Greening India Mission

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The Government of India has announced the Greening India Mission (GIM) under the National Climate Change Action Plan. The Mission aims to restore and afforest about 10 mha over the period 2010–2020 under different sub-missions covering moderately dense and open forests, scrub/grasslands, mangroves, wetlands, croplands and urban areas. Even though the main focus of the Mission is to address mitigation and adaptation aspects in the context of climate change, the adaptation component is inadequately addressed. There is a need for increased scientific input in the preparation of the Mission. The mitigation potential is estimated by simply multiplying global default biomass growth rate values and area. It is incomplete as it does not include all the carbon pools, phasing, differing growth rates, etc. The mitigation potential estimated using the Comprehensive Mitigation Analysis Process model for the GIM for the year 2020 has the potential to offset 6.4% of the projected national greenhouse gas emissions, compared to the GIM estimate of only 1.5%, excluding any emissions due to harvesting or disturbances. The selection of potential locations for different interventions and species choice under the GIM must be based on the use of modelling, remote sensing and field studies. The forest sector provides an opportunity to promote mitigation and adaptation synergy, which is not adequately addressed in the GIM. Since many of the interventions proposed are innovative and limited scientific knowledge exists, there is need for an unprecedented level of collaboration between the research institutions and the implementing agencies such as the Forest Departments, which is currently non-existent. The GIM could propel systematic research into forestry and climate change issues and thereby provide global leadership in this new and emerging science.

Keywords: Adaptation, afforestation, climate change, Greening India Mission, mitigation.

DEFORESTATION and land-use change is estimated to contribute to 17% of the global CO_2-eq emissions[1]. Further, mitigation potential of forest sector is estimated to be ranging from 1.3–4.2 Gt CO_2 to a high of 13.8 Gt CO_2 by 2030. At the global level, the importance of the forest sector in the mitigation of climate change is recognized, and afforestation and reforestation are included under the Clean Development Mechanism (CDM) of the Kyoto Protocol. In the post-Kyoto negotiations, REDD*plus* (Reducing Emissions from Deforestation and Degradation, and the plus activities include forest conservation, sustainable forest management and carbon stock enhancement) mechanism has been included as one of the key strategies to mitigate climate change. The Government of India under the National Action Plan on Climate Change (NAPCC) has identified the 'National Mission for Greening India' as one of the eight missions. The Ministry of Environment and Forests, Government of India has prepared a draft strategy on the 'Greening India Mission' (GIM) and the strategy is currently under public consultation in India[2]. This article provides a critical review of the GIM strategy and suggests potential options to improve the effectiveness of the strategy to maximize global environmental benefits of mitigation and adaptation, and at the same time maximizing the local environmental and socio-economic benefits. Further, the mitigation potential of the interventions considered under the GIM is estimated by adopting a modelling approach.

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GIM puts 'greening' in the context of climate change adaptation and mitigation meant to enhance ecosystem services like carbon sequestration and storage (in forests and other ecosystems), hydrological services and biodiversity, along with provisioning services like fuel, fodder, small timber and Non-timber Forest Products (NTFPs) (http://moef.nic.in/downloads/public-information/green-india-mission.pdf). The Mission aims at addressing climate change by: (i) enhancing carbon sinks in sustainably managed forests and other ecosystems, and (ii) enhancing the resilience and ability of vulnerable species/ecosystems to adapt to the changing climate, and enabling

adaptation of forest-dependant local communities in the face of climatic variability.

Objectives of GIM

GIM highlights the following three objectives.

(i) Double the area to be taken up for afforestation/eco-restoration in India in the next 10 years, taking the total area to be afforested or eco-restored to 20 mha (i.e. 10 mha of additional forest/non-forest area to be treated under the Mission, in addition to the 10 mha which is likely to be treated by the Forest Department and other agencies through other interventions).

(ii) Increase the greenhouse gas (GHG) removals by India's forests to 6.35% of the country's annual total GHG emissions by 2020 (an increase of 1.5% over what it would be in the absence of the Mission). This would require an increase in aboveground and belowground biomass in 10 mha of forests/ecosystems, resulting in increased carbon sequestration of 43 Mt CO_2-eq annually.

(iii) Enhance the resilience of forests/ecosystems being treated under the Mission – enhance infiltration, groundwater recharge, stream and spring flows, biodiversity value, provisioning of services (fuel wood, fodder, timber, NTFPs, etc.) to help local communities adapt to climatic variability.

GIM targets (outputs)

The Mission will have clear targets for different forest types and ecosystems which will enable achieving its overall objectives. The Mission targets can be classified into the following:

- 2.0 mha of moderately dense forests show increased cover and density.
- 4.0 mha of degraded forests are regenerated/afforested and sustainably managed.
- 0.10 mha of mangroves restored/established.
- 0.10 mha of wetlands show enhanced conservation status.
- 0.20 mha of urban/peri-urban forest lands and institutional lands are under tree cover.
- 1.50 mha of degraded agricultural lands and fallows are brought under agro-forestry.
- 0.10 mha of corridor areas, critical to wildlife migration are secured.
- Improved fuel-wood use-efficiency devices adopted in about 10 million households (along with alternative energy devices).
- Biomass/NTFP-based community livelihoods are enhanced that lead to reduced vulnerability.

The key elements of the GIM include a holistic view to 'greening' (broader than plantations), integrated cross-sectoral approach to implementation, key role for local communities and decentralized governance, vulnerability and mitigation potential as criteria for intervention, and a robust and effective monitoring framework.

Mission of the GIM

Significance of forests in relation to climate change

The GHG emission estimates made by the National Communications for the land-use change and forest sector for the year 1994, is 14.2 Mt CO_2-eq. The GIM quotes a study[2] which estimates the carbon stocks in Indian forests at 6622 Mt C in 2005. This is an underestimate compared to a published study[3] which estimated the carbon stock in Indian forests to be 8790 Mt C. This study also estimated that the forest sector alone, considering the current afforestation rate (of about 1.2 mha/annum), could lead to an enhancement of carbon stock from 8790 Mt C in 2006 to 9750 Mt C by 2030, with an annual offset potential of 6% of the projected GHG emissions for India by 2020.

Forests and climate change – key challenges

This section highlights a few key challenges in addressing climate change through the forest sector. However, the following challenges also need to be adequately addressed:

- How to synergize carbon sequestration in forests and degraded lands without affecting food security, livestock grazing, etc. and meeting the diverse biomass needs of local communities?
- Conserving biodiversity, another global environmental threat, along with carbon benefits.
- Maximizing carbon benefits per hectare through appropriate practices that promote sustainable management of forests, conservation of biodiversity and provide multiple local benefits.
- Promoting adaptation to climate change, while mitigating climate change through REDD, afforestation and restoration programmes. The GIM document incorrectly quotes a study by Ravindranath *et al.*[4] in the Indian Institute Science (IISc), Bangalore using the BIOME4 model, by stating that more than 50% of the vegetation in India will be impacted by climate change while the study actually states that nearly 77% and 68% of the forests would be impacted by climate change leading to shifts in forest types with adverse implications for biodiversity under the A2 and B2 scenarios respectively[4]. A recent study by Chaturvedi *et al.*[5] at IISc using dynamic global vegetation model IBIS states that at the national level about 34–39% of the forests are likely to be impacted by climate change by 2085 under different emission scenarios[5]. This study

also presents the regions and forest types that are most vulnerable to climate change. In the forest-dominant states such as Chhattisgarh, Karnataka and Andhra Pradesh, up to 73%, 67% and 62% of forested grids respectively, are projected to undergo change.

First, the Mission aims at enhancing the carbon sinks in the sustainably managed forests and other ecosystems, while there is little understanding of sustainably managed forests in India. Secondly, it aims at enhancing the resilience of vulnerable species and ecosystems to climate change. Thirdly, it aims at enabling forest-dependent local communities to adapt to climate change. In the GIM strategy only the carbon enhancement aspect is considered in some detail, whereas the vulnerability and adaptation of the forest ecosystems and dependent local communities is inadequately considered. The existing studies and knowledge on impacts and adaptation (particularly from the modelling studies of IISc) could be incorporated into the GIM strategy[5].

Mission objectives

The GIM draft has listed the following objectives.

- The first objective states that the Mission would double the area through afforestation and eco-restoration by treating about 10 mha. Afforestation would be an activity and not an objective in itself.
- According to the second objective, the Mission would contribute to enhancing the resilience of forests to climate change through enhanced groundwater recharge as well as stream and spring flows. The resilience of the forests may not be enhanced through such processes, but mainly through other activities such as anticipatory planting, mixed species forestry with native species and fire-protection measures. A study by Murthy *et al.*[6] at IISc has listed potential adaptation strategies and practices, which are presented later in the article.
- The third objective states that the Mission would lead to an increase in aboveground and belowground biomass. The potential significant enhancement of soil organic carbon is not included. The mitigation potential estimates are conservative and not based on any modelling since projection of net CO_2 benefit would require consideration of the stocks and rates of growth of aboveground and belowground biomass, soil carbon and litter, and not a simple multiplication of growth rate with area. The values are likely to be significantly different and are presented later in the article.
- The objective of capacity-building, technical inputs to proposed interventions and enhancing the adaptive capacity and participation of the local communities, conservation of biodiversity and other ecosystem services, needs to be included. These are mentioned at different places of the Mission document.

Mission targets

This section provides the areas proposed to be brought under different interventions under the GIM. The rationale for the proposed area under different interventions covering different land and forest types is not clear. A question arises as to why only 2 mha of degraded/scrub grasslands is included, while 4 mha of degraded/open forests (crown cover 10–40%) is included? One would have expected larger coverage of degraded scrub/grasslands. The Mission document states that the current afforestation and regeneration on forest and non-forest area would double. Annex 3 states that 2 mha of moderately dense forest (40–70% crown cover) and 6 mha of open forests + scrub/grasslands are likely to be covered under the existing programmes. These numbers may not be correct since first, the area brought under afforestation largely in degraded scrub/grasslands and wastelands is nearly 1.2 mha over the last several years (http://envfor.nic.in/nfap/forest-plantation.html). Further, under the current programmes, moderate dense forests and open forests are not treated and the focus is largely on wastelands.

Means to achieve the Mission targets and outcomes

Though India has been implementing one of the largest afforestation programmes in the world since the launching of social forestry in the early 1980s, there seems to be little innovation or technical input into the afforestation programmes. Any afforestation model in a given state seems to be the same no matter what the programme or project objectives, even though several projects funded by the Government of India and external agencies with differing goals have been implemented in the states since the early 1980s. One of the major limitations of the large afforestation programme is the lack of research and its application in the field. Forest Departments at the all-important 'forest range or beat level' continue to adopt the same practices in the absence of any scientific input or capacity-building. The GIM includes several innovative interventions and the Forest Departments are supposed to begin implementation from 2011. The innovative interventions of the GIM include practices for enhancing carbon stocks in moderately dense forests, open forests, and treatment of degraded scrub/grasslands for soil and water conservation and grass productivity. It is not clear how silvicultural practices will become available by 2011 and how these will be communicated to the forest-range and beat-level staff. It seems unlikely. Thus, the GIM funds will be used to implement the routine ongoing afforestation practices, more of the same.

Mission strategy

The Mission strategy has many innovative interventions and the Ministry should be complimented for attempting to introduce them in the GIM, even though little research and knowledge exists for implementing these interventions. The focus of the strategy is rightly promotion of mitigation and adaptation. The Mission also has commendable components with respect to providing incentives to the local communities and to ensure robust tenure security and benefit-sharing arrangements, which may of course require many legislations and legal support. Ravindranath[8] has highlighted the unique potential of promoting synergy between mitigation and adaptation in the land-use and forest sector. The overall strategy of the Mission does mention incorporating the adaptation component in the afforestation programmes. However, the strategy has not adequately addressed this component. Chaturvedi *et al.*[5] have conducted an assessment of the impact of climate change on forest ecosystems, and have identified and ranked the vulnerable forest ecosystems and states. Such an assessment of the most vulnerable regions should be used to identify locations for pilot projects incorporating the adaptation component. Currently, there is little research and practical knowledge on incorporating adaptation practices into mitigation projects.

Enhancing climatic resilience

Enhancing climate resilience or adaptation to climate change is considered only for sub-mission 1 for moderately dense forests (tree crown 40–70%). Adaptation practices should be incorporated in all the sub-missions such as restoration of open forests and scrub/grasslands. Murthy *et al.*[6] have identified a number of 'no-regret' or 'win–win' adaptation measures for the forest sector:

- Anticipatory planting of species along latitude and altitude.
- Promote assisted natural regeneration and mixed species forestry.
- Promote species-mix adapted to different temperature tolerance regimes.
- Develop and implement fire protection and management practices.
- Develop and adopt thinning, sanitation and other silvicultural practices.
- Promote *in situ* and *ex situ* conservation of genetic diversity.
- Develop drought and pest resistance in commercial tree species such as teak and eucalyptus.
- Develop and adopt sustainable forest management practices.
- Expand Protected Areas (PAs) and link them wherever possible to promote migration of species.
- Conserve forests and reduce forest fragmentation to enable species migration.

India will be one of the first countries in the world to incorporate adaptation practices and strategies into forest conservation, forest management and afforestation programmes on a large scale. India will be generating valuable scientific knowledge on the implications of incorporating adaptation practices in forest management programmes. Adaptation pilot projects should be implemented initially in the most vulnerable forest ecosystems and in particular, hilly or mountain regions, where practices such as anticipatory planting could be effectively implemented.

Silvicultural and management practices

Sub-missions 1 and 2 involving restoration of moderately dense and open forests: There is limited research and information on silvicultural and management practices for restoration of moderately dense and open forests, included in sub-missions 1 and 2. In India the focus has largely been on afforestation of degraded forests, wastelands and farmlands. The State Forest Departments are familiar with routine afforestation programmes, largely dominated by one of the species, including eucalyptus, *Acacia auriculiformis*, teak (*Tectona grandis*), sal (*Shorea robusta*), pines, poplar, *Acacia tortilis*, etc.

Sub-mission 3 involving restoration of scrub/grasslands: Normally under the State Forest Department Programmes, these lands would have been brought under afforestation programmes dominated by one of the fast-growing species. The GIM needs to be complimented for suggesting an alternate approach to restoration of scrub/grasslands, particularly with the aim of soil and moisture conservation and generating grass and fodder for livestock. There is need for a mechanism to ensure restoration practices leading to soil moisture conservation and grass production are indeed implemented unlike in the routine afforestation programmes.

Sub-missions 4 and 5 involving restoration of mangroves and wetlands: GIM needs to be complimented for including mangroves and wetlands, since both these ecosystems are subjected to degradation and are vulnerable to climate change. Mangrove restoration will also contribute to adaptation of coastal communities and agricultural systems to climate change. If feasible, more area could be restored under the mangroves.

Sub-mission 7 – agro-forestry and social forestry: Traditionally agro-forestry and social forestry under the previous programmes involved raising largely monoculture plantations of eucalyptus, teak, mango, etc. There is a need for developing agro-forestry modules for different

Table 1. Incremental and cumulative mitigation potential (Mt CO_2) of different sub-missions estimated using COMAP model

Intervention/ sub-mission	Area (mha)	Incremental annual mitigation potential 2020 (Mt CO_2)	Incremental cumulative mitigation potential 2010–20 (Mt CO_2)	Incremental cumulative mitigation potential 2010–2030 (Mt CO_2)
Moderately dense forests (MDF)	2.0	21.7	114.4	343.1
Degraded/open forests (D/O)	4.0	70.1	369.1	1107.4
Scrub/grassland ecosystems (S/G)	2.0	20.2	106.2	318.6
Mangrove and wetland ecosystems (M–W)	0.2	24.2	127.6	382.8
Agro-forestry and social forestry including urban forestry + corridors (AF–SF–UF–C)	1.8	12.5	65.9	197.6
Total	10.0	148.8	783.1	2349.4

Carbon pools considered. Aboveground and belowground biomass, soil and litter pools; Area to be planted: 10 mha phased equally over 10 years, starting 2011. Growth rates: MDF: 2.5 t/ha/yr[12]; S/G: 1.51 t/ha/yr[10]; M–W: 3.2 t/ha/yr[13]; AF–SF–UF–C: 0.84 t/ha/yr[14].

agro-climatic regions of India, with multiple choices of species to the farmers and local communities. Agro-forestry is also an excellent example of promotion of mitigation–adaptation synergy. Agro-forestry practices should aim at planting trees/species (such as khair, tamarind, mango, jackfruit and jamun), providing multiple products. Such species provide fruits, fodder, etc. and also income even during a drought year, reducing the vulnerability of arid and semi-arid farming communities. The proposed area under agro-forestry is only 1.5 mha, whereas the area under agriculture is about 180 mha. Thus, the GIM could consider expanding the area under agro-forestry systems.

Sub-mission 8 – securing corridors as an adaptation strategy: This is one of the prioritized adaptation actions suggested by an earlier study[6] to facilitate migration of flora and fauna subjected to climate change. The first priority of the GIM under adaptation should be to link PAs and nature reserves to enable migration of plant and animal species.

Means to achieve the targets of the GIM

One of the most important components required for promoting mitigation and adaptation is to promote research and modelling, and the use of remote sensing to identify locations for implementing pilot mitigation and adaptation actions. The area considered for different missions is limited; for example, 2 mha out of 33.92 mha under moderately dense forest, 4 mha out of 28.78 mha under open forest and 1.5 mha out of 180 mha under cropland. Thus, there is a need to select prioritized locations for interventions under the different missions using a combination of remote sensing (to identify degraded or fragmented forest patches) and dynamic global vegetation modelling (to identify the most vulnerable forest types to climate change) and field studies (for agro-forestry). It may be good to consider GIM as a large-scale pilot project to learn, since many innovative forest conservation, restoration and afforestation programmes and practices are included. The research areas have been correctly identified in the Mission. In India, few institutions are involved in research and modelling related to climate change. The scientific and technical capacity of the forest research institutions, including the Indian Council for Forestry Research and Education need to be significantly enhanced, particularly for ecological research and modelling of climate change impact, mitigation and adaptation aspects. These institutions have their strengths in research on silviculture and plantation studies.

Carbon mitigation potential of GIM

GIM makes a crude estimate of the mitigation potential of different options by simply multiplying IPCC global default value for growth rates with area. Further, the GIM seems to consider only aboveground living biomass, excluding other carbon pools. Mitigation potential is determined by various factors such as consideration of:

- Different carbon pools (aboveground and belowground biomass, soil organic carbon and dead organic matter).
- Rates of change in the carbon pools.
- Transfer and dynamics of different carbon pools.
- Harvest and extraction of timber, fuelwood, etc.
- Initial stock of different carbon pools.
- Species-mix and density.
- Phasing of the activity and area planted during different years.

Various models are available for estimating the mitigation potential, viz. COMAP, GCOMAP, CO_2Fix, Roth C and CENTURY[8]. The mitigation potential is estimated using COMAP for the area proposed under different sub-missions in the GIM. Table 1 provides the estimates of incremental and cumulative mitigation potential for the different interventions.

The mitigation potential was estimated using the COMAP model, as done by other studies[3,9,10]. The growth

rates for aboveground biomass and soil organic carbon were obtained from the literature and belowground biomass was computed using the IPCC default value of 0.26. The incremental annual mitigation potential of only the GIM interventions was estimated to be 148.8 Mt CO_2 for 2020. This alone has the potential to offset 6.4% of the national GHG emissions[11] projected for 2020. GIM provides an incomplete estimate (e.g. excluding soil carbon) of the mitigation offset potential of only 1.5% of the projected GHG emissions. If the mitigation potential of the ongoing afforestation programme (of 1.2–1.3 mha, annually) under different schemes of the Government of India, State governments and externally aided agencies is considered based on a earlier study[3], the total mitigation potential (ongoing afforestation + GIM interventions) is estimated to be 246 Mt CO_2, with a potential to offset 10.5% of the projected national GHG emissions. These estimates exclude any emissions resulting from harvest and disturbance. Thus the forest sector can significantly contribute to reducing GHG emissions in India in the coming years.

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