writing and professional conferences to reach a broader community and political audience who will make the call on restoration funding. Such a dialogue must remain science-based. For example, evaluation of cost-effectiveness based on ecosystem service return showed that many dry forest restoration approaches may be economic failures (*38*). Robust analyses like this are important for identifying false, politically damaging assumptions of restoration programs, e.g., China's Great Green Wall (*7*).

However, in some cases, given the social and ecological values of restoration, costs need not be considered a hurdle, but a challenge to improve our technology in developing more cost-effective techniques.

Not a Magic Bullet

Restoration is often viewed simplistically, as if science and practice were well established. Restoration ecology is not a magic bullet that provides instant ecosystems of the desired type, but an emerging science less than four decades old. In many cases, restoration projects fall short of reinstating functional ecosystems akin to their natural reference sites (*10*). For example, restoration projects developed in exchange for habitat destruction elsewhere are becoming more prevalent, resulting in losses of high-quality ecosystems that we are not yet able to restore (*10*). Deciding on useful targets in a period of rapid environmental change is another area of discussion in restoration ecology (*11*, *13*).

Restoration knowledge hubs are most often associated with developed, boreal economies. For landscape-scale restoration to be effective, science funding and technology development need to realize targets that go beyond such local scales. Restoration is but one tool; with effective management and prevention of further damage to natural areas, restoration would become less urgent.

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