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Van Sangyan

Note to Authors:

We welcome the readers of Van Sangyan to write to us about their views and issues in forestry. Those who wish to share their knowledge and experiences can send them:

by e-mail to vansangyan_tfri@icfre.org

or, through post to The Editor, Van Sangyan,
Tropical Forest Research Institute,
PO-RFRC, Mandla Road,
Jabalpur (M.P.) - 482021.

The articles can be in English, Hindi, Marathi, Chhattisgarhi and Oriya, and should contain the writers name, designation and full postal address, including e-mail id and contact number. TFRI, Jabalpur houses experts from all fields of forestry who would be happy to answer reader's queries on various scientific issues. Your queries may be sent to The Editor, and the expert's reply to the same will be published in the next issue of Van Sangyan.

Cover Photo: Panoramic view of Achanakmar-Amarkantak Biosphere Reserve

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From the Editor's desk

At global level, availability of data on TOF is often scarce, despite its increasing importance in a continually urbanizing world. In many countries, official government assessments of national forest resources do not inventory trees outside forests and therefore TOF status and characterization has until now, been unknown. Furthermore, trees outside forests are difficult to detect using the medium-resolution satellite data on which current global-scale forest monitoring systems rely. However, importance of TOF is increasing as continued rate of urbanization worldwide is driving a concern for the separation of people from the natural environment. Under this scenario, TOF may provide critical products, including fruits, firewood plus ecosystem services that natual forest provides, albeit to a little extent than large intact forests. TOF are also capable of contributing significantly to biomass stocks but are generally overlooked in rural or agricultural areas.

In line with the above this issue of Van Sangyan contains an article on Trees outside forests: Prospects and opportunities. There are also useful articles viz. Grewia optiva Drummond a multipurpose tree in north western Himalayas, Fruit based agroforestry systems in Himachal Pradesh, Plantix app: A success story of Artificial Intelligence in plant protection, Potential timber trees for homegardens: A quick glance from Kerala, Quality planting material production of three major timber trees in agroforestry: seed and nursery techniques, Soil microbiome: A natural terrestrial saviour for healthy ecosystem and A bird's eye view on major agroforestry practices and systems in Andhra Pradesh.

I hope that readers would find maximum information in this issue relevant and valuable to the sustainable management of forests. Van Sangyan welcomes articles, views and queries on various such issues in the field of forest science.

Looking forward to meet you all through forthcoming issues

Dr. Naseer Mohammad

Chief Editor

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Contents **Page**

1. **Trees outside forests: Prospects and opportunities** 1
   - P.A. Clara Manasa, Supriya K. Salimath., Ramakrishna Hegde, N.L. Deepthi Dechamma and Manjunath Gooli

2. ***Grewia optiva* Drummond a multipurpose tree in north western Himalayas** 12
   - Sanatan Katna

3. **Fruit based agroforestry systems in Himachal Pradesh** 16
   - Parul Bhushan, D.R. Bhardwaj, Prashant Sharma, Dhirender Kumar, Nasam Midhun Kumar, Alok Kumar Singh

4. **Plantix app: A success story of Artificial Intelligence in plant protection** 24
   - Ipsita Samal, Tanmaya Kumar Bhoi, Asit Kumar Pradhan, Deepak Kumar Mahanta

5. **Potential timber trees for homegardens: A quick glance from Kerala** 27
   - P V Nikhil and S Sarath

6. **Quality planting material production of three major timber trees in agroforestry: seed and nursery techniques** 32
   - T S Krishnanunni and S Sarath

7. **Soil microbiome: A natural terrestrial saviour for healthy ecosystem** 36
   - Jaya Prajapati, Janardan Yadav and Brajkishor Prajapati

8. **A bird's eye view on major agroforestry practices and systems in Andhra Pradesh** 40
   - P R Sandra, P V Nikhil and S Sarath

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Trees outside forests: Prospects and opportunities

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Introduction

Globally, human-induced land degradation negatively impacts 3.2 billion people, contributing to distressed migration and increased conflict. Degrading lands drive species extinction and intensify climate change (IPBES, 2018). There is a consensus that land management strategies contribute to climate change mitigation and adaptation, combat desertification, and enhance food security (IPCC 2018, 2019). Landscape restoration, which is the long-term process of regaining ecological integrity and enhancing human well-being, includes a range of interventions such as natural regeneration, mixed-species plantation, and agroforestry, among others (Chazdon*et al*., 2017). In India, where 700 million people in rural areas are dependent on forestry and agriculture for their livelihoods and sustenance, landscape restoration provides a sustainable pathway for rejuvenating land, strengthening the flow ofecosystem services, ensuring food and nutritional security, and enhancing livelihoods. The government of India (GOI) has made several international commitments to restore lands. This includes the Bonn Challenge and the Land Degradation Neutrality (LDN target commitment to restore combined 26 million hectares of degraded and deforested land by 2030; India's goal under the Nationally Determined Contribution (NDC) to create an additional carbon sink of 2.5 to 3.0 billion tons of carbon dioxide–equivalent (gigatons [Gt] CO_2e) by 2030 through an improved forest and tree cover; and biodiversity targets to achieve the globally shared Biodiversity Vision 2050.

Hence the concept of sustainable land management came into existence. Sustainable land management refers to practices and technologies that aim to integrate the management of land, water, and other environmental resources to meet human needs while ensuring long-term sustainability, ecosystem services, biodiversity, and livelihoods. There are several sustainable strategies, like sustainable forest management, watershed management, and climate-smart agriculture, through which land can be managed sustainably. TOFs can also help sustainable development by conservating biodiversity in an agriculture-dominated landscape. Global climatic change and biodiversity loss are the two crucial issues for sustaining future generations and debatable issues among the global scientific community and policymakers.

Trees outside forests (TOFs)

Earlier, all lands other than the recorded forest area with a tree canopy density of 10 per cent or more can be considered TOF (Chhabra, 2004). Trees outside forests

(TOF) refer to tree resources found outside of Recorded Forest Areas (RFAs) (areas recorded as forests by the government) irrespective of patch size or area (FSI, 2019). Forest Area (or recorded forest area) refers to all the geographic areas recorded as forest in government records.TOF plays a significant role in the livelihood of rural and urban people of the country. Recorded forest areas comprise Reserved Forests (RF) and Protected Forests (PF), which have been constituted under the Indian Forest Act, 1927. Besides RFs and PFs, the recorded forest area may include all such areas, which have been recorded as forests under any State Act, local laws, or revenue records. Forest cover consists of all lands having trees more than one hectare in an area with a tree canopy density of more than 10 percent, irrespective of ownership, the legal status of the land, and species composition of trees. Very Dense Forest is all lands with tree canopy density of 70 percent and above. The relative composition of forest cover under this category is 3.02 percent. Moderately Dense Forests are all lands with tree canopy density of 40 percent and more but less than 70 percent. Forest cover under this category is 9.39 percent. Open Forest is all lands with tree canopy density of 10 percent and more but less than 40 percent. Forest cover of 9.26 percent falls under this category. Tree cover is all patches of trees occurring outside RFA, which are of size less than 1 ha, including the scattered trees. Tree cover forms an integral part of the trees outside forests (TOF). Therefore, tree cover can be considered as a subset of TOF.

Trees outside forests (TOF'S) and FAO

The concept of "Trees outside Forests" emerged in 1995 to designate trees growing outside the forest and not belonging to Forest or Other Wooded Land. An expert meeting in Finland in 1996 recommended that FAO address the need for complex data on TOF. As a result, a thematic study on TOF was included in the Global Forest Resource Assessment (FRA) 2000. In November 2001, FAO organized an expert consultation in Rome on "improving the contribution of Trees Outside Forests to Sustainable Livelihoods." The FAO Forestry Department also conducted regional training workshops such as a workshop on "Assessment of Trees outside Forests (TOF)" held in April 2002 in Dehradun, India (FSI, 2002), and carried out a project on "the role of planted forests and trees outside forests in landscape restoration in low forest cover countries" (FAO, 2004).

In its endeavour to assess forest resources globally, FAO uses an internationally accepted definition of "forest" that countries likewise use in reporting to the FAO's Global Forest Resource Assessment (FRA). FAO developed another forest-like category for reporting purposes: "Other Wooded Land" (OWL). These two categories still only comprise some trees, particularly those growing on agricultural land and in settlements. In many countries, these trees fall outside the "forest" and "OWL" categories yet represent a significant and increasing share of the wood resource because of forest conversion. They also form a resource increasingly acknowledged as important for livelihood and the environment. Thus, for the Global Forest Resource Assessment

2000, FAO - FRA coined the expression "Trees Outside Forests"(TOF) to designate those trees that grew neither in "forest" nor on "OWL.TOF, or more precisely Land with TOF, as a category, should thus be understood about the FAO-FRA classification scheme, and especially about its two main forestry categories: "Forest" and "Other Wooded Land." The definitions of these two categories have slightly evolved since 2001, which means that TOF as a category has also evolved and needs to be clarified, although the definition of TOF given by FAO in (Bellefontaine *et al*., 2002; de Foresta*et al.* 2010) remains valid: "Trees outside forests refer to trees on land not defined as Forest and Other Wooded Land."

Status of TOFs in India

The Forest Survey of India (FSI) estimated the extent of TOF as 29.38 million ha, which is 36.4 percent of the country's total forest and tree cover (FSI, 2021). State-wise, Maharashtra (26,866 sq km) has the most considerable extent of TOF in the country, followed by Odisha (24,474 sq km) and Karnataka (23,676 sq. km).

The "Restoration Opportunities Atlas of India" developed by World Resources Institute India (WRI India) identifies an area of over 50 Mhaof opportunity for TOF, referred to as mosaic restoration in the atlas(Chaturvedi *et al*., 2018). The Forest Survey of India (FSI) classifies areas with tree cover density greater than 70 percent as very dense forests and areas with tree cover density between 40 percent and 70 percent as moderately dense forests (FSI, 2021). Very dense and moderately dense forests have good tree cover with high potential for natural regeneration. During analysis, the LULC layer was overlaid with the tree cover layers to identify forest areas with more than 40 percent tree cover density. These areas were classified for protection.

Additionally, mangroves were also classified under protection. Areas under protection were estimated to be 17.98 million hectares, constituting 5 percent of India's total geographic area. Wide-scale restoration potential was identified in areas where the dominant land use was forests, tree cover density was less than 40 percent, and population density was less than 200 persons per sq. km. Ten percent of India's geographic area, equaling 33.6 million ha, was identified as suitable for wide-scale restoration. The remaining regions were classified as ideal for mosaic restoration. These included rainfed croplands. They have less than 40 percent tree cover density and a population density of less than 400 people per sq. km. The potential for mosaic restoration in India is 87.22 million ha, constituting 26 percent of India's geographic area.

Scope of TOFs in India

Trees outside forests (TOF), can be found on agricultural land, meadows and grazing lands, unproductive lands, along canals, railways, roads, etc. Tree species like Peepal (*Ficus religiosa*) and Banyan (*Ficus bengalensis*) have been traditionally worshipped and are commonly found on temple premises and roadsides. Agroforestry, community forestry, farm forestry, social forestry, and urban forestry are the most critical terms representing small-scale tree planting efforts. Agroforestry and farm forestry are the backbones of TOFs (the most prominent type of TOF). Trees outside Forest have been defined differently by different

countries and international agencies. In India, TOF is defined as all trees found outside the recorded forest, in line with the FAO's definition of TOF as trees available on lands which is not defined as 'forests' or 'other wooded land'.

In the agroforestry sector, comprehensive classification schemes have been elaborated by eminent agriculturists, yet there is only a broad classification system exists that embraces all TOF. A key question is whether TOF constitutes an area (i.e., having a geometrical identity) or whether the resource must be described in other ways, such as growing stock per unit of area on non-forest land. Both options

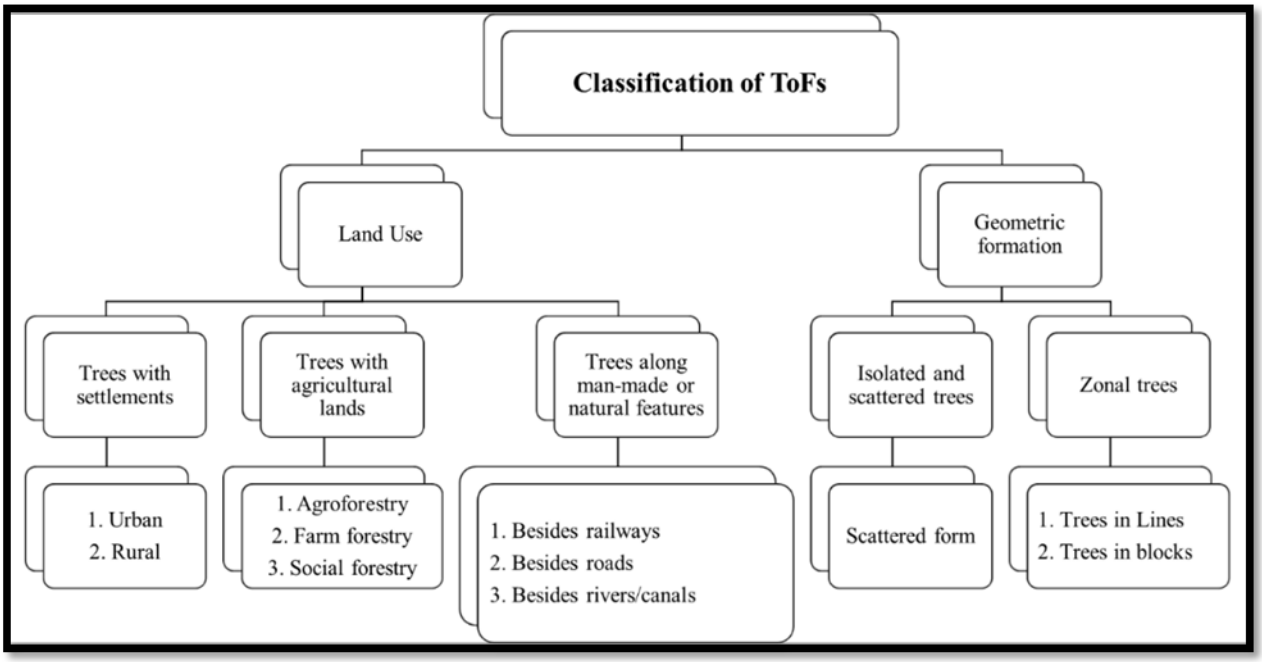

Figure 1: Schematic representation of various Classifications of TOFs (Sources: FSI, 2020)

are valid and allow map representations of the resource that are useful for different purposes. A study documented the existence of at least 47 systems of TOF in India, including agroforestry, urban forestry, block plantations, and linear plantations. The expansion of TOFcan support India's international commitments, including the Nationally Determined Contribution (NDC), the Bonn Challenge, Land Degradation Neutrality target, and Sustainable Development Goals (SDGs). In the last decade, India increased focus on TOFexpansion through policies and schemes that incentivize and support farmers and other practitioners to take up TOFsystems, particularly agroforestry (Duraisami*et al.*, 2022).

In classifying TOF, the lands where TOF are found, both land cover (biophysical: how much of the land is covered by tree crowns) and land use (socio-economic), should be considered. The various classification of TOF resources as per the land use and geometrical formation are given in Figure 1.

Potential of TOFs

TOF plays a significant role in the livelihood of rural and urban people of the country. They also act as important timber and fuel wood sources, contribute to carbon sequestration and biodiversity conservation, provide wildlife habitat, stabilize microclimate etc. They significantly impact rural family economics, food security, and sustainable agriculture. Like forests, they offer a wide range of goods and services. They stave off drought and desertification while preserving water supplies by shielding crops and soil from wind and water erosion. TOF in India has emerged as the primary source of wood-based industries, including plywood and wood panel industries. TOF resources are essential from the national perspective and are also part of the global strategies for combating ecological problems (Figure 2).

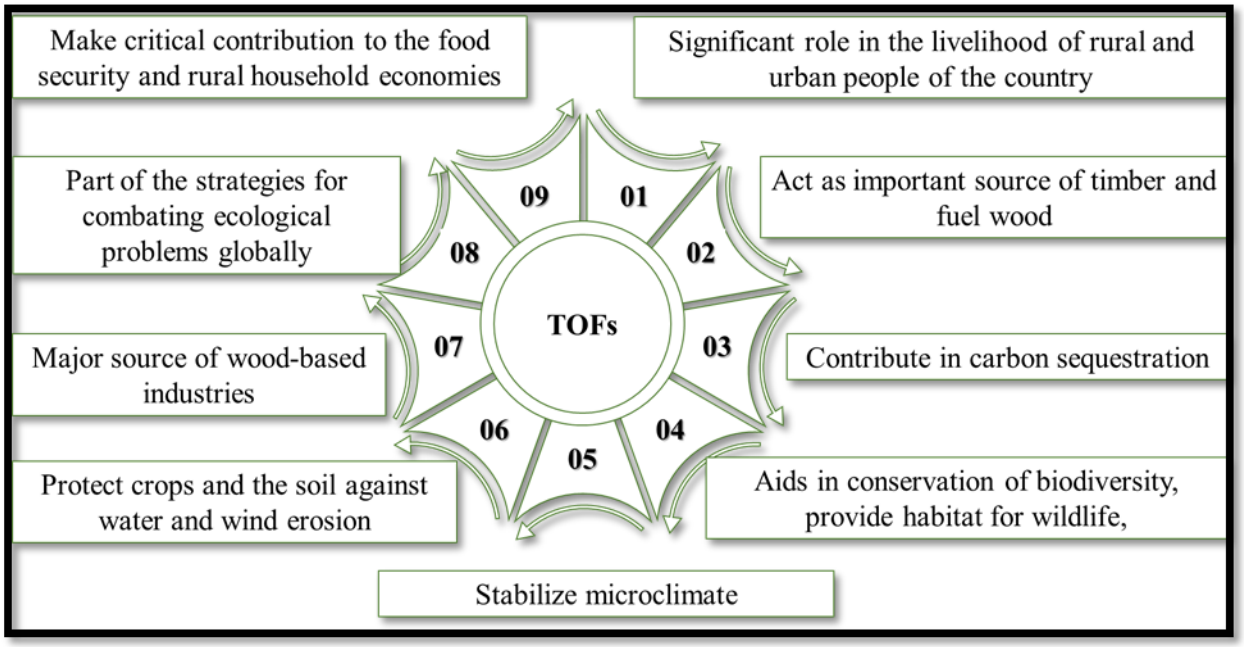

Figure 2: Various potentials of Trees outside Forests

Potential of TOFs: Source of timber

The potential of TOFs as an alternative source for timber production was realized after rising in imports. Various reports and studies suggest that TOFs hold tremendous potential to contribute to the country's timber production and growing stock. TOFs are managed differently among states under different state-level acts and policies (GoI, 2012). Most of the states have a low forest cover; thus utilization of TOF becomes more important. Furthermore, with support from government sectors, especially the Forest Department and wood industries, timber production from TOF has become more lucrative for farmers in these states. This approach could be replicated in other states, particularly those with high forest covers, such as Madhya Pradesh, Maharashtra, Karnataka, and Kerala. The most important aspects of TOF management are existing regulations on species under felling and transit rules and the lack of developed market linkages. The felling and transit regulations vary

considerably for different TOF species, especially between reserved and non-reserved species from private lands (Ghosh and Sinha, 2018).

The growing stock of TOF has remained almost static across recent decades, so it can be assumed that timber production from TOF has also remained static or grown marginally, considering a marginal growth of 25 million cum in the 2015 assessment over the 2011 assessment (TOF growing stock in 2015 was 1,573 million cum). Timber production from TOF is almost 14 times that from forests, nearly two-thirds of which come from Forest Development Corporations (FDCs). In addition, we have 5.38 million cum of annual bamboo production, which is also used as a substitute for timber and in the cottage industry (Shrivastava and Saxena, 2017). With an estimated growing stock of 2.7 billion m^3 in 2005, the predominant product from Indian forests was fuelwood, augmented by supplies from trees outside forests (TOF), which met the country's fuelwood requirement. The TOF covered nearly 2 percent of the land area and played an essential role in meeting the raw material needs for plywood and the pulp and paper industries.

Krishnankutty *et al*. (2008) documented the importance of trees outside forests, particularly in home gardens renowned for their mixed cropping multi-tier agroforestrysystem. The home gardens with a variety of multi-purpose trees may be considered as a model for extension to other similarly endowedregions within and outside the country, not only for wood production but also for social and environmental benefits.National-level estimation ofthe number of trees and their volume for major species by diameter class in TOF is presented in ISFR 2021 report. The report highlighted that *Mangifera indica* and *Azadicahta indica* are two important timber-yielding species that are topping the list. According to Hanumantha *et al*. (2022), 35 timber-yielding species belonging to 17 families were documented in TOF's of Shivamogga, Karnataka. A maximum number of farmers preferred to grow *Tectona grandis* (80.0%) and *Mangifera indica* (63.33%) on their farmlands.

Potential of TOFs: Source of Fuelwood

TOF supplies approximately 49 percent of the fuelwood (Rai and Chakraborty, 2001). Of the total fuelwood consumed (58 million tonnes), that provided through official channels from forests was only 1.23 million tonnes, while that from TOF was 19.25 million tonnes. Krishnankutty *et al*. (2008) opined and presented the demand (consumption plus export) for wood in Kerala during the reference year 2001. The estimated total demand for wood (timber and fuelwood) is 12.261 million m^3 roundwood equivalents, of which wood as fuel accounted for 83 percent and wood as timber for 17 percent. Most of the fuelwood was sourced from Homegardens and rubber estates, a part of TOFs. According to Hanumantha*et al*. (2022), out of the 35 timber-yielding species, a maximum number of species (25) was utilized for fuel wood in Shivamogga, Karnataka.

Potential of TOFs: Source of NTFPs

TOF, including urban and other plantations like roadside, homestead gardens, residential areas, or in various institutional or academic landscapes, contribute positively to the living

conditions of different towns and cities and ensure continuous tree cover to attain benefits for current and future generations. Evaluation of TOF and their services is important to improve our understanding of the status and dynamics of all tree resources. Tamang *et al.* (2018) claimed that the contribution of 95 tree species in the Pundibari campus of Uttar Banga Krishi Viswavidyalaya academic campus could supplement the TOF and are effective in terms of providing different NTFP uses.

Potential of TOFs: Climate change mitigation

A key advantage of TOFs is that it provides private benefits for poor farmers in developing countries and global environmental payoffs. Trees increase ecosystem biodiversity above and below ground, and they can help alleviate global climate change by sequestering carbon – in their live biomass as well as in the soil – that otherwise would be added to the earth's atmosphere. Given their substantial carbon stores and capacity as both carbon sources and sinks for the atmosphere, trees outside of forests (TOF) play a significant role in the global carbon cycle. Because of the importance of biomass estimates in the global carbon (C) cycle, a study by Singh and Chand (2012) demonstrates the potential of the stand wise tree outside forest inventory data and finer spatial resolution of IRS-P6 LISS-IV satellite data to classify TOF, to estimate above-ground TOFphytomass and the carbon content of TOF in a semi-arid region of the southern Haryana, India. According to the study, Haryana's semi-arid region has a significant potential to increase its tree cover because a substantial portion of the state's overall geographic area is made up of cultural non-forest sites. Bio-sequestration potential of trees outside the forest around the agricultural field was higher than strips along the link roads, distributaries/canals, defense ditches, and sample plots in sacred groves (Kour and Sharma, 2017).

Potential of TOFs: Other Ecosystem services

Trees outside the forest (TOF) have potential ecosystem services and have begun to attract more attention due to their economic importance. Planting trees is a successful method for restoring biodiversity, and the world's forest resources play a significant part in the carbon cycle. TOF plays a critical role in sustaining sustainable agriculture, food security, household economy, and supply of many products and services apart from being reservoirs of ecological functions like conservation of biodiversity and carbon sequestration (Tamang *et al.*, 2018). Evaluation of TOF and their services is important to improve our understanding of status and dynamics of all tree resources.

Trees outside forest (TOF) certification standard

The Network for Certification of Conservation of Forests (NCCF) is a non-profit organization established in January 2015, registered under the Societies Registration Act 1860. NCCF aims to develop globally aligned certification schemes for Forest, Trees outside Forests (TOF), Non-Wood Forest Products, Protected Areas and Wetland, etc., within India. NCCF is to address the concerns for sustainable management of forests, biodiversity, plantations, agroforestry, and

urban trees and forests while developing a standard for forests and TOF and also making the Indian wood and fibre-based industry globally competitive, ensuring raw material sustainability. NCCF is a national member from India of the Geneva-based global alliance of national forest certification systems called Programme for Endorsement of Forest Certification (PEFC), which endorses national forest and trees outside forests (TOF) certification systems.

The NCCF has developed the certification standard for the TOF resource through the Standard Development Group (SDG) following an open, transparent and consultative process. The SDG comprises of a wide range of stakeholders *viz*, tree growers, wood-based and paper pulp industries, research and academic institutions, experts, forest departments, NGOs etc. Besides a series of meetings, there have been online consultations, workshops, field visits, public consultations, and finally, pilot testing of the standard in the field.

Policies, schemes, programs, and missions

The goal of India's national agroforestry policy, which was adopted in 2014, is to increase environmental security, supplement the demand for wood, and improve the productivity and lives of rural communities. There are numerous flagship missions: Sub-Mission on agroforestry, Green India Mission, Green highway mission and Nagar van. However, TOFs are managed differently among states under different state-level acts and policies (GoI, 2012). Most states have a low forest cover, thus utilization of TOF becomes more important.

Barriers that impede the uptake of TOF

Implementation of experience through stakeholder consultations highlighted gaps in existing incentives and the need to design customized incentives to suit local contexts. Several of these gaps arise due to the need for a landscape approach in planning TOF activities. The barriers impede the effectiveness of TOF policies and incentives. The following are the different barriers recognized by Duraisami *et al.* (2022) that hinder the uptake of TOFs.

Policy and regulatory barriers

- Lack of landscape approach
- Lack of incentives for existing TOF and traditional practices
- Poor awareness and access to existing policy incentives
- Complicated mechanisms for tree felling, and transit
- Inadequate attention to land tenure and tree tenure
- Lack of an enabling environment in TOF markets
- Poor consideration around gender and social inclusion

Economic and market barriers

- Lack of market and value chains
- The economic viability of agroforestry models and associated business models
- Appropriate certification standards that incentives flow of multiple ecosystem services

Technical knowledge

- Lack of cadre of extension workers who can provide the technical capacities and knowledge gaps to small land-holding farmers and especially women, and incorporate their choices

- Knowledge gaps om traditional TOF models and tree species

Conclusion

In India, due to the increasing population, rapid urbanization, rising demand for quality forest products and limited land mass have resulted in limited options for afforestation, except for wastelands. TOF can bring back harmony to the environment by providing ecosystem services. By fixing the carbon in its biomass and preventing climate change, they significantly contribute to balancing the earth's CO_2 levels. Adopting improved practices for scientific development and sustainable management of plantations on TOF resources with efficient technical extension is essential. Despite the fact that India's forest cover is expanding, it still falls short of the 33 percent of the nation's total geographic area which is the country's forest policy's aim. This target could be reached with the expansion of TOFs.

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Grewia optiva Drummond a multipurpose tree in north western Himalayas

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Introduction

The sub-tropical region of the Western Himalayas is home to *Grewia optiva*, often known locally as Bhimal or Beul, Dhaman which is evenly dispersed between 500-2500 m (Semwal et al.). The species can we found in abundance in the foothills and midhills of Jammu & Kashmir, Himachal

Pradesh and Uttarakhand. It manifests itself on field margins and terrace risers than in a woodland region (Thakur et al.). Beul is a species of moderately sized deciduous tree that lives in a subtropical climate and has highest temperature of 38 degree C an minimum temperature of -2 degree C. This species is prone to frost in autumn and winter season. Where the annual rainfall ranges from 120-150 cm it's widely spread there. Regarding soil it have the ability to thrive on any kind of soil but sandy loam soil with the right amount of moisture is best for it's optimal development. The tree can grow and live in the rainfed seetings, although it does considerably better near the edges of irrigated lands than it does in the rainfed lands. It is strong light demander and requires complete illumination at its best. It can simply be multiplied by the methods of Seeds and Cuttings. It's fully grown leaves makes excellent fodder for cattle, especially during the winter season.

The beul tree grows to a height of 9–12 m, has a clear bole of 3–4 m, and a spreading crown. An established tree is modest in size, with a spreading crown that can grow up to 12 m in height, a clear bole that is 3–4 m in length, and a girth that is about 80 cm. The bark is dark brown, thick, and roughish, peeling off in little woody scales; the branches are smooth and pale silvery-brown; the blaze is fairly fibrous, pale yellow, frequently tinted pink on the

outside, and the juice is sticky. Leaves are opposite, 5-13 cm x 3-6 cm, ovate, acuminate and closely serrate; teeth are small, blunt; rough and hairy above, pubescent beneath, base rounded, lightly oblique, 3-nerved; petiole 0.3-1 cm long, stout, tomentose; stipules 0.5 cm long, linear subulate, caducous. Flowers are 1-8, together; peduncles solitary, leaves are opposite or exceptionally a few axillary; tomentose and 0.8-1.8 cm long. Sepals are 1-1.5 cm long, linear oblong, 3-ribbed, green outside, white, pale yellow or red inside; petals are white or pale yellow, shorter than the sepals, linear and claw distinct.In March–April, the tree shades its leaves, and in April–May, it bears new ones. Having the appearance of flowers with new flush of leaves in the month of April-May and soon after, fruits appears. The fruits reach their full size by September and, depending on the local climate, mature between October and December. The fruit is olive green when it is immature and turns black as it ripens. Birds are the primary means of dissemination, adore fruits. On shoots from the previous year, the fruits are produced. Fruit is a drupe that is 1-4 lobed, with lobes that are around 0.8 cm in diameter and turn from olive green to black when ripe (Orawa et al.).

Multipurpose Uses

Tangible Uses

Food

The ripe fruits can be eaten. It has a tasty acid taste whether it is raw or cooked.

Fodder

Trees are heavily lopped in the winter for this purpose since the leaves provide for good fodder. Other green fodder is typically not offered. About 70% of the weight of the green leaves on the branches is made up of leaves. According to reports, 2-year-old plants produce 11 tonnes of leaf fodder per hectare, and mature trees produce 12 to 30 kg of green fodder per hectare.

The protein and other nutrients in leaves are rather abundant, while tannins are not present. Young leaves and winter leaves have the crudest protein, however during the wet season, it decreases.

Fuel

Since wood has a bad smell, it is rarely utilised as fuel when an alternative is available.

Fibre

The bark produces a fibre that is used to make garments and cordage.

Timber

The wood is whitish with a small amount of reddish-brown heartwood and weighs 801 kg/cu. M. It has a characteristic delicate texture with distinct annual rings. It has strong flexibility and strength qualities and is tough and hard. Once seasoned, manual labour becomes challenging. The wood is utilised for oar shafts, poles, frames, tool handles, and other things that call for strength and flexibility. Its branches are used to make baskets, and it is deemed good for paper manufacture.

Environmental Benefits

Boundary, obstruction, or assistance

The tree is frequently planted in field margins and hedges.

Alley Cropping

The tree and climax grass are planted together.

Management Practices

Planting Method

In pits dug throughout the summer or at the start of the rainy season, planting takes place in July. For block planting along the fields, the spacing is 3 x 3 m, and for single row planting, it is 4-5 m. Plantation areas are prone to the incidents of grazing, browsing and fire so they should be secured from grazing, browsing and fire.

Coppicing & Pollarding

The tree coppices and pollards well, and each year, whippy branches are lopped for fibre and fodder.

Germplasm management

There are 10 000–15 000 seeds per kg, and they can be left out for at least a year without losing viability. To remove the flesh, fruits are rubbed and given a water wash. Each fruit has two to four seeds.

Insect Pest

Defoliation of tree is done by larvae of *Diacrisia* sp. *Var. indica* and *Chasmina tibialis.* The larvae of the family Cerambycidae bore in dead and dry wood.

Conclusion

The Indian Himalayan Region, is under the pressure ofhigh populationgrowth in terms of people and animals, also under increasing pressure due to rising levels of soil degradation.The world's mountain system is now more vulnerable than ever.Bhimal is a multipurpose tree which is used widely in North Western Himalayas from Uttarakhand to Jammu &

Kashmir. Integrating Bhimal with farming system can help in extracting many products from it and also maintaing soil health and environmental benefits. So sustainable management practices should be encouraged for it's optimum utilisation.

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Fruit based agroforestry systems in Himachal Pradesh

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Agroforestry is a technique of intensive land management that aims to maximize the advantages of the biological interactions that result from the selective pairing of trees and/or shrubs with crops and/or livestock (Sharma et al., 2017a) For small-scale farmers in particular, it is a realistic and affordable way to apply many types of integrated land management because it incorporates the cultivation and use of trees in farming systems. It may also improve the sustainability of agriculture while lowering the dangers related to small- and large-scale farming(Sharma et al., 2017b). Therefore, these solutions have the potential to significantly reduce poverty.There are number of agroforestry systems based on fruit plants and almost all the systems are being used in one or other parts of Temperate and semi-arid tropics of India. These systems not only produce fruits but also contribute in meeting the needs for wood, food, fuel, and fodder. They also provide jobs, guarantee a healthy diet, lower GHG emissions, regulate environmental pollution, enhance soil health, and promote economic stability (Verma et al., 2021).Fruit based agroforestry has proven as an important tool for crop diversification. India's National Agricultural Policy, 2000 recommends agroforestry for sustainable agriculture and advocates bringing up agroforestry in areas currently under shifting cultivation. Task Force on Greening India, 2001 projected that additional 28 million ha area should be brought under plantation through agroforestry. For the purpose, 10 million ha of irrigated lands which are suffering from water logging, salinity and water erosion and another 18 million ha of rainfed lands have been ear marked for agroforestry development.

Despite recent advancements, farmers in the northwest region typically lack agroforestry technical skills. In terms of appropriate species composition, ideal plant arrangement and spacing, and management techniques to optimize the delivery of goods and ecosystem services through time, it includes fruit tree-based agroforestry. Diversified tree-based farming systems may have more economic, social, and environmental advantages under good management (Kumar et al., 2021). In the early years after planting before tree canopy closure, most frequently in the first to third year following tree planting, farmers in the area typically create "temporary" agroforestry by fusing fruit trees with annual crops like maize or pulses, and vegetables. Reliable scientific-based information on permanent combinations of fruit trees and annual crops is necessary to promote agroforestry systems that can offer long-term and

diverse income sources through product diversification to farmers in the region rees-based agroforestry system has great roles to play in the livelihood of the farming community because of its multiple benefits.

Agri-horti-silvisystem

- In this system, horticultural crops, silvicultural plantations and fodder crops are being grown together on the same unit of land.

Fruit-based agroforestry systems

- Fruit based systems or agri-horti-silviculture system consists of growing agricultural crops, trees and fruit trees orornamental trees or vegetables/flower in same land at the same time.
- The fruit-based agroforestry system consists of a mix of annual and perennial plants pecies as distinct parts on the same plot of land that are arranged in a geometry thatallows for maximum use of space in all four dimensions (length, breadth, height, anddepth),which in turn leads tomaximum economic production of the system.
- Fruit crops that are drought resistant can endure and generate money for farmers even during severe drought. Silvicultural plantations would control sand drift, provide forage, fuel, and timber, and aid to create ideal microclimates.
- This agroforestry system contributes goods and services, some of which have the potential to be profitable cash crops (Sharma et al., 2022). Fruits have a high market value due to their relatively short juvenile (pre-production) phase and the contribution they make to household diet and nutrition; as a result, this system offers farmers subsistence and sizable economic returns even in unfavorable agro-ecological conditions. This system contains a variety of year-round items (fruits, vegetables, spices, etc.) available in systemslike home gardens that not only assure food but also help with food security during times of famine.

Apple-based Agroforestry System

- The trees start bearing fruits when 4-year-old and the economic life of tree exceeds 30 years.

Spacing

Planted at 4.5 m×4.5 m, 5 m ×5 m and 6 m×6 m.

Suitable intercrops

The interspaces effectively utilized for raising of fodder (*Trifolium repense*, *Dactylis glomerata*, *Trifolium alexandrium*, *Medicago sativa*) and agricultural crops (cereals, pulses, vegetables and beans).

Fruit productivity

Orchard yields 12-14 t ha^{-1} yr^{-1}. Depending on variety and season, a well-managed apple tree gives fruits at 10-20 kg $tree^{-1}yr^{-1}$.

Uses

Apples are primarily consumed raw, although a small portion of the crop is processed to make juices, jellies, canned slices, and other products.

Economics

The overall net income of apple + lucerne

and apple +orchard grass is Rs.134400 and Rs.123400 ha^{-1} yr^{-1} respectively. Cost of cultivation is Rs.73600 ha^{-1} yr^{-1} while as income averaged at Rs 128900 ha^{-1} yr^{-1}.

Environmental Benefits

Apple-based Agroforestry System

Apple-based agroforestry system helps to sequester 77 tha^{-1}

Apricot-based Agroforestry System

Apricot (*Prunus armeniaca*) is found in the sub-temperate mid-hills of Himachal Pradesh.

Rotation

Economically yields upto 30-35 years

Spacing

6m×6m and 8m×8m

Suitable intercrops

Intercrops like soybean, peas, barley, cowpea, mustard andvegetablescan becultivated up to 3-4 years of plantation.

Fruit productivity

12-15 t ha^{-1} yr^{-1} from well-established orchard. An averageyieldof25-35 kg obtained from6–8-year-old tree.

Uses

Apricot is an excellent dessert fruit and used for table purposes. Fresh apricots fruit is a good source of fibres, minerals

especially potassium and vitamins.

Economics

A net income of Rs. 90000-120000 ha^{-1} yr^{-1} with a B: C ratio of 1:2.5 over 20 years. Generally, intercrops help to return invested amount over orchard upto 6-7 years of planting with average net return of Rs. 20000 to 30000 $ha^{-1}yr^{-1}$.

Apricot- based Agroforestry System Environmental benefits

Provides soil improvement and enrichment through perennial systems on eroded areas.

The apricot helps to store atmospheric carbon into wood at a rate of 1-1.5 t $ha^{-1}yr^{-1}$ in Himalaya.

Mulberry-basedAgroforestrySystem

Rotation

10-12 years for bent instrument and sports equipment. It takes 2-3yearsto bear fruits.

Spacing

Generally, 3m×3 m recommended for gentle slopes

Suitable intercrops

Morus alba maintained on boundaries of fields, risers, contours and terraces. Mainly rice, wheat, soybean, vegetables and for age intercropped.

Tree productivity

Middle sized Morus trees provides 12-15 kg yr^{-1} $tree^{-1}$ of green leaf fodder, 22-30 kg yr^{-1} $tree^{-1}$ of fuelwood and 80-120 kg $tree^{-1}$ of main bole.

Uses

Morus is pollarded at a height of 5-6 ft by farmers for nutritious fodder during lean period of May-September. Wood is much valued for sports equipment such as hockey sticks, tennis and badminton rackets, and cricket bats (Bhuyan et al., 2021).

Economics

The net income of degraded grassland is Rs. 12000 to Rs. 14000ha^{-1} yr^{-1} in the initial years, which increases up to Rs. 30000 to Rs 35000 ha^{-1}yr^{-1} registering a B:C ratio of 1.53 to 2.13on a cycle of 10 years.

Mulberry- based Agroforestry System

Environmental benefits

Morus dominated agroforestry system reduces thesoilloss and increases soil available nutrients.

Peach-basedAgroforestry System

Peach (*Prunus persica*) also known as 'God's Fruit' prevails in low and midhills of Western Himalayan region comprises of Himachal Pradesh, Jammu and Kashmir, Uttarakhand and also grown in Eastern hills.

Rotation

25-30years

Spacing

4m×4m, 6m×6m

Suitable intercrops

Beans, vegetables, pulses are intercropped up to 3 years of plantation. The poplar is widely planted along the boundaries of peach orchard.

Fruit productivity

10-12tha^{-1} yr^{-1}from well-established orchard.

Uses

Peach fruits used to prevent obesity-related diseases such as diabetes, metabolic syndrome, and cardiovascular disease.

Economics

The net present value of Rs. 1,72,272 per 100 trees at 10% discount rate obtained

with B:C ratio of 1.42. Also well-

established peach orchard can provide a net income ofRs. 1,85,000 ha^{-1}yr^{-1}.

Environmental Benefits

Peach cultivation helps to maintain green cover oversoil for longer period. It also helps to sequester atmospheric carbon (0.7-1.8 tha^{-1}yr^{-1}) in the tree biomass as well as the soil.

Walnut-based Agroforestry System

Walnut (*Juglans regia*) is grown in the north-western Himalaya expanding toSikkim and Darjeeling. Commercially, it cultivated in Jammu & Kashmir, Uttarakhand, Himachal Pradesh and Arunachal Pradesh. It grows well in temperate zone of 900 m to 2700 m altitude.

Rotation

100-120 years (seedling origin) and 40-50 years (improved cultivars).

Spacing

12m×12 m,10 m×10 m and 8m×8 m

Suitable intercrops

Intercrops like legume fodders, vegetables and mustard etc. up to 4-5 years of planting. The fruit trees like peach, plum and apple are widely preferred as filler trees under walnut plantation.

Tree productivity

Natural grown trees give an average 50-60 kg tree up to 80-100 years. In Improved cultivars (CITH-W-1, 4 & 5, Hamdan and Sulaiman), average yield of30-40 kg tree^{-1}obtained in age18-20 years.

Uses

Walnut is also excellent source of omega-3 fatty acids, vitamins and minerals, and valued as healthy snack food. The wood of the walnut is highly prized, due to its strong, attractive and easy to work.

Environmental benefits

Grows on degraded lands, reduces soil loss. The carbon stock of walnut orchard varies from 6-14t C ha^{-1} from15-20years age.

Impact and contribution of fruit-based agroforestry systems in sustainable production

- Agroforestry has the ability to contribute and meet the country's fundamental needs through increasing output based on predicted demands for food, fruit, fuel, timber, and fodder in addition to improving export prospects in the medicinal and aromatic cropsectors.
- The total potential for agroforestry area by 2025 has been estimated at 25.36 million ha (moderate scenario) with almost half of it under tree borne oil seeds (TBOs), followed byhorti-pastureand others (NRCAF, 2007).

Efficient land use

- The marginal and degraded sites where arable farming is either impossible or unprofitable can benefit from horticulture-based production systems.
- Adopting horti-pastoral or horti-silvi-pastoral system can ameliorate these lands in along term due to soil conservation and improvement in Fertility levels.
- An additional benefit will be the wind break effect created by living fences and tree planting, which will improves oil moisture retention and decrease transpiration.

Productivity improvement

- Several studies in different parts of the country suggested that agroforestry is more profitable to farmers than agriculture or forestry for a particular area of land.
- CAFRI, Jhansi has been working since 1989 on agri-silvi-horticulture system which included four varieties of *E. officinalis*, namely Chakaiya, Kanchan, Krishna and NA7 as fruit trees, *Leucaena* as multipurpose tree and black gram as intercrop in rainfedarea.
- After the age of 13 years, the B: C ratio from the system was 3.28 and on discounted rate, it was 2.61which indicated that *E. officinalis* - based agroforestry system is a profitable enterprise in marginal lands unde rrainfed conditions (Newaj and Rai, 2005).

Soil conservation and fertility enhancement-

- The primary objective of agroforestry is to conserve soil and improve/maintain itsfertility.

- Ecologically sound agroforestry systems suchas intercropping and mixed arable-livestock systems have been found to be effective for soil organic matter restoration and can increase the sustainability of agriculturalproduction.
- Suitable alternate land-use systems involving agriculture, horticulture, forestry and agroforestry have been designed with the support of local natural resources for identical hydrological behaviour. The model land-use suggests utilization of slopes below 50% towards lower foothills and valley lands for agricultural crops, middle slopes between 50 and 100% for horticulture and top Slopes over 100% for forestry/silvi-pastoral establishment. Under agri-horti-silvi-pastoral systems, the reduction in run-off was 99% (Singh, 1988).

Socio-economicissues -

- Adoption of horticulture-based production systems can improve the socio-economic conditions of resource deficient farming community.
- Many underutilized fruit species play an important role in the social economy and livelihoods of tribal, small, marginal and land less farmers.
- In addition to providing these farmers with additional money and a significant amountof livelihood support, the produce from trees also ensures the nutritional security of the women and children.

Biodiversity conservation

- Over exploitation of natural resources is a major challenge for sustainable production and livelihood security.
- Agroforestry with components like timber trees, fruit trees, agricultural crops, grasses, livestock, etc. provides all kind of life supports.
- Trees in agroforestry system act as a refuge to biodiversity after catastrophic events such as fire (Griffith, 2000). The traditional society of coastal belts and tropics of the country practicing home-gardens and sacred groves help in biodiversity conservation.

Carbon sequestration

- Inclusion of fruit trees along with timber trees in agricultural production systems can increase the amount of C stored in lands devoted to agriculture while still allowing for the growing of food crops (Kursten, 2000).
- In fruit-based agroforestry system, tree components are managed, often intensively by pruning for minimizing competition and maximizing complementarity.
- The pruned materials are mostly non-timber products and often returned to the soil.Besides, the amount of biomass and C, harvested and exported from the system, is relatively low in relation to the productivity of the tree (Nasamet al., 2022) The C storage capacity variesfrom region to region and also depends upon the growth and nature of tree species

involved in the system.

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Plantix app: A success story of artificial intelligence in plant protection

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Introduction

Agriculture is the most significant sector of the Indian economy, accounting for around 16% of GDP and employing 60% of the workforce. major constrains in Indian agriculture include the possibility of pests attacking crops, a delayed monsoon, moneylenders who have monopolised agricultural lending, and intermediaries offering farmers a low price for their produce, to mention a few. The United Nations Food and Agriculture Organization estimates that plant diseases and pests destroy 20 to 40% of worldwide agricultural production each year. The majority of farmers in India own cellphones. Digital agriculture can help farmers overcome plant damage caused by insects, pests, and diseases by makinghigh-quality ualitative and quantitative information available to target farmers (Dutta et al., 2020). Collaboration can be doneamong researchers, scientists, technology businesses, and the government to make research findings more widely available. Detection success is now at 85 % accuracy and some diseases with shorter life-cycles needing only four hundred pictures to help identify the problem. Others may require 5,000 images for disease detection algorithms. The database now contains 500 diseases, with a focus on those affecting groundnuts, rice, wheat, tomato, and cotton.

During a visit to the Amazon forest in quest of soil data, Simone and Robert Strey encountered an extraordinary demand from indigenous agricultural tribes to tackle particular pest and disease problems. As a result, they shifted their focus and approached ICRISAT about collaborating with Dr.Rupavatharam (ICRISAT, 2017). This collaboration resulted in today's most popular app, “Plantix”. Plantix is an B2C (Business to Consumers) approach powered by the Strey’sBerlin-based startup PEAT GmbH uses machine-learning and scientific image data supplied by ICRISAT and local research institutions to bring 75,000 daily users information about pests and diseases. Currently the database has half a million pictures covering 30 crops worldwide and offers remedies for over 120 crop diseases. Plantix has grossed 3.8 million downloads and has been rolled out in over 10 languages. The app helps farmers diagnose pest damage, plant disease and nutrient deficiencies by taking a photo of their affected crop. Users can discuss possible causes and solutions with each other, or with experts paid to monitor infestations

and provide scientifically verified solutions (Vennila, 2022). The app has been downloaded by almost 12 million users globally, with the majority of these in India, where it is available in eight local languages.

Application

Farmers take pictures of the affected crop and upload them on the app. The photographs are analyzed using artificial intelligence algorithms. The results are then returned immediately to the farmer. Critical information on symptoms, triggers, chemicals as well as biological treatments are provided. All pictures sent using the app, are geo-tagged thereby enabling real-time monitoring of pest and diseases. The resulting metadata provides valuable insights into the spatial distribution of cultivated crops and most significant plant diseases e.g., in the form of high resolution maps. Furthermore, the app encompasses a weather information system specific to the farmers' location and a community feature that facilitates interaction with other actors interested in plant protection services. It provides real-time diagnosis to small holder farmers as end users and is successfully tested. Uploaded crop photos are analyzed using image-recognition technology that uses a database of half a million pictures covering 30 crops and offers prescriptions for over 120 crop diseases and the small holder framers are provided with required information free of cost, with an easy-to-use dashboard in local languages. Besides diagnosis, the automatic image recognition app geo-tags uploaded images to monitor crop health across regions with easy-to-understand diagnostic suggestions, which would be helpful in achieving profitable and sustainable farming for smallholder farmers (LekshmiPriya, 2019).

In the beginning of 2020, Plantix merged with another Indian startupSalesbee, based out of Indore, to strengthen their activities in the agricultural purchase vertical. This has helped the company to approach producers, purchase in bulk, and supply quality agricultural input products like seeds, fertilisers, and pesticides to retail shops. Besides, Plantix also works together with agro-chemical companies as these large companies have a big interest in the data acquired through the image recognition. The plan ahead is to scale up further not only in India but also in neighbouring countries like Bangladesh and Pakistan. Plantix wants to add more users in the coming months. The startup has set its mission towards making agriculture more sustainable in India while increasing yields and incomes for smallholder farmers.

plantix
your crop doctor

Figure 1: Plantix app used for plant disease and pest induced damage diagnosis

Conclusion

The app could prove to be a game changer in the field, providing farmers free, reliable and quick diagnosis of crop

damage. The simplified dashboard with easy-to-use features helps the app take on the role of an extension worker as well. The app is a novel experiment in using digital technologies for agriculture. This success story encourages more agristartups and collaborative activities among diverse disciplines of agriculture like plant protection specialists and extension functionaries to attain the goal of plant protection.

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Potential timber trees for homegardens: A quick glance from Kerala

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In the National Agroforestry Policy of 2014, numerous objectives were stated. Among the most notable were the material requirements of wood-based industries; the reduction of importing wood and wood products; encouraging and expanding the integration of plantations with crops and livestock, thereby improving productivity; and meeting the goal of expanding forest and tree cover to help with ecological stability, particularly in sensitive areas. Agroforestry systems like agri-silvicultural, silvopastoral, agro-silvopastoral, and others in which trees are vital components should be used as instruments to accomplish these aims.

Agro-silvopastoral systems are agroforestry systems in which trees, crops, and animals are deliberately integrated on the same unit of land in some form of spatial and temporal sequence. The home gardens, which are one of the oldest agroforestry practices, common in areas with extensive rainfall, fall under this category. Home gardens are highly productive, adaptive, practicable, and sustainable agroforestry systems. Home gardens are widely practised in South and Southeast Asia, where they are linked to the socio-economic conditions of these areas. Home gardens are pretty prevalent in India, particularly in the southern states of Kerala and Tamil Nadu, as well as the Northeastern states of Tripura, Assam, and West Bengal, and some regions of the Andaman and Nicobar Islands.

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Fig 1 & 2: Home gardens in Kerala with timber trees and their combinations with agricultural and horticultural crops.

Home gardens as a timber source

According to the FSI Report 2021, 59.79% of the state's total forest cover is within the category "Trees outside Forest (TOF)". According to Krishnankutty et al. (2008), TOF accounts for 90% of Kerala's total timber supply, with 36% of it coming from home gardens. It should also be noted that most of the timber-yielding species in Kerala are suitable for being integrated into a home garden.

Important timber species from Homegardens in Kerala

Common Name (Species Name)

Teak (*Tectona grandis*)

Family: Lamiaceae

Silvicultural characteristics

Teak thrives on alluvial soils, a moderate amount of moisture, a warm, tropical climate, and a pH range of 6.5 to 7.5. It is a light-requiring species that may be found from sea level to an altitude of around 1200 m with a rainfall regime of 800–2500 mm. It can also thrive in areas with more than 3,500 mm of rainfall annually.

Wood properties

Fine to coarsely grained, even texture, medium lustre, yellow-brown to dark golden-brown heartwood, and greyish or white sapwood. A high degree of durability, moderately hard and heavy with low stiffness. moderate bending strength, steam bending and excellent dimensional stability.

Utilization

Furniture making, handicrafts, etc

Common Name (Species Name)

Jack (*Artocarpus heterophyllus*)

Family: Moraceae

Silvicultural characteristics

Jack needs sandy loam soil that is rich and well-drained. Jack sets a significant emphasis on soil drainage. Although lime and chlorine are present, the jackfruit tree can somewhat survive moisture stress. Ideal locations for its cultivation are close to riverbeds. Jackfruit can be grown in warm, humid plains, and it thrives in moist, hilly areas up to a height of 1,500 metres. Fruit quality declines at higher elevations yet thrive in South India's arid and warm plains.

Wood properties

Heartwood yellow to yellowish brown or pinkish brown with darker streaks. Moderately hard and moderately heavy.

Utilization

a versatile building material also used for blockboard, concrete shuttering plywood, marine plywood, furniture & cabinets, carving, and turnery. handicrafts, etc

Common Name (Species Name)

Anjili (*Artocarpus hirsutus*)

Family: Moraceae

Silvicultural characteristics

At heights of up to 1,300 metres, tropical trees can be found. It can withstand temperatures as low as 16°C and thrives best in environments with annual daytime temperatures of between 22 and 32°C. It prefers a mean annual rainfall of between 2,500 and 3,500 mm but may tolerate 1,700 to 4,500 mm of precipitation yearly. New trees require shade, although older plants prefer full sun or little shade. but does well in most soil types, especially those with good drainage. It can handle pH levels between 4.5 and 7.5 but prefers a range of 5 to 6.5.

Wood properties

Heartwood is golden yellow to yellowish brown, and sapwood is greyish or yellowish white, moderately hard and heavy, with a medium to coarse texture

Utilization

Furniture making, handicrafts, etc

Common Name (Species Name)

Rosewood (*Dalbergia latifolia*)

Family: Fabaceae

Silvicultural characteristics

It is a tropical, lowland monsoonal plant species that can be grown with success at altitudes of up to 1,000 metres. In its native environment, there is an annual rainfall range of 750 to 5,000 mm. The tree grows well in regions with a mean monthly rainfall of less than 40 mm and up to 6 dry months. It can withstand minimum temperatures ranging from 0 to 6 °C. It grows best in deep, wet soils with good drainage. Alluvial, lateritic, gneissic, and fractured rock soils, among other types of soil, are among the circumstances where the species can flourish. It must be in a sunny location. Although seedlings require some light, they can tolerate some shadow. Trees tend to become crooked and branchy in overly open areas. Older trees are particularly resistant to drought.

Wood properties

Heartwood varies from a golden brown to a deep purplish brown and has darker brown streaks. Wood is very hard, close-grained, strong and durable.

Utilization

It is used for many purposes, like furniture, panelling, ornamental work, agricultural implements, etc.

Common Name (Species Name)

Coconut (*Cocos nucifera*)

Family: Moraceae

Silvicultural characteristics

Coconut has been discovered to thrive in a variety of agro-climatic environments. According to studies, the ideal temperature for optimum production and maximum yield is 27°C, with daily variations between 6°C and 7°C and relative humidity levels of at least 60%. The coconut palm grows well up to 600 metres above mean sea level. The coconut palm does well with an annual rainfall of 1000–3000 mm that is equally distributed. Laterite, alluvial, red sandy loam, coastal sandy and reclaimed soils with a pH range of 5.2 to 8.0 are the main soil types that support coconut in India. Coconut farming is best suited to soil with a minimum depth of 1.2 m and a moderately excellent water-holding capacity.

Wood properties

The heartwood is brown to reddish brown and is lustrous. Wood is moderately hard and non-durable.

Utilization

Used in flooring, furniture making, pulping, and construction work.

Conclusion

By 2030, India's consumption of wood would have significantly increased, worsening the country's already-existing deficit between supply and demand for wood and increasing its dependency on imported wood (ITTO 2021). On arable lands, agroforestry must be encouraged to address this timber shortage. The home gardens of Kerala are versatile agroforestry systems that play an important part in the socio-economic aspects of Kerala. The distinctiveness of home gardens is in the multispecies, multi-story arrangements of trees and crops that are continuously maintained by households for ecological harmony, food and nutrition security, and possibilities for livelihood. The commercial potential to produce timber is being diminished by unscientific tree management practices, a

Table 1. List of other potential timber trees in Homegardens of Kerala

Sl. No	Species Name	Common Name/Trade Name	Family	Utility
1	*Swietenia macrophylla*	Mahogany	Meliaceae	Furniture, wooden doors, handicrafts, veneering, plywood making etc
2	*Toona ciliata*	Red cedar	Meliaceae	Furniture, cabinetry, veneer, musical instruments (guitar tops), and boatbuilding.
3	*Cassia fistula*	Indian laburnum	Fabaceae	Used to make furniture, farm implements, posts, wheels and mortars.
4	*Thespesia populnea*	Indian tulip tree	Malvaceae	Used for light construction, flooring moulds, musical instruments, utensils and vehicle bodies, popular for boat building, horse-drawn carts, carving canoe paddles, bowls, plates and utensils.
5	*Ceiba pentandra*	Kapok tree	Malvaceae	For rafts and canoes, Veneer making, Plywood and pulping
6	*Anthocephalus kadamba*	Kadamba	Rubiaceae	Used in plywood, light construction, pulp and paper, boxes and crates, dug-out canoes, and furniture components.
7	*Melia dubia*	Malabar Neem	Meliaceae	Used in making agricultural tools, pencils, cigar boxes, ceiling planks, building materials, and packaging cases

8	*Azadirachta indica*	Neem tree	Meliaceae	Used in light construction, furniture, doors and window frames boards and panels, cabinets, boxes and crates, agricultural implements, tool handles, musical instruments, matches, plywood, veneers, carving, and toys
9	*Xylia xylocarpa*	Irul	Fabaceae	Used for making heavy constructions like railway sleepers, bridges, piles, girders, and decking, and pit- props and also in making wrapping paper
10	*Macaranga peltata*	Vatta	Euphorbiaceae	Light wood used for construction, planks, low-grade furniture, knife sheaths, boxes, crates, water pots and stools, and as firewood.

lack of proper marketing strategies, increasing fragmentation of homesteads, and government prohibitions on timber extraction.

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Quality planting material production of three major timber trees in agroforestry: Seed and nursery techniques

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Integration of trees with crop cultivation, livestock production, and other farm activities is popularly known as "agroforestry," and woody perennials are the core of this integrated farming system because it provides multiple outputs or benefits to the stakeholders. A higher yield from the trees could be obtained with reliable planting material and good management practices. Generally, agroforestry is considered a subset of trees outside of forests (TOF), and most of the cultivation practices are present on private farmlands, wastelands, community lands, etc., but harsh environmental conditions in these sites will have a severe impact on the quality and quantity of the outputs. So, in this regard, we need good-quality planting materials to meet the various demands of farmers as well as ensure quality raw materials for wood-based industries.

Quality Planting Material (QPM) may be defined as "the production of uniform, healthy, disease-free planting material raised through seed or vegetative methods with an overall goal to raise the physiological and phytosanitary quality of the plant and make it available to stakeholders to increase productivity." Particularly for economically relevant timber species, quality plant material (QPM) from agroforestry species is necessary. To produce high-quality planting materials on a large scale, it is important to have a thorough understanding of seed and nursery processes.

Seeds of *Tectona grandis* Seeds of *Dalbergia latifolia* Seeds of *Swietenia macrophylla*
(Source:https://www.google.com/wikipedia)

Seed technology of *Tectona grandis*

Seed characteristics

Marble-white, egg-shaped seeds having a 1-2 cm length, 1 cm width, and 1, 433 to 3, 527 fruits/kg in seed weight. Seeds are generally dispersed by insects.

Seed collection

Typically, the cleared area is where seeds are gathered. We can also physically harvest seeds from trees by shaking the branches with a long pole equipped with a hook.

Seed processing

By rubbing the seeds in gunny bags forcefully, the bladder-like calyx is removed. By winnowing, the calyx parts are separated (Chacko et al., 2002). Fruits are soaked in water for 72 hours, then mixed with equal parts of sand and small stones (1:1:1), before being placed in a machine with two revolving discs (100 rpm) with a slightly concave shape and ribbed surface to remove the pericarp and create a more uniformly shaped and brittle material. This processed material is put into a second component that has two parallel cylinders that rotate at 520 rpm and have a diameter of 35 mm. This second component crushes the fruits and releases the seeds.

Seed storage

Seeds are orthodox in nature. For two to three years, seeds can be dry stored in metal tins, airtight plastic containers, or gunny bags (Chacko et al., 2002). When seeds are kept in airtight metal containers as opposed to loose bags, their viability lasts longer, and they germinate more successfully.

Viability period

Enduring for more than a year (Chacko et al., 2002)

Seed pre-treatment

Teak seeds with rocky seed coats need to be pre-treated to germinate more quickly. The germination of seeds is improved by letting termites consume the mesocarp, leaving behind seeds with stony endocarp, and by immersing the seeds in a cow dung solution for 24 hours.

Germination details

Epigeous type of germination and germination percentage is goes up to 75 to 77 (Chacko et al., 2002). Germination period ranges mostly 8 to 60 days.

Nursery technique of *Tectona grandis*

Traditionally, between the summer and the rainy season, seeds are put on raised nursery beds (30 cm height). Compared to root trainers and sand medium, nursery beds are the best place for teak drupes to sprout. The seeds are planted in 20 centimetre raised nursery beds, spaced 5 cm apart in lines 10 cm apart, and covered with 1 cm of sand. A 5 cm top layer of sand with well-rotted FYM should be present in the beds. The seedbeds are irrigated three times each day until 75 days after sowing is reached for the end of the process.Compared to survival rate of stumps (58-96%), container seedlings have a greater survival rate (96–100%).Root coiling and multiple shoot development were additional characteristics of container seedlings, and their management was not economical.As a result, it encourages the use of stumps. At 7 months of age, stumps should be between 1 and 2 cm in size. From seedlings that are one year old, 2.5 cm shoot length, 15 to 20 cm root length, and 1 to 2 cm diameter at the thickest region of the root are prepared. Root trainer seedlings, which are 60 to 90 days old, and polybag seedlings, which are 40

to 60 days old, are also utilised for planting (Chacko et al., 2002).

Seed Technology of *Dalbergia latifolia*

Seed characteristics

Reddish brown in colour and have a seed length of 5-7 mm, seed width of 3-5 mm, and seed thickness of 1-2 mm and 21, 000 to 40,000 seeds/kg in seed weight.

Seed collection

By pruning the branches of the trees, ripe dark brown pods can be harvested

Seed processing

The seeds are manually taken from the dried pods by crushing them, or the pods can be baked in an oven at 50°C for 3.5 hours to extract the seeds.

Seed storage

Seeds are probably orthodox in nature. The pods are kept for six months in earthened pots and gunny bags. Seeds that are improperly dried before storage typically lose viability quickly (Chacko et al., 2002).

Viability period

Enduring for six months (Chacko et al., 2002).

Seed pre-treatment

Soaking in cold water for 24 hours prior to seeding will help with germination (Chacko et al., 2002). At lower concentrations (1–20 ppm), IAA can increase plant percentages and germination by up to 10%.

Germination details

Epigeous type of germination and germination percentage is goes up to 80. Germination period ranges mostly 7 to 21 days (Chacko et al., 2002).

Nursery technique of *Dalbergia latifolia*

In vermiculite-lined germination trays, seeds are sown and then watered. When the seedlings are between 5 and 6 cm tall, they are pricked out into plastic bags about 22.5 x 17.5 cm and filled with potting soil. *Rhizoctonia solani* causes seedling collar rot, which can be prevented in nurseries by using the fungicide carboxin (1.0 percent) (Chacko et al., 2002). Seedlings planted in root trainers using potting medium made of 60% compost, 30% sand, and 10% soil show great growth.

Seed Technology of *Swietenia macrophylla*

Seed characteristics

Flat winged brown seeds have a seed length of 8.3 cm, seed width of 2.5 cm, and 1, 600 to 2, 300 seeds/kg in seed weight.

Seed collection

Before they dehisce, mature fruits are harvested from the trees before their grain turns brown from grey grain.

Seed processing

The seeds are manually harvested after the fruits have been sun dried till they open (Chacko et al., 2002)

Seed storage

Orthodox; Intermediate (Chacko et al., 2002). The viability of seeds has an intermediate seed storage behaviour. Could well be preserved in the plastic bags at 10°C for more than two years.

Viability period

It is viable for up to three months in typical circumstances

Seed pre-treatment

Pre-treatment is not necessary. It is advantageous to de-wing before planting

Germination details

Hypogeal type of germination with germination percentage is about 90 and germination period10-112 days (Chacko et al., 2002).

Nursery technique of *Swietenia macrophylla*

Vermiculite-filled germination trays are used to horizontally sow seeds at a depth of 2 cm. When the seedlings reach a height of 15 cm, they are moved into polythene bags measuring 22.5 x 17.5 cm that are filled with soil or root trainers. Three months after being potted, the seedlings are prepared for planting (Chacko et al., 2002).

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Soil microbiome: A natural terrestrial saviour for healthy ecosystem

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How microorganisms interact with each other in a complex ecosystem is essential for understanding terrestrial systems. A healthy ecosystem must be strong enough to withstand outside pressures while maintaining its structure and function over time. Self-regulation is a capability that all healthy ecosystems possess (Morris and Blackwood, 2015). Biodiversity preservation is essential to ensure ecosystem stability, as it dilutes the strength of a food chain's interactions among species. In complex communities, there are few strong linkages embedded within a majority of weak interactions, which is associated with greater stability than in communities where strong links are comparatively few (Tilman, 1996). A community like this is less likely to undergo abrupt structural changes because of its greater functional tenacity. Soil communities are typically self-organizing entities influenced by the complex spatially and temporally dynamic factors that affect soil ecosystems at multiple levels in a hierarchical fashion (Giller, 1996). Complex ecological networks found in healthy soils enable them to control and sustain a variety of soil populations. These multitrophic interactions take place at all levels of ecological organization and are crucial in how ecosystems react to environmental and anthropogenic changes (Tsiafouli *et al*., 2017). Strangely, ecologists have only recently started to show interest in the structure and function of microbial communities as fundamental pillars of both terrestrial and aquatic ecological systems and this interest has led to the foundation of numerous studies that look at soil microbes within the context of ecological research.

One of the Earth's ecosystems with the highest species diversity is soil. Soils are one of the main global reservoirs of biodiversity; because more than 40% of living organisms in terrestrial ecosystems are associated during their life-cycle directly with soils (Decaëns *et al*., 2010). Nowhere else in the nature, possible to find such a variety of species packed so tightly together as in soil ecosystems. The importance of soil biodiversity in ensuring proper soil functioning and supporting all soil-based ecosystem services and goods is undeniable, even though the true extent of soil biodiversity is still largely unknown (Parker, 2010). Therefore, increasing our understanding of the mechanisms for soil health, managing the ecosystem services provided by soil, and predicting future trends and scenarios for the Anthropocene all depend on our ability to understand soil biodiversity. Soil organisms are typically

classified based on their body width, which varies by several orders of magnitude within soil communities. The majority of soil diversity is related to microbiota such as bacteria, archaea, and fungi, but it also includes a wide range of microfauna, mesofauna, macrofauna, and even megafauna (e.g., mammals and reptiles) (Zhang, 2013 and Stork, 2018). The soil microbiota primarily aids in the decomposition processes that promote the cycling of carbon (C) and nutrients, but they also play a significant part in the plant growth promotion and diseases biocontrol. The microbiota have vital role in soil fertility under diverse ecosystems, and their functional diversity plays a critical role in maintaining soil biodiversity, food web stability, and ecosystem functioning (Li *et al*., 2019). Instance, a chemolithotroph group of bacteria derives their energy from inorganic compounds such as sulphur, nitrogen, iron and other elements and converts them into a more usable form for plants (Madigan ***et al***., 2015). These organisms also have significant symbiotic relationship with plants, which are essential for the plant root axis, nutrient uptake (e.g., aiding nitrogen fixation), and hormone regulation (Heygarth and Ritz, 2009).

To better understand their ecological roles within soil ecosystems, the soil organisms can also be classified by their functional characteristics. There are three all-inclusive functional groups recommended by Turbe *et al.* (2010): (a) chemical engineers, (b) biological regulators, and (c) ecosystem engineers. Organisms like decomposers and transformers are examples of chemical engineers because they are directly involved in the cycling of carbon and nutrients. By regulating the dynamics of biological populations, biological regulators help soil ecosystems remain resilient and stable. Ecosystem engineers are in charge of maintaining soil structure by promoting aggregate stability, macro and micro pore network formation, and the development of complex bio-structures (Heemsbergen *et al*., 2004; Lindahl *et al*., 2006, Mendes *et al*., 2013, Fenner *et al*., 2013).

Knowledge gap and challenges

Human activities and man-made disasters such as deforestation, acidification, salinization, pollution, urbanization, fire, and intensive cultivation create a negative pressure on soil microbial diversity and ecosystem functions. There is clear evidence that forest ecosystems benefit not only below-ground soil microbial diversity but also boost ecosystem services such as soil formation, nutrient cycling, climate regulation, disease and pest regulation, and the provision of fuel, food, water, and genetic resources. Despite all this collective understanding, soil biodiversity is still little recognised in forest management planning and ecosystem policies.

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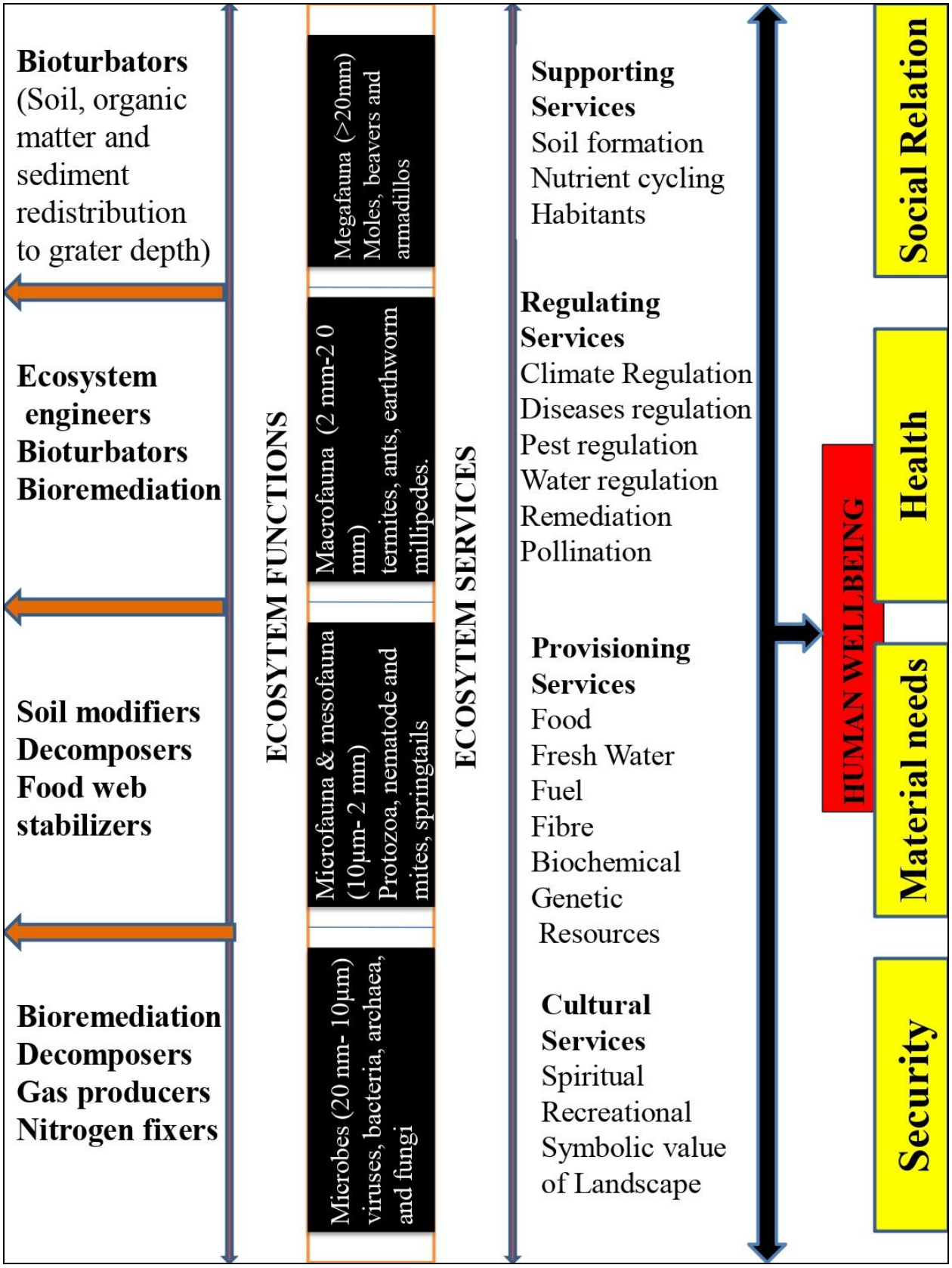

Figure 1: Microbial diversity in relation to ecosystem services, ecosystem functioning and human well being (FAO- reports 2020)

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A bird's eye view on major agroforestry practices and systems in Andhra Pradesh

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Agroforestry offers a wide array of perks for the agriculture and forestry sectors of the country. It stands out as one of the best ways for climate change mitigation and adaptation, the restoration of degraded agricultural lands, and the improvement of local people's livelihoods through economic and environmental security. Agroforestry practices explore a dynamic interaction between the environment and its surroundings. It is often a means of increasing the productivity of the land area, which also seeks to enhance the rich diversity of the space. Agroforestry accounts for a significant portion of the global carbon sink. The intricate interactions between the many components of the agroforestry system, which include both trees and crops, greatly enhance the soil structure, thereby improving fertility and drainage capacity.

It is the best way to practice even in harsh environmental conditions, such as hot and dry areas where tree components significantly provide adequate shade and a lower surface temperature for agricultural crops. The trees provide a way of providing moisture from deep soil, making it available to the crops. Most of the area in the country is dependent on rainfall for agricultural practices. This sector appears to undergo too many disagreements to support a regular farm management operation because of quick and unpredictable changes in the rainfall pattern and climatic changes. Agroforestry typically seeks to address the current problem in a straightforward manner as a result.

Agroforestry systems of Andhra Pradesh

Andhra Pradesh is a region with an area of 1,62,968 sq km, which is 4.96% of the geographical area of the country (ISFR 2021) and a population of 49.39 million as per the 2011 census. More than half of the population of the state (70.42%) lives in rural communities where the practice of agriculture is a primary means of income generation. Andhra Pradesh is among the top countries with the highest concentration of AFS land (1.17 million ha). Agroforestry in Andhra Pradesh is an age-old farming practice wherein farmers are actively associated with different ways of generating income through farming. The state is situated in a transitional climatic zone from tropical to sub-tropical India and is endowed with a rich variety of soils, ranging from coastal to highly productive alluvial soils near the rivers. The state is divided into two regions, according to the ISFR 2021 report: coastal Andhra and much drier Rayalaseema. According to the varying climate and soil conditions, different parts of the state practice varied agroforestry combinations.

Agroforestry in different zones

North Coastal Zone

Vizianagaram, Srikakulam, and Visakhapatnam districts make up this zone. Horsegram, cowpea, and various vegetables are planted as intercrops in these districts, which are mostly cashew-nut-based agri-horticulture systems. In addition to this, there is a coconut garden with several intercrops growing. Teak plantations have currently been planted as a source of wood and trees like *Prosophis juliflora* as a source of fuel. In the Vizianagaram regions, betel vine gardens with sesbania are a popular practice and a common source of revenue for the rural community.

High altitude and tribal zone

This region, which is in high-mountainous and rugged terrain, is primarily populated by tribal populations, some of which use the Taungya system. It encompasses the East Godavari, Visakhapatnam, Srikakulam, and Vizianagaram districts. The indigenous people have long grown rice as well as some pulse crops like rajma and vegetables. Both *Madhucalongifolia* and tamarind species are preferred, with the latter generating cash for the growers through the sale of tamarind that has been processed. The Andhra Pradesh Forest Development Corporation introduced coffee and black pepper with silver oak and it has since become a model for farmers to use more of these combinations.

Krishna- Godavari zone

This zone includes a region with an abundance of fertile soils and thoughtfully constructed irrigation systems. Mango and coconut-based agroforestry techniques are more prevalent in this region. Bananas, paddy, sugarcane, and other crops are the principal ones grown here. *Azadirachta indica* is extensively used for furniture, fuelwood, and building materials. Moreover, *Prosophis juliflora* and *Casuarina equisetifolia* are cultivated for fuelwood.Numerous industries also use *Casuarina equisetifolia* and eucalyptus plantations as raw materials (paper). Sesbania and betel nut systems are also widely used in this area, much like in other zones. Mango agro horticulture is also practised in this region, notably in the Krishna districts' Nuziveedu region.

Southern zone

This region, which has an arid environment, contains the districts of Praksam, Nellore, Chittoor, and parts of Caddapah. The main agroforestry systems are mango-based agroforestry systems and acid lime gardens with Ragi and Korra as intercrops. Aquaculture is a popular practise in several areas of the district, mainly in the coastal region. In the Chittoor district, fuelwood from Prosopis and Tamarind trees is used in groundnut fields. The residents of these districts also rely on the sale of processed tamarind as a source of income.

Scarce rainfall zone

The yearly rainfall in this area ranges from 300 to 500 nm. It comprises the Cudapah, Kurnool, and AnantapurRayalasema districts. Groundnut and vegetable farming communities grow tomatoes and other vegetables. Additionally, they generate a sizeable amount of cash via sweet orange gardens and agroforestry systems based on fruit trees. *Ficusbengalensis, Acacia nilotica*, and other trees are used as fodder. *Prosopis juliflora, Pithocellobium dulce, Pterocarpus santalinus,* and *Dalbergia latifolia* are also seen in this drought-prone area. Betel vine and sesbania cultivation

practices are widespread here, as they are in other zones.

Farmers frequently require effective training and extension services in order to implement healthy and standardized agroforestry models in farmlands. Agroforestry is an age-old practice that was often carried out in early agricultural life. As a result, the successful integration of indigenous knowledge with modern technological practices and research would promote more sustainable thinking in the field of agroforestry. Through agroforestry activities, which also tangentially contribute to the extension of the state's green cover, farmers have a significant potential to increase their daily revenue.

Studies conducted by the World Agroforestry Centre revealed alarmingly low levels of soil organic carbon, aboveground biomass, and plant diversity in Andhra Pradesh, denoting the biophysical constraints for the agroecosystems in use at the time, negatively impacting ecosystem resilience and the welfare of those who depend on it. Similarly, Sreenivas et al. (2021) pointed out that Andhra Pradesh stands in the third position in the land degradation status of different states in India, with an area of 5,510,756 ha of land under degradation, but on a positive note, Andhra Pradesh (647 sq km) has shown an increase in its forest cover (ISFR 2021). So, in this context, agroforestry models offer a great deal of promise to improve the lives of the farming communities in Andhra Pradesh because monoculture systems never produce as much as more diversified systems do. By broadening and investigating its rich scientific foundation, agroforestry would become one of the most promising sustainable farming practices in the state of Andhra Pradesh.

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