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Importance of quality planting material in Indian agroforestry systems and bio-energy plantations: A review

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Abstract
Different agroclimatic conditions prevailing in India make Agroforestry fit for sustained living. Agroforestry, even though it has the potential to improve the economic status of the farmers still farmers are one step behind to adopt it as it works in the long run, but one discomfort won't keep this practice out of the box. The developing countries are facing major global warming and climate change problems because of the less green cover therefore the solution comes here by practicing Tree outside forest / Agroforestry. The success of Agroforestry mainly depends on the selection and procurement of quality planting materials and region-specific plant selection. This review highlights the huge demand for forests and their byproducts also quality planting materials, which are important in Agroforestry.

Keywords: Agroforestry, quality planting material, tree outside forest

Introduction
India's diverse agroclimatic conditions allow for the cultivation of various agricultural, horticultural, and forest species. Its four biodiversity hotspots make it one of the 17 megadiverse countries in the world. India's habitat and climatic conditions make it rich in biological diversity resources. (Venkataraman, K. and Sivaperuman, C., 2018) [23]. We also have Forests which are known to be critically important habitats in terms of the biological diversity they contain and ecological functions they serve. Taking species counts as an illustration of biological diversity, the number of described organisms constitutes a total of 1.75 million and it is conjectured that this may be just 13% of the true total (Heywood, V. H. and Watson, R. T., 1995) [13] What fraction of this uncertain total resides in the world's forests is unknown. The values of forests therefore embody the values of the biological diversity they contain.

Forests provide essential resources such as oxygen, shelter, water, nourishment, and fuel. Over 1.6 billion people depend on forests for survival, and 70 million people, including indigenous communities, call forests home. (Costanza *et al*., 1997) [5].

The fate of our forests is deeply intertwined with the fate of people who depend on them. Therefore, it is crucial to conserve tree species. Currently, around 7,800 tree species are threatened with extinction on a global scale (Newton, A. C., 2008) [19]. Despite the significant global importance of trees, many species are under threat in the wild.

It is currently estimated that 17,500 species of trees are at risk of extinction in the wild, which represents one-third of the world's tree species. This puts the crucial services they provide to people and the planet in jeopardy. Over-exploitation is a major threat to many of these species, as some are harvested for their timber or medicinal properties, while others are experiencing population decline due to habitat loss and deforestation caused by human development and land use changes in dominated landscapes (Oldfield *et al*., 1998) [20].

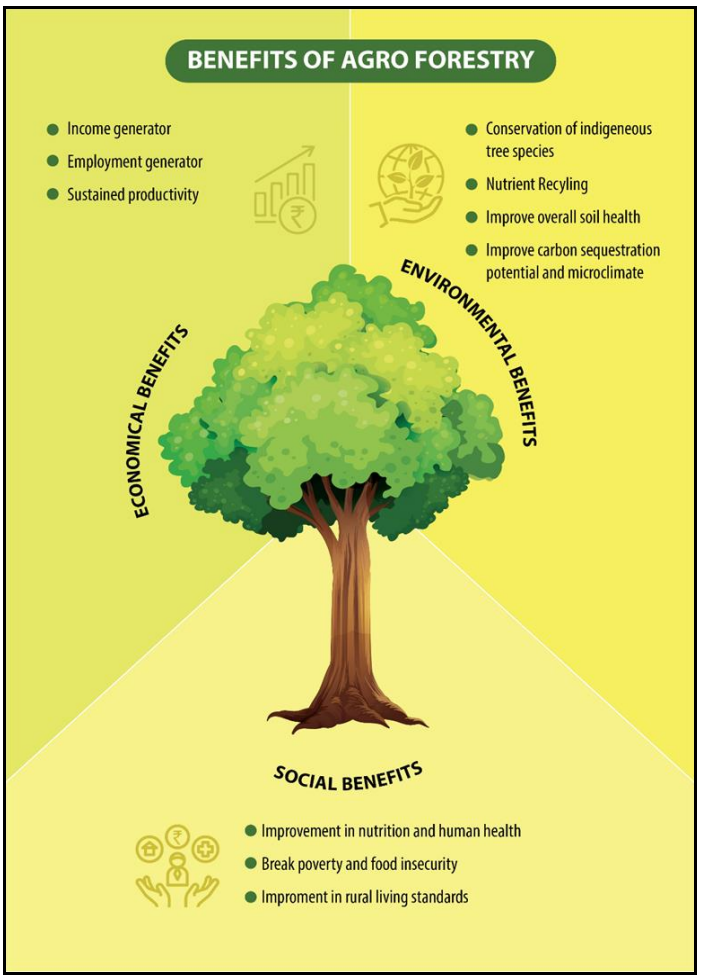
Climate change is posing several threats to tree species, including an increase in the occurrence of fire or cyclones. Globalization has facilitated the transfer of exotic pests and diseases across the world, which has made many common tree species vulnerable to invasive species. This susceptibility to invasive species has put these trees at risk of extinction (Pan *et al*., 2013) [21].

The forest cover in India is only 24.39%, which is below the recommended 33% stated in the National Forest Policy of 1952 and 1988. The policy advocates the use of agroforestry to increase the country's green cover.

Trees and floral species are crucial for maintaining ecological balance. They provide habitats for numerous species, regulate climate, purify air and water, and contribute to soil fertility. Humans also depend on them for food, fuel, timber, medicine, and more. Therefore, conserving tree species is essential.

It is now widely acknowledged that the loss and degradation of native forests is a global environmental crisis. From 2000 to 2005, the global forest area was reduced by approximately 20 million hectares per year (Hansen *et al*., 2010) [10], with undisturbed primary forests declining by an estimated 4.2 million hectares (or 0.4%) annually (FAO, 2010).

The loss and degradation of forest ecosystems is one of the major causes of global biodiversity loss due to human activity (UNEP, 2009) [22]. The clearance of forests for agriculture, mining, urbanization, and industrial development contributes to the loss of forests and tree species in the wild. To alleviate the pressure on forests and ensure the availability of timber sustainability, it is essential to implement trees outside the forest operations and agroforestry with the best quality planting material.



Source: https://www.multiplexgroup.com/

Fig 1: Benefits of AGROFORESTRY

Tree outside the Forest

Forests and trees contribute significantly to the world's energy consumption, accounting for about 7 percent of the total energy used. Wood fuel is more important in developing countries than in industrialized ones. In developing countries, approximately 15 percent of energy needs are met through wood fuel, with around 80 percent of the wood used for this purpose. (Wright *et al*., 2013) [24]

According to the reports, the total forest area has increased from 708,273 km2 (21.54%) in 2017 to 713,789 km2 (24.39%) in 2023. Additionally, there is a rising trend of trees outside forests, from 93,815 km2 (2.85%) in 2017 to 95,027 km2 (2.89%) in 2019.

Currently, the combined land cover of forests and trees outside forests makes up around 25% of the total geographical area of the country. The total estimated growing stock is 5,915.76 million m^3, of which 4,273.47 million m^3 is located inside forests, with an average growing stock of 55.69 m^3 per hectare. The growing stock of trees located outside forests is estimated to be 1,642.29 million m^3 (Jadhav *et al*., 2019) [14].

Table 1: India, round wood demand forecasts by wood-based sector, 2021-2030 (million m^3 RWE)

Year	Pulp and Paper	Furniture	Plywood and other wood-based industries	Construction	Total
2021	12.5	8.98	15.45	22.71	59.64
2022	12.5	9.47	17.88	21.79	61.64
2023	12.5	9.95	20.69	20.88	64.02
2024	12.5	10.44	23.94	19.96	66.84
2025	12.5	10.92	27.70	19.05	70.17
2026	12.5	11.40	32.06	18.14	74.10
2027	12.5	11.89	37.10	17.22	78.71
2028	12.5	12.37	42.93	16.31	84.11
2029	12.5	12.86	49.68	15.39	90.43
2030	12.5	13.34	57.49	14.48	97.81

Source: (Kant, P. and Nautiyal, R., 2021) [16]

Table 1 shows the total requirement of wood for various purposes, highlighting the significantly high demand. Due to deficient timber production in the country, this high demand can only be met through imports. This is because the country has become more focused on conservation after the notification of the National Forest Policy in 1988. In 1996, the Government of India classified wood under the Open General License (OGL) in an attempt to ease the wood shortage and reduce the demand for timber from natural forests (Jenkins *et al*., 2018) [15].

According to the OGL policies, the majority of the round wood needed in India is sourced from trees outside the forest. Specifically, out of the yearly production of 47 million m3, 45 million m3 is sourced from these trees, while the remaining 2 million m3 is obtained from state-owned forests (Gamfeldt *et al*., 2013) [8].

Agroforestry

According to the Global Forest Resources Assessment 2020 by FAO, the world has a total forest area of 4.06 billion hectares (10.0 billion acres), which accounts for 31% of the total land area. More than one-third of the world's forest cover is primary forest that is naturally regenerated with native species and no visible indication of human activity. The FAO estimates that deforestation causes a loss of 13 million hectares of forest each year (CAFRI VISION 2050) [2]. Due to deforestation, existing biodiversity is lost, which would take 1000 years to recreate, and sometimes it is irreversibly damaged due to the extinction of species and loss of habitat, exacerbating global climate change.

Agroforestry is a technique that can help improve soil fertility by increasing root proliferation (Murthy *et al*., 2013) [17]. It also boosts soil physical and chemical properties and increases

beneficial microbe load through litter decomposition. For instance, a study showed that agroforestry of poplar with wheat in winter and black gram in summer doubled the organic carbon content compared to sole cropping, which in turn enhances overall soil health (Gupta *et al*., 2013) [9].

In certain northern and northeastern states of India, farmers who have adopted agroforestry practices are experiencing greater social and economic benefits as compared to other farmers (Chakraborty *et al*. 2015) [3]. Agroforestry is especially beneficial for small and marginal landholding farmers who live near forests, as it helps to increase productivity on the same piece of land. Furthermore, women in larger Indian states living with agroforestry are also reaping health and income benefits from this practice (Bose 2015) [1].

One limiting factor in the adoption of agroforestry is the delayed initial return. It may take up to two decades to see significant returns, according to Dagar *et al*. (2013) [6]. In contrast, agriculture typically generates quicker benefits due to the income generated directly from the sole crop system every year, and a fixed return can be expected after a certain duration. The benefits of incorporating agroforestry are illustrated in Figure 1.

Agroforestry in India

In India, deforestation is becoming a significant concern due to various activities carried out in the name of development, such as the construction of dams, mining, and other large-scale projects. The increase in population, industrialization, urbanization, and timber industry further exacerbates the issue. Shockingly, India is ranked second in global deforestation rates, having destroyed an average of 668,400 hectares of forests between 2015-2020, according to CAFRI's Vision 2050 report.

Illegal logging due to timber demand and fuel wood consumption driven by growing population has led to deforestation. Agroforestry, a traditional land management system practiced in India for centuries, is an effective way of integrating trees and shrubs into various crops and crop-livestock production systems. India is leading research, education, and policy-level support to agroforestry, which has increased its coverage in the world for the past three decades.

In 2014, India launched its National Agroforestry Policy, which has been hailed as the world's most dynamic policy aimed at promoting agroforestry. As a significant move, the Corporate Social Responsibility (CSR) law of India was amended to include agroforestry as a legitimate CSR activity. The establishment of a dedicated Sub-Mission on Agroforestry (SMAF) was also recommended by the National Agroforestry Policy (NAP) (Dhyani and Handa, 2013) [7]. The Government of India established SMAF under the framework of the National Mission for Sustainable Agriculture (NMSA), with a budget of Rs 935 crore for four years, starting from 2016-17.

The SMAF aims to improve tree cover, soil organic matter, planting material, livelihoods, and productivity. The National Bamboo Mission was launched in 2018 to support this goal. Increasing productivity through intercropping multi-purpose trees is a proven way to diversify farmers' income and achieve the government's target of doubling farmers' income by 2022-23. Agroforestry has the potential to be a game changer in achieving India's target of increasing its tree cover by 5 million hectares. While India has made impressive progress in food production, it still faces the challenges of climate change and the risks associated with rain-fed agriculture.

Over 55 countries have implemented Agroforestry as a solution to mitigate climate change. In India, the forest cover is only 24.39%, which is below the recommended 33% by the National Forest Policy. Agroforestry can help increase the green cover of the country, as highlighted by Dhyani and Handa in 2013 [12]. State governments are organizing huge plantation drives to support this cause. However, the survival rate of plants used in these drives is poor, and the quality of plants is not up to the mark.

The emission of greenhouse gases and its alarming consequences have made it necessary to establish carbon sequestration mechanisms. The carbon credit mechanism also calls for a green economy. Perennial plants, which are accessible to populations outside reserve forests, offer a possibility of mitigating climate change while providing a range of products such as fruits, spices, medicines, fuelwood, fodder, timber, pulp, and paper. Therefore, it is essential to pursue the strategy of increasing Trees outside the Forest (TOF) urgently.

Quality Planting Material

"Quality Planting Material" refers to the process of producing healthy and uniform planting material, whether by seed or vegetative methods. The ultimate goal is to raise the overall quality of the plant, both in terms of its physiological and phytosanitary properties, in order to enhance productivity and benefit stakeholders.

Agroforestry requires trees and appropriate planting materials. It's mostly practiced on private, community, and government lands, which may have harsh environmental conditions. Quality planting materials are crucial for successful agroforestry. However, many nurseries don't follow recommended practices for production, which affects the quality of plantations.

The quality of planting material is often unreliable due to issues such as genetic makeup, varietal purity, and the presence of diseases and pests. While private nurseries cannot be solely blamed for this, factors such as poor stock sourcing, inadequate mother block establishment, propagation methods, and nursery stock-management practices also contribute to the problem. In addition, the lack of QPM production guidelines and relevant training opportunities for the nursery industry further exacerbates the issue. It's worth noting that the annual demand for commercially important tree propagules, such as eucalypts, poplars, Multi-Purpose Tree Species, and casuarinas is around 10 million, while the supply is only about 8 million (Chaturvedi *et al*., 2017) [4].

India plants 3 billion plants every year covering 1.5 million ha of forest and private land. A decentralized nursery network following national guidelines is needed to produce QPM for the increasing demand of fruit and timber species. In India, there are approximately 6,000 plant nurseries, both small and large. Among them, 70% are privately owned, while the remaining 30% are government-owned. It is crucial to regulate these nurseries to ensure that they produce high-quality planting material based on scientific knowledge and principles (Handa *et al*., 2019) [11].

Source: https://www.multiplexgroup.com

Fig 2: Quality planting Material Procedures

Identification of source of planting material

It is important to ensure the accurate identification of tree species, which should be performed by a certified expert in tree taxonomy. Therefore, a group of such experts should be designated and available to accrediting agencies. The use of DNA barcoding is a modern technology that can be further expanded and utilized to confirm the identity of the species. Genetically superior trees at the mature stage of growth and with the documented flowering cycle should be used for multiplication in accredited nurseries (Handa *et al*., 2019; Muralidharan *et al*., 2015) [11, 18]. The establishment of clonal and seed orchards at nurseries, State Forest Departments, research institutes, and agricultural universities ensures the availability of tested seeds and clones for mass propagation.

Important Agroforestry species based on Agro-climatic zones of INDIA

Agro-ecological zones	States	Rainfall	Soil type	Agroforestry species	
				Rainfed	Irrigated
Arid ecosystems					
1) Western Himalaya (Cold Arid)	J&K and Himachal Pradesh	<150 mm	Shallow skeletal soils	*Ulmus wallichiana*, *Hippophae*, *Betula*,	Poplar species, *Salix*
2) Western Plain, Kutch and Part of Kathiawar Peninsula (Hotarid)	Gujarat, Rajasthan, Haryana, Punjab	<400 mm	Desert & saline soils	*Prosopis cineraria*, *Dalbergia sissoo*, *Tecomella undulata*, *Acacia tortilis*	*Poplar* hybrid, *Eucalyptus camaldulensis*, *Melia*, *Ailanthus excelsa*, *Acacia nilotica*
Semi Arid					
3) Deccan Plateau	Andhra Pradesh, Telangana and Karnataka	400-500 mm	Red & black soils	*Acacia nilotica*, *Leucaena leucocephala*, *Ailanthus Excelsa*	*Eucalyptus* hybrid, *Melia*, *Tectona grandis*
4) Northern Plains and Central Highlands including Arvallis	Gujarat, Rajasthan, UP, Haryana and Punjab	500-1000 mm	Alluvial derived soils	*Acacia nilotica*, *Hardwickia binata*, *Acacia nilotica*, *Azadirachta indica*	*Populus deltoides*, *Ailanthus excelsa*, *Eucalyptus* hybrid, Subabul
5) Central Highlands (Malwa), Gujarat plains	Gujarat and MP	500-1000 mm	Medium & and deep black soils	*Acacia nilotica*, *Dalbergia sissoo*, *Millettia pinnata*	*Tectona grandis*, *Gliricidia sepium*
6) Deccan Plateau	Karnataka, Andhra Pradesh, Maharashtra MP	600-1000 mm	Shallow deep) black soils	*Eucalyptus tereticornis* and *Bambusa* spp. *Santalum album Tectona grandis*	*Acacia catechu*, Aonla (*Emblica officinalis*),Ber, Mango
7) Deccan Plateau and Eastern Ghat	Telangana & Andhra Pradesh	600-1100 mm	Red & black soils	*Leucaena leucocephala*, *Millettia pinnata*	*Tectona grandis*, *Eucalyptus* hybrid, *Mahogany*
8) Eastern Ghat, TN uplands and Deccan Plateau	Karnataka, Tamil Nadu, Kerala	600-1000 mm	Red loamy soils	*Ceiba pentandra*, *Acacia leucocephala*, *Santalum album Mahogany*	*Casuarina equisetifolia*, *Melia*, *Eucalyptus* hybrid, Neem, Moringa, Tamarind,
Sub-Humid					
9) Northern Plains	Bihar, Uttar Pradesh and Punjab	1000-1200 mm	Alluvial derived soils	*Dalbergia sissoo*, *Melia composita*, *Bamboo*, *Millettia pinnata*	*Populus deltoides*, *Eucalyptus tereticornis*
10) Central Highlands (Malwa, Bundelkhand and Eastern Satpura)	Madhya Pradesh and Maharashtra	1000-1500 mm	Black and red soils	*Leucaena leucocephala*, *Dalbergia sissoo*, *Acacia nilotica*, *Hardwickia binata*, *Cordia rothii*	*Tectona grandis*, *Butea monosperma Bambusa* spp *Mahogany*
11) Eastern Plateau	Chhattisgarh	1200-1600 mm	Red & Yellow soils	*Terminalia* spp., *Butea monosperma*, *Albizia procera*, bamboo *Acacia nilotica*	*Gmelina arborea*,
12) Eastern (Chhota Nagpur) Plateau and Eastern Ghat	Orissa, WB, Bihar, Chhattisgarh, MP and MH	1000-1600 mm	Red & lateritic soils	*Ceiba pentandra*, *Eucalyptus* hybrid	*Gmelina arborea*, *Casuarina equisetifolia*,
13) Eastern Plains	Uttar Pradesh and Bihar	1400-1800 mm	Alluvium derived soils	*Dalbergia sissoo*, *D. latifolia*	Mulberry (*Morus alba*)
14) Western Himalaya	J&K, and HP Uttarakhand	1000-2000 mm	Brown forest podzolic soils	*Grewia optiva*, *Eucalyptus* hybrid, *Celtis australis*, *Melia azedarach*	*Populus deltoides*, *Salix* spp.,
Humidper-humid					
15) Bengal and Assam Plains-Brahmaputra plains and Ganga Plain ranges	West Bengal and Assam	and 1800-2000 mm	Alluvium derived soils	*Bombax ceiba*, *Eucalyptus*, *Lagerstroemia speciosa*,	*Anthocephalus cadamba*, *Tectona grandis*
16) Eastern Himalaya	Arunachal Pradesh, Sikkim, west Bengal	2000 mm	Brown and red hill soils	*Alnus nepalensis*, Bamboo, *Anthocephalus cadamba*	*Flemingia macrophylla*, *Indigofera tinctoria*
17) North Eastern Hills (Purvanchal)	Tripura, Mizoram and Meghalaya	2000 -3000 mm	Red and lateritic soils	*Alnus nepalensis*, *Albizia lebbeck*, *Lagerstroemia speciosa*, *Bombax ceiba*	*Gmelina arborea*, *Bamboo*,
Coastal					
18) Eastern Coastal Plains	Tamil Nadu, Puducherry, Andhra Pradesh, Odisha and West Bengal	900-1100 mm	Coastal alluvium derived soils	*Borassus Flabellifer*, *Ceiba pentandra*, *Erythrina indica*	*Casuarina equisetifolia*, *Acacia mangium*,
19) Western Ghats and coastal Plains	Gujarat, Diu& Daman, Maharashtra, Goa, Karnataka, Kerala	>2000 mm	Red, lateritic and alluvium-derived soils	*Terminalia* spp., *Grevillea robusta*, *Erythrina indica*	Bamboo, *Tectona grandis*,
20) Andaman, Nicobar and Lakshadweep	Andaman, Nicobar and Lakshadweep	Andaman and Nicobar 3000 mm, Lakshadweep Islands 1600 mm	Red loamy and sandy soils	*Erythrina indica*, *Ceiba petandra*, *Albizia lebbeck*,	*Pterocarpus dalbergioides*, *Tectona grandis*

Source: Handa *et al*., 2019 [12].

Conclusion

The availability of quality planting material is crucial for the economic growth of forest lands that supply timber. Short-duration plantations need to be followed by long-duration ones to prevent putting pressure on the forest while providing economic benefits to growers. This also serves as a link to timber supply markets that rely on wood. To execute successful plantations, it is essential to identify accredited nurseries that provide good-quality plants and have agroforestry knowledge for implementation in the farm field. Knowledge for executing energy plantations is the most critical aspect during plantation activities based on different agroclimatic zones. India currently imports timber, and the demand for timber is long-lasting. Therefore, investing in agroforestry can be executed without many difficulties. Instead of calculating direct economic benefits, we can benefit from hidden benefits like carbon sequestration, climate change mitigation, global warming, and conservation of indigenous species, which can be done effectively. It is, therefore, the right time to adopt agroforestry as a successful economic model.

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