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Effectiveness of Forest and Land Rehabilitation Programs in Increasing Vegetation Cover: A Systematic Review

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ABSTRAK

Forest and land rehabilitation programs have emerged as a central strategy in global efforts to reverse land degradation, restore ecosystem services, and mitigate climate change. This systematic review synthesizes evidence from sixteen peer-reviewed studies published between 2021 and 2025, examining the effectiveness of reforestation and land rehabilitation programs across multiple countries including China, Indonesia, Pakistan, Guatemala, the Philippines, and Ethiopia. The primary outcome of interest is change in vegetation cover, assessed through remote sensing indices, land-use classification, and field measurements. Results indicate that, overall, rehabilitation programs are effective in increasing vegetation cover when implemented in areas with significant existing land degradation, complemented by sound site selection, integrated management, and long-term monitoring. China's large-scale programs—particularly the Sloping Land Conversion Program and the Returning Farmland to Forest Program—demonstrated the most consistent and quantifiable gains, with vegetation cover on the Loess Plateau rising from 45% in 2000 to 64% in 2018. Programs in Pakistan, Guatemala, and Indonesia also reported meaningful improvements, while the National Greening Program in the Philippines showed comparatively limited outcomes. Key moderating factors include biophysical context, species diversity, land tenure, and governance quality. The review concludes that monoculture-oriented afforestation, while increasing canopy cover, may compromise ecosystem quality, and that integrating biodiversity and socioeconomic sustainability into program design is essential for long-term effectiveness.

INTRODUCTION

Global land degradation affects approximately 3.2 billion people and threatens the ecological foundations upon which human civilizations depend. Forests, which cover nearly 31% of the Earth's land surface, play a pivotal role in regulating the water cycle, sequestering carbon, maintaining biodiversity, and sustaining local livelihoods. However, centuries of agricultural expansion, unsustainable logging, urban

encroachment, and climate-driven disturbances have significantly eroded these ecosystems, prompting urgent calls for coordinated restoration efforts.

In response to this challenge, governments and international organizations have launched ambitious forest and land rehabilitation programs at national and sub-national scales. These programs aim not only to restore vegetation cover but also to enhance ecosystem services, support rural livelihoods, and fulfill international commitments under the Paris Agreement, the Convention on Biological Diversity, and the United Nations Decade on Ecosystem Restoration (2021–2030). Yet, despite considerable investments, the effectiveness of these programs—measured in terms of actual gains in vegetation cover—remains inconsistently documented and highly context-dependent.

The scientific literature on forest rehabilitation has grown substantially over the past two decades, facilitated by advances in remote sensing, satellite-based vegetation indices such as the Normalized Difference Vegetation Index (NDVI) and the Fractional Vegetation Cover (FVC), and high-resolution land-use change data. Studies conducted in China, for example, have documented large-scale greening trends attributable to government programs such as the Sloping Land Conversion Program (SLCP), also known as Grain for Green, and the Returning Farmland to Forest Program (RFFP) (Deng et al., 2022; Li et al., 2021; Zhao et al., 2021). Similar inquiries in Southeast Asia, South Asia, Latin America, and Africa have generated mixed evidence, reflecting the heterogeneity of ecological, climatic, socioeconomic, and institutional conditions under which these programs operate.

A critical gap in the literature is the absence of comprehensive cross-contextual syntheses that evaluate what factors determine whether rehabilitation programs succeed or fall short of their vegetation cover goals. Understanding these determinants is essential not only for refining ongoing programs but also for informing the design of future interventions in an era of escalating climate risks and biodiversity loss.

This systematic review addresses that gap by synthesizing findings from sixteen peer-reviewed studies spanning multiple countries and ecological contexts. The primary research questions guiding this review are: (1) To what extent do forest and land rehabilitation programs increase vegetation cover? (2) What contextual and programmatic factors moderate program effectiveness? And (3) What limitations and caveats must be considered when interpreting outcomes? The paper proceeds through a methods section describing the systematic search and inclusion criteria, followed by a results and discussion section integrating quantitative and qualitative evidence, and concludes with practical recommendations for policy and program design.

METHODOLOGY

2.1 Study Design and Search Strategy

This study follows the principles of a systematic narrative review, guided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework. A structured literature search was conducted across multiple scholarly databases, including Web of Science, Scopus, and Google Scholar, as well as AI-assisted academic search platforms. The search query combined terms relating to forest rehabilitation, land restoration, reforestation, afforestation, vegetation cover, NDVI, and fractional vegetation cover. The temporal scope was set from 2021 to 2025 to capture the most recent evidence while ensuring relevance to current program designs and policy contexts.

2.2 Inclusion and Exclusion Criteria

Studies were included in this review if they: (a) examined a formally implemented forest or land rehabilitation program at the national, regional, or project scale; (b) reported quantitative or mixed-methods evidence on changes in vegetation cover or related metrics (e.g., NDVI, FVC, land cover class transitions); (c) were published in peer-reviewed journals in English; and (d) were published between 2021 and 2025. Studies were excluded if they focused exclusively on theoretical modeling without empirical data, reported outcomes exclusively for non-vegetation ecosystem services (e.g., carbon stocks in isolation from vegetation), or represented gray literature without rigorous peer review. Following screening, sixteen studies met all inclusion criteria and were retained for synthesis.

2.3 Data Extraction and Synthesis

For each included study, the following information was systematically extracted: country and region, program name and type, study period, vegetation metrics assessed, magnitude of change in vegetation cover, statistical significance, key drivers identified, and limitations reported. Extracted data were organized into thematic categories including program type, geographic region, and outcome magnitude. Given the heterogeneity of study designs, regions, and outcome metrics, a formal meta-analysis was not feasible; instead, a systematic narrative synthesis was performed, with qualitative comparisons complemented by tabulated summaries. Studies are cited throughout the discussion using the author-date convention consistent with APA 7th edition.

Table 1. Summary of included studies by country, program, outcome metric, and key finding

Country	Program / Study	Period	Metric	Key Finding
China (Loess Plateau)	SLCP / Grain for Green (Deng et al., 2022)	2000–2018	FVC; NDVI	Vegetation cover increased from 45% to 64%; strong ecological recovery in sloped farmland
China (national)	Forest conservation programs (Zhao et al., 2021)	1999–2015	Tree cover trend	Greening area ~5× larger post-intensification; ~30% of forested land showed human-induced cover gain
China (national)	CAP, CCFP (Cai et al., 2022; Jiang et al., 2021)	2000–2020	FVC class shift	Significant shift from low/medium to high/very-high vegetation cover classes
China (Yunnan)	RFFP (Li et al., 2021)	2000–2018	NDVI; land cover	Farmland reconversion to forest improved cover; effects scaled with program intensity
China (Yangtze River)	Shoreline conservation (Huang et al., 2024)	2015–2022	FVC class	35.7% of study area improved vegetation class; moderate-to-high cover zones expanded
China (Loess Plateau)	SLCP ecological assessment (Ding & Yao, 2022)	2000–2020	NDVI; restoration type	Grassland restoration outperformed monoculture plantations in drier zones

China (mine dumps)	Reforestation on mine dumps (Yang et al., 2022)	–	Biomass; NDVI; spatial structure	Cover and biomass improved but spatial diversity structure did not recover in semi-arid mines
Indonesia (East Java)	Community–private partnership (Hapsari et al., 2023)	2018–2022	Vegetation cover; carbon stock	Marked improvement in vegetation cover and carbon on degraded lands
Indonesia (Sulawesi)	Mangrove restoration (Djamaluddin et al., 2023)	14–16 yrs post	Canopy; diversity	Vegetation structure improved but biodiversity remained below natural reference conditions
Pakistan	Billion Tree Tsunami (Mumtaz et al., 2023)	2014–2020	Green fraction; LST	Green fraction up by 5.35%; land surface temperature reduced significantly
Guatemala	PES incentives (Patrick et al., 2023)	20+ years	Forest cover	~15% increase in forest cover at project sites; additionality limited relative to national targets
Philippines	National Greening Program (Pansit & Parilla, 2024)	2013–2019	NDVI change	Very slight, statistically non-significant NDVI improvement; low effectiveness at study sites
Ethiopia	Forest landscape restoration (Kassa et al., 2022)	2010–2021	Cover; governance	Progress made but limited by governance gaps and monitoring deficiencies
Spain / Portugal	Dryland stand management (Köbel et al., 2023)	20 yrs post	Diversity; structure; function	Cover increased; ecosystem diversity and function improved with diversified management vs monoculture
Brazil (Atlantic Forest)	Atlantic Forest Restoration Pact (Toto et al., 2025)	2009–2023	Forest cover; scaling	Restoration scaled effectively but additionality and long-term monitoring required strengthening
China (SW)	Mountain vegetation analysis (Jiang et al., 2021)	2000–2018	NDVI; land use	Human land-use change dominated vegetation gain over climate factors in southwest China

RESULTS AND DISCUSSION

3.1 Overall Evidence for Vegetation Cover Improvement

The preponderance of evidence from the sixteen included studies indicates that forest and land rehabilitation programs generate measurable improvements in vegetation cover. Across all geographic contexts examined, fourteen of sixteen studies reported positive trajectories in at least one vegetation metric, representing 87.5% of the reviewed literature. The consistency of this directional finding—spanning diverse biomes, institutional arrangements, and program scales—provides a robust basis for concluding that well-implemented rehabilitation programs contribute meaningfully to reversing land degradation.

However, the magnitude of improvement varies substantially. The most dramatic gains were documented in China, where decades of sustained programmatic investment

and centralized administrative capacity have enabled large-scale land-use transitions. Zhao et al. (2021) conducted a national-scale analysis and found that forest areas showing significant greening trends expanded nearly fivefold following the intensification of major conservation programs after 1999, with approximately 30% of forested land demonstrating human-induced cover gains over the 1999–2015 study period. This finding underscores the transformative potential of sustained, government-backed programs when coupled with robust monitoring infrastructure.

At the regional scale within China, Deng et al. (2022) documented one of the most compelling case studies of rehabilitation success on the Loess Plateau, historically one of the most severely degraded landscapes in the world. Through the combined implementation of the Sloping Land Conversion Program and associated land management initiatives, vegetation cover rose from 45% in 2000 to 64% in 2018—a net gain of 19 percentage points over less than two decades. This recovery was attributable primarily to the reconversion of steeply sloping farmland to terraced forests and grasslands, combined with sediment control infrastructure and sustained institutional support.

Along the Yangtze River shoreline, Huang et al. (2024) assessed the spatial distribution of vegetation quality changes and found that 35.7% of the study area experienced upward shifts in vegetation cover class, with particular gains in the moderate-to-high cover range. These findings align with evidence from Cai et al. (2022), who demonstrated at the national scale that government programs including the Conversion of Cropland to Forest and Grassland Program (CCFP) and the Comprehensive Agricultural Improvement Policy (CAP) contributed to widespread transitions from low- and medium-cover classes to high- and very-high-cover classes across China's major ecological zones between 2000 and 2020.

3.2 Evidence from Southeast Asia, South Asia, and Latin America

Beyond China, the evidence base is more heterogeneous, reflecting variations in program design, institutional capacity, and ecological context. In Indonesia, Hapsari et al. (2023) evaluated a community-private partnership initiative in East Java and documented marked improvements in vegetation cover and carbon stocks in previously degraded lands. The collaborative model, which combined local community engagement with private sector financing, appeared to overcome some of the governance and financial sustainability challenges that have undermined purely top-down state programs in other contexts.

Mangrove restoration efforts in Sulawesi, Indonesia, studied by Djamaluddin et al. (2023), present a nuanced picture. Fourteen to sixteen years after replanting, restored mangrove stands had achieved structurally complex vegetation covers resembling mature stands in terms of canopy height and stem density. However, species diversity indices remained significantly below reference conditions in undisturbed natural mangroves, reflecting the ecological trade-offs inherent in plantation-based restoration when seed source diversity is limited.

Pakistan's Billion Tree Tsunami program, one of the most widely publicized reforestation initiatives of the 2010s, was examined by Mumtaz et al. (2023) using remote sensing data spanning 2014 to 2020. The analysis detected a 5.35% increase in the green fraction across the program area, accompanied by a statistically significant reduction in land surface temperature—a proxy for the cooling effect of increased canopy density. These findings suggest that even within the relatively short timeframe of six years, large-scale afforestation can generate detectable land surface responses, although the long-term

persistence of planted stands under Pakistan's variable precipitation regime warrants continued monitoring.

In Guatemala, Patrick et al. (2023) assessed more than twenty years of Payment for Ecosystem Services (PES) incentives designed to stimulate private reforestation. Project sites receiving PES support demonstrated approximately 15% greater forest cover compared to control areas, a meaningful addition at the plot level. Nevertheless, the authors cautioned that aggregate additionality at the national scale remained modest relative to Guatemala's ambitious reforestation commitments, partly because program enrollment was concentrated in areas already predisposed to natural regeneration rather than the most degraded lands where intervention is most urgently needed.

3.3 Cases of Limited Effectiveness

Not all programs in the review produced substantive vegetation cover gains. Pansit and Parilla (2024) evaluated the National Greening Program (NGP) in Central Visayas, Philippines, using multi-temporal satellite imagery from 2013 to 2019, and found only negligible and statistically non-significant changes in NDVI at reforestation sites. The authors attributed this outcome to a combination of factors including site-level mismatches between planted species and local soil and climate conditions, inadequate post-planting maintenance, high seedling mortality rates, and insufficient community engagement in program governance. This case illustrates that simply scaling up tree planting without addressing contextual site-selection criteria and post-planting management substantially reduces the probability of achieving measurable vegetation cover gains.

In Ethiopia, Kassa et al. (2022) documented genuine progress in forest landscape restoration across several regions but also highlighted persistent structural challenges including weak land tenure security, fragmented institutional coordination across ministries, insufficient financing for long-term maintenance, and inadequate monitoring and evaluation systems. These governance deficiencies constrained the ability of restoration programs to achieve their vegetation cover targets, even where ecological conditions were broadly favorable.

Table 2. Cross-country comparison of vegetation cover outcomes and program effectiveness rating

Country / Region	Program Type	Cover Change	Effectiveness	Primary Limiting Factor
China (Loess Plateau)	Government-led SLCP/RFFP	+19 pp (45%→64%)	High	Water availability in extreme drylands
China (national)	Multi-program conservation	~30% of forest greened	High	Spatial targeting of programs
Pakistan	Billion Tree Tsunami	+5.35% green fraction	Moderate–High	Precipitation variability; seedling survival
Indonesia (East Java)	Community–private partnership	Marked improvement	Moderate–High	Scalability; monitoring capacity
Guatemala	PES incentive scheme	~+15% at project sites	Moderate	Low additionality; site selection bias
Brazil (Atlantic Forest)	Atlantic Forest Restoration Pact	Scaled; quantification ongoing	Moderate	Additionality verification; monitoring
Ethiopia	Forest landscape	Variable; partial	Low–	Land tenure;

	restoration	gains	Moderate	governance; financing
Philippines	National Greening Program	Negligible NDVI gain	Low	Species–site mismatch; maintenance failure

3.4 Drivers of Vegetation Cover Change

Across the reviewed literature, several recurring drivers emerge as primary determinants of vegetation cover change. The conversion of agricultural land—particularly steeply sloping cropland and bare or sparsely vegetated land—to forest, shrubland, or grassland consistently emerges as the most powerful proximal mechanism of vegetation cover increase. Huang et al. (2024), Jiang et al. (2021), Zhao et al. (2021), Deng et al. (2022), and Ding and Yao (2022) all identify land-use transition as the dominant driver in their respective study areas, consistently explaining more variance in vegetation trajectories than interannual climate variability.

Program design and species selection also emerge as critical determinants of both the speed and quality of vegetation recovery. Ding and Yao (2022) demonstrated on the Northern Shaanxi Loess Plateau that restoration outcomes varied significantly by vegetation restoration type: grassland and mixed vegetation types frequently outperformed monoculture tree plantations in terms of net primary productivity and ecological stability, particularly in drier sub-regions where planted trees sometimes failed to establish or experienced high mortality. This finding converges with evidence from Yang et al. (2022), who found that while reforestation on semi-arid mine dumps improved vegetation coverage and biomass, it failed to restore natural spatial structure and compositional diversity, limiting the recovery of broader ecosystem functions.

The quality of stand management in the years following initial planting also plays a crucial mediating role. Köbel et al. (2023), studying dryland forest restoration sites in the Iberian Peninsula twenty years after initial planting, found that diversified stand management—including thinning, understory management, and the promotion of native species—significantly enhanced ecosystem diversity, structural complexity, and functional performance relative to unmanaged monoculture plots. These findings reinforce the principle that restoration is not a one-time intervention but a process requiring sustained adaptive management over decadal time scales.

3.5 Biophysical and Socioeconomic Moderators

Beyond proximal drivers, the reviewed literature identifies a suite of biophysical and socioeconomic factors that moderate program effectiveness. Climatic water availability constitutes perhaps the most important biophysical moderator: studies spanning arid and semi-arid zones—including portions of China's Loess Plateau, northern Shaanxi, and the dryland regions of the Iberian Peninsula—consistently report lower vegetation cover gains and higher restoration failure rates than those in more humid zones. Zhao et al. (2021) found that the relationship between afforestation program intensity and vegetation cover change was significantly attenuated in regions with mean annual precipitation below approximately 400 mm, suggesting that ecological carrying capacity must be respected in program design. Ding and Yao (2022) reinforced this finding by demonstrating that the misalignment between restoration plant selection and site-level water availability is a primary cause of limited program effectiveness in drylands.

Socioeconomic and governance factors represent an equally important set of

moderators. Land tenure security shapes whether communities are willing to invest in long-term vegetation restoration, as insecure tenure removes the incentive for sustained stewardship. Kassa et al. (2022) identified this as a key constraint in Ethiopia, where customary land rights are frequently unrecognized in formal rehabilitation program frameworks. Community participation and local ownership of restoration initiatives appear to improve outcomes, as evidenced by the relative success of the community-private partnership in East Java (Hapsari et al., 2023) compared to more top-down approaches. Patrick et al. (2023) similarly found that PES programs in Guatemala performed best where payment structures were aligned with long-term maintenance obligations rather than initial planting alone.

3.6 Ecosystem Quality vs. Vegetation Cover

A recurring and important tension in the reviewed literature concerns the distinction between vegetation cover as a quantity metric and ecosystem quality as a broader measure of restoration success. Several studies demonstrate that programs can achieve significant quantitative gains in cover metrics while simultaneously underperforming on indicators of biodiversity, habitat complexity, and resilience. Yang et al. (2022) documented this phenomenon on mine dumps, where reforested plots exhibited higher biomass and NDVI than control plots but lacked the spatial heterogeneity, understory diversity, and soil biota associated with natural reference ecosystems. Similarly, Djamaluddin et al. (2023) found that restored mangroves in Sulawesi, while structurally mature after fourteen to sixteen years, harbored species assemblages significantly poorer than those of undisturbed reference sites.

Köbel et al. (2023) argue forcefully that stand management strategies must be evaluated not solely on canopy cover gains but on their capacity to promote ecosystem diversity, structure, and functioning. This perspective has important implications for how program success is defined, monitored, and reported. A shift toward multi-dimensional evaluation frameworks—incorporating biodiversity indices, soil health, hydrological function, and social welfare alongside vegetation cover—would provide a more complete and accurate picture of rehabilitation effectiveness and support more adaptive program management.

Table 3. Key success factors and common limitations identified across reviewed studies

Dimension	Success Factors	Common Limitations
Program Design	Site-specific species selection; mixed vegetation types; phased implementation	Monoculture orientation; inadequate maintenance provisions; scale-up without adaptation
Biophysical Context	Humid/sub-humid climates; severely degraded baseline conditions; moderate slopes	Arid/semi-arid zones; water deficit; poor soils; extreme topography
Governance	Centralized administrative capacity; integrated inter-agency coordination; long-term financing	Land tenure insecurity; fragmented institutional mandates; short funding cycles
Community Engagement	Community co-ownership; participatory monitoring; aligned incentive structures	Top-down imposition; exclusion of local knowledge; insufficient livelihood linkages
Monitoring & Evaluation	Multi-temporal remote sensing; plot-level field validation; multi-indicator frameworks	Single-metric (NDVI-only) approaches; short observation windows; absence of counterfactual designs
Ecosystem Quality	Diversified management; native species emphasis; understory promotion; soil	Focus on canopy cover at the expense of biodiversity, function, and

3.7 Scale, Additionality, and Long-Term Sustainability

Questions of additionality—the extent to which observed vegetation cover gains would not have occurred in the absence of the program—represent a persistent methodological challenge across the reviewed literature. Several studies that document cover improvements do so without a rigorous counterfactual design, making it difficult to disentangle program effects from concurrent drivers such as natural regeneration, improved rainfall, or autonomous land-use changes by farmers responding to market signals. Patrick et al. (2023) addressed this challenge in Guatemala by comparing PES-enrolled sites with matched non-enrolled control parcels, finding genuine but geographically concentrated program effects. Toto et al. (2025) raised analogous concerns about the Atlantic Forest Restoration Pact in Brazil, noting that scaling restoration commitments must be accompanied by rigorous independent monitoring to verify additionality and prevent double-counting of natural regeneration as program-induced restoration.

Long-term sustainability of vegetation cover gains also remains underexamined. Most studies in this review report outcomes over time horizons of five to twenty years—a relatively short window in ecological terms—and few provide evidence on whether gains persisted beyond the active program period or were maintained in the absence of ongoing subsidies or administrative oversight. The exception is Köbel et al. (2023), who assessed restored dryland forests twenty years post-planting and found that management quality during this period was a more reliable predictor of ecosystem state than the initial planting density, suggesting that the post-establishment phase deserves greater programmatic attention and resource allocation.

CONCLUSION

This systematic review synthesizes evidence from sixteen peer-reviewed studies to evaluate the effectiveness of forest and land rehabilitation programs in increasing vegetation cover. The overall weight of evidence confirms that such programs are effective under the right conditions, with the majority of studies documenting positive vegetation cover trajectories. Programs in China, Pakistan, Indonesia, and Guatemala provide compelling evidence that coordinated, sustained, and well-resourced rehabilitation efforts can generate substantial and measurable greening of degraded landscapes.

At the same time, the review reveals important limitations and conditionalities that qualify this general finding. Effectiveness is strongly moderated by biophysical context, particularly climatic water availability; by program design, particularly species selection and the avoidance of monoculture-dominated plantations; by governance quality, including land tenure security and institutional coordination; and by the depth of community engagement and the sustainability of incentive structures. Programs that neglect these contextual determinants—such as the Philippine National Greening Program in this review—risk achieving negligible vegetation cover outcomes despite large nominal investments.

A further and arguably underappreciated concern is the divergence between vegetation cover as a quantity metric and ecosystem quality as a more holistic measure

of restoration success. Several reviewed studies demonstrate that programs can increase canopy cover while simultaneously failing to restore biodiversity, spatial structure, soil health, and functional resilience. Future rehabilitation programs would benefit from adopting multi-indicator evaluation frameworks that move beyond NDVI and cover class metrics to encompass the full suite of ecosystem services and biodiversity outcomes that healthy forests provide.

For practitioners and policymakers, the evidence from this review supports several actionable principles. Site selection should prioritize genuinely degraded land with demonstrated restoration potential, avoiding the enrollment of areas likely to regenerate naturally regardless of intervention. Species selection should favor diverse, native, and climate-adapted mixes over monoculture plantations, particularly in water-limited environments. Post-planting management must be planned, resourced, and sustained over decadal time scales. Monitoring and evaluation systems should be designed prospectively, with embedded counterfactual controls and multi-temporal remote sensing protocols. Finally, community engagement and land tenure security must be treated not as peripheral concerns but as foundational prerequisites for achieving durable vegetation cover gains.

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