Received: 8 April 2022 | Revised: 19 July 2022 | Accepted: 22 August 2022

DOI: 10.1002/ldr.4452

RESEARCH ARTICLE

WILEY

Exploring synergies between India's climate change and land degradation targets: Lessons from the Glasgow Climate COP

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Abstract

Land degradation, extending over 96 million hectares is a primary ecological issue for India that has resulted in catastrophic biodiversity loss and exacerbated extreme weather occurrences. One of the major sources of land degradation is large-scale coal mining to realize country's expanding energy demands. By 2050 climate change and land degradation, will result in US$1730 billion loss for India. Climate COP in Glasgow, 2021 was a watershed event to confront broader climate change challenges. India made one of the boldest pledges to pursue the road of climate justice, protect the most vulnerable, and committed to achieving net-zero emissions by 2070. This means gradually phasing down coal, reducing emissions and mainstreaming renewable sources. Given the prospect of five challenging but attainable targets, we examine India's readiness and the ramifications of these targets on land degradation reduction. Indian government is continuously increasing strategic support for improved mine closure and mine void restoration while, ensuring that land restoration supports 'green' job creation for poverty alleviation. While there is focus on investing significant amounts of national funding to address land degradation, international and private finances can enable to accomplish the larger goals. To enhance the effectiveness of the promises, we propose embedding diverse knowledge systems including indigenous knowledge systems and capabilities by formulating policies that incentivize environmental restoration, people-centric, climate sensitive strategies, convergence between different government departments as well as schemes, and mainstreaming of systems thinking as a social transformation approach for achieving coupled Climate and Land Degradation Neutrality targets by 2030 and 2070.

KEYWORDS

climate commitment, coal mining, deforestation, Glasgow COP, land restoration

1 | INTRODUCTION

Almost 70% of Asia's population lives in rural regions and is reliant on land or land-based ecosystem services (Gebre & Gebremedhin, 2019; Olsson et al., 2019). These services are adversely impacted as a result of land degradation, desertification, and drought, which are in their most severe stages in Asia (Mendoza-Ponce et al., 2021). A majority of the land degradation (490 million ha) in Asia is centered in India and China (Gibbs & Salmon, 2015). The IPCC special report on Climate Change and Land and the IPBES assessment report on Land Degradation and Restoration have highlighted the compromised wellbeing of 1.3–3.2 billion people living in developing and underdeveloped countries, due to land degradation (IPBES, 2018; Olsson et al., 2019).

India is highlighted as the third biggest greenhouse gas (GHG) emitter, behind China (10.6 Gt) and the United States (5 Gt), emitting roughly 3 billion tonnes of CO_2 per year, with a projected growth of 30–32 billion tonnes between 2021 and 2030, if current trends continue (Olivier & Peters, 2020). From a climate viewpoint, energy, which accounts for 69% of India's GHG emissions, is an especially important aspect of the Country's development decisions and is linked with increasing land degradation (Dubash et al., 2018). Increasing energy demand in India is largely fulfilled by coal and has resulted in enhanced deforestation and land degradation (Ahuja & Tatsutani, 2009). According to the Indian Space Research Organization's *Desertification and Land Degradation Atlas*, degraded land is steadily rising in the Country and presently, 97.85 million ha of land equaling 29.7% of India's total geographical area is degraded (Sengupta, 2021). desertification and droughts have compromised India's GDP by up to 5% in 20 years (DTE Staff, 2022). In 2014–2015, India's gross domestic product (GDP) dropped by 2.5%, which equals $73.4 billion, due to land degradation whereas, (Peddi, 2017; Tripathi, 2018). According to estimates by (Mohanty, 2021), India can lose US$1730 billion by 2050 as a result of climate change and land degradation.

To counter the looming threats of land degradation, India has spearheaded commendable initiatives both nationally and internationally. India hosted the COP14 of the United Nations Convention to Combat Desertification in 2019. India has already committed to the Bonn Challenge and to the United Nations Decade on Ecosystem Restoration 2021–2030 (a joint initiative by UNEP and FAO). India joined the Bonn Challenge in 2015 with a pledge to restore 13 million hectares of degraded and deforested land by 2020 and an additional 8 million hectares by 2030 (Dhyani et al., 2020; Dhyani et al., 2022). Significant progress has been made since 2015, post-approval of the Agenda 2030 of UNCCD for Land Degradation Neutrality. The Indian target of restoring 21 million hectares under the Bonn Challenge was increased to a target of 26 million hectares by 2030 during the UNCCD COP in 2019 (Singh et al., 2021). Presently, India as Party to the UNCCD in the Delhi Declaration, 2019 has committed to Land Degradation Neutrality (LDN) targets to ensure food and nutritional security, reduce biodiversity and ecosystem services loss, and to enhance climate change adaptation and mitigation (Almuedo, 2021; IRP, 2019; IUCN, 2016). India has also committed to the creation of carbon sink of 2.5–3 billion tonnes of carbon dioxide equivalent (CO_2e) through additional forest and tree cover by 2030 as one of its three nationally determined contributions (Dhyani et al., 2021; Mathur et al., 2021).

Climate change, meanwhile, has exacerbated the impacts of land degradation and vice versa. A recent report highlighted that intense rain occurrences that had increased threefold in the country over the last 65 years, mostly attributable to climate change (Kramer & Ware, 2020). According to the *State of the Climate in Asia 2020*, climate hazards have significantly affected India in the last few years by directly impacting food and agricultural security, enhancing displacement and aggravating environmental challenges by natural ecosystem losses (WMO, 2021). Climate-related calamities have also been reported as causes for the largest death toll, with millions of people displaced by floods, cyclones, droughts, and landslides in India (Basu, 2021). The adverse impacts of climate change are interlinked with land degradation and it is clear that through the NDCs and promises to achieve LDN adaptation and mitigation of climate change in India could be achieved. When taken together, these factors have a substantial impact on long-term sustainable development, particularly performance toward the UN SDGs.

Narratives on the existing mismatch between the distressed populations due to climate change versus the catalysts of the observed impacts rarely surface; such discussions are pushed to the sidelines in vulnerable countries, due to the complex politics and overlap with other historic liabilities such as imperialism and economic factors, such as the growing budget deficit (Timperley, 2021). The Glasgow Climate Conference or COP 26, which took place in the aftermath of a dramatic series of catastrophic weather events as well as the threat of a pandemic in 2021 brought climate justice to the forefront of climate action. COP 26 was a watershed moment for global commitments to address larger issues related to climate change and governments announced bigger promises as part of the Paris Agreement's 'ratchet mechanism' in their upgraded NDCs. One of the boldest announcements came from India when the Indian Prime Minister stated that India would achieve net zero emissions by 2070. In order for the world to meet its target of net-zero emissions by 2050, developing countries should be provided more time to adapt, as the principle of climate justice demands. India's pledge to achieve net-zero emissions by 2070 embeds the climate justice concern by enhancing dependence on renewable sources of energy and phasing down coal instead of phasing out coal (Shrivastava, 2021). The projected targets though bold are visionary and way ahead of many developed countries and will help reduce land degradation challenges in India, especially from coal mining that contributes to 51.6% of the energy demands of the Country. However, it is important to understand the roadmap to achieving this commitment. In this paper, we explore the preparedness of India to achieve LDN, and specifically:

1. Implications of implementation of India's commitments at Glasgow for addressing land degradation in India
2. Opportunities and potential in India's commitments at Glasgow for 'greening' degraded lands in India.

2 | GLASGOW CLIMATE PACT, INDIA'S COMMITMENTS AND LAND DEGRADATION

The Glasgow Climate Pact was adopted as a key outcome from the United Nations Climate Change Conference in Glasgow for increasing global initiatives to minimize CO_2 emissions, to keep temperature increase, below 1.5°C by 197 Parties. The pact recognized the interconnected global problems of climate change and biodiversity loss, as well as the vital role of nature and ecosystems in delivering advantages for climate adaptation and mitigation while maintaining social and environmental safeguards. It also emphasized that to attain these goals, it was critical to protect, conserve, and restore the environment and ecosystems, particularly forest areas and other terrestrial and marine ecosystems. The Pact (Section 8, para 59), further explored ways to increase adaptation and mitigation while addressing issues of land through climate action. Para 59 requested that the Chair of the Subsidiary Body for Scientific and Technological Advice compile an informal summary report on the matter and provide it to the Conference of the parties at its 27th session (UNFCC, 2021). It is at this COP meeting that India made the historic announcement to achieve net-zero emissions by 2070 at the opening plenary at Glasgow and called it "Panchamrit" a word originating in the Sanskrit Language, where "Panch" refers to the number "five" and "Amrut" refers to "nectar of Gods", (or the fabled beverage used to achieve immortality). The proposed strategy for achieve-zero emissions by 2070, the ultimate target among *Panchamrit* includes significant near-term goals and one long term goal, demonstrating India's commitment and ambition to reduce the larger impacts of climate change (Figure 1). These five goals include:

1. India's non-fossil energy capacity reaching 500 GW by 2030.
2. Renewable energy to cover 50% of India's energy by 2030.
3. Reduction in India's carbon emissions by 1 billion tonnes by 2030.
4. Reduction in carbon intensity by 45% from 2005 levels by 2030 (up from 33%–35% target).
5. By the year 2070, India will have achieved carbon neutrality and net zero emissions.

It is important to mention here that despite these bold commitments, India's intervention during the closing plenary sparked outrage

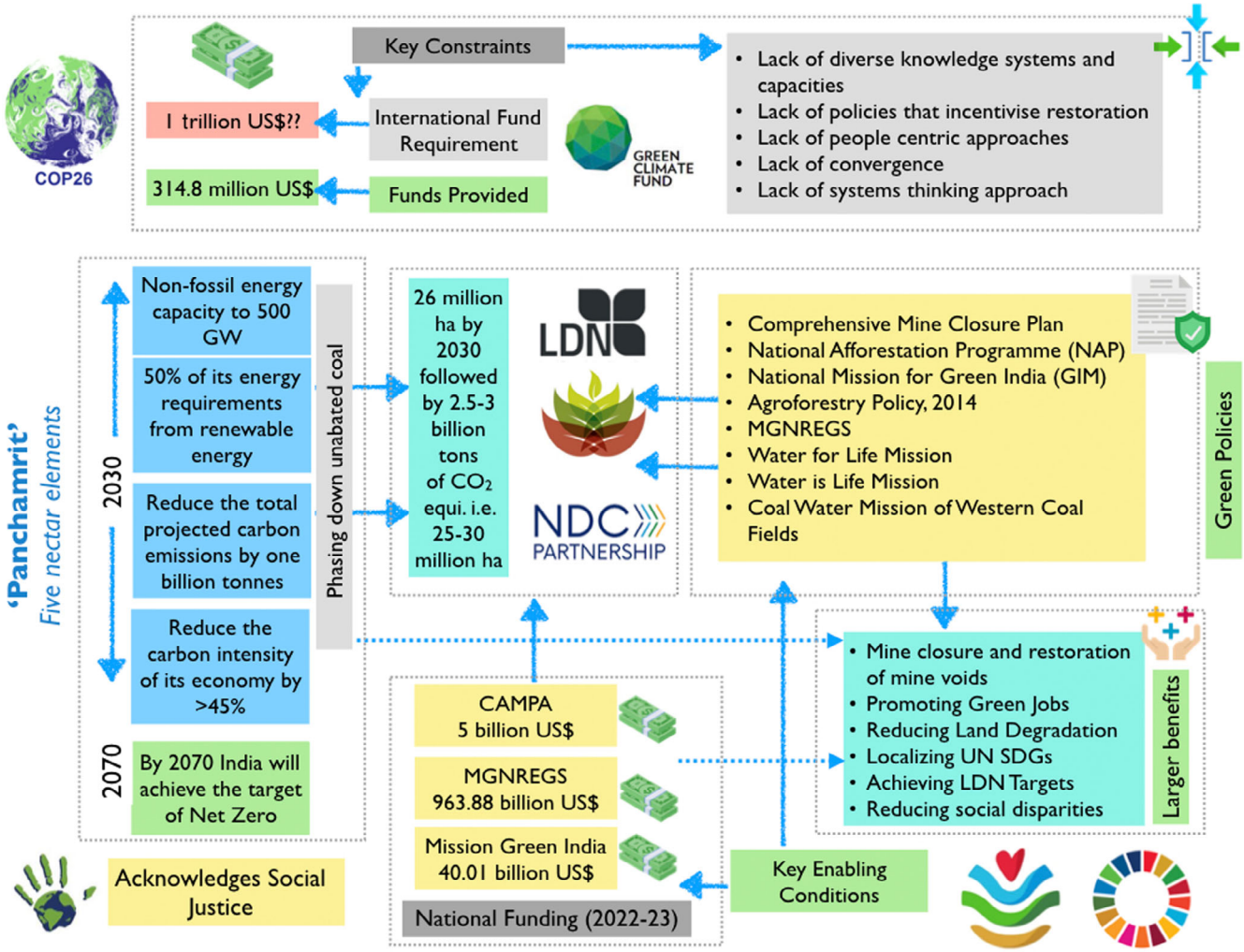

FIGURE 1 Assessing key enabling and constraining conditions to improve synergies between India's climate change and land degradation targets as proposed in the "Panchamrit" statement by India at the Glasgow Climate COP, 2021 [Colour figure can be viewed at wileyonlinelibrary.com]

among rich countries when India committed to only 'scale down' unabated coal (coal used without trapping or storing the carbon released) power along with phase out of inefficient fossil fuel subsidies, rather than a 'phase out' of coal. While developed countries consider that India's engagement 'dilutes' the Glasgow Pact; analysts believe that India's focus on the obligation of supporting the poorest and most vulnerable is commendable (Parsons & Taylor, 2021). It emphasizes the UNFCCC principle of common but differentiated responsibilities. While all parties should reduce carbon emissions, common but differentiated responsibilities (CBDR) recognizes that not all parties are equally responsible (Sirur., 2021). Meeting the climate targets as proposed by India in Paris and Glasgow, and achieving net-zero by 2070 will also help to significantly reduce land degradation and help restoring degraded ecosystems. Meeting climate targets also happens to be a potential pathway for avoidance, reduction, and reversal of land degradation supported by local landscape restoration approaches. These approaches for delivering climate benefits and reducing land degradation are vital for protecting regional biodiversity and ecosystem services for human wellbeing (Giuliani et al., 2020). For India, this means significantly reducing the energy support from coal by gradually phasing down coal and reducing land degradation due to coal mining.

3 | LAND DEGRADATION, COAL MINING, AND PROMISES TO ENHANCE RESTORATION

National-level land degradation geospatial surveys by the National Remote Sensing Centre (NRSC) provides implications for the future land degradation (LD) scenarios in India (Kandrika et al., 2021). This becomes important from the perspective of achieving LDN through land-based natural capital investment and ecosystem services enhancements (Orr et al., 2017). Distinguishing degraded versus degrading and/or vulnerable lands can provide the impetus to pursue appropriate approaches to address LD. The amplified emphasis on urbanization, industrialization, and infrastructure development in India has resulted in a considerable rise in power generation, with coal playing a key role (Rai, 2020). Present, India's installed energy generation capacity is 59.7% that is, 2,35,929 MW from fossil fuels (coal, lignite, gas, and diesel), and 40.3% from non-fossil fuels that is, 6780 MW (hydro, solar, wind, cogen, small hydro, waste to energy, and nuclear) (https://powermin.gov.in). According to the 19th Electric Power Survey, coal-based projects will account for roughly 2,38,150 MW of the cumulative installed capacity of 6,19,066 MW by the close of 2026–2027, out of the total installed capacity of 6,19,066 MW (Singh et al., 2019). More than 90% of the coal produced in India comes from surface or open-cast mines, posing environmental risks due to the loss of forests and ecosystems, disturbance of ecosystems and local communities, and concomitant degradation to agriculture, water resources, and local air quality (Srikanth & Nathan, 2018). Coal mining has been one of the potential drivers of land degradation in many parts of India, especially Central India, and climate change is projected to further aggravate the impacts of land degradation in the Country (Mohanty, 2021; Thakur et al., 2022). The electric power survey also indicates a big addition (from current levels of just about 1,00,000 MW to over 2,75,000 MW by 2026–2027) in renewable energy capacity in India. The focus of the Indian Government is to increase the share of renewable energy, which is available in plenty within the Country to meet the national power requirements and also export to neighbouring countries to substantially reduce land degradation due to coal mining (IANS, 2021). India is presently the world's second-largest coal producer and Coal India Ltd. (CIL) through its subsidiaries in 84 mining locations extracts coal from eight (8) Indian states, with 352 mines (as of 2020), including 158 underground mines, 174 open-cast mines, and 20 mixed mines. There are 107 active mining projects with a total annual capacity of 625.91 MT, contributing 295.37 MT in 2019–2020. In 2019–2020, 49 new prospective projects were started with a total capacity of 485.84 MT to boost coal production to 1 billion tonnes by 2023–24 (coalindia.in). Despite a strong push for renewable/non-fossil energy sources, India's coal demand is expected to rise to 1.3–1.5 billion tonnes by 2030 a 63% increase from current levels (ANI, 2022). A 4:1 stripping rate indicates approximately 4 tonnes of overburden removed for every ton of ore extracted meaning around 4.3–4.5 billion tonnes of overburden and waste would be generated to meet the additional energy demands of the country. However, with growing coal demands, companies are mining deeper and even choosing lesser grades of coal, with plans to produce D and F grade coal from 300 m depths at a stripping ratio of 1:15, translating to 15.5 billion tonnes of overburden being produced for every 1.5 billion tonnes of coal mined. This demands land space to store the overburden, leading to extended degradation of productive land (Sahu & Dash, 2011). Another issue is the abandoned coal mines (this includes subsided areas, excavated pits, soil dumps, and overburden dumps) and in India, more than 293 such mines are present that are under eight different Subsidiary Companies of Coal India Ltd., which is under administrative control of the Ministry of Coal (PIB, 2022).

Panchamrit strategies, while increasing the installation capacity of solar panels, can also boost the growing of crops and forests to provide resources for bioenergy production. Agrivoltaic schemes combining solar photovoltaic panels and food crops could optimize land utilization, especially in degraded agricultural and wastelands including mine spoil dumps (Dupraz et al., 2011). The bioenergy sector of renewables along with reducing our dependency on fossil fuels can provide ecological and economic benefits. For instance, the cultivation of degraded lands will enhance carbon sequestration, and provide biodiversity support, ecosystem services and economic gains to stakeholders specifically to communities engaged in the process of land restoration in the coal mining belt of the Country.

4 | STRENGTHS AND OPPORTUNITIES TO ACHIEVE LDN AND CLIMATE PROMISES

The Glasgow Pact recognizes the importance of ecosystem protection, conservation, and restoration to provide critical services such as GHG sinks and reservoirs, reducing vulnerability to climate change

impacts, and assisting sustainable livelihoods, including indigenous peoples and local communities (UNFCCC, 2021). To meet the 2030 NDC targets, India continues to maintain momentum by boosting energy efficiency, shifting significantly to renewable sources while also increasing its pace of afforestation. This aim should be viewed as an opportunity, with all connected actions contributing to the enhancement of ecological security and improvement of the Country's vast open forests, degraded lands, and spaces having trees outside forests (Dhyani et al., 2022; 2021; Dhyani et al., 2021; Mathur et al., 2021). Restoration of mine voids and degraded landscapes such as Tree outside Forests (ToF) or agroforests in diverse agro-climatic zones of the Country using indigenous and traditional ecological knowledge (ITK) will help meet Glasgow promises by reducing emissions from agriculture and help fulfilling the livelihood requirements of millions (Dhyani et al., 2020; Dhyani et al., 2021; Dhyani et al., 2021).

There are strict compliance mechanisms for reclamation of coal mines before mine closure and compensatory afforestation if forest land is diverted for non-forested purposes. The Indian Government is proactively implementing diverse schemes to reduce land degradation in the Country. Closing coal mines in India owing to reserve exhaustion, harsh geo-mining conditions, safety concerns, and other factors is planned to be protected and made environmentally stable by safeguarding the livelihood of individuals who have been directly or indirectly reliant on them. The Ministry of Coal has completed a thorough mine closure framework founded on the principles of just transition, with a focus on three important components of institutional governance: people and communities, environmental reclamation, and land repurposing. The larger aim is to develop a 'self-sustaining ecosystem' while maximizing the use of mined land for the support of local inhabitants (Santhanam & Srikanth, 2019; Srikanth & Nathan, 2018). In collaboration with the World Bank, the Ministry is building a framework of best practices and standards for dealing with mine closure instances. Degraded lands will be repurposed for community and state economic purposes, such as ecotourism, recreation, forestry, farming, horticulture, townships, and so on (PIB, 2021a). While tremendous technological, financial and political efforts are ongoing to reduce dependence on coal, a roadmap to restore the degraded coal mine voids involving local communities by creating green job opportunity requires additional efforts by different government line departments including Forest andCoal Ministries of the Government of India. Phasing down coal mines is going to significantly affect local livelihoods hence, diverting mining laborers and providing green jobs demand a well thought and prepared road map that should include restoration and rehabilitation of mine spoil dump as a relevant option (Chauhan et al., 2020). Further, the creation of water assets in mined-out lands can provide novel methodologies for achieving LDN and sustainable water usage of mine drainage water. Several such strategies as part of the *Jal Jeevan* (water for life) mission and the *Jal Shakthi Abhiyan* (water energy mission) programmes of India have been adopted by coal companies in India to reuse the water from underground mines as well as open-cast coal mines [Ministry of Coal (MoC) & Sustainable Development Cell (SDC), 2021]. These water assets can be effective methods to improve water management efficiency, decreasing soil losses and hence improve the overall quality of the land. For example, tertiary-treated underground mine water, branded as "Coal Neer" (coal water) for irrigational purposes, is being produced by Western Coalfields Ltd., in India (PIB, 2021b). Another promising strategy that can transform the degraded landscapes into functional ecosystems is in the form of 'pit lakes'; these can be unique nature-based infrastructural options as nature-based solutions for both eco-restoration and sustainable management of open-cast coal mines (Santhanam & Srikanth, 2019).

Nationally, ecological restoration and combatting land degradation is funded through various government programmes. The National Afforestation & Eco Development Board (NAEB) Division of the Ministry of Environment, Forest and Climate Change (MoEF&CC) is implementing the "National Afforestation Programme (NAP)" that focuses on the rehabilitation of degraded forests and afforestation around forests while, *National Mission for a Green India* under the *National Action Plan on Climate Change* (NAPCC; Table 1) aims at improving and increasing tree cover as a climate adaptation and mitigation strategy (Figure 1). While NAP focuses on reforestation of degraded forest lands, GIM focuses on enhancing forest quality and increasing forest cover, as well as cross-sectoral actions on a landscape basis. Agricultural Ministry's National Project on Agro-forestry and the National Mission for Green India one of the components NAPCC, are examples. In 2022–2023, the Green India Mission received more than 10% of the overall budget of the Environment Ministry (Rs 3030 i.e., US$ 40.01 billion). Since the NAP's commencement (2000–2002), a total of Rs. 3874.02 (US$ 5.07 billion) has been given to various states and is being used for treatment/afforestation over a sanctioned area of 2.1 million ha (PIB, 2019). Whenever natural forests are removed for 'development' or reasons of national security or importance, compensatory afforestation is undertaken on non-forest or degraded forestlands. Between 2008 and 2020, India lost 257,950 ha of natural forests to deforestation (Agarwal, 2021). Funds under compensatory afforestation fund management and planning authority, *Nagar Van Yojana* (Urban Forest Mission), Green Highway Mission, etc., help in checking the degradation and restoration of degraded land across India. Compensatory afforestation is also a significant source of funds for forest bureaucracies, and the CAMPA fund, which has accumulated more than US$ 5 billion (roughly Rs 38,000) from a variety of contributors, including private and public-sector companies, until 2015, could accelerate the achievement of the ambitious NDC target (Agarwal, 2021). The MoEF&CC, Government of India also promotes ToF realizing that the Country has a huge potential for increasing its ToF area primarily through expansion of agroforestry, optimum use of wastelands and degraded lands. Other schemes, such as State-run initiatives, have also promoted plantations aggressively. To fast track agroforestry adoption and expansion, and to remove the strict rules against felling and transporting trees, India approved and implemented its National Agroforestry Policy in 2014. It is one of the four interventions proposed in the Union budget for the years 2022–2023 for the Country's transition to a carbon-neutral economy. The Government encourages agroforestry and forests on private land through

TABLE 1 Missions associated with NAPCC with implications for mainstreaming LDN targets for India by 2030

NAPCC missions	Key programmes, missions, platforms, frameworks or interventions in force or planned	Insights for LD monitoring	Considerations for LDN
National Solar Mission	*Kisan Urja Suraksha Evam Uthhan Mahabhiyan* (KUSUM) (Farmer Energy Security and Development Movement)	Heat stressed areas, dust prone areas, drought prone areas and areas with high land surface temperatures	Installation of solar panels over high land surface temperature regions can decrease evaporative cooling and lower LD till end of life cycle of photovoltaics (PV) Help to achieve co-benefits of energy sufficiency for rural communities. However, the high-water demand for cleaning solar PVs in dust prone and water stressed regions can indirectly aggravate LD
National Mission for Enhanced Energy Efficiency	Perform Achieve and Trade (PAT) scheme; Energy Efficiency Financing Platform; Market Transformation for Energy Efficiency (MTEE); Framework for Energy Efficiency Economic Development; *Unnat Jyoti* Affordable LED for All (UJALA) scheme; Super-Efficient Equipment Programme; Partial Risk Guarantee Fund for Energy Efficiency; Venture Capital Fund for Energy Efficiency	Carbon sequestration targets through monitoring of CO_2 emissions	Increase in energy efficiency, along with reduction in specific energy consumption can control accelerated energy production, lower demand/reliance on coal-based power plants. Co-management by creation of carbon sinks/reservoirs for better sequestration can help to alleviate LD
National Mission on Sustainable Habitat	Atal Mission on Rejuvenation and Urban Transformation (AMRUT), *Swacch Bharat* Mission; Smart Cities Mission; Urban Transport Program	Reduction in greenhouse gas emissions; reduction in water logging and salinization of water tables	Sustainable transportation can reduce emissions and energy efficient constructions can help prevent intensification of urban heat island effects, and reduce the demand for cooling. Further effective urban wastewater and solid waste management may prevent water logging, solid waste accumulation
National Water Mission	MGNREGS, Garib Kalyan Rojgar Abhiyan, Jal Jeevan Mission, Jal Shakthi Abhiyan, Sahi Fasal, Arsenic mitigation	Losses and gains due to water pollution, water quality related to soil quality and water budgets	Integrated water resources management and conjunctive water use strategies can lower climate change enforcers with LD co-management. Water conservation projects linked to MGNREGA have been crucial in creating carbon neutral assets for rural communities
National Mission for Sustainable Himalayan Ecosystem	Strategic Programs, Large Initiatives and Coordinated Action Enabler (SPLICE), Climate Change Programme (CCP); Task Force – II enforcements (Water, Snow, and Ice including Glaciers)	Losses and gains of vegetation cover, gully erosions and eolian erosion monitoring directly indicates the intensity of LD	Valuation of ecosystem services and use of ecosystem-based adaptation measures as a part of the mission are crucial to achieve LDN targets
National Mission for Green India	India Cooling Action Plan, forest-based livelihood schemes	Determination of success of India's NDC goals, assessment of the extent of de-greening, improvement of forest and tree covers in forested and non-forested lands, agroforestry practices, diversification of forest-based livelihoods, promotion of eco-restoration are linked to alleviation of LD	Valuation of the provisioning capacities of India's forests is crucial to develop policies for mainstreaming LDN, Cooling Action Plan implementation through promotion of climate friendly resilient infrastructure will reduce cooling demands, indirectly cutting down emissions

(Continues)

TABLE 1 (Continued)

NAPCC missions	Key programmes, missions, platforms, frameworks or interventions in force or planned	Insights for LD monitoring	Considerations for LDN
National Mission for Sustainable Agriculture	*Paramparagat Krishi Vikas Yojana* (Traditional Agriculture Development Scheme), *Pradhan Mantri Krishi Sinchai Yojana* (Prime Minister's Agriculture Irrigation Scheme), Bamboo Cultivation Scheme, Scheme for Organic Value Chain Development for North-East Region, Rainfed Area Development Programme, National Bamboo Mission, Sub Mission on Agro-Forestry, Soil Health Card Scheme, etc.	Soil health indicators, vegetation cover, agricultural soil productivity, rainfed area status are directly linked to the gains and losses due to LD	Conjunctive farm water management, rainfed area development, promotion of reforestation can positively improve LDN indicators for India
National Mission on Strategic Knowledge for Climate Change	National Climate Change Monitoring and Research Network; Centre for Climate Change Research (CCCR) at the Indian Institute of Tropical Meteorology (IITM), Pune; Indian National Network for Climate Change Assessment (INCCA); National Knowledge Network (NKN)	Knowledge sharing and transfer on climate change can help effective detection and monitoring of LD	Institutionalized support for data sharing, research and development are key for mainstreaming LDN measures

appropriate policies and essential legislative amendments, positioning these interventions as important climate actions. For 2016–2020, India committed US$ 410 million to implement the agroforestry policy and the policy facilitates support by private funding through Corporate Social Responsibility of about a US$ 3.5 billion annual investment (Dhyani et al., 2021) (Figure 1).

Recognition that natural resources, their conservation and restoration are intrinsically linked to rural livelihoods is reflected in flagship schemes of *Mahatma Gandhi National Rural Employment Guarantee Scheme* (MGNREGS) under the Mahatma Gandhi Employment Guarantee Act (MGNREGA) a social security programme guaranteeing the 'right to work' and support rural livelihood and economic security through more than 250 diverse works, and the National Rural Livelihood Mission (Figure 1) (Dhyani et al., 2021). The Government has set aside Rs 73,000 (US$ 963.88 billion) for the MGNREGA project in the financial year 2022–23 however, this is a reduction of 34% from the expected amount of Rs 98,000 (US$ 1293.97 billion) last year. *Har Khet Ko Pani* (Irrigation to All Agriculture Fields), *More Crop Per Drop* (Improving Agriculture Efficiency per Drop of irrigation), NAP, *Pradhan Mantri Krishi Sinchayee Yojna* (Prime Minister's Irrigation Scheme), *Rashtriya Krishi Vikas Yojana* (National Agriculture Development Scheme) and the Soil Health Card Scheme are various Indian Government initiatives to achieve LDN targets and also to enhance carbon sinks (UNCCD, 2019). MGNREGS synergizes the ecological benefits of reclamation of degraded lands, with socio-economic outcomes of increased crop and livestock production, generation of employment and income to rural communities (Esteves et al., 2013; Kumar et al., 2011; Sebastian & Azeez, 2014). Table 1 summarizes some of the key national missions associated with NAPCC in different sectors, with implications for assessing, monitoring and/or mainstreaming LDN targets for India by 2030.

5 | CONSTRAINTS FOR INDIA IN SYNERGIZING LDN AND CLIMATE COMMITMENTS

According to the State of Finance for Nature report by the UN, to address planetary crises, investments in nature-based solutions (NbS) must triple by 2030 and double by 2050. With public money accounting for 86% (US$ 133 billion) of nature conservation and restoration funding, private sector investment and engagement must be greatly increased (UNEP, 2021a). A serious challenge for achieving both the climate targets as well as LDN is the inadequate finance at hand for the country. The sixth edition of the UNEP Adaptation Gap Report concludes that climate adaptation financing must be increased immediately. Adaptation costs in developing nations are estimated to be 5–10-times higher than the present public adaptation financial flows, and the gap is growing (UNEP, 2021b). The climate adaptation fund received a record-breaking US$ 356 million in new funding from participating national and regional governments at the Glasgow COP. However, it is crucial to underline that current climate adaptation financial provisions are insufficient to handle the growing global

climate scenario in developing countries (UNFCCC, 2021). Glasgow Pact, 2021 emphasized the need to mobilize climate finance from all sources to achieve the level required to meet the Paris Agreement's goals, including considerably boosting support for developing country parties beyond US$ 100 billion per year (UNFCCC, 2021). In a recent development, Green Climate Fund Board (A UNFCCC-created fund having headquarters in Incheon, South Korea is an operating body of the financial mechanism to support climate change adaptation and mitigation efforts) approved major changes to its accreditation framework in its efforts to streamline access to climate finance enhancing and accelerating access to finance by developing countries, including creation of a new, one-step process to fund climate projects. The board has allocated US$ 187.7 million of new GCF resources for promoting climate action increasing its portfolio to US$ 10.2 billion (GCF, 2022) (Figure 1). India, in order to scale up renewable energy initiatives requires additional outside capital (Vaidyanathan., 2021). The Economics of Land Degradation (ELD) of the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) and the UNEP Asia Study found that if all Asian countries find value and develop sustainable land management technologies on their 487 million ha of agricultural land over the next 13 years, the total cost would be US$ 1214 billion, or US$ 2494 per ha. The anticipated present value of long term benefits through encouraging investment inland management would be US$ 4216 billion, or US$ 8663 per ha (Kumar, 2019). India has sought a trillion dollars (around US$ 13.33 billion) from rich countries over the next decade to adapt to and mitigate the challenges posed by global warming and has made this a condition for meeting climate promises for achieving the NDCs. India has received GCF financing worth US$ 314.8 million so far (https://www.greenclimate.fund/countries/india). India's compliance with international pressure on climate action is dependent on funding from developed countries, and it is indicated in the NDC that it will require USD 2.5 trillion from international (rather than domestic) sources to accomplish its commitments between now and 2030 (https://www.indiaghgp.org/climate-finance) (Parsons & Taylor, 2021). Several climate and forestry experts in India have stressed that for India, to realize the forestry NDC needs the land, and a plan apart from funding (Deshpande, 2021). Afforestation at this scale will necessitate 25–30 million hectares of land. Planting along railroad tracks, waterways, and mine voids could only be a minor part of the solution (Chaturvedi et al., 2022). INR one trillion (around US$ 13.33 billion) as well as an appropriate and timely operational strategy is required each year to achieve this NDC (Figure 1). Therefore, India should make 2020 the base year for this NDC, and current forests should be maintained as well since organic carbon in the soil takes many years to replenish once trees are lost (Dubash et al., 2018).

6 | CONCLUSIONS AND WAY FORWARD

A robust restoration strategy involves a triple bottom line approach to ensure that stakeholders and socio-economic outcomes, in addition to the environmental objectives, are considered in decision-making. This is imperative as most of the local communities living in coal mining areas of India are below poverty level (BPL). Finally, a new economic model that emphasizes investment in natural capital will require transdisciplinary policies that connect various economic and environmental sectors to address the larger challenge (Mansuy, 2020). India boasts some of the most inclusive land and forest governance structures in the world, allowing communities to legally participate in resource management and take advantage of multiple benefits while ensuring climate justice for the Country's most vulnerable communities. Nevertheless, there are some key challenges (Figure 1) that need to be addressed for implementation of these strategies, which include:

1. *Integrating diverse knowledge systems and capacity*: Successful implementation of ecosystem restoration for carbon neutrality is plagued by multiple constraints such as lack of multi-criteria optimization approach to identify priority areas for restoration and estimation of restoration benefits and costs. Investment in restoration returns manifold economic benefits, but comprehensive cost–benefit analyzes for restoration of various ecosystems is quite challenging (UNEP, 2021a). Poor understanding of species, their functions (morphological and functional traits), ecological succession patterns (what to plant first and where) and socio-ecological inter-linkages (including the various tradeoffs), in addition to defective approaches for economic evaluation of ecosystem services and lack of uniform approach for carbon stock assessments are all significant constraints. Insufficient monitoring and post plantation care often leads to failure of many greening projects, indicating the need of capacity building and long term research (Dhyani et al., 2020). Hence, India with its diverse agro-climatic conditions needs context specific interventions that are people centric and climate sensitive rather than a 'one size fits al' approach to improve restoration efforts and enhancing the success rates.
2. *Developing policies that incentivize ecosystem restoration*: Increasing livelihood-based social assistance programmes can be a game-changing strategy for achieving LDN as well as global restoration while achieving climate goals. Creating green jobs to encourage local partnership and participation in the restoration of degraded lands can be a transformative approach. To revolutionize the process, we suggest evolving and mainstreaming national-level landscape restoration guidelines by addressing gaps, defining institutions and their responsibilities, strengthening community capabilities, utilizing technology to support decision-making, encouraging multi-stakeholder involvement, and promoting inclusivity and community participation using locally relevant knowledge (Dhyani et al., 2020; Dhyani et al., 2021).
3. *Promoting people-centric approaches*: Participation of a varied set of stakeholders, including civil society, academic institutions, women's groups, indigenous communities, youth, farmer's groups, and the marginalized, is essential to achieve restoration at scale (UNEP, 2021a). However, in India top-down approaches of afforestation has created a rift between local communities and forest bureaucracies, for instance CAMPA programmes that have been of negligible use for people, alienate them from such projects. Many

of the renewable energy and afforestation projects also result in 'green grabbing' of land belonging to forest dwelling and marginalized communities and appropriation of ecological commons such as grazing lands vital for local livelihood sustenance (Choudhury, 2019; Saxena, 2019). Recent reports describe the violation of act of the remarkable Forest Rights Act, 2006 for procuring land for afforestation projects (Kukreti, 2017). It is important that while evoking environmental justice as a principle for international negotiations government needs to redress such local injustices to make restoration sustainable and equitable by creating local ownership.

4. *Improving multi sectoral and multi departmental collaboration*: Although many of the national strategies such as NAPCC envisage close coordination of various departments ranging from Ministry of Energy to Ministry of Agriculture and MoEF&CC, lack of convergence in their approaches have led to low scale of impacts. Departments working in siloes or even at cross purposes are hampering serious progress toward many of our NDCs hence, enhancing convergence between different government line departments can improve functioning and productivity at a much lower financial cost.
5. *Mainstreaming systems thinking approach*: Exclusive focus on carbon sequestration without recognizing the societal needs often arises from piecemeal strategies, which fail to recognize the synergies and tradeoffs between development, conservation and climate goals and targets. For instance, carbon capture projects often use exotic fast growing species that sucks aquifers and provides negligible local benefits. Mainstreaming systems thinking approach by involving ecologists, scientists, local communities and practitioners can help choosing appropriate native species for enhancing benefits as well as many associated co-benefits.

It has been established that supporting communities to manage and repair ecosystems have global climate, biodiversity, and sustainable development advantages hence we conclude that India should prepare to go beyond the NDCs. To achieve carbon neutrality, reducing emissions and linked land degradation it is important to strengthen the resilience of ecosystems and landscapes that support people who are disproportionately affected by climate change although their contribution to the problem is small.

ACKNOWLEDGMENTS

Authors acknowledge the support from the Knowledge Resource Centre (KRC), CSIR-NEERI, Nagpur for plagiarism check using a licensed version of iThenticate under the KRC number. No. CSIR-NEERI/KRC/2022/JULY/WTMD/1.

CONFLICT OF INTEREST

Authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

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How to cite this article: Dhyani, S., Santhanam, H., Dasgupta, R., Bhaskar, D., Murthy, I. K., & Singh, K. (2023). Exploring synergies between India's climate change and land degradation targets: Lessons from the Glasgow Climate COP. *Land Degradation & Development*, *34*(1), 196–206. https://doi.org/10.1002/ldr.4452