WRI INDIA

WORKING PAPER

Landscape restoration for climate action in India: Insights from a systematic review

Raghav Srivastava, Marie Duraisami, Ruchika Singh, Srishti Kochhar, and Sandip Chowdhury

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Working Papers contain preliminary research, analysis, findings, and recommendations. They are circulated to stimulate timely discussion and critical feedback, and to influence ongoing debate on emerging issues.

Suggested Citation: Srivastava, R., M. Duraisami, R. Singh, S. Kochhar, and S. Chowdhury. 2025. "Landscape Restoration for Climate Action in India: Insights from a Systematic Review." Working Paper. WRI India. Available online at https://doi.org/10.46830/wriwp.23.00132.

Highlights

- This systematic literature review highlights the linkages between landscape restoration, climate change mitigation, and adaptation in Indian restoration research and scholarship. This review follows from the global recognition of the need for large-scale restoration as a strategy to address carbon emissions from land degradation.
- Climate adaptation linkages with landscape restoration are present in the literature reviewed but these are less explicit than mitigation linkages.
- Agroforestry has received the greatest attention in research and practice as a restoration intervention with the potential for climate mitigation and adaptation benefits in India—present in 42.9 percent of the reviewed literature.
- Local community-led, community-sensitive, and socio-culturally attentive implementation of interventions has been found from a significant portion (28 percent) of the reviewed literature to be crucial, enabling conditions for mitigation and adaptation benefits of restoration projects in India.
- Key gaps and challenges to implementing and scaling climate-linked restoration interventions in India are methodological (measuring the carbon sequestered), institutional (insufficient market linkages), and legal (insecure land tenure).

Executive summary

Background

Large-scale restoration is a strategy to address emissions from land degradation, and a consensus has begun to emerge from global forums—such as the Bonn Challenge, the United Nations Convention to Combat Desertification (UNCCD), and Aichi Target 15 of the Convention on Biological Diversity (CBD)—and global studies on the contribution of landscape restoration to climate change mitigation and adaptation (Locatelli et al. 2011; 2015b; Pramova et al. 2015; Stanturf et al. 2015).

In India alone, well over 700 million people, who are also the most vulnerable to the impacts of climate change, depend on forests and agriculture for their livelihoods (Chaturvedi et al. 2018). Improving and protecting forest and tree cover form a substantial basis of India's Nationally Determined Contributions (NDCs) to the Paris Agreement and commitments toward the Sustainable Development Goals (SDGs). Multiple benefits planned for through interventions like agroforestry, afforestation and/or reforestation (A/R), and assisted natural regeneration (ANR) have been realized at various spatial and temporal scales (Chaturvedi et al. 2018).

However, these experiences, and the general empirical wisdom around the contribution of landscape restoration interventions to climate change mitigation and adaptation, are still dispersed and unclear. Specifically, there is a gap in understanding

- the experience of landscape restoration projects in supporting climate change mitigation and adaptation; and
- the conditions necessary for simultaneously planning and achieving the twin objectives of climate mitigation and adaptation.

About this working paper

Through a systematic literature review of India's experience with landscape restoration, this working paper addresses this gap in understanding. It responds to two questions:

1. What are the benefits of restoration interventions that support climate change mitigation or adaptation, or both?
2. What conditions enable landscape restoration to deliver mitigation and adaptation benefits?

We carried out a systematic review of scientific literature to answer our questions. We analyzed 268 peer-reviewed publications and augmented this with a review of 87 relevant items of gray literature. A more detailed description is set out in the main body's methodology section.

Key findings

Our findings from India's rich experience with landscape restoration interventions show a range of techniques and projects with benefits for climate mitigation and adaptation. At least 61 different types of restoration interventions/techniques have been either studied or implemented, and agroforestry and afforestation/reforestation were the most frequently implemented and studied.

Landscape restoration emerges from a historical development of the concepts of conservation and ecological restoration, as a people-centric process. Our review highlights discussions around definitions, strategies, and enabling conditions for restoration in Indian literature, with reference to select authoritative global works in the field. It so emerged that the earliest literature in our review is from 1995, indicating that the identification of landscape restoration as an approach to address climate change in India is roughly contemporaneous with the emergence of climate change as a global issue in the 1990s.

Our findings around benefits from landscape restoration indicate the following:

- A single restoration intervention can be, and is often, used to achieve an array of objectives; for instance, several projects have used ANR to conserve biodiversity while others have used it to increase the availability of fuelwood and non-timber forest produce (NTFP) for local communities.
- Although multiple benefits were possible, many projects focused on a single benefit, with co-benefits emerging as unplanned outcomes.
- The opportunity cost of prior land uses (at the site of the restoration intervention) should be less than the expected joint mitigation-adaptation benefits (4 percent of all reviewed papers). This can happen only when people derive reasonable income by adding value to primary products, which in turn implicates enabling conditions such as tenurial security, market linkages, and access to technologies and know-how.

Our findings on enabling conditions indicate the following:

- Bottom-up approaches—where local communities are meaningfully involved and consulted and tree species chosen depending on the social and agroecological contexts of the landscape—are generally the most appropriate for a restoration mitigation adaptation synergy in India.
- Facilitating agencies include nongovernmental organizations (NGOs), technical institutes, and line departments tasked with implementing restoration interventions. These agencies are important stakeholders who need to play the crucial role of technology transfer and initial handholding for communities.
- The present review reinforces scientific guidance that adoption of multispecies plantations instead of monocultures should be non-negotiable for both (1) ecosystem functioning and vitality and community adaptation and (2) resilience to climate change. There is also evidence (6.7 percent of all reviewed papers) that

restoration tends to do well for the mitigation adaptation synergy when market linkages are developed well for the NTFP derived from restoration interventions. Therefore, the presence of nearby markets and the opportunity for value addition by micro enterprises becomes an important enabler for the long term sustainability of the restoration intervention.

- Top down planning approaches and the role of participatory democracy—aspects of community ownership and participation in restoration projects—have changed somewhat over time in value and social meaning. Learnings from the Joint Forest Management[1] (JFM) program indicate that planning processes that involve local communities in tokenistic ways and do not address tenurial insecurity cannot effectively substitute for more successful restoration through participatory self-governance models and land rights.

Introduction

The 28th Conference of Parties (CoP) to the United Nationals Framework Convention on Climate Change (UNFCCC) was held in 2023. The first global stocktake, released there, shows that countries are well short of their commitments to the Paris Climate Agreement. To limit global warming to 1.5°C by the end of the century, immediate changes are needed.

Accelerating land degradation is driving species extinction, intensifying climate change, and exacerbating poverty—one in three people are affected by land degradation (UNCCD 2022). Recent reports show that half of the world's population is affected by the interrelated factors of declining biodiversity, water availability, and food security (IPBES 2024). There is consensus that limiting the global temperature rise to safe levels, and securing the lives and livelihoods of people, requires fundamental alterations to the way the world protects, manages, and restores land.

Land, which sequesters almost a third of all human-caused CO_2 emissions, presents an immense opportunity to combat climate change (IPCC 2014). Climate change can be combated effectively by restoring landscapes and ecosystems while being attentive to issues of gender-inclusive tenure systems (SDGs 5, 10), sustainable healthy diets (SDG 2), and other SDGs like 13; viz, climate action (IPBES 2024). As countries develop strategies toward a net zero emissions future, the emphasis on removing carbon, and improving the resilience of people and ecosystems—particularly through nature-based solutions (NbS), such as conserving and restoring landscapes—is concerted. Forest landscape restoration (FLR)—defined as a long-term, planned process of regaining ecological integrity and human well-being across unproductive, fragmented, and degraded forest landscapes in the reviewed literature wherever the term is used explicitly (IUCN and WRI 2014; Rizvi et al. 2015; Singh et al. 2021; Chazdon et al. 2017)—sequesters carbon and improves the flow of ecosystem services. Forest landscape restoration is a type of NbS that has emerged as an efficient and cost effective strategy (Chazdon et al. 2017; IPCC 2018, 2019). In this paper, we adapt both the term and definition of landscape restoration from FLR by highlighting the mosaic nature of landscapes and the applicability of interventions across different land uses.

Scientific studies in our reviewed literature explicitly discuss restoration as being "ecological" or "ecosystem" as well (Aronson and Alexander 2013; Everard 2015; Edrisi et al. 2015; Malhotra et al. 2023; Osuri et al. 2024). Ecological or ecosystem restoration is "the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed," according to the definition proposed by the Society for Ecological Restoration (SER 2004). Edrisi, Tripathi & Abhilash (2018) and Malhotra et al. (2023) use the term explicitly and interchangeably with "land restoration" and Choksi et al. (2023) use it synonymously with "biophysical restoration." Osuri et al. (2024) use "forest restoration" as a sub-type of ecological restoration, in the context of degraded forests.

In their meta-analysis of the global restoration literature published between 2000 and 2008, Aronson et al. (2010) found that "restoration practitioners are failing to signal links between ecological restoration, society, and policy, and are underselling the evidence of benefits of restoration as a worthwhile investment for society." In the Indian context, Choksi et al. (2023) both affirm and address these gaps in the practice of ecological restoration by demonstrating a methodology to make restoration practice more people-centric and helping policymakers translate global restoration studies and tools for application in Indian contexts.

Forest landscape restoration and landscape restoration provide an alternative conception that addresses the well-established critique of ecological/ecosystem restoration (and similar approaches) of "leaving people off the map" (Choksi et al. 2023). Practitioners and scholars have previously indicated three ways in which FLR differs from ecological restoration—in scale, intention to restore ecological integrity but without reference to historical states, and in emphasizing human well-being (Elias et al. 2022; Mansourian 2021; Stanturf et al. 2015).

A landscape approach to restoration recognizes the interactions between diverse stakeholders and multiple land uses and focuses on addressing environmental and socioeconomic problems jointly (GLF 2014; Kakani et al. 2024). Broadly, landscape restoration entails integrating trees (or grasses in open natural ecosystems) within mosaics of land uses to strengthen delivery of ecosystem goods and services and enhance rural livelihoods. These goals are achieved while protecting well-functioning natural ecosystems such as forests, if any, and fostering natural regeneration. The IPCC (2019; 2022) identifies cost-effective land management strategies, particularly through agroforestry interventions, as one of the key responses that can contribute to climate change mitigation and adaptation, combat desertification and land degradation, and enhance food and nutritional security. The landscape restoration approach is uniquely positioned to deliver both climate change mitigation and adaptation benefits by successfully restoring lands, improving land productivity while creating jobs, securing livelihoods, and growing rural economies. Landscape restoration, then, can be understood as a long-term, planned process of regaining ecological integrity and human well-being across unproductive, fragmented, or degraded landscapes (rather than just forest landscapes).

Devising sustainable land management strategies, becomes particularly important for a country like India, which has 2.4 percent of the world's total land area to sustain 18 percent of its population (Singh et al. 2023). Studies shows that 114 million hectares (Mha) of land is degraded in India, of which 47 percent is agricultural land (ICAR and NAAS 2010). Almost 30 percent (96.85 Mha) of land faces the threat of desertification (SAC 2024). The soil and land degradation in India impacts the lives and livelihoods of 700 million rural people who are dependent on forest and agriculture for sustenance. This includes 89 million tribal men and women dependent only on forests for their livelihood, 117 million smallholder farmers who cultivate less than 2 hectares of land, and 80 to 100 million women involved in agricultural labor but are not recognized as farmers and are predominantly without land titles (Kumar et al. 2021).

The Government of India has made several international commitments that are achievable in large part through landscape restoration. For instance, India's NDC to the Paris Climate Agreement includes the goal to sequester an additional 2.5 to 3 gigatons of quivalent (gt CO_2e) by 2030 through improved forest and tree cover. Other commitments include the Bonn Challenge commitment to restore 21 Mha of degraded and deforested land by 2030, and the land degradation neutrality (LDN) target to restore an additional 5 Mha.

Achieving India's targets related to forestry and tree cover will help mitigate climate change by sequestering carbon. Importantly, when planned well, the targets can support climate change adaptation by improving the livelihoods of people dependent on land. Given the focus on landscape restoration in India and impetus by the Indian government, the focus of this paper is on delineating the contribution of different landscape restoration interventions like agroforestry, ANR, plantations, and many more to climate change mitigation and adaptation. This paper specifically addresses the gap in understanding of

- the potential of various restoration interventions in supporting climate change mitigation and adaptation, and
- the enabling conditions that are necessary for planning and achieving the dual objective simultaneously.

The following Methodology section discusses the methodological approach of this systematic literature review—specifically, the methods employed to collect data and assimilate findings from peer-reviewed and gray literature for India. In the Key Findings section, we discuss the major findings from the review in terms of restoration interventions and their contribution to climate change mitigation and adaptation.

In the section titled 'Enabling conditions for achieving climate change mitigation and adaptation', we address and analyze the enabling conditions for restoration that support mitigation and adaptation benefits. The fifth section discusses the major gaps and challenges that emerged from the review. The sixth section concludes this paper with a summary of findings, implications, and recommendations for studying and scaling landscape restoration for climate change mitigation and adaptation in India.

Methodology

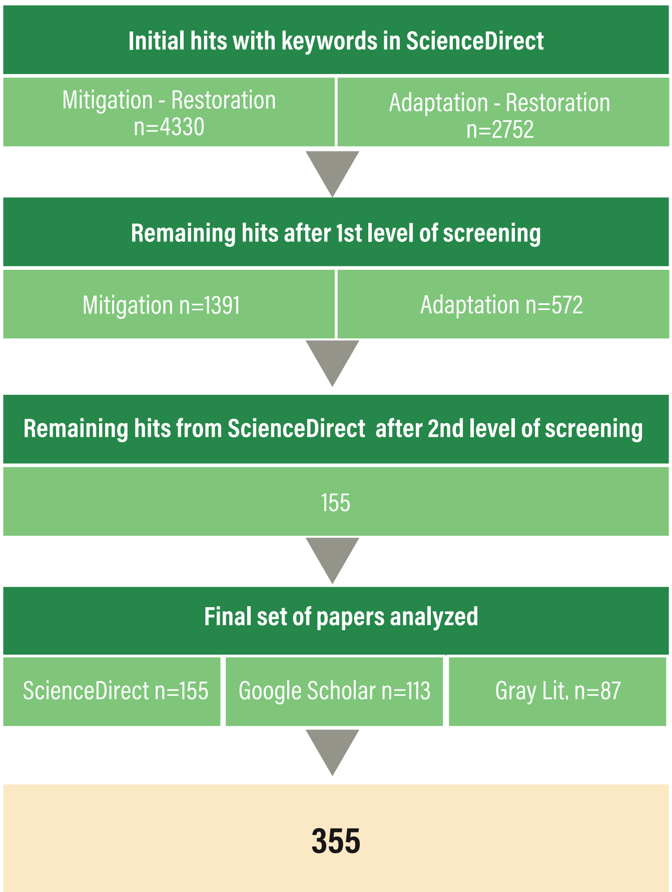
A systematic literature review is an explicit, reproducible method for synthesizing and analyzing a body of literature to draw inferences that are not possible to draw from isolated studies. A systematic review of a body of literature on specific research questions can help identify current and future research priorities—and methodologies, and gaps and challenges—while reducing bias in the selection of literature. To address our research questions, we conducted a systematic review of the scientific and gray literature on past and ongoing primarily tree based[2] landscape restoration–related projects, studies, and interventions in India.

In conducting our review, we have taken guidance from the Protocol, Search, Appraisal, Synthesis, Analysis and Reporting results (PSALSAR) approach—developed for systematic reviews of environmental science literature that are a mix of qualitative and quantitative studies (Mengist et al. 2020)—and the Preferred Reporting Items in Systematic Reviews and Meta Analyses (PRISMA) 2009 guidelines.

To identify the relevant peer reviewed journal articles in English, we used the database ScienceDirect. Through a quick primary scan of the literature, we identified keywords and proxy terms for restoration, mitigation, and adaptation, and had experts[3] validate the keywords. Using several combinations of those keywords, we carried out separate searches for "landscape restoration-mitigation" and "landscape restoration-adaptation." Using the logical operator "OR," we separated search terms used as proxies for landscape restoration; to combine search terms with proxies for mitigation and adaptation, we used the logical operator "AND." An example of a search string used in ScienceDirect is ("ANR" OR "assisted natural regeneration") AND mitigation AND India. Similar search strings with Boolean operators were also used for Google Scholar.

To filter out the literature on unrelated topics and retrieve only those articles that are germane to our questions, we limited the systematic search to titles, keywords, and abstracts (Figure 1).

Figure 1 | **Overview of the publication selection process**



Source: WRI India authors.

To shortlist the relevant publications, we screened all the search results.

1. First, to get an initial list of hits from our keyword searches, we removed all duplicates.
2. To remove irrelevant articles from the initial hits, we screened the titles, abstracts, and keywords; we selected only those article that discuss all three themes—landscape restoration, mitigation, and India; landscape restoration; adaptation and India. We conducted a Kappa test for bias; the result was satisfactory.[4]
3. We reviewed the full manuscripts of the articles we selected in stage 3 to make our final selections.
4. To collect articles that we could not access through these database searches, we used snowballing and Google search, and we also visited websites.

Since the study was systematic but also exploratory in nature, the intention was not to apply the selected keywords as a restricted framework (Table 1).

As new themes emerged from the literature from keyword searches, we complemented the search of peer reviewed articles with dedicated searches in Google and Google Scholar. Through cross-referencing, we adopted a snowballing approach. We included additional publications in the final analysis that were key reviews of global literature or contained seminal findings that, while not from India, were either relevant or adaptable.

We used keyword internet searches using Google, and snowballing from the authors' experience with current practices in India, to search for gray literature. The search helped us incorporate key technical reports, working papers (including those of 10 forest divisions),[5] conference proceedings, and policy papers from government organizations, non-governmental organizations (NGOs), and research institutions. We also referred to the proceedings of workshops and conferences conducted by WRI India. And we included project documents from scoping visits to the Tropical Forest Research Institute and the State Forest Research Institute, Jabalpur.

Using this methodology, we analyzed 355 items of literature—268 peer reviewed studies and 87 publications from either global or Indian gray literature—published between 1990 and 2024 to identify synergies between landscape restoration, climate change mitigation, and adaptation.

Table 1 | **Keywords used for the systematic literature review**

LANDSCAPE RESTORATION	MITIGATION	ADAPTATION
restor*	mitigation	adaptation
ANR	Carbon	"poverty alleviation"
"assisted natural regeneration"	sequestration	livelihood
Landscape	biomass	"ecosystem services"
reforest*	emissions	biodiversity
afforest*	"soil organic"	resilience
Plantation	stock	"adaptive capacity"
rehabilit*	bioenergy	vulnerability
recla*m*	permanence	EbA
Agroforestry	REDD	CbA
agr? horticulture	SFM	income
silv? past*	CDM	"watershed conservation"
Wadi	biofuels	NAMAs
Mangrove	"sustainable forest management"	NAPAs
commons		"food secur*"
"Green India Mission"		"water availability"
"home gardens"		flood
		Fire
		jobs

Source: WRI India authors.

Framework

In their review of FLR case studies from across the globe, Stanturf et al. (2015) identified synergies between restoration, climate change mitigation, and adaptation (the International Union of Forest Research Organizations (IUFRO) framework). Their framework captured information in three key categories—biophysical characteristics, ecological factors, and socioeconomic factors—for the baseline characterization of restoration interventions. We have adapted this framework to capture the biophysical characteristics, flow of benefits, and enabling conditions of restoration interventions as follows:

- The focus of our analysis on **biophysical characteristics** helped categorize geographical locations and types of landscape restoration intervention used. Given India's climatic and geographical diversity, the landscape restoration experience encompasses a gamut of interventions across multiple land uses and categories. We classified the restoration intervention based on the objective of the restoration project or program as indicated in each item of literature. Consequently, the final list of interventions consists of a combination of interventions and techniques: for instance, increased connectivity between forest patches, mixed species plantations, and natural regeneration are provided as different interventions; though "increasing connectivity" may involve the technique of mixed plantation or natural regeneration, given the specific purpose of the intervention, we classified it separately.
- The focus of our analysis on **benefits and services** captures the outcomes of restoration projects under the provisioning of food, fodder, fuelwood, timber, NTFP, or minor forest produce (MFP); conservation of biodiversity; protection and enhancement of water flow and quality; carbon

sequestration; and other ecosystem resilience benefits such as soil moisture conservation, erosion control, landslide prevention, and flood control. Following the IUFRO framework (Stanturf et al. 2015), we linked benefits and services to climate change mitigation and adaptation;[6] for instance, climate change mitigation benefits are those that contributed to carbon sequestration, reduction in fossil fuel emissions, and reduction in emissions from burning biomass; and climate change adaptation benefits relate to maintaining or protecting forest areas, maintaining ecosystem services, and reducing the vulnerability of ecosystems and people. Figure 5 indicates landscape restoration benefits by intervention.

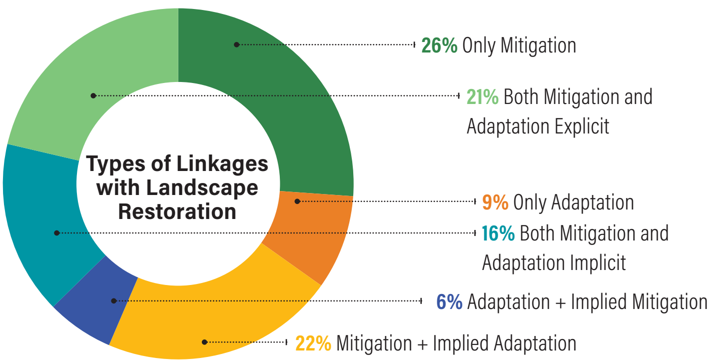
- The third focus of our analysis is on the **enabling conditions** that underpin the implementation of restoration interventions. We identified the enabling conditions by adapting the framework used to build the Restoration Diagnostic (Hanson et al. 2015) that aims to bring restoration commitments into action on the ground. We divided the enabling conditions into ecological, institutional, economic, and social.

We have tried to be as transparent and explicit as possible in the reporting of our methods, analyses, and results.

Key findings

About 21 percent of the publications reviewed dealt with the synergy between landscape restoration, mitigation, and adaptation explicitly. Adaptation linkages with landscape restoration were either present or implied in 74 percent of the papers while mitigation linkages were either explicit or implied in 91 percent of the papers reviewed—indicating a disparity between the focus on climate change adaptation and mitigation in landscape restoration research and practice in India (Figure 2).

Figure 2 | **Linkages between landscape restoration, mitigation, and adaptation in reviewed literature**



Source: WRI India authors.

The review showed that adaptation is implied in 22 percent of mitigation-explicit papers but mitigation is implied in only 6 percent of adaptation-explicit papers. The reason for the relative paucity of explicit empirical discussions on adaptation in the literature is elaborated in Landscape restoration and climate change mitigation below.

Our review brought up literature starting from the year 1990, contemporaneous with the emergence of the links between landscape ecology and restoration ecology in the global literature (de Souza Leite et al. 2013) and also when the impacts of climate change began to be studied in earnest around the world (von Holle et al. 2020).

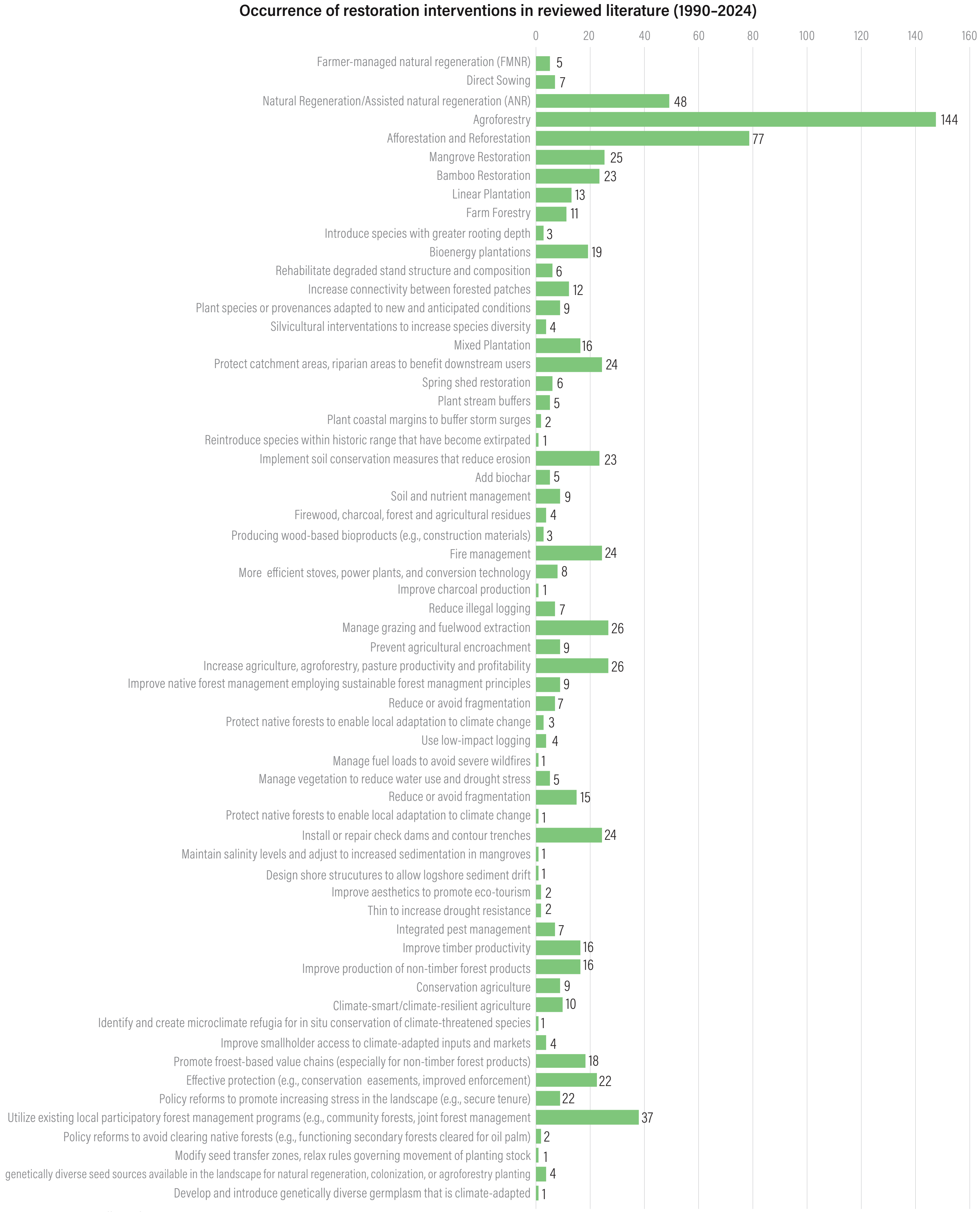
The review identified 61 types of landscape restoration interventions that have been implemented in India in both forest and nonforest areas (areas not recorded or classified by the state as forests or falling under the dictionary meaning of forests—as per the current legal definition in India) (Figure 3). The list—prepared to capture the specific goals and outcomes of the restoration practices and techniques identified—contains a mix of restoration practices and techniques such as direct sowing, natural regeneration, rehabilitation of degraded sand structures, mixed species plantation, and spring shed restoration.

Agroforestry emerged as the most studied and discussed restoration intervention, present in around 43 percent of the reviewed literature, with an increasing trend in research interest over the years (Figure 6). It emerged from other reviews and meta-analyses of agroforestry in India that the realized potential for agroforestry as a climate mitigation intervention is highest in humid and temperate contexts (Dhyani et al. 2021; Nath et al. 2021) and that rainfall is a significant predictor of carbon sequestration in agroforestry systems (Kumara T.M. et al. 2023).

Yet, of the 144 papers pertaining to agroforestry that we reviewed, 26 percent are explicitly and specifically regarding water-stressed contexts (dry, arid, semiarid, or drought-prone regions). Further, over 25 percent of these are from the past four years alone (2021–2024), showing an increasing degree of research interest in agroforestry as a restoration and climate mitigation intervention in drier geographies. This interest is reflected in current agroforestry policy in India, which promotes agroforestry as a climate positive intervention in rain-fed and drought-prone areas (CAZRI 2007; GoI 2014; GoI 2016).

Our review indicates agroforestry is popular as a subject of research. However, insecure land tenure and adverse policies on ownership of trees on private land constrain Indian farmers from adopting agroforestry, our review indicates (Sahoo et al. 2020; Dhyani et al. 2021; Datta et al. 2024).

Figure 3 | **List of major landscape restoration interventions/techniques emerging from the literature review**

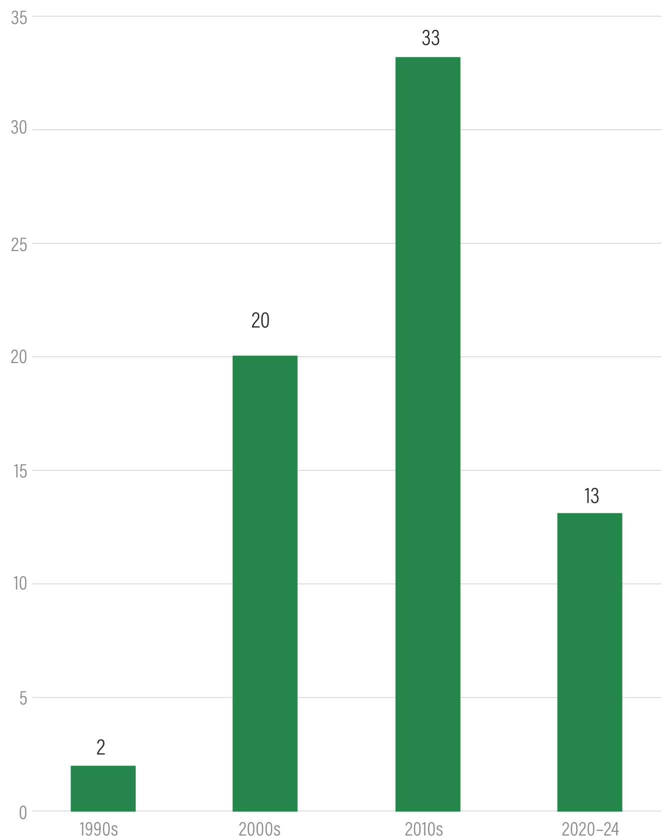


Source: WRI India authors.

In the reviewed literature, the second most frequently observed restoration intervention was A/R (Figure 4). It is ubiquitous in research, and interest is increasing nearly constantly, owing to the fairly conventional, commonsensical, and (to some extent) habitual associations of forests with ecosystem and livelihood benefits. The largest number of empirical studies of implemented restoration projects in our literature corresponded to A/R interventions—26 percent of all peer reviewed papers we analyzed that had "case," "case study," or "example" in their title were in the context of A/R - based restoration. Further, 40 percent of this peer reviewed A/R literature explicitly and closely discusses social and cultural factors, and community ownership and participation, as critical enabling conditions for the success of such restoration projects.

Our primary focus was on tree-based landscape restoration interventions. However, we also recorded interventions—soil and moisture conservation measures, fire management, removal of invasive species, climate-smart agriculture, pest management—implemented and/or studied as supporting and augmenting tree-based interventions (See Appendix A.).

Figure 4 | **Occurrence of afforestation and/or reforestation in reviewed literature**



Source: WRI India authors.

Landscape restoration interventions contribute to multiple ecosystem service benefits

In India, landscape restoration has contributed to a range of regulating, provisioning, and cultural ecosystem services (Figure 5). Our analysis of publications that study the flow of benefits from restoration interventions indicates that, often, a single intervention is used to achieve an array of objectives: several projects used ANR for biodiversity conservation while others used it to increase the availability of fuelwood and NTFP for local communities. Interestingly, ANR using specific tree species also contributed to food and fodder availability for local communities.

Agroforestry interventions have contributed to a wide range of benefits: food security; carbon sequestration; and the conservation of biodiversity, soil moisture, and water (Narain et al. 1997; Pandey et al. 2005; Sarvade and Singh 2014). Similarly, multiple benefits were traced to other interventions. The flow of multiple benefits emerged as a key feature of landscape restoration that contribute to both climate change mitigation and adaptation. For instance, while carbon sequestration contributes to mitigation strategies, the flow of provisioning services like water, food, and fuelwood increase the adaptive capacities of communities and ecosystems to climate change.

Our study shows that though multiple benefits were possible, many projects focused on a single benefit; co-benefits emerged as unplanned outcomes. We also noted the presence of key enabling conditions that catalyze the flow of multiple benefits (Enabling conditions for achieving climate change mitigation and adaptation through landscape restoration).

Landscape restoration for addressing climate change

Carbon sequestration, one of the benefits of landscape restoration, directly contributes to climate change mitigation by reducing greenhouse gas (GHG) emissions. The remaining benefits contribute in varying degrees to the increase in the adaptive capacity of ecosystems and local communities, thereby strengthening their response and resilience to a changing climate. However, the analysis highlights the dearth of framing related to "climate change" in India's restoration literature. Only 21 percent of the papers reviewed explicitly recognized the connection between landscape restoration and both climate change mitigation and adaptation; and only 16 percent recognized that connection implicitly.

Figure 5 | **Restoration interventions and associated benefits**

RESTORATION INTERVENTION	FOOD	FODDER	FUEL	TIMBER	NTFP	BIODIVERSITY	WATER	ECO-SYSTEM RESILIENCE	CARBON SEQUES TRATION
FOREST AREAS									
Farmer-managed natural regeneration (FMNR)	2	2	2	2	2	2	2	2	2
Direct Sowing	2	2	2	2	2	2	0	2	2
Assisted natural regeneration (ANR)	1	1	1	0	1	2	0	2	1
Afforestation and Reforestation	1	2	2	1	1	2	0	2	2
Mangrove Restoration	2	0	2	0	2	2	2	2	2
Bamboo Restoration	1	2	0	2	2	2	2	2	2
Linear Plantation	1	2	2	2	1	2	0	1	1
Farm Forestry	2	2	2	2	1	0	0	0	1
NON-FOREST AREAS									
Introduce species with greater rooting depth	1	1	1	1	1	1	1	2	2
Establish windbreaks to reduce wind erosion	0	0	0	0	0	0	0	2	1
Bioenergy plantations	0	1	2	0	0	0	2	2	2
Rehabilitate degraded stand structure and composition	1	2	2	1	1	2	0	2	1
Increase connectivity between forested patches	0	0	0	0	0	1	0	2	2
Plant species or provenances adapted to new and anticipated conditions (plantations, enrichment plantings in native forests)	1	1	1	1	2	2	1	1	2
Silvicultural interventions to increase species diversity	1	2	2	0	2	2	0	2	1
Afforest, reforest, or agroforest with mixed species	2	2	2	2	2	2	1	2	2
Protect catchment areas, riparian areas to benefit downstream users	2	2	2	0	1	1	2	2	2
Spring shed Restoration	0	2	0	0	0	0	2	2	1

Legend: DIS: Data Insufficient 2: Services provided 1: Provision of service is conditional to species type, spatial and temporal scale, geography etc. 0: Services not provided

Figure 5 | **Restoration interventions and associated benefits (Cont.)**

RESTORATION INTERVENTION	FOOD	FODDER	FUEL	TIMBER	NTFP	BIODIVERSITY	WATER	ECO-SYSTEM RESILIENCE	CARBON SEQUES TRATION
Plant stream buffers	2	2	1	0	2	0	2	2	1
Plant coastal margins to buffer storm surges	0	0	2	2	1	2	2	2	2
Reintroduce species within historic range that have become extirpated	0	0	0	0	0	2	0	2	1
Agroforestry	2	2	2	2	2	1	0	2	2
Homegardens	2	2	2	2	2	2	0	1	2
Traditional agroforestry	2	2	2	2	2	2	2	2	2
Alley cropping / Hedgerow intercropping	2	2	1	1	1	1	2	2	0
Boundary Plantation	0	2	2	2	0	1	1	2	2
Block Plantation	1	1	2	2	0	0	0	2	2
Energy Plantation	0	0	2	0	1	0	0	2	1
Agri-silviculture	2	2	2	2	2	2	0	2	2
Agri-horticulture	2	2	2	2	2	1	0	2	2
Agri-silvi-horticulture/ Agrohortisilviculture/WADI/ Agri-horti-forestry	2	2	2	2	2	2	1	2	2
Agri-silvi-pasture/Agro-silvo-pastoral systems	2	2	2	2	2	2	0	2	1
Agri-hortipasture	2	2	2	0	2	1	1	2	2
Silvi or horti-olericulture	2	DIS	DIS	DIS	1	2	DIS	DIS	DIS
Horti-pasture	0	2	2	0	2	2	0	2	2
Silvi-pasture/ Silvopasture/ Pastoral-silviculture	2	2	2	2	1	2	0	2	2
Shelter-belts	2	2	2	2	2	1	0	2	1
Wind-breaks	2	2	2	2	2	1	0	2	1
Live fence	1	2	1	0	1	2	0	2	0
Silvi or Horti-sericulture/ Entomoforestry	0	DIS	DIS	DIS	2	2	0	DIS	DIS
Silvi or Horti-apiculture	2	DIS	DIS	DIS	2	DIS	DIS	2	DIS

Legend: DIS: Data Insufficient 2: Services provided 1: Provision of service is conditional to species type, spatial and temporal scale, geography etc. 0: Services not provided

Figure 5 | **Restoration interventions and associated benefits (Cont.)**

RESTORATION INTERVENTION	FOOD	FODDER	FUEL	TIMBER	NTFP	BIODIVERSITY	WATER	ECO-SYSTEM RESILIENCE	CARBON SEQUES TRATION
Aqua-forestry/ Aqua-silviculture/ Silvofishery/ Pisci-silviculture	2	1	1	1	1	2	1	1	1
Silvi-horticulture/ Hortisilviculture	0	0	2	2	2	1	0	1	1
Ethnoforestry	2	2	2	2	2	2	1	2	2
Scattered trees/Dispersed trees on farms	2	2	2	0	2	1	0	2	1
Shifting cultivation	2	0	0	0	0	0	0	0	0
Taungya cultivation	2	0	0	2	0	0	0	0	1
Woodlots	0	2	2	2	1	1	0	2	2
Silvi-horti-pastoral systems/ Hortisilvipasture / Horti-silvo-pasture	0	2	2	2	2	2	2	2	2
Agrohortisilvipastoral/ Agri-silvi-horti-pasture/ Agri-horti-silvo-pastoral	2	2	1	1	2	DIS	2	2	2
Improved Fallow	0	2	2	0	1	1	0	2	1
Multipurpose trees and shrubs on farm lands (MPT)	2	2	2	2	2	2	2	2	2
Forage Forestry	0	2	2	DIS	DIS	DIS	DIS	DIS	DIS
Fodder banks	0	2	DIS	0	1	1	DIS	1	1
Agri-pisci-silviculture	2	DIS	DIS	DIS	DIS	DIS	DIS	DIS	DIS
Multistory tree garden	1	2	2	2	2	2	DIS	2	1

Legend: DIS: Data Insufficient 2: Services provided 1: Provision of service is conditional to species type, spatial and temporal scale, geography etc. 0: Services not provided

Source: WRI India authors.

Landscape restoration and climate change mitigation

The contribution of tree-based interventions to climate change mitigation through carbon sequestration is well established. The choice of tree species impacts the quantity of sequestration achieved (Kishwan et al. 2009).

The contribution of landscape restoration to climate mitigation was explicitly discussed or brought out by 69 percent of the literature reviewed. The review indicates that India has largely conserved forests and avoided large-scale deforestation—due to a partial policy shift, since 1988, from exploitative forestry to various forms of participatory and conservation-oriented forest management programs (FAO 2016b; P.J.D. Kumar 2014). However, this comes with a qualification—there is some debate over the definitions of "forest," "forest cover," and "tree cover" currently employed in the India State of Forest Report published biennially by the Forest Survey of India (Balaji et al. 2022). Since the introduction of trees (or grasses) would necessarily imply some amount of carbon sequestration, another 22 percent of the papers implied the connection to mitigation.

Traditionally, restoration and FLR research has prioritized forested or tree-covered areas for climate change mitigation opportunities. However, now, and as seen in the increasing interest in agroforestry in our reviewed literature (Figure 6), the attentiveness toward restoration in research and practice is growing beyond classical forestry interventions such as A/R toward mangrove restoration (Padhy et al. 2022), mixed bioenergy plantations (Ahirwal et al. 2022), and soil carbon sequestration (Srinivasarao et al. 2014).

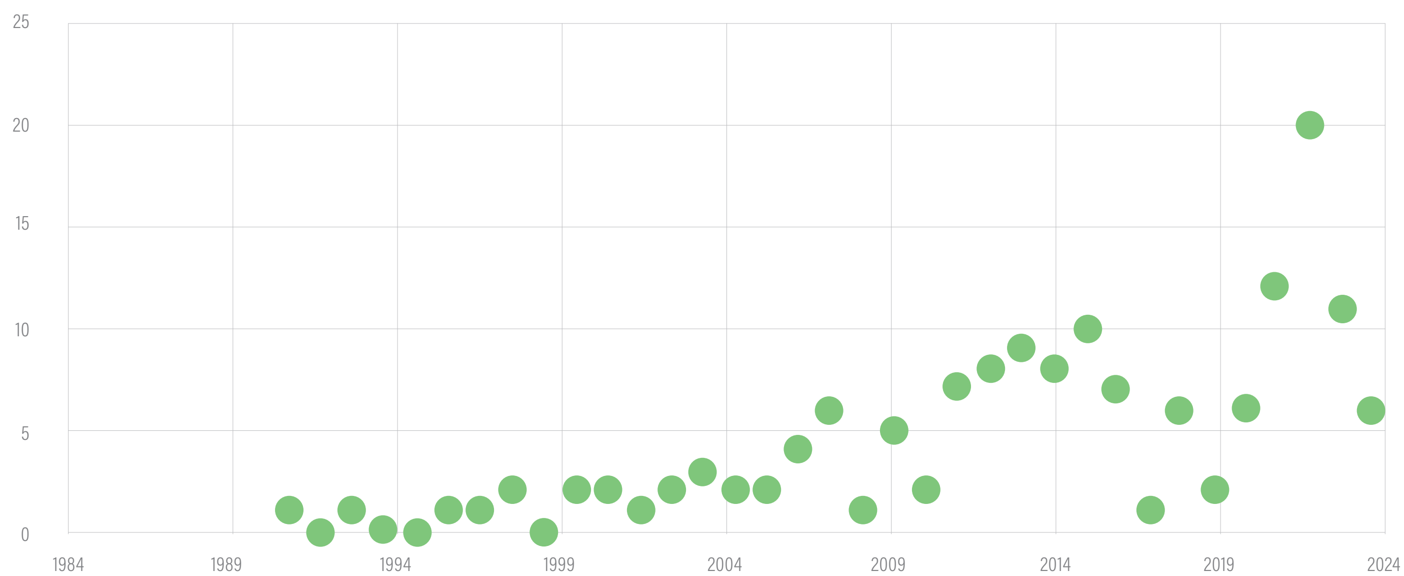
The analysis highlights the ways in which agroforestry contributes to mitigation: direct carbon capture through the use of numerous tree species; increased carbon storage in soil due to soil conservation techniques; and decreased pressure on forests due to self-sufficiency of fuelwood and fodder needs from farmlands (Handa et al. 2013; Murthy et al. 2013).

Landscape restoration and adaptation

The restoration literature discusses associations with climate change mitigation and adaptation but less than 40 percent recognizes both mitigation and adaptation as productive outcomes of restoration—in contrast with the global acknowledgment that FLR has the potential for both mitigation of climate change and adaptation to it (Stanturf et al. 2015; von Holle et al. 2020). In the global literature, climate change adaptation is discussed more in the context of habitat conservation and less in the context of landscape restoration interventions, finds a comprehensive review of global landscape-level restoration interventions (von Holle et al. 2020). The time and expense of landscape-level studies is another factor that contributes to their paucity in the restoration literature. It is, after all, difficult, if not impractical, for localized, empirical studies to meaningfully account for restoration-linked adaptation metrics like practice/behavior, green infrastructure, and technology (Stanturf et al. 2015).

Though adaptation linkages (74 percent) did not appear in the reviewed literature as often as mitigation (91 percent), a total of 263 papers in our review did bring out the potential of landscape restoration to increase the adaptive capacity of mosaic landscapes and of rural populations across such

Figure 6 | **Agroforestry as a primary restoration intervention in reviewed literature by year**



Source: WRI India authors.

landscapes (Tambe et al. 2012; Rizvi et al. 2015; Angom et al. 2021; Datta and Behera 2022). The adaptation benefits of landscape restoration were noted explicitly in 36 percent of papers reviewed and implied in 38 percent. Adaptation benefits are achieved mostly through the enhanced flow of provisioning services—such as food, fuelwood, and fodder—and through an increase in ecosystem resilience by means of biodiversity conservation and restoration of catchment areas. Our analysis shows that—through services such as control of erosion, landslides, and floods—landscape restoration impacts the response of communities to climate change (Satapathy et al. 2011; Angom et al. 2021; Choudhury et al. 2022).

As a restoration intervention, agroforestry helps climate-vulnerable communities adapt to climate change in multiple ways (Handa et al. 2013). By increasing productivity and/or preventing land degradation, agroforestry helps in the sustenance of agriculture. Depending on its type and the tree species, agroforestry provides fruit, food, vegetables, and fiber; fuelwood, fodder, and timber; and medicines—ensuring nutritional and livelihood security. Enhanced income makes farmers more resilient to the future impacts of climate change. If climatic aberrations cause crops to fail, agroforestry systems act as crucial safety nets (Handa et al. 2013).

Landscape restoration for both climate change mitigation and adaptation

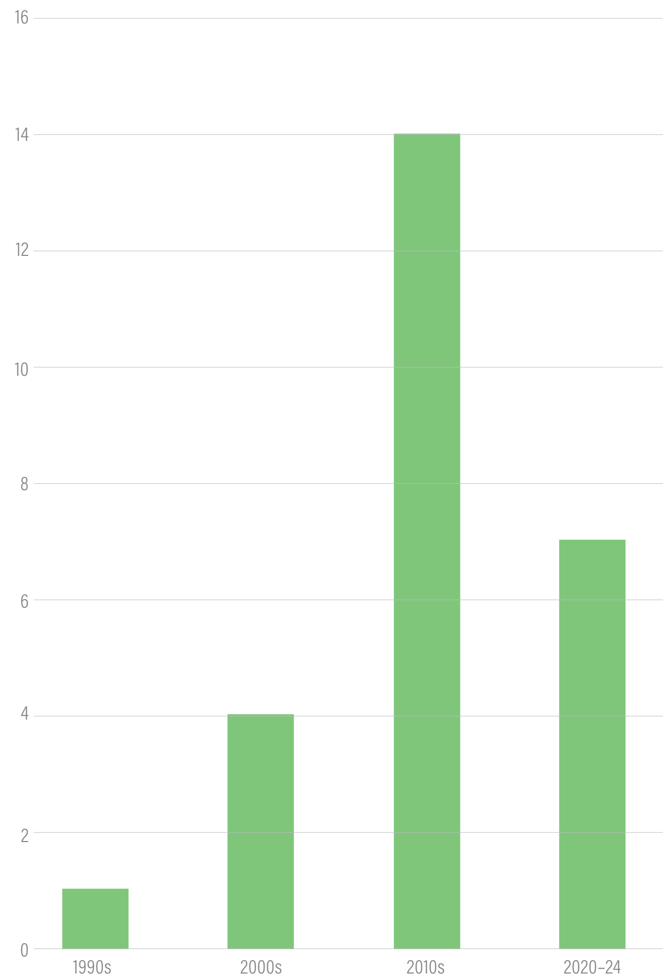
In our review, 21 percent of the papers explicitly discussed specific contributions of landscape restoration to mitigation and adaptation in India.

In the forestry sector, mitigation and adaptation can complement each other in various ways (Ravindranath 2007). The study highlights the potential for forestry mitigation interventions to facilitate adaptation by incorporating choices—natural regeneration, mixed species plantations, soil and water conservation, short rotation forestry, and fire management—that positively impact local communities and their adaptive capacities.

Participatory forest management and agroforestry emerged as effective interventions for achieving mitigation and adaptation (Bijalwan et al. 2016; Dhyani and Ajit 2013; Murthy et al. 2013; Satapathy et al. 2011; Palm et al. 2009; Pandey 2007). In a further 16 percent of the papers, the flow of benefits contributed to both strategies implicitly: in many adaptation projects, the inclusion of tree-based interventions resulted in mitigation as a co-benefit in the form of carbon sequestered as aboveground biomass (Aggarwal, Das and Paul 2009a; Melkania 2009; Ravindranath 2007; Ravindranath and Sukumar 1998). In coastal areas, mangrove restoration, a popular theme of study and practice for local communities since 1997 (Figure 7), can contribute to this synergy through carbon sequestration and livelihood benefits (Rao 2009; Kandasamy et al. 2021; Padhy et al. 2022). Other tree-based interventions that address the synergy are A/R, ANR, mixed species plantations, bamboo restoration, and catchment area treatment. These mitigation and adaptation benefits are meaningfully supported and/or constrained by a range of enabling conditions—explored in the following section.

India's Third Biennial Update Report to the UNFCCC reported a "progressive decoupling" of economic growth and GHG emissions between 2005 and 2016 (MoEFCC 2021). The report highlighted the contribution of agriculture and forest sector policies and schemes to mitigation and adaptation. National-level schemes include the National Mission for Development of Integrated Horticulture; National Food Security Mission; Sub Mission on Agroforestry (following the National Agroforestry Policy of 2014); Van Dhan Yojana; National Green Highways Mission;

Figure 7 | **Mangroves in restoration interventions in reviewed literature**



Source: WRI India authors.

Pradhan Mantri Unnat Gram Yojana; Pradhan Mantri Krishi Sinchayee Yojana; Pradhan Mantri Khanij Kshetra Kalyan Yojana; and the Green India Mission (GIM). Many states have launched schemes that dovetail into and converge with central sector schemes, such as the Karnataka government's Krushi Aranya Protsaha Yojane, which seeks to provide seedlings and monetary incentives for planting trees on farmlands (Duraisami et al. 2022).

Enabling conditions for achieving climate change mitigation and adaptation

In general, mitigation and adaptation strategies are viewed as separate approaches that present notable differences in objective and in spatial and temporal scales (IPCC 2022). Our review of the literature shows that landscape restoration is a viable, broad based strategy for achieving mitigation and adaptation benefits. Through our review, we identified key enabling conditions that supported the flow of mitigation and adaptation benefits and categorized these conditions into social, ecological, economic, and institutional.

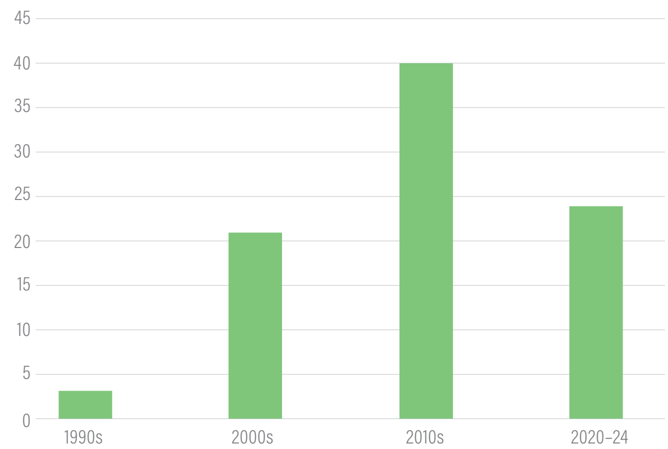
Social conditions

The involvement of local communities in the planning, design, implementation, and monitoring of landscape restoration interventions is a critical enabling condition for achieving mitigation and adaptation benefits (Francis and Weston 2015; Satapathy et al. 2011; Singh, Pandey, and Prakash 2011; Conroy, Mishra, and Rai 2002). Recent reviews of the global literature and of studies on socio-ecological restoration have identified that foregrounding the voices and needs of local and native populations is a common feature of successful restoration projects (Elias et al. 2022; Maniraho et al. 2023; Kakani et al. 2024).

Ensuring the participation of all local communities —including obtaining free, prior, and informed consent— features as a critical enabler in over 27 percent of all papers in our review (Figure 8). "Ensuring participation of local community" occurred 168 percent more in our analysis than the next highest enabling condition—viz., "strengthening field capacities and better monitoring systems." Within these, 17 percent spoke explicitly to women's involvement being a critical feature of community participation and/or leadership. Establishing clear modalities for use rights and sharing of benefits emerged as another critical enabling condition (occurring in 18 percent of the reviewed literature).

We also observed that certain aspects of community ownership of, and participation in, restoration projects—such as top-down planning approaches and the role of participatory

Figure 8 | **Frequency of community as a critical enabling condition in reviewed literature**



Source: WRI India authors.

democracy—have changed somewhat over time in their values and social meanings. For example, the JFM program, which was intended to take a participatory approach to restoration, and which was generally agreed upon to have contributed positively to restoration and climate goals (Bhattacharya et al. 2010; Singh, Pandey & Prakash 2011; TERI 2011), began to be critiqued frequently in the 2010s as not being an effective guarantee of meaningful local community participation—owing to skewed power dynamics with state forest departments translating to low ownership by local communities, both figuratively and materially (Aggarwal 2014; Vijge and Gupta 2014; Aggarwal 2020).

Further, eight of the nine items of literature in our review that discuss tenurial security oriented policy reforms as restoration interventions were published after 2013, indicating that, in the context of climate change, participatory democracy and land rights are still new and underattended themes in the planning and study of landscape restoration.

Ecological conditions

The analysis highlighted the importance of selecting diverse and native tree species appropriate for the target agroecological zones. Important factors to consider are mixed species plantations in forest areas, higher species richness in agroforestry systems, appropriate silvi-pastoral combination of trees and grass, and selection of trees based on their ability to survive and regenerate in the local environment (Ravi and Priyadarsanan 2015; Chaudhry et al. 2011; Singh, Pandey & Prakash 2011; Sheoran et al. 2010; Aggarwal, Das, and Paul 2009a).

The study reinforces the importance of adopting multispecies plantations instead of monocultures for community and ecosystem adaptation—mixed species plantations were found to be an enabling condition in 25 papers in our review. A bottom-up approach where local communities are consulted, and tree species are chosen depending on the agro-ecology of the region, can enable the flow of adaptation and mitigation benefits (Singh et al. 2021).

Economic and market conditions

Several papers (29) stressed the importance of establishing adequate opportunities for the economic benefits of stakeholders involved in the restoration. At the local level, these conditions include the value chain, and market conditions such as the development of new micro enterprises for restoration products, presence of and linkage to nearby markets, value addition by local communities, and involving the private sector to augment market linkages (Saha and Sundriyal 2012; Bhattacharya et al. 2010; Bawa et al. 2007; Kakade 2002). Important national-level conditions are aligning economic and infrastructural development with conservation goals (Wylie et al. 2016) and ensuring that the benefits of carbon sequestration are higher than the opportunity costs (Aggarwal 2014).

Institutional conditions

Multiple institutional stakeholders—NGOs, civil society organizations (CSOs), technical and research institutions, extension service providers, and government departments—play crucial technical, financial, and facilitating roles in building capacity, facilitating technology transfer, and providing support to communities in implementing and monitoring restoration activities (Reddy et al. 1999; Bawa et al. 2007; Reddy 2000; Rao 2009) for restoration to be impactful in the long term (9 percent of all papers reviewed).

Apart from actions by NGOs, institutional actions that support and incentivize both mitigation and adaptation benefits through landscape restoration are removing legal barriers such as felling and transit restrictions; implementing input subsidies to cover the cost of saplings, fertilizer, and irrigation; increasing access to low-interest loans for farmers to promote agroforestry; and providing incentives to switch to climate friendly practices, such as efficient cookstoves in the place of fuelwood (Stone et al. 2008; Kishwan et al. 2009; Milne et al. 2006; Davidar et al. 2010; Padhy et al. 2022). The role of public/governmental, community based, and technical institutions like NGOs emerged as contributing to creating awareness, supporting planning and implementation, providing technical assistance, and building capacity to monitor the progress of restoration (Vijge and Gupta 2014; Saigalet al. 2008; Bawa et al. 2007; Milne et al. 2006; Kakade 2002; Reddy 2000; Sawarkar et al. 2023: Kumara et al. 2023).

Challenges and gaps in current research and practice

We prioritized current and recent literature in our review, synthesized the gaps and challenges in the implementation of landscape restoration for climate benefits in India, and grouped them into measurement-related, policy institutional, and socioeconomic challenges.

Measurement and methodological challenges

Overall, and from recent meta-analyses of the Indian restoration literature, there is credible agreement around the lack of accurate and comprehensive methodologies to estimate or account for carbon sequestration and above-ground biomass (Ghosh and Behera 2021; Kumara et al. 2023; Singh et al. 2024) in restoration projects. This has been noted as a major gap also in agroforestry systems (Dhyani et al. 2021; Nagar et al. 2021; Kumara et al. 2023) and mangrove ecosystems (Chanda and Akhand 2023; Sigamani et al. 2023).

One plausible explanation is the sheer variety of factors with varying difficulties of measurement that influence carbon sequestration, including land use history, tree species composition, tree density, farming practices, and soil conditions (Singh et al. 2024). Gaps in the context of sustainable agricultural practices (SAPs) are the lack of long-term, landscape-level, and multi-variable studies regarding the contributions of SAPs to climate mitigation or adaptation (Gupta et al. 2021).

Institutional and policy challenges

Limited investment and financial support, contradictions and ambiguities in government directives, and data gathering incapacity act as potential and actual institutional constraints to the adoption of agroforestry in India (Dhyani et al. 2021; Duraisami et al. 2022). Structural issues in terms of policy are insecure land tenure, complex transit rules, and taxes on agriculture-based commodities (Duraisami et al. 2022; Dhyani et al. 2021).

Wasteful and poorly executed government tree planting programs—such as projects that have limited carbon storage and restoration potential—present implementation challenges (Coleman et al. 2021; Rana et al. 2022), due to spatial constraints, such as in multifunctional agropastoral landscapes, which are often treated as wastelands and sites of tree plantation programs, but where the space for planting trees is limited (Coleman et al. 2021). Insecure tenure and competing land uses constrain the survival of plantations on such sites, which are often also divorced from their socio-ecological contexts (Rana et al. 2022).

Socioeconomic challenges

Non-existent or inadequate local markets, small landholding sizes and livestock herd sizes have been identified as key challenges in the adoption of climate-beneficial agroforestry practices (Dhyani et al. 2021). The lack of access to global capital—another major economic constraint, particularly for the already marginalized groups that steward mosaic landscapes—has been connected to the generally insufficient baseline databases and reporting frameworks of carbon stocks in the South Asian region (Nagar et al. 2021; Dhyani et al. 2021). Despite the contributions of women and other marginalized groups to the sustenance of many agroforestry systems, restoration policy or practice does not focus on them (Duraisami et al. 2022.

Conclusions

As countries fight the triple challenge—keeping global warming under 1.5°C, eliminating poverty, and protecting the natural environment—it is more important than ever to identify actions that can contribute to mitigation and adaptation simultaneously. Recent studies have shown that landscape restoration is one such strategy (Pramova et al. 2015; Stanturf et al. 2015; Rizvi et al. 2015; Locatelli et al. 2011, 2015b; Elias et al. 2014; Ravindranath 2007).

In our study, we aimed to analyze the contribution of landscape restoration interventions in India to mitigation and adaptation benefits. We also attempted to determine the enabling conditions for realizing the twin benefits. Our study found 268 peer reviewed papers and 87 items of gray literature which connected the benefits of landscape restoration with climate mitigation and adaptation. The study found only a handful of papers that addressed the mitigation and adaptation synergy explicitly. Climate linkages with restoration were implicit in most of the papers.

While mitigation in the context of tree-based restoration seems to be clearly understood, the language around adaptation is expressed in terms of development outcomes; adaptation is rarely discussed explicitly in the Indian restoration literature. Agroforestry emerged as the most relevant and popular intervention that can contribute to the twin climate goals in India, followed by A/R. To ensure that the mitigation-adaptation synergy is harnessed for landscape restoration, certain enabling conditions emerged as critical. These conditions range from

- meaningful community participation, involving multiple stakeholders in the planning and execution of restoration interventions;
- favorable ecological conditions (native and multispecies plantations, for example);
- strong market linkages and economic support (through converging public funds or otherwise); and
- policy and institutional conditions that resolve constraints such as insecure tenure and ownership rights over trees.

Meaningful participation in restoration projects by local communities emerged as the most important factor for the success of restoration interventions in India. This finding reflects a growing realization around the world that landscapes are protected and conserved better when tenure and resource rights are secure (Ding et al. 2016; Elias et al. 2022). Unless local communities are involved in all the stages—planning, implementation, management, and monitoring—achieving landscape restoration for the desired mitigation-adaptation synergy will be difficult.

Our findings underscored the roles of other stakeholders such as NGOs, technical agencies, and the private sector. Their contributions—in terms of awareness creation, technology transfer, species selection, and forward and backward market linkages—serve as important enabling conditions that can increase the chances of mitigation-adaptation synergy. The scope to leverage this synergy at both policy level and in on-ground practices is ample, as is evident from our systematic literature review.

We observed that certain aspects of community ownership and participation in such projects, such as top-down planning approaches and the role of participatory democracy, have changed somewhat over time in value and social meaning. Critiques of top-down approaches seem to have proliferated since the late 2010s (Aggarwal 2014; Aggarwak 2020; Vijge and Gupta 2014; Ding et al. 2016; RRI 2021; Deb et al. 2021; Elias et al. 2022; PwC and ORF 2023). A critical theme for future research might be a deeper empirical dive into these critiques in the Indian context to understand the principles and models of community involvement and tenurial frameworks that translate into restoration successes, we feel.

To strengthen the case for landscape restoration for climate benefits (climate adaptation in particular), there is a critical and urgent need for developing MEL frameworks and innovations in project design that disaggregate, and specifically account for, gender and other relevant intersectionalities (caste, for example) in restoration contexts. In addition, critical studies and/or reviews of the current state of valuation of climate mitigation and adaptation benefits—and measurements of the impacts of landscape restoration interventions—would be a valuable endeavor for future research in Indian contexts.

We hope this study helps restoration planners and practitioners in India to contextualize the extant body of research and practice and draw on this synthesis of learnings and challenges while designing and implementing restoration projects.

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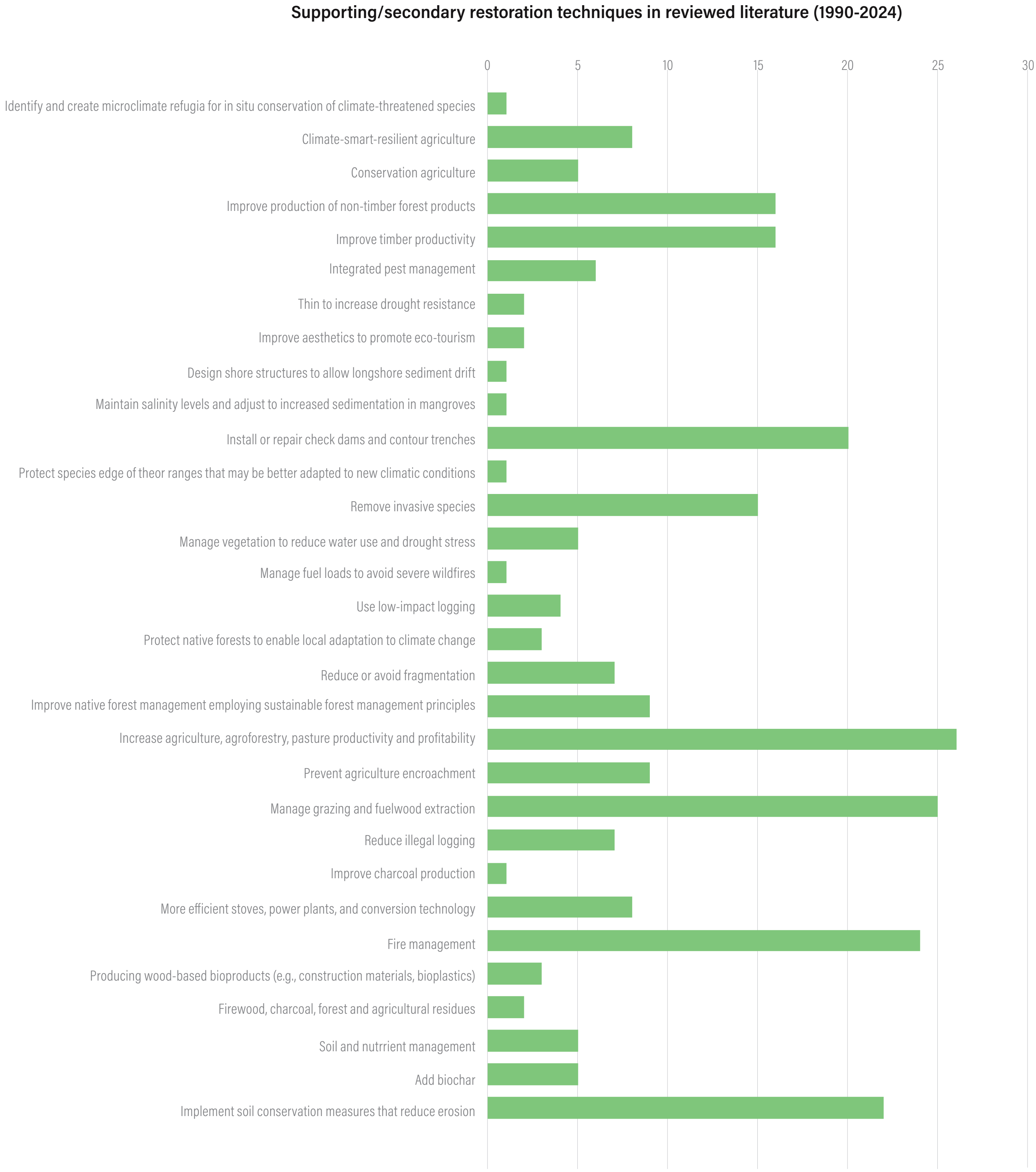
Farmer -managed natural regeneration (FMNR)

Appendix A

List of supporting interventions/techniques emerging from the literature review



Source: WRI India authors.

Appendix B

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Endnotes

1. A participatory forest management program that was intended to be a joint effort between state forest departments and local communities implemented by the Union Ministry of Environment, Forests and Climate Change (MoEFCC) in the 1990s.
2. With some exceptions, such as grasses in grassland ecosystems.
3. In the domains of climate change, climate resilience practice, landscape restoration, and renewable energy, from WRI.
4. We randomly selected 59 articles from this set and subjected those to a Kappa analysis to check for researcher bias. For randomization, weightage was first calculated (53/32 = 1.66), so that a proportionate number of papers could be selected from the two buckets of mitigation and adaptation. Accordingly, 37 papers from the mitigation bucket and 22 papers from the adaptation bucket (37/22=1.68) were to be selected for Kappa analysis. A random sequence generator (from www.random.org) was used to create a randomization sequence of 1 to 53 for mitigation papers and 1 to 32 for adaptation papers. The two sets of papers were put in separate Excel columns and the two randomization sequences were placed against them, respectively. Thus, unique numbers were randomly assigned to each of the papers. Only those papers that were assigned numbers from 1 to 37 (mitigation papers) and 1 to 22 (adaptation papers) were selected for Kappa analysis. Kappa values of 0.72 and 0.67 were derived from two independent raters, indicating substantial agreement in the selection of papers.
5. We reviewed working plans from several divisions: Udhampur (2015–16), Patiala (2012–13), Ajmer (2012–13), East Nashik (2012–13), Porahat (2003–04), Aie Valley (2003–04), Sidhi (2012–13), Koriya (2006–07), Hassan (2001–02), and Chalakudy (2005–06).
6. As part of a collaborative project entitled "Inspire, Support, and Mobilize Forest and Landscape Restoration" between the World Resources Institute (WRI) and the International Union of Forest Research Organizations (IUFRO), IUFRO scientists developed a framework to demonstrate how forest landscape restoration (FLR) can contribute to the twin climate objectives of climate change mitigation and adaptation (Stanturf et al. 2015). The framework was developed based on available scientific literature on restoration and 15 case studies of forest restoration from projects in South Asia and Southeast Asia, East Africa, Europe, Latin America, and North America. At the end of this study, the authors came up with a long list of potential FLR activities and benefits that could enhance the contribution to mitigation and adaptation objectives.

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Acknowledgments

This working paper was produced under grants by Rainier Climate and Pirojsha Godrej Foundation. We would like to thank Anar Bhatt, Elisa Scalise, Katharina Wache, Lubaina Rangwala, Manu Mathai, Mike Badzmierowski, Prateek Barapatre, Renata Andrade, Shahana Chattaraj and Visakha G—whose insights and suggestions helped improve this paper.

Special thanks to our external reviewers: Dhanapal Govindrajulu (University of Manchester) and Divya Gupta (SUNY Binghamton), for their valuable feedback. Finally, our deep gratitude to Shweta Prajapati, Meenakshi Kakar, Robin Infant Raj Devadoss, Karthikeyan Shanmugam, The Rewriting Company and Zebrakross for administrative, editorial, and design support.

About the authors

Raghav Srivastava is a Senior Program Research Analyst, Landscape Restoration, at WRI India.

Marie Duraisami is a former Manager, Sustainable Landscapes & Restoration at WRI India.

Ruchika Singh is Executive Program Director, Food, Land and Water Program at WRI India.

Srishti Kochhar is presently Program Lead, Strategy and Program Management with the Energy Program at WRI India. She was previously Senior Program Manager, Restoration, WRI India.

Sandip Chowdhury is a former Consultant, WRI India.

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