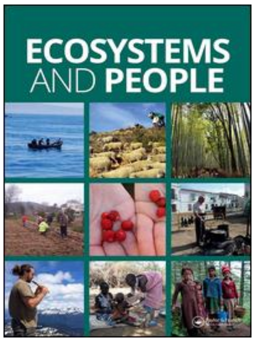

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A framework to evaluate land degradation and restoration responses for improved planning and decision-making

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ABSTRACT
Avoiding, reducing or reversing land degradation will require increased restoration investments, carefully targeted and implemented to maximize environmental, economic and social benefits. Our objective was to develop a multi-criteria framework to assess effectiveness of land degradation responses for enhanced land use planning and restoration by evaluating both direct biophysical and socio-economic responses and indirect effects of various restoration strategies. The effectiveness of restoration responses is demonstrated for degraded forestland using a comprehensive literature review and case study in Nepal. The results show that most forestland restoration responses have an ecological focus with tree planting being the dominant direct response and economic and financial instruments the indirect responses. The results confirmed that environmental desirability was the dominant factor and economic feasibility was secondary for assessing restoration responses. Cultural acceptability was given the least consideration. Among sub-criteria, improved vegetative structure was the dominant restoration response. This study, originating from the Land Degradation and Restoration Assessment of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, supports the view that the scientific community and decision-makers must give greater attention to cultural, social, technical, and political dimensions that influence the outcomes of restoration responses to solve the pervasive problem of land degradation.

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1. Introduction

Land degradation is a complex, pervasive and global problem with context-specific solutions. It refers to the many processes that drive the decline or loss in biodiversity, ecosystem functions or services and includes the degradation of all terrestrial ecosystems (IPBES 2018a). Addressing it through international collaboration is extremely important because approximately 75% of the Earth's land surface is degraded in some manner due to a range of direct and indirect drivers and processes that interact in complex ways (IPBES 2018a). Land degradation is estimated to negatively affect the direct well-being of at least 3.2 billion people and indirectly affect them through lost biodiversity and ecosystem services at a cost exceeding 10% of the annual global gross product income (IPBES 2018a). The pervasive nature of land degradation makes it particularly challenging to effectively address. Thus, the societal need to do so has prompted research aimed at understanding land degradation drivers, processes, responses and their interactive effects on both ecosystem services and quality of human life. This paper is inspired by and related to the Land Degradation and Restoration Assessment of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES).

Restoration, which is defined as 'any intentional activity that initiates or accelerates the recovery of an ecosystem from a degraded state' (IPBES 2018a), has emerged as a tool to address land degradation. Indeed, on 1 March 2019, the United Nations announced 2021–2030 as the 'Decade on Ecosystem Restoration' to fast-track the restoration of severely degraded landscapes worldwide. Similarly, Target 15.3 (achieving land degradation neutrality) of the Sustainable Development Goals 2030 promotes prioritization and acceleration of land restoration activities (Cowie et al. 2018; ADB 2019). In this context, it is important to be able to consistently and comprehensively assess the effectiveness (or efficacy or performance) of existing and new restoration responses to meet intended or desired objectives of land restoration in the pursuit of these global goals. Critically, this means that

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Supplemental data for this article can be accessed here.

responses must work to arrest the biophysical processes of land degradation in ways that are appropriate to context-specific development situations while improving enabling conditions that may or may not have been explicitly considered by planners.

Here, we define restoration in the broadest sense, to include avoiding, reducing and reversing land degradation. *Avoiding* land degradation refers to addressing the drivers of degradation through proactive measures to prevent adverse change in the quality of non-degraded land and confer resilience, via appropriate regulation, planning and management practices (UNCCD 2017). *Reducing* land degradation refers to mitigating degradation on agricultural and forestland through the application of sustainable land, water and forest management practices (UNCCD 2017). *Reversing* land degradation refers to restoring or rehabilitating some (but rarely all) of the productive potential and ecological services of degraded land, where feasible, by actively assisting the recovery of ecosystem functions (UNCCD 2017). Hereafter, 'restoration' is used as a shorthand term to represent all three of these restoration aims.

The complex interplay of direct and indirect drivers, and context-specific nature of land degradation, has hampered progress towards effectively responding to land degradation (Winslow et al. 2011). Therefore, the need to quantify the success or effectiveness of any on-the-ground restoration actions (direct responses) which depend on the enabling environment (indirect responses) has been recognized (Geist and Lambin 2002; Reed et al. 2011; Hessel et al. 2014). In other words, a conducive enabling environment (i.e. supportive policies, institutions and governance arrangements) is a prerequisite for success in avoiding, reducing and reversing land degradation. Thus, for restoration aims to have a long-lasting positive impact, restoration responses should be designed to fit implementation contexts, and tailored to meet needs, preferences and available resources with the aim to generate biophysical, economic and social benefits (Hessel et al. 2014).

In this respect, the success of restoration programs is contingent on a range of context-dependent factors that reflect the biophysical, social, economic and governance realities of the landscapes under consideration (Mansourian and Parrotta 2018b; Stanturf et al. 2019). Therefore, to design successful restoration programs, it is important to know what type and combination of responses can most effectively address particular drivers, processes and/or forms of land degradation, especially allowing for contextual variations in environmental, economic, social, technical, cultural and political conditions. Most effective land restoration responses will be those that: (1) are adaptive and have a wide domain of application; (2) are cost-effective, feasible and practical for a specific degradation or restoration context; and (3) provide multiple biodiversity and ecosystem service benefits (Jacobs et al. 2015; Pandit et al. 2018; Löf et al. 2019). Given the diversity of intended outcomes and the constraints imposed by limited financial and other resources, it is important to use an integrated framework to assess the efficacy of response options, identifying those that are more likely to generate optimal benefits (Brancalion et al. 2019; Chazdon and Brancalion 2019). Such assessments could also provide guidance to planners and policy makers, enabling them to prioritize anticipated responses and thus guide policies and restoration investments (Aronson et al. 2010; Stanturf et al. 2017; Mansourian et al. 2019).

Within the conceptual framework of the IPBES (Díaz et al. 2015) and the Economics of Land Degradation (Mirzabaev et al. 2015), the proposed framework draws upon the IPBES's Land Degradation and Restoration Assessment (IPBES 2018b), to assess restoration responses based on multiple biophysical and/or socio-economic criteria. The framework focuses on six criteria – environmental, economic, social, technical, cultural and political – and 20 sub-criteria. The goal is to assess response effectiveness to avoid (prevent) or reduce (mitigate) land degradation, and to reverse degradation (i.e. restore previously degraded land). The framework, initially developed by the authors during the course of their work as IPBES experts of the Land Degradation and Restoration Assessment team (Pandit et al. 2018, in IPBES 2018b), has been adapted to assess effectiveness of response strategies designed to address forestland degradation using a systematic literature review and case study on community forestry (in Nepal) to obtain some empirical lessons and evaluate its usefulness.

Our emphasis on forest restoration process reflects disciplinary expertise of the authors and the fact that, for decades, forest degradation and restoration has been the primary focus for a wide range of local, national, and international initiatives, as well as available research data for examining biophysical and socio-economic aspects of deforestation, forest degradation, and restoration. Herein, we describe the conceptual framework, propose consensus-based response criteria, and then assess response effectiveness for restoring degraded forestland based on (1) a systematic review of literature, and (2) a site-specific policy response study focused on community forestry in Nepal.

2. Land degradation and restoration response framework

Our land degradation and restoration response framework has three components (Figure 1): (1) causes and consequences of land degradation – drivers, processes and impacts; (2) indirect and direct land degradations responses, and (3) restoration outcomes and assessments of response effectiveness. The form (type), extent (prevalence or magnitude) and state (condition or intensity) of land degradation depends on both direct drivers and the severity of different land degradation

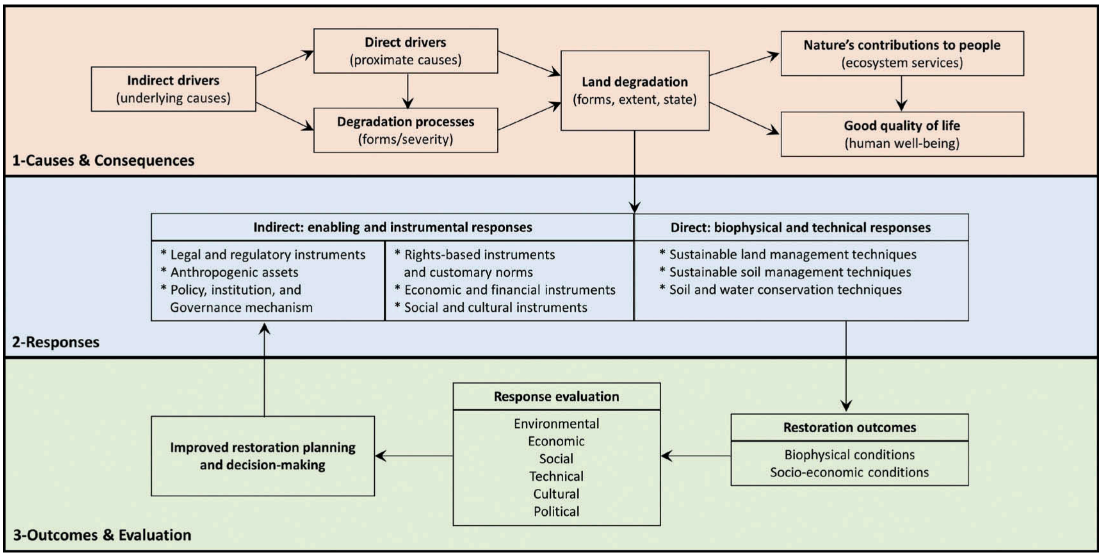

Figure 1. Conceptual framework linking land degradation causes and consequences, restoration responses (both indirect and direct), and response outcomes and evaluation.

processes, both of which are influenced by the nature and pervasiveness of underlying or indirect drivers. Land degradation in turn reduces 'nature's contributions to people' (or ecosystem services) and provisions for 'good quality of life' (or provisions for human well-being) such as food, feed, fiber, and fuel (Kadykalo et al. 2019). To avoid, reduce or reverse negative impacts of land degradation on ecosystem services and human well-being, land degradation drivers and processes need to be identified and subsequently controlled or effectively managed (Lal et al. 2012; IPBES 2018a).

In addressing land degradation, appropriate *indirect* responses can create supportive enabling conditions for direct responses (Millennium Ecosystem Assessment 2005). Such indirect responses may include legal and regulatory instruments; anthropogenic assets (i.e. human and physical resources); policy, institution and governance mechanisms; rights-based instruments and customary norms; economic and financial instruments; and social and cultural instruments. *Direct* responses to address land degradation (SERI 2004) include a variety of on-the-ground management activities that directly affect the degradation drivers or biophysical processes, such as sustainable land and soil management techniques and water conservation techniques.

There is no single 'right way' to restore land. Each direct and indirect response category includes a range of possible response options or strategies that may be more or less appropriate depending on the form (type), extent (prevalence or magnitude) and state (condition or severity) of land degradation (Hobbs and Harris 2001; Hessel et al. 2014; Stanturf et al. 2017; Mansourian and Parrotta 2018a). Various land degradation drivers, processes and impacts determine which indirect and/or direct responses will be most effective to achieve restoration goals and enhance resilience of social-ecological systems, which are fundamental considerations in assessing the effectiveness of responses (Yang et al. 2018; Sala and Torchio 2019).

For the purpose here, we consider the effectiveness of restoration responses in terms of achievement of intended positive impact on biophysical and/or socio-economic conditions (i.e. *planned outcomes*). Furthermore, our assessment of effectiveness also considers the suitability of restoration responses for the specific degradation context (i.e. *process outcomes*). It does this in two ways. First, it considers compatibility of responses with existing antecedent conditions as these determine social and political acceptability. Second, it considers how the responses themselves mediate existing or create new enabling conditions that can facilitate restoration management and implementation. Through this analysis, our goal was to improve restoration planning and decision-making, and ultimately increase overall success of restoration responses.

Generally, restoration responses that are technically and environmentally sound, economically viable, socially and culturally acceptable, and politically feasible will be more effective and enduring in the long term than those that are not. Furthermore, to achieve restoration goals, particularly at a landscape scale, complementary land degradation responses need to be implemented simultaneously and in a coordinated manner (Hobbs et al. 2014). This requires using interdisciplinary and transdisciplinary approaches (Reed and Stringer 2015; Mansourian and Parrotta 2018a), incorporating cultural (Robertson et al. 2000) as well as social and political perspectives (Baker and Eckerberg 2013; Sala and Torchio 2019). Examples of synergistic land degradation responses and restoration strategies might include:

- Corrective methods (land rehabilitation and ecosystem restoration practices) that aim to halt and reverse degradation through, for example, conservation of soil and water, protection of vegetation, ecological engineering, and re-establishment of functional ecosystems.

- Techniques to improve land use and management such as agroecology, agroforestry, conservation agriculture and other sustainable agricultural practices.
- Implementation of appropriate institutional, economic and political mechanisms, e.g. access to markets and sale of sustainably produced agricultural or forest products; diversification of rural economies; payment for ecosystem services; land ownership rights; access to credit; training for farmers; and insurance systems.
- Collaboration and knowledge exchange between land management, research and policy communities, as well as participatory approaches in research and development.

To help prioritize these various strategies, multiple perspectives can be reflected in the framework as criteria and sub-criteria needed to evaluate response effectiveness. They can be subsequently used to assess relevance and suitability of various restoration responses.

3. Restoration response evaluation framework

The restoration response evaluation framework proposed in Table 1 aims to assess effectiveness based on several different criteria. The inclusion of multiple response criteria is essential since most restoration programs want to achieve multiple objectives defined by diverse stakeholders. For example, tree planting programs in denuded hills developed to improve environmental conditions also need to be viable from economic, social, cultural, technical and political perspectives if they are to have long-term sustainability (Pandit et al. 2018).

Reflecting multiple perspectives, the proposed evaluation framework includes six sets of response criteria (Table 1, column 1) and at least two sub-criteria per criterion (column 2). Several of the criteria (and sub-criteria) reflect a combination of biophysical impacts and/or enabling conditions. More specifically, the environmental desirability criteria and sub-criteria focus on biophysical conditions (i.e. outcomes) of restoration actions, while cultural acceptability and political feasibility criteria and sub-criteria focus on enabling conditions. Regarding economic feasibility, social acceptability and technical feasibility, the sub-criteria include a combination of enabling conditions (i.e. economic efficiency, procedural equity) and socio-economic conditions (i.e. economic impact, distributional equity). Moreover, social acceptability and political feasibility are enabling criteria as well as simultaneously the characteristics of the response options.

Each restoration response is ranked using a relative effectiveness or performance rating scale of low (L), moderate (M), or high (H). These *effectiveness response* ratings for each sub-criterion also reflect no (or minimal), some (or moderate) and major (or substantial) improvement, respectively, relative to the initial condition (pre-response). For technical feasibility, three sub-criteria – adoption lag, replicability, and technical sophistication – have been defined. Adoption lag is considered low, moderate, and high for a restoration response that takes >10, 5 to 10, or <5 years to be adopted, respectively. For technological replicability, low, moderate, or high effectiveness reflects operational suitability at local, regional to national, or global scales, respectively. For technical sophistication, a similar response structure is used with low, moderate, and high reflecting substantial, some or no need for external scientific or technical assistance from experts, respectively. Finally, the response effectiveness is coded as *Not Applicable* (NA), if it is irrelevant to the specific sub-criterion or if it is relevant but its effectiveness is not considered in the evaluation.

4. Framework application: evaluating restoration response on degraded forestland

The proposed framework was evaluated by assessing the effectiveness of direct and indirect forestland restoration responses using a systematic analysis of relevant literature. The anticipated responses could focus on one or more restoration aims – avoiding, reducing, or reversing forestland degradation (Cowie et al. 2018). Our specific goals were to evaluate the extent to which existing literature assesses forestland restoration responses from multiple perspectives and to determine what could be learned from the exercise. Without question, it was possible that restoration responses would simply reflect planned outcomes (i.e. achieving a particular target or objective) and the response effectiveness could be evaluated solely based on specific criteria associated with the target or objective. However, given the increased demand and interest in examining restoration responses from multiple perspectives and to include synergies and trade-offs associated with various responses, we felt it was important to evaluate restoration responses more broadly (i.e. with regard to impacts on biophysical, socio-economic, and enabling conditions).

4.1. Identifying relevant literature

Three databases [Web of Science (WoS), Scopus, and Google Scholar] were searched using 'effectiveness' as a topic in WoS, as title, abstract and keywords in Scopus, and with all of the words in Google Scholar Advance Search. The keywords 'forest restoration' OR 'forest revegetation' OR 'forest reclamation' OR 'forest rehabilitation' OR 'forest management' OR 'reforestation' OR 'afforestation' were also searched in titles from

Table 1. Framework criteria, sub-criteria, and their relevance to assess effectiveness of land degradation and restoration responses.

Assessment criteria	Sub-criteria	Relevance to impact on biophysical/ socio-economic or enabling conditions
Environmental desirability	• Biodiversity enhancement (i.e. floral, faunal, microbial richness or abundance) • Ecological processes (i.e. nutrient availability – soil organic matter, soil nitrogen and organic carbon) • Forest fire risk (i.e. fuel loads) • Sediment yield (i.e. rate of soil erosion/loss) • Vegetation structure (i.e. plant cover, density, basal area/biomass) • Water yield	All sub-criteria are relevant to *biophysical conditions*
Economic feasibility	• Cost-effectiveness (least cost, cost sensitivity) • Economic efficiency (benefit–cost ratio, independent of direct and indirect subsidies/ incentives) • Economic impact (income/employment generation)	• Socio-economic conditions • Socio-economic/enabling conditions • Socio-economic conditions
Social acceptability	• Distributional equity (benefit sharing and decision-making, rights-based access) • Procedural equity (inclusivity and participatory) in response planning and designing • Social preference (over current practices, access to resources and services)	• Socio-economic conditions • Enabling conditions • Enabling conditions
Technical feasibility	• Adoption lag: waiting period required to adopt the response • Replicability of the response • Technical sophistication associated with response (requirement of skills, technical knowledge, physical assets, technical risk)	• Socio-economic/enabling conditions • Enabling conditions • Enabling conditions
Cultural acceptability	• Alignment with cultural, spiritual and aesthetic heritage values, beliefs and social norms • Use of traditional (indigenous and local) knowledge and practices	Both sub-criteria are relevant to enabling conditions
Political feasibility	• Enabled by existing policy/legislation • Governance mechanism (clarity on roles/responsibilities of stakeholders) • Institutional structures (establishment of new institutions and strengthening existing institutions)	All sub-criteria are relevant to enabling conditions

all three databases. This resulted in 177, 220, and 172 hits in WoS, Scopus, and Google Scholar, respectively, as of 9 February 2019. 'Effectiveness' was used as proxy to represent a high-level construct for performance or impact or suitability or success or appropriateness of restoration responses. The articles were collated into an Microsoft Excel data file and carefully examined to remove duplicates from the three databases. This process resulted in 245 unique articles.

4.2. Article screening, data coding and analysis

Each article was screened by examining the content of its abstract. The selected articles were reviewed by authors and relevant details were coded in an Excel spreadsheet using a predefined coding template. If an article reported more than one response action or strategy, each response was considered as a unique datapoint or observation. This process identified 141 as being relevant for further analysis. Fourteen studies for which only the abstract was provided in English and 90 studies which were determined to have no relevance to our sub-criteria were excluded. Eight studies contributed multiple observations, one contributed six, and the rest contributed to two each (Supplemental material, Table S1). Each observation was coded for its general focus, nature of response (avoid, reduce or reverse), response category (direct or indirect), specific response option, and its effectiveness across each sub-criterion of the six response evaluation criteria (Table 1). Each entry was cross-checked by the senior author to ensure consistency. An exploratory analysis of the coded data was conducted in Excel and R, using cross-tabulation and figures to summarise the findings.

4.3. Review findings

4.3.1. Type and geographic coverage

Of the 141 relevant studies, 23 were review articles and 118 were research articles (Supplemental material, Table S2). Among the review articles, 70% covered more than one country or geographic region, while 30% were country-specific (i.e. China, Canada, Czech Republic, New Zealand and the USA). Among the research articles, most (96%) were country-specific with only 4% covering more than one country. Overall, 37 countries were represented in the database with 62% of the studies being from USA (15), Spain (14), China (12), Brazil (12), Canada (7), India (7) and Indonesia (5) (Table S2). Figure 2 shows the number and distribution of research articles across countries. It also highlights the fact that there are relatively few studies in Africa despite the importance of land degradation and restoration issues in the region.

4.3.2. Focus areas and the nature of restoration responses

All relevant studies (n = 141) fell into one of the five general focus areas (Figure 3). A significantly higher proportion of restoration studies had an ecological focus (35%) whereas only 4% of studies had a social focus. Overall the studies also focused on one or more broad restoration aims: avoiding, reducing or reversing

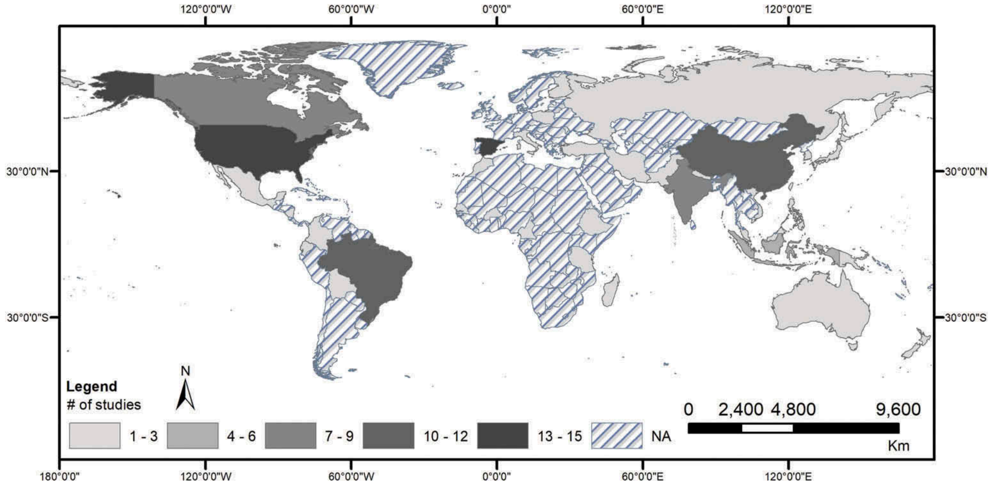

Figure 2. Number of research articles reviewed and their geographic distribution.

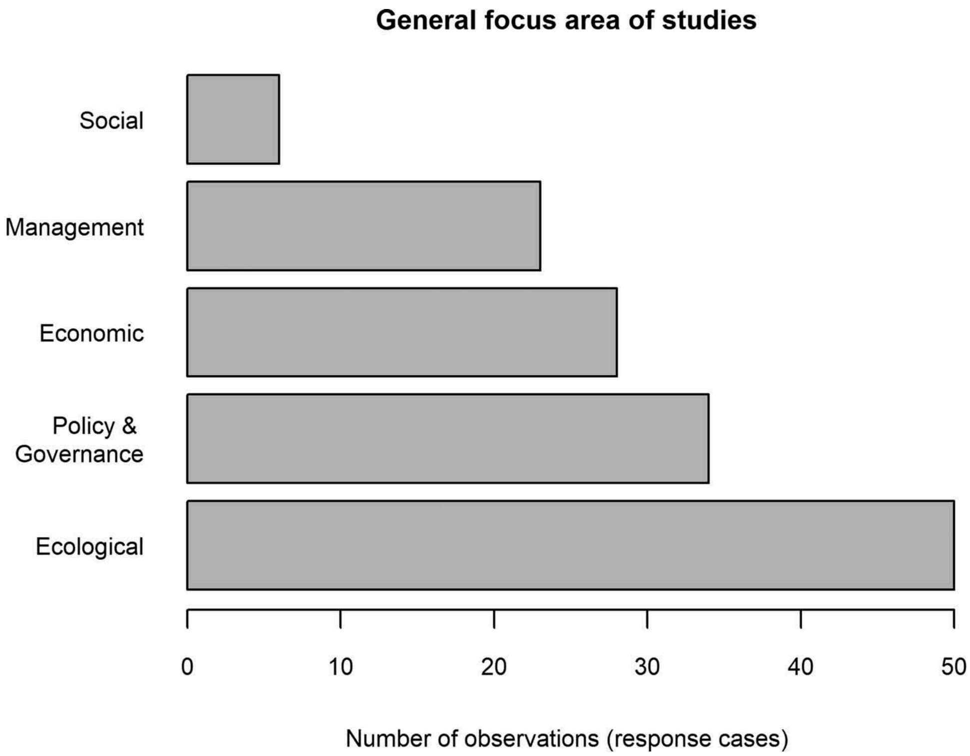

Figure 3. Number of land degradation and restoration response studies reviewed by their general focus areas (n = 141).

forestland degradation (Table 2). For example, 18 response cases (observations) were solely related to avoidance of forestland degradation, whereas 52 focused on reducing and reversing degradation, and 23 focused on all three goals. Among the eight studies that had multiple observations, two studies covered all three aims, one covered reducing and reversing aims, and five covered only the reversing aim.

Following our conceptual framework, restoration responses were grouped into direct and indirect responses. Direct responses were broadly related to land management, soil management, and soil and water conservation techniques (Figures 1, 2-Responses). To analyse response to forestland degradation, these direct responses were grouped into five categories (i.e. tree planting, natural and assisted regeneration or restoration, silvicultural

Table 2. Number of observations (response options) examined based on their relevance to three of the restoration aims – avoiding, reducing, and reversing land degradation.

	Number of observations covering one or more aims		
Restoration aim(s)	*Only one*	*Two*	*All three*
Avoiding	18	-	-
Reducing	3	-	-
Reversing	53	-	-
Avoiding and reducing	-	41	-
Avoiding and reversing	-	32	-
Reducing and reversing	-	52	-
Avoiding, reducing and reversing	-	-	23

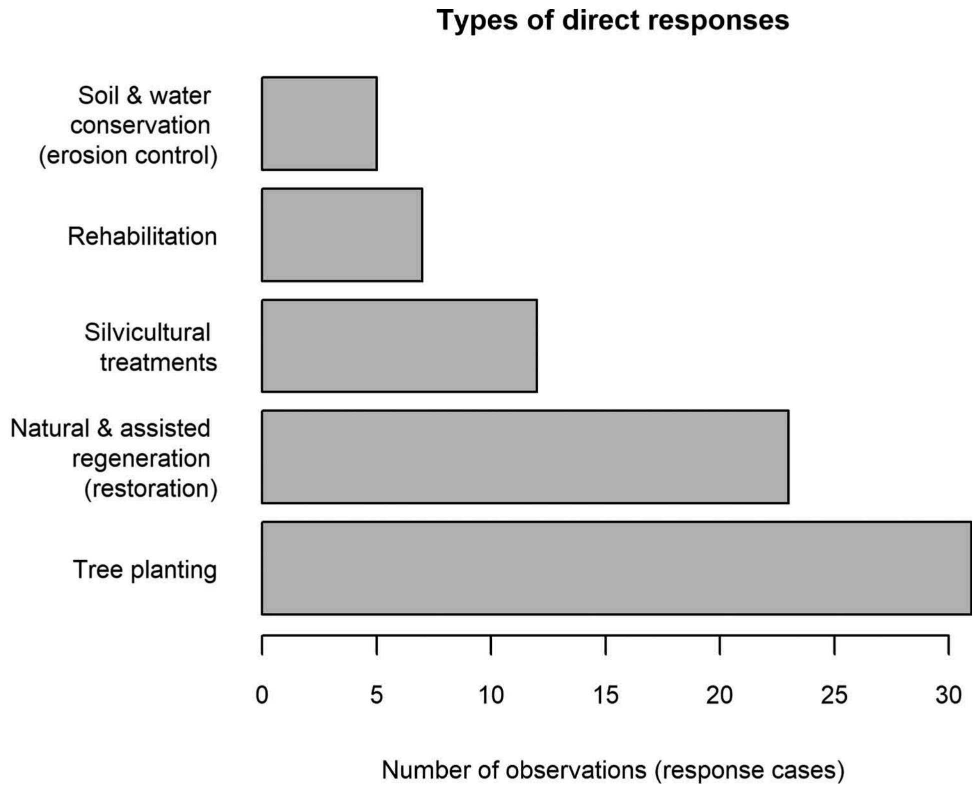

Figure 4. Number of observations related to direct responses to forestland degradation by response type (n = 78).

techniques, erosion control, and other management practices) through which the capacity of degraded forestland to deliver forest products and services could be restored. Indirect responses addressing enabling conditions (i.e. policy, institution and governance mechanisms) were categorized into six types of responses of which five are policy instruments: legal and regulatory, rights-based instruments and customary norms, financial and economic, social and cultural, and anthropogenic assets (Figures 1, 2-Responses).

Of the 153 response cases (observations), about 51% (n = 78) and 49% (n = 75) involved direct and indirect responses, respectively. Figure 4 shows the distribution of 78 direct responses, of which 31 were related to tree planting (i.e. afforestation, reforestation, seedling planting, plantation, and restoration), 23 were related to natural and assisted regeneration/restoration (seeding, passive restoration, natural regeneration, mycorrhizal inoculation, seed dispersal, and planting techniques), 12 were related to silvicultural measures (i.e. thinning, enrichment planting, silvicultural treatments, and harvesting), seven were rehabilitation responses and five were soil and water conservation (i.e. erosion control) responses. Active and passive restoration measures (tree planting and natural/assisted regeneration) constituted about 69% of the direct responses to forestland degradation.

Figure 5 represents the distribution of indirect responses found in the literature. Economic and financial instruments (e.g. incentives, scenarios based on benefit-cost analysis, 27%) and enabling conditions (i.e. policy, institution and governance, 24%) dominate the indirect responses, followed by legal and regulatory instruments (e.g. restrictions or halting logging, 17%) and anthropogenic assets (e.g. monitoring, 17%). Less prominent indirect responses examined in the literature were social and cultural instruments (11%), such as certification, and right-based instrument and customary norms, i.e. use of indigenous practices (4%).

The foregoing results on distribution of direct and indirect responses to forestland degradation provide an overview of response types and the extent to which they have been evaluated in the literature. In the following sections, we use the proposed framework with a three-point effectiveness rating scale – low, moderate, or high – to evaluate effectiveness of various restoration responses (Table 1).

4.3.3. Effectiveness of restoration responses based on criteria and sub-criteria

A summary of restoration response effectiveness is given in Table 3. In some cases, responses were applicable to, and could be assessed against, only a sub-set of criteria with varying levels of response effectiveness among them. For example, tree planting as a direct response to forestland degradation might be rated as highly effective in terms of enhancing vegetation structure, but rated least effective for erosion control, and considered as not applicable to the sub-criterion 'alignment with cultural, spiritual and aesthetic heritage values, beliefs and social norms', if that factor was not considered in the article. Therefore, the number of observations listed in Table 3 (column 4) are mutually non-exclusive across the sub-criteria.

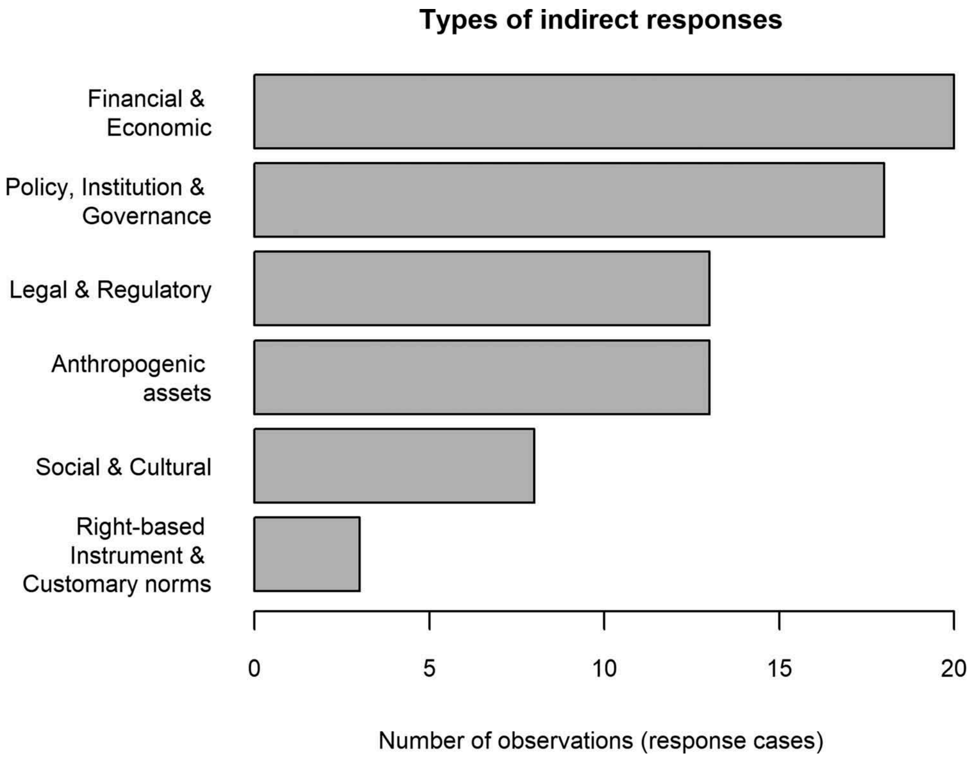

Figure 5. Number of observations related to indirect responses to forestland degradation by response type (n = 75).

The table also provides a snapshot of the relevance, extent and effectiveness of restoration responses in terms of their impacts on biophysical/socio-economic conditions or enabling conditions in the reviewed articles. The environmental desirability sub-criteria are all relevant to impacts on biophysical conditions from restoration responses. With the exception of four sub-criteria – two under economic feasibility (i.e. economic impact and cost-effectiveness), one each under social acceptability (distributional equity) and technical feasibility (adoption time lag) – all others are relevant to impacts of responses on enabling conditions.

Figure 6 shows the response effectiveness based on (a) ecological desirability, (b) economic feasibility, (c) social acceptability, (d) technical feasibility, (e) cultural acceptability, and (f) political acceptability. Of the 153 response cases (observations), 48 were applicable to biodiversity enhancement outcomes (i.e. floral, faunal or microbial abundance and richness) within the environmental desirability criteria. Among those 48 observations, 10, 11 and 27 were assessed as low, moderate, and highly effective, respectively (Figure 6(a)). On the other hand, less than 10% of the observations were relevant to cultural acceptability sub-criteria. Specifically, out of the 11 observations using traditional indigenous and local knowledge and practices, four were assessed as least effective and seven as highly effective. None were assessed as moderately effective (Figure 6(d)).

The most widely covered sub-criterion was 'vegetation structure', which was evaluated in over half (n = 86) of the reviewed cases (Table 3). Of those response evaluations, 34%, 17% and 49% were rated low, moderate and highly effective, respectively, for improving forest vegetation structure and related biophysical conditions (Figure 6(a)). The provision of policy or legislation was the most commonly featured and highly effective restoration response (i.e. 54 out of 59 responses) (Figure 6(f)). On the other hand, only five out of the 29 responses were assessed as highly effective with respect to their effects on water yield (Figure 6(a)).

In testing the proposed framework, we found only one study Poudyal et al. (2018) that assessed all 20 sub-criteria. Using the three-point rating scale (low, moderate, or high), it showed that selective logging was least effective with regard to institutional structure, moderately effective for (biodiversity, water yield, cultural values and social norms, adoption lag, replicability), and highly effective for the remaining 14 sub-criteria. Furthermore, only seven other studies were deemed relevant for our evaluation since they provided ratings for 15 or more sub-criteria. Those studies were by Bowler et al. (2012) on community forest management, Dawes et al. (2018) on urban tree planting in the USA, Fabusoro et al. (2014) on community institutions and sustainable forest management in southern Japan, Lescuyer et al. (2015) on multiple-use forest management in central Africa, Huang et al. (2012) on ecological, social and economic impacts of restoration program in southern China, Santika et al. (2017) on avoided deforestation from community forestry scheme in Indonesia, and Zhang et al. (2008) on impact of afforestation on water yield in southwest China.

Table 3. Summary of the effectiveness rating of restoration responses by assessment criteria, sub-criteria, and their relevance to impact on biophysical/socio-economic or enabling conditions.

Assessment Criteria	Sub-criteria	Relevance to impact on biophysical/socio-economic or enabling conditions	Number of mutually non-exclusive observations by sub-criterion (out of n = 153)	Effectiveness rating scale and frequency		
				Least	Moderate	High
Environmental desirability	Biodiversity enhancement (i.e. floral, faunal, microbial richness or abundance)	Biophysical conditions	48	10	11	27
	Ecological processes (i.e. nutrient availability – soil organic matter, soil nitrogen and organic carbon)		19	7	3	9
	Forest fire risk (i.e. fuel loads)		19	5	5	9
	Sediment yield (i.e. rate of soil erosion/loss)		31	5	8	18
	Vegetation structure (i.e. plant cover, density, basal area/biomass)		86	29	15	42
	Water yield		29	16	8	5
Economic feasibility	Cost effectiveness (least cost, cost sensitivity)	Socio-economic conditions	55	13	6	36
	Economic efficiency (benefit-cost ratio, independent of subsidies/tax)	Socio-economic/enabling conditions	47	18	6	23
	Economic impact (income/employment generation)	Socio-economic conditions	49	19	7	23
Social acceptability	Distributional equity (benefit sharing and decision-making, right-based access)	Socio-economic conditions	32	15	1	16
	Procedural equity (inclusivity and participatory) in response planning and designing	Enabling conditions	54	16	6	32
	Social preference (over current practices, access to resources and services)	Enabling conditions	41	7	12	22
Technical feasibility	Adoption lag: waiting period required to adopt the response	Socio-economic/enabling conditions	32	13	5	14
	Replicability of the response	Enabling conditions	48	4	9	35
	Technical sophistication associated with response (requirement of skills, technical knowledge, physical assets, technical risk)	Enabling conditions	58	20	11	27
Cultural acceptability	Alignment with cultural, spiritual and aesthetic heritage values, beliefs and social norms	Enabling conditions	14	3	5	6
	Use of traditional (indigenous and local) knowledge and practices		11	4	0	7
Political feasibility	Enabled by existing policy/legislation	Enabling conditions	59	5	0	54
	Governance mechanism (clarity on roles/responsibilities of stakeholders)		52	8	2	42
	Institutional structures (establishment of new institutions and strengthening existing institutions)		53	9	2	42

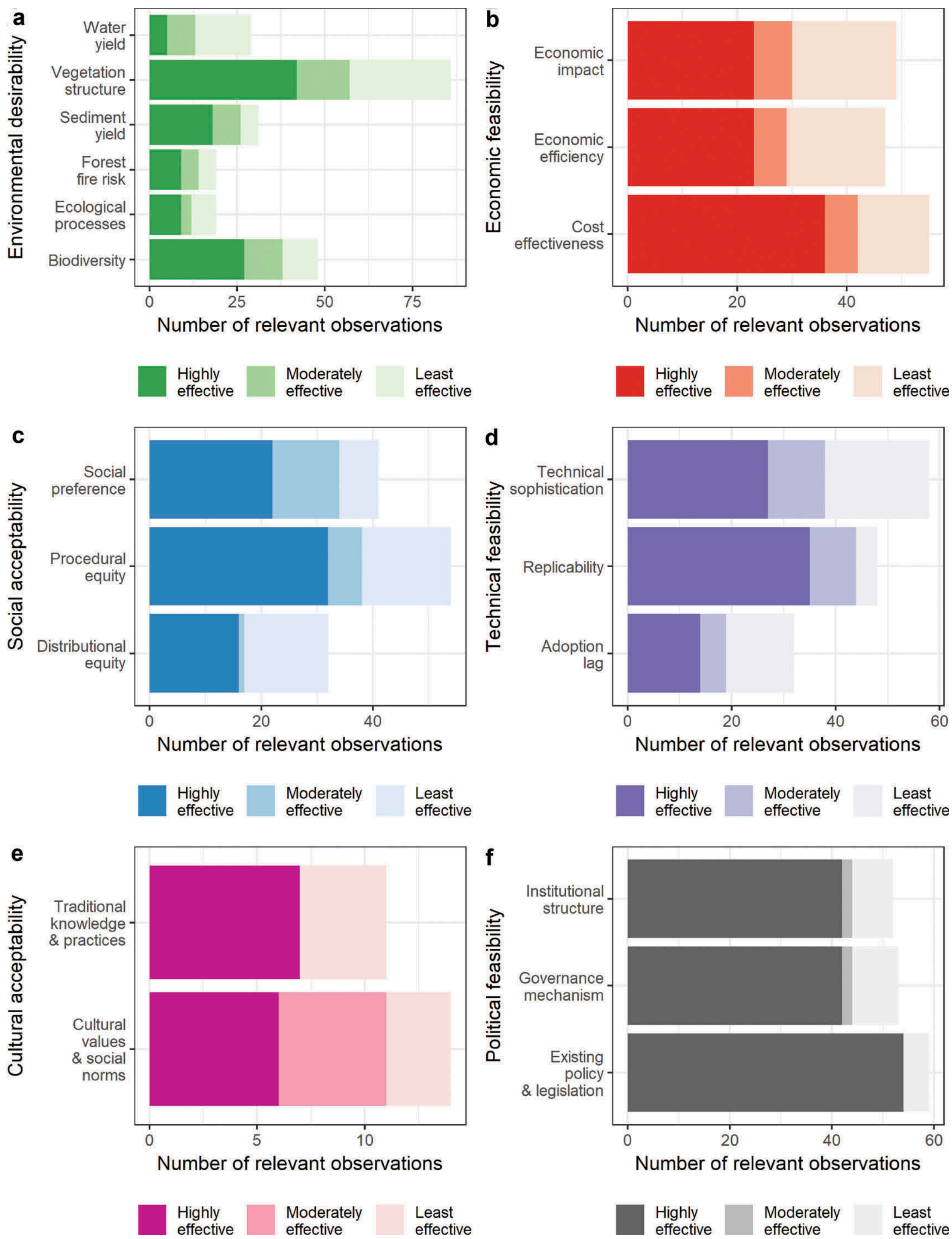

Figure 6. Effectiveness of responses and number of relevant observations related to forestland restoration by assessment criteria (environmental desirability, economic feasibility, social acceptability, technical feasibility, cultural acceptability, and political feasibility) and a range of sub-criteria (Panel a–f).

It is important to note, however, that the summary data (Table 3) overlook the role of restoration context; i.e. a given response might have been effective in relation to a particular criterion in one location (or study) but not effective, or effective at a different level, in another context (or study). To bring context into a finer-grained analysis, the assessment must focus on only one type of response or sub-criterion effectiveness. However, after closely examining the data at a sub-criteria level, we acknowledge that evaluation of context specificity is beyond the scope of this paper.

Table 4 provides an overview of consistency in effectiveness ratings for the assessment criteria and sub-criteria among 153 observations. Based on the environmental desirability criteria, 41 observations were rated least effective for at least one of the six sub-criteria, three observations were rated moderately effective for three sub-criteria, one observation was consistently rated highly effective for five sub-criteria, but none were highly effective for all six sub-criteria (Table 4). Similarly, 39 out of 153 observations were considered not applicable (i.e.

Table 4. Number of relevant observations consistently rated at the same effectiveness level across sub-criteria by response effectiveness rating scale.

Criteria	Response effectiveness rating scale	Number of observations consistently rated at the same effectiveness level across number of sub-criteria[1] (n = 153)						
		Not Applicable (NA)	1	2	3	4	5	6
Environmental desirability (Common NA = 39)	Least	99	41	8	5	0	0	0
	Moderate	118	25	6	3	1	0	0
	High	92	35	17	4	6	1	0
Economic feasibility (Common NA = 65)	Least	116	27	7	3	-	-	-
	Moderate	138	12	2	1	-	-	-
	High	103	30	8	12	-	-	-
Social acceptability (Common NA = 79)	Least	126	19	5	3	-	-	-
	Moderate	136	16	0	1	-	-	-
	High	110	24	11	8	-	-	-
Technical feasibility (Common NA = 77)	Least	125	20	7	1	-	-	-
	Moderate	132	17	4	0	-	-	-
	High	92	46	15	0	-	-	-
Cultural acceptability (Common NA = 136)	Least	146	7	0	-	-	-	-
	Moderate	148	5	0	-	-	-	-
	High	143	7	3	-	-	-	-
Political acceptability (Common NA = 82)	Least	140	7	3	3	-	-	-
	Moderate	149	4	0	0	-	-	-
	High	91	15	18	29	-	-	-

[1]The number 1 to 6 in the next row refers to how many times the observations are rated as least, moderately or highly effective across the sub-criteria. Except environmental desirability that has six sub-criteria and Cultural acceptability that has two sub-criteria, all other criteria have three sub-criteria.

they could not be assessed by any one of the environmental desirability sub-criteria). Overall, 99, 118, and 92 observations were not applicable for using a three-point (low, moderate, or high) effectiveness rating, respectively (Table 4).

Considering economic feasibility criteria, 65 observations were not applicable to any of the three economic sub-criteria (Table 4). Of the 88 applicable cases, the restoration responses were consistently rated least effective for three studies (Smith and Applegate 2004; Castro et al. 2015; Kim and Langpap 2015), moderately effective for one (Fabusoro et al. 2014), and highly effective for 12 (Henly et al. 1990; Caravaca et al. 2002, 2004; Johnson et al. 2003; Zhang et al. 2008; Nguyen et al. 2010; Bowler et al. 2012; Xi et al. 2014; Lescuyer et al. 2015; Santika et al. 2017; Dawes et al. 2018; Poudyal et al. 2018) studies across all three sub-criteria.

With regard to social acceptability, the effectiveness of restoration responses was not applicable for 79 observations (Table 4). Three studies (Saigal 2000; de Jong 2010; Ameha et al. 2014) were rated low, one (Azadi et al. 2013) was moderate, and eight (Kant and Brubacher 2008; Zhang et al. 2008; Bowler et al. 2012; Huang et al. 2012; Santika et al. 2017; Dawes et al. 2018; Hajjar and Oldekop 2018; Poudyal et al. 2018) were rated as highly effective for all three sub-criteria (i.e. distributional equity, procedural equity and social preference).

Considering technical feasibility, 77 observations were deemed not applicable (Table 4). Several observations were rated highly effective for one (46) or two (15) sub-criteria, but none were rated highly effective for all three sub-criteria. There were four responses (Smith and Applegate 2004; Monkkonen et al. 2014; Dawes et al. 2018; Poudyal et al. 2018) rated as moderately effective for two sub-criteria but none for three. However, only one observation was rated as least effective (Bowler et al. 2012) for all three sub-criteria.

Overall, most restoration responses discussed in the reviewed papers were not relevant for assessment from a cultural perspective (Table 4). Depending on interpretation, only 11 to 14 out of 153 observations were relevant at the sub-criteria level (Table 3). Among those that were considered relevant, 7 of 11 observations (Robiglio and Mala 2005; Bowler et al. 2012; Fabusoro et al. 2014; Kim and Langpap 2015; Lescuyer et al. 2015; Hajjar and Oldekop 2018; Poudyal et al. 2018) were rated as highly effective because they included traditional (indigenous and local) knowledge and practices sub-criteria. Six of the 14 observations (Kant and Brubacher 2008; Bowler et al. 2012; Fabusoro et al. 2014; Mengual et al. 2014; Hajjar and Oldekop 2018; Baker et al. 2019) included assessments of sub-criteria focused on cultural, spiritual and aesthetic heritage values, beliefs and social norms. Among those six studies, three (Bowler et al. 2012; Fabusoro et al. 2014; Hajjar and Oldekop 2018) were rated highly effective with regard to cultural acceptability impacts of restoration.

Finally, with regard to political feasibility (i.e. policy, institution, and governance), 82 observations were considered not applicable, three were rated least effective (Smith and Applegate 2004; Ameha et al. 2014; Monkkonen et al. 2014), and 29 observations from 28 studies were rated as highly effective across all three sub-criteria affecting enabling conditions for restoration (Table 4). Those studies were Banerjee et al. (2009), Baskent et al. (2008), Bhattacharya et al. (2010), Borja et al. (2018), Bowler et al. (2012), Chen and Innes (2013), Etongo et al. (2018), Fabusoro et al. (2014), Hajjar and

Oldekop (2018), Hickey (2004), Hickey and Innes (2008), Hickey et al. (2005), Kishchuk et al. (2018), Kishor and Belle (2004), Kumar (2001), Leone (2019), Lescuyer et al. (2015), Loehle et al. (2002), Nguyen et al. (2015), Rantala and German (2013), Rasolofoson et al. (2015), Rasolofoson et al. (2017), Saigal (2000), Santika et al. (2017), Viani et al. (2018), Xi et al. (2014), Yasmi et al. (2009), and Zhang et al. (2016).

Considering the effectiveness of responses to forestland restoration, the existing literature focuses primarily on biophysical conditions (environmental desirability criteria) followed by economic conditions (economic feasibility criteria) and much less on other enabling conditions, particularly those related to cultural acceptability. Although political acceptability criteria were not applicable in over 50% of the observations in our review, it is rated as highly effective in the remaining observations across all three sub-criteria.

As discussed earlier, effective implementation of forestland restoration requires an integrated and ecological systems approach (Yang et al. 2018; Mansourian and Parrotta 2018b) to achieve Target 15.3 of the Sustainable Development Goals (i.e. land degradation neutrality) and aspirations of UN Decade on Ecosystem Restoration (2021–2030). The lack of explicit consideration of traditional knowledge and practices in the literature reviewed reveals that this is a significant gap, and points perhaps to the underutilized potential of indigenous and local knowledge in restoration responses (Lake et al. 2018; Pandit et al. 2018). The findings of our literature analysis on effectiveness of forestland restoration suggest a need for greater focus and inclusion of currently under-represented criteria and sub-criteria as they represent perspectives that are important for long-term success of forestland restoration efforts and associated investments.

5. Case study application of the framework: community forestry policy as an indirect response to forestland degradation in Nepal

We applied the response evaluation framework developed in this paper to assess effectiveness of the community forestry policy in Nepal as discussed in the published literature. Community forestry was introduced in 1978, initially as participatory forest management policy, to control deforestation and associated environmental problems in the hills of Nepal (Pandit and Bevilacqua 2011a). This policy allows local forest users to organise themselves in the form of an institution – a Forest Users Group – to practice forest management practices, including customary norms, by formally owning the use-rights of the local forests (HMG/ADB/FINNIDA 1988; Pandit and Bevilacqua 2011b). The policy was further revised, improved, and applied throughout Nepal by 1993. As a result, a total of 2.238 million ha of forests (about 37.5% of a total of 5.963 million ha forest area in Nepal) have been managed by 22,266 Community Forest User Groups, benefitting nearly 2.908 million households by 2018 (DoFSC 2019). Over the years forest cover in Nepal increased from about 38% of the country's area (147,181 km^2) in 1978/79 to 44.74% in 2015 (DFRS 2015). Most of this gain in forest cover has been in the hills, where community forestry activities have transformed many degraded hills into productive forests and have either halted or at least reduced deforestation and associated land degradation. However, evaluation of its success from a multi-dimensional perspective is still lacking.

Against this background, we followed the same protocol of literature search and screening described earlier but limited our search to Web of Science only with 'effectiveness' and 'impact' as two alternative keywords. The search string 'community forestry' AND 'effectiveness' AND 'Nepal' produced only three hits, while 'community forestry' AND 'impact' AND 'Nepal' produced 24 hits (as of 20 March 2019). Finally, 22 articles were found relevant and evaluated using response effectiveness criteria (Supplemental material, Table S3).

The effectiveness or impact of community forestry policy has been evaluated in the reviewed papers from the perspectives of four out of six criteria (except cultural acceptability and technical feasibility) (Supplemental material, Table S4 for details and Figure 7 for summary). At the sub-criteria level, distributional equity (social), procedural equity (social), institution (political), and improved vegetation structure (environmental) appear to be most often used sub-criteria to evaluate the effectiveness of community forestry. In fact, 50% of the reviewed papers considered distributional equity as a basis to evaluate the policy, and all of these rated it least effective (Figure 7(c)). Procedural equity (stakeholder engagement) was rated highly effective in two studies (Gautam et al. 2002; Poudel 2014) but least effective in six others (Agarwal 2001; Dougill et al. 2001; Timsina 2003; Maharjan et al. 2009; Bastakoti and Davidsen 2014; Yadav et al. 2015). All political feasibility sub-criteria, including institutional structure (Figure 7(d)), were rated highly effective by the relevant studies (Chhetri et al. 2012; Paudel and Weiss 2013; Bastakoti and Davidsen 2014; Yadav et al. 2015; Gharti-Chhetri et al. 2016).

The improved vegetation structure sub-criterion had mixed ratings with two studies rating it highly effective (Gautam et al. 2002; Poudel et al. 2015) and five (Pandit and Bevilacqua 2011a; Niraula et al. 2013; Pokharel et al. 2015; Gharti-Chhetri et al. 2016; Luintel et al. 2018) rating it least effective (Figure 7(a)). The Luintel et al. (2018) study looked at biodiversity conservation and carbon storage in community forests rated community forestry a highly effective policy intervention. The few studies that assessed community forestry from economic feasibility perspective rated it least effective (Figure 7(b))

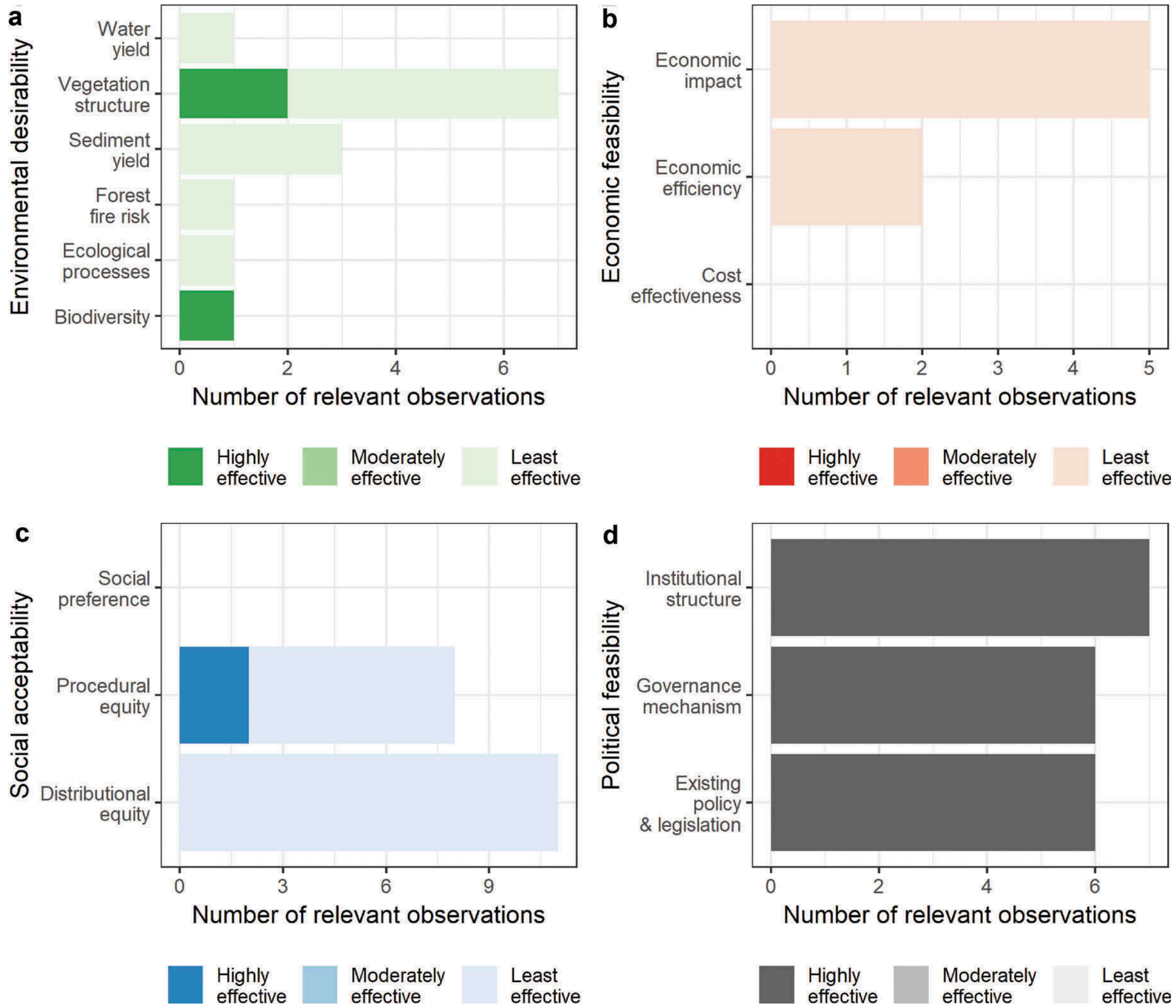

Figure 7. Effectiveness of community forestry policy and number of relevant observations by assessment criteria (environmental desirability, economic feasibility, social acceptability, and political feasibility) and a range of sub-criteria (Panel a–d).

based on both economic impact and efficiency sub-criteria (Dougill et al. 2001; Maharjan et al. 2009; Bastakoti and Davidsen 2014; Poudel 2014; Parajuli et al. 2015; Pokharel et al. 2015; Gharti-Chhetri et al. 2016).

Based on our analysis of this case study, we are confident our structured response evaluation framework can be applied to indirect responses to forestland degradation. Furthermore, with some level of flexibility and adaptation, the framework will also be suitable within the restoration context.

6. Conclusions

This paper presents a conceptual framework to evaluate the effectiveness of responses to arrest land degradation and restore the functioning of land-based ecosystems for sustainability. The framework is demonstrated through an application to forestland degradation. The framework outlines degradation drivers/processes, impacts, restoration responses, and evaluation criteria. Our literature review of direct (e.g. management) and indirect (e.g. policy instrument) responses to forest degradation suggest that among the direct responses, tree planting is the most widely used and most effective restoration option when judged against a range of evaluation criteria. With regards to indirect responses, financial and economic instruments were the most widely used followed by the creation of enabling conditions in the form of policy, institutions and governance mechanism for successful restoration.

Our analysis shows that the success of restoration programs depends on their suitability to context-specific circumstances and practices. It is apparent, however, that cultural desirability and compatibility with local values, beliefs, knowledge and skills, of restoration responses have consistently been poorly represented in studies that assessed restoration effectiveness. While social acceptability, technical feasibility, and political acceptability criteria were generally widely represented, they were not assessed as commonly as environmental and economic criteria. There is also unevenness in the detailed coverage of evaluation sub-criteria in published assessments of restoration responses. There is much greater variability in the coverage of social acceptability sub-criteria as this deals with distributional/procedural equity and social preferences, and of technical feasibility sub-criteria as this deals with adoption and replicability of responses.

It should be noted that a possible limitation of our review is that we confined ourselves to accessible peer-reviewed literature. Including 'grey' literature and studies published in languages other than English may have extended the geographic coverage of studies as well as the assessment criteria, especially regarding cultural acceptability criterion. Nonetheless, our results indicate a clear need for future research that evaluates restoration responses in a broader context, in particular from social and cultural perspectives. Without such research, it will be difficult to mobilize the social, economic, cultural, and political support for restoration at the scale needed to avoid current land degradation and to restore or reverse the degraded lands, particularly in the context of Target 15.3 of the Sustainable Development Goals, i.e. land degradation neutrality.

Land degradation is a fundamental environmental challenge of our time. To meet this challenge, the effectiveness of restoration responses needs to be assessed from a holistic perspective that is simultaneously sensitive to local contextual issues, as these affect the causes of degradation and the suitability of sustainable solutions. Our review shows that this requires moving beyond assessment of simple economic and ecological benefits that dominate current analyses towards a broader consideration of cultural, social, technical, and political perspectives. While this may represent yet another call for interdisciplinary working, it also calls for developing guidance for policymakers and practitioners on the design and implementation of restoration programs attuned to local needs, supporting and drawing on exemplar cases of success. The framework presented in this paper can contribute to the evaluation of restoration responses and thus help decision-makers and planners design restoration programs to better and more efficiently deliver broader and enduring benefits to society and the natural and managed ecosystems upon which our futures ultimately depend.

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Disclosure statement

No potential conflict of interest was reported by the authors.

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