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Sustainable forest management

The United Nations Forum on Forests (UNFF) defines sustainable forest management (SFM) as a dynamic and evolving concept aimed at maintaining and enhancing the economic, social, and environmental value of all types of forests[1] to benefit present and future generations (FAO n.d.). Globally, forests occupy ~31 per cent of the total geographical area (TGA) (FAO 2024) and serve as vital ecosystems delivering a broad array of ecosystem services[2]. Additionally, forests directly support the livelihoods of ~25 per cent of the global population by providing food, timber, and other essential resources, thereby contributing significantly to economic development (MoSPI 2022; United Nations 2021). Despite their vitality, they are one of the most threatened ecosystems facing challenges of deforestation[3], degradation caused by land conversions and expansion of economic activities (FAO 2024)[4].

Indian forests occupying ~24 per cent of the TGA are critical carbon sinks, contributing significantly to the net-negative emissions trend since 2018 in the Agriculture, Forestry and Land Use (AFOLU) sector (Biennial Update Report 2021). Under its Nationally Determined Contributions (NDCs), India aims to enhance forest and tree cover to sequester an additional 2.5-3 billion tonnes of CO2 equivalent and restore 26 million hectares of degraded land by 2030 (MoEFCC 2023). Additionally, the Forest Policy of 1988 targets 33 per cent forest cover for India (PIB n.d.). However, in recent times, the country has witnessed a significant rise in deforestation between 2015 and 2020 compared to the previous 30 years (Utility Bidder, 2024). Furthering this is a trend of declining growing stocks by 8 per cent over the last two decades (Bhushan 2022). While overall forest cover and net gains have increased (FAO 2024), severe degradation has affected over 15,000 sq. km of forest areas within two years (ISFR 2019; ISFR 2021).

The National Forest Commission Report (2006) identifies that 41 per cent of India's forests are degraded, with 70 per cent lacking the capacity for natural regeneration and 55 per cent classified as fire-prone (Banerjee and Madhurima 2013). India's National Biodiversity Action Plan (NBAP) (2008), in conjunction with the Forest Commission Report, identifies three primary drivers of forest degradation in India:

1. Desertification and loss of natural regeneration potential
2. Spread of invasive alien species
3. Damage caused by forest fires (NBAP 2008)

[1] Forest ecosystems, despite variations in their composition and structure, are generally defined as land areas exceeding 0.5 hectares, with tree canopy cover greater than 10 per cent, and not designated for agricultural or other specific non-forest land uses (CBD 2006; Schoener 1989).
[2] Ecosystem services from forests include biodiversity conservation, carbon sequestration for climate change mitigation, soil conservation, water flow regulation, reduction of risks associated with droughts, floods, and landslides etc.
[3] The rate of deforestation declined over the period, from 15.8 million ha per year in 1990–2000 to 10.2 million ha per year in 2015–2020.
[4] An estimated 420 million ha of forests was converted to other land uses between 1990 and 2020.

Particularly in the state of Odisha, despite 37 per cent and ~40 per cent of the state's TGA having forest cover and forest area respectively higher than the national average and target, the AFOLU sector of the state has net-positive trends in emissions, in contrast to the national trend. This anomaly is largely due to the varied degrees of degradation in 44 per cent of the state's forested areas. Additionally, 23 per cent of Odisha's forests are categorised as highly fire-prone (ISFR 2021), with approximately 16 per cent of the forest area experiencing fire incidents annually. These fires accounted for over 35 per cent of the total forest fires recorded nationally in 2023 (Sudhakar Reddy et al. 2017). In response, the state has committed to enhancing forest cover to surpass 40 per cent of the TGA by 2030 (SAPCC 2018). Achieving this target and mitigation necessitates not only expanding forested areas but also improving forest health through the implementation of SFM practices, which are pivotal to arresting and managing forest degradation in the state.

Recognising the issues highlighted by NBAP and considering the principles of SFM as defined by UNFF, practices relevant to Odisha[5] towards enhancing forest stocks, health and ecosystem services are listed below as:

1. Assisted natural regeneration (ANR)
2. Forest fire prevention and management (FFPM)
3. Terrestrial invasive alien species management (IASM)

Assisted natural regeneration (ANR):

ANR is a restoration technique that aims to accelerate natural succession processes and effectively enhance deforested or degraded lands[6] productivity and ecosystem functions. It is a flexible approach to enhance forest recovery by aiding the growth of natural seedlings and promoting biodiversity by reducing or restricting the external disturbances to the ecosystem (Wilson et al. 2020). To address the degradation in 44 per cent of its forest areas, Odisha has already recognised ANR as a viable solution to promote natural forest recovery through enrichment plantations in their State Action Plan for Climate Change (SAPCC). Accelerating ANR in suitable areas of Odisha could help the state achieve net-negative trends in AFOLU sector emissions through forest restoration, and enhanced growing stocks, while creating local employment through community engagement.

Forest fire prevention and management (FFPM):

Fire is a key ecological process in many ecosystems that determines a wide range of ecosystem attributes spanning cycling nutrients to shaping vegetation structure (Pais et al. 2023). However, uncontrolled large fires lead to major ecological losses and in India, these fires have caused ecological losses worth INR 1,101 crore per year (World Bank 2018). In addition, large fires also significantly contribute to emissions and pollutants in the country and also lead to income losses for the forest-dependent communities. It is estimated that 90-95 per cent of the forest fires in India are man-made, whether deliberate or accidental (iForest 2023).

[5] Stakeholder consultations

[6] Degraded areas are defined as open and moderately dense forests which are defined based on forest cover inside the recorded forest area (RFA) of the state.

Prolonged dry seasons, intensified by climate change, have significantly increased the frequency of large forest fires by 52 per cent between 2011 and 2019 (CEEW 2022), compounding the largely human-driven causes of these incidents. In 2023, Odisha alone accounted for over 35 per cent of

India's forest fire incidents (Barik 2023). Recognising the impacts of forest fires on ecosystems, Odisha currently mandates a district level action plan with annual targets "zero forest fires". However, the execution of such plans relies heavily on the inadequately funded centrally sponsored schemes like FFPM[7] and CAMPA[8] that lead to inefficient staffing and untimely management (NDMA 2022). Long-term prevention of forest fire mechanisms can be achieved through implementing cost-effective nature-based practices such as soil moisture conservation, promoting fire-resistant species, and timely restoration of burnt areas with increasing density of firelines and their timely maintenance (NDMA 2022). Odisha could leverage nature-based solutions (NbS) to become an exemplary state in managing large fires, avoiding significant emissions from forests, and maintaining their ecological wealth in a people-friendly and cost-effective manner.

Invasive alien species management (IASM) - Terrestrial flora in forest area

Alien species introduced through human activities often include a subset known as invasive alien species (IAS), which establish and proliferate, severely impacting biodiversity, ecosystems, and human well-being. IAS disrupt ecosystem services, degrade resources, and rank among the top five global drivers of environmental change alongside land-use change, exploitation, climate change, and pollution (Bongaarts 2019). Alarmingly, one-sixth of the global land area is highly vulnerable to bio-invasions (Early et al. 2016). In response, Target 6 of the Global Biodiversity Framework seeks a 50 per cent reduction in IAS introduction and establishment rates (CBD n.d.).

India has acknowledged IAS as a significant biodiversity threat but relies primarily on regulatory frameworks like the Prevention and Control of Infectious and Contagious Diseases in Animals Act (2009), the Plant Quarantine Order (2003), and the Destructive Insects and Pests Act (1914). Despite these measures, 22 per cent of India's natural areas are impacted by 11 terrestrial floral IAS (Mungi, Qureshi, & Jhala 2023). Odisha, a hotspot for biological invasions, exemplifies this challenge. For instance, in the Gandhamardan Hill range, *Ageratum conyzoides* are among 64 exotic species threatening dense forest interiors (Reddy & Pattanaik 2009).

Effective IAS management strategies, when integrated into broader forest management frameworks, are vital for curbing biological invasions, restoring ecosystems, and enhancing ecosystem services. While Tamil Nadu is leading the efforts on IAS management with a state policy, Odisha could become the first state in India to roll out a concentrated action or an action plan towards controlling and managing IAS in order to protect and maintain their ecosystems while maximising its contribution to India's commitment to the Global Biodiversity Framework.

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[7] Forest Fire Prevention and Management Scheme is a centrally funded programme specifically dedicated to assisting the states in prevention, preparedness, and management of forest fires

[8] The Compensatory Afforestation Fund Management and Planning Authority (CAMPA) scheme is meant to promote afforestation and regeneration activities as a way of compensating for forest land diverted to non-forest uses.

Opportunities for 2030

Jobs, market, and investment opportunity[9]

I. Assisted natural regeneration (ANR)

Assuming that the entirety of 44 per cent degraded forest areas in Odisha amounting to 23,000 sq. km of recorded forest area (RFA) can be restored by 2030,

- ANR can generate ~ **223,000 full-time equivalent (FTE) jobs[10]** by 2030 through the restoration process with a 5-year implementation period[11] per hectare[12]. The jobs generated include

  aspects of nursery development for producing quality planting material (QPM)/nursery development and management, site identification, site preparation for restoration, restoration activities, and maintenance and conservation activities. It is important to note that all the job opportunities are non-permanent and annual jobs except for the nursery development category, lasting only for the 5-year implementation period.

  During the 5-year ANR implementation period per hectare, ~24.5 per cent of the job creation can be attributed to maintenance and conservation activities, primarily occurring in the final four years. Similarly, ~59.4 per cent of jobs created can be attributed to site preparation and ~15.8 per cent to plantation activities, both existing solely during the first year of ANR activities. Additionally, a minor fraction, about 0.3 per cent, of jobs can be attributed to the nursery development phase serving as indirect employment, aimed at producing QPM for enrichment plantation activities.

- Implementing ANR in 23,000 sq.km of degraded forests will require **USD 2,000 million[13]** to execute until 2030. The cost of implementation includes capital costs of nursery development, costs of labour of restoration activities and cost of inputs for restoration activities across a 5-year implementation period.

- Non-timber forest products (NTFPs) are assumed to be the direct economic output of the ANR activities. As a result, ANR implementation would lead to a **~USD 300 million[8]** of market opportunity through sustainable harvesting of NTFPs[14] from completely restored areas in 2030.

[9] For detailed methodology, refer to Annexure
[10] Authors' analysis of stakeholder consultations
[11] 5 year implementation period is assumed as the period post which the ANR restored site will become naturally resilient and can support forest regrowth without any assistance or intervention
[12] 1 hectare of forest area is considered as standard unit area of land for the analysis
[13] Authors' analysis
[14] Sustainable harvesting rate of 50 per cent was assumed for NTFPs of value of $1,880 per ha of dry deciduous forests that are predominant in Odisha (Bhattacharya, n.d.). Harvesting is assumed to be eligible in those areas that have completed their restoration implementation period of 5 years.

- The RFA in **Angul, Kandhamal, Keonjhar, Malkangiri, Rayagada, and Sambalpur** face comparatively higher degradation levels, offering significant potential for implementing ANR.

II. Forest fire prevention and management (FFPM)

Our analysis considers additional jobs that can be created, and market and investment opportunity to manage a maximum of 40 per cent[15] of large fire incidents across 5 fire-prone classes (ISFR 2021) inside the RFA.

- To achieve the Government of Odisha's goal of establishing zero-forest fire villages, as outlined in the District Forest Fire Action Plan for Mayurbhanj (2023), an estimated **~18,000** additional FTE jobs can be created. These roles, complementing the existing fire squads and other resources allocated by the Forest Department, aim to reduce forest fire incidents in the state by 40 per cent.
  The jobs created are spread across activities including establishment of new fuel breaks, implementation of soil-moisture conservation measures in high-fire-prone classes of forest areas, maintenance of additional fuel breaks, increased controlled burning operations in dry forests, awareness activities among forest fringe villages through community institutions like Van Suraksha Samities (VSSs) and eco-development committees (EDCs), and fire squads for monitoring during fire seasons.

  Among these, 16.4 per cent of jobs are permanent that are needed for maintenance and monitoring of forest fires, and the rest of the jobs are created in the first year of establishing NbS infrastructure. In addition, **~400** FTE jobs among the total jobs will be created for post-fire management activities such as burnt-area assessments and burnt-area restoration activities by 2030.

- Accordingly, an additional investment of **USD ~34 million** will be required to achieve the target, which includes cost of equipment, labour costs, and costs of QPM for post-fire management activities.

- Average annual avoided emission by reducing 40 per cent of large forest fire incidents has been considered to calculate the amount of carbon credits generated by 2030. As a result, **USD ~87 million**[16] the worth of carbon credits can be generated by 2030.

- According to the forest fire vulnerability analysis in ISFR 2021, **Kandhamal, Mayurbhanj, and Sundargarh** districts exhibit high susceptibility to forest fires, underscoring the urgent need for NbS to prevent and manage forest fire incidents effectively.

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[15] Based on stakeholder consultation - Without technological interventions, NbS practices for forest fire management cannot help to manage more than 40 per cent of large fires.
[16] The annual avoided emissions attributed to a 40 per cent reduction in large forest fire incidents are estimated at 32.9 $TgCO_2e$/year, with each generated carbon credit valued at $6.6.

III. Invasive alien species management (IASM) - Terrestrial flora in forest area

For our analysis, we consider the whole of RFA except for the total protected area (PA) in the state to be susceptible to biological invasions.

Considering the case where 70,000 ha[17] of area under invasions inside RFA can be restored by 2030:

- Mechanical control methods for managing and controlling IAS in Odisha can generate **~3,000 full-time equivalent (FTE) jobs** by 2030 through the restoration process with a 5 year implementation period per hectare.

  One per cent of these jobs are to produce QPM for post-management restoration activities and the **99 per cent** of jobs are for controlling and removing IASM activities executed through "cut-root-stock" methods which include removal of biomass, drying of biomass, transportation and restoration of the infested area.

- To restore 70,000 ha of infested area inside RFA by 2030, an investment of **USD ~20 million** will be required which includes costs of equipment, inputs, QPM, transportation and labor costs.

- A market opportunity of **USD ~5 million** can be unveiled by 2030 when the biomass removed from the infested areas considered is utilised equally for fuelwood and biochar production at the community level.

Why should Odisha invest in sustainable forest management and practices?

- **Net-negative emission from AFOLU sector:** Sustainable forest management practices present an opportunity for Odisha to enhance its carbon sink capacity through enabling the natural regeneration capacity of the ecosystems. It is estimated that natural regeneration could absorb approximately 23 per cent of global CO2 emissions annually, a rate that is 32 per cent higher than previous estimates reported by the Intergovernmental Panel on Climate Change (IPCC) (Cook-Patton et al. 2020). Recognising the critical role of forest cover in mitigating climate change, Odisha has committed to increasing its forest cover to 43 per cent of the TGA (SAPCC 2018). While complementing expansion in forested areas, the state can adopt sustainable forest mat gain of management practices to improve the quality and productivity of existing forests resulting in a potential ne4 Mg C ha-1 on a landscape scale (Imai et al. 2009) increasing the overall sink without compromising on the required land-use changes in the state. For Odisha, sustainable forest management can become an effective tool for enhancement of the state's rich forest ecosystems.

- **Cost-effective strategies:** Despite its labour-intensive nature, sustainable forest management practices have demonstrated substantial cost-effectiveness in enhancing

[17] 70000 ha of invasion or infested area is benchmarked against Bhutan's IASM strategy to restore Himalayan Oak forests in 5 years.

ecosystem services and achieving ecological balance compared to traditional tree plantations. According to estimates by the World Resources Institute (WRI 2022), the cost of ANR is approximately one-third that of tree plantation efforts. Furthermore, evidence from Brazil indicates that the expenses associated with ANR amounted to only 77 per cent of those incurred for total afforestation projects (Crouzeilles et al. 2020). In the context of Odisha, our analysis shows that ANR amounts to merely one-fifth of the total Compensatory Afforestation Fund Management and Planning Authority (CAMPA) expenditure on a per-hectare basis, as per the financial outlay declared in the Annual Plan of Operations (APO) 2023-24 by the Odisha Forest Department (Forest Department GoO 2023). While cost-effectiveness may vary across different methodologies, ANR consistently outperforms traditional tree planting and extensive afforestation programmes in terms of financial efficiency, underscoring its value in sustainable environmental management. In addition, nature-based forest fire prevention techniques have also proven to be much more cost-effective than human intervention-based forest fire prevention techniques (Nicholas Institute n.d.). On the other hand, the IPBES report highlighted that IAS cost humanity more than $400 billion a year as per 2019 estimates. These economic costs measured as cost of outputs/ecosystem services of natural ecosystems have been found to have quadrupled from 1970 to 2019 (IPBES 2023). A study estimated that India has borne an expense of $182.6 billion from 1960-2020 due to just 10 IAS (Bang, Cuthbert, and Haubrock 2022). These costs could be avoided by eradication and management of invasive alien species. Odisha could leverage these cost-effective strategies to enhance their sink capacity, maintain ecosystem balance, and enhance ecosystem services.

- **Biodiversity conservation:** Odisha has actively engaged in plantation initiatives to mitigate biodiversity risks, as outlined in its SAPCC for 2021-30. The state acknowledges climate change as a significant threat to biodiversity. Biodiversity and wildlife conservation have been earmarked as a key priority (Priority 10) within its SAPCC. Despite the recognition of plantations in reducing biodiversity risks, evidence suggests that naturally regenerating forests have demonstrated greater efficacy in reviving and safeguarding biodiversity compared to active plantations (Crouzeilles et al. 2016). While not entirely replenishing the original biodiversity, natural regeneration presents a more authentic approach to restoring degraded ecosystems, aiming to approximate the original ecosystem services and biodiversity levels. The state can leverage sustainable forest management practices to enhance natural forests to maintain ecosystem health for enhancing biodiversity.

Inspiration from a success story

An initiative in Mandla, facilitated by the Foundation for Ecological Security (FES), eradicated invasive lantana from 7,000 hectares, benefiting local agriculture and biodiversity in forest areas. Technical and financial support led to significant environmental and economic outcomes: 50 per cent of farmers now cultivate previously infested lands, with a remarkable 94 per cent utilising these areas for grazing or fodder collection, increasing fodder production by eight-fold in village commons. Additionally, 46 per cent of farmers have observed the increased return of forest produce and reduced human-wildlife conflicts across Mandla. Persistent community management, including penalties for damaging the recovering ecosystem, has been vital in maintaining these achievements. Similarly, FES has been undertaking initiatives of IASM in Barkhedi where 77 ha of forest land has been cleared of lantana. It is now used as grazing land for animals (FES 2023) by the 370-odd Gond tribal families who live there. In Odisha, FES has undertaken initiatives in Angul to clear invasions of *A.conyzoides* in 30 ha of "village forests" since 2019. Within 3 to 4 years of IASM, the forest-dwelling communities in Angul have seen positive change in forest composition. Some communities also highlighted the reduced search costs for non-timber forest produce (NTFPs) as a result of the interventions[18].

Who could support in scaling SFM?

1. **Role of departments:**
    a. **Forest, Environment and Climate Change Department:** to be the nodal department for setting Project management unit for sustainable forest management value chain, resource allocation through convergence central and state level schemes (Ama Jangal Yojana, FFPM scheme, GIM, CAMPA etc), from state to beat level strategies, coordination between multiple departments, stakeholders, etc.

    b. **Department of Water Resources:** to play a crucial role in supporting the implementation team of Forest, Environment and Climate Change Department in controlling aquatic weeds, provides resources for suppression of forest fires, and scientific tools for water table maintenance in degraded ecosystems.

    c. **Revenue and Disaster Management Department** to coordinate for land allocation, ensure legal support, and assists in mitigating environmental disasters that may impact regenerated areas. Also, supports districts with respect to coordination and allocation of resources for forest fire management. The department could play a role in bridging land owners and the forest department during implementation through incentives for private forests management.

[18] Stakeholder consultation

d. **Department of Panchayati Raj and Drinking Water:** to align community-led SFM activities and incentivise community action and voluntary work, allocation of man-power for implementation through MGNREGA, maintain the bioresources compendium at the Gram panchayat level, coordinate procurement for gram panchayat or village levels for Minor Forest Produces/invasive species, etc. It could develop guidelines for managing village forests with the help of VSSs and EDCs.

e. **ST & SC Development, Minorities & Backward Classes Welfare Department** to leverage Odisha's Tribal Empowerment and Livelihoods programme with DoEF to implement ANR and IASM value chains through disbursement of pounding petitions of community forest rights (CFR).

f. **Odisha Skill Development Authority (OSDA):** ANR necessitates maintaining and ensuring productivity of the ecosystem by developing skills of village and community-based institutions for monitoring the ecosystems which could be facilitated through ground level initiatives of OSDA. It could also develop capacities through certifications and courses for temporary and hi-tech nursery establishments.

g. **Department of Micro, Medium and Small Enterprises:** Setting up nurseries or raising seedlings is capital intensive. The department could develop modules with DoEF and devise schemes to promote nursery developments for QPM manufacturing. It could also develop standardization certification with DoEF to ensure production of quality nursery materials and seedling production.

h. **Odisha Biodiversity Board:** with DoEF the boards can provide technical assistance for mapping and generating status reports of IAS in Odisha through Biodiversity Management Committees (BMCs) and support DoEF to conduct periodic and annual burnt area assessments.

i. **Science and Technology Department, Odisha:** Plays a crucial role in integration of technology by developing tools for maintaining resource maps, coordination of forest fire alerts across the state, mapping ecosystem health, and conducting site assessments through OCR technologies that can help village- and beat-level assessments across the forests without high-skilled labour.

j. **Odisha Rural Development and Marketing Society:** SFM is associated with value addition and supply chain interlinkages for minor forest producers. ORMAS could play a role in helping BMCs/FPOs/SHGs to manufacture and market value-added products such as biochar, furniture, value added MFPs etc.

2. Role of the private sector

a. **Investment and financing:** Private investors and financiers can provide essential capital for SFM projects, either through direct investments, loans, or partnerships. They could utilize impact investing channels and develop metrics focused on ecological resilience and ecosystem productivity through SFM activities.

b. **Innovation and technology**: Companies, especially in the tech and manufacturing sectors, can contribute innovative solutions for efficient resource management, monitoring efforts, and data analysis related to ANR, forest fire and IASM activities. This includes advancements in satellite imagery, drone technology, and GIS systems.

3. **Role of civil society organisations (CSOs):**

a. **Community mobilisation and participation:** Many CSOs work directly with local communities, ensuring that ANR initiatives are aligned with their needs, rights, and traditional knowledge. They could help in mobilising community participation, which is crucial for the success and sustainability of SFM projects.

b. **Technical assistance and capacity buildin**g: CSOs often provide training and resources for SFM methods in lines with DoEF, helping communities and other stakeholders understand and implement best practices in conservation and regeneration.

c. **Research and monitoring:** Some CSOs focus on collecting data, conducting research, and monitoring & evaluation of IASM and ANR projects, contributing to a better understanding of best practices and outcomes.

d. **Networking and partnerships:** CSOs can facilitate partnerships between governments, local communities, international agencies, and the private sector, creating a collaborative network that enhances the scope and impact of all SFM initiatives.

Overcoming challenges to scale sustainable forest management

1. **Lack of direct economic benefits through SFMs:** State policies emphasise SFM through initiatives such as the Green India Mission and Compensatory Afforestation. However, resource allocation and implementation often replicate plantation-centric approaches. Despite being a policy priority since the early 2000s, the extent of degraded lands remains unchanged (Land Desertification Atlas 2019), signaling significant gaps in policy execution. This stagnation may stem from inadequate technical expertise, resulting in ineffective restoration practices, as well as operational barriers such as insecure land tenure and limited community rights.

   Moreover, restrictive regulations on tree harvesting in natural forests and limited access to forest resources, including grazing and NTFPs, under the stringent oversight of the Forest Department, further deter community involvement in sustainable regeneration and restoration efforts. These challenges not only hinder community participation but also risk prioritising monoculture plantations over the restoration of biodiverse natural forests.

   Way forward: Incentivising community participation is equally critical through dissipating community rights over natural landscapes. Introducing monetary incentives for landowners, including communities and individuals, can encourage active involvement in SFM while maintaining ecological productivity. These financial measures can align local efforts with restoration and sustainable forest management goals. To ensure long-term sustainability, performance-based models like Payment for Ecosystem Services (PES) or green credits should be adopted.

2. **Lack of biophysical data on degradation:** Although the Odisha Forest Department (OFD) serves as the nodal agency for SFM, insufficient data at the institutional level, coupled with a lack of technical expertise for ground truthing and limited technological capabilities for spatial recognition, hampers effective implementation. For example: the absence of comprehensive state-level bioresource mapping has led to misclassification, where understory forests are often included in the broader forest cover, resulting in highly infested areas being misidentified as forests rather than degraded ecosystems.

   Way forward: To enhance sustainable forest management, it is crucial to integrate resources from the National Biodiversity Authority (NBA) and Odisha Biodiversity Board (OBB) with the Forest Survey of India (FSI) satellite imagery analysis. This can facilitate the development of tools for identifying species and mapping bioresources at the state level in regular intervals. Collaborating with CSOs will further support the identification and restoration of degraded ecosystems, ensuring a more accurate and actionable approach to sustainable forest management while indicating socio-economic dependencies on the identified land.

3. **Insufficient departmental resources and expertise:** A survey conducted by the World Bank across Forest Departments in India identifies significant constraints in managing and preventing large forest fires, including limitations in equipment, technology, infrastructure, and labour shortages within the departments (World Bank 2018). While this is regarding forest fires, our stakeholder consultation indicates that this reality is exacerbated by non-timely allocation of financial resources that restrict Forest Departments' capabilities for effective and timely implementation of sustainable forest management practices.

   Way forward: To address the resource gap, a seasonal co-management model for forest areas should be developed, involving both forest fringe communities and private players. Private entities can contribute technology, knowledge, and capital, while forest-fringe communities can help mitigate labour shortages. The Forest Department should explore tripartite public-private-community partnerships, structured around equity-sharing agreements with local forest community institutions such as Joint Forest Management Committees (JFMCs), Village Forest Societies (VSSs), Eco-Development Committees (EDCs), and Gram Panchayats. This collaborative approach can enhance resource management capacity, integrate local knowledge, and build long-term sustainable forest management practices.

Risk-proofing the scale-up of sustainable forest management

1. **Socio-economic risks:** Degraded forests might be linked to producing non-timber forest products (NTFPs), fuelwood, and other socio-economic uses by the forest-fringe and forest-residing communities. Naturally regenerated forests require lesser and reduced disturbances until they become resilient. Aiming to restore native species might compromise incomes and other socioeconomic outcomes temporarily for a few years for these

communities. As a result, communities may not support natural regeneration prerequisites, in turn, disturbing the regeneration.

Mitigation: Such risks can be mitigated through inclusive sustainable forest management plans utilising socio-economic interaction-based planning to increase the success rates of the restoration and management. Hence, a community-centric approach in SFM project planning and execution by engaging forest-dwelling and local communities in all phases to align their needs with conservation goals.

2. **Technical failures:** The chances of failure of natural regeneration are higher than those of tree planting in cases where external uncontrollable disturbance risks are higher, such as cyclones, forest fires, frost, etc (Minore 1987). These failures could result from overstory mortality that eliminates seed sources of desired species, reduces sources of vegetative reproduction, causes problems related to limited seed dispersal, and releases competing vegetation in the understory (Dey et al. 2018). As restoration and forest management is a technical and time-sensitive process, any deviation might become counterproductive. For example, *L.camara* have higher seed dispersal rates and presence of seeds in soils. As a result, *L.camara* propagates immensely due to fires. Similarly, any management or eradication-based strategies must coincide with dry-season and non-flowering seasons.

   Mitigation: Building localised technical restoration capacities by leveraging indigenous ecosystem knowledge becomes critical to ensure successful restoration. However, to ensure long-term sustenance of the restored area and conservation, resolving land tenure issues, granting community forest rights, and empowering community-based institutions like VSSs andEDCs through legal recognition becomes inevitable.

Annexure

Scoping of the sustainable forest management value chain

In this analysis, we focus on employment opportunities created specifically for the SFM value chain, from input production to maintenance and conservation activities required for the ecosystems. In simple words, we restrict the scope of the value chain to restoration and conservation only. As a result, we exclude harvesting and value-addition of forestry products and associated activities, as these activities typically are not interlinked with the restoration process.

SFM is categorised into three key nature-based practices for this analysis: **assisted natural regeneration (ANR)**, **forest fire prevention and management (FFPM)**, and **invasive alien species management (IASM)**. The scope of these practices focuses on RFA in Odisha, as reported in the **India State of Forest Report (ISFR) 2021**, as sustainable forest management practices can happen in the areas of designated forests as per the Forest Conservation Act, 1980 under the jurisdiction of the Department of Forests[19].

Scoping for SFM Practices:

1. **Assisted natural regeneration (ANR)**: We limit our scope of analysis for ANR to degraded forest areas, characterised by reduced forest cover in terms of percentage of their canopy coverage below <70 per cent. These include forest classes identified as **open forests** and **moderately dense forests** (TERI 2017).
2. **Forest fire prevention and management (FFPM)**: We restrict the FFPM practices to ground-level, nature-based fire management techniques that aid in large fire prevention, management and post-fire management activities. As a result, while FFPM includes aspects of technology for detection and management, we exclude these owing to them not being considered as nature-based solutions. Consequently, NbS for FFPM can prevent and manage not more than 40 per cent of large fire incidents[20].
3. **Invasive alien species management (IASM)**: The scope of IASM focuses solely on terrestrial flora invasions occurring outside the **protected area network (PAN)**. We exclude PANs due to their classification as pristine forests with minimal human interaction[22]. Additionally, we consider only mechanical methods for managing invasive alien species, as stakeholders identified chemical and biological approaches as either ineffective or risky.[22]

Jobs and market estimation (in units)

I. **ANR:**

ANR aims to enhance the classification of degraded forests by improving their forest cover to the next larger category (open forests to moderately dense forest and moderately dense forest to very dense forest). This process typically involves activities such as the production of high-quality planting

[19] Stakeholder consultation
[20] Stakeholder consultation

material, site identification and preparation, and ongoing maintenance and conservation efforts. These activities are designed to be implemented at the scale of one hectare of degraded land as defined earlier. The implementation period for ANR is assumed to span 5 years per unit area, after which the ecosystem is expected to attain resilience to disturbances. Beyond this period, natural regeneration processes are anticipated to sustain and yield desired ecological outcomes.

For Odisha, our analysis estimates that restoring 100 per cent of degraded forest areas—approximately 15,945.01 sq. km (open and moderately dense forests within recorded forest areas)—will require nearly doubling the annual effort outlined in the SAPCC. The target area estimated based on the ISFR 2021 is assumed to be not subjected to change based on any external events, shocks or conversions.

II. **FFPM**:

We limit the scope of FFPM activities to RFAs, categorised into five fire-prone classes as per ISFR 2021 (indicated in table 1).

Table 1: RFA and their forest fire prone classes

Fire-Prone Class	**Area (sq. km)**
Extreme Fire Prone	1,725.96
Highly Fire Prone	4,731.08
Moderately Fire Prone	8,152.40
Less Fire Prone	12,216.35
Least Fire Prone	34,378.38
Total Recorded Forest Area	61,204.17

These activities include fire prevention, management, and post-fire restoration of burnt areas. Given the cyclic nature of forest fires, we base our analysis on historical trends to achieve a 40 per cent reduction in large fire incidents through FFPM interventions.

Our consultations indicate that NbS-based measures—such as soil and moisture conservation, controlled burning, and other ground-level activities—can independently prevent 40 per cent of large fire occurrences. FFPM efforts complement technological interventions to enhance fire prevention and management outcomes. Odisha aims to achieve “zero forest fire villages” by managing 100 per cent of large forest fires, of which we consider the benchmark target of reducing their occurrence by 40 per cent for our analysis.

III. **IASM**

For our analysis, we consider the current invasive species infestation in 22 per cent of the RFA, excluding the PAN, as reported by Mungi, Qureshi, and Jhala (2023). This corresponds to an estimated 7,977.96 sq. km eligible for restoration. Infestation densities within this area were determined using a case study approach in Odisha, categorising 20 per cent as high density, 30 per cent as medium density, and 50 per cent as low density. Restoration efforts vary across these categories, reflecting the increased complexity and intensity required for areas with higher infestation levels.

We define high-density infestation as covering 70 per cent or more of the area, medium density as 40–70 per cent, and low density as less than 40 per cent. The implementation period for restoration is assumed to span five years, after which ecosystems are expected to achieve resilience to external disturbances and support natural regeneration processes.

In the absence of targeted policies or initiatives to manage invasive alien species (IAS) in India, we adopt an ambitious restoration scenario inspired by Bhutan's effort to restore 70,000 hectares of Himalayan oak forests over five years. By comparison, we consider the feasibility of restoring 700 sq. km of infested forest area within a similar timeframe.

Restoration of infested areas incorporates activities predominantly reliant on manual restoration methods. These activities include site mapping, cutting and drying of invasive species, transportation, plantation and site maintenance. Efforts are distributed across the five-year implementation period, with varying intensity tailored to each stage of restoration.

Data collection:

To assess labour requirements for each stage across SFM practices, a total of 20 key informant interviews (KIIs) were conducted with nursery managers, project developers and CSOs across Odisha and other states. The KIIs focused on gathering data on the activities in production of quality planting material, and effort required in terms, transportation of planting material, site prepping, plantation, infrastructural requirements and maintenance and conservation. A mix of purposive and convenience sampling was employed to select project developers, ensuring relevance and accessibility of data sources.

The KIIs were structured to capture quantitative and qualitative information on forestry as practice. The quantitative section focused on the number of people employed or effort required at various stages. Additionally, qualitative questions explored risks, and challenges, alongside potential interventions to address these challenges in various stages of the value chain.

FTE calculation

The FTE for SFM, was calculated using 1 hectare of land as the standard unit. A man-day was defined as 8 hours of labour, and 360 standard working days were assumed for the restoration sector per year. The total man-days required for each restoration activity per hectare were summed and divided by the standard 360 working days. This method provided an estimate of the annual labour required, expressed as FTE, offering a clear metric for understanding the full-time workforce needed to achieve restoration goals per hectare under standard work conditions.

Annual FTE for per hectare across activities:

$$Full\ time\ equivalent\ (per\ hectare\ per\ activity) = \frac{Total\ number\ of\ mandays\ for\ the\ activity}{Total\ number\ of\ working\ days\ in\ a\ year}$$

Total FTE per hectare:

$$Total\ FTE\ per\ hectare\ \ =\ \sum Sum\ of\ FTE\ per\ hectare\ per\ activity\ across\ 3\ value\ chain\ and\ activities$$

Total FTE

$$Total\ FTE\ =\ \sum Total\ FTE\ per\ hectare\ \ *\ Total\ area\ considered\ for\ restoration\ for\ value\ chain$$

Note: The jobs created last only until the restoration activity is completed in the considered sites.

I. **ANR**

The job multiplier for ANR-related activities was derived from consultations with two organisations with over 20 years of experience in ANR implementation. The multipliers include:

- 0.42 for site preparation during Year 1,
- 0.11 for plantation at a density of 800 seedlings per hectare in Year 1,
- 0.07 for maintenance and conservation per hectare each year from Year 2 through Year 5.

These figures were derived from consultations that involved collecting data on the total period of implementation, hours of labour engagement across all activities over the 5-year period, and the days of labour engagement across the activities. The data were subsequently validated using the Cost-of-Norm documents developed for ANR implementation by the Government of Odisha.

The total FTE was then calculated for the implementation area between 2025 and 2030 based on activities per hectare. This was done by multiplying the FTE per hectare for each year with the area considered for uniform implementation, and then normalising the total with the global average tenure for a job, which is typically 5 years. This calculation yielded a total of 222,850 FTE jobs for the scenario under consideration.

The distribution of FTE for ANR activities is as follows:

- Year 1: Site Preparation and Plantation: 0.53 FTE/hectare
- Year 2: Maintenance and Conservation: 0.07 FTE/hectare
- Year 3: Maintenance and Conservation: 0.07 FTE/hectare
- Year 4: Maintenance and Conservation: 0.07 FTE/hectare
- Year 5: Maintenance and Conservation: 0.07 FTE/hectare

In parallel, for nursery activities, the FTE for local nurseries involved in the development of native species was also calculated based on consultations with the two aforementioned organisations. Data on the number of labourers engaged, their respective days of engagement, and the capacity of local nurseries for seedling production were collected. The total number of seedlings was estimated, factoring in a 10 per cent attrition rate. Accordingly, the FTE per nursery with a production capacity of 10,000 seedlings per year was estimated to be 0.10 FTE. The FTE per nursery was then multiplied by the total number of nurseries required based on the annual seedling production requirements.

II. **FFPM**

The Forest Department has implemented various on-ground measures to curb, control, and prevent forest fires. Our estimation focuses on the additional interventions required to meet the projected scenarios, building upon these existing efforts. These interventions vary in relevance and intensity based on the forest fire-prone area classes outlined by the Government.

For certain activities, we estimate the FTE per hectare by calculating the man-days required for each activity annually per hectare, then multiplying by the total number of working days in a year. We then apply the FTE per hectare to the relevant areas within each forest fire-prone class.

For other activities, such as awareness creation, which is a critical annual task, we calculate the FTE per EDC or VSS based on the man-days required for labour engagement in creating awareness within local institutions. We then multiply the FTE per EDC or VSS by the total number of existing EDCs and VSSs, as well as those planned for formation in the next six years, in line with government targets to establish 1,000 additional EDCs and VSSs.

III. **IASM**

Similar to Assisted Natural Regeneration (ANR), we estimate the FTE per hectare based on the man-days required annually per hectare for the three infestation classes (high, medium, and low) over the five-year implementation period. For nursery and seedling production, we calculate the FTE per nursery, then multiply it by the total number of nurseries required based on the annual seedling demand.

Market opportunity estimation

I. **ANR:**

Non-Timber Forest Products (NTFPs) represent the direct outputs obtained from Assisted Natural Regeneration (ANR) sites. A natural dry deciduous forest is estimated to generate an average annual net revenue of $1,880 per hectare. However, considering the sustainability of resource extraction, it is assumed that only 50% of the NTFP value can be harvested sustainably, based on averages derived from various sustainable harvesting rates. Using this assumption, the annual monetary opportunity (MO) for 2030 was projected.

The estimation accounts for a three-year lag in harvesting activities, corresponding to the implementation period of ANR. Furthermore, only the additional or restored forest areas are considered eligible for sustainable harvesting to ensure that the calculation reflects additional Full-Time Equivalents (FTEs) generated beyond those already supported by community harvesting practices.

II. **FFPM:**

Since Forest Fire Prevention and Management (FFPM) practices do not yield direct tangible products, the potential carbon credits generated annually—calculated as a function of avoided emissions through the reduction of forest fire incidences by 40%—serve as an indicative measure of effectiveness. The average annual reduction in emissions is estimated based on current emissions, which amount to approximately 360.06 Tg CO_2e/year from forest fires in Odisha, as reported in secondary literature. To estimate the annual monetary opportunity, the avoided emissions were valued using an average carbon price of $6.6 per tCO_2e.

III. IASM

During the five-year implementation period of the IASM, the harvested biomass from IAS serves as a direct output of the intervention. The market opportunity associated with IASM is calculated by quantifying the total biomass accumulated over the implementation period. This estimation is influenced by the infestation density and the variability in biomass availability across different infestation levels during the intervention.

For utilization, it is assumed that 50% of the harvested biomass will be allocated for use as fuelwood, valued at INR 5 per kilogram, based on Ministry of Statistics and Programme Implementation (MoSPI) guidelines. The remaining 50% is designated for conversion into biochar, valued at INR 150 per kilogram, as per prevailing market prices.

Investment opportunity estimation:

For SFM, we view the total investment as an input towards creating natural capital, establishing mangroves as a tangible ecological asset. To estimate the investment opportunity, we account for all costs incurred throughout the restoration process. This includes:

1. Capital costs for setting up nurseries
2. Labour costs involved in nursery operations and various phases of restoration, and
3. Costs for planting materials and other necessary inputs for restoration activities

Type of Cost	Cost in units (INR/unit)
Capital Cost - nursery set up	1 lakh/nursery of 10000 seedling generation capacity per year
Labour costs	INR 280/per man-day of work

We estimate the total investment opportunity by aggregating the annual expenditures of all sites across different stages of the restoration process through 2030.

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