Review Article

MGNREGA-Assisted Afforestation for Climate Moderation in India: An Overview

Abstract

Although the influence of climate on the distribution, production, and operation of vegetation on earth is widely recognized, little is known about how local climate is impacted by forests and tree cover. Studies on climate-forest feedbacks are becoming more prevalent as a result of climate change. By analyzing previous scientific research on the effects of forests on climate, this study seeks to give an in-depth look at how forests, climate, and water interact. The MGNREGA is a programme that not only reduces rural unemployment but also combats poverty. This flagship program improves not only the economic side at the grassroots level, but also the social and environmental aspects through various initiatives such as water harvesting, social forestry, flood management, drought proofing, land development, efficient rural connectivity, and so on. All of India's sustainable development objectives are being directly or indirectly achieved the federal government-sponsored programme MGNREGA, which employs a decentralized strategy. It is a strategy for more efficiently using resources to meet the needs of the present while preserving them for use by future generations in order to sustain development. It makes sense that it is founded on economic, social, and ecological principles to advance sustainable human development. The present article is focused on to evaluate the effect MGNREGA-assisted afforestation program on climate change over the past few years in nationwide of India. This article is based on visit of MGNREGA basic (Natural Resource Management) schemes afforestation program in India that are closely associated to climate change.

Keywords: Climate, environment, forest, MGNREGA- afforestation, NRM, social forestry

1. Introduction

The Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA), or scheme, was launched in 2005 to boost the rural economy by providing 100 days of

work annually. This flagship programme improves not only the economic side at the grassroots level but also the social and environmental aspects through various initiatives such as traditional water harvesting, social forestry, flood management, drought proofing, land development, efficient rural connectivity, and so on.

A total of 60% of the MGNREGA projects are dedicated to protecting and conserving natural resources. These MGNREGS projects might have a positive impact on the environment by recharging groundwater, conserving soil, water, and biodiversity, sustaining food production, slowing land degradation, and enhancing resiliency to climate threats including moisture stress, delayed rains, droughts, and floods (Anonymous, 2022b). The MGNREGA programme has been crucial in reducing rural communities' vulnerability to climate change (Subba, 2019). With a variety of job activities linked to water harvesting, MGNREGA creates enormous possibilities for improving and developing sustainable rural economies and eco-restoration (Nautiyal et al., 2016). MGNREGA raised income, agricultural productivity, land fertility, and availability of water (Mandla et al., 2020, Fischer, 2021). It also enhanced income and income availability (Prasanna et al., 2014, Peedikakandi et al., 2015), decreased climatic risk exposure (Godfrey-Wood and Flower, 2018, Fischer, 2020), and increased employment (Reimingam, 2016, Upendranadh and Subbaiah, 2016). Additionally, it offers desperately needed ways to include women, members of Scheduled Castes and Tribes, landless farmers, and other marginalised groups (Lal et al., 2019, Dhaktode 2021). These benefits are crucial to take into account because the poor frequently experience issues with low literacy, low economic status, and a lack of awareness of social issues (Nedungadi et al., 2018, Rajeevan et al., 2020).

Hence, in such situations, it is crucial to take into account variables like poverty reduction, community growth, and the development of livelihood possibilities associated with enhanced ecological services (Olesen et al., 2021). This makes it possible to create policies like MGNREGA that take advantage of the connections between environmental restoration and local economic growth (Hartman and Cleveland, 2018). Restoration efforts should also be better aligned with national ecological policies (Singh et al. 2021). MGNREGA recovered damaged lands (Huizinga, 2012). For the past few years, India has tailored its development strategy to address its top goals of job creation, economic expansion, energy, water, and food security, catastrophe resistance, and poverty alleviation (Bhamra et al., 2015). The

repair of the Dodda Kere Lake in Karnataka, which employed 91 people, including 60 women, was one of several instances given by MGNREGA of how funds and labour may be directed for ecosystem restoration during the epidemic (Kumar, 2020). An extensive watershed and land restoration project in Chhattisgarh that spans 26 blocks in 12 districts (Nanda and Kaushal, 2020), planned plantation work on more than 40,000 ha in Odisha (Anonymous, 2020), and restoration of the Kalyani River in Uttar Pradesh that has been requested for 30 years but has only recently begun and created employment for more than 800 people are just a few examples (Karelia, 2020).

MGNREGA-funded afforestation projects are gaining popularity as a result of their dual benefits. Nearly 28,995 hectares have been afforested as part of MGNREGS (Pujar et al., 2022). The forest cover of India accounts for a mere 24.62% of its geographical area, which is very little compared to the envisaged 33% according to the National Forest Policy 1988 (Anonymous, 2021). The total wasteland area in India is 16.96% of the total geographical area in 2016, while it was 17.22% in 2008–09 (Anonymous, 2019). Wastelands covering 14,536 km^2 are transformed into non-wasteland categories during this time. Between 2008–09 and 2015–16, the country's various wasteland categories underwent a net conversion of 0.26% (Anonymous, 2019).

As a significant type of approved activity under the MGNREGA, green employment that promotes environmental conservation and drought resistance involves a variety of forest conservation and mitigation strategies, such as afforestation, growing nurseries, plantations, and forest protection. Afforestation has the potential to be a significant generator of greenhouse emissions when trees are destroyed, as well as a significant sink of those same gases when they are managed sustainably. Another factor contributing to a rise in atmospheric greenhouse gases is the change in the natural ecosystem due to agricultural use and other development activity (Tilman et al., 2002). By storing carbon, afforestation helps to improve soil nutrient status and lower greenhouse gas emissions. The forest ecosystem can act as both a source and sink of carbon.

2. Effect of Climate change on India

The effects of climate change, which have begun to manifest in India throughout the summer, have received considerable attention. With temperatures in the capital city

exceeding 49°C, the soaring heat has surpassed records. Heatwaves are becoming more common, which is distressing for a huge portion of India's population. According to the most recent Sixth Assessment Report by Working Group II of the IPCC, failure to take prompt action to prevent or adapt to climate change could have disastrous effects, particularly in India. The earth's temperature has increased by 1.1°C since the late 1800s, which indicates that emissions are at an all-time high. The hottest decade on record occurred between 2011 and 2020. The Paris Agreement, which was endorsed by 200 governments at COP21 in December 2015, had its scientific foundation in the previous assessment report from 2014. Three working committee reports from the 5th assessment cycle gave distinct projections of the climate's consequences under various emission scenarios. By 2100, the average global temperature was predicted to rise by more than 1.5°C compared to pre-industrial levels. As a result, several countries, including India, made commitments to reduce their carbon emissions and achieve carbon neutrality by 2030 (Rej and Nag, 2022). The analysis and conclusions of the report are based on the interdependence of the climate, ecology, and biodiversity, as well as human societies. The analysis found that emissions would need to be zero by 2050 in order to keep below the 1.5° barrier. The sixth assessment report details a number of effects of the aforementioned estimates, including a decline in water and food security, effects on social as well as economic human systems, reduced operation of crucial infrastructure owing to heatwaves and air pollution, etc. Additionally, it foresees negative impacts on industries that are susceptible to the climate, such as forestry, agriculture, energy, fisheries, tourism, as well as humanitarian issues like migration brought on by the climate, etc.

The report claims that depending on the place, an ecosystem’s, and a population's susceptibility to the impact of climate change vary greatly. Patterns of socioeconomic development, inequality, marginalization, historical patterns of colonialism, and the style of government all are influenced the impact of climate change and their effect on human system. Due to pollution, a deteriorated ecology, and the irresponsible exploitation of natural resources, certain places are more vulnerable than others. West, Central, and East Africa; South Africa; Central and South America; Small Island Developing States; and the Arctic are among the regions of the world with the highest levels of human vulnerability. Beyond 2040, the majority of mid- to long-term hazards are dependent on immediate climate change and global warming.

According to local and international research on the Climate Vulnerability Index (CVI), India is one of the world's hotspots in terms of both socio-economic and geographical vulnerabilities. India's main climate action plan i.e., The National Action Plan on Climate Change (NAPCC), comprises eight sub-plans. Since there is no one legal structure or organization that addresses the subject of climate change, each mission falls under a separate ministry. India will fall short of the IPCC guidelines, like the majority of nations, despite its efforts to combat climate change, unless its policies abandon all other development objectives in favor of combating climate change. However, the IPCC assessment and regional studies from India both show that the country is already in a dangerous position. The study found that Andhra Pradesh, Assam, Karnataka, Maharashtra, and Bihar are the states that are most susceptible to climatic risks such as floods, droughts, and cyclones.

India's climate change strategy has both national and international components. The NAPCC is the domestic and regional action plan, and it has been in effect since 2008. As a result, India's policymakers are cognizant of the importance of development that is climate change sensitive, ecologically friendly, and sustainable. Various ministries also use similar policies in their work, although inconsistently. Although there are goals, there aren't any concrete solutions in place to address the problems caused by climate change.

India is one of the world's most climate-vulnerable nation, hence it may make certain adjustments to its current policies to combat climate change more effectively. India must thus map out all the sensitive areas, industries, and population groupings at the district level. India's terrain and geography are diverse enough to call for various approaches depending on the location. An effective framework for addressing climate change must begin with planning and execution. A research and knowledge committee must be established to provide frequent updates on new scientific resources and metrics, as well as a periodic monitoring system to assess the progress. Mapping out weaknesses and creating a long-term sustainable action plan with effective governance and finance are the solutions to the problems that climate change presents for India, considering the challenges of a developing country (Anonymous, 2022a).

3. Overview of different environmental services

Rural poverty is caused by elements like low agricultural and animal output, a lack of water for irrigation and drinking, as well as a paucity of fuel sources like wood and grass. This may be connected to the deterioration of natural resources including soil, water, grazing areas, and forests. Water shortages are brought on by a number of issues, including soil erosion and loss of soil fertility, siltation of water bodies and poor water percolation rates, more groundwater extraction, overgrazing, and over-harvesting of forests. The only way to improve and sustain agricultural and animal output as well as water availability is to conserve natural resources and boost their potential to deliver greater levels of environmental services. The main natural resources affecting agricultural and animal production are water, soil, and land, which are closely related to MGNREGA operations. They may have a favorable or unfavorable impact on all these natural resources, which may or may not affect their capacity to offer environmental services. Groundwater recharge, increased rainwater percolation, water conservation, increased irrigation area, reduced soil erosion, increased soil fertility, preserved biodiversity, reclamation of degraded crop and grazing lands, increased availability of leaf manure, fuelwood, and non-wood forest products, and carbon sequestration are some examples of environmental services (Table 1). The purpose of MGNREGA operations must be the preservation of natural resources and the improvement of environmental services to support the production of food and live animals, more pure water for drinking, and more grass and forest products (Table 2). Some of the consequences of MGNREGA may be observed immediately, such as a quantitative increase in the area irrigated, the storage capacity of a water body, the area covered by trees, the production of food, fodder, or grass, and other factors related to the health of the ecosystems. However, because of the intricate relationships between different processes and resources in village ecosystems, any changes or interventions are likely to have long-term effects that may be very extensive. Understanding and calculating the effect of MGNREGA activities depends on identifying the possible environmental services that arise from such activities. In this context, the term "services" has been broadened to include quantifiable physical, biological, socioeconomic, and livelihood factors. The relevance of global issues including food security, water security, climate change adaptation, and sustainable livelihoods has been appropriately emphasized. Services that directly affect the ecological border of the activity and associated system components are regarded as local. The boundaries of villages or micro-watersheds have been regarded as local. Services that have effects

beyond geographical boundaries are considered global services (for example, climate change mitigation through carbon sequestration). These services fall under the provisional and regulatory categories.

Table 1: Environmental Services through MGNREGA Activity

Sl. No	MGNREGA Activity	Local context	Regional and global context
1	Water conservation and harvesting	Groundwater recharge, soil moisture conservation, provision of irrigation, drinking water, and nutrient cycling	Water conservation
2	Irrigation provisioning	Supplying irrigation, enhancing agriculture and livelihoods, and increasing agricultural yield	Water conservation and utilization
3	Renovation of traditional water bodies	Enhanced capacity for storage, accessibility of irrigation, recharge of groundwater, nutrient cycling, biomass, and agricultural production	Water conservation
4	Land development	Increased irrigation, improved agriculture, and an improved way of life on reclaimed land	Land restoration, biodiversity upkeep
5	Drought proofing	Control soil moisture and soil erosion, management of nutrient cycling, flood control and biomass production, microclimate enhancement	Water and biodiversity conservation, carbon sequestration
6	Flood control	Recharging the groundwater, preserving soil moisture, preventing erosion, and floods	Water conservation

Table 2: Environmental benefits under MGNREGA		
Natural resources	**MGNREGA works**	**Potential environmental benefits**
Water	Water conservation and harvesting, irrigation provisioning and improvement, renovation of traditional water bodies and flood control	Recharge of groundwater, preservation of soil moisture, protection from erosion, provision irrigation, accessibility to drinking water and improvement of nutrient cycling, boosting soil fertility and crop production, water storage capacity and carbon sequestration.
Land	Land development through contours, bund and bench terraces. Development of drought resistance and flood prevention vegetation.	Recovering deteriorated land to agriculture by enhanced soil organic matter, biomass carbon sequestration, moisture retention, capacity to control erosion, crop productivity, and resilience.
Crop production Systems	Preserving and harvesting water, improving irrigation, restoration of traditional water body, flood prevention and development of land	Improving moisture retention, regulate erosion, maintain good soil quality, irrigation, reclaiming degraded land, carbon sequestration, and reducing floods. These have instant impact on agrobiodiversity, cropping patterns, and revenues.
Forests	Strategies to withstand droughts including reforestation, afforestation. Establishment of silvi-pastures and mixed plantations for provisional benefits.	Enhancing soil moisture retention and protection through conservation and regeneration of biomass and carbon stocks and flood management. It also enhances local climate, and gives people forage and firewood, an alternative source of income, which increase household resilience.

4. Impact of MGNREGA on climate change

Environmental renewal takes place when MGNREGA assets are developed, and as a result, many spin-off benefits to the environment are produced in a sustainable manner. The programme makes a significant contribution to natural resource management (NRM) by requiring that 60% of its annual total spending go toward water collection and conservation, plantation, land and soil improvement, and other NRM-related projects. Study showed that MGNREGA's initiatives have reduced the vulnerability of agricultural productivity, water resources, and livelihoods to unpredictable rainfall, water shortages, and low soil fertility conditions (Tiwari et al., 2011). Another study found that the programme is producing many environmental advantages that enhance water availability and soil fertility and increase agricultural productivity. People's socioeconomic and cultural existence in rural areas is inextricably linked to the environment. In general, seasonality, topography, forests, soil, rivers, and other natural features such as these are intimately tied to the traditional cultural structures and agro-based economic activities of rural civilizations. The various MGNREGA programmes are closely connected in their efforts to safeguard natural resources and develop their potential sustainability. The most significant programmes are conservation and harvesting of water, plantations, drought-proofing, land development, micro irrigation, flood control, and flood protection (Plate 1, Figure 1).

Land Development work in Rajasthan

Water conservation work in Rajasthan

MGNREGA Afforestation in Bihar (Hajipur and Muzaffarpur)

Plate 1: Impact of MGNREGA assisted afforestation on climate change mitigation

4.1. Water harvesting and conservation

It is one of the most significant programmes of MGNREGA. The scheme's major goals are to preserve traditional wet land and its biological habitat, safeguard surface runoff that replenishes groundwater, maintain the irrigation system during dry seasons, and use water bodies for angling. The total water conservation and water harvesting work in the years 2021–22 at national level were 4, 222, 958, and 1, 209, 629 ha in the years 2021–22 respectively (Anonymous, 2022b).

4.1.1. Renovation of Traditional Water Bodies

Desilting has contributed to improved soil fertility, a rise in irrigated land, and a rise in groundwater levels, all of which have lasting environmental benefits. These improvements have increased food production and improved water and food stability in regions that are prone to drought. Loss of vegetative cover, heavy grazing, and improper farming methods in water catchment regions have resulted inside the silting of bodies of water like tanks and dams, which has reduced their ability to store water and decreased groundwater recharge. Desilting is the process of manually removing silt from a body of water. To increase soil fertility, farmers are urged to gather the silt and spread it over agricultural areas.

4.1.2. Enhanced irrigation area

Groundwater recharge has led to an expansion in irrigated land and a change in farming practices. Based on agricultural water needs and green water availability, the amount of water needed for irrigation was calculated. While the impact was considerably less noticeable in Village Panchayats with canal networks. The MGNREGA contribution was considerable in terms of growth in area under supplementary irrigation in Gram Panchayats that were entirely dependent on rainfall for example, in Abhay Pura, Rajasthan, made the most contribution. The total of 3,600,292 ha of irrigated land was increased under irrigation (Anonymous, 2022b).

4.2. Drought Proofing

A region experiences a drought when its average precipitation is below normal for the area. The duration might be either short or long. Due to the crises of surface and ground water, long-term drought conditions are extremely destructive to the ecology, economy, agriculture, and human livelihood security of a given region. Drought affects

nearly 16% of India's land area. For the livelihood stability of the drought-affected region, the MGNREGA recommended a number of strategies, including planting trees, digging ponds, emphasizing traditional water gathering and conservation methods, and improving irrigation management using micro irrigation systems.

4.2.1. Implications for Biomass Production

A prospective rate of growth of 3 Mg ha^{-1} $year^{-1}$ was used to forecast biomass output, or wood, and sequestering carbon potential. In order to calculate the amount of potential dry leaf biomass that may be extracted for manure and firewood, one-third of the yearly biomass increase is considered. Below ground biomass was estimated by considering 30% of the above ground biomass (Anonymous, 2000). Total standing biomass was computed by adding the above and below ground biomass and the estimates of biomass are transformed into carbon using a 0.5 carbon fraction factor (Dinesha et al., 2023).

4.2.2. Carbon sequestration

One of the targets of India's NDC is to "create an additional carbon sink of 2.5–3.0 billion metric tons of CO_2-equivalent through additional forest and tree cover by 2030" (Anonymous, 2015). According to estimates, the mean annual carbon sequestration from MGNREGA activities will rise 62 $MtCO_2$ in 2017–18 to 249 $MtCO_2$ by 2030. The calculated and predicted carbon sequestration rate includes all NRM activities. The NRM practice such as drought-proofing involves planting trees. For this action, it is predicted that 25 $mtCO_2$ of carbon will be sequestered in 2017. By 2030, it is anticipated that this would rise to 85 $MtCO_2$ $year^{-1}$. The Second Biennial Update Report of India (Anonymous, 2018) estimates that 301 $MtCO_2$ was removed or sequestered across all land types in India in 2010. In contrast, it is predicted that MGNREGA will sequester 62 $MtCO_2$ of carbon in 2017. The contribution might be as low as 150 $MtCO_2$ or as high as 249 Mt CO_2 by 2030. This demonstrates how the land use sector of India's MGNREGA programme may significantly contribute to the climate mitigation.

4.3. Flood Control and Flood Protection

A flood is a type of natural catastrophe that occurs when large areas of a given region are submerged by an excess of water. On the economy, environment, and people, it has

negative effects. The MGNREGA is implementing a variety of plans and programmes for flood control, including building flood control bandhs (embankments) on both sides of rivers and along coastlines, planting vegetation on flood control bands to prevent soil erosion, excavating rivers, and building check dams, among other things. Construction of Pakki Nali and drainage from the village to ponds are two flood management strategies that have been used to solve the issue of waterlogging.

4.4. Micro Irrigation

One of the key programmes within the MGNREGA is called "Micro Irrigation," and it aims to manage irrigation in such way that promotes agricultural sustainability along with improving water management. This plan works very well in arid areas by the construction of irrigation canals, water conservation through water bodies, and the installation of conventional water tanks. The sustainability of the ecosystem is greatly influenced by the plantations (Dinesha et al., 2020). The main significance of this plan is that it preserves the natural ecosystem, controls soil erosion and landslides in hilly areas, satisfies local demand for forest products, protects against drought, floods, and desertification, and maintains local weather conditions for the physical and mental wellbeing of living species in their natural habitats. Numerous strategies and programmes have been used in this design to improve the forest area. For example, planting trees on waste land, in forest fringe zones, through agroforestry, on both sides of roads and railways, in drought- and desert-affected areas, and along riverbanks and coastal areas. The three most important plantation-related programs were Road Side Plantation, Block Plantation, and Bund Plantation. Status of plantations under MGNREGA in different states of India were reported (Table 3). West Bengal recorded the greatest roadside and block plantations, with 19,101.08 km and 3,943.63 ha, respectively, while Bihar reported the lowest, with 3.45 km and 3.16 ha, respectively (Table 3). Andhra Pradesh reported the most bund plantation (16,705.66 ha) while Bihar reported the lowest of 3.16 ha (Table 3) (Anonymous, 2022b)

4.5. Land Development

The primary goals of land development are to promote environmentally, economically, and socially sustainable land use. The major goals of the plan are to reduce soil erosion, reclaim waste land, safeguard the natural ecosystem of the land, and improve land use for long-term economic viability. On fallow or marginal farmland owned by

farmers from scheduled castes and scheduled tribes, the MGNREGA operations included land levelling, bund construction, and terracing. Following the land development efforts, these areas that had not been farmed in the past because of their slope or deteriorated character are now being done so. Individual farmers levelled wastelands or fallow spaces that had previously been unsuitable for growing crops. The earnings of individual farmers have significantly increased from zero to one lakh rupees per acre per year. Therefore, land levelling and reclaiming initiatives have aided in land management while also greatly benefiting individuals' farmers financially.

The MGNREGA initiatives relating to water, agriculture, and livelihoods were evaluated for their capacity to lessen susceptibility to climate changes using pertinent indices. Food production and fresh water availability are both impacted by climate changes and will likely be affected in the future. Climate vulnerability may result in unstable agricultural production, fresh water supplies, and livelihoods. By protecting natural resources and offering continuing environmental services like groundwater recharge, decreased soil erosion, improved soil fertility, and water conservation, MGNREGA initiatives have the potential to lessen vulnerability. The resilience and, eventually, the capacity for adaptation of the system are also strengthened by improving the resource base.

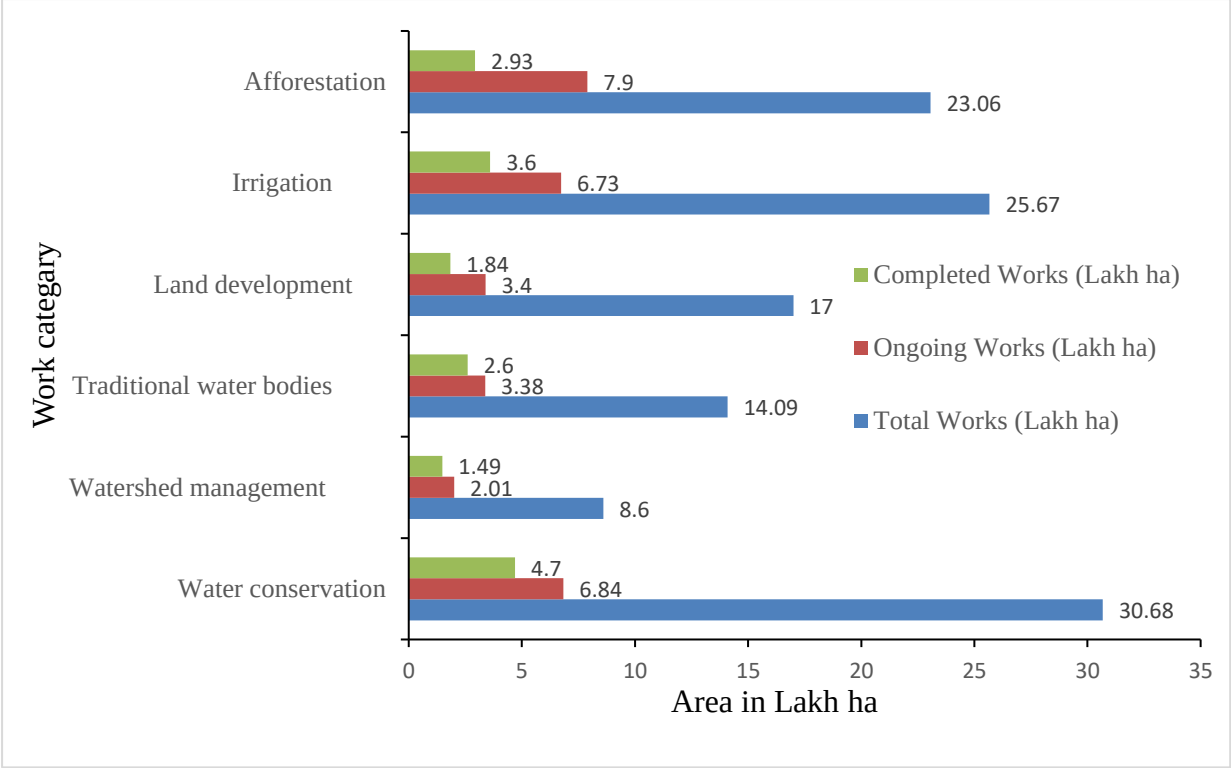

Figure 1: Work Category-Wise Analysis for FY: 2021–2022 in India

Table 3: Status of plantations under MGNREGA (2021–22) in different states of India

Sl. No.	State	Species scientific name	Plantation location	Area/ Length (ha)	Survived plants
1	Andhra Pradesh	*Casuarina equisetifolia*, *Pongamia pinnata*, *Azadirachta indica*, *Tectona grandis*, *Pterocarpus santalinus*	Bund Plantation (ha)	16705.66	4464195
2	Bihar	*Swietenia mahogany*, *Terminalia arjuna*, *Bombax ceiba*, *Neolamarckia cadamba Populus spp.*	Roadside Plantations (km)	3.45	200
			Block plantations	38.44	97

			(ha)		
			Bund Plantation (ha)	3.16	0
3	Chhattisgarh	*Tectona grandis*, *indica, Delonix regia*, *Azadirachta indica*, *Bamboo spp*., *Syzygium cumini*	Roadside Plantations (km)	87	4720
			Block plantations (ha)	2.62	932
4	Manipur	*Ailanthus excelsa*, *Moringa oleifera*, *Heavea brezilensis*, *Swietenia mahogany*, *Bamboo spp.*	Roadside Plantations (km)	12	48
5	Mizoram	*Ailanthus excelsa*, *Tectona grandis*, *Moringa oleifera*, *Heavea brezilensis*, *Bamboo spp.*	Roadside Plantations (km)	260.64	47416
6	Odisha	*Tectona grandis*, *Eucalyptus spp.*, *Acacia auriculiformis*, *Heavea brezilensis*	Block plantations (ha)	15.09	0
7	Telangana	*Tectona grandis*, *Moringa oleifera*, *Leucaena leucocephala*, *Emblica offocinalis*	Bund Plantation (ha)	2795	0
8	Tripura	*Ailanthus excelsa*, *Moringa oleifera*, *Artocarpus heterophyllus*, *Heavea brezilensis*, *Bamboo spp.*	Roadside Plantations (km)	12	2364
			Block plantations (ha)	40.5	0

9	West Bengal	*Dalbergia sissoo*, *Swietenia macrophylla*, *Tectona grandis*, *Santalum album*, *Acacia catechu*	Roadside Plantations (km)	19101.08	3207317
			Block plantations (ha)	3943.63	358335
			Bund Plantation (ha)	207.52	17796
10	Rajasthan	*Acacia leucophloea*, *Acacia catechu*, *Balenitis aegyptica*, *Prosopis cineraria*, *Delonix regia*	Roadside Plantations (km)	6	2040

5. Conclusion

This study showed how MGNREGA enhanced environmental services and decreased vulnerability to climate change, in addition to bringing jobs and investment to rural areas. This scheme provides a greater employment opportunity to rural households, which have tremendously increased during COVID-19 with the return of migrants from urban areas. Groundwater recharge, water percolation, greater water storage in tanks, higher soil fertility, rehabilitation of damaged areas, and carbon sequestration are some of the improved environmental services. These services supported higher agricultural and livestock output and had favourable effects on it.

6. References

Anonymous, 2000. Global Forest Resources Assessment. United Nations Food and Agriculture Organization (FAO-UN), Rome. Available at https://www.fao.org/docrep/004/Y1997E/Y1997E00.HTM. Accessed on 22th February 2023.

Anonymous, 2015. India's intended nationally determined contribution: Working towards climate justice. Government of India. Available at

http://www4.unfccc.int/submissions/INDC/Published Documents/India/1/INDIA INDC TO UNFCCC.pdf. Accessed on 15th February 2023.

Anonymous, 2018. MoEFCC report. Framework Convention on Climate Change, United Nations. Available at https://undocs.org/FCCC/CP/2018/L.22. Accessed on 5th January 2023.

Anonymous, 2019. Wasteland atlas of India. Department of Land Resources, Ministry of Rural Development, Government of India. Available at https://dolr.gov.in/en/documents/wasteland-atlas-of-india. Accessed on 25th December 2022.

Anonymous, 2020. Odisha to execute forestry projects worth Rs 602 cr under MGNREGAin FY21. Business Standard, PTI. Available at https://www.business-standard.com/article/current-affairs/odisha-to-execute-forestry-projects-worth-rs-602-cr-under-mgnrega-in-fy21-120082301017_1.html. Accessed on 30 Jan, 2023.

Anonymous, 2021. India State of Forest Report. Forest Survey of India, Ministry of Environment, Forest and Climate Change, Government of India, Dehradun, India. Available at https://fsi.nic.in/forest-report-2021. Accessed on 18th January 2023.

Anonymous, 2022a. IPCC-Climate-Change Report 2022 and its Implications for India. Ishani Kumar Singh. Available at https://india.wcs.org/Newsroom/Blog/ID/17734/IPCC-Climate-Change-Report-2022-and-its-Implications-for-IndiaAccessed on 27th February 2023.

Anonymous, 2022b. MIS report. Department of Rural Development Ministry of Rural Development Govt. of India. Available at http://mnregaweb4.nic.in/netnrega/MISreport4.aspx. Accessed on 20th January 2023.

Bhamra, A., Shanker, H., Niazi, Z., Sharma, B., Krishnaswamy, S., Mehta, R., 2015. Achieving the sustainable development goals in India. Technology and Action for Rural Advancement, Development Alternatives Group. Available at http:// www.devalt.org/images/L3_ProjectPdfs/AchievingSDGsinIndia_DA_21Sept.pdf.

Dhatkode, N., 2021. Caste in MGNREGA works and social audits. *Economic & Political Weekly*, *56*(2), 35-41.

Dinesha, S., Dey, A.N., Vineeta, Deb, S., Debnath, M.K., 2020. Litterfall pattern and nutrient dynamics of *Swietenia macrophylla* plantation in Terai region, West Bengal, India. Indian Forester 146(1), 7–12.

Dinesha, S., Panda, M.R., Pradhan, D., Rakesh, S., Dey, A.N., Bhat, J.A., Pandey, R., 2023. Ecosystem carbon budgeting under *Swietenia macrophylla* King Plantation in sub humid foothills of Eastern Himalayans of India. Environment, Development and Sustainability 2023, 1–17. DOI https://doi.org/10.1007/s10668-022-02902-6

Fischer, H.W., 2020. Policy innovations for pro-poor climate support: Social protection, small-scale infrastructure, and active citizenship under India's MGNREGA. Climate and Development 12(8), 689–702.

Fischer, H.W., 2021. Decentralization and the governance of climate adaptation: Situating community-based planning within broader trajectories of political transformation. World Development 140, 105335.

Giribabu, D., Mohapatra, C., Reddy, C.S., Prasada Rao, P.V.V., 2019. Holistic correlation of world's largest social safety net and its outcomes with sustainable development goals. International Journal of Sustainable Development and World Ecology 26(2), 113–128.

Godfrey-Wood, R., Flower, B.C., 2018. Does guaranteed employment promote resilience to climate change? The case of India's Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA). Development Policy Review 36, O586–O604.

Hartman, B.D., Cleveland, D.A., 2018. The socioeconomic factors that facilitate or constrain restoration management: Watershed rehabilitation and wet meadow (bofedal) restoration in the Bolivian Andes. Journal of Environmental Management 209, 93–104.

Huizinga, J., 2012. A global civilian conservation corps. Silviculture Magazine 2012 (spring), 10–11.

Karelia, G., 2020. IAS officer uses lockdown time to restore river, generate jobs for 800 people! The Better India. Available at https://www.thebetterindia.com/230547/ias-hero-kalyani-river-cleanup-uttar-pradesh-lockdown-jobs-methods-workers-inspiring-gop94/. Accessed on 01 Feb, 2021.

Lal, AK., Sarangadharan, DP., Roshia, MS., Manoharan, TG., 2019. Impact of MGNREGA on the livelihood of scheduled tribe. Journal of Advanced Research in Dynamical and Control Systems 11, 994–998.

Lengefeld, E., Stringer, L. C., & Nedungadi, P. (2022). Livelihood security policy can support ecosystem restoration. *Restoration Ecology*, *30*(7), e13621.

Mandla, V.R., Nerella, S.P., Choudhary, M., Peddinti, V.S.S., 2020. Impact study on desiltation of water tanks in rural areas using spatial technology: A case study work under MGNREGA. In: Saride, S., Umashankar, B., Avirneni, D. (Eds.), Advances in Geotechnical and Transportation Engineering. Springer, 85–99.

Nanda, A., Kaushal, S., 2020. Agriculture and MGNREGA as rural livelihoods amidst Covid-19. Pradan, sampark.net. Available at https://www.pradan.net/sampark/agriculture-and-mgnrega-as-rural-livelihoods-amidst-covid-19/. Accessed on 30 Jan, 2021.

Nautiyal, S., Schaldah, R., Raju, K.V., Kaechele, H., Pritchard, B., Rao, K.S., 2016. Climate change challenge (3C) and social-economic-ecological interface-building - Exploring potential adaptation strategies for bio-resource conservation and livelihood development: Epilogue. In: Nautiyal, S., Schaldah, R., Raju, K.V., Kaechele, H., Pritchard, B., Rao, K.S. (Eds.), Climate Change Challenge (3C) and Social-Economic-Ecological Interface-Building - Exploring Potential Adaptation Strategies for Bio-Resource Conservation and Livelihood Development. Springer, 631–639.

Nedungadi, P.P., Menon, R., Gutjahr, G., Erickson, L., Raman, R., 2018. Towards an inclusive digital literacy framework for digital India. *Education+ Training*, *60*(6), 516-528.

Olesen, R.S., Rasmussen, L.V., Fold, N., Shackleton, S., 2021. Direct and indirect socio-economic benefits from ecological infrastructure interventions in the Western Cape, South Africa. Restoration Ecology 29(7), 13423.

Peedikakandi, S., Prema, A., Anitha, S., 2015. Performance of MGNREGS on income and employment of agricultural labourers. Journal of Tropical Agriculture 53(1), 91–94.

Prasanna, N., Natarajamurthy, P., Kurinjimalar, R., 2014. Socio-economic impact of MGNREGA in Tamil Nadu, India. International Journal of Economic Policy in Emerging Economies 7(4), 399–409.

Pujar, G.S., Pasha, S.V., Balaji, Y., Reddy, K.M., Kalyandeep, K., Lesslie, A., Singh, R.P., 2022. National assessment of afforestation activities in India, a key SDG target, under the world's largest social safety scheme. Journal of the Indian Society of Remote Sensing 50(8), 1423–1436.

Rajeevan, T. V., Rajendrakumar, S., Senthilkumar, T., Udhaya Kumar, S., & Subramaniam, P. (2019, November). Community development through sustainable technology—a proposed study with Irula tribe of Masinagudi and Ebbanad villages of Nilgiri District. In *First International Conference on Sustainable Technologies for Computational Intelligence: Proceedings of ICTSCI 2019*, 257-267.

Reimeingam, M., 2016. Impact of MGNREGA scheduled tribe workers on poverty in Sikkim. Journal of Rural Development 35(1), 77–95.

Rej, S., Nag, B., 2022. Investigating the role of capital formation to achieve carbon neutrality in India. Environmental Science and Pollution Research 29(40), 60472–60490.

Shiva Kumar MT (2020) Lake restoration work helps villagers near Maddur. The Hindu, Available at https://www.thehindu.com/news/national/karnataka/lake-restoration-work-helps-villagers-nearmaddur/article31366165.ece, Accessed 14 January 2023.

Singh, K., Singh, RP., Tewari, SK., 2021. Ecosystem restoration: challenges and opportunities for India. Restoration Ecology 29, 13341.

Subba, A.B., 2019. MGNREGA-Climate change and adaptation: Sikkim. SSRN Product and Services, 3375976. DOI https://dx.doi.org/10.2139/ssrn.3375976.

Tilman, D., Cassman, K.G., Matson, P.A., Naylor, R., Polasky, S., 2002. Agricultural sustainability and intensive production practices. Nature 418(6898), 671–677.

Tiwari, R., Somashekhar, H.I., Parama, V.R., Murthy, I.K., Kumar, M.M., Kumar, B.M., Ravindranath, N.H., 2011. MGNREGA for environmental service enhancement and vulnerability reduction: rapid appraisal in Chitradurga district, Karnataka. Economic and Political Weekly 46(20), 39–47.

Upendranadh, C., Subbaiah, C.A., 2016. Labour shortage in coffee plantation areas: Coping strategies of small growers in Kodagu district. In: Joseph, K.J., Viswanathan, P.K. (Eds.), Globalisation, Development and Plantation Labour in India. Routledge, 167–195.