Successful Agroforestry Models for Different Agro-Ecological Regions in India

Editors

A.K. Handa, Inder Dev, R.H. Rizvi, Naresh Kumar, Asha Ram, Dheeraj Kumar, Anil Kumar, S. Bhaskar, S.K. Dhyani and Javed Rizvi

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CAFRI
The Indian Council of Agricultural Research (ICAR) established Central Agroforestry Research Institute (CAFRI), erstwhile known as the National Research Centre for Agroforestry (NRCAF), at Jhansi on 8 May 1988 to cater to basic, strategic and applied research needs in the field of agroforestry. The Institute coordinates a large agroforestry network--the All India Coordinated Research Project on Agroforestry--with 37 centres located in different agro-climates of the country.

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The Indian Council of Agricultural Research (ICAR) is an autonomous organization under the Department of Agricultural Research and Education (DARE), Ministry of Agriculture and Farmers Welfare, Government of India. ICAR, established on 16 July 1929 with headquarters at New Delhi, is the apex body for coordinating, guiding and managing research and education in agriculture including horticulture, fisheries and animal sciences in the country. With 101 ICAR institutes and 71 agricultural universities spread across the country this is one of the largest national agricultural systems in the world. The ICAR has played a pioneering role in ushering in Green Revolution and subsequent developments in agriculture in India through its research and technology development; and has actively contributed in formulation and implementation of agroforestry policy and mission.

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ICRAF is the only institution that does globally significant agroforestry research in and for all of the developing tropics. Knowledge produced by ICRAF enables governments, development agencies and farmers to utilize the power of trees to make farming and livelihoods more environmentally, socially and economically sustainable at scales.

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CGIAR (Consultative Group on International Agricultural Research), as the world's largest global agricultural innovation network, brings evidence to policy makers, innovation to partners, and new tools to harness the economic, environmental and nutritional power of agriculture. CGIAR integrates and coordinates the research of its 15 member-centers in producing new knowledge and technology that is needed to meet the Sustainable Development Goals (SDGs).

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Population of India is expected to touch more than 1500 million by 2030; and land under agriculture is decreasing at a rate 0.03 million (30,000 hectares) per year. Besides this intensive agriculture is putting immense pressure on land to produce more food accelerate the process of soil degradation. Overuse of chemical fertilizers and pesticides, and adverse effect on livestock population due to shrinking fodder production are other concerns. Ever increasing challenge of climate change and threats posed by extreme weather further compound the vulnerability of small holders' livelihoods and food security.

Agroforestry has been recognised by more than 140 countries as one of the most effective tools to mitigate and to adopt the adverse effects of climate change; support restoration and arrest degradation of soil; ensure livelihood, food, nutrition, energy, fodder, and increased income for farmers; and to adapt to mitigate climate change. India has been on the forefront of agroforestry research and development. Implementation of a National Agroforestry Policy, a Sub-Mission on Agroforestry, and a National Bamboo Mission clearly demonstrate the commitment and the will of the Government of India to mainstream and implement agroforestry at large scale.

Indian Council of Agricultural Research (ICAR), its research institutes, and its international partners like World Agroforestry (ICRAF) have recognized the lack of easy access to credible knowledge about scientifically proven agroforestry systems and associated best practices as one of the most hampering factors in the adoption of agroforestry. The present book "Successful Agroforestry Models for Different Agro-Ecological Regions in India" is a joint effort of ICAR and ICRAF, attempted to address the above challenge. The contributors and editors of the book have

compiled practical information about 40 successfully tested and demonstrated agroforestry Models for 20 different agro-ecological regions of India. The information provided is easy to understand and implement by promoters of agroforestry.

I hope this publication will be useful for practitioners, promoters, planners, forest officials, farmers, teachers, researchers and students of agroforestry.

T. Mohapatra
Secretary,
Department of Agricultural Research and Education &
Director General, ICAR, Government of India
New Delhi

2 January 2019

Preface

Though agroforestry is practiced the world over, Indian farmers have the distinction of having used it since time immemorial. Covered under the umbrella of agriculture before, it was only recently that agroforestry emerged as a distinct branch of science. The past three decades have witnessed a tremendous boost to agroforestry research, education, and training, against the backdrop of its multiple benefits including improved land use leading to increased farm income through diversification, sustained natural resource management, increased resilience to climate change, ecosystem services, biodiversity conservation, medicinal and aromatic plants, and enhanced food, nutrition, fodder, fuel, timber, and economic security of farmers. Implementation of the National Agroforestry Policy (2014), the Sub-Mission on Agroforestry (2016), and the National Mission on Bamboo (2018) have further accelerated the momentum of adoption and expansion of agroforestry in India. Inclusion of agroforestry as one of the eligible activities for funding through Corporate Social Responsibility (2014) funding, and consideration of 14th Finance Commission of India to include green cover (over forest cover) to provide additional funding to State Governments is expected to further promote agroforestry in the country.

Practitioners, promoters and supporters of agroforestry often face the tough question about which successful agroforestry systems to adopt. This is because site-specific systems are complex and must consider edaphic and climatic parameters, ecology, vegetation, site-specificity, and structure and livelihood security of different stakeholders.

Researchers in India have developed best practices and benefits

of several agroforestry systems, but the information is scattered and not easily available to those in need of it. This book is an effort to fill that gap in accessing available knowledge. It brings together at one place the successful, famer- and environment-friendly agroforestry models that promise prosperity to the poor in different agro-ecological regions of India. Majority of the models were developed and tested by ICAR-CAFRI, All India Coordinated Research Project on Agroforestry, State Agricultural Universities, and others

This volume is second in a series of joint publications by ICAR-Central Agroforestry Research Institute (CAFRI), Jhansi and World Agroforestry (ICRAF) as part of the ICAR--ICRAF collaborative Work Plan in India. We sincerely thank the contributors for their valuable submissions, working under tight deadlines. We thank our Consultant Science Editor, Dr S. Varma, who edited the manuscripts and worked closely with designers and printers. We also thank the Communication Unit, and the office of the Deputy Director General (Research) of ICRAF, Nairobi for their support. The overall support extended by ICAR-CAFRI and South Asia Regional Programme of ICRAF is also thankfully acknowledged. Financial support from the Indian Council of Agricultural Research through its funding to ICRAF is gratefully acknowledged.

We sincerely hope that farmers, extensionists, researchers, teachers, students, and agroforestry-dependent industries will find this volume useful.

A.K.Handa, Inder Dev, R.H.Rizvi,
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Editors

Introduction

Agroforestry is an effective land use system which contributes to food, nutritional and environmental security. Besides its multifarious use as food, fuel, fodder, fibre and timber, it enables smallholder farmers to optimize their land use. Agroforestry has significant potential to provide employment and additional income to farmers as well as to increase the forest/tree cover to meet specific national targets. ICRAF defines agroforestry as the practice and science of the interface and interactions between agriculture and forestry, involving farmers, livestock, trees and forests at multiple scales. Agroforestry is one of the most multi-disciplinary sciences which deals with a whole gamut of important aspects of human life.

The most comprehensive definition of agroforestry explains it as the interaction of agriculture and trees, including the agricultural use of trees. This includes trees on farms and in agricultural landscapes, farming in forests and at forest margins and tree-crop production, including cocoa, coffee, rubber and oil palm. Interactions between trees and other components of agriculture may be important at a range of scales: in fields (where trees and crops are grown together), on farms (where trees may provide fodder for livestock, fuel, food, shelter or income from products including timber) and landscapes (where agricultural and forest land uses combine in determining the provision of ecosystem services). At national and global scales, forestry and agriculture interact ecologically and through policies relating to land use and trade and are important with respect to climate change and other environmental concerns. Agroforestry embraces an agro-ecological approach putting emphasis on multi-functionality and the management of complex systems and polycultures rather than focusing exclusively on monoculture. We use the word 'tree' inclusively, to refer to trees and shrubs, all woody perennials, palms and bamboo. We also use the word 'agriculture', inclusively, to refer to human activity, carried out primarily to produce food, fibre and fuel by the deliberate and controlled use of plants and animals.
(http://www.worldagroforestry.org/downloads/Publications/PDFS/RP17128.pdf).

Given the fact that land-holding size is shrinking, tree farming combined with agriculture is perhaps the only way forward to optimize farm productivity and, thus, enhance livelihood opportunities of smallholder

farmers, landless labourers and especially the women farmers. In the recent past, a paradigm shift towards environmental protection and sustainable land use has taken place and the tree-based production systems are being promoted in India.

Agroforestry Research in India: Background

Organized research on agroforestry started in India with the establishment of the All India Coordinated Research Project (AICRP) on Agroforestry in 1983. The research initiatives gained further momentum with the commencement of forestry education programmes in the State Agricultural Universities of India during 1985-86, and establishment of the National Research Centre for Agroforestry (NRCAF) at Jhansi, Uttar Pradesh in 1988. The Centre was upgraded in 2014 as Central Agroforestry Research Institute (CAFRI). At present there are 37 centres of AICRP on Agroforestry representing all agro-climates of the country. In addition, the Indian Council of Forestry Research & Education (ICFRE) also conducts agroforestry research through its institutes and advanced research centres.

National Agroforestry Policy

In India, agroforestry has been receiving increasing attention of researchers, policy-makers and others for its perceived ability to contribute significantly to economic growth, poverty alleviation and environmental quality. Agroforestry is now recognized as an important part of the 'evergreen revolution' movement in the country. This all helped the country to launch the National Agroforestry Policy (NAP 2014) (http://www.indiaenvironmentportal.org.in/content/389156/national-agroforestry-policy-2014/) on 10 February 2014 and India became the first country in the world to have a National Agroforestry Policy (http://ccafs.cgiar.org/publications/indias-new-national-agroforestry-policy). The policy is not only seen as crucial to India's ambitious goal of achieving 33% tree cover but also to mitigate greenhouse gas emissions from agriculture sector.

Since the launch of the policy in 2014, considerable progress has been made in terms of putting it into practice. To implement the recommendations, an inter-ministerial committee has been set up. The Department of Agriculture Cooperation & Farmers Welfare (DAC&FW) under the Ministry of Agriculture and Farmers Welfare (MOA&FW) is now the nodal Ministry for implementing agroforestry policies and initiatives. In another significant move, the Corporate Social Responsibility (CSR) laws of

India were modified in 2014, and agroforestry was included as a legitimate CSR activity. As of now, 27 states have ratified the recommendations of the NAP.

Sub-Mission on Agroforestry (SMAF) & National Bamboo Mission

Based on the recommendations of the National Agroforestry Policy (NAP), a dedicated Sub-Mission on Agroforestry (SMAF) was established by Government of India under the framework of National Mission for Sustainable Agriculture (NMSA) with an outlay of Rs 935.00 crore for a period of 4 years starting from 2016-17. The SMAF is focused to achieve increased tree cover to enhance carbon sequestration, enrichment of soil organic matter, availability of quality planting material, improved livelihood and productivity. Relaxation of transit regulations is a pre-requisite for assistance under Sub-Mission on Agroforestry (SMAF).

Keeping in view the vast untapped potential of the bamboo sector, to boost the domestic production for supply to the industry, recently (2018) a National Bamboo Mission (NBM) has been launched. This is expected to give a big boost to bamboo-based agroforestry systems.

Agro-Ecological Regions of India

India, with 329 million hectares of the geographical area, represents diverse agro-climatic conditions. The climatic variability affects tree and crop choices, and their productivity. Delineation of agro-climatic zones based on soil, water, rainfall, temperature etc. is the first essential step for sustainable production since climatic, edaphic and biotic factors which play a major role in determining the vegetation type in various physiographic areas

The National Bureau of Soil Survey & Land Use Planning (NBSSLUP) has divided the country into 20 agro-ecological regions (Sehgal et al. 1992). This classification is based on the integrated criteria of effective rainfall, soil groups with delineated boundaries adjusted to district boundaries with a minimal number of regions. These 20 agro-ecological regions (AERs) (Fig. 1) are further sub-divided into 60 sub-regions (AESRs) (Velayutham et al. 1999). A detailed description of each of the 20 AERs, and 60 AESRs with reference to climate, soil and land use, and the distinguishing features of the AESRs is available at the website of the NBSSLUP. The criteria used for AER delineation are discussed by Mandal et al. (1999).

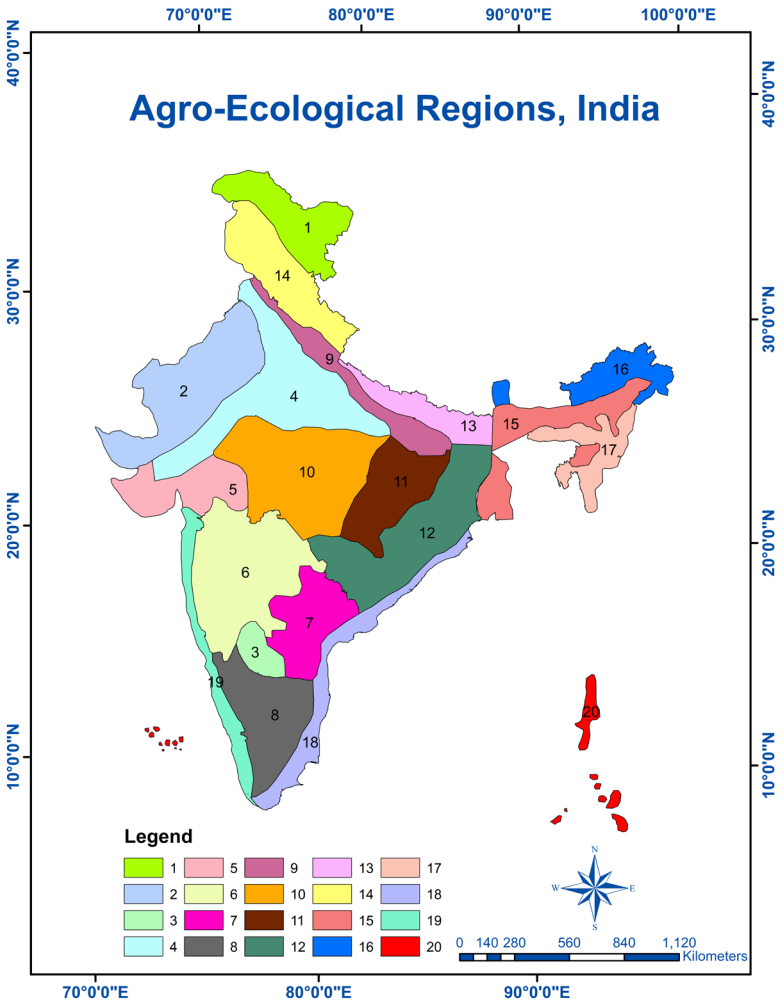

Fig. 1

1. Western Himalaya (Cold Arid); 2. Western Plain, Kutch and Part of Kathiwar Peninsula (Hot Arid); 3. Deccan Plateau (400-500 mm rainfall); 4. Northern Plains and Central Highlands including Aravallis; 5. Central Highlands (Malwa), Gujarat Plains and Kathiwar Peninsula; 6. Deccan Plateau (600-1000 mm rainfall); 7. Deccan Plateau (Telangana) and Eastern Ghats; 8. Eastern Ghats, TN Uplands and Deccan Plateau; 9. Northern Plains; 10. Central Highlands (Malwa, Bundelkhand and Eastern Satpura); 11. Eastern Plateau (Chattisgarh); 12. Eastern (Chhota Nagpur) Plateau and Eastern Ghats; 13. Eastern Plain; 14. Western Himalayas; 15. Bengal and Assam Plains; 16. Eastern Himalaya; 17. North Eastern Hills (Purvanchal); 18. Eastern Coastal Plain; 19. Western Ghats and Coastal Plains; 20. Islands of Andaman-Nicobar and Lakshadweep

Agroforestry is practiced in India ranging from humid tropical lowlands to high-altitude temperate biomes, and from humid rainforest zones to parched drylands. In order to maximize the production and economic returns from the available limited resources under prevailing climatic conditions, introduction of location (agro-ecology region) specific agroforestry systems is imperative.

While the potential of agroforestry in India is enormous, there are also challenges that must be met. Besides critical bottlenecks, such as a shortage of quality planting material, un-regulated nurseries, lack of credit and insurance; promoters, practitioners and supporters of agroforestry are very often faced with tough questions on absence and/or non-availability of proven and successful agroforestry systems to promote or adopt. Though research institutions have generated valuable data on best practices and benefits of several agroforestry systems, the desired information is not easily available to agroforestry practitioners and promoters. This book is an effort to fill that gap in access to well tested and proven agroforestry systems.

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Agro-Ecological Region (AER) 1

Western Himalaya (Cold Arid)

1.1 Agroforestry Model: Mulberry based Silvi-pastural System

Area of adoption: Jammu & Kashmir, Himachal Pradesh, and eight districts of UP hills
Tree component: *Morus alba*
Common name: Toot
Family: Moraceae

Habit and Habitat

Morus is a fast growing tree with a ragged and irregular branching habit, vigorous and upright, rounded to pendulous and generally 20 to 60 feet in height. It is found growing in sub-tropical or mild temperate climates where maximum shade temperature never exceeds 48°C, the annual rainfall varies from 400 to

***Morus alba* based silvi-pastural system in a farmer's field in Himachal Pradesh**

4500 mm and mostly, the rain is received in monsoon season. It grows on a variety of soils. Alluvial soils with sufficient moisture content support good growth. The tree cannot tolerate salinity.

Distribution

Morus is a cultivated tree found growing in northern India from J&K State to Assam. It ascends up to an elevation of 1200 m. It does not grow on dry slopes or shallow soils.

Phenology

Young leaves appear at end of February. Leaves are alternate, medium green, with serrate margins, glaborus to scabrous adaxial surface with pronounced patterns of veination on the abaxial surface, 3 to 6 inches long, turning yellow in late fall; leaf shape can be highly variable ranging from entire and ovate with serrate margins to clefted with lobed margins; medium coarse texture.

Flowering occurs in April. Plants are normally dioecious (male and female flowers on separate plants). Male flowers are small, green and occur in 1-2 inches (2.5-5.1 cm) long catkins. Female flowers are inconspicuous and crowded in short spikes.

Package of Practices

Propagation Technology

Natural: Seeds, coppice
Artificial: Seeds, cutting

Cultural Operations

Preparation of land: If the land is having gentle slope, it can be levelled with minor land shaping and providing suitable type of bunds across the slope. If the slope is more, contour bunding, terrace planting or contour line planting can be adopted. In more sloping areas, platforms for individual plants on contour lines may be ideal as this will involve less soil cutting.

Spacing: Spacing for tree planting depends on soil topography, extent of land available for cultivation and training method. In general 3 x 3 m is recommended for gentle slopes.

Pit size: In case of deep textured loose soils, 45 x 45 cm and in shallow soils 60 cm x 60 cm x 60 cm pits are used..
Fertilizer: For each pit, about 5 kg (one iron pan) of well decomposed FYM or compost is applied at the time of plantation along with 50 g SSP. NPK fertilizer is applied at100:50:50 kg/ha/yr. The whole P & K and 1/3rd N is applied in April, 1/3rd N in July and the remaining 1/3rd N in October.

Planting: It is done in winter, preferably in December and January. Monsoon planting is also recommended provided the saplings are in polybags. Five-month-old saplings are suitable for planting during the onset of monsoon. One sapling/pit should be planted.

Tending Operations

After-care of plantation: After one month, all the buds except top 5-6 should be removed carefully by rubbing with gunny bags without damaging the bark. Weeds around the plant should be removed and regular pot watering should be given as necessary. After three months of planting a second weeding should be given. Plants must be protected from grazing.

Pollarding: Trees are pollarded in the third year of establishment, at a height of 5 feet. Three cuts of fodder can be taken in a year in May, July and September when planted in the fields and also on the boundary to obtain maximum tree fodder and to minimize the shade on adjacent grass. A single cleared bole is to be maintained up to the height of 5 feet.

Coppicing: To obtain additional fodder and also to minimize shade on grass/crop, trees are coppiced in the third year of establishment, at a height of 50 cm.

Tree Protection

Major pests: Wood borers, defoliators and sap-suckers

Control: For the management of wood borer, plug the hole completely with cotton ball dipped in kerosene and cover it with mud. In case of severe attack of defoliators/sap-suckers, spray chloropyrophos at 1-2 ml/litre on the leaves.

Diseases: Powdery mildew and Bacterial blight

Control: Fungal disease can be controlled with the application of Dithane M-45 (Mancozeb) at 75 WP or other suitable fungicides. Bacterial blight can be managed by pruning and removing the infected parts after proper sanitization of pruning tools. Sound cultural practices help in the recovery from this disease.

Orientation: Boundary/in field/on bunds

Suitable intercrops: Fast growing grasses like Napier-Bajra hybrid/*Setaria anceps* etc. are planted in rows.

Seed rate: Grass is planted @ 2 root slips per hill. Establishment of *Setaria* grass from the seed directly in the field is not recommended keeping in view the delicate roots of the newly sprouted grass which take more time to establish because of more competition from the existing grasses.

Spacing: Row-to-row and plant-to-plant spacing is 40 cm. Grass rows are planted at a distance of 1 m from the tree line.

Fertilizer: NPK is applied @120: 60: 40 in Napier-Bajra Hybrid and @ 90: 60: 40 in case of *Setaria*. Phosphorus and potash are applied every alternate year, whereas nitrogen is given every year in split doses.

Method of plantation: A small hole is dug and a handful of FYM is added at the time of planting root slips along with recommended NPK dose of phosphorus, potash and first split dose of nitrogen.

Irrigation and other management requirements for grass: After transplantation, light irrigation is required if there is no rain.

Weeding: Manual weeding is to be done in the initial years of establishment of grass.

Yield/Annual Return

Morus-based silvi-pastoral system results in the production of about 8000 kg/ha green tree fodder and 24,000 kg/ha green grass fodder.

Farmer can take three cuts of tree fodder as well as quality green grass fodder during lean period also.

Economics

Availability of quality fodder throughout the year boosts the livestock-based economy of the farmers in the region. The overall net income per hectare per year from degraded grassland is Rs. 12000/- to Rs 14000/- per ha in the initial years which increases up to Rs 50,000 to Rs 60,000 per ha with the complete establishment of the system.

Environmental Benefits

Silvi-pasture system has been identified as the most promising for forage production in different agro-climatic regions. In this system tree foliage is of high quality for animals and the shade of its canopy is likely to benefit livestock directly, by moderating temperatures in hot environments, and indirectly by stimulating improved grass growth. In view of rise in temperature, it is a matter of significance that a large number of forage species (trees, grasses, shrubs) are drought resistant, they are still able to provide fodder, fruits and other products when the crops fail, as frequent droughts are a common phenomenon particularly in the arid and semi-arid regions.

Intervention of silvi-pastoral system helps in protecting the grasslands from degradation and sustaining the natural grass cover. Tree cover helps in recycling of nutrients and improving the soil health.

Utilization: Fodder

Improved varieties/accessions: *Morus alba*-China White, *Setaria anceps*: PSS-1, Napier-Bajra Hybrid-37

Source of planting material: AICRP on Agroforestry Centre, CSKHPKV, Palampur,

Benefits Accrued to Farmers/Public

Availability of quality green fodder throughout the year is encouraging farmers to raise quality milch animals and, thus, contribute to food security.

Silvi-pasture system on an average cycle of 10 years could generate 120 person days\ha\yr employment and the cost: benefit ratio of 1:1.53 to 1:2.13 clearly indicates the viability of these systems in the arid and semi-arid regions.

Validated technology transferred to other departments or agencies: About 5 ha

Way Forward

The silvi-pastoral agroforestry system has tremendous scope especially in mid-hills of Himachal Pradesh and in Uttrakhand where grasslands are increasingly turning into degraded lands particularly due to overgrazing and climate change. Increased availability of quality fodder will promote adoption of milch animals by farmers and thus boost the economy at household level.

Contributors

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Agro-Ecological Region (AER) 2

Western Plain, Kutch and Part of Kathiawar Peninsula

2.1. Agroforestry Model: Bakain (*Melia azedarach*) based Agri-silvicultural System

Area of adoption: Gujarat, Kathiawar Peninsula, Western areas of Madhya Pradesh, South-Eastern part of Gujarat and Rajasthan, Haryana, Punjab, and also in Mahaboobnagar, Nalgonda, Medak districts in Telangana, and Cuddapah and Kurnool districts in Andhra Pradesh.

Tree component: *Melia azedarach*

Common name: Bakain, Adavi vepa, Bead tree, Turaka Vepa

Family: Meliaceae

Habit and Habitat

Melia azedarach is a small to medium, deciduous tree from 6 to 35 m in height. The bark is brown, narrow which gives a striped appearance It tolerates a wide range of climate and soil conditions. Young trees are vulnerable to high temperature. It is a drought resistant tree.

Phenology

Flowers are pink and fruits are yellow and they are in clusters, leaves are bi-pinnate and dark in colour.

Package of Practices

The tree is propagated through seed. The land should ploughed and well levelled before digging pits of size 45 cm x 45 cm x 45 cm. The following spacing may be used: bund 3 m, boundary 3 m, and block 4 m x 4 m. FYM@ 5t/ha and 60:60:40 NPK/ha should be applied at the time of planting. For tending side branches should be removed.

***Melia azedarach* with intercrops**

***Melia azedarach* + Foxtail millet based agri-silvi system**

Orientation: Facing East-West direction
Suitable intercrops: Foxtail millet
Seed rate: 4 kg/ha
Fertilizer: 80-50-40 kg NPK/ha
Irrigation: 1 or 2 protective irrigations in prolonged drought conditions.
Weeding: Manual weeding is done in initial years.

Yield (Productivity)

About 30.5 t/ha (crop + tree) biomass products; inter-crop yield: 1.8 -2.0 t/ha

Economics: Rs 50,000 per hectare (tree age 3-4 years)

Environmental Benefits: High carbon assimilation by tree + crop combination.

Utilization: Timber

Improved Varieties/Accessions: *Melia azedarach/* Foxtail millet

Source of Planting Material: AICRP on Agroforestry, PJTSAU, Hyderabad.

Benefits Accrued to Farmers: The technology is suitable for small and marginal lands for getting higher returns.

Validated Technology: About 5 ha

Way Forward

The technology is suitable for arid and dry regions in Telangana where arable crops are not profitable. This system will give both timber and food crops from the same piece of land.

Contributors

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Agro-Ecological Region (AER) 3

Deccan Plateau (400-500 mm annual rainfall)

3.1 Agroforestry Model: *Melia dubia* based Agri-sylvicultural System

Area of adoption: Karnataka, Andhra Pradesh and Tamil Nadu
Tree component: *Melia dubia*
Common name: Hebbevu, Kadubevu, Malabar Neem, Maha Neem, Persian Lilac
Family: Meliaceae

Habit and Habitat

It is a fairly large, handsome, deciduous tree, attaining a girth of 1.2-1.5 m and a height of 20 m, with a spreading crown and a cylindrical, straight bole of about 9 m.

Distribution

35 districts of Karnataka, Andhra Pradesh and Tamil Nadu

Phenology

The tree is leafless for a short time from December to February. The new leaves appear in February to March along with the flowers. The fruits ripen during the cold season from October to February. Young branches densely clothed with stellate pubescence.

Young branches densely clothed with stellate pubescence. Bark reddish brown or dark brown, exfoliating in thin, narrow strips. Blaze thin, crimson then white. Leaves clustered towards the ends of the branches. Flowers greenish white, 0.6-1.0 cm long, fragrant,

in stellately pubescent, many flowered, branched panicles shorter than the leaves. Calyx 5 partite. Petals 0.6 cm long, linear spatulate. Drupes ovoid or ellipsoid, 2-4 cm x 1.8-2.3 cm, yellowish, smooth with very hard endocarp and one seed.

Package of Practices

Propagation technology: Vegetative propagation

Spacing:	Bund	2-2.5 m x 2-2.5 m
	Boundary	3- 4.5 m x 3-5 m
	Block	5 m x 5 m

Pit size: 60 cm x 60 cm x 60 cm

Tending operation: Removal of side branches

Orientation: Facing East-West direction

Melia dubia based Agroforestry Systems –Bund planting

Technology details: *Melia dubia* is planted at a spacing of 2.5 to 3.0 m apart on the bunds which are spaced at 30 m apart in arable lands, where finger millet, soybean, dolichos, red gram and other field crops are cultivated under rainfed conditions. Under irrigated conditions, vegetable crops, flower crops and plantation crops are also cultivated.

Crop yield: As Melia is spaced wide apart and planted on bunds, not much reduction in yield of the crops is noticed both in rainfed and irrigated conditions.

Bund planting of *Melia dubia* in a farmer's field

Timber yield: Under rainfed conditions, the yield of each tree varies between 12 cft and 14 cft at the age of 10 to 12 years. In many situations, Melia is often harvested at 10 to 12 years.

Under irrigated conditions, Melia is harvested at 8 to 10 years, when the timber yield varies between 12 and 15 cft per tree.

Economics: Rainfed, Rs 2,49,000 after 10 to 12 years. Irrigated, Rs 2,60,000 after 8 to 10 years.

Area of adoption: Mysore, Ramanagara, Mandya, Hassan, Bangalore Rural, Tumkur, Chitradurga & Chamarajanagar districts of Karnataka.

Suitability: This technology is highly suitable for small and marginal farmers.

Melia dubia based Agroforestry Systems – Boundary planting

Technology details: *Melia dubia* is planted at a spacing of 3 to 4.5 m apart, at 3 to 5 m within the boundary of lands. Boundary planting is very common in cultivated lands.

Yield: On an average, each tree recorded 15 cft in 10 years.

Economics: Net returns: Rs 4,72,500 per acre.

Area of adoption: Mysore, Ramanagara, Mandya, Hassan, Bangalore Rural, Tumkur, Chitradurga & Chamarajanagar districts of Karnataka.

Suitability: Irrigated garden lands.

Boundary plantations of *Melia dubia*

Melia dubia based agroforestry systems – Block planting

Technology details: *Melia dubia* is planted at a spacing of 5 x 5 m and 6 x 4 m apart, accommodating 160 to 165 tree per acre.. Block plantation is recommended both under rainfed and irrigated conditions for medium and large farmers, and also for small holders in areas of continuous fallow lands.

Block plantations of *Melia dubia*

Yield: Up to three to four years of tree growth any field crops are recommended. However, after four years a drastic yield reduction in field crops can occur. Hence, adopting perennial forage crops for rearing of animal components as an integrated system is recommended. On an average, each tree recorded 10 to 12 cft after 10 years.

Economics: Net returns Rs7,92,000 per acre.

Area of adoption: Mysore, Ramanagara, Mandya, Hassan, Tumkur and Chamarajanagar districts of Karnataka.

Suitable intercrops : Finger millet and Cowpea

Kharif (Sole crop)

Crop	Seed rate (kg/ha)	Duration (Days)	Spacing (cm)	Fertilizer (kg N:P_2O_5:K_2O / ha)	Grain yield (x100 kg/ha)
Finger millet	13-15	115-120	12 x 5	100:50:50	25-30
Cowpea	25-30	100-110	20 x 5	25:50:25	7.5-9

Intercrops yield

Crop	Yield (x100 kg/ha)				
	First year	Second year	Third year	Fourth year	Fifth year
Finger millet	20-25	18-20	15-18	10-12	1-2
Cowpea	6.0-6.5	5.0-6.0	3.5-4.0	2.0-3.0	0.75-1.25

Suitability: For medium and large land holdings and also for fallow lands.

Environmental benefit: *Melia dubia* leaf litter may alter soil chemistry, with increased pH and mineralizable nitrogen over time.

Utilization

The wood is used for packing cases, match box sticks, photo frames, pencils, mini furniture like stools, benches, wooden tables, interior decoration, window doors, wooden racks & packing industries, musical instruments, tea powder boxes, cigar boxes, building purposes, ceiling planks agricultural implements, splints and katamarans (multi-hulled watercrafts). It is a good secondary timber and the most preferred species for plywood industry.

The leaves are used for fodder and, thus, play a vital role in multi-farming of sheep, goat and dairy animals.

Improved varieties/accessions: MTP 1 and MTP 2. Indian Council of Forestry Research & Education (ICFRE), Dehradun also has released 10 cultivated varieties/clones of *Melia dubia.*

Source of planting maerial: State Department of Forestry/Private Nurseries

Benefits Accrued to Farmers/Public

Increased annual income and better standard of living of farmers.

Contributors

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Agro-Ecological Region: 4

Northern Plains and Central Highlands including Aravallis

4.1 Agroforestry Model: *Ailanthus* based Agri-silvicultural System under Rainfed Conditions

Area of adoption: Gujarat, Rajasthan, Bihar, Orissa, Uttar Pradesh, Madhya Pradesh, Maharashtra, Karnataka and Tamil Nadu
Tree component: *Ailanthus excelsa*
Common name: Ardusa, Ardu
Family: Simaroubaceae

Habit and Habitat

Ailanthus excelsa grows well in semi-arid and semi-moist regions and has been found suitable for planting in dry areas with annual rainfall of about 400 mm. It is commonly found in mixed deciduous forests and some sal forests, but it is difficult to cultivate in moist areas with high monsoons. Plant associations include *Acacia catechu*, *Acacia leucophloea* and *Azadirachta indica*. It is a relatively salt-tolerant species.

Distribution

A. excelsa is extensively cultivated in many parts of India towards the vicinity of villages. The tree is indigenous to Southern and Central India and distributed in Western Peninsula, Rajasthan, Bihar, Orissa, Bundelkhand, Madhya Pradesh, central, north and north-west part of Gujarat, in dry deciduous forests of Maharashtra, the Deccan plateau, Karnataka and Tamil Nadu. It is often planted along the roads.

***Ailanthus* as sole crop and with intercrops such as moong bean and cluster bean under rainfed conditions**

Phenology

Ardusa is a large deciduous tree, 18-25 m tall; trunk straight, 60 to 80 cm in diameter; bark light gray-brown and rough on large trees, aromatic slightly bitter. Leaves alternate, pinnately compound, large, 30-60 cm or more in length; leaflets 8-14 or more pairs, long stalked, ovate or broadly lanced shaped from very unequal base, 6-10 cm long , 3-5 cm wide, often curved, long pointed, hairy gland; edges coarsely toothed and often lobed. Flower cluster lobed at leaf base, shorter than leaves, much branched; flowers many, mostly male and females on different trees, shorter stalked, greenish-yellow.

Package of Practices

Propagation Technology/Vegetative Propagation

Generally, Ardusa is propagated through seeds. Natural reproduction occurs through seed and coppice. Seedling regeneration is generally

scanty and cannot be relied upon to regenerate natural stands. Natural regeneration through coppice and root suckers is adequate so long as the trees harvested are healthy. Artificial regeneration is through direct seeding or planting pre-germinated seeds.

Cultural Operations

Spacing: 5 x 5 m under rainfed conditions and as a block and boundary plantation the spacing should be 3 x 3 m.

Pit size: Optimum size of pit is 30 x 30 x 30 cm, planting should be done during rainy season.

Tending Operations

Seed collection and storage: The seeds are light and winged and are easily blown away by wind. Therefore, the fruit bunches at the end of the branches should be cut with long handled tools as soon as they show signs of ripening. The seeds are dried on a clean floor and then separated and stored in sealed air-tight tins. The seeds lose viability fast but under proper storage conditions they can remain viable for up to 240 days; otherwise, the normal viability is 4-5 months. The number of seeds in one kg is 8000-10,000.

Sowing: Sowing of seeds in beds is carried out in July-August. The seeds are sown in light soils in drills about 23 cm apart and lightly covered with soils. The seeds may also be sown directly in polybags. After sowing, watering is done regularly but sparingly. Too much moisture leads to damping off disease in seedlings. The germination is epigeous. Germination starts in 8-10 days. No pre-treatment is required for germination. About 15 gm of seeds are required for sowing 1 sq. m of bed. Mixing of seeds with ash or pulverized soil ensures uniform germination.

Preparation of pits: Optimum size of a pit for Ardusa plantation is 30 x 30 x 30 cm during summer season with a planting distance of 3 x 3 m/4 x 4 m/5 x 5 m. The pits are then filled with soil.

Transplanting of saplings: Optimum time for transplanting of saplings is onset of the monsoon. The saplings should be planted in

pre-dug pits by applying 5 kg FYM or 1 kg vermicompost per pit along with chloroyriphos for the control of termite.

Manuring and fertilization: The Ardu tree is fast growing and normally does not require organic or inorganic fertilizers in plantations but in the arid regions of the country and in sandy soils, nitrogenous fertilizer application has given good response. Application of 100 g urea or 5 kg FYM or 1 kg vermicompost is required in the first year of growth and in subsequent years the increment of urea, i.e. 100 g per plant each year and the highest up to 500 gm and the increment of FYM @ 1 kg per plant per year and the highest amount up to 10 kg per plant. The optimum time for fertilization is onset of the monsoon.

Irrigation:- Ardusa requires less amount of water but for optimum growth and development it should be irrigated at 20 days intervals in winter and 15 days in summer.

Weeding and inter-culturing: Timely and regular weeding is required especially for the first two years and soil working stimulates growth. Generally the weeds emerge in monsoon season which requires timely weeding and inter-culturing in the field. Weeding should always be accompanied by hoeing, soil working, mulching and casualty replacement.

Lopping and pollarding of branches: Trees are pollarded after the third year of establishment, which increases the light intensity to the intercrops and also the growth of Ardusa will be better.

Major Insect Pests and Diseases

Seedlings are susceptible to damping off disease, therefore heavy watering should be avoided and only optimum level of moisture should be maintained.

The seedlings or saplings may be affected by web worm *Atteva fabriciella,* which causes severe defoliation which affects plant growth and may cause death of the plant. The full grown larvae are grey in colour and live gregariously under a silk web spun over the leaves and shoots. They are controlled by application of 0.1% of endosulphan or malathion.

Insects

The tree is affected by several insect larvae. Repeated defoliation impedes the growth of trees making them vulnerable to the attack of borers.

Severe defoliation due to *Batocera rufomaculata* causes the branches to fall off, leaving prominent scars with cracks on the main stem, which act as suitable spots for oviposition by the beetles.

Atteva fabriciella (Ailanthus webworm) is fatal and a serious defoliator (occurring from April to June), which damages fruits, seeds and leaves. It is controlled by spraying 0.01 to 0.02% formothion and fenvaluate and also by aldrin, dieldrin, endosulphan and malathion.

Atteva niveigutta is another serious defoliator. It is controlled by contact insecticides such as authio and chloridimeform or by sevin (0.01-0.02%) and sumicidin (0.01 – 0.02%).

Batocera rufomaculata is a serious pest which bores into the stems of young trees. The larvae bore irregular and extensive galleries. Spraying of kerosene or fuel oil is done in the larvae tunnels or the tunnels are plugged with cotton saturated with kerosene oil. Sometimes the bottom portion of the trunk is completely hollowed and the tree is blown down by wind.

The grub *Diboma proura* bores the young shoots and forms long tunnels. It is controlled by spraying 0.05% phosphamidon or monocrotophos.

Diseases and Deficiencies

The leaf spot is caused by *Cercospora ailanthicola, C. glandulosa, C. simarrubacienses* and *Alternaria* sp. The disease appears in the form of necrotic spots on the leaves. The control measures include foliar spray of Bavistin or Dithane M-45 or fytolan (0.2%) at fortnightly intervals.

Powdery mildew in the species is caused by *Ovulariopsis* and *Oidium* sp. It is controlled by foliar spray of karathane E.C. 0.05% at 20 days intervals.

Phome medicogines causes light brown leaf spots with red halo on leaflets of *Ailanthus excelsa*. The disease occurs in monsoon season in both nurseries and plantations. Foliar spray of Cu-based fungicides can reduce the incidence of disease.

Orientation: *Ailanthus excelsa* is planted at boundary, block and in agroforestry systems. The planting in pits is carried out in the month of July.

(A) **Block planting**: For block planting nursery-raised seedlings 6 to 10 months old are used in pits at a spacing of 3 m x 3 m or 4 m x 4 m. The seedlings which attain a height of 50-100 cm are suitable for planting. The root shoot ratio of 1:2 is considered good for stump planting.

(B) **Boundary planting:** Generally the farmers plant *Ailanthus excelsa* on their farm bunds at a spacing of 3 x 3 m or 4 x 4 m to generate some extra income.

***Ailanthus* as boundary plantation**

(C) **Agroforestry:** Farmers of this region generally grow pulses, i.e. green gram, cluster bean and cowpea as intercrops in between the Ardusa plantations.

(D) **Mixed Plantations:** *Ailanthus excelsa* can be raised in mixed plantations. In degraded, denuded and semi-arid soils it is able to grow successfully with *Prosopis juliflora*. The spikes of *P. juliflora* give protection to Ailanthus plants.

Suitable intercrops: Green gram, cluster bean and cowpea

Requirements of Intercrops:

Crop	Seed rate	Fertilizer	Irrigation	Weeding & Inter-culturing
Green gram	15- 18 kg/ha	20-40 kg N-P_2O_5 /ha	Irrigate the field during dry spell	Weeding and Inter-culturing at 20 and 35 DAS
Cluster bean	15- 20 kg/ha	20-40 kg N-P_2O_5 /ha		
Cowpea	15- 20 kg/ha[1]	20-40 kg N-P_2O_5 /ha		

Yield/Products Obtained from the System

Table 1. Yield/products obtained from different crops with and without association of Ardusa under rainfed conditions of North Gujarat during 2000/01 to 2005/06 (average of six years)

S No.	Treatment	Seed yield (kg/ ha)	Stover yield (kg/h)	Timber volume (feet)^3/ha	Fuelwood (kg/ha)	Green leaf fodder (kg/ha)
1	Ardu tree sole	-	-	944.2	10834	5544
2	Ardu + cluster bean	65.4	271.4	946.8	8809	5438
3	Ardu + cowpea	195.0	382.0	932.7	13589	5148
4	Ardu + green gram	199.0	486.3	980.2	12427	4962
5	Ardu+ til	87.1	320.8	918.7	11415	6072
6	Cluster bean sole	71.6	329.2	-	-	-
7	Cowpea sole	213.1	498.5	-	-	-
8	Green gram sole	237.5	778.4	-	-	-
9	Til sole	105.4	396.6	-	-	-

Economics

Table 2. Economics of Ardu (*Ailanthus excelsa*) based agrisilvi-system under rainfed conditions of North Gujarat during 2000/01 to 2005/06 (average of six years)

S No.	Treatmens	Total income from tree produce (Rs/ha)	Total income from arable crops (Rs/ha)	Total income from system (Rs/ha)	Cost of cultivation (Rs/ha)	Net income from the system (Rs/ ha)	B:C ratio
1	Ardu tree sole	75324	-	75324	7900	67424	8.53
2	Ardu + cluster bean	73532	5510	79047	23220	55827	2.40
3	Ardu + cowpea	77640	13249	90893	24130	66763	2.77
4	Ardu + green gram	79520	20998	100524	24500	76024	3.10
5	Ardu+ til	74918	7960	82878	21640	61238	2.83
6	Cluster bean sole	-	6195	6195	15320	-9125	-0.59
7	Cowpea sole	-	15742	15742	16230	-488	0.03
8	Green gram sole	-	25769	25769	16600	9169	0.55
9	Til sole	-	9454	9454	13740	-4286	-0.31
	SEM ±	-	-	11955	-	-	-
	CD at 5%	-	-	35842	-	-	-
	C.V. (%)	-	-	38.36	-	-	-

Soil Improvement

Table 3. Physico-chemical properties of soil after harvest of different field crops with and without association of Ardu (after seven years of plantation)

S No.	Treatment	EC (dS/m) (1:2.5)	pH (1:2.5)	O.C. (%)	Available Nutrients (kg/h)			B.D. (g/cc)	Porosity (%)	WHC (%)
					N	P_2O_5	K_2O			
1	Ardu tree sole	0.020	7.86	0.27	180.6	32.62	203.7	1.58	23.66	39.33
2	Ardu + cluster bean	0.030	7.96	0.29	181.7	35.23	194.3	1.57	26.44	41.71
3	Ardu + cowpea	0.033	7.89	0.32	172.7	33.50	203.7	1.57	26.10	39.71
4	Ardu + green gram	0.023	8.01	0.28	188.3	37.17	192.7	1.56	24.17	40.35
5	Ardu+ til	0.027	7.93	0.30	179.7	35.62	189.0	1.58	24.49	39.59
6	Cluster bean	0.033	7.96	0.19	152.7	26.95	168.3	1.59	22.43	37.95
7	Cowpea	0.037	8.00	0.20	146.3	28.85	164.3	1.61	23.02	38.28
8	Green gram	0.030	7.81	0.18	149.0	28.58	163.0	1.60	22.24	38.56
9	Til	0.023	7.98	0.21	151.7	27.51	160.7	1.60	21.37	37.70
	SEM ±	0.01	0.07	0.02	7.76	2.04	7.63	0.007	0.071	0.30
	CD at 5%	NS	NS	0.06	23.28	6.13	22.87	0.020	2.101	0.90
	C.V. (%)	32.19	1.47	14.62	8.06	11.14	7.25	0.85	5.90	1.33

Green fodder from *Ailanthus* for sheep and goat rearing

The net return from Ardu intercropping with green gram was highest (Rs 76,024/ha) over sole and other agri-silvi system. The B:C ratio from sole Ardu was higher (8.53) than from the ardu + green gram system. The income from sole ardusa system was obtained at the end of 9th year, whereas the agri-silvi system (ardu + green gram) gave an income every year from the arable crops. Hence ardu + green gram system is more profitable than sole ardu plantation.

The physical and chemical properties of soil improved significantly under agri-silvi system of agroforestry as compared to sole crops. Significant improvement in organic carbon, N, P_2O_5, K_2O, porosity and water-holding capacity of soil while significant decrease in bulk density of soil was obtained under agrisilvi system over sole crops.

Environmental Benefits

Ardusa is resistant to drought and poor soil conditions. It grows well on slopes. The species has been extensively used for soil conservation purposes. Even in arid regions of Rajasthan it has been planted as an avenue tree along the road side. The tree has been

used successfully in agroforestry for planting around the margins of cultivated fields. Lopping of foliage is done twice in a year during the main cropping season, thus reducing competition. The tree is suitable for degraded and denuded areas and wastelands. It grows as a shade and avenue tree almost throughout the hotter parts of India. It grows well in arid and semi-arid regions as well as both in plains and hills.

Utilization

Wood is straight grained, fairly even and very coarse textured. It is soft but fairly strong and holds nails well. Annual growth rings are indistinct. It is very easy to saw and work both by hand and machines. The timber is very light and perishable and the air dry weight is 12 kg/cubic ft.

The timber may develop fine, long widely spaced surface cracks. It is also liable to blue stain. It is of box plank class, being light and fairly strong. The wood is used for packing cases, fishing floats and sword sheaths, match boxes and splints, toys, and as Grade III and Grade IV plywood

The pulp is obtained from debarked wood and is used in paper industry as a substitute for aspen, for printing papers. It improves the surface quality of paper. The leaves are highly palatable and protein-rich nutritious fodder for sheep and goats and help augment milk production. The tree is, therefore, largely planted on farm lands. An average tree yields about 500 to 700 kg of green leaves twice a year. The stem and branches are used for fuelwood which is considered of poor quality as it burns quickly and does not sustain heat for long. The bark is bitter, astringent, anthelmintic and is used to treat dysentery, bronchitis, asthma, dyspepsia and earache. The bark is also utilized in indigenous veterinary practices. Quassinoids and ailantic acid are isolated from bark.

The tree yields gum of inferior quality. The bitter and aromatic leaves of the plant have medicinal properties. The leaves are used for the preparation of lotions for scabies.

Improved varieties/accessions: The AICRP on Agroforestry, SDAU, Sardarkrushinagar, Gujarat has 30 genotypes of *Ailanthus excelsa* which are under evaluation.

Source of planting material: Research Scientist, Agroforestry Research Station, S.D. Agricultural University, Sardarkrushinagar, Gujarat, and State Forest Department Nurseries

Benefits Accrued to Farmers/Public

This technology, developed by AICRP on Agroforestry, is very popular among the farmers of the arid and semi-arid region of Gujarat.

Contributors

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4.2. Agroforestry Model: Shisham based Agri-silvicultural and Silvi-pastoral System

Area of adoption:	Bundelkhand region of Uttar Pradesh and Madhya Pradesh and other arid and semi-arid region of the country
Tree component:	*Dalbergia sissoo*
Common name:	Shisham, Sissoo
Family:	Fabaceae

Habit and Habitat

Dalbergia sisso is a medium- to large-sized deciduous, nitrogen-fixing and light-demanding tree. It coppices vigorously and produces profuse root suckers. It is widely distributed in many parts of India up to 900 .m. in sub-Himalayan tracts, occasionally ascending, up to 1500 m.. In its natural habitat the tree grows rigorously in the new alluviums formed deposits of sand, boulders and gravels in the sub-

Himalayan river beds and river banks. It prefers well drained sandy loam soils with adequate moisture supply. Under natural distribution the tree avoids clayey soils.

Phenology

Shisham sheds its leaves from November to February and flowers in March-April following new flush of leaves closely. The small bisexual flowers are borne on small branches from the leaf axis. Mature pods are light brown, flat and thin, 5 to 9 cm long and 8 to 12 mm wide. They contain up to five seeds. Mature pods remain attached to the tree for 7-8 months and are then dispersed by wind and water.

Package of Practices

Propagation technology

Through seed: It can be easily propagated by seed. The 1000-seed weight is 18–25 g. When stored dry or in a cold store, seeds remain viable for up to 1.5 years. Usually seeds are not extracted from the pods, but the pods are broken into 1-seeded pieces. Seeds germinate easily with germination percent up to 100, but soaking in water for 12–24 hours accelerates germination. Germination of fresh seed takes 7–21 days.

Vegetative propagation: For true to type multiplication of promising elite trees, efforts were made to standardize asexual propagation technique like air layering, stem cuttings and root suckers. Among these techniques, air layering was 100 % successful with treatment of 800–1000 ppm IBA solution during rainy season. No mortality occurred during transplantation of air layered plants in polybags and polybags to field. Stump planting is very successful, it is recommended to use stumps from 0.5–2-year-old seedlings with a root length of about 25 cm and a shoot length of about 7.5 cm. In India successful methods of tissue culture have been developed, and in-vitro mass multiplication of *D. sissoo* is carried out from callus of shoot tips and shoot segments. Root suckers and root and stem cuttings can also be used for propagation.

Pit size: 45 cm x 45 cm x 45 cm.

Rotation: On a good site, marketable timber can be produced on a 20 to 25 years rotation. To produce large-diameter logs with a high percentage of valuable heartwood, a rotation age of 60 years is adopted.

Tending operations: Weeding, hoeing and cleaning. Thinning is recommended every 10 years where the rotation is 30-60 years.

Tree protection (major pest and diseases): Collar/root rot of *D. sissoo* seedlings: Soil drench with Dithane M-45 (zinc ion and manganese ethylene bisdithio-carbamate) or Kavach (chlorothalonil) @ 0.5g/ 500 ml water/pot gives good control of pre- and post-emergence seeding mortality of *D. sissoo* caused by *Fusarium* sp. in nursery.

Leaf blight:It can be effectively managed through proper sanitation, weeding and foliar application of fungicide solution (Bayleton 0.1% at fortnightly intervals).

Powdery Mildew:Application of sulphur based fungicide was found most effective followed by Baycor, Mortesan and Calixin in controlling powdery mildew disease on *D. sissoo* seedlings in nursery.

Rust disease: The disease may be effectively controlled by foliar application of 0.08% Bayleton at fortnightly intervals.

The trees are attacked by various insects such as leaf miners, defoliators and stem borers. To control these pests, it is necessary to cut the branches that have been attacked.

Orientation: Field, bund and block plantation.

Shisham with wheat intercrop in a farmer's field in Punjab

Suitable inter-crops: Wheat, mustard, barley, lentil (*Rabi*) and green gram, black gram, sesame (*Kharif*). Shisham with Napier and other suitable grasses is a successful silvi-pastoral system.

Fodder component: *Pennisetum purpureum*

Common name: Napier hybrid grass, Elephant grass
Family: Poaceae

Habit and Habitat

Hybrid Napier is a perennial plant. It requires warm and moist climate, clay to clay loam soil for good growth. It is a prolific yielder. The crop grows throughout the year in south and northern India, and is sown during end of February to end of August. This grass is resistant to most of pests and diseases. It forms large, broad clumps. It is a tall (200-300 cm), erect, stout, deep rooted, perennial grass. The hybrid is a triploid, hence sterile, and does not produce seed.

Distribution

Hybrid Napier is widely distributed in tropical and sub-tropical regions of India. Among the improved fodder grass species, it is a multicut perennial grass with profuse tillering and very good tonnage throughout the year. It can be grown in saline soils, wastelands, bunds and terraces. It grows well in the arid and semi-arid regions of India.

Phenology

Hybrid Napier performs well in areas having temperatures above 15 ^{o}C. It is a tropical grass, which can withstand drought for a short spell, and regenerate with rains.

Package of Practices

Fast growing grasses like Napier-Bajra hybrid are planted in rows.

Seed rate: Grass is planted at 2 root slips per hill. Establishment of *Setaria* grass from the seed directly in the field is not recommended keeping in view the delicate roots of the newly sprouted grass which

take more time to establish because of more competition from the existing grasses.

Spacing: Row-to-row and plant-to-plant spacing is 40 cm. Grass rows are planted at a distance of 1 m from the tree line.

Fertiliser: NPK is applied at 120: 60: 40 in Napier-Bajra Hybrid. Phosphorus and potash are applied every alternate year, whereas nitrogen is given every year in split doses.

Method of plantation: A small hole is dug and a handful of FYM is added at the time of planting root slips along with recommended NPK dose of phosphorus, potash and first split dose of nitrogen.

Irrigation and other management requirements for grass: After transplantation, light irrigation is required if there is no rain.

Weeding: Manual weeding is to be done in the initial years of establishment of grass.

Yield/Annual Returns and Economics:

The overall net income per year with Shisham+Paddy+Wheat based agri-silvicultural system rose from Rs 7500 to Rs11,000 after 7 years of plantation under irrigated conditions.

The overall net income pee year with Shisham+Nappier based silvi-pastoral system rose from Rs 35,000 to Rs 50,000 after 11 years of plantation under irrigated conditions.

Irrigated plantations are reported to yield fair quantities of timber and fuelwood. Trees may attain a girth of 1.2 m in 25 years. A height of 7 m in 20 months has been reported. Based on studies of 40 natural riverine sites, it was concluded that 10-year stands yield about 10 cu m/ha, 20-year 100 cu m/ha (5 cu m/ha/yr), 30-year 210 cu m/ha (7 cu m/ha/yr), 40-year 280 cu m/ha (7 cu m/ha/yr), 50-year 370 Cu m/ha (7.5 cu m/ha/yr), and 60-year-old stands 460 cu m/ha (7.5 cu m/ha/yr).

Source of planting material: More than 32 trees of *D. sissoo* have been selected in Bundelkhand region by ICAR-CAFRI, Jhansi. Progenies PT-2 and PT-6 are outstanding in respect of tree growth.

MAI of these progenies for tree volume is more than 15 m^3/ha/yr. PT-2 is highly straight and thus suitable for agroforestry systems.

Benefits Accrued to Farmers/Public

Shisham based plantation helps farmers to get higher and regular returns on their investment. Industries have fast access to raw materials. Shisham plantation improves soil sodicity as well as soil fertility. It also checks soil erosion. It also fulfills the fodder requirement for livestock in the region (Tewari et al. 2013).

This system has a positive impact on conservation of soil and water, restoration of soil organic matter and livelihood support to the farmers in arid and semi-arid region of central India.

Way Forward

The shisham based agri-silvi model could be one of the best alternative land use systems for the farmers of Bundelkhand region.

Reference

Tewari, R.K., Dev, Inder., Singh, Ramesh., Tiwari, Rajeev and Srivastava, Rajesh. 2013. 25 Years of Agroforestry Research (1988-2013). Technical Bulletin 1/2013. Published by NRCAF, Jhansi. pp 128

Contributors

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4.3. Agroforestry Model: Aonla based Agri-horticultural System

Area of adoption: Bundelkhand region of Uttar Pradesh and Madhya Pradesh
Tree component: *Phyllanthus emblica*
Common name: Aonla, Gooseberry
Family: Phyllanthaceae

Habit and Habitat

Phyllanthus emblica is a small- to medium-size deciduous tree reaching up to 8 m height. Aonla prefers dry sub-tropical climate and can successfully be grown up to 2000 msl. Heavy frost during the winter season is not suitable for its cultivation. Slightly acidic to saline/sodic soil having pH between 6.5 and 9.5 is suitable for cultivation.

Distribution

Aonla is mostly cultivated in the states of Uttar Pradesh, Maharashtra, Gujarat, Rajasthan, Andhra Pradesh, Karnataka, Tamil Nadu and Himachal Pradesh.

Phenology

The plant defoliates during January-February and shows emergence of new leaves in the months of March-April. Blooming and fruiting activity of the species occurs during March-April. Immediately after fruit set, it undergoes dormancy (April-July). During rainy season (July-September) fruit growth and vegetative growth takes place. Fruits attain maturity in October-November and harvesting starts from November-December.

Package of Practices

Propagation Technology

Aonla can be propagated by

(a) Seeds

(b) Vegetative propagation

i) Patch budding, Modified ring budding

ii) Soft wood cleft grafting

Improved varieties: Chakaiya, Kanchan, NA-7, Krishna, Banarasi

Cultural Operations

Spacing: 6 m x 6 m or 8 m x 8 m

Pit size: Pits of 1.0 m x 1.0 m x 1.0m size should be dug two months prior to planting.

Planting time: July-August.

Fertilizer: At the time of pit filling, 15 kg of well rotten FYM, 1 kg neem cake, 100 g N and 50 g P should be mixed with soil and filled in pits. During the first year after planting, 100 g N, 50 g P and 10 kg FYM should be applied. Later on, every year fertilizers should be applied in increments of 100 g N, 50 g P, and 100 g K and 5 kg FYM up to the age of 10 years. For trees more than 10 years old, 1kg N, 0.5kg P and 60 kg of FYM should be applied. Fertilizers should be applied in 2 split doses in fruit bearing trees, first dose at new flush and second during monsoon.

Irrigation: Aonla is mostly grown as rainfed fruit tree and can tolerate drought conditions. Irrigation should be given at an interval of 10-15 days in dry summer during first 3-4 years.

Mulching: Mulching of straw or stone should be done in tree basin for moisture conservation and weed control.

Tending Operations

Pruning: Aonla trees do not require regular pruning. However, main branches should be allowed to appear at a height of 1 m above the ground level during early years. Plants should be trained to modified central leader system and two to four branches with wide crotch angle, appearing in the opposite directions should be encouraged in early years. While pruning, dead, diseased, broken, weak, crossing branches and suckers appearing, from root stock should be removed.

Tree Protection

Diseases: Rust and Soft rot

Control: Three sprays of wettable sulphur (0.4%) or Dithane- Z-78 (0.2%) during July- September for control of rust. Treatment of fruits with Difolatan (0.15%) or Dithane M-45 or Bavistin (0.1%) during November for control of soft rot disease.

Insects: Bark eating caterpillar, Gall caterpillar and mealy bug

Control: Remove webs and insert swab of cotton wool soaked in 0.025% dichlorvos or inject water emulsion of chlorpyriphos (0.05%) and plug the holes to keep bark eating caterpillar in control. Prophylactic spray of systemic insecticide like Dimethoate 0.03% will control the Gall caterpillar. In case of severe infestation of mealy bug, spray spinosad (0.25 ml/l) or quinalphos (0.05%).

Physiological disorder: Necrosis.

Control: 1. Combined spray of zinc sulphate (0.4%) + copper sulphate (0.4%) and borax (0.4%) during September-October has been found effective. 2. Spray of 0.5 to 0.6% borax in the month of September-October. 3. Resistant cvs like Chakaiya, NA6 & NA-7 should be planted.

Orientation: Block plantation.

Suitable intercrops: In Bundlekhand conditions green gram, black gram and sesame can be grown in *Kharif* season while in some cases depending upon soil type and irrigation facilities mustard or chickpea can also be grown during *Rabi* season by following standard package of practices and improved varieties.

Yield/Annual Returns and Economics

Aonla starts fruiting after 4 years of plantation and can give 400 to 500 kg/ha fruits and gradually the fruit yield increases with increasing age of trees. At the age of 10 years, it can yield up to 120 kg fruits per plant. After seven years of Aonla based agri-horticulture system (Aonla+ green gram/black gram), the B:C ratio of the system was 1.84. However, it increased to 3.28 at the age of 13 years of the system.

Aonla with wheat under Aonla based Agri-horticultural system in a farmer's field in Bndelkhand region

Benefits Accrued to Farmers/Public

The Aonla based agri-horticulture system has been proven to be one of the most profitable agroforestry systems in poor and marginal lands of drought-prone Bundelkhand region. It helps farmers to earn profits even in conditions of crop failure due to weather vagaries (Newaj et al. 2006).

Validated technology transferred to other departments/ agencies: The Aonla based agri-horti system has been popularized through various farmers training programmes as well as through distribution of planting material.

Way Forward

Aonla based agri-horticulture system is one of the best with respect to alternate land use and economic returns for Bundelkhand region. However, better availability of market and storage facility will further improve the livelihood of practitioners of this system.

Reference

Newaj R., Tewari R.K., Ajit, and Yadav, R.S. 2006. Aonla based Agroforestry: A promising system for rainfed areas. Technical Bulletin No./06, National Research Centre for Agroforestry, Jhansi. pp 1-20.

Contributors

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Agro-Ecological Region 5

Central Highlands (Malwa), Gujarat Plains and Kathiwar Peninsula

5.1. Agroforestry Model: Melia (*Melia azedarach*) based Agroforestry System

Area of adoption: Karnataka, Maharashtra
Tree component: *Melia azedarach*
Common name: Persian Lilac, Arabevu
Family: Meliaceae

Habit and Habitat

Melia azedarach is a fast growing deciduous to semi-evergreen tree. The adult tree has a rounded crown, and commonly measures 7–12 m. The leaves are up to 50 cm long, alternate, long-petioled, two or three times compound (odd-pinnate); the leaflets are dark green above and lighter green below, with serrate margins. The flowers are small and fragrant, with five pale purple or lilac petals, growing in clusters. The fruit is a drupe, marble-sized, light yellow at maturity, hanging on the tree all winter, and gradually becoming wrinkled and almost white.

Distribution

M. azedarach is native to Indomalaya and Australasia. It invades along roadsides, fence rows, and other disturbed areas. It grows in India, Afghanistan, Bangladesh, Indonesia, Japan, Laos and Pakistan. In India it is widely distributed in Karnataka, Gujarat, Maharashtra, Assam, Haryana, Himachal Pradesh and Orissa.

Phenology

The tree has a rounded crown, and commonly measures 7–12 m tall; however, in exceptional circumstances, *M. azedarach* can attain a height of 45 m. The leaves are long, alternate, long-petioled, two or three times compound (odd-pinnate); the leaflets are dark green above and lighter green below, with serrate margins. The flowers are small and fragrant, with five pale purple or lilac petals, growing in clusters. The fruit is a drupe, marble-sized, light yellow at maturity, hanging on the tree all winter, and gradually becoming wrinkled and almost white.

Package of Practices

A field trial on *Melia azedarach* based agroforestry system was initiated at the Main Agricultural Research Station, University of Agricultural Sciences, Dharwad on medium black clay soil under rainfed conditions during 2002. The experiment consisted of *Melia azedarach* planted at four spacings, *viz,* 5 x 1 m, 5 x 2 m, 5 x 3 m and 5 x 4 m. Soybean (JS-335) crop was grown in the interspace of melia rows during *Kharif* season every year. Recommended package of practices was followed for soybean. Fertilizer dose of 100:50:100 NPK kg/ha was applied to melia in the initial four years. All the silvi-cultural practices were followed for better development of *M. azedarach*.

Major Pests and Diseases

Soybean: Leaf eating caterpillar was observed. As a control measure, 2 ml of Chlorpyriphos 20 EC per litre of water was sprayed to the affected crop.

Orientation: Boundary/Block/In field

Suitable intercrops: *Kharif,* Soybean (JS-335)

Seed rate, fertilizer and irrigation

Crop	Seed Rate (kg/ha)	Fertilizer Dosage N, P_2O_5, K_2O (kg/ha)	Irrigation
Soybean	7.5	37.5 : 37.5 : 35.5	Rainfed
Melia azedarach	-	100:50:100 for first four years	Rainfed

Management requirement for crops

Soybean: Inter cultivation, weeding, chemical control measures for pests and diseases

Melia azedarach: Pruning up to two-thirds from the base is essential.

Yield/Annual Returns

Soybean: Grain yield was 1000-1200 kg/ha in 5 x 4 m spacing of *Melia azedarach*.

Tree Productivity

Melia azedarach: Productivity was higher in 5 x 4 m spacing after the 10th year and was used for small timber/pole purpose.

Economics

An economic evaluation was made based on prevailing market rate of soybean during the different years and also income from *Melia azedarach* which was worked out based on pole/biomass. At the end of the 10th year net returns and BCR were higher in melia at 5 x 4 m + field crop (Rs 10502/ha/yr and Rs 1.86:1, respectively) followed by sole field crop (Rs 6410/ha/yr and Rs 1.73:1, respectively) as compared to *Melia azedarach* at 5 x 1m + field crops (Rs 4351/ha/yr and Rs 1.27:1, respectively). The findings of the investigation reveal that *Melia azedarach* can be grown at a wider spacing of 5 x 4 m and the interspace can be used to raise agricultural crops. The system is economically viable.

Environmental Benefits

Melia azedarach is considered a multipurpose tree because of its multiple uses in agriculture. It is commonly planted along the bund/canal in irrigated area and its foliage is used as fodder. The technology is helpful for increasing green cover, soil fertility and income of farmers. It also has fungicidal, bacterial, anti-tumor and other medicinal properties.

Source of planting material: Research Institutions/SAUs/AICRP Centers: AICRP on Agroforestry, UAS, Dharwad ;State Forest Department Nursery: State Forest Department, Near K.C. Park, Dharwad, Karnataka

Benefits Accrued to Farmers/Public

The technology has been transferred to, and demonstrated in farmers' field under agroforestry training programs conducted by the Department.

Validated technology transferred to other departments/ agencies: The technology has been popularized through conducting agroforestry training programmes for the farmers/officers of the developmental departments from the Dharwad district and also farmers of the transitional and protective irrigation tract of Karnataka.

Way Forward

Melia azedarach can be planted on bunds/canal embankments in irrigated areas.

Contributors

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Agro-Ecological Region 6

Deccan Plateau (600-1000 mm rainfall)

6.1. Agroforestry Model: Three-tier Agroforestry System for Paddy Growing Area

Area of adoption: Eastern Maharashtra (Vidarbha), Konkan and Chhattisgarh
Tree component: *Tectona grandis*
Common name: Teak, Sagaun
Family: Verbanaceae

Habit and Habitat
Tall growing deciduous tree.

Distribution
Teak is native to India, Myanmar and Thailand. It occurs throughout India excluding J & K. and Himalayan region. It is introduced in moist deciduous forests of West Bengal, Assam, Bihar, Uttar Pradesh, Odisha and Andamans.

Phenology
Flowering, July to September, leaf shedding occurs in November to early January. It seeds every year, seed maturity November to January.

Package of Practices

Propagation technology
Saplings are raised from seed. One-year-old saplings/ stump are better for plantation.

Vegetative propagation: Tissue culture saplings are successfully raised and are equally good for plantation.

Cultural operation: Weeding around the plants for first two years

Spacing: Two metre in single row on paddy bunds (500 trees/ha).

Pit size: 45 x 45 x 45 cm.

Rotation: 20 years.

Tending operations

Fertilizer application (for first three years N: P: K; 100: 50: 50 gm., in two splits); pruning/lopping of side branches once a year (summer); thinning 50% of trees at 6th year; thinning 25% of trees at 12th year; final harvesting at 20th year.

Major pests and diseases and their control: Leaf defoliator, skeletonisers, rust. Chemical control through insecticides is advocated in nursery and small plantations only.

Orientation: Paddy bund-cum-mount plantation system.

Package of Practices for Mango Plantation

Propagation technology

Grafted saplings, improved variety; one-year-old saplings are better for plantation.

Spacing: Mango planted on soil mount 10 m apart (E-W: N-S), in paddy bundies (80 trees/ha).

Mount size: Circular base: 150 cm, Height 100 cm.

Rotation: 30 years.

Tending Operations

Fertilizer application (for first three years N: P K; 200: 50 : 100 g in two splits); pruning/lopping of side branches once a year (after harvest).

Suitable intercrops: *Kharif* – Paddy; *Rabi* – Gram, Black gram, Linseed, Lathyrus.

Economics

Table 1. Yield/ha of tree and intercrops

Year	Yield of Intercrop		Trees	
	Kharif -Paddy ton/ha	*Rabi* - Gram ton/ha	Teak	Mango fruits ton/ha
1 to 5th	2.56	1.00	-	-
6	2.10	0.50	250 poles	1.20
7th to 11 yr.	2.00	0.50		1.70
12	2.00	0.50	125 poles + 7.03 cum timber	2.15
13th to 19th yr	1.80	0.50		2.50
20th	2.00	0.40	125 poles + 13.62 cum timber	3.00

Table 2. Annual Returns from the AF system.

Year	Monetary Returns from Intercrop		Monetary Returns Trees		Total Rs.
	Kharif ton/ha	*Rabi* ton/ha	Teak	Mango ton/ha	
1 to 5th	51000	40000	-	-	91000
6	42000	23000	50000	24000	139000
7th to 11 yr.	41000	20000		34000	95000
12	40000	20000	25000 poles +281200 cum timber	43000	349200
13th to 19 th yr	36000	20000		50000	106000
20th	36000	16000	40000 poles +544800 cum timber	61000	645800
1 to 20 yrs.	Total Rs. 2806000				

C/B ratio: 1: 5.30

Environmental Benefits

This System is capable of creating an orchard-like microclimate. Carbon sequestration is estimated to be 10.23 ton/ha at the end of rotation.

Utilization

Intercrops such as paddy, sorghum, etc. are traditional food crops of this region. Mango fruits are commercially important. Teak trees produce valuable timber, fuel and biomass for composting.

Improved varieties/accessions: This centre has developed PDKV/ AF 1 selection type improved varieties of teak.

Source of planting material: OIC, AICRP on Agroforestry, PDKV, Nagpur State Forest Department (SFD) Nursery, Nagpur. Accredited private nurseries are also available locally.

Benefits Accrued to Farmers/Public

Socio-economic upliftment of farmers was observed.

Validated technology transferred to other departments/ agencies: Successfully transferred the technology to farmers under the Tibal Sub-Plan (TSP) programme.

Way Forward

The technology is recognised as PDKV-*Vanwadi* and the model is becoming popular among paddy farming communities.

Contributors

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6.2. Agroforestry Model: Teak based Agri-silvicultural System

Area of adoption: Karnataka, Maharashtra
Tree component: *Tectona grandis*
Common name: Teak
Family: Lamiaceae (syn. Verbanaceae

Habit and Habitat

Tectona grandis is one of three species in the genus Tectona. The other two, *T. hamiltoniana* and *T. philippinensis*, are endemics with relatively small native distribution in Myanmar and the Philippines, respectively. Teak is found in a variety of habitats and climatic conditions from arid areas with only 500 mm of rain per year to very moist forests with up to 5,000 mm of annual rainfall.

Distribution

Tectona grandis is native to South and Southeast Asia, mainly India, Sri Lanka, Indonesia, Malaysia, Thailand, Myanmar, but has been naturalized and is now cultivated in many countries in Africa and the Caribbean.

Phenology

Teak is a large, long, deciduous tree, up to 40 m tall, with gray to grayish brown branches. It is mostly known for its finest quality wood. Leaves are ovate-elliptic to ovate, 15–45 cm long, 8–23 cm wide, and are held on robust petioles. Fragrant white flowers are borne from June to August and fruit from September to December. Wood texture is hard and ring porous and free from termite/insect attacks. Teak is called the 'King of Timber' as it bears all the positive timber properties.

Package of Practices

In order to develop a suitable agroforestry system for red gravely soil in transitional tract of Karnataka, an experiment was in 1984 with teak at an alley of 20 m/10 m and 2 m apart within the line. The

interspace was used for raising a set of arable crops, namely, sorghum and groundnut in a sequence. Papaya was planted in between teak to harness the extra resources available in the initial three years. If the slope is more than 1%, Guinea grass slips and subabul at 60 x 60 cm and 60 x 20 cm, respectively, may be used along with teak row. Fodder can be harvested at regular intervals at 15 cm height, forming a 'live bund' which reduces runoff and thus helps to conserve soil and moisture.

Teak with groundnut and sorghum in a farmer's field

Major Pests and Diseases

In Teak, Stem borer and Leaf skeletonizer were observed. For controlling stem borer apply 0.2% quinolphos at the site of infection. Skeletonizers can be controlled by quinolphos 25 EC 0.05% spray.

Orientation: Boundary/Block/In field

Suitable intercrops: Arable crops, *viz*, sorghum and groundnut were grown in sequence.

Seed rate, fertilizer dosage and irrigation

Crop	Seed Rate (kg/ha)	Fertilizer Dosage N, P_2O_5, K_2O (kg/ha)	Irrigation
Sorghum	7.5	100 : 75 : 37.5	Rainfed
Groundnut	100	25 : 50 : 25	Rainfed

Management requirements for crops

Sorghum and groundnut: Inter-cultivation, weeding and suitable chemical control measures were carried out for the control of pests and diseases.

Teak: Proper pruning up to two-thirds of tree height from the base is essential.

Yield/Annual Returns

Papaya fruit yield: 30 kg/tree in the initial three years.
Sorghum grain yield: 800-1500 kg/ha/yr
Groundnut pod yield: 700-1200 kg/ha/yr.
Fodder Yield: 3.42 t/ha at 10 m alley and 1.89 t/ha at 20m alley
Teak: At the end of 22 years timber yield obtained was 24.35m^3/ha in 10 m alleys and 13.46m^3/ha in 20 m alleys.

Economics

An economic evaluation was carried out (22 years) by estimation of the value of standing trees (timber, fuel wood etc.), income from fruit yield of papaya, income from fodder and crop yield. The results at the end of 22 years revealed that the highest net returns of Rs.12,316/ha/yr were realized with field crop + teak + papaya and the Unit Cost of Rs 5838/ha/yr (average of 10 and 20 m alley). The contribution of income from various components was 39 to 47% by arable crops and 48 to 58% by teak. Hence this system was recognized as a sustainable and viable system suitable for transitional and irrigated areas with red/shallow black soils.

Environmental Benefits

Teak can be used for pole purpose and teak timber is used for furniture and agricultural implements. In the initial years farmer can get the income from crop yields and fodder.

In the initial three years, papaya can be used for juice, pulp at home and by and canning industries. There was a marked improvement in soil fertility over the years as indicated by improvement of bulk density, pH and electrical conductivity (EC) of soil and also an increase in organic carbon, potassium and phosphorus due to incorporation of leaf litter fall/decomposition.

It also helps to increase the green cover of the land. This technology is suitable for red/red gravely soil in the transitional and irrigated tract of Karnataka.

Source of planting material: AICRP on Agroforestry, UAS,

Dharwad; State Forest Department Nursery; State Forest Department, Near K.C. Park, Dharwad, Karnataka
Any other crops can be incorporated based on local conditions.

Benefits Accrued to Farmers/Public

Technology has been transferred to, and demonstrated in, farmers' fields under agroforestry training programmes conducted by the Department.

Validated technology transferred to other departments or agencies: The technology has been popularized through conducting agroforestry training programmes for the farmers/officers of the developmental departments from the Dharwad district and also farmers of the transitional and protective irrigation tract of Karnataka.

Way Forward

Teak bund/ boundary/canal plantings are suitable for small/marginal farmers.

Contributors

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6.3. Agroforestry Model: Sapota-Teak based Agroforestry System for Hill Zone of Karnataka

Area of adoption: Karnataka, Maharashtra Zone of Karnataka
Tree component: *Manilkara zapota and Tectona grandis*
Common name: Sapota and Teak
Family: Sapotaceae

Component 1. *Manilkara zapota*

Habit and Habitat

Manilkara zapota is a long-lived, evergreen tree. It is adapted to tropical and warm sub-tropical climates. It can grow to more than 30 m height with an average trunk diameter of 1.5 m. It is wind resistant and its bark is rich in white, gummy latex called chicle. The ornamental leaves are medium green and glossy. The white flowers are inconspicuous and bell-like, with a six-lobed corolla. A fully ripened fruit has saggy skin and does not release chicle when picked. The fruit is a large berry. Inside, its flesh ranges from a pale yellow to an earthy brown colour with a grainy texture. Each fruit contains one to six seeds. The seeds are hard, glossy, and black, resembling beans, with a hook at one end that can catch in the throat if swallowed. The fruit has an exceptionally sweet, malty flavour. The unripe fruit is hard to the touch and contains high amounts of saponin, which has astringent properties similar to tannin, drying out the mouth. The trees can only survive in warm, typically tropical environments, dying easily if the temperature drops below freezing. From germination, the sapota tree usually takes five to eight years to bear fruit. The trees yield fruit twice a year, though flowering may continue year round.

Distribution

Sapota is native to southern Mexico, Central America and the Caribbean. It grows in India, Bangladesh, China, America, Philippines, Malaysia, Thailand, Vietnam and Cambodia. In India it is widely distributed in Karnataka, Gujarat, Maharashtra and Orissa.

Phenology

The ornamental leaves are medium green and glossy. They are alternate, elliptic to ovate, 7–15 cm long, with an entire margin. The fruit is a large berry, 4–8 cm in diameter. Each fruit contains one to six seeds. The seeds are hard, glossy and black. The unripe fruit is hard to the touch and contains high amounts of saponin, which has astringent properties similar to tannin.

Component 2. *Tectona grandis*

Habit and Habitat

Tectona grandis is one of three species in the genus *Tectona*. The other two species, *T. hamiltoniana* and *T. philippinensis*, are endemics with relatively small native distributions in Myanmar and the Philippines, respectively. Teak is found in a variety of habitats and climatic conditions from arid areas with only 500 mm of annual rainfall to very moist forests with up to 5,000 mm of annual rainfall.

Distribution

Tectona grandis is native to South and Southeast Asia--mainly India, Sri Lanka, Indonesia, Malaysia, Thailand, Myanmar--and Africa and the Caribbean.

Phenology

Teak is a large, long, deciduous tree, up to 40 m tall, with gray to grayish brown branches. The tree is known known mostly for its finest quality wood. Leaves are ovate-elliptic to ovate, 15–45 cm long by 8–23 cm wide, and are held on robust petioles. Fragrant white flowers are borne from June to August and fruit from September to December. Wood texture is hard and ring porous and free from termite and insect attacks. Teak is called the 'King of Timber' as it bears all the positive timber properties.

Package of Practices

In order to develop a sustainable agroforestry model for the high/ assured rainfall areas of Karnataka state, a multi-component agroforestry system was initiated in 1976 involving sapota as a base crop planted at a recommended spacing of 10 m x 10 m. Three teak plants were planted in between two sapota plants. The tree rows were across the slope. The first teak was at 3 m from sapota and subsequent 2 teak trees at 2 m, thus leaving 3 m again between the last tree and sapota. On either side of the sapota and teak, Guinea grass was planted in a strip of 1 m width. In between two rows of sapota + trees, a field crop was grown for initial 8 to 10 years based on canopy coverage. Initially, paddy was grown for 5 years and South

African Maize for 3 years and Sun hemp for next 3 years until crown coverage. The perennial component was silvi-culturally managed and at the end of 17 years, two trees adjoining sapota were felled for pole purpose and the central one retained for timber purpose (28 years) and felled after 30 years.

Teak with sapota in a farmer's field--a suitable system for Karnataka hill areas

Major Pests and Diseases

Paddy: Leaf Blight, Blast, Stem Borer
Sapota: Fruit Sucker insect, Stem Borer
Teak: Stem borer, Leaf skeletonizer
Suitable measures were taken for the control of pests and diseases as and when noticed.

Orientation: Boundary/Block /In field

Suitable intercrops: For the first 5 years, paddy was grown and South African Maize for 3 years and Sun hemp for next 3 years until crown coverage.

Seed rate, fertilizer and irrigation

Crops	Seed Rate (kg/ha)	Fertilizer Dosage N, P_2O_5, K_2O (kg/ha)	Irrigation
Paddy	7.5	100 : 50 : 50	Rainfed
South African Maize	20	120 : 75 : 37.5	Rainfed
Sun hemp	20-	-	Rainfed

Management requirements for crops:

Paddy: Proper inter-cultivation and weeding, chemical measures for the control of pests and diseases

Sun hemp: In-situ incorporation in field at 75 days after sowing.
Teak: Proper pruning up to two-thirds of tree height from the base
Sapota: Soil working, fertilizer application and protective irrigation

Yield/Annual Returns

Paddy: Grain yield was 2500-3000 kg/ha/yr for initial 5 years
South African maize: Yield was 25-26 t/ha/yr for next 3 years.
Teak: 85 m^3/ha after 30 years.

Economics

An economic evaluation was carried out at 28 years by estimation of standing trees (timber, fuelwood etc.), income from fruit yield of sapota, receipt from felled trees at the end of 17 years and income from grass and crop yield. After felling teak trees adjoining sapota at the end of 17 years, the benefit cost ratio was 1:9.31 in sapota-teak-based agroforestry system. At the end of 28 years, the net returns were higher (12% discounted interest) in sapota + teak + field crop (Rs 38,977/ha/yr) and benefit cost ratio was 3.23 . Income from sapota fruit yield at 28 years was Rs 10, 417.50 kg/ha/yr.

Environmental Benefits

Sapota is used for juice and pulp at home and by canning industries. Teak is used for pole purpose and teak timber is used for furniture and agricultural implements. In the initial years farmer can get the income from crop yields.

Source of planting material: AICRP on Agroforestry, UAS, Dharwad and State Forest Department Nursery, Dharwad, Karnataka,

Benefits Accrued to Farmers/Public

The technology has been transferred under Technology Extension Programme and the system demonstrated in farmers' fields in Dharwad and Belgaum districts of Karnataka.

Validated technology transferred to other departments/ agencies: The technology has been popularized through conducting agroforestry training programmes for the farmers/officers of the developmental departments from the Dharwad district and

also farmers of the transitional and protective irrigation tract of Karnataka.

Way Forward

The system can be modified where mango can be used as base crop instead of sapota and any local fast-growing tree species can be incorporated.

Contributors

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6.4. Agroforestry Model: Sapota-Eucalyptus based Horti-silvi-pastoral System for Degraded Lands

Area of adoption: Karnataka, Maharashtra
Tree component: *Manilkara zapota and Eucalyptus tereticornis*
Common name: Sapota and Eucalyptus
Family: Sapotaceae

Tree component 1: *Manilkara zapota*

Habit and Habitat

Manilkara zapota is a long-lived, evergreen tree. It is adapted to tropical and warm sub-tropical climates. It can grow to more than 30 m height with an average trunk diameter of 1.5 m. It is wind resistant and its bark is rich in white, gummy latex called chicle. The ornamental leaves are medium green and glossy. The white flowers are inconspicuous and bell-like, with a six-lobed corolla. A

fully ripened fruit has saggy skin and does not release chicle when picked. The fruit is a large berry. Inside, its flesh ranges from a pale yellow to an earthy brown colour with a grainy texture. Each fruit contains one to six seeds. The seeds are hard, glossy, and black, resembling beans, with a hook at one end that can catch in the throat if swallowed. The fruit has an exceptionally sweet, malty flavour. The unripe fruit is hard to the touch and contains high amounts of saponin, which has astringent properties similar to tannin, drying out the mouth. The trees can only survive in warm, typically tropical environments, dying easily if the temperature drops below freezing. From germination, the sapota tree usually takes five to eight years to bear fruit. The trees yield fruit twice a year, though flowering may continue year round.

Distribution

M. zapota is native to southern Mexico, Central America and the Caribbean. It grows in India, Bangladesh, China, Philippines, Malaysia, Thailand, Vietnam and Cambodia. In India it is widely distributed in Karnataka, Gujarat, Maharashtra and Orissa.

Phenology

Sapota tree can grow to more than 30 m height with an average trunk diameter of 1.5 m. It is wind resistant and the bark is rich in white, gummy latex called chicle. The ornamental leaves are medium green and glossy. They are alternate, elliptic to ovate, 7–15 cm long, with an entire margin. The fruit is a large berry, 4–8 cm in diameter. Each fruit contains one to six seeds. The seeds are hard, glossy and black. The unripe fruit is hard to the touch and contains high amounts of saponin, which has astringent properties similar to tannin.

Tree component 2: *Eucalyptus tereticornis*

Common name: Eucalyptus
Family: Myrtaceae

Habit and Habitat

Eucalyptus is a fast-growing, medium-sized to tall tree. It has a deep

tap root system with mycorrhizal associations which increases its ability to survive in adverse conditions. The tree has a smooth silvery white stem. The leaves are leathery in texture and are studded with glands containing aromatic oil. Flowers in bud are covered with membrane, fruits are surrounded by a woody cup-shaped receptacle and contain numerous minute seeds.

Distribution

Eucalyptus, a native of Australia, was introduced about 200 years ago in India. Except in the north-eastern states it is widely planted in other states. Now, most of the Eucalyptus trees planted every year in the country are clones, which have been developed to suit the climate and topography of this land. Out of more than 600 species Eucalyptus species, around 200 species, varieties and provenances have been tried in India. The common species are *Eucalyptus camaldulensis, E. citriodora, E. globulus, E. grandis, E. pellita, E. tereticornis, E. torelliana and E. urophyla,* their hybrids and clones are now widely planted in the country.

Phenology

Flowering takes place during July-August, while fruiting occurs during September-October.

Package of Practices

An experiment was conducted in degraded shallow clayey soils of hilly zone of Karnataka under rainfed conditions. During 1977, Sapota was planted at 10 x 10 m spacing. In between two rows of sapota, three rows of Eucalyptus trees were grown, with the first row at 3 m from sapota and subsequent two rows at 2 m and thus leaving 3 m again between last Eucalyptus row and sapota. Intra-row spacing given for eucalyptus was 2 m. Natural grass was allowed to grow between plantations. All the trees were felled after 8-10 years and only sapota was allowed for further growth.

Major Pests and Diseases

Sapota - Stem Borer/Fruit fly is observed. Spraying with phosalone 35 EC (2 ml/l) chloropyriphos 20 EC or Endosulfan 35 EC has been found effective to control pests. Application of Dithane M 45, copper

oxychloride (3g/l) has been found effective in control of diseases. Suitable control measures were taken whenever the occurrence was noticed.

Orientation: Boundary/Block/In field

Suitable intercrops: Natural grass

Management requirements for crops: Sapota: Soil working, fertilizer application, protective irrigation and chemical control measures for pests and diseases.

Yield/Annual Return:
Sapota fruit yield: 3.54 q/ha/yr
Natural grass yield: 1-2 t/ha/yr

Tree productivity: Eucalyptus biomass yield: 35.8 t/ha

Economics

An economic evaluation was carried out by estimation of standing trees (timber pole, fuel wood etc.), income from fruit yield of sapota and from the grass. The results revealed that the highest net returns of Rs 9864/ha/yr were obtained with the unit cost of Rs 4183/ha/yr. Benefit Cost ratio in this technology was 2.24 : 1. Hence, this system was recognized as a sustainable and viable system for sloping and marginal degraded soils of hill zones of Karnataka where crop cultivation is not possible/limited.

Environmental Benefits

Sapota is used for preparation of juice and pulp at home and by canning industries. Eucalyptus can be used for pole/timber, fuel, furniture and medicinal purposes. In the initial years farmer can get the income from grass yield.

The technology is helpful for increasing green cover, soil fertility and increasing income of the farmers having 'D' type (infertile, degraded forests) of land holding. This technology is also suitable for low fertility/degraded soils/wasteland area of sloping lands.

Source of planting material: AICRP on Agroforestry, UAS,

Dharwad; State Forest Department Nursery: State Forest Department, Near K.C. Park, Dharwad, Karnataka

The local trees can be incorporated based on site and market facilities, *viz.*, Casuarina/Subabul.

Benefits Accrued to Farmers/Public

The technology has been transferred to, and demonstrated in, farmers' fields under the technology extension programme.

Validated technology transferred to other departments or other agencies: The technology has been popularized through conducting agroforestry training programmes for the farmers/officers of the developmental departments from the Dharwad district and also farmers of the transitional and protective irrigation tract of Karnataka.

Way Forward

The technology can be modified where mango can be used as base crop in place of sapota and fast growing tree species such as Melia can be incorporated.

Contributors

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6.5. Agroforestry Model: Tamarind based Silvi-horticultural System

Area of adoption: Karnataka, Maharashtra
Tree component: *Tamarindus indica*
Common name: Tamarind
Family: Fabaceae

Habit and Habitat

Tamarind is native to tropical Africa. It was introduced into India long ago. It is a semi-evergreen tree and. prefers semi-arid areas and wooded grassland, and can also be found growing along roadsides, streams and riverbanks.

Distribution

Tamarind grows wild in the drier parts of tropical Africa, where it is native, but it has been cultivated for so long on the Indian subcontinent that it is sometimes reported to be indigenous here. It is widely distributed throughout the tropical belt in the country.

Phenology

The tamarind is a long-lived, medium-growth tree, which attains a maximum crown height of 12 to 18 m. The crown has an irregular, vase-shaped outline of dense foliage. The tree grows well in full sun. It prefers clay, loam, sandy, and acidic soil types, with a high resistance to drought and aerosol salt (wind-borne salt as found in coastal areas). The evergreen leaves are alternately arranged and pinnately lobed. The leaflets are bright green, elliptic-ovular, pinnately veined. The branches droop from a single, central trunk as the tree matures, and are often pruned to optimize tree density and ease of fruit harvest. At night, the leaflets close up. As a tropical species, it is frost sensitive. Tamarind timber consists of hard, dark red heartwood and softer, yellowish sapwood. The fruit has a fleshy, juicy, acidulous pulp. It is mature when the flesh is coloured brown or reddish brown. The fruit is best described as sweet and sour in taste, and is high in tartaric acid, sugar, B vitamins, and, unusual for a fruit, calcium.

Package of Practices

The Tamarind was planted at 12 x 12 m apart on degraded sloping land of hilly zone of Karnataka. Five saplings of Eucalyptus and Casuarina trees were planted in between two tamarind plants at 2 m apart. Eucalyptus and Casuarina were planted in tamarind rows. The natural grass was allowed to grow in the experiments. Based on their growth after 12-15 years, both Eucalyptus and Casuarina were removed.

Orientation: Boundary/Block/In field

Suitable intercrops: Natural grass

Management requirements for crops

Tamarind: Soil working, fertilizer application and soil and moisture conservation structures, application of organic manuring
Eucalyptus: Pruning is essential up to two-thirds of height from the base.

Yield/Annual Returns

Tamarind fruits: 2.54 kg/ha/yr
Natural grass: 1.85 t/ha/yr

Tree productivity

Eucalyptus: 10–15 t/ha

Economics

Economic evaluation was made of standing trees (timber, fuel, pole etc). The net income from tamarind + Eucalyptus was Rs 6180/ha/yr. Benefit: Cost Ratio in this technology was 1.79: 1. This system is suitable and adopted for degraded and stony soils where crop cultivation is limited.

Environmental Benefits

Tamarind: fruit, fodder, fuelwood, timber. Eucalyptus: pole, timber, fuelwood and furniture. Improving soil fertility and greening of degraded sites.

Improved varieties/accessions: DTS-1, DTS-2 and SMG-13 can be used instead of local varieties.

Source of planting material:
Research Institutions/SAUs/AICRP Centers: AICRP on Agroforestry, UAS, Dharwad;
State Forest Department Nursery: State Forest Department, Near K.C. Park, Dharwad, Karnataka

Benefits Accrued to Farmers/Public

The technology is helpful in increasing income from 'D' type land holding, where crop cultivation is limited.

Validated technology transferred to other departments/agencies:
The technology has been popularized through conducting agroforestry training programmes for the farmers/officers of the developmental departments from the Dharwad district and also farmers of the transitional and protective irrigation tract of Karnataka.

Way Forward

The technology can be adopted by inclusion of improved varieties of tamarind, viz., DTS-1, DTS-2 and SMG-13 and integrating such trees as *Melia dubia, Casuarina equisetifolia* etc. instead of Eucalyptus.

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6.6. Agroforestry Model: Tamarind + Curry leaf based Agroforestry System in Degraded Soils with Protective Irrigation

Area of adoption: Karnataka, Maharashtra
Tree component: *Tamarindus indica*
Common name: Tamarind
Family: Fabaceae

(For Habit and Habitat, Distribution, Phenology and other information about Tamarind, please refer to Agroforestry Model 6.5 above.)

Component 2: ***Murrayya koenigii***
Common name: Curry leaf
Family: Rutaceae

Habit and Habitat

The curry leaf (*Murraya koenigii*) is a tropical to sub-tropical tree which is native to India and Sri Lanka. It is a small tree, growing 4–6 m tall, with a trunk up to 40 cm diameter.

Distribution

Found in deciduous forests from plains to 1000 m, often planted in the home gardens. Common in India, Sri Lanka, Myanmar, Thailand, Indo-China, S.China and Hainan. In India, it is found in Assam, Karnataka, Maharastra, Odisha, Punjab, Tamil Nadu, Uttar Pradesh and other states.

Phenology

The aromatic leaves are pinnate, with 11–21 leaflets, each leaflet 2–4 cm long and 1–2 cm broad. The plant produces small white flowers which can self-pollinate to produce small shiny-black drupes containing a single, large, viable seed. Though the berry pulp is edible with a sweet but medicinal flavour in general, neither the pulp nor seed is used for culinary purposes.

Package of Practices

Tamarind is planted at 6 x 6 m spacing in the degraded soil conditions. Curry leaf is planted at 2 x 2 m spacing in between two tamarind trees with protective irrigation.

Orientation: Boundary/Block/In field

Yield/Annual Returns

Curry leaf: Yield was 1-1.5 kg for first seven years
Tamarind: Fruit yield was 8-12 kg/yr

Improved varieties/accessions:DTS-1, DTS-2 and SMG-13 tamarind varieties are recommended for higher productivity..

Economics

From the tamarind + curry leaf based agroforestry system net returns obtained amounted to Rs 6125/ha/yr with the Benefit Cost ratio of 1.68:1.

Environmental Benefits

Tamarind: fruit, fodder, fuel, timber.
Greening the degraded lands.

Source of planting material

Research Institutions/SAUs/AICRP Centers:AICRP on Agroforestry, UAS, Dharwad; State Forest Department Nursery; :State Forest Department, Near K.C. Park, Dharwad, Karnataka

Benefits Accrued to the Farmers/Public

The technology has been transferred to, and demonstrated in, farmers' fields under agroforestry/biofuel training programmes conducted by the Department..

Validated technology transferred to other departments/agencies:

The technology has been popularized through conducting agroforestry training programmes for the farmers/officers of the developmental departments from the Dharwad district and also farmers of the transitional and protective irrigation tract of Karnataka.

Way Forward

The technology has been adopted by the farmers in the Dharwad, Bagalkot and Belgaum districts of Karnataka with protective irrigation facilities.

Contributors

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Agro-Ecological Region 7

Deccan Plateau (Telangana) and Eastern Ghats

7.1. Agroforestry Model: *Terminalia* based Agri-silvicultural System

Area of adoption: Mahaboobnagar, Nalgonda, Medak districts in Telangana; Cuddapah and Kurnool districts in Andhra Pradesh.
Tree component: *Terminalia bellirica*
Common name: Bedda nut tree, Beach almond, Kassha phalam, Baheda, Tanikaya
Family: Combretaceae

Habit and Habitat

Terminalia bellirica is a large deciduous tree common in plains and lower hills in Southeast Asia. A fast growing tree with a large globose crown, it can grow up to 50 metres tall. The buttered bole can be up to 200 cm in diameter and be branchless for up to 20 metres. The tree is cultivated everywhere in India because of its multiple uses in the Indian system of medicine.

Phenology

Leaves are alternately arranged or fascicled elliptic, leathery, dotted, leaf tip is rounded or pointed. Flowers are greenish yellow. Fruit is obovoid. Fruiting appears during November-February.

Package of Practices

The tree is propagated by seed. The land should be ploughed well before digging pits of size 45 cm x. 45 cm x 45 cm. A spacing of 3 m x 3 m or 4 m x 4 m may be used. FYM @ 5t/ha and NPK at 60:60:40 should be applied at the time of planting. Side branches should be removed up to a height of 5 feet.

Orientation: Facing East West direction

Suitable intercrops

Shade-loving crops like *Aloe vera* can be grown in-between trees. Root slips are used for planting. Approx 60,000-70,000 root slips are required per hectare The growth of *Aloe vera* is better with organic manures. Application of vermicompost @ 1.5 t/ ha produced higher leaf yield. This is applied twice a year (July and November)

***Terminelia bellarica* with Aloe vera under agri-silvicultural system**

Irrigation is required in the absence of sufficient rainfall at least once in 15 days during winter and once in 10 days during summer months. Manual weeding should be done in initial years.

Yield (Productivity)

Terminelia bellarica seed yield could range from 4 to 5 t/ha. *Aloe vera* leaf yield could range from 6 to 8 t/ha.

Economics

Income in initial years: Rs 15,000 to 20,000 per ha. After 5 years: Rs 25,000 to 30,000 per ha

Environmental Benefits

This agroforestry system is suitable for improving soil fertility and decreasing erosion of degraded lands.

Utilization
Useful in medicinal products.

Improved varieties/accessions: *Terminelia bellarica* and *Aloe vera* improved varieties are available.

Source of planting material: AICRP on Agroforestry, Professor Jayashankar Telangana State Agricultural University, Hyderabad, Telangana

Benefits Accrued to Farmers
Farmers can generate an income even from degraded lands/low fertility soils.

Validated technology: About 5 ha

Way Forward
The technology has good scope to encourage cultivation of medicinal plants for use in production of a variety of medicinal products, including *Aloe vera* gel, soaps etc.

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7.2. Agroforestry Model: Tamarind based Agri-silvicultural System

Area of adoption:	Mahaboobnagar, Nalgonda, Medak districts in Telangana; Cuddapah and Kurnool districts in Andhra Pradesh.
Tree component:	*Tamarindus indica*
Common name:	Tamarind
Family:	Leguminosae

Habit and Habitat

Tamarind is a slow-growing, long lived massive tree. Grown under favourable conditions, it can attain a height of 20-30 m. It is a wind and drought resistant tree.

Phenology

Tamarind is a semi evergreen tree with large alternately arranged and pinnately compound leaves. The flowers are pale yellow and staked with red. The fruits are thick with rough pods usually curved. Each pod contains up to 10 seeds embedded in a brown, sticky, fibrous edible pulp.

Package of Practices

The tree is propagated either by seed or grafting. After ploughing and levelling the land, pits of size 45 cm x 45 cm x 45 cm should be dug at a spacing of 10 m x 10 m. FYM @ 10 kg per plant and 60:60:40 NPK/ha should be applied every year up to 5 years. P and K should be then be every alternate year, and N every year.

Orientation: Facing East West direction

Suitable intercrops

Henna is grown as an intercrop with tamarind. It is maintained with Neem cake @ 2kg per plant and irrigation every 15 days.

Tamarind with henna based agri-silvicultural system

Yield

2560 kg/ha of tamarind pods and 560 kg/ha of Henna leaves.

Economics

Rs 42,600/ha (net returns)

Environmental Benefits
The tree sequesters maximum carbon from atmosphere and once established it reduces soil erosion.

Utilization
Culinary purposes.

Improved varieties/accessions: PKM-1

Source of planting material: Grafted material is available from TNAU, Coimbatore.

Benefits Accrued to Farmers
Suitable for dryland areas and low productivity soils.

Validated technology: About 5 ha

Way Forward
The technology is suitable for arid and dry regions in Telangana where arable crops are not profitable. This system will give fruits and Henna biomass together from the same piece of land.

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7.3. Agroforestry Model: Mango based Agri-horticultural System

Area of adoption:	Mahaboobnagar, Nalgonda, Medak districts in Telangana; Cuddapah and Kurnool districts in Andhra Pradesh.
Tree component:	*Mangifera indica*
Common name:	Mango
Family:	Anacardiaceae

Habit and Habitat

Mango is predominant in hot tropical or sub-tropical regions of the world with medium rainfall. Mango can be grown on a wide range of soil types from light sandy loam to red clay soils.

Phenology

Mango tree is erect and branches with a thick trunk and broad, rounded canopy. The leaves are dark. The fruit is drupe, with an outer flesh surrounding a stone.

Package of Practices

Mango is propagated by grafting. After ploughing and levelling the land, pits of size 45 cm x 45 cm x 45 cm are dug at a spacing of 10 m x 10 m. FYM @ 4 t/ha + 60-60-40 NPK/ha should be applied every year up to 5 years. The tree should be tended by removing side branches.

Orientation: Facing North-South direction

Suitable intercrops: Sorghum, Safflower, Cowpea

Filler crops: Curry leaf, Moringa

Yield: Sorghum 2.5 to 2.7 t/ha
Safflower 0.76 t/ha
Cowpea 1.5 t/ha (forage yield)

Sorghum–safflower–cowpea cropping system in mango based agri-horti-system

Economics: Rs 63,500/ha (From intercrop + filler crops)

Source of planting material: Seedling (Benishan)

Seed rate: Sorghum – 5-6 kg/ha
Safflower – 2-3 kg/ha
Cowpea – 4 kg/ha

Fertilizer: FYM @ 5 t/ha
Sorghum – 80-50-40 kg NPK/ha
Safflower – 60-40-40 kg NPK/ha
Cowpea – 30-40-40 kg NPK/ha

Irrigation: During critical stages (protective irrigation)

Management: Three crops are taken in a year. All the need-based plant protection and cultural operations are carried out.

Utilization: Fruit/seeds.

Improved varieties:
Mango-- (Benishan)
Sorghum – CSH-17
Safflower – DSH-185
Cowpea – PK-302

Environmental Benefits

This is an intensive agri-horti system under assured water availability which allows the best utilization of resources.

Source of planting material

Mango grafts –FRS, Sanga Reddy
Sorghum, Safflower and Cowpea-PJTSAU, Rajendranagar

Way Forward

This technology assures food, fruit and fodder availability which contributes to both financial and nutritional security of the farmer.

Contributors

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Agro-Ecological Region 8

Eastern Ghats, Tamil Nadu Uplands & Deccan Plateau

8.1. Agroforestry Model: Block Plantation of Sandal Wood

Tree component: *Santalum album*
Common name: Sandal, Chandan
Family: Santalaceae

Habit and Habitat

Small to medium size tree naturally found in dry deciduous forests of Deccan in South India.

Distribution

Naturally distributed throughout the Indian peninsular region in Karnataka, Tamil Nadu and also found in Kerala, Maharashtra, Madhya Pradesh, Odisha, Uttar Pradesh, Bihar and Manipur, and reported to be found in eastern Indonesia and north Australia.

Phenology

An evergreen tree, with two distinct flowering periods: May and November. Mature fruits appear during December and June.

Package of Practices

Propagation Technology: Preferably through seeds, seed treatment with gibberellic acid is beneficial. Primary hosts like red gram required during the nursery stage.

Vegetative Propagation: Air layering, Grafting (Srimathi, 1983) and Root cuttings (Uniyal et al. 1985).

Cultural Operations: Periodic inter-cultivation during initial years.

Spacing: 3 m x 3 m, host plant planted in Quincunx raised as block plantation; 6 m x 3 m with *Phyllanthus emblica* (amla) at the same spacing in between sandal in quincuncial design as for agroforestry.

Pit size: 50 cm^3

Rotation: 15 years

Tending Operations: Soil working to approximately 50 cm around the plants, weeding in 6 months interval for two to three years, and pruning of host plants to control suppression of sandal seedlings.

Other management requirements including tree protection: Root parasite requires host plants, preferably a leguminous plant or tree to grow beyond a year old (Rama Rao, 1903, 1918), fire and grazing control.

Major Pests and diseases and their control: Spike disease can be controlled through integrated management including host management, vector management and tending operations.

Orientation: Block, in field (during initial years of tree crop).

Suitable intercrops: *Phyllanthus emblica* as fruit crop and host, horse gram, field bean, low spreading legume fodder during initial years, *Sesbania grandiflora* as fodder crop and host.

Yield/Annual Returns

Equivalent annual income at 10 % discount rate for Sandal block plantation is Rs 3,52,756, Sandal+Amla+horse gram is Rs 3,38,191 and Sandal+Amla is Rs 3,36,217 (Viswanath et al. 2007)

Economics

B:C ratio at 10 % discount rate for Sandal block plantation is 4.4, Sandal+Amla+horse gram is 3.8 and Sandal+Amla is 3.8. (Viswanath et al. 2007)

Utilization: Heart wood for carving, wood and root for oil extraction, Sap wood in agarbatti industry, Ayurveda.

Source of planting material: ACZ Institute of Wood Science and Technology, Malleshwaram, Bangaluru; College of Forestry, Ponnampet,, Kodagu; Karnataka Forest Department Mysore Division, Mysore

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8.2. Agroforestry Model: *Melia dubia* based Agroforestry Systems: Mini Clonal Technology for Mass Multiplication

Area of adoption: Tamil Nadu, Karnataka, Andhra Pradesh, Kerala, Telangana, Maharashtra and Gujarat
Tree component: *Melia dubia*
Common name: Malabar Neem
Family: Meliaceae

Habit and Habitat

Melia dubia is an indigenous tree species to India, Southeast Asia and Australia. It is also called Mahaneem or Forest Neem or Malabar Neem. Malabar Neem is a fast growing tree species naturally

distributed in dry and moist deciduous forests of Western Ghats. The species has been naturally dispersed and is found sporadically distributed across farm lands in the hilly regions of Tamil Nadu and Karnataka and exhibits wide genetic variability. It is a large, deciduous tree with wide spreading branches on a stout, straight and a clean bole. Young shoots with inflorescence are covered with mealy stellate hairs. The tree is a light demander and the seedlings suffer from drought and frost. The species is adaptable to a wide range of soils, but good growth has been found in well drained loamy soils.

Distribution

M. dubia is distributed in India, Sri Lanka, Malaysia, Bhutan, Myanmar, Australia and Africa. In India, Melia is found in Sikkim, Himalayas, North Bengal, Upper Assam, Khasi hills, Hills of Orissa, Deccan plateau, Nallamalai hills and Western Ghats from southwards of South Canara at an altitude ranging between 1500 and 1800 msl. The species occurs predominantly in both tropical moist and dry deciduous forests of South India.

Phenology

Melia is a large deciduous tree which reaches a height of up to 35 m with a straight and clean bole height of 9 m. The tree reaches a girth of 1.2-1.5 m in about 15- 20 years. The bark is dark brown, exfoliating in thin, narrow strips with broad, shallow, longitudinal cracks. Leaves bi-pinnate or occasionally tri-pinnate. Leaflets ovate–lanceolate to ovate round, entire or crenulate; flowers greenish white, fragrant, intense panicles; fruit an ovoid or ellipsoid drupe with five or less seeds.

***Melia dubia* block plantation with improved planting material**

Package of Practices

Propagation through Mini Clonal Technology

Tamil Nadu Agricultural University (TNA) has developed a mini clonal technology exclusively for mass multiplication of *M. dubia*. Details of the technology for mass multiplication are given below.

Clonal Selection Programme

The first stage in clonal propagation is selection of a clone. It is the selection of the individual trees based on its morphogenic superiority from the existing plantations. Individual trees are selected based on growth attributes, tree morphology, tree health

Mini Clonal technology for *Melia dubia* mass multiplication

and apical dominance. In general, superior trees are selected from well established plantations through a comparison or check tree method. Clonal selection also depends on the species, objectives of management and also the end utility coupled with commercial value.

Once the trees are selected, they are cut at the base preferably at 15 cm above the ground level and are allowed to coppice. These coppice shoots are harvested and treated with rooting hormone and ramets are multiplied for field testing and evaluation. Based on the field productivity coupled with wood quality, the superior most clones are identified and the selected clones are finally screened and deployed for mass multiplication through mini clonal technology.

Clonal Multiplication Process

The clones identified in the above process are multiplied through the mini clonal technology for mass multiplication of *M. dubia*. The clonal materials are first established through micro propagation under controlled light and temperature conditions. The shoots produced are rooted under *in vitro* conditions and they are planted in mother clonal garden. The general clonal multiplication process followed is depicted in Fig. 1.

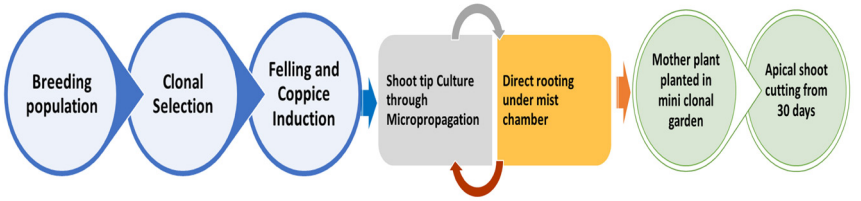

Fig. 1. Mini Clonal Technology protocol for mass multiplication

Construction of Sand Bed Trough

Screened Melia clones are planted in sand bed trough for mass multiplication. The sand bed trough can be of various sizes, viz., 10 x 1 x 0.6 m or 5 x 1 x 0.6 m or 3 x 1 x 0.6 m depending on the annual planting material requirement and associated management technologies. The troughs of the required sizes are constructed using cement concretes or fabricated through GI sheets. Once the bed size is designed and established, the bottom of the trough is filled with 20 mm stones up to the height of 20 to 25 cm from the base upwards. Then the portion above stone filling is filled with finely sieved river sand. The trough should have a provision for proper drainage at both the ends. The trough is covered with 100 micron UV stabilized polyethylene film on the top and covered with insect-proof mesh along the sides in order to protect the plants from pest and diseases. The bed is properly connected with drip lines to facilitate irrigation and fertilization.

Planting and Management of Clones

Once the trough is established, the prioritized clones of *M. dubia* are planted for mass multiplication. The ramets are planted at a spacing

of 10 cm x 10 cm (between rows and between plants) so as to cover 100 plants/m^2. In 10 m^2 plot, about 1000 plants can be planted. This establishment is pronounced as mother clonal garden or mini garden.

Irrigation: After planting, the clones are to be irrigated at an interval of every one hour in order to activate the cell division and induce new micro shoots for early harvest.

Fertigation: The mini clonal garden is maintained with irrigation at an interval of every one hour and supplemented with the following nutrients.

- ❖ All 17 (17:17:17) – 250 – 400 g/ m^2 area

Alternatively, the mother garden is applied with the following nutrients.

- ❖ Urea – 300-400 g/m^2 area
- ❖ SSP – 150-175 g/m^2 area
- ❖ KCL – 175-250 g/m^2 area
- ❖ Micro nutrient mixture – 100 g/m^2 area

The nutrients are applied twice or thrice depending on the rate of growth of plants and the clones involved in the multiplication process.

Clonal Management

The plants are allowed to grow up to 30-60 days by applying the required nutrient composition. After 60 days, the plants are pruned at required size preferably at half of the plant height to induce new shoots.

Harvesting of Apical Shoot Cuttings

With continuous irrigation and nutrient management, the cut end stem will start producing new shoots from 8-10 days onwards, and after 15-20 days the apical shoot cuttings can be collected and treated with 2% carbendazim solution. After each and every harvest, irrigation and fertilizer application should be continued daily to induce next cycle of shoots.

Mini Cutting Treatment

The apical shoot tip cuttings do not require basal hormone treatment for root initiation due to active cell division and the presence of balanced hormonal regulation. These shoot tip cuttings form new apical meristems and the leading growing tip do not originate from the lateral buds. Similarly the roots tend to grow straight down from the base of the cutting as opposed to growing from the side of the stem. This resulted in rapid growth and development and quality planting material. However, some of the Melia clones are recalcitrant towards root induction and require hormonal treatment with IBA at 1500 ppm.

Planting of Apical Shoot Cuttings

The newly induced shoots are separated from the plants and are planted in 90 cc root trainers filled with decomposed coir pith without any external hormonal treatment. Rooting starts in 15 days and 25 days old rooted plants are ready for hardening. Some clones require hormonal treatment for which IBA at 1500–3000 ppm powder formulation can be applied before transplanting in the root trainer.

Greenhouse Conditions

The root trainers are kept under green house conditions with a temperature regime of 32– 35°C and a relative humidity of 85-95%. Periodical watering once in every 30 minutes will ensure early, easy and uniform rooting process.

No. of Cycles of Shoot Harvest

Through this intensive and innovative mini garden management, at least one harvest per month is possible. For every harvest, a minimum of 3 to 5 shoots per plant is ensured for *M. dubia* barring a few clones.

Acclimatization and Hardening

The rooted plants are hardened in shade house condition with 50% shading for 7-15 days and maintained with adequate irrigation. After growing in hardening chamber, the plants are lifted to open nursery for 30 days. Watering is done two times a day. All 19 (N:P:K)

fertilizer can be applied at the rate of 5g/plant. During this hardening process, application of carbendazim (2g/l) or triazophos (2ml/l) is recommended based on the incidence of diseases and pests.

Spacing

S.No.	Purpose	Spacing	Number of Plants/hectare
1.	Plywood	5 m x 5m	400 plants/ha
2.	Pulpwood	2m x 2m	2500 plants/ha
3.	Biomass	1.5 m x 1.5 m	4500 plants/ha
4.	Pulp and plywood	2 m x 2m	2500 plants/ha with mechanical thinning at the end of 2, 4 and 6 years.
5.	Bund Planting	2 m distance	600– 000 plants /ha
6.	Agroforestry	5 m x 5 m to 8 m x 8 m	80–160 plants/ha

Pit Size: 30 cm x 30 cm x 30 cm

Basal application: 250g of Vermi-compost or 2kg of Farmyard manure per pit with 50-100 g DAP

Irrigation: The tree responds well to irrigation. The water requirement varies from 10 litres/day to 25 litres/day, depending on the age, through drip irrigation system.

Fertilizer: Application of organic manure (Vermicompost) @ 0.5 kg for each pit at the time of planting is advisable. Application of DAP at 50 g per tree as basal dose is recommended. The recommended dose of fertilizer is 250:125:250 NPK per hectare which could be applied in 3 to 4 split doses per annum.

Pruning: Pruning is essential in order to get straight and clean bole. Pruning is recommended up to 20 ft height.

Major Pests

S.No.	Pest	Nature of Damage and symptoms	Management
1.	Red spider mite, *Tetranychus urticae* (Tetranychidae: Acarina)	❖ Presence of chlorotic spots which coalesce to pale patches indicates the presence of mite infestation ❖ Extensive webbing underneath the leaves. ❖ Leaves start drying from the edges and slowly wither away	❖ Application of 5 per cent neem seed kernel extract (NSKE) or 3 per cent neem oil and soap solution emulsion towards the underside of the leaves can reduce the population level ❖ Foliar application of dicofol or propargite @ 2 ml per litre of water can be applied during severe infestation.
2.	Thrips (Phleothripidae: Thysanoptera)	❖ Both adults and nymphs suck the sap and scrap off tissue of unfolding young leaves leading to curling and chlorosis of young terminal leaves. ❖ Crinkling and curling of young leaves	❖ Application of 5% NSKE every 10 to 15 days interval is effective. When the thrips population is heavy, foliar application of dimethoate @ 2 ml/litre or fipronil @ 1.5 ml/litre or imidacloprid 0.6 ml/litre is recommended

Major Diseases

S.No.	Diseases	Symptoms	Management
1.	**Leaf blight:** *Colletotrichum* sp.	❖ Affected plants show symptoms like decaying of leaf tip in nurseries ❖ The infected leaves often crinkle and become distorted before shedding	❖ lndofil M-45 or Blitox fungicide application can control the problem
2.	***Ganoderma* root rot:** *Ganoderma lucidum*	❖ Water stress, one-sided mottling of the canopy, flattening of the crown, multiple unopened spears and production of basidiocarps on the lower stem.	❖ Drenching the root zone with Bavastin (0.1 %) solution can manage the problem. ❖ Removal of affected plants and use of *Trichoderma viride* and *Pseudomonas fluorescens* is effective.
3.	**Root rot disease: *Fusarium***	❖ Seedlings show yellow color leaves which fall leading to drying of plant.	❖ Drenching the root zone with Bavastin (0.1 %) solution can manage the problem. ❖ Removal of affected plants and use of *Trichoderma viride* and *Pseudomonas fluorescens* is effective.

Orientation: Bunds, boundary and block plantations

Suitable intercrops:

S.No	Tree component	Major crops	Crop component	Agroforestry system
1	*Melia dubia*	Pulses	Black gram, Green gram, Red gram	Silviagriculture
2	*Melia dubia*	Oilseeds	Sunflower, Groundnut, Gingelly	Silviagriculture
3	*Melia dubia*	Vegetables	Tomato, Brinjal, Ladies Finger,	Sivihorticulture
4	*Melia dubia*	Gourds	Bitter gourd, Bottle gourd, Snake gourd, Ridge gourd	Sivihorticulture
5	*Melia dubia*	Greens	Amaranthus, coriander	Sivihorticulture
6	*Melia dubia*	Palms	Coconut, Oil palm, Arecanut	Agrisilvihorti-culture
7	*Melia dubia*	Fruit crops	Banana, Papaya, Pomegranate, Lemon	Silvihorticulture
8	*Melia dubia*	Tree crops	Casuarina, Teak, Gmelina, Jack	Mixed species tree garden
9	*Melia dubia*	Medicinal Plants	Vetiver, Tulsi, Adathoda, Senna, Aloe Vera	Medicinal plant based agroforestry
10	*Melia dubia*	Flowering crops	Jasmine	Silvihorticulture
11	*Melia dubia*	Other Crops	Turmeric, Curry Leaf, Mulberry, Moringa	Silvihorticulture, Silvisericulture
12	*Melia dubia*	Grasses	African Tall Maize, CO(FS) 29, CO(CN) 4 grass, CO(GG) 3, *Desmanthus virgatus, Stylosanthes hamata, Sesbania grandiflora*	Silvipasture

Thinning: Under high density plantations particularly in pulp and ply model (2500 trees/ha) the following thinning regime is recommended.

a) Thinning of alternate rows at the beginning of 3rd year

b) Thinning alternate diagonals at the beginning of 5th year

c) Final harvest at the beginning of 7th year

Yield

- For pulpwood: 100-150 tonnes/ha in three years.
- For plywood: 200 tonnes/ha in six years

Economics

The cost of cultivation of *Melia dubia* for one hectare and financial analysis for three different models are furnished below.

S.No.	Financial analysis	Pulpwood model	Plywood model	Pulp and Ply model
1	BC ratio at 15%	2.18	3.94	2.92
2	NPV at 15%	446183	484083	611940
3	IRR	90%	79.50%	84%

Environmental Benefits

The Melia based agroforestry system is able to generate 100 tonnes of wood as a short duration pulpwood which has a potential to sequester 50 tonnes of carbon and hence can play a vital role in environmental amelioration. Similarly, under medium rotation practices, the Melia clone based agroforestry plantation is able to generate 200 tonnes of wood which has a potential to sequester a 100 tonnes of carbon and hence Melia based agroforestry system could play a vital role in climate change mitigation and adaptation process.

Utilization

The wood is mainly used as a raw material for plywood and paper industries due to medium density coupled with higher cellulose to lignin ratio. The wood is also used for packing cases, cigar boxes, ceiling planks, building purposes, agricultural implements, pencils, match boxes, splints and Kattamarams (multi-hulled watercrafts). It is employed for outriggers of boats. It is suitable for musical instruments, tea boxes and plyboard. It is a good fuelwood (calorific value: 3,400 - 4,100 cal.). The leaves are an excellent fodder for cattle.

Improved varieties/accessions

Released clones: MTP 1 and MTP 2
Pre release cultures: MD 44, MD 27 and MDCW 5

Source of planting material: Department of Agroforestry, Forest College and Research Institute, Tamil Nadu Agricultural University, Kothagiri Road, Mettupalayam,, Tamil Nadu

Benefits Accrued to Farmers/Public

i. Productivity impact

The Melia based agroforestry system has made significant impact in terms of productivity improvement. The productivity level has improved from 10 m^3/ha /annum to over 25 m^3/ha/annum.

ii. Impact on profitability

The Melia based silviagricultural system has created significant profitability improvement which resulted in income realization of over 1 lakh /acre/annum compared to less than Rs.50,000/annum from the traditional agricultural practices.

iii. Impact on income and employment generation

The Melia based agro and farm forestry system has witnessed adequate income and employment generation activities in the form of nursery establishment, plantation establishment and management, felling, transportation, loading and unloading of farm grown products. It has been estimated that 1 ha of Melia based agroforestry plantation is able to generate over 300 man days of employment from the entire production to consumption system.

iv. Assured raw material supply

Due to the promotion of Melia based agroforestry system, the plywood and paper industries are able to get assured supply of raw materials.. It is estimated that the organized promotion of Melia based agroforestry plantation is able to generate at least 20% of the raw material resources of the industries.

Validated technology transferred to other departments/ agencies

The variety and the associated Melia based Agroforestry system has been transferred to two plywood industries,, M/S Century Ply Board (I) Ltd, Chennai and Ambiply Panels and Doors, Mettupalayam through necessary Memorandum of Agreement which resulted in area expansion of over 2000 ha under Melia based agroforestry system in the entire south India. Similarly, two paper industries in Tamil Nadu also adopted *M. dubia* as an alternate pulpwood species and are involved in consortia mode agroforestry promotion.

Way Forward

The Melia based agroforestry system has gained significant attention across the state of Tamil Nadu due to its fast growth, higher productivity coupled with multifarious industrial utility and increased adoption by the farmers. This species needs to be promoted further as boundary plantation, organized farm forestry plantation and also in varied multifunctional agroforestry systems. The participation and integration of wide range of wood-based industries in Melia based promotional activity and strengthening Melia based contract farming system will ensure assured buyback and profitable value chain system. The intensification of consortia mode promotion of Melia based agroforestry system will further help to achieve the objectives envisaged in National Forest and Agroforestry Policies besides creating self-reliance in raw material security for both domestic and industrial wood requirement.

Contributor

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8.3. Agroforestry Model: Coconut (*Cocos nucifera*) based Horti-pastural System

Area of adoption: Kerala, Tamil Nadu, Andhra Pradesh and Karnataka
Tree component: *Cocos nucifera*
Common name: Coconut
Family: Arecaceae

Habit and Habitat

Cocos nucifera grows with a single unbranched trunk up to 30 m in height and 50 cm in diameter and the base gets thicker. Its habitats range from areas of human habitation to sandy beaches.

Distribution

Coconut is distributed in the states of Kerala, Tamil Nadu, Karnataka, Andhra Pradesh, Orissa, West Bengal, Pondicherry, Maharashtra and Islands of Lakshadweep and Andaman and Nicobar in India. Four southern states account for 92% of the total production in the country (Kerala 45.22%, Tamil Nadu 26.56%, Karnataka 10.85%, Andhra Pradesh 8.93% and other states 8.44%).

Phenology

The primordial of the inflorescence is reported to develop in the leaf axils about 32 months before the opening of the inflorescence. The primordia of the branches of florescence develop in about 16 months and male and female flowers in about 11 and 12 months, respectively, before the opening of the inflorescence. The ovary is first differentiated about 6-7 months before the opening of the inflorescence. Seasonal factors prevailing during the developmental stages during the period of 32 months before the inflorescence opens do affect the yield of nut. The number of nuts harvested per palm during April - May (second half summer) is significantly high and distinct while low during the first half of southwest monsoon (May-June).

Fodder Component

Name of Species:	Hybrid Napier (*Pennisetum purpureum*)
Common Name:	Cumbu Napier hybrid grass, Elephant grass
Family:	Poaceae

Habit and Habitat

Hybrid Napier is a perennial plant. Napier grass requires warm and moist climate, clay to clay loam soil for good growth. It is a prolific yielder. The crop grows throughout the year in south and northern India, and is sown during end of February to end of August. This grass is resistant to most of pest and diseases. It forms large, broad clumps. It is a tall (200-300 cm), erect, stout, deep rooted, perennial grass. The hybrid is a triploid, hence sterile, and does not produce seed.

Distribution

Hybrid Napier is widely distributed in tropical and sub-tropical regions of India. Among the improved fodder grass species, it is a multicut perennial grass with profuse tillering and very good tonnage throughout the year. It can be grown in saline soils, wastelands, bunds and terraces. It grows well in the arid and semi-arid regions of India.

Phenology

Hybrid Napier performs well in areas having temperatures above 15 ^{o}C. It is a tropical grass, which can withstand drought for a short spell, and regenerate with rains.

Package of Practices

Propagation Technology

Coconut is propagated through seedlings raised from selected seed nuts. Generally 9 to 12 month old seedlings are used for planting. Seedlings are selected which have 6-8 leaves and 10-12 cm collar girth when they are 9 to12- month old. Early splitting of leaves is another criterion in the selection of coconut seedling.

Planting

A pit size of 90 cm x 90 cm x90 cm is recommended. Under hortipasture system square planting with a spacing of 7.5 x 7.5 m is recommended.

Before planting the pits are filled up with top soil and powdered cow dung/compost up to a depth of 60 cm. Then take a small pit inside this, so as to accommodate the nut attached to the seedling. Plant the seedling inside this pit and fill up with soil. Press the soil well so as to avoid water stagnation. Burying 25 to 30 coconut husks per pit in layers will be useful for moisture conservation.

Irrigation

Irrigate the palms during summer months in basins around the palm. The irrigation requirement varies according to the soil type and climatic conditions. Generally, an adult palm requires 600 to 800 litres of water once in four to seven days. Irrigate in basins of 1.8 m radius and 10-20 cm depth. Drip irrigation is the best suited method of irrigation for coconut. It saves water, labour and energy.

Manuring

Regular manuring from the first year of planting is essential to achieve higher productivity. – Organic manure, 20-50 kg, should be applied per palm per year with the onset of south-west monsoon, when soil moisture content is high. In addition to this, the following Fertilizer Schedule is recommended.

Age (Years)	FYM (kg/tree)	Urea (kg/tree)	Super Phosphate (kg/tree)	Muriate of Potash(kg/tree)
1	10	0.308	0.500	0.480
2	20	0.616	1.000	0.960
3	30	0.924	1.500	1.440
4	40	1.23	2.000	1.920
5th year onwards	50	1.23	2.000	1.920

Apply manures and fertilizers in circular basins of 1.8 m from the base of the palm, incorporate and irrigate. The fertilizers should be applied in two split doses, in June–July and in December--January.

Major Pests and Diseases

The major insect pests of the coconut palm are the rhinoceros beetle, red palm weevil and black headed caterpillar.

Control measures for rhinoceros beetle: Green muscardine fungus, *Metarhizium anisopliae* (spray 250 ml Metarhizium culture + 750 ml water in manure pits and other breeding sites of the beetle). Practice clean cultivation.

Control measures for red palm weevil: Use pheromone trap for attracting weevils and kill the collected ones. Inject attacked palms with 1% Carbaryl (20 gm/litre).

Control measures for black headed caterpillar: Biological control is very effective against this pest through release of parasitoids like *Goniozus nephantidis, Elasmus nephantidis* and *Brachymeria nosatoi*. In case of severe attack, remove the affected leaves and destroy by burning. Then spray the under surface of leaves with 0.02% Dichlorvos (Dichlorvos 100EC).

Orientation: Boundary/Block/In field

Suitable intercrops: Perennial fodder, Cumbu Napier hybrid grass is planted as understorey of *Cocos nucifera*.

Seed rate: It is propagated by stem cuttings with two buds or rooted slips. About 33,333 rooted slips or stem cuttings/ha are needed. They should be planted in the field with a spacing of 60 x 50 cm.

Coconut with Napier for degraded lands under a horti-pastural system at the Research Farm of TNVAU, Kattupakkam

Irrigation: Irrigation should be done immediately after the

planting of crop; life irrigation on the third day and thereafter once in 10 days.

Fertilizer: FYM: 25 t/ha, NPK: 150: 50: 40 kg/ha
Basal - FYM25t/ha, NPK 75:50:40 Kg/ha
Top dressing - 75 kg N/ha 30 days after planting, 75 kg N/ha after each cut

Harvesting: First harvest at 75 days after planting and subsequent harvests once in 45 days

Yield

Coconut (*Cocoss nucifera*) based horti-pasture system produces about 270 MT/hectare/year of Cumbu Napier hybrid grass. One hectare of this pasture in a year can support the active growth of 30 crossbred calves.

Economics

Establishment of Horticultural component

Crop	Area (acre)	No. of trees	Cost of Establishment (Rs)	Yield	Cost (Rs/ coconut)	Return (Rs)
Coconut (8 x 8 m)	1.0	62	60,000	60 Nos./ tree	15	55,800

Additional cost of establishment of introducing pasture as understorey in Horticultural component

Crop	Area of culti-vation	Establi-shment cost (Rs)	Labour and electricity cost (Rs)	Yield (tonnes/ acre)	Sale @ Rs	Return (Rs)
Hybrid Napier	1 acre	15,000/-	10,000/-	108 tonnes	2/kg	2,16,000/-

By sale of fodder to needy farmers, Rs 1, 86, 800/- additional income will be generated. Or, A farmer can rear five cows and their fodder requirement will be met through this horti-pasture system.

Expenditure :

Cost of purchase of five cows @ Rs. 35,000	= Rs 1,75,000/-
Cost of concentrate	
2 kg/ cow x 5 cows x Rs 24/kg x 305 days	= Rs 73,200/-
Total expenditure	= Rs 2,48,200/-

Income:

8 litres/cow/day x	
305 days x 5 animals x Rs 25/litre	= Rs 3,05,000/-
By sale of manure	= Rs 5,000/-
Total income	= Rs 3,10,000/-
Net return	= Rs 61,800/-

Environmental Benefits

Farmers establishing this agroforestry model will be able to meet the green fodder requirement of their livestock. The livestock productivity will be enhanced as their nutritional requirement will be satisfied. Farmers will be benefitted economically by the enhanced productivity of livestock. Ecologically sound agroforestry systems such as intercropping and mixed arable livestock systems can increase the sustainability of agricultural production.

Utilization: Fodder and fruits

Improved varieties/accessions

Coconut:
Tall cultivars - West Coast Tall and East Coast Tall
Dwarf variety - Tall x Dwarf (TxD), Dwarf x Tall (DxT)
Cumbu Napier Hybrid grass*:* Co (BN) 5

Source of planting material

Coconut*:* State Forest Department Nursery
Cumbu Napier Hybrid grass*:* AICRP on Agroforestry, TANUVAS, Kattupakkam

Benefits Accrued to Farmers/Public

Farmers can enjoy multiple benefits such as fruit, fodder and leaf litter needed for organic manure production. The sale of fruits and fodder contributes to the sustainability of farmers' livelihoods.

Validated technology transferred to other departments/agencies:
About 50 hectares

Way Forward

This technology has a wide scope for livestock farmers in this region. To augment fodder availability throughout the year this hortipasture model has been developed for this region. The surplus fodder harvested from this model can be conserved as silage and provide quality fodder to livestock during scarcity period.

Contributors

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Agro-Ecological Region 9

Northern Plains

9.1. Agroforestry Model: Poplar based Agri-silvicultural System

Area of adoption: Punjab, Haryana, Himachal Pradesh, Uttar Pradesh and parts of Uttarakhand under AER 4 (semi-arid) and AER 9 (hot sub-humid dry)
Tree component: *Populus deltoides*
Common name: Poplar
Family: Santalaceae

Habit and Habitat

Populus deltoides is a fast growing medium to large tree. It grows mostly in warm and cold temperate regions; wetlands, riparian corridors or uplands; few taxa found in tundra and alpine zones.

Distribution

P. deltoides is the most widely planted species of poplar in India. It was introduced in India in the late 1950s. It is planted in plains of North-West India, i.e., Western Uttar Pradesh, Punjab and Haryana and to some extent in the outer plains/valleys of Uttarakhand and Himachal Pradesh. It is widely planted in the Tarai belt extending up to Bihar and West Bengal.

China is recognized as the country with one of the richest resources of natural poplar forests in the world and by 2010 it had also become the world leader in poplar cultivation for timber, fibre,

pulp and paper, agroforestry and environmental uses. Chile has a history of planting poplars in the mid-19th century. Since mid 1980s, private industries in India have contributed significantly to sustainable rural development by planting poplars.

Phenology

Poplar is a genus of 25–35 species of deciduous flowering plants native to most of the Northern Hemisphere. English names commonly applied to different species include poplar, aspen and cottonwood**.** The genus has a large genetic diversity where plants grow from 15–50 m (49–164 ft) tall with trunks up to 2.5 m in diameter.

Bark: The bark on young trees is smooth, white to greenish or dark grey, and often has conspicuous lenticels; on old trees, it remains smooth in some species, but becomes rough and deeply fissured in others.

Flowers: The flowers are mostly dioecious (rarely monoecious) and appear in early spring before the leaves. They are borne in long, drooping, sessile or pedunculate catkins produced from buds formed in the axils of the leaves of the previous year. The flowers are each seated in a cup-shaped disk which is borne on the base of a scale which is itself attached to the rachis of the catkin. The scales are obovate, lobed, and fringed, membranous, hairy or smooth, and usually caducous. The male flowers are without calyx or corolla, and comprise a group of 4 to 60 stamens inserted on a disk; filaments are short and pale yellow; anthers are oblong, purple or red, and two-celled; the cells open longitudinally. The female flower also has no calyx or corolla, and comprises a single-celled ovary seated in a cup-shaped disk. The style is short, with two to four stigmata, variously lobed, and numerous ovules. Pollination is by wind, with the female catkins lengthening considerably between pollination and maturity.

Fruits: The fruit is a two- to four-valved dehiscent capsule, green to reddish-brown, mature in mid-summer, containing numerous minute light brown seeds surrounded by tufts of long, soft, white hairs which aid wind dispersal.

Leaves: Variable in shape – deltoid to cordate to ovate to lanceolate, occasionally palmately lobed; venation palmatopinnate; margins serrate or dentate and glandular. Indeterminate shoots heterophyllous; heteroblasty occurs in some taxa. The leaves are spirally arranged, and vary in shape from triangular to circular or (rarely) lobed, and with a long petiole; in species in the sections *Populus* and *Aigeiros*, the petioles are laterally flattened, so that breezes easily cause the leaves to wobble back and forth, giving the whole tree a "twinkling" appearance in a breeze. Leaf size is very variable even on a single tree, typically with small leaves on side shoots, and very large leaves on strong-growing lead shoots. The leaves often turn bright gold to yellow before they fall in autumn.

Petioles: Long, sometimes flattened transversely; glands may occur at junction of petiole and leaf blade

Buds: Elongated, often pointed, covered by several overlapping scales, sometimes resinous and fragrant; usually divergent from twig; mostly monopodial with prominent terminal bud.

Shoots: Moderately stout; brown, purple or red in colour; circular or angular in cross section; lenticels prominent; pith pentagonal in cross section; heterophyllous (dwarf shoots may be present). Many taxa produce root suckers

Wood: Light (specific gravity 0.31–0.40), straight grained, soft, pale, not durable, often with a disagreeable odour when wet; rays homocellular.

Package of Practices

Propagation Technology and Production of Nursery: Poplar is propagated through cuttings. Cuttings of about 1.5 - 2 cm diameter and 20-25 cm length with four to six live buds are prepared from one-year-old plants from the previous year nursery, during January-February when the plants are leafless. They are planted at a spacing of 50 cm x 50 cm during last week of January to the first fortnight of February (before bud opening). These are inserted into the holes made with the help of a planting rod. Different operations are done to

grow healthy and vigorous plants in the nursery. These poplar plants shed their leaves during winter and these can be lifted at any time after leaf shedding. Care must be taken that the time period between lifting of plants and their planting in the field is minimum. The lifted plants with bare roots are called as entire transplants (ETPs). The roots of ETPs are pruned leaving about 20– 0 cm long main root and about 10-5 cm lateral roots. Care must be taken against the loss of moisture of ETPs since the time these are uprooted from the nursery till planted in the field.

Spacing: Trees can be planted on field boundaries or in blocks. The spacing and choice of planting depends on the size of land holding, management practices and objectives of farmer. Small or marginal farmers should plant trees on field boundaries preferably in north–south row direction at a distance of 2.5–3 m. This row direction will minimize the shade effect of trees on adjoining crops. Farmers generally follow 5 x 4 m spacing for block plantation that accommodates about 200 plants per acre. It is now recommended to plant poplar at a spacing of 8 x 2.5 m, i.e. increase distance between rows (8 m) and decrease distance within rows (2.5 m) accommodating same number (200) of plants per unit area. In this 8 x 2.5 m spacing, the wider strip (8 m) should be used for growing crops and it should be in north-south row direction.

Planting technique: Prepare the pits of 15–25 cm diameter with the help of an auger or *boki* (used for boring water pump) up to a depth of about 100 cm. Plant one-year-old ETPs in January–February before the rise of temperature. It is recommended to keep the ETPs with bare roots in running water for at least 48 hours to promote root buds. Before planting, treat the ETPs (bottom 1m) with Chlorpyriphos 20-EC (500 ml in 100 L water) and Emisan-6 (250 g in 100 L water) for 10 minutes each separately. After planting, fill the pits with topsoil mixed with 50 g urea and 85 g DAP (or 85 g urea and 250 g SSP) to promote root development. The loose soil in the pit should be properly compacted so that no air space is left. Do not fill the pits up to ground level so as to help retain some water in pit during irrigation. The plants should be watered immediately after planting.

Irrigation: Poplar being fast growing tree requires lot of water especially during growing season from April to October. During first year, after transplanting, more frequent irrigations (once a week) are required. Subsequently, irrigate fortnightly during October-February and at 7-10 days interval during March-June. Trees are usually provided irrigation as per the requirement of crops. Sometimes trees suffer badly for want of irrigation especially during growing season. Common example of this is wheat ripening and harvesting stage. For proper irrigation, each row of poplar trees should have an independent channel throughout the rotation age. The intercrops should be grown in the area between two such rows. The growth parameters of trees in channels are higher than those without channels. This way trees are saved from any water stress during wheat maturity period (April).

Fertilizer application: In this agroforestry system, better tree height and girth of poplar can be obtained with the application of N as depicted in Table 1. Every year, apply 1/3rd N during May after harvesting of the intercrop, 1/3rd N in July and the remaining 1/3rd N in September. The doses in table are for the soils which are medium in available N. In low N soils, apply 25% more and in high N soils apply 25% less N than the above doses. There is no need of P application to poplar every year.

Table 1. Fertilizer requirement of poplar plantation in agroforestry system

Growth year	Nitrogen (g/plant)	Urea (g/plant)	Area of application
1	80	170	1 m diameter ring
2	120	260	2 m diameter ring
3	160	350	3 m wide strip (1.5 m on both sides of tree row)
4	200	430	- do -
5	240	520	- do -
6	280	610	- do -

In addition to N, Zn should be applied to poplar plantations. Deficiency of Zn appears in most of the plantations. The deficiency symptoms of Zn initially appear on the recently matured leaves (5th or 6th leaf from top of branch). The deficiency is exhibited by irregular interveinal yellowing of leaves. In case of severe deficiency, the veins also start turning yellow. Zinc deficiency can be cured by application of 100, 200 and 300 g/plant zinc sulphate heptahydrate (21 % Zn) or 60, 120 and 180 g/plant zinc sulphate monohydrate (33 % Zn) in Zn-deficient soils during 1st, 3rd and 5th year of poplar growth in 1 m diameter ring, 2 m diameter ring or 3 m wide strip (1.5 m on each side of tree row), respectively, around the plants after harvesting of the *rabi* intercrop.

Tending operations: In the first year, debudding is done after rainy season to remove newly formed buds. This can be done by gently rubbing the stems with a wet gunny bag up to lower one-third height of plant. Second year onwards, pruning should be done during winter season when trees are leafless. This is important to produce quality timber with large clear bole free from knots. Avoid excessive pruning as it negatively affects growth of plants. Main emphasis in pruning should be to prune thick and vertical branches that compete with the main stem. Bordeaux paste (2 kg Copper sulphate + 3 kg Lime + 25 L water) should be applied on cut ends to avoid infection by pathogens.

Tree protection

Major pests

Poplar is attacked by poplar leaf defoliators (PLDs), poplar leaf webber, bark eating caterpillar and stem borer.

Management:

PLDs: Cultural practices followed to raise intercrops in poplar plantation help in reducing the population load of the defoliator larvae in the subsequent year. The pupae of the defoliators (which are enclosed in leaf folds) fallen on the ground during deciduous phase are either cut or buried in soil due to ploughing, tilling and irrigation practices which result in lower incidence. Plants should

be sprayed alternatively with Ekalux 25EC @ 2 L (Quinalphos) or Curacron 50EC (Profenophos) @ 1 L using 500 litres of water per hectare.

Bark eating caterpillar: Dissolve 2.5 ml Dursban 20 EC per litre water or 1.5 ml Thiodan 35 EC per litre water or 2 ml Ekalux 25 EC per litre water to get the required concentration of the spray material and spray using 500 L of water per hectare.

Stem borer: Prune the infected branches in August-September before larvae enter the main stem. Locate all ejection holes for live infection in each tree and plug them with wet clay, leaving only lowermost hole untouched. Inject into this lowest hole 2 ml of Dursban 20 EC (Chlorpyriphos) or 5 ml of Paradichlorobenzene saturated in kerosene oil.

Major diseases

Leaf spots are generally formed during and after a rainy season in both nursery and plantations. The infection is usually from the last season infected leaves lying buried under soil. Thus the spots are first observed from the lower leaves of tree.

Management: Avoid raising nursery on the same piece of land every year. In case of fallow plantations, deep ploughing during winter will help bury and early decomposition of leaves. Spray Tilt 25 EC 0.1% or Folicar 0.1% or Dithane M45 + Bavistan 50 WP (0.3+0.1%) before the start of rains.

Suitable Intercrops

Intercropping is the practice of planting crops in the rows between trees. This gives farmers the

Poplar with intercrops such as wheat, mustard and turmeric in a farmer's fields

benefit of annually producing an income-generating crop in the poplar plantation while they continue growing the trees for 6-7 years. All the *rabi* and *kharif* crops can be grown successfully under poplar plantations during the first three years except paddy (Table 2).

Table 2. Crops that could be successfully grown under different aged poplar

Year	*Kharif*	*Rabi*	Annual
1	Mentha, Moong, Maize, Sorghum, Colocasia	Wheat, Mustard, Potato, Berseem, Marigold	Turmeric, Sugarcane
2	Mentha, Moong, Pearl millet, Sorghum, Cowpea, Colocasia	Wheat, Mustard, Potato, Berseem, Oats, Marigold	Turmeric, Sugarcane
3	Pearl millet, Cowpea, Colocasia	Wheat, Potato, Mustard, Berseem, Oats, Marigold	Turmeric
4-6	Not economical to grow crops	Wheat, Potato, Mustard, Berseem, Oats	-

Seed rate and fertilizers: Application of 25% higher seed rate and nitrogenous fertilizer to the intercropped wheat is advisable for obtaining higher grain yield than the recommended practices for sole wheat.

Yield/Annual Return

The yield of crops decreases with increase in age of plantation. Yield and its reduction in some of the crops in poplar spaced at 8 x 2.5 m are given in Table 3.

Table 3. Reduction (%) in yield of crops under Poplar block plantation as compared to sole crops

Age of poplar (years)	Wheat		Potato		Turmeric	
	Yield (t/ha)	Reduction in yield (%)	Yield (t/ha)	Reduction in yield (%)	Yield (t/ha)	Reduction in yield (%)
1	5.14	5.51	21.5	5.28	19.0	20.5
2	4.75	12.6	19.4	14.5	18.4	23.0
3	4.09	24.8	18.5	18.5	17.0	28.8
4	3.90	28.3	17.3	23.8	15.1	36.8
5	3.50	35.7	14.8	34.8	11.3	52.7
6	3.26	40.1	13.1	42.3	9.1	61.9
Open	5.44	-	22.7	-	23.9	-

The monetary losses in terms of crop yield are often compensated from the sale of wood at end of rotation. Timber yield from 6-year poplar block plantation varies from 20-25 t/ha/year depending on the management practices followed by different growers.

Economics

Based on research trials and data collected from farmers' fields, the returns from poplar based agroforestry system vary from Rs. 1,75,000 to Rs. 2,00,000/ha/year (including income from crops). Adoption of fast growing tree based agroforestry models and their proper cultural and management practices often leads to high economic returns compared to traditionally followed rice-wheat rotation.

Environmental Benefits

Carbon sequestration in the biomass and soil under the trees is a major advantage of poplar based agroforestry. Tree based systems act as nutrient pumps by circulating the nutrients from deeper layers to the surface and add organic matter by leaf litter helping maintain soil health. It has been observed that poplar plantation added about 20 t/ha litterfall throughout its rotation of 6 years which returned about 175, 22, 132 and 368 kg/ha N, P, K and Ca, respectively, in the plantation.

Utilization

The fast growing capability has made poplar attractive to the forest products industry and to the agricultural producers. The industry takes poplar as an alternative source of wood fibre for plywood, paper and other timber based products.

Improved varieties

Clones PL–1, PL–2, PL–3, PL–4, PL–5, L–47/88 and L–48/89 are suitable for planting in central plain region of Punjab and PL–3, PL–6, PL–7 and L–48/89 on semi arid region.

Source of planting material in the concerned zone

Planting material can either be purchased from the nurseries of State Forest Department, Punjab Agricultural University or from well established private nurseries.

Impact of Technology

In addition to improving the income of the farmers, the technology would increase the area under tree cover which is the need of the day for improving the quality of environment.

Approximate area under technology: 50,000 ha

Way Forward

The poplar based agri-silviculture system has been socially accepted by the farmers of the region. The adoption of the system is broadly concentrated in the riverine tracts of the region, but can be extended to other parts having light to medium textured soils and irrigation facility under well management conditions. Further, new poplar clones with higher productivity and resistance to insect pests and diseases with combinations of high value intercrops can improve the economic status of the farmers.

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Agro-Ecological Region 10

Central Highlands (Malwa, Bundelkhand and Eastern Satpura)

10.1. Agroforestry Model: Bamboo based Agri-silvicultural System

Area of adoption: Bundelkhand region of Uttar Pradesh, and Madhya Pradesh, Maharastraand other arid and semi-arid regions of the country
Tree component: *Bambusa vulgaris*
Common name: Common bamboo, Golden Bamboo, Yellow Bamboo
Family: Poaceae

Habit and Habitat

Bambusa vulgaris forms moderately loose clumps and has no thorns. The culms are yellow with green stripes. The densely tufted culms grow 10–20 m high and 4–10 cm thick. It is a fast growing and one of the world's most important and versatile plants. Several branches develop from mid-culm nodes and above. Culm leaves are deciduous with dense pubescence. *B. vulgaris* is the most widely grown bamboo throughout the tropics and sub-tropics in the world. It can be found on sandy loam to loamy clay soils. Usually common bamboo prefers well-drained soils but it is also found on swampy or wet stream beds. The species is one of the most successful bamboos in India. It has the potential to be incorporated into agroforestry systems in the semi-arid tropics due to their diverse adaptability, multiple utility and quick returns.

Distribution

B. vulgaris is native to Indochina and to the southern China, but it has been widely cultivated in many other places and has become naturalized in several countries including India. Among bamboo species, it is one of the largest, most easily recognized and most widely grown throughout the tropics and sub-tropics. It is found in all the 13 districts of Bundelkhand region of central India, other areas in Madhya Pradesh and Maharashtra.

Phenology

For many tropical bamboos, flowering intervals range from 40 to 80 years. Fruits ripen from February to April, or in some locations as late as June. Seeds germinate quickly, and can be preserved for 3 months to 2 years.

Package of Practices

Propagation Technology:

Effective method of propagation is through rhizome offset, culm cutting (use 2-3 node cuttings planted horizontally with rooting media) as well as through seeds. It can also be multiplied by burying whole culm during pre-monsoon season. The culm planting methods result in prolific rooting pattern during monsoon season. Rooted sprouts are separated from each productive node along with fibrous roots attached to it and can be planted in polythene bag as new plantlets. This technique promises large number of planting material and readily acceptable technology to the farmers.

Cultural Operations:

Pit size: 60 cm x 60 cm x 60 cm

Planting Spacing: 10 m x 10 m or 10 m x 12 m (as block plantation) and 4 m x 4m (as bund plantation)

Planting time: July-August (Monsoon season)

Fertilizer application: The pits should be filled with the mixture of 15-20 kg FYM + Top soil of same field + 100 g DAP per pit.

Irrigation: Protective irrigation is given to bamboo clumps at fortnight interval

Mulching: Grasses and sedges are used for mulching each bamboo clump to retain soil moisture for longer period.

Plant Protection

Management of bamboo insect pests and diseases

1. Silvi-cultural measures should be taken to manage most of the insect and diseases.
2. Physically removing and burning the infected culms and witches' brooms.
3. Rhizome or culms from diseased clumps should not be used for vegetative propagation.
4. Many broad-spectrum pesticides have been recommended wherever some outbreak of defoliators or sap-suckers occurred.
5. Sap-sucking pests can be managed by spraying of dimethoate or imidacloprid and defoliators can be managed with chlorpyrifos or profenofos or pyrethroids.
6. Soil drench of chlorpyrifos has been shown to destroy termites and other root feeders.
7. Blight: Application of carbendazim combined with mancozeb (carbendazim 0.25% a.i. + mancozeb 0.3% a.i.) or with Fytolan (0.3% a.i.) is recommended.
8. Culm rot*:* Application of carbendazim (@0.2% a.i.) or mancozeb (@ 0.3% a.i.) is recommended.

Post-harvest pests of bamboo and their management

Nearly 40% of stored bamboo is damaged severely by borer attack. Termites and shot hole borers are known to cause severe damage to the post-harvest bamboos. Major borers include *Dinoderus* spp., *Lyctus africanus, Heterobostrychus aequalis, Stromatium barbatum, Chlorophorus annularis, Cryptotermes dudleyi,* and *Coptotermes heimi.* The management may include the following measures:

1. Bomboo should be dried thoroughly under the sun.
2. Bamboos harvested during dry season and before flowering are highly susceptible to borer attack, while those harvested during wet season are comparatively resistant, and those harvested after flowering were completely resistant to borer attack.
3. After felling, immerse felled culms in water, it can significantly improve their resistance to borers as well as to fungi.
4. Coat wood surface with paraffin wax, varnishes and paints to avoid egg laying by the adult borers.
5. Treat bamboo with a mixture of 2 kg of boric acid + 2 kg of borax +500 g of sodium dichromate in 100 litres of water (available as Tim-bor or SoluBor). Bamboo can be impregnated, submerged or sprayed with this chemical.
6. Treating culm splits by immersing them in 0.2% phoxim for 3 minutes can protect the treated split from attack for over 1 year.
7. Soaking in an aqueous solution of 2% boric acid, 0.5% pentachlorophenate and 5% alcohol can treat bamboo rind and similar semi-finished products.
8. Treat Bamboo with cypermethrin and permethrin insecticides.
9. Fumigation in closed chambers or storehouses with sulphuryl fluoride at a rate of 30 to 50 g/m^3 of timber for 24 hours.
10. Treat unfinished bamboo wood, plywood, particle board with “Boracare” can be sprayed, brushed, or foamed.
11. Treat bamboo structure with UV blocking polyurethane but need to re-coat it every year in moderate climates, and re-coat every 6 months in heavily rainy climates.
12. The use of borates (disodium octaborate tetrahydrate) for the control of termites results in eliminating existing infestations.
13. Treat soil round the storage logs with cypermethrin, fipronil,

fenvalerate, imidacloprid and permethrin to prevent termite attack.

14. Preservation with sea water: Dry bamboo thoroughly under the sun. Then soak them in the sea for 2 months. Bamboos easily absorb the salt of the sea. It protects them from termites, borers and fungi. This method is widely used in Asia.

Rotation: On a good site, marketable bamboo can be produced in 4 to 5 years of plantation.

Tending Operation

Depending on the intensity of weed growth, weeding and hoeing may have to be repeated in the second and third year. Soil should be heaped around the developing clump to allow and ease shoot production, which takes place mainly in the periphery of the clump. The very small and thin culms, and broken and over-hanging culms should be regularly removed.

Orientation: Field bund and block plantation.

Suitable intercrops: Green gram, black gram and sesame during *Kharif* season and mustard, chickpea and barley during *Rabi* season can be grown by following standard package of practices and improved varieties.

Yield/Annual Returns and Economics

During 2008, 85 plants of common bamboo were planted on field boundary spaced 4.0 m apart at village Hastinapur under National Bamboo Mission. Over a period of seven years, farmers earned more than Rs 26,000.00 per annum from bamboo as net profit.

Source of planting material: AICRP on Agroforestry at Govind Ballabh Pant University of Agricultural & Technology (GBPUAT), Pantnagar, Uttarakhand

Benefits Accrued to Farmers/Public

Many farmers of the Bundelkhand region especially the farmers of Garhkundar-Dabar watershed, Parasai-Sindh watershed and

MGMG villages adopted by the ICAR-CAFRI have adopted the *B. vulgaris* based agroforestry system as an alternative livelihood system. This system has improved the socio-economic conditions of a large number of farmers in the Bundelkhand region.

Build-up of organic matter (OM) and plant nutrients in *B. vulgaris* plantation takes place in course of time. Bamboo contributes substantially to environment protection through carbon sequestration.

Validated technology transferred to other departments/ agencies: Popularised this technology through training programmes, kisan melas, kisan gosthi and distribution of planting materials.

Utilization

B. vulgaris is used extensively for house construction, farm fencing, production of pulp and paper, making agricultural implements, mats, screen, wall plate, basket, agarbatti stick and food grain container. Good, strong bamboo is used for scaffolding and ladders.

Way Forward

B. vulgaris based agroforestry system has the potential to meet the needs of farmers for fodder, small timber, fuelwood and provide the raw material to pulp and paper based industries.

Contributors

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Agro-Ecological Region 11

Eastern Plateau (Chattisgarh)

11.1. Agroforestry Model: *Gmelina* and Eucalyptus based Agri-silvi-horticultural System

Area of adoption: Chattisgarh, Madhya Pradesh and West Bengal. In West Bengal Purulia, parts of Burdwan, Birbhum, Bankura, Paschim Medinipur and Jhargram districts

Tree Component: *Gmelina arborea* and *Eucalyptus* spp.

Common name: Gamari, Gumhar

Family: Verbenaceae

1. *Gmelina arborea*

Habit and Habitat

Gmelina arborea is one of the indigenous multipurpose tree species which produces one of the best quality timbers in India. It is a medium to large-sized deciduous tree of up to 40 m height. It grows best in areas with a mean annual rainfall from 800 mm to- 2,500 mm, and an annual average temperature of 15-36°C. Plants can withstand a dry season of 4 to 8 months and prefer a heavy soil and damp situation. This plant grows best in loamy alluvial soils, but ranges from gravel to sand to clay. It is a fast growing tree, annual increments of 3.0 metres in height and 4.5 cm in diameter with wood density of about 439 kg/cu m at 15% moisture content. A mean annual diameter increment of 3 cm is common. Wood is

used for furniture, bent-wood articles, boat-building, panelling, brushes, slate frames, figure and pattern making. Wood-pulp is used for wrapping, writing and printing papers. An excellent agroforestry tree, it is commonly planted to restore land as well as to provide wood for poles, fuel etc.

Distribution

The species occurs in a variety of forest habitats, including tropical semi-evergreen tree, distributed in Eastern sub-Himalayan tract, Indo-Gangetic plains. It grows well in eastern sub-Himalayan belt but extends into mixed-deciduous forest of central India.

Phenology

In *G. arborea*, flower panicles appear during February when trees are leafless and continue until April, by that time the trees start bearing young green leaves. Old leaves fall during January-February and new ones appear during March-April.

Package of Practices

Propagation Technology

The species is normally propagated through seeds. There are 700-1400 seeds per kilogram (Evans, 1982). It can also be propagated by stumps.

2. *Eucalyptus tereticornis*

Common name: Eucalyptus
Family: Myrtaceae

Habit and Habitat

Eucalyptus tereticornis is a fast-growing, medium-sized to tall tree attaining 20-50 metre in height and up to 2 m in diameter with wood density of about 863 kg/cu m at 15% moisture content. The tree has a deep tap root system with mycorrhizal associations which increases its ability to draw nutrients and water. The tree has a smooth silvery white stem. The leaves are leathery in texture, hang obliquely or vertically and are studded with glands containing aromatic oil. Wood pulp is suitable for preparing writing and printing-paper. This tree is

planted in agroforestry to restore land and provide wood for poles, fuel, etc.

Distribution

In India Eucalyptus is the second most widely planted species. Except in north-eastern states, it has been planted on a large scale in Andhra Pradesh, Punjab, Tamil Nadu, Uttar Pradesh, Haryana, West Bengal, Maharashtra, Kerala and Madhya Pradesh. It is an afforestation species on boundary in small holding plots growing well under ever wet climatic conditions.

Phenology

Flowering during July-August. Fruiting during September-October.

Package of Practices

Propagation Technology

Eucalyptus is normally propagated through seeds. Seeds are obtained from seed orchards. It can also be propagated through coppice shoots. Eucalyptus is also propagated through micro-and mini-cuttings.

Cultural Operations

Preparation of land: The land can be levelled with minor land shaping and providing suitable type of bunds across the slope. If the slope is more, contour bunding, terrace planting or contour line planting can be adopted. In areas with sharp slopes, making platforms for individual plants on contour lines is more suitable as it involves less soil cutting.

Spacing: Spacing for tree planting depends on soil topography, extent of land available for cultivation and training method. In general 3 x 3 m is recommended for gentle slopes.

Pit size: For deep textured loose soils: 45 cm x 45 cm x 45cm; for shallow soils: 60 cm x 60 cm x 60 cm

Fertilizer application: For each pit, about 5 kg (one iron pan) of well decomposed FYM or compost is applied at the time of

plantation along with 50g SSP. NPK fertilizer @100:50:50 kg/ha/yr. The whole of P & K and one-third of N is applied in April, one-third N in July and the remaining one-third in October.

Planting: It is done in rainy season preferably during June to September. Monsoon planting is recommended provided the saplings are in polybags. Five-month old saplings are suitable to plant during the regular onset of monsoon. One sapling/pit should be planted.

Tending Operations

Aftercare of plantation: After one month, all the buds except the top 5-6 should be removed carefully by rubbing with gunny bags without damaging the bark. Weeds around the plants should be removed and regular pot watering should be given as and when required. After three months of planting, second weeding should be given. Plants must be protected from grazing.

Pollarding: Trees are pollarded in the third year of establishment, at a height of 5 feet. Single cleared bole should be maintained up to the height of 5 feet.

Tree Protection

Major Pests: Wood borers, defoliators and sap-suckers

Control: For the management of wood borer, plug the hole completely with cotton ball dipped in kerosene and cover it with mud. In case of severe attack of defoliators/sap-suckers, spray chlorpyriphos @1-2ml/litre on the leaves.

Diseases: Powdery mildew and Bacterial blight

Control: Fungal disease can be controlled with the application of Dithane M-45(Mancozeb) @ 75 WP or other suitable fungicides. Bacterial blight can be managed by pruning and removing the infected parts after proper sanitization of pruning tools. Sound cultural practices help in the recovery from this disease.

Fruit Trees: Mango, Guava, Sweet orange, Ber

Suitable intercrops (*Kharif–Rabi*): Rice, Mustard, Linseed, Lentil, Okra,Pointed gourd, Bottle gourd and fodder. For raising intercrops NPK is applied @120: 60:40 in this agroforestry system. Phosphorus and Potash are applied every alternate year, whereas Nitrogen is given every year in 2-3 split doses.

For raising fodder crops a small hole is dug and a handful of FYM is added at the time of planting root slips along with recommended NPK dose of phosphorus, potash and first split dose of nitrogen at the rate of 120:60:40..

After sowing of seed, light irrigation is required if there is no rain. Manual weeding is to be done in the initial years of establishment of this agroforestry system.

Orientation: Boundary/in field /on bunds

Yield/Annual Return

G. arborea and *E. tereticornis* are fast growing trees in fruit based agroforestry system with annual increments of more than 3.0 m in height and 3.5 cm in diameter. A mean annual diameter increment of 2.5 cm is common.

Economics

The overall net income is Rs 75,000 to Rs 1,25,000/ha/ per year in the initial years and Rs 2,25,000 to Rs 3,50,000/ ha with the complete establishment of the system.

Environmental Benefits

Intervention of fruit based agroforestry system is protecting the sloping land from degradation and sustaining the production. Tree cover is helping in recycling of nutrients and improving the soil health.

Benefits Accrued to Farmers/Public Availability of quality fruits and different crops along with vegetables throughout the year is encouraging the farmers to raise quality production aiming at better food security.

Validated technology transferred to other departments or other agencies: Highly accepted by the farmers.

Way Forward

The technology has tremendous scope especially in small holdings in Red and Leterite Zone as increased availability of quality fodder leads to adoption of milch animals. This, along with raising fruit trees, is resulting in boosting the health of local people and their economy.

Reference

Evans, J. 1982. Plantation forestry in the tropics. Clarendon Press, Oxford, UK, 472 pp.

Contributors

Pratap Kumar Dhara, Professor, Dept. of Soil and Water Conservation, BCKV, Mohanpur; and Subhabrata Panda, Assistant Professor of Soil & Water Conservation, AICRP on Agroforestry, RRS, BCKV, Jhargram, West Bengal.

Agro-Ecological Region 12

Eastern (Chhota Nagpur) Plateau and Eastern Ghats

12.1 Agroforestry Model: Mango based Agri-horticultural System

Area of adoption: Entire state of Odisha
Tree/Fruit components: *Mangifera indica*
Common name: Mango
Family: Anacardiaceae

Habit and Habitat

Mango is a perennial, ever green, seed propagated fruit tree. It grows from sea level up to 1200 m on riversides, coastal forests and natural grasslands. It also thrives in open and disturbed areas along roadsides, pastures and dry forests (Orwa et al. 2009).

Distribution

Mango is found in all 30 districts of Odisha. A number of improved varieties of mango are available for farmers to cultivate, including Amrapalli, Dussehri, Mallika, Keshari and Langra and the rest are local and indigenous varieties.

Phenology

Flowering starts at the beginning of the winter season. The inflorescence can reach full bloom from the time of flower initiation within 25-30 days and the fruits ripen after 3-4 months.

Package of Practices

Propagation technology: Mango is a highly heterozygous and

cross-pollinated crop. True to the type seedlings are found in polyembryonic condition, and vegetative propagation is done in mono-embryonic situation. The species can be propagated through inarching, veener, side grafting and the popular epicotyls grafting.

Cultural operations: Weeding, cleaning, training, pruning, manuring and fertilization, irrigation and intercropping.

Pit size: 1m x 1m x 1m.

Rotation: Mango trees may remain in production for 40 years or more.

Tending operations: NA for fruit trees but pruning, thinning may be done as required..

Tree protection (major pest and diseases):: Diseases: Anthracnose, mango malformation, sooty mold, powdery mildew, tip burn. Pests: Mango weevil, mango shoot caterpillar, mango stem borer, Oriental fruit fly. Need based use of fungicide and insecticide is recommended.

Orientation: Block plantation and with intercrops under agroforestry system.

Mango with shisham and intercrops such as turmeric, pineapple and mango ginger at the Research Farm of OUAT, Bhubaneswar

Mango with *Gmelina* and intercrops such as arrowroot at the Research Farm of OUAT, Bhubaneswar

Suitable intercrops: Pineapple (*Ananas comosus),* mango ginger (*Curcuma amada),* turmeric (*Curcuma longa)* and arrowroot (*Maranta arundinacea)* by following standard package of practices and improved varieties.

Yield/Annual Returns and Economics

Fruit productivity is 8 t/ha per annum after 5 years of plantation with a B:C ratio of 2.85 or more.

Source of planting material: Department of Horticulture, OUAT, Bhubaneswar; State Horticulture Department; and private nurseries.

Benefit Accrued to Farmers/Public

This agroforestry system helps farmers to manipulate and manage their land by growing fruit trees with shade loving intercrops to get service or product and attractive higher economic returns. It acts as a carbon sink which helps mitigate the climate change effects.

Impact of the Technology

This system has a positive impact on conservation of soil and water, restoration of soil organic matter and on supporting livelihood of farmers in humid and sub-humid regions of eastern India.

Validated technology transferred to other department or agencies: Popularised this agroforestry based production system through State extension department and Krishi Vigyan Kendras.

Way Forward

This agroforestry system is one of the best with respect to economic returns, employment generation and carbon sequestration to mitigate the ill effects of changing climate.

Reference

Orwa, C., Mutua, A., Kindt, R., Jamnadass, R. and Anthony, S. 2009. Agroforestry Database: a tree reference and selection guide version 4.0. World Agroforestry Centre, Kenya

Contributors

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Agro-Ecological Region 13

Eastern Plain

13.1. Agroforestry Model: *Dalbergia sissoo* based Agri-silvicultural System

Area of adoption: Uttar Pradesh, Bihar and entire state of Odisha
Tree component: *Dalbergia sissoo*
Common name: Shisham, sissoo
Family: Fabaceae

Habit and Habitat

Dalbergia sissoo is a medium- to large-sized fast-growing deciduous tree, with a crown wide spreading and thin. It grows well in a wide range of soils, and has been recorded in forest gaps and edges.

Distribution

D. sissoo is found in all 30 districts of Odisha, but is most popular in coastal districts.

Phenology

D. sissoo normally flowers between February and April. Following the appearance of buds, the flowers take from 13 to 15 days to come into full bloom and a further 20 to 25 days to develop pods.

Package of Practices

Propagation technology: Normal propagation technique is by seed, which should be soaked in water for 48 hours before sowing and 60% – 80% germination can be expected in 1–3 weeks. However, vegetative propagation could be practised with use of growth

regulators. The possibility of vegetative propagation of cuttings using mist propagation chambers and rooting hormones from adult trees (Puri and Verma, 1996), softwood nodal shoot cuttings from hedge gardens by rooting these in a mist chamber, and the seasonal effect in the rooting of cuttings (Husain, 2004) have been tested.

Cultural operations: Weeding, cleaning, intercultural operation and nutrient application are done in pre- and post-monsoon period.

Pit size: 45 cm x 45 cm x 45 cm

Rotation: On a good site, marketable timber can be produced on a 20- to 25-year rotation. To produce large-diameter logs with a high percentage of valuable heartwood, a rotation age of 60 years is not uncommon. The price per unit volume of a 60-year-old tree can be 20 times higher than the price of a 20-year-old tree.

Tending operations: Weeding, hoeing and cleaning. Thinning is recommended every 10 years where the rotation is 30-60 years.

Tree protection (major pest and diseases): Diseases: Wilt, Chlorosis and leaf drop. Pests: Leaf defoliator, Leaf miner, Leaf roller and Sap sucking bug.

Need-based use of fungicide and insecticide be made to control these pests and diseases.

Orientation: Field, bund and block plantation.

Suitable intercrops: Pineapple (*Ananas comosus),* mango ginger (*Curcuma amada),* turmeric (*Curcuma longa)* and arrowroot (*Maranta arundinacea)* by following standard package of practices and improved varieties.

Yield/Annual Returns and Economics

D. sissoo trees are generally 10 to 20 m tall with clear boles of 3 to 6 m. Final harvests at 20 years averaged 90 to 100 m^3/ha. The mean annual increment (MAI) for 20-year-old, non-irrigated plantations averaged 11.2 m^3/ha on good sites, 8.4 m^3/ha on fair sites, and 5.9 m^3/ ha on poor sites. At the end of 20 years the system yields a B:C ratio of 2.35.

Source of planting material: AICRP on Agroforestry at OUAT, Bhubaneswar, State government and private nurseries

Benefits Accrued to Farmers/Public

This agroforestry system helps farmers to manipulate and manage their land by growing agroforestry trees with shade loving intercrops to get service or product and receive best economic returns. The system also serves as a carbon sink to mitigate the effects of climate change.

Impact of the technology

This system has a positive impact on conservation of soil and water, restoration of soil organic matter and livelihood support to the farmers in humid and sub-humid region of eastern India.

Validated technology transferred to other department or agencies: Popularised this agroforestry based production system through the state extension department and Krishi Vigyan Kendras.

Way Forward

This agroforestry system is one of the best with respect to economic returns, employment generation and carbon sequestration to mitigate the ill effects of changing climate.

References

Husain, A. 2004. Clonal propagation of *Dalbergia sissoo* Roxb. by softwood nodal cuttings: effects of genotypes, application of IBA and position of cuttings on shoots. *Silv Genet* 53(2): 50–55

Puri, S. and Verma, R. C. 1996. Vegetative propagation of *Dalbergia sissoo* Roxb. using softwood and hardwood stem cuttings. *J Arid Environ* 34: 235–245

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Agro-Ecological Region 14

Western Himalaya

14.1. Agroforestry model: *Grewia* based Agri-silvicultural System

Area of adoption: Jammu & Kashmir, Himachal Pradesh and Uttarakhand
Tree component: *Grewia optiva*
Common name: Beul, Bhimal and Dhaman
Family: Tiliaceae

Habit and Habitat

A full-grown tree of *Grewia optiva* is moderate in size with a spreading crown, reaching a height up to 12 m with a clear bole of 3-4 m and a girth of about 80 cm. The species grows in the Himalayas from Jammu and Kashmir to Nepal up to an elevation of about 2,000 m. It is sparingly found in forest areas and is mostly found along the cultivated agricultural fields. It is a tree of sub-tropical climate. In its natural habitat, the maximum shade temperature seldom exceeds 38 ^{o}C and the minimum rarely drops below -2 ^{o}C. It grows on a variety of soils. Sandy loam soil with adequate moisture supply supports good growth. The growth is poor on shallow dry soil. The growth of trees along the irrigated fields is much better than that of those growing under rainfed conditions.

Distribution

G. optiva is distributed in tropical and sub-tropical regions in Asia, Australia and Africa. It is distributed from the foothills of the Western Himalayas from Jammu and Kashmir to Nepal up to 2000

m elevation. It is not a common forest tree and is generally grown on field boundaries or terraces raised by the hill farmers.

Phenology

The leaf-fall begins during March-April and the new flushes of leaves appear during April-May. Flowering occurs during April-May and the fruiting during June-July. The fruit starts ripening during October-November.

Package of Practices

Propagation Technology

a. Natural: Seeds, Coppice
b. Artificial Propagation: Seeds, Cutting

Cultural Operations

Preparation of site

Gradonii or trench planting/ contour planting technique is used for planting trees in place of ordinary pit methods. Site characterized by shallow soil depth, poor fertility, low moisture, site slope (30-80%) and receiving annual rainfall of below 1200 mm is suitable for the preparation of gradonii. Gradonii terraces were built along the contour on the hillside with outside rim/side higher than inner edge. The spacing between the two gradonii terraces was kept 4- 6 m. But it depended upon the slope. If the slope is more, then the distance between the two gradonii/rows should be decreased so as to reduce runoff and increase moisture availability.

Grewia based Agri-silvicultural system with intercrops such as black gram at Research Farm

Planting Technique

Planting is done in July. Late planting usually results in poor survival. The seedlings are uprooted from the nursery with balls of earth and wrapped in moist

gunny bags. Planting is done in pits of 30 cm^2 dug during summers or with the beginning of rainy season. Spacing adopted is 3 × 3 m for block planting and 4-5 m for single-row planting along the fields. For creating hedgerows of fodder trees, a close spacing of 0.50 m × 1 m is ideal for planting in the gradonii space. This will form two rows of trees in each gradonii. *Setaria anceps* grass was introduced in the interspace by replacing the existing low-value natural grasses.

Plant management

Two or three years after the establishment and growth, trees should be cut at a height of 1.5 m from the ground to harvesting maximum leaf and branch wood biomass. Each year, the height of these trees should be maintained at 1.5 m. Complete lopping of the tree should be in the absence of hedgerow system, as complete lopping is not advisable. One to two top shoots should be retained on each tree for better growth and development.

Grass tufts are planted with the onset of monsoon season for better and early establishment. For planting grass tufts, turning of soil is done with the pick-axe or spade for better establishment. Afterwards, tufts having 4-5 tillers are planted at a distance of 30 × 30 cm.

Tree Protection

Protection of seedlings against defoliators with the application of insecticides is necessary. Larvae of *Diacrisia* spp. and *Chasmina tibialis* defoliate the tree while the larvae of family Cerambycidae bore into the dry and dead wood. The plantation areas need to be protected against browsing by cattle and also against fire.

Orientation: Boundary/in field/on bunds

Yield-Annual Return

This system can produce leaf and branch wood biomass of about 1300 and 2000 kg/ha. The grass production also increases from 4 to 5 times, i.e. 30-40 t/ha.

Economics

Availability of quality fodder throughout the year particularly during lean periods is very helpful to ensure livelihood options from

degraded lands and diversify through livestock-based economy in the region. The overall net income per hectare per year from degraded grassland is Rs 10000 to Rs 12000 in the initial years which increases up to Rs. 40,000 to Rs 50,000 per ha with the complete establishment of the system.

Environmental Benefits

This system is useful for the development of sloping/undulated grasslands of the region. The system protects nature grasslands from degradation and reduces soil and nutrient loss from the sloping denuded and degraded hilly pastures.

Utilization

The calorific value of the *G. optiva* tree is 4920 kcal/kg, which makes it a very good fuelwood tree and an alternative source of energy. It also provides fibre and edible fruits, and is used medicinally. Villagers extract the fibre by retting process. Branches of the tree are cut during winter and dipped in water for a month. The soaked branches are beaten and fibre is extracted. Extracted fiber is used for making ropes. The leaves are used as fodder. The bark extract is used as hair wash by some women.

Source of planting material in the concerned Zone

AICRP on Agroforestry, Dr Y S Parmar University of Horticulture and Forestry, Solan (HP)

Benefits Accrued to Farmers/Public

Availability of quality fodder for livestock particularly during lean periods.

Contributors

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Agro-Ecological Region 15

Bengal and Assam Plains

15.1. Agroforestry Model: *Litsea glutinosa* based Agri-silvicultural System

Area of adoption: Assam, Arunachal Pradesh and Nagaland
Tree component: *Litsea glutinosa* (Lour.) C. B. Robinson
Common name: Indian Laurel, Maidalakri (Hindi), Baghnala (Assamese)
Family: Lauraceae

Habit and Habitat

Indian Laurel (*Litsea glutinosa*) is an evergreen or deciduous tree of medium size which grows to a height of about 6-15 m. It is usually found below 1,000 m elevation in humid areas. Average annual temperature requirement is 19-21^{0}C with 7-8 months > 20^{0}C. It grows best in hot and humid situations under sub-tropical climate with annual rainfall of 2500 mm. It prefers alluvial soil and also red soil with acidic reaction having pH value of 5.0 to 7.0. Soil depth should be 0.5 to 1.0 m and well drained. It is suitable to high land, hilly and flat tropical

Litsea tree in its natural habitat in Assam

conditions and grows in secondary forest or rehabilitated forest after slash-and-burn cultivation. The tree requires moderate moisture and average light.

Distribution

L. glutinosa is native to India from where it spread to China and then to Malayasia and northern Australia. It is found in North East India mostly within sub-tropical zone. It occurs in agricultural land, coastland, natural forests and urban areas. It colonizes all open areas but also survives in more shaded areas and undisturbed forests. In India, it occurs in mixed primary and secondary forests and thickets in the northeastern region.

Phenology

Indian Laurel is an evergreen or deciduous tall tree. Young branchlets are gray-yellow velvety. Alternately arranged leaves are carried on 1-2.6 cm long gray-yellow velvety stalks. Leaves are mostly elliptic but variable, 7-15 x 3-7 cm; velvety on both surfaces when young, lateral veins 5-12 pairs. Leaf base is wedge-shaped blunt or rounded, tip blunt or shortly tapering. Flowers are borne in solitary or several, few-flowered umbels on short branchlets. Stalks carrying the umbels are 1-1.5 cm. Male flowers have petals imperfect or missing. Fertile stamens are often 15 or more. Fruit is round, 5-7 mm in diameter; fruit-stalk is 3-6 mm, slightly thickened at the top. Flowering occurs in May-June.

Package of Practices (Ahmed and Barua, 2013)

Propagation Technology

a. Natural: Seeds, Coppice
b. Artificial: Seeds, Coppice

Seed selection: The ripe fruits are collected in October-November and rinsed to remove the fruit coat. The seeds are sown in moist sand. They sprout within 10-15 days and are then planted in polybags of size 20 x 10 cm. Partial shade is provided for the seedlings (40 %). Germination is not very rapid; approximately 85 % germination is achieved in 15-45 days.

Cultural Operations

Preparation of land: Land is prepared after clearing of bushes and shrubs, if any. Areas having gentle slope can be leveled with minor land shaping and providing suitable type of bunds across the slope.

Spacing: For mono crop, spacing is 3 m x 3 m and for mixed crop a wider spacing is adopted.

Pit size: The planting of the saplings is done in well prepared pits of size 45 cm x 45 cm x 45 cm in deep soil and 60 cm x 60 cm x 60 cm in shallow soil.

Manure application: For each pit, about 5 kg of well decomposed FYM or compost is applied at the time of planting... Well decomposed cow dung/FYM @ 10 to 15 kg/tree should be applied from 2nd year onwards.

Planting: Ideal planting time is May-June. One sapling/pit should be planted.

Tending Operation

Coppicing for regeneration, lopping for fodder

Tree Protection

Not many diseases and insect pests are observed in *L. glutinosa*. However, the common mime butterfly, *Papilio clytia* Linn., (Lepidoptera: Papilionidae) is recorded as a defoliator. In severe attack of this pest complete eradication of leaves may happen.

Control: For the management of leaf eating caterpillar collection and destruction of early instars of caterpillar should be done. At severe attack spraying of contact insecticides like Quinalphos 25 EC @ 2ml/litre of water at 10-15 days interval should be done.

Orientation

Boundary/in field/on bunds/on pond dyke/ in homestead garden

Suitable Intercrops

Indian Laurel can be inter-cultivated with other species with broad leaves and a preference for light. Mixed planting of bean, groundnut

and other legumes can be done in first two years. It is recommended for forest planting in mixed system/agroforestry system. Planting can be done in row mixture or cluster plantation. Management rotation is for 10-15 years.

Yield

Harvesting: Leaves, twigs, ripe berries and bark are harvested. The tree survives for about 50 years. Bark is removed from 10 years onwards. If irrigation and fertilizers are provided, the stumps will regenerate to new coppice shoots, which can be intercropped and be harvested again after 6-7 years. Alternatively, bark can be collected without felling the tree. The bark is peeled off in vertical stripes with 6 cm interspaced between each stripe. The peeled off area is renewed with fresh bark in one to two years. Then, the bark on the other areas can be peeled off without cutting the tree. The tree may remain productive for 30 years. This non-destructive method is recommended for bark harvesting.

Essential oil: The seed contains aromatic oil which has been used to make candle and soap.

Fodder: The young leaves are used to feed livestock.

Yield of bark: Harvested at 7.5 years after planting, i.e., felling 15 cm above ground level enabling to regenerate the coppice shoots, and the total bark is removed.

Fresh weight of the wood (without bark)	=100 kg/tree
Fresh weight of the bark	= 20 kg/tree
Dry weight of the bark (sun drying)	= 2.8 kg/tree
Number of trees after mortality	= 1000/ha
Dry weight of the bark	= 2800 kg/ha
Fresh leaf as fodder	= 150 kg/tree

Economics

Fresh bark @ Rs 50/kg x 20 kg/tree x 1000 tree/ha = Rs 10, 00,000/ha/7.5 years ≈ Rs 1,30,000/ha/year

Fresh wood (without bark) @ R. 3/kg x 100 kg/tree x 1000 tree/ha = Rs 3, 00,000/ha/7.5 year ≈ Rs 40,000/ha/year

Fresh leaf as fodder @ Rs 1/kg x 150 kg/tree x 1000 tree/ha = Rs 1,50,000/ha/year ≈ Rs 20,000/ha/year
Income from intercrops (average) @ Rs.25,000/ha/year
Total income = Rs (1,30,000 + 40,000 + 20,000 + 25,000) = Rs 2,15,000/ha/year

Cost of cultivation = Rs 30,000/ha/year

Net Income = Rs (2,15,000 – 30,000) = R. 1,85,000/ha/year

B:C ratio = 6.16

Uses

L. glutinosa is traditionally used for treating various human ailments and diseases. Almost all parts of the tree are used traditionally but only the bark has high commercial value and in fact it is over-harvested unscientifically causing the death of the trees throughout its distribution range including India, especially in the north eastern region. It is principally used as a binding agent in incense-stick industry and is being considered as the binding agent in tablet formulations and as plasters for fractured limbs. The wood is used for making agricultural tools, root fiber for making ropes and paper pulp, young leaves for fodder, seed oil for making candles, soaps and seed powder for treating skin boils. The pounded seeds are also applied against boils. The bark also acts as a demulcent and mild astringent in diarrhea and dysentery. The leaves and the mucilage in the gum from the bark have been used for poultices.

Environmental Benefits

L. glutinosa has a high invasion potential and replaces regenerating native plant species in disturbed environments. Its utilization as fodder somewhat alleviates its pest status. The invasive properties of the tree can also be used for restoration of damaged soils.

Reference

Ahmed, M. and Barua, I.C. 2013. Package of Practices for Medicinal Plants of Assam. Published by the Directorate of Horticulture & Food Processing, Govt. of Assam, Khanapara, Guwahati. pp. 107-115.

Contributors

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15.2 Agroforestry Model: *Dysoxylum* and Kadamb based Agri-silvi-horticultural System

Area of adoption:	Dakshin Dinajpur, part of Uttar Dinajpur, Malda, Murshidabad, Nadia, parts of North 24 Parganas, South 24 Parganas, Howrah, Hooghly and Birbhum districts
Tree component:	*Dysoxylum binectariferum* and *Anthocephalus cadamba*
Common name:	*Dysoxylum* has common names such as Lamboo, Karakil, Akil, Chembil, Lassuni Amari, Aguni agil etc., and *Anthocephalus* is known as Kadamb
Family:	Meliaceae (Lamboo) and Rubiaceae (Kadamb)

Habit and Habitat

Dysoxylum binectariferum is a fast growing evergreen tree reaching a height of up to 25 metres.. It has a straight bole that is around 80 cm in diameter, occasionally up to 1.5 metres, with a wood density of about 606 kg/cu m at 15% moisture content. It grows best in areas with a mean annual rainfall of 800 2,500 mm, and an annual average temperature of 15-36 °C. Mature trees tolerate some frost and can withstand a dry season of 4-8 months and prefer a heavy soil and damp situation. They prefer moist and well drained soils, including loam and loamy sand gravel, sand and clay. *D. binectariferum* is

a fast growing tree, with annual increments of 4.0 metres in height and 4.5 cm in diameter. A mean annual diameter increment of 3 cm is common. Wood is used for canoes and turnery, and for match-boxes, splints and ply board. An excellent agroforestry tree, *D. binectariferum* is commonly planted to restore degraded lands and to provide wood for poles, fuel, etc.

Distribution

An evergreen tree, *D. binectariferum* is distributed in Assam, Sikkim, West Bengal and Western Ghats. It is an afforestation species on boundary in small holding plots growing well under prolonged wet climatic conditions.

Phenology

D. binectariferum, has a yellowish-grey; blaze creamy-yellow bark; and inflorescence minutely pubescent. Leaves imparipinnate, alternate, estipulate; rachis 12.5-19 cm long, stout, angular, swollen at base, pubescent; leaflets 5-9, alternate, stout, pubescent; lamina 6-17 x 2.5-8 cm, ovate-lanceolate. Flowers bisexual, 7-9 x 10 mm, white, in axillary panicles; pedicels short, articulated; nearly half of the length of petals. Fruit a capsule 5-8 x 6 cm, red, depressed at apex, smooth; seeds 4, 5 x 2.5 cm, dark purple with yellow hilum and white aril, shiny.

Package of Practices

Propagation Technology

Generally Lamboo is propagated through seeds. Natural reproduction occurs through seed only. Seedling regeneration is generally scanty and cannot be relied upon to regenerate natural stands. Artificial regeneration is through direct seeding or planting pre-germinated seeds.

Tree component: ***Anthocephalus cadamba***

Common name: Kadamba

Family: Rubiaceae

Habit and Habitat

A large tree with a broad crown and straight cylindrical bole.

The tree may reach a height of 45 m with trunk diameters of 100 - 160 cm. The tree sometimes has small buttresses.. The bark is grey, smooth in young trees, rough and longitudinally fissured in old trees. The fresh leaves are fed to cattle.

The fragrant orange flowers attract pollinators. Timber with white sapwood with a light yellow tinge becoming creamy yellow on exposure, is not clearly differentiated from the heartwood. The wood has a density of 290-560 kg/cu m at 15% moisture content, a fine to medium texture; straight grain; low lustre and has no characteristic odour or taste. It is easy to work with hand and machine tools, cuts cleanly, gives a very good surface and is easy to nail. Kadamba wood is very easy to preserve using either open tank or pressure-vacuum systems. An excellent agroforestry tree, it is commonly planted to restore degraded land, for apiculture, and to provide wood for poles, fuel etc. The timber is used for plywood, light construction, pulp and paper, boxes and crates, dug-out canoes, and furniture components. Kadamba yields a pulp of satisfactory brightness and performance as a hand sheet. The wood can be easily impregnated with synthetic resins to increase its density and compressive strength

Distribution

Kadamba tree is common in Assam, West Bengal and the Andaman. It is an afforestation species on boundary in small holding plots, and grows well under wet climatic conditions.

Phenology

The leaves of Kadamba are glossy green, opposite, simple more or less sessile to petiolate, ovate to elliptical (15-50 x 8-25 cm). Inflorescence in clusters; terminal globose heads without bracteoles, subsessile fragrant, orange or yellow flowers. Flowers bisexual, 5-merous, calyx tube funnel-shaped, corolla gamopetalous saucer-shaped with a narrow tube, the narrow lobes imbricate in bud. Large amounts of leaf and non-leaf litter which on decomposition improves some physical and chemical properties of soil under its canopy. This reflects in increases in the level of soil organic carbon, cation exchange capacity, available plant nutrients and exchangeable bases.

Package of Practices

Propagation Technology: Kadamb is propagated through seeds. Natural reproduction occurs through seed and coppice. Artificial regeneration is through direct seeding or planting pre-germinated seeds. Coppicing is another method used for regeneration of the species.

Cultural Operations

Preparation of land: The land can be levelled with minor land shaping and providing suitable type of bunds across the slope. If the slope is more, contour bunding, terrace planting or contour line planting can be adopted. In areas with steep slopes, platforms for individual plants on contour lines work better as this involves less soil cutting.

Spacing: Spacing for tree planting depends on soil topography, extent of land available for cultivation and training method. In general 3 x 3 m is recommended for gentle slopes.

Pit size: In case of deep textured loose soils, 45 cm x 45 cm x 45cm and in shallow soils 60 cm x 60 cm x 60 cm pits are used.

Fertilizer Application: For each pit, about 5 kg (one iron pan) of well decomposed FYM or compost is applied at the time of planting along with 50g SSP. NPK fertilizer @100:50:50 kg/ha/yr. The whole of P and K and one-third of N is applied in the month of April, the next one-third in July and the remaining one-third in October.

Planting: It is done in rainy season preferably during June to September. Monsoon planting is recommended provided the saplings are in polybags. Five-month old saplings are suitable to plant during the regular onset of monsoon. One sapling/pit should be planted.

Tending Operations

After-care of plantation: After one month, all the buds except

the top 5-6 should be removed carefully by rubbing with gunny bags without damaging the bark. Weeds around the plant should be removed and regular pot watering should be given as necessary. After three months of planting, a second weeding should be given. Plants must be protected from grazing.

Pollarding: Trees are pollarded in the third year of establishment, at a height of 5 feet. Single cleared bole is to be maintained up to the height of 5 feet.

Tree Protection

Major Pests: Wood borers, defoliators and sap-suckers

Control: For the management of wood borer, plug the hole completely with cotton ball dipped in kerosene and cover it with mud. In case of severe attack of defoliators/sap-suckers, spray chlorpyriphos @1-2ml/litre on the leaves.

Diseases: Powdery mildew and Bacterial blight

Control: Fungal diseases can be controlled with the application of Dithane M-45(Mancozeb) @ 75 WP or other suitable fungicides. Bacterial blight can be managed by pruning and removing the infected parts after proper sanitization of pruning tools. Sound cultural practices help in the recovery from this disease.

Orientation: Boundary/in field/on bunds

Fruit Trees: Mango, Guava, Ber and Litchi

Suitable intercrops *(Kharif –Rabi)***:** Rice, Mustard, Lentil, Cabbage, Cauliflower, Pointed gourd, Bottle gourd and fodder.

For raising intercrops, NPK is applied @120: 60:40 in this agroforestry system. Phosphorus and Potash are applied every alternate year, whereas Nitrogen is given every year in 2-3 split doses.

For raising fodder crops a small hole is dug and a handful of FYM is added at the time of planting root slips along with recommended NPK dose of phosphorus, potash and first split dose of nitrogen at the rate of 120:60:40.

After sowing of seed or plantation, light irrigation is required if there is no rain. Manual weeding is to be done in the initial years of establishment of this agroforestry system.

Yield/Annual Returns

A. cadamba and *D. binectariferum* are both fast growing trees in fruit based agroforestry systems with annual increments of more than 3.0 metres in height and 3.5 cm in diameter. A mean annual diameter increment of 3.0 cm is common.

Economics

The overall net income is Rs 1,50,000/- to Rs 1,80,000/ha/ year in the initial years and Rs 2,25,000/- to Rs 3,50,000/ha with the complete establishment of the system.

Environmental Benefits

Introducing the fruit based agroforestry system is helping to protect the sloping land from degradation and sustaining the production. Tree cover is helping in recycling of nutrients and improving the soil health.

Benefits Accrued to Farmers/Public

Availability of quality fruits, different crops, and vegetables throughout the year in this agroforestry system is helping to raise farmers' income, improve their quality of life and ensure better food security.

Validated technology transferred to other departments or agencies: Highly accepted by the farmers.

Way Forward

The technology has tremendous scope especially in smallholdings in New alluvial Zone where increased availability of quality fodder will lead to adoption of milch animals along with raising of fruit trees, resulting in boosting the health of local people and their economy.

Contributors

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15.3. Agroforestry Model: *Bambusa balcooa* based Agri-silvicultural System

Area of adoption: Assam, Arunachal Pradesh, Nagaland and West Bengal
Tree component: *Bambusa balcooa*
Common name: Balcooa Bamboo; Assamese: Bhaluka; Bengali: Balku bans
Family: Poaceae

Introduction

Bamboo is basically a household plant species grown in homestead, on farmlands and other available places on farm holding. It is grown in homestead as every part of the bamboo finds one use or another in daily life of a farmer. Bamboo has an advantage over other perennial cash crop as it has low gestation period, fast growth, diversified uses and easier marketability; all ensuring its potential as an excellent agroforestry crop.

Habit and Habitat

Bambusa balcooa is an evergreen or deciduous gregarious bamboo, 7-23 m in height and 5-10 cm in diameter. Bamboo grows well at temp 8^0 to 36^0 C, annual rainfall 1200-4000 mm, and high humidity. It prefers moist valleys, sheltered depressions and areas along stream and hill slopes up to 600 m. It succeeds in any type of soil but prefers heavy textured ones with good drainage and pH of about 5.5 (it can tolerate 4.5 – 7.5 pH).

Distribution

B. balcooa is a common homestead bamboo in North East India and West Bengal. It also occurs in Bihar, Jharkhand and Uttarakhand.

Phenology

The culm is dark green , thick-walled, diameter of the cavity is one-third of culm; nodes thickened with a whitish ring above, hairy below; internodes 20-40 cm long; branches from lower nodes are leafless and hard, mostly spreading, sometimes thorn like; young shoots blackish green, green with yellow, brown or orange tinged culm sheath, clothed sparsely with dark brown hairs. Leaves are 15-30 cm long, 2.5-5.0 cm broad, oblong lanceolate, glabrous above, pale and puberulous beneath, margins rough, apex pointed, somewhat heart shaped or rounded at base with a short stalk. Inflorescence is a large panicle, bearing spikate branching with bracteate heads, 0.6-1.2 cm long, 4-6 mm broad with 0-2 empty glumes.

***Bambusa balcooa* in a farmer's field and its rhizome in Assam**

Package of Practices

Propagation Technology: Rhizome, stem cutting, tissue culture

Rhizome: Bamboo rhizomes of one-year-old culm, one metre long and with at least 2-3 internodes, should be selected for planting. Rhizome should be planted during March-August in pit size of 45 cm x 45 cm x 45 cm at 45^0 angles inclined towards North; the base should be compacted tightly.

Culm cutting/branch cutting: Modified vegetative methods like culm cutting/branch cutting are more effective than conventional

methods for large-scale multiplication of bamboo. In culm-cutting, horizontal planting of two-nodal cuttings is more effective than three-nodal culm cuttings of *B. balcooa* during summer in sand bed. Culms with shoots are taken out of each bed after emergence of well established shoots and roots; these plantlets should be transferred to plastic pots filled with sand in greenhouse for one month.

Micro propagation: Nodal segments are surface sterilized with 0.1% mercuric chloride for 10 min, and cultured on Murashige and Skoog (MS) medium supplemented with 4.4 µ M 6-benzylaminopurine (BAP), 2.32 µ M kinetin (Kn), and gelled with 0.2% *w*/*v* gelrite. Eighty-five percent of explants could be established *in vitro* with 90% of them achieving bud break. *In vitro*-formed shoots are being successfully multiplied in MS liquid medium supplemented with 6.6 µM BAP, 2.32 µM Kn, 2.5% *v*/*v* coconut water, and 100 mg l^{-1} *myo*-inositol. Sub-culturing shoots every 3 weeks yields a consistent proliferation rate of 4.11-fold without decline in vigour. Shoot clusters, containing 5 to 8 shoots, are rooted with 87.5% success in 1/2 MS supplemented with 5.71 µM indole-3-acetic acid (IAA), 4.9 µM indole-3-butyric acid (IBA), and 5.37 µM naphthaleneacetic acid (NAA) within 3 weeks. Plants regenerated in this manner should be acclimatized in the greenhouse and under a shade net with 88% success.

Cultural Operations

Preparation of land: The area should be demarcated with fence and bushes be cut down following ploughing at least 15 days prior to planting.

Spacing: *B. balcooa* should be planted at a spacing of 5 m x 5 m for edible shoot production and 7 m x 7 m for culm production. A wider spacing of 12 m x 10 m may be suitable for growing intercrops at least for 4-5 years.

Pit size: 45 cm x 45 cm x 45 cm pits should be dug, half filled and kept exposed to sun for top soil sterilization.

Fertilizer application: Just prior to planting dry FYM @ 10 kg/

plant or vermicompost @ 5 kg/plant, 200g neem cake 50g Urea, 50g super phosphate and 50g muriate of potash should be applied in the pit.

Planting: With the onset of pre-monsoon shower, the pit is to be filled with top soil and one-year-old seedling should be planted in upright position. Care should be taken so that the roots do not curl during planting in pits. Level the pit with enriched soil and compacted to eliminate all air pockets. Mulch the soil around the plants to keep it moist and control weeds.

Tending Operations

Soil loosening: Soil should be loosened to a depth of 10–15 cm, and 30–45cm away from the bamboo clump at least twice a year to help improve the growth of shoots and the root system.

Weeding: Regular weeding is necessary to prevent weeds and other vegetation from competing with the young bamboo for sustenance. Weeding should be done at least for the first two years after the rains and end of the wet season. Once the clump gets established there is considerable leaf shedding and this acts as a barrier to the emergence of weeds.

Mulching: Mulching reduces loss of moisture due to evaporation from the planting pits and checks weed growth. In a grown up bamboo field, fallen bamboo leaves serve as good on-site mulching material. Bamboos have a requirement of silica for growth that can also be contributed by bamboo leaf mulch.

Mounding: Rhizomes grow laterally under the soil surface and when ready to throw up shoots, begin to grow upwardly and at an inclined angle as well. In this period of growth, exposure to sunlight retards and may even stop the growth of rhizomes. Mounding or heaping fresh, loose soil around and over the base of the plant is important as a preventive measure against lodging.

Pruning and cleaning: Regular pruning and cleaning should be carried from the fourth year of clump establishment. All dry and dead culms should be removed from the clump so as to provide

sufficient space in the clump for new shoots. Branch pruning also provides sufficient space for the emerging culms to grow upwards quickly without any hindrance. These operations need to be carried out every year during January-February.

Thinning: Thinning of clump is essential from third year onwards to avoid congestion. It ensures proper growth and helps in easy extraction of culms. Weak and deformed culms should not be retained in the culm. An appropriate clump structure should be maintained through thinning as well as through extraction or retention of shoots during January-February.

Tree Protection

Major pests: If managed properly with routine pruning, thinning and cleaning bamboo usually escapes pest infestations.

Diseases: Bamboo blight caused due to *Sarocladium oryzae*

Control: Fungal disease can be controlled with the application of Indofil M-45 at 75 WP or other suitable fungicides as soil drench. Blight can be managed by pruning and removing the infected parts after proper sanitation of pruning tools.

Protection from animals: Clumps managed for edible shoots need protection from porcupines, wild pigs and household animals.

Control: This can cheaply be provided by encircling the clump with fishing net as barrier.

Orientation

Homestead/boundary/field/bunds

Suitable Intercrops

Intercrops such as pineapple, banana, ginger and turmeric can be grown up to fourth year. However, due to profuse canopy of bamboo intercrops cannot be grown thereafter.

Harvesting

For edible shoots: Tender sprouts are harvested within 3 weeks of

emergence when they are about 30 to 40 cm in length. Ensure that not more than 60% of the sprouts are removed in one season. Soon after extraction the tender sprouts should be taken for processing to avoid drying which is detrimental for further processing.

For Poles: Harvesting of bamboo culms every year will induces the emergence of new shoots and ensures regular and healthy culm production. Harvesting of bamboo for commercial purpose can begin from the third year of establishing a plantation. However the clump will mature and yield culms of full physical dimensions only after the fourth year. The best time of the year to harvest culm is in the post monsoon season extending through the winter.

The age of the culm is an important factor in the uses which it is meant for. For non-structural applications and those that do not require their peak physical and mechanical properties, 2-3-year- old culms from a mature clump may be harvested. For most purposes, however, culms should be harvested when they are 4 years old. Culms that are more than 5 years old begin to turn brittle and week and then die. As a norm, culms over 5 years should not be retained in a commercial plantation.

Yield

Harvestable bamboo yield = 500 to 700 nos./ha/year

Economics

System	Income (Rs/ha/yr.)*		B:C ratio*	Remarks
	Up to 4th year	5th year onwards		
Bambusa balcooa + Pineapple	4, 79,400.00	1,50,270.00	7.00	Income up to 4th year from intercrop and 5th year onwards from bamboo
Bambusa balcooa + Banana	2, 26,000.00	98,740.00	3.89	
Bambusa balcooa + Turmeric	4, 76,200.00	1,23,070.00	4.07	

* AICRP on Agroforestry, Kahikuchi Centre, Assam

Environmental Benefits

Nutrient build up: Build up of organic matter (OM) and plant nutrients in *B. balcooa* plantation take place enormously. After 8 years of plantation build up of OM, available N and P_2O_5 of soil was enhanced from 1.43 to 2.01%, 247.1-279.4 kg/ha and 28.7-31.3 kg/ha, respectively, in an experiment in Assam.

Carbon sequestration: Bamboo being a C_4 plant contributes substantially to r cleaning the environment by carbon sequestration. In a 7-year old plantation of *B. balcooa* the above- ground C stock is equivalent to120.8 Mg/ha as recorded at AICRP on Agroforestry, Kahikuchi Centre, Assam.

Utilization

Bamboo is used extensively for house construction, farm fencing, production of pulp and paper, making agricultural implements, mats, screen, wall plate, basket, and agarbatti stick and food grain container. Good, strong bamboo is used for scaffolding and ladders. Shoots of *B. balcooa* bamboo are consumed as vegetable and its leaves are used as fodder.

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Agro-Ecological Region 16

Eastern Himalaya

16.1. Agroforestry Model: Agar based Agroforestry System

Area of adoption: Assam, Arunachal Pradesh and Nagaland
Tree component: *Aquilaria malaccensis*
Common name: Agar
Family: Thymelaeaceae

Introduction

Aquilaria malaccensis is one of the most utilized high-value aromatic trees of North East India. Two variants of Agar tree are found in the region: '*Jati Sanchi*' and '*Bhola Sanchi*'. Usually *Jati Sanchi* yields more agar products than the latter. Agar is famous for two of its high-value products: agar wood and agar oil. These are the most illustrious perfumery raw materials obtained from the infected wood of Agar tree. In natural conditions all trees don't produce these products but those trees which get infected during their early growth phase by certain micro-organisms gradually accumulate a fragrant oleoresin in wood tissues and produce dark lesions of different sizes. A large lesion impregnated heavily with oleoresin is separated from the healthy part of wood and is marketed as agar wood (*Agaru*). Market value of agar wood varies depending on its quality (colour, weight, fragrance, shape and extent of accumulation of oleoresin). Agar oil is extracted only from small and developing agar lesions and partially infected wood by steam distillation process and not from the uninfected tree. Quality agar oil is dark brown in

colour and does not set into a semi-solid mass at room temperature. Very low quality of agar oil is produced by distillation of wood of immature and healthy tree without showing any sign of significant infection; this oil is locally known as '*Boya*' which is pale brown in colour and easily sets into a waxy mass at room temperature.

Habit and Habitat

A. malaccensis is a medium-size evergreen and heliotropic tree usually 18-20 m tall and 1.5-2.4 m in girth with straight and fluted bole with medium crown. Agar prefers high humid sub-tropical climate with rainfall 1800-3500 mm per annum. It grows from sea level up to 500 m altitude and requires bright sun shine. Its performance is best in well drained deep sandy loam to loam soil rich in organic matters. It grows well in hill slopes and forest environment preferably in acidic soil.

Distribution

A. malaccensis is distributed in the Eastern Himalayas of India, Bangladesh, Myanmar and South East Asia. Within India, it has been recorded in Assam, Arunachal Pradesh, Nagaland, Meghalaya, Manipur and Tripura. In Assam it was originally found in abundance in old Sivsagar district and also sporadically in other districts of the Upper Brahmaputra Valley. The plant was also reported in Darrang and Sonitpur districts especially in areas bordering Arunachal Pradesh. The plant is so heavily exploited that it is now almost completely extinct from its natural habitat of North East region. However, the plant is now extensively cultivated throughout Assam especially in the districts of Golaghat, Jorhat, Sivsagar, Tinsukia, Nagaon, Hojai, Goalpara, Karimganj, Hailakandi and Dubri and in the sub-tropical conditions of other neighbouring states. Limited natural vegetation still exists in Bhutan, Arunachal Pradesh and Nagaland.

Phenology

Leaves are alternate 0.5-10 cm long, oblong, lanceolate or elliptic, caudate, acuminate and glabrous with slender nerves. Venation is parallel and petiole is 0.3-0.5 cm long. Flowers are white in colour,

bisexual, pedicellate, in both axillary and terminal umbellate cymes, shortly pedunculed, perianth, companulate, lobes 5 spreading and densely pilose. Pedicels is 0.5-0.8 cm long slender, perianth 1.3-1.5 cm long, silky, densely villous, connate at base remains persistent in fruit. Stamens are 10, anther 10 with subsessile disc. Ovary is subsessile, villous and two- celled. Stigma is large and subsessile. Fruit is capsular, 3-5 cm long, ovoid, pericarp coriaceous and densely tomentose. Seeds are ovoid with a long tail.

Package of Practices

Propagation technologies: Agar is propagated by seed which ripens in June-July. In some trees viable seed can be harvested during late September to first week of October. Germination of seed is epigeal; therefore, special care should be taken in nursery management. They are first germinated in sand bed and after 25 days of emergence seedlings are transferred to polybags of size 5 cm x 10 cm under temporary shade or seed can directly be sown in raised bed. Seed has short viability for 7-10 days. Shifting of bag should be done at monthly interval to prevent the penetration of roots in to the soil followed by light irrigation.

Cultural Operations

Preparation of land: Land should be prepared after clearing of bushes and shrubs, if any.

Spacing: For mono crop, spacing is 2.5 m x 2.5 m. However, after 10 years of growth 50 % of trees may be harvested.

Pit size: The planting of the saplings is done in well prepared pits of size 50 cm x 50 cm x 50 cm.

Planting: When the planting is done with some other tree species, the spacing should be maintained accordingly. After planting, staking is done to keep the seedling in upright position. Watering is necessary immediately after planting. The best time of planting is April to July and may be continued up to September depending upon the soil, temperature and rainfall.

Manuring: Well decomposed cow dung/FYM @ 10 to 15 kg/ pit should be applied and well mixed with soil prior to planting. The rhizosphere of agar tree (0 to 45 cm) exhibit a higher rate of microbial population when beneficial-microbe-mediated organic manure is used.

Fertilizer application: N, P_2O_5 and K_2O at the ratio of 10:10:4 is applied in second year @ 200g/tree followed by 400g/tree and 500g /tree, respectively in the third and fourth year. Fertilizer should preferably be applied in two splits, one at onset of monsoon and another at cessation of monsoon. Fertilizer should be applied along with decomposed cow dung/ FYM. From 6-7 year onwards, an additional dose of nitrogenous fertilizer @ 400-500 g/tree/year may be applied in two splits during pre- and post-monsoon period. This will help in keeping the tree wood soft, with higher content of cell sap enabling easy insect boring followed by fungal infection and spread of infected area over a larger wood volume.

Orientation

Boundary plantation: Agar tree is suitable for growing in field boundaries and for dividing whole plot into sub-plots. It is also grown in border of garden, school compound, office compound, parks, residential sites and small tea garden.

Pond dyke plantation: Agar tree is successfully grown for strip planting along bank of tank, pond, canal and road.

Homestead plantation: In homestead garden agar is grown along with areca nut, coconut, banana, bamboo etc.

Block plantation: Agar plantation is also done in block. Different intercrops are grown during early growth stages.

Intercropping: Vegetables/pulses/fruits or medicinal and aromatic crops like Patchouli (*Pogostemon cablin*), Sugandh mantri (*Homalomena aromatica*), Kalmegh (*Andrographis paniculata*), Gathion (*Kaempferia galanga*), pineapple, etc. can be cultivated during first 3-5 years of plantation. Ginger/turmeric may also be planted during initial 2 to 3 years. In later stages shade-tolerant

medicinal plants like Sarpagandha (*Rouvolfia serpentine*), Pipali (*Piper longum*) and Kalmegh can be grown successfully depending on tree population and land situation.

Soil working: Soil working to a radius of 50 cm around tree is to be done once in 3 to 4 months. Manure and fertilizer application should also be followed by this operation preferably twice in a year, before and after monsoon from second year onwards.

Fencing: Agar seedlings are browsed by goat and cattle. Therefore, the plant requires protection for at least 4 to 5 years from farm animals. Trenching around the plantation can also give good protection.

Tending Operations

Coppicing: In agar plantation regeneration takes place freely which facilitates harvesting of infected tree leaving the tree trunk for quick regeneration for a second crop as well as seed production from the coppiced tree once identified as a good mother plant. In coppicing during 10-15 years of age, the growth of new shoots is fast and they attain harvestable stage within the next 10-15 years with comparatively higher distillable wood. Higher infestation of wood borer and fungal infection are observed in coppiced tree. Best results are obtained during March-May. Coppicing during monsoon and winter months gives poor results.

Tree Protection

Major pests: In agar plantation generally no serious insect pests and diseases have been observed. However, *Hoertia viressoides*, a leaf eating caterpillar, is considered to be the most destructive pest causing damage by complete defoliation of agar trees and has become a real menace to the plantations in the North East Region. The intensity of attack is more in the trees grown in open condition than under shade. During March/April (dry season) the infestation is comparatively higher than July/August (rainy season). The pest has been found to cause defoliation twice in a year in May/June and August/September. The intensity of attack is more severe during

May/June and can cause death of well grown trees due to complete defoliation.

Control: For the management of leaf eating caterpillar collection and destruction of early instars of caterpillar clusters should be done. At severe attack spraying of contact insecticides like Quinalphos 25 EC @ 2ml/litre of water at 10-15 days interval should be done; while spraying, it is kept in mind that the beneficial insect borer associated with agar formation is not affected. Severely infected tree should be given an extra dose of nitrogen.

Augmentation of Oil Formation

Cultural treatment to augment oil formation: Formation of agar wood can be initiated by creation of open wounds on the trunk of agar tree. It is a common practice for early infection. This is done just before breaking the dormancy i.e. before spring by giving a deep slanting cut in trunk with a sharp *Dao*. These injuries facilitate infection and also to push the tree to undergo a stress condition, which helps in spreading of infection. Under favourable climatic conditions, this practice yields better result where there is already a build-up of beneficial microbial population in soil. These cut injuries serve the initial sites of fungal infection.

The '*Dum type*' product obtained out of this treatment for oil extraction is locally known as '*Ghap mal*'. A 20-year old tree that may produce only 5-10 kg of '*Dum*' without any treatment but treatment by mechanical injuries resulted more than 30 kg in about 2 years.

Artificial inoculation: In artificial inoculation method 6-8 holes of 1.0-1.5 cm diameter are made in the trunk of the tree at a distance of 30 cm, followed by inserting suitable inoculum and the holes then closed with cotton for 6-7 months. The holes are then reopened to provide suitable environment for fungal activities. In this method, essential oil production starts after 9-10 months. Work on commercialization of this method is in progress.

Detection of productive trees: Since agar is located deep within the trunk, its detection from outer appearance of the trunk is not easy.

Generally, such trees are distinguished by certain external symptoms whether or not the tree harbours precious agar oil or agaru deposits.

- A poor crown, decayed branches, and uneven bole;
- Swelling or depressions and cankers on the bole;
- The appearance of hordes of ants in the fissures;
- A distinctly yellowish to brownish tinge in the wood under the outer bark; and
- Signs of ill-health partially a die-back symptom of the top and outer branches and a yellow tint to the woody tissues.

Harvest, Yield and Post-harvest Operations

Harvesting: The age, growth rate and/or wood volume or physiological maturity do not govern the harvesting age of agar tree for commercial purpose. It is the infected trees whose further growth is arrested due to physiological imbalance that are harvested for agar wood and oil. The healthy trees are left to undergo stresses and/or get infecteds either naturally or artificially to induce oil formation. Harvesting is done on selection and continues for a longer period from a plantation raised at the same time. Although harvesting of agar trees for oil extraction as well as for agaru is done almost throughout the year, the best time is during February-May, dry season when the plants remain almost dormant or less active. During this period maximum concentration of oil with less waxy substances is obtained. When stress is more bio-molecule concentration is also more. The extracted oil during dry season possesses the finest odour and note compared to that obtained during rainy season when the plant remains active in growth.

A profitable plantation of agar is 15 years cycle or more. 'Agar attar' of low quality i.e., *Boya* oil is found from the short cycle plantation. The plantation is done in two ways: (a) planting at wider spacing along with suitable intercrops and harvesting at the end of crop cycle, and (b) planting at relatively closer spacing and harvesting in two to three phases. One of the important approaches is to harvest about 40 % selected trees after 10 to 12 years of growth with a view to thin out the plantation for better growth and development of the remaining trees and also to get a substantial mid-term income.

Yield: The yield of commercial product of agar tree is not uniform in all productive trees. It varies greatly and is almost unpredictable. After 10 years of planting with intensive management each infected tree may yield about 30-40 kg 'Dum type' to 'Kolasanchi' product for oil extraction, depending on infection intensity. Therefore, quality of oil varies depending on types of wood used for distillation.

Post-harvest processing: The harvested tree is processed for two products: (a) agaru or agar wood that is used as incense and (b) essential oil or agar oil or agar attar. Agaru is obtained from older trees while oil is distilled from old as well as younger trees. After felling a tree, the smaller branches are removed. Then the tree is cut into logs (pieces of 2-2.5 ft.). Thereafter, the logs are split to separate out the infected and non-infected woods. The agar wood of any grade, if detected, is first separated out with the help of indigenous tool like hacksaw blade and '*Batali*' and graded them based on the oleoresin impregnation, colour density, specific gravity and finally the odour. These are then dried, cleaned by removing the white woody portions as far as practicable, polished and graded for marketing.

Agar oil is obtained by steam distillation of harvested wood chips or coarse powder in special type of stainless steel made distillation unit. Distillation is continued for 5-10 days or more using firewood as the energy source.

Economics

Estimated economics of cultivation per hectare of *Aquilaria malaccensis*

Expen-diture (Rs)	**1st yr.**	**2nd yr.**	**3rd yr.**	**4th yr.**	**5th yr.**	**6-8th yr.**	**9-15th yr.**
Cost of fencing & repair	15,000	-	3,000	-	5,000	5,000	7,000
Land preparation	5,000	-	-	-	-	-	-

Pit making 1700xRs.2/ pit	3,400	-	-	-	-	-	-
Cost of sapling 1700 x Rs. 5/sapling	85,000	-	-	-	-	-	-
Cost of planting Rs. 2/plant	3,400	-	-	-	-	-	-
Compost	9,000	8,000	8,000	8,000	8,000	-	-
Fertilizer	-	5,000	6,000	8,000	9,000	-	-
Cost of application Rs. 2/plant	3,400	3,400	3,400	3,400	3,400	-	-
After care/ year	5,000	5,000	5,000	5,000	6,000	20,000	30,000
Misc.	1,300	1,600	1,600	1,600	1,500	30,000	7,000
Total	54,000	23,000	27,000	27,000	33,000	1,58,000	82,000

Total expenditure - up to 8th year = Rs 3, 22,000/ha
Next 9-15 years = Rs 82,000/ha
Total = Rs 4, 04,000/ha

Anticipated yield and income: Assuming 1500 nos. of trees at 8th year out of total, we may harvest 40 % of the selected trees i.e. 600 with a view to thin out the population for remaining 900 trees for further growth and development and also to generate an interim income. The final harvesting of 900 trees would be done at 15th year.

Assumptions: Yield of distillable wood (low quality *Dum* or *Boya*) from 8-10 years old tree 20 kg/tree @ Rs. 10/kg; yield of *Dum* at 15th year 50 kg/tree @ Rs 50/kg; yield of *Kalagachi/Batali mal* (agar wood) 0.5 kg/tree @ Rs 2000/kg from about 500 trees.

Returns

Gross returns:

at 8-10 years *Dum* 600 x 20 x10		= Rs 1, 20,000/ha
at final harvest *Dum* 900 x 50 x 50		= Rs 22,50,000/ha
Agar wood 500 x 0.5 x 2000		= Rs 5,00,000/ha
	Total	**= Rs 28, 70,000/ha**

Net returns:

(Rs. 28, 70,000 – Rs. 4, 04,000) = **Rs 24, 66,000/ha**

From an established plantation, thus, a net income of Rs. 25-30 lakh/ha after 15 years may be generated giving an average of Rs 1, 96,400/year/ha. Intercropping in the early stages of growth can generate extra income.

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Agro-Ecological Region 17

North Eastern Hills (Purvanchal)

17.1. Agroforestry Model: Alder based Agri-silvi-horticultural System

Area of adoption: Tripura, Mizoram, Meghalaya, Sikkim, Arunachal Pradeshand Darjeeling and Jalpaiguri districts of West Bengal
Tree component: *Alnus nepalensis*
Common name: Nepalese Alder, Utis
Family: Betulaceae

Habit and Habitat

Alnus nepalensis is a fast growing deciduous or semi- deciduous tree reaching a height of up to 30 metres. It has a straight bole that is around 60 cm in diameter, but occasionally up to 2 metres. It grows best in areas with a mean annual rainfall from 500 to 2,500 mm, and an annual average temperature of 19-23°C. Mature trees can tolerate some frost and withstand a dry season of 4-8 months. They prefer moist and well drained soils, including loam and loamy sand gravel, sand and clay. *A. nepalensis* is a fast growing tree, with annual increments of 2.7 metres in height and 2.9 cm in diameter. A mean annual diameter increment of 2 cm is common. The tree coppices after cutting, but successful regrowth seems to depend on seasonal and locality variations, with wet season felling and moist localities being best. This species has a symbiotic relationship with certain soil micro-organisms; these form nodules on the roots of the plants and fix atmospheric nitrogen. Some of this nitrogen is utilized by the growing plant but some can also be used by other plants

growing nearby. It is an excellent agroforestry tree and is commonly planted to restore land as well as to provide wood for poles etc.

Distribution

Alnus nepalensis grows between 1000 m and 2500 m elevation belt most predominantly in the eastern Himalaya which encompasses eastern Nepal, Sikkim, Darjeeling, Bhutan, Arunachal Pradesh, Nagaland and the Khasi hills of Meghalaya. It is a pioneer species on freshly exposed landslide soils. It grows on sandy eroded soils, denuded habitats, rocky slopes, landslide-affected slopes, steep stream sides and in natural areas. It has been a common species in natural forests and recently has also become an important species of plantation forests in the Sikkim Himalaya. It has been considered as a useful species in social forestry and agroforestry in the region.

Phenology

The first peak period of leaf flushing was observed in the beginning of warm dry season (March-April) whereas the second peak occurred during the mid wet season (August-September) and flowering is mostly after leaf flushing.

Fruits, which resemble the cones of the pine family, are dark brown, upright on short stalks, elliptical, composed of many spreading, hardwood scales; seeds light brown, circular and flat with 2 broad, membranous wings, more than 2 mm across (Orwa et al. 2009).

Package of Practices

Propagation Technology:

Natural: Seeds, coppice

Artificial: Seeds, cuttings

Cultural Operations

Preparation of land: If the land is having gentle slope, it can be levelled with minor land shaping and providing suitable type of bunds across the slope. If the slope is more, contour bunding, terrace

planting or contour line planting can be adopted. In more sloping areas, a platform for individual plants on contour lines works better as it involves less soil cutting.

Spacing: In general 3 x 3 m spacing is recommended for gentle slopes.

Pit size: Deep textured loose soils : 45 cm x 45 cm x 45 cm; shallow soils 60 cm x 60 cm x 60 cm

Fertilizer Application: For each pit, about 5 kg (one iron pan) of well decomposed FYM or compost is applied at the time of plantation along with 50g SSP. NPK fertilizer is applied @100:50:50 kg/ha/yr. The whole P & K and 1/3rd N is applied in April, 1/3rd N in July and the remaining 1/3rd N in October.

Planting: It is done in rainy season preferably during June to September. Monsoon planting is recommended provided the saplings are in polybags. Five-month old saplings are suitable to plant during the regular onset of monsoon. One sapling/pit should be planted.

Tending Operations

After-care of plantation: After one month, all the buds, except top 5-6, should be removed carefully by rubbing with gunny bags without damaging the bark. Weeds around the plant should be removed and regular pot watering should be given as needed. After 3 months of planting, a second weeding should be given. Plants must be protected from grazing.

Pollarding: Trees are pollarded in the third year of establishment, at a height of 5 feet. Single cleared bole should be maintained up to the height of 5 feet.

Coppicing: Trees are coppiced in the third year of establishment, at a height of 50 cm.

Tree Protection

Major Pests: Wood borers, defoliators and sap-suckers

Control: For the management of wood borer, plug the hole completely with cotton ball dipped in kerosene and cover it with mud. In case of severe attack of defoliators/sap-suckers, spray chlorpyriphos @1-2 ml/litre on the leaves.

Diseases: Powdery mildew and Bacterial blight

Control: Fungal disease can be controlled with the application of Dithane M-45(Mancozeb) @ 75 WP or other suitable fungicides. Bacterial blight can be managed by pruning and removing the infected parts after proper sanitization of pruning tools. Sound cultural practices help in the recovery from this disease.

Fruit plants: *Citrus reticulata* Blanco (Orange) and *Pyrus communis* (Pear)

Suitable intercrops (*Kharif–Rabi*): Tea, Coffee, Maize, Rice, Ginger, Potato, Chilli and *Amomum subulatum* Roxb. (Large cardamom).

Cardamom-based traditional agroforestry systems are prevalent in eastern Himalaya. The large cardamom is a perennial cash crop grown traditionally beneath the natural forest tree cover on marginal lands and slopes. It is a shade loving plant and requires high moisture and is usually cultivated in areas where mean annual rainfall varies between 1500 and 3500 mm the combination with cardamom is synchronized and has proved to be ecologically and economically viable (Dhyani, 1998).

Fertilizer: NPK is applied @120: 60:40 in agroforestry system. Phosphorus and Potash are applied every alternate year, whereas Nitrogen is given every year in split doses.

Method of plantation: A small hole is dug and a handful of FYM is added at the time of planting root slips along with recommended NPK dose of phosphorus, potash and first split dose of nitrogen.

Irrigation and other management requirements for crops: After sowing of seed or plantation, light irrigation is required if there is no rain.

Weeding: Manual weeding should be done in the initial years of establishment of grass.

Orientation: Boundary on bunds and with crops in fields

Yield/Annual Return

Alnus nepalensis is a fast growing tree in a fruit-based agroforestry system with annual increments of 2.7 metres in height and 2.9 cm in diameter. A mean annual diameter increment of 2 cm is common.

Economics

The overall net income on degraded hilly soil was Rs 50,000 to Rs 70,000/ha in the initial years and Rs 1,25,000 to Rs 1,60,000/ha on establishment of the system.

Environmental Benefits

This agroforestry system helps in protecting the sloping lands from degradation and sustaining production. The tree cover helps in recycling of nutrients and improving soil health.

Benefits Accrued to Farmers/Public

Availability of quality fruits and different crops along with vegetables throughout the year generates income as well as ensures food security for farmers.

Validated technology transferred to other departments or other agencies: Farmers are increasingly adopting this technology driven by its economic returns.

Way Forward

The technology has a tremendous scope especially in mid-hills of Eastern Himalayan districts of Darjeeling and parts of Jalpaiguri where an increasing number of grasslands are turning into degraded lands due to inefficient land management.. Increased availability of quality fodder will lead to adoption of milch animals along with raising of fruit trees resulting in better health of local people and boosting their economy at household level.

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Agro-Ecological Region 18

Eastern Coastal Plain

18.1. Agroforestry Model: *Gliricidia sepium* and *Leucaena leucocephala* based Silvi-pasture System

Area of adoption: Tamil Nadu
Tree Component: *Gliricidia sepium*
Common name: Gliricidia, Mother of Cocoa, Mexican Lilac
Family: Fabaceae

Habit and Habitat

Gliricidia sepium is a medium-sized tropical plant, 3 to 13 metres tall. The plant is deciduous, flowers sporadically through the year in areas with year round rainfall. It can tolerate a wide range of soil types, both alkaline and acidic, including low-fertility ones. The preferable pH range is 5.5 - 6.2 but the tree can tolerate up to 8.0 pH. This species has been widely introduced across tropical and sub-tropical regions and is used for fuel--wood, animal feed, green manure, shade, poles, and living fences. *Gliricidia sepium* can be propagated either from seeds or through stem cuttings.

***Gliricidia* and *Leucaena* based Silvi-Pastural System for fodder production at the Research Farm of TNVAU, Kattupakkam**

Distribution

Gliricidia sepium is native to tropical dry forests of Mexica and Central America and widely grown in most parts of India except in Jammu & Kashmir, Himachal Pradesh and Sikkim.-

Phenology

The flowering season lasts from January to April, fruiting season from March to May, and seeding season from March to May. Leaves fall during summer season.

Package of Practices

Propagation Technology

Gliricidia sepium can be propagated either from seeds or through stem cuttings. Green, mature branches measuring 2-5 cm in width and 100 cm in length should be used and are obliquely cut at the ends. Seeds are soaked overnight in water and planted in polybags in nursery to produce seedlings. The polythene bags are filled with 2 part soil + 1 part farm yard manure. If farm yard manure is not available, for each bag 2 g of NPK (15:15:15) could be used.

The stem cuttings or seedlings are planted on bunds after rains. The first cutting is done after 5-6 months at a height of 70–80 cm from the ground level at a time when the plants reach a height of 1.5 - 1.75 m. Subsequent harvests can be made at 50 - 60 days interval depending on the regrowth.

Utilization

G. sepium is used as live fencing, fodder, firewood, green manure, intercropping and as shade plant.

Tree Component: *Leucaena leucocephala*
Common name: Subabul
Family: Fabaceae

Habit and Habitat

A leguminous tree, usually2.5-13 m tall and 12-33 cm in diameter;older trees may be18 - 20 m tall and 45 cm in diameter.

Leaves are bipinnate and leaflets are small with a concave, cup-shaped, elliptic petiole gland. Pods are wide, linear-oblong and flat with papery pod walls.

Distribution

Leucaena leucocepahala is native to southern Mexico and northern Central America and is now naturalized throughout the tropics. During the 1970s and 1980s, it was promoted as a "miracle tree" for its multiple uses. In India it was tried extensively in Andhra Pradesh, Karnataka, Tamil Nadu, Himachal Pradesh, Maharashtra, Gujarat, Punjab, Haryana, Bihar and Uttar Pradesh

Phenology

L. leucocephala is self-fertile and produces exceptional quantities of seed from the first year, more or less throughout the year as moisture permits, across a wide range of environments. Fruits ripen within 10-15 weeks, completely deciduous depending on the length and severity of the dry season.

Propagation Technology

Seedlings of *L. leucocephala* can be planted with the onset of rains. To hasten germination seeds should be dipped in concentrated sulphuric acid for four minutes and then washed or put in hot water at 80°C for four minutes. Sun dry the seeds afterwards for about one hour before sowing. A seed rate of 3-4 kg/ha is recommended. Seedlings around 1.5-3 months old are planted in the main field. A spacing of 1 m x 0.1 m is recommended for a pure crop of fodder, 1.5 m x 0.2 m for planting in boundaries and borders of coconut gardens and 2 m x 0.2 m when raised along boundaries.

Utilization

Leucaena has multiple uses. Leaves are highly nutritious for ruminants. In the southern and central states of India, *Leucaena leucocephala* is the most important species for making pulp. It serves an alternative crop choice for farmers in Andhra Pradesh and Telangana states of India along with cotton and chillies.

Fodder Component: *Stylosanthus scabra*
Common name: Shrubby Stylo
Family: Fabaceae

Habit and Habitat

A perennial grass which can grow to a height of 75 cm. Stems are fine; trifoliolate leaves; central leaflet 12-23 mm long and 2-5 mm wide. Seeds are very small and pale brown.

Distribution

Stylosanthus sp. is a tropical legume shrub widely grown for forage throughout the tropics and subtropics. *S. hamata* is being used for intercropping with grain crops in India. *Stylosanthus* sp. is found from 20° N to 32° S, in fallow land, and can grow up to a mean sea level of 1500 m. *Stylosanthus* sp. ranges do better between 1000 and 2500 mm annual rainfall.

Stylosanthus sp. is a pasture grass capable of nitrogen fixation to improve soil fertility and be used as animal feed.

Propagation Technology

Stylosanthus sp. can be sown alone or mixed with companion species. Seeds can be broadcasted at a rate of 10 kg/ha. Acid scarification should be done by dipping the seeds in concentrated sulphuric acid for three minutes. Scarified seeds are again pre-soaked in cold water overnight. In humid areas, *Stylosanthus* sp. can be sown at any time. In drier parts, it should be sown as soon as possible after the start of the rainy season. First harvest can be taken 75 days after sowing at flowering stage, and subsequent harvests depending upon the growth.

Major Pests and Diseases

Diseases caused by fungi, bacteria, a possible virus and nematodes have been recorded on *L. leucocephala*. Most diseases are caused by fungi and include leaf spots, gummosis, pod rots, root and collar rots, stem cankers, anthracnoses, damping off, rusts and shoot and twig blights. Control strategies based on resistance and cultural management through cutting and grazing are considered the most practical and economical. Treatments to control seed-borne

pathogens are essential to reduce establishment problems and for low risk germplasm movement.

Orientation: Block Plantation

Suitable intercrop: *Stylosanthus* sp.

Fertilizer

A basal application of N:P:K at the rate of 20:50:30 kg/ha is recommended for *L. leucocephala* and *G. sepium,* and 20:60:15 kg of NPK/ha for *Stylosanthus* sp.

Harvest

The total edible leaf biomass in *L. leucocephala* and *G. sepium* was 9.20 MT/ha and 18.54 MT/ha, respectively. The edible leaves can be converted into tree leaf meal for inclusion in the ration of ruminants.

Tree leaf meal preparation

For preparing a leaf meal, leaves of *L. leucocephala* and *G. sepium* are sun-dried for three days so the moisture content is reduced to 10-13% and then ground to pass through 1 mm sieve and stored in sacks. A tree leaf meal mix was prepared by mixing *L. leucocephala* and *G. sepium* leaf meal in the ratio of 1:1 to be incorporated in the concentrate feed for ruminants.

Economics

Initial establishment during first year requires Rs 25,000 – 30,000 to prepare land, purchase seeds and seedlings. The output from the silvi-pasture obtained after 10 months is presented in the following table.

Biomass production and income from a 10-month Silvi-pasture system

Species	Yield (kg)	Amount (Rs)*
Leucaena leucocephala	9,500	19,000
Gliricidia sepium	18,500	37,000
Stylosanthes scabra	5,840	11,680
Total (Rs.)		**67,680**

*Cost of return in terms of biomass production - (Rs 4/kg of Stylosanthes and Rs 2 kg of tree fodder)

Rs 67,680/- was obtained from the agroforestry model as revenue. In this model, the farmer can hold 40 goats and their kids. From these 60 kids (@ 1.5 kidding percentage) can be sold at 6 months of age with 15-20 kg body weight @ 250/kg live weight. This generates Rs 3,00,000 as additional income to the farmers..

The excess fodder can be conveted into tree leaf mal for inclusion in the concentrate feed of ruminants.

Tree leaf meal

Tree leaf meal (*L. leucocephala*/*G. sepium* -- 1:1) can be included up to 30% level in concentrate feed for goat kids and buffalo calves without any change in the growth rate but reducing feed cost by Rs 4.7 /kg.

Environmental Benefits

The unutilized calcareous lands can be effectively utilized by cultivating fodder trees to alleviate the fodder shortage. Soil erosion is prevented and soil fertility improved.

Social Benefits

Farmers establishing this agroforestry model will be able to meet the green fodder requirement of their livestock. The livestock productivity will be enhanced with better nutrition thereby improving the livelihood security of poor farmers.

Utilization: Fodder and value addition of tree fodders

Source of planting material

Leucaena leucocephala, Gliricidia sepium and *Stylosanthus* sp.*:* AICRP on Agroforesty, Tamil Nadu Veterinary and Animal Sciences University (TANUVAS), Kattupakkam, Tamil Nadu

Benefits Accrued to Farmers/Public

The unutilized barren calcareous land can be used for fodder production. Soil status and fertility is improved. Sale of fodder, milk and meat generates additional income for the farmers and improves their livelihood security.

Validated technology transferred to other departments/ agencies

Establishment of silvipasture model and tree leaf meal preparation

has been propagated among the livestock farmers of Tamil Nadu through different trainings courses for farmers. Inputs and technical details were provided to establish the silvipasture model across Tamil Nadu (32 hectares). The importance of tree leaf meal preparation as a feed ingredient was popularized by conducting animal trials in farmers' field.

Contributors

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18.2. Agroforestry Model: Guava (*Psidium guajava*) with *Cenchrus ciliaris* based Horti-pasture System for Degraded Lands

Area of adoption: Tamil Nadu
Tree component: *Psidium guajava*
Common name: Guava, Amrud
Family: *Myrtaceae*

Habit and Habitat

Guava is a popular, commercial fruit of India; it can grow well both in wet and dry regions and is widely cultivated in tropical and subtropical areas around the world. It can be grown up to 1500 m altitude and thrives well in all types of soil with pH ranging from 4.5 - 8.2. It can tolerate well high temperatures and drought conditions. Young plants are susceptible to severe frost. An annual rainfall of about 100 cm is sufficient during the rainy season (July-September). Rainfall during the harvesting period deteriorates the quality of fruits.

Distribution

Guava is a native fruit tree to tropical America. It was introduced in India in the 17thcentury. The fruit tree is distributed in the following states of India - Uttar Pradesh, Bihar, West Bengal, Maharashtra, Chhattisgarh, Tamil Nadu, Karnataka, Madhya Pradesh, Gujarat and Andhra Pradesh.

Phenology

The interval between blooming and fruit set is one of the most important phenological stages. The period from bud bursting to leaf emergence is nine days. The period from flower bud initiation (from when the flower bud becomes visible) to full bloom is 20 days. The time of flowering is from February to April and August to September. The time from occurrence of first flowering to last flowering is 65 days. Days taken to 50% flowering from the initial flowering are 30. The pollen viability assessment is 80.34 %, duration of flowering to fruit set days is 15 days, and duration of fruit set to harvest is 120 days.

Fodder component: *Cenchrus ciliaris*
Common name: Buffel grass
Family: *Poaceae*

Habit and Habitat

Cenchrus ciliaris, a perennial grass species, is most suitable for arid and semi arid region of India. It is one of the most drought tolerant of the commonly sown grasses in arid areas and can be found in environments with annual rainfall as low as 100 mm. The thin

***Cenchrus ciliaris* with guava under a Horti-pastural System at the Research Farm of TNVAU, Kattupakkam**

stems often produce roots from nodes and are branched above the base of the plant. The leaf is made up of a sheath, partly encloses the stem and diffused leaf blade. The leaf blades (3-37 cm long and 2-13 mm wide) are very elongated (i.e. linear) in shape, usually flat, and have a pointed tip.

Distribution

In India, *Cenchrus ciliaris* is a natural species largely found in Rajasthan, Haryana, Punjab, Gujarat and parts of western Uttar Pradesh and Tamil Nadu. It is considered a good forage grass in Africa. In the Mexican part of the Sonoran Desert, it is still planted and irrigated for livestock grazing. It is also sown in Queensland, Australia for grazing, hay and silage.

Package of Practices

Propagation Technology

Psidium guajava: Cuttings and graftings are more commonly used as propagation methods in commercial groves.

Spacing/Pit size: A spacing of 5-6 m either way is generally followed. Plant the layers with the ball of earth in the centre of pit of 45 cm x 45 cm x 45 cm size filled with farm yard manure 10 kg, neem cake 1 kg and top soil.

Cenchrus ciliaris: Sowing of *Cenchrus ciliaris* seeds should be done in lines using 4 to 5 kg seeds/ha after the first shower in monsoon. Five to six weeks old seedlings or rooted slips can also be transplanted at 50 cm row-to-row and 30 cm plant-to-plant spacing. Thus, more than 33,000 seedlings or rooted slips are required for one hectare area.

Major Pests and Diseases

The insect pests mostly observed are fruit fly, stem borer, bark eating caterpillar, thrips, nematodes, mealy bug and scale insect. Spraying with Malathion (2ml), phosphamidon (0.5ml per litre of water), monocrotophos, dimethoate etc., has been found to be effective in most cases.

The main diseases reported are wilt, fruit canker, fruit rot, anthracnose and grey leaf spot. Application of Carbendazim/ Thiophanate methyl (1g/litre) or Kavach/Mancozeb (2 g/ litre) depending upon the type of infection has been found to be effective in controlling the diseases.

Orientation: Block plantation

Suitable intercrop: *Cenchrus ciliaris*

Fertilizer

Guava: Farm yard manure 50 kg and one kg each of N, P and K per tree in two split doses during March and October should be applied. To increase the yield, spray Urea 1% + Zinc sulphate 0.5 % twice a year during March and October. To correct the boron deficiency (reduction in size of leaves, fruit cracking and hardening), spray 0.3 % borax during flowering and fruit set stage.

Cenchrus ciliaris*:* In the first year, a basal application of 5 tonnes of farm yard manure (FYM) along with 40 kg N + 20 kg P/ha should be mixed thoroughly in the soil using a plough at the time of land preparation. Afterwards, 20 kg N/ha is required at one month crop through top dressing. However, in subsequent years, 40 kg N + 20 kg P/should be top dressed as a single dose, and another dose of 20 kg N/ha may be applied after the first harvest.

Micronutrients spray for controlling bronzing of leaves

A combined spray should be given containing $ZnSO_4$, $MgSO_4$ and $MnSO_4$ @ 0.5% and $CuSO_4$ and $FeSO_4$ @ 0.25 % plus Teepol @ 1ml per 5 lit of solution on various stages as follows:

1. New flush
2. One month after
3. Flowering
4. Fruit set

Irrigation

Copious irrigation is needed immediately after planting, again on third day and afterwards once in 10 days or as and when necessary. Drip irrigation has proved to be very beneficial for guava. About 60% of the water used for irrigation is saved, besides substantial increase in size and number of fruits has been observed.

Yield/Annual Returns including Tree Productivity

Guava: The first crop can be harvested during February - July and the second one during September - January. The fruit yield is about 29.16 t/ha.

***Cenchrus ciliaris*:** Yield greatly varies on distribution and amount of rainfall in arid tract. A well established pasture produces 11.6 t/ha green matter. A well established pasture yield seed between 150 and-500 kg/ha. Seeds remain viable for 2 to 3 years.

Economics

The revenue generated by adopting this model (*Cenchrus ciliaris* grass under *Psidium guajava)* is in the range of Rs 81, 526/- per year through the sale of fruit and fodder.

Environmental Benefits

Farmers can successfully meet the green fodder requirement, and enhance productivity, of their livestock with this horti-pasture model. Over time, the model will result in an improvement in the soil quality of the land. More efficient recycling of nutrients by trees, improvement of micro-climate, such as lowering of soil surface temperature and reduction of evaporation of soil moisture through shading, increment in soil nutrients through addition and decomposition of litter fall and improvement of soil structure through the constant addition of organic matter from decomposed litter. These systems contribute to increased sustainability of agricultural production.

Utilization: Fodder and fruits.

Source of planting material:

***Guava tree*:** State Forest Department Nursery

***Cenchrus ciliaris*:** AICRP on Agroforesty, Tamil Nadu Veterinary and Animal Sciences University (TANUVAS), Kattupakkam, Tamil Nadu

Benefits Accrued to Farmers/Public

By adopting *Cenchrus ciliaris* grass under *Psidium guajava* tree based hortipasture model the farmers are able to sell guava fruits in

the market which helps in improving their nutritional security. The understorey crops cater to the fodder needs of their livestock. They can also sell the fodder to other farmers.

Validated technology transferred to other departments/other agencies

Establishment of the horti-pasture model has been popularized among the livestock farmers through trainings at peripheral centres of Tamil Nadu Veterinary and Animal Sciences University. This model has been adopted by farmers in an area of 10 ha in rainfed conditions of Tamil Nadu for feeding their livestock.

Way Forward

This technology will help meet the fodder demand in dry belts of Tamil Nadu.

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18.3. Agroforestry Model: *Acacia mangium* based Agri-silvicultural System

Area of adoption: Entire state of Odisha
Tree components: *Acacia mangium*
Common name: Australian teak
Family: Fabaceae

Habit and Habitat

Acacia mangium is a fast-growing evergreen tree with a dense, spreading crown. It occurs in humid tropics, primary and secondary forests, regrowth of woodland, open grassland, poorly drained flood plains and behind mangroves.

Distribution

A. mangium covers all 30 districts of Odisha, but is most popular in coastal districts.

Phenology

Flowering phenology differs throughout the tree's natural and planted range. In its natural habitat, flowers are present during September to December and mature fruits appear 3-4 months after flowering.

Package of Practices

Propagation technology: Seed pre-treatment is necessary to break the hard seed coat. To encourage uniform germination, seed should be scarified either by submerging in boiled water that is allowed to cool for 24 hours, or by soaking in concentrated sulphuric acid for 10-30 minutes followed by soaking in cool water for 24 hours.

Cultural operations: Weeding, cleaning, intercultural operation and nutrient application should be carried out both during pre- and post-monsoon period.

Pit size: 45 cm x 45 cm x 45 cm

Rotation: Trees are felled for pulpwood 6-7 years after planting; for sawn timber the rotation is 15-20 years (PROSEA, 1995).

Tending operations: Tending operations such as thinning are typically used to increase production of usable-sized trees (Zeide, 2001). The 1st thinning is done when trees are 9 m tall, that is, before 2 years of age. Pruning some branches increases the growth rate of the remaining branches (Ramos et al. 1998). Singling is undertaken routinely at about age 4–6 months.

Tree protection (major pests and diseases): Diseases: Damping-off, heart rot, pink rot. Pests: Carpenter ants, pinhole borers and subterranean termites. Need based use of fungicide and insecticide is recommended to control these diseases and pests.

Orientation: Block, field bund and boundary plantation.

Suitable intercrops: Pineapple (*Ananas comosus), m*ango ginger (*Curcuma amada),* turmeric (*Curcuma longa)* and arrowroot (*Maranta arundinacea)* by following standard package of practices and improved varieties.

Yield/Annual Returns and Economics

The total cost of cultivation per hectare in 12 years of *A. mangium* with sesame, arrowroot and pineapple was Rs 9,90,200, gross return Rs 33,07,440 and net return Rs 23,17,240 with a B:C ratio of 3.34 (as per 2015 price). The average annual increases in volume of *A. mangium* are from 0.5 m^3/year to 41.6 m^3/year, with an average of 13.9 m^3/year. During the initial two years the system yields a B: C ratio of 2.37. At 6-8 years of planting arrowroot produced 5.66 t/ ha with a B:C ratio of 2.83 and at 9-12 years of planting pineapple produced 7.65 t/ha with a B:C ratio of 4.54 resulting a higher net profit. At the end of 12 years the system produced 4238 cft/ha of timber and 30 t/ ha of firewood.

Source of planting material: AICRP on Agroforestry at OUAT, Bhubaneswar, State government and Private nurseries.

Benefits Accrued to Farmers/Public

This agroforestry system helps farmers to manipulate and manage their land by growing agroforestry trees with shade loving intercrops to get service or product and receive best economic returns. The system also serves as a carbon sink to mitigate the effects of climate change.

Impact of the Technology

This agroforestry model has positive impact on conservation of soil and water, restoration of soil organic matter and supporting livelihood of the farmers in humid and sub-humid region of eastern India.

Validated technology transferred to other department or agencies: Popularised this agroforestry based production system through the state extension department and Krishi Vigyan Kendras.

Way Forward

This agroforestry system is one of the best with respect to economics, employment generation and carbon sequestration and mitigates to the ill effect of changing climate.

A. mangium is an important source of wattle timber; the wood is used for construction, boat building, particle board, furniture and cabinet making, and veneer. It makes attractive furniture and cabinets, mouldings, and door and window components. With a calorific value of 4800-4900 kcal/kg, *A. mangium* provides good quality charcoal and is suitable for the manufacture of charcoal briquettes and artificial carbon. It can also serve as a wind or firebreak. The species has high carbon sequestration potential.

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18.4. Agroforestry Model: *Gmelina arborea* based Agri-silvicultural System

Area of adoption: Entire state of Odisha
Tree component: *Gmelina arborea*
Common name: Gamhar
Family: Lamiaceae

Habit and Habitat

Gmelina arborea is a moderate-sized, fast-growing deciduous tree up to 12 m in height. It grows well in moist and dry deciduous forests, also in the plains. It is common in the deciduous areas close to grasslands and rivers, hills above 350-900 m in the Indian sub-continent.

Distribution

Throughout the Indian sub-continent, except Jammu & Kashmir, Himachal Pradesh and Sikkim.

Phenology

The tree is in leafless condition between February and end of April and new foliage starts in May; flower initiation occurs in February to April and the tree bears fruit in May to June, and reaches full canopy coverage in July to January when leaf fall also happens.

Package of Practices

Propagation technology: The species can be propagated by seedlings, rooted cuttings, and grafting. Seed should be soaked in cold water for 24 hours before planting. To maintain uniformity in planting and tree quality, rooted cutting is usually used.

Cultural operations: Weeding, cleaning, intercultural operation and nutrient application are done in pre- and post-monsoon period.

Pit size: 45 cm x 45 cm x 45 cm

Rotation: Marketable small diameter timber harvested at the age of 7-10 years. Bent stems and heavy low branches are removed in the cleaning and tending operations during the first and second years. Thinning of coppices to one stem per stool is practiced to supply good building poles.

Tending operations: Weeding, hoeing and cleaning. Thinning is recommended every 10 years where the rotation is 30-60 years.

Tree protection: Diseases: Damping-off, root-collar disease, Anthracnose. Pests: Defoliators are very common, both on seedlings and mature trees. Need-based use of fungicides and insecticides is recommended.

Orientation: Boundary and block plantation.

Suitable intercrops: Pineapple (*Ananas comosus),* mango ginger (*Curcuma amada),* turmeric (*Curcuma longa)* and arrowroot (*Maranta arundinacea)* by following standard package of practices and improved varieties.

Yield/Annual Returns and Economics

Under favourable conditions *Gmelina* is capable of reaching an annual increment of 20–25 m^3/ha with impressive exceptions of over 30 m^3/ha. On poor sandy soils a yield of only 84 m^3/ha after 12 years was reported, whereas on rich soils a production of 304 m^3/ha after 10 years can be reached. At the end of 12 years the system yields a B:C ratio of 2.33.

Source of planting material: AICRP on Agroforestry, OUAT, Bhubaneswar, State government and private nurseries

Benefit Accrued to Farmers/Public

This agroforestry system helps farmers to manipulate and manage their land by growing agroforestry trees with shade-loving intercrops to get service or product and best economic returns. The system acts as a carbon sink which helps mitigate the climate change effects.

Impact of the technology

This system has positive impact on conservation of soil and water,

restoration of soil organic matter and livelihood support to the farmers in humid and sub-humid region of eastern India.

Validated technology transferred to other department or agencies: Popularised this agroforestry based production system through the state extension department and Krishi Vigyan Kendras.

Way Forward

This agroforestry system is one of the best with respect to economic returns, employment generation and carbon sequestration to mitigate the ill effects of changing climate.

Contributors

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Agro-Ecological Region 19

Western Ghats and Coastal Plains

19.1. Agroforestry Model: Block Planting of Burma Bamboo

Tree Component: *Dendrocalamus brandisii* Kurz (Munro)
Common name: Burma bamboo, Velvet Leaf Bamboo, Teddy Bear Bamboo
Family: Poaceae

Habit and Habitat

Dendrocalamus brandisii forms dense clumps and grows best in wet evergreen tropical forests up to 1,300 m altitude. It can grows on different soil types but prefers well-drained loamy soil.

Distribution

Found mainly in the states of Manipur and Andamans, it can also be grown in south Indian states of Kerala, and parts of Andhra Pradesh, Tamil Nadu and Karnataka

Phenology

This species usually flowers sporadically as well as gregariously. Flowering cycle is reported to be 45-50 years.

Package of Practices

Propagation Technology:

1. Seeds can be used for the propagation and the germination percentage is > 90 %.

2. Vegetative propagated planting stock (Cuttings, Offsets, Root cuttings, culm cuttings) is also followed.
3. *In vitro* propagation may be the only reliable method for establishing new bamboo plantation in large areas once the micro propagation protocol is standardized.
4. Macro proliferation of 6 months old macro and micro propagated plants consisting of 4-5 tillers with miniature rhizome can be used.

Cultural Operations: All dead and dying culms to be cut and removed from the third year of establishment preferably in the months of November to February.

Spacing: Scientifically managed block plantations of *D. brandisii* can be a viable alternative in upland paddy fields. At 6 m x 6 m spacing, around 278 bamboo plants can be accommodated in one hectare.

Pit size: 45 x 45 x 45 cm^3 pits, to be half filled and kept exposed to sun for top soil sterilization for about a month.

Rotation: 10-40 years.

Tending Operations: Regular thinning and cleaning should be carried out from the 4th year of clump establishment. All dry, dead and drying culms are to be removed from the clump so as to create sufficient space in the clump for new sprouts to grow up straight.

Protection:

1. Major pests and their control: Among the pests of *D. brandisii*, aphids, leaf miners and termites are the major ones. Aphids can best be controlled by targeting the carrier ants using chloropyriphos 0.05% near the base of the emerging shoot. Leaf miners are not a major pest in established plantations and may be a problem only during the nursery stage.

2. Major diseases and their control: Leaf blight disease and Alternaria leaf spot is often noticed in this species, especially in nursery, caused by *Fusarium* sp. and *Alternaria* sp. For control, 0.12% concentration of Dithane M-45, Captaf, Blitox, Bavistin and Emisan as well as botanical extracts (0.1, 0.5 and 1% of leaf and

bark of *Prosopis juliflora*) have been found to be effective against both of these pathogens.

Orientation: Boundary/Block/In field: Block

Suitable intercrops: Ginger

Other management requirement

Fertilization: Responds well to NPK and organic fertilizers like compost, vermi compost and dried farm yard manure (FYM).

Irrigation: Responds well to irrigation, which is essential only during the first two years to ensure better establishment and quicker culm production. Moisture retention through trenches should also be practiced.

Yield

Bamboo block plantation: The harvestable yield varies from an average of 2 culms/clump in the third year to 10 or more culms/clump from eighth year up to 40 years. Each harvested culm is valued at Rs. 100 to 200 at current farm gate prices.

Bamboo intercropped with ginger: In such a situation, four rotations, up to 15th year may be possible, though the number of ginger bed rows may decrease progressively, from six in first year to one in 15th year. Intercropping offers better returns due to multiple yields, when both the crops are managed properly.

Economics: Financial Analysis (at 15%) of different farming systems in one hectare of upland paddy field in Coorg District for 40 years (Vishwanath et al. 2013):

Farming Situation	NPV (Rs)	B:C	LEV	Ranking
Ginger + paddy	14692 7.09	1.5 2	14747 7.66	4
D. brandisii at 6 m x 6 m	20742 2.39	2.9 2	20819 9.60	2

D. brandisii + Ginger (6 m x 6 m)	27201 6.02	2.40	27303 5.33	1
D. brandisii + Ginger (6 m x10 m)	226332.79	2.27	227180.93	3

Utilization

Culms of *Dendrocalamus brandisii* are mainly used as fuel, food and in incense sticks in agarbatti industry, construction, making furniture, farm implements, baskets, handicrafts and for making 'chandraki' in sericulture industry. Bamboos are excellent resource of renewable green energy and as raw material for ethanol production. Bamboos being fast in growth have high carbon sequestration potential and as such can be an effective tool against climate change.

Source of planting material: College of Forestry, Ponnampet, University of Agricultural and Horticultural Sciences, Shivamogga, Karnataka; Institute of Wood Science and Technology (Indian Council of Forestry Research and Education) 18th Cross, Malleshwaram, Bangalore Kerala Forest Research Institute, Peechi, Thrissure District, Kerala

Benefits Accrued to Farmers

Intensively managed block plantations of *D. brandisii* may be a viable alternative in abandoned paddy fields since it requires low investments. Further, integrating ginger as the intercrop helps to provide additional benefit to the famers. The output from bamboo is an added advantage as the leaves from bamboo act as a mulch which is of greater need in areas like Coorg. (Viswanath et al. 2007).

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19.2. Agroforestry Model: Bamboo based Agri-silvicultural System

Area of adoption: Konkan Region of Maharashtra
Tree component: *Dendrocalamus stocksii* **(Munro.)**
Common name: Manga bamboo (Marathi)
Family: Poaceae

Habit and Habitat

It grows well in dry, moist deciduous and semi-evergreen tropical forest up to 650 msl and having annual rainfall up to 3500 mm. Though the natural distribution of this species is in humid tropics with lateritic soil type, this species has a wide adaptability and comes up well in sub- humid and semi-arid conditions under black and red soils as well.

Distribution

This species is endemic to Central Western Ghats and is found in Karnataka, Goa, Kerala and Maharashtra.

Phenology

This species usually flowers sporadically as well as gregariously. Flowering cycle is reported to be 50-55 years. Seed is sterile.

Package of Practices

Propagation Technology/Vegetative Propagation:
Vegetatively propagated plating stock (Offsets, Rooted cuttings, Culm cuttings) is a major source of propagation.

Researchers have recommended to commercially propagate Manga Bamboo through three nodal Culm cuttings of 6-month-old stick under 50% shade in a raised bed of (sand : soil : FYM 1:2:2) in December-January, followed by transferring the proliferated individual shoots in polybags after 6 months under Konkan conditions.

In vitro propagation may be used where protocol of micro propagation is standardized.

Cultural Operations

All unwanted materials like dead and dried culms, branches should be removed from the third year of plantation mostly after November when rainfall stops.

Land preparation: Usually all types of well drained soils are conducive to bamboo cultivation. However, high and medium high land with exposure to sunlight throughout the day and having alluvium or fertile soil should be identified. The depth of soil should be 2-2.5 feet. The sand, stones, pebbles, hard layer or soda containing layers at a depth of 1-1.5 m may be removed for growth of plants and also land be well levelled.

Spacing: Block plantation should use 3 x 3 m or 4 x 4 m spacing depending on fertility status of soil. If one is using finger millet (*Elucine coracana*) as an intercrop during rainy season then 10 x 10 m distance is to be adopted.

Pit size: Before filling the pit, a mixture of well decomposed FYM @ 2 kg, 100 g SSP and fenvulrate dust @ 100 g pet pit is prepared and mixed with upper as well as lower soil of the pit in Lateritic soils of Konkan. Pit size should be 2 x 2 x 2 feet dimension and having sufficient crack at the base. The mixture of upper soil is filled first, followed by lower soil mixture. The pits are kept exposed to sun for top soil sterilization for about one month.

Rotation: Every year one can rotate finger millet as an intercrop in Bamboo plantation, other wise 35-40 years may be the rotation period.

Tending Operations

Regular thinning and cleaning operation should be carried out from

the third year of clump establishment. All dead, dry, weak and disease and pest infested culms to be removed immediately so as to make space available to new culms, and to grow straight. For getting maximum bamboo height, girth and culm production of bamboo from the lateritic soil of Konkan region, 300 kg N/ha and 200 kg P_2O_5/ha fertilizers should be applied in three split equal doses in June, July and August every year after five years of plantation.

In bamboo+nagli agroforestry system, finger millet may be cultivated in *Kharif* (monsoon) as an intercrop in bamboo plantation. The nursery of finger millet is grown during onset of monsoon and 4 to 5 kg seed per ha is used. Twenty-five to 30 days old seedlings are transplanted at 15 cm x 15 cm spacing. A fertilizer dose of 80 kg N + 40 kg P_2O_5 is applied. Out of this, 50 % N and 100 % P_2O_5 is given at the time of transplanting and the remaining 50% N one month after planting. One to two hand-weeding are necessary before one month of planting. The yield of finger millet averaged at 1174 kg/ha with an annual culm production of 542 culms/ha. The B:C ratio of a bamboo+nagli agroforestry system is 1.41.

Fertilization: Bamboo as well as finger millet respond to organic fertilizer.

Irrigation: Inter-crop does not require any irrigation as there is assured rainfall during crop growth. But bamboo requires protective irrigation during first three years of establishment, and it responds well in terms of growth and culms production to irrigation. Moisture retention through trenches may be also practiced.

Protection

Major pests of bamboo: Termite is the major pest. It can be controlled by applying Cholopyriphos 0.05 % at place of origin.

Major diseases, physiological and nutritional disorder: The major diseases of bamboo are leaf blight and alternaria leaf spot. Bavistin (0.1%), oxychloride(0.3 %), hexaconazole (0.01%), Carbendazim (0.1%), etc. Bordeaux mixture (1.5%) should be sprayed on the plants and the soil at weekly intervals if infection is above threshold level.

Harvesting

Block plantation: The annual emergence of bamboo species was observed to range from 8 to 12 culms per year per clump and the harvest potential of this species ranged from 18 to 24 sticks per clump at alternate years. The harvesting age for this species was observed to be 2 years as there was no significant improvement in mechanical and physical properties thereafter. A study conducted to understand the supply chain of this species and it was observed that the farm gate price for a single stick culm ranged from Rs 40 to 60.

Bamboo inter-cropped with finger millet: Intercropping offers better returns due to multiple yields. Moreover, finger millet provides food to farmer's family and helps sustain economics during the juvenile period of 3 to 4 years of bamboo production. An evaluation of 10 bamboo species for cultivation in Konkan conditions concluded that Manga bamboo produced more culms per clump with the NPV of 3,71,000 at the age of 10 years old plantation with the highest B:C ratio of 2.99.

Bamboo plantation- sole and with intercrops such as finger millet in a farmer's field in Konkan region

Orientation: Boundary/Block/In field

Suitable intercrops: Finger millet, Proso millet

Environmental Benefits

To improve the economic status of farmers and maintaining food web of the ecosystem, bamboo based agroforestry models not only improve fertility status of soil (cultivable waste land) but also improve productivity of poor lands by continuous addition of manures, fertilizers, crop residues and leaf litter, which ultimately improve soil organic carbon and moisture holding capacity.

Utilization

Bamboo is popularly known as the poor man's timber**.** As it is solid in nature, it is mostly used for construction and furniture. At village level it is used for farm implements, baskets, handicrafts, agarbattis and making Chandrika in sericulture industry. It is also used as fodder and for fencing.

Improved varieties/accessions: Superior variants in Manga bamboo have been identified by researchers.

Varieties of finger millet developed by the University

Sr. No.	Varieties	Yield (kg/ ha)	Special characters.
1.	Dapoli-1	1200-1500	Red grain with open panicle
2.	Dapoli-2	1500-2000	Rich in iron nutrients
3.	Dapoli safed-1	1200-1500	White grain with semi compact panicle

Source of planting material

AICRP on Agroforestry, College of Forestry, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Tal. Dapoli, Dist: Ratnagiri, Maharashtra

State Forest Department Nursery: Training given on bamboo nursery techniques.

Reputed/accredited nurseries: 12 Manga bamboo nurseries established by the farmers throughout Konkan and Western Maharashtra under RKVY project during last three years.

Mr Milind Patil, a bamboo nursery-owner farmer earns about Rs 1.5 lakh/year from the sale of saplings

Benefits Accrued to Farmers/Public

Intensively managed block plantations of Bamboos may be a viable alternative in abandoned fields since it requires low investments. Further, integrating rhizomatous crops such as ginger, as an intercrop helps to provide additional benefit to the famers. The output from bamboo is an added advantage as the leaves from bamboo act as a mulch which is of greater need in these areas.

Way Forward

Plans are underway to establish bamboo processing industries, e.g. agarbatti sticks and handicrafts and to initiate paper industry.

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19.3. Agroforestry Model: Jackfruit and Acacia based Silvi-horticultural System

Area of adoption: Tropical regions of Kerala that enjoy annual rainfall >2000 mm

Tree Component 1: *Artocarpus heterophyllus*
Common name: Jackfruit
Family: Moraceae

Habit and Habitat
Large tree, grows well in moderate to high rainfall and well drained alluvial soil.

Distribution
Humid tropical regions including Kerala, Konkan, North East states, coastal Odisha.

Phenology
Flowering: December-November; Fruiting and seed dispersal: March-May.

Tree Component 2: *Acacia auriculiformis*
Common names: Auri, Earleaf, Acacia, Earpod wattle
Family: Fabaceae

Habit and Habitat
Small evergreen, medium sized tree with drooping branches that grows from 15 to30 m tall, with a trunk up to 12 m long and 50 cm in diameter. Prefers, moderate to high rainfall, red soil and lateritic.

Distribution
Native of Australia and Papua New Guinea, grows well in humid and sub-humid tracts of India even on poor soils.

Phenology
Flowering: Jan- Feb; Seed dispersal: March - May

Package of Practices

Acacia auriculiformis and *Artocarpus heterophyllus* are two multipurpose support tree species suitable for block cultivation of black pepper (*Piper nigrum* L.). Pepper yields are promising when trees are grown in high density (3 x 3 m spacing; 1111 trees/ha^{-}) block plantations (Kunhamu et al. 2012). Jackfruit seeds are recalcitrant in nature hence should be sown in polybags within 2-3 weeks after extraction from fruit. *A. auriculiformis* seeds need hot water pre-treatment (dipping in near boiling water for 30 seconds followed by overnight soaking in cold water). Both the species should be raised in separate blocks depending on land availability. Three-month-old seedlings are planted in pits of size 30 cm x 30cm x 30 cm during the onset of monsoon at 3 x 3m spacing (1111 trees/ha). Farmyard manure (FYM) and cow dung (each @ 25 kg/tree^{-}) may be applied once annually before the onset of monsoon rains. Shade tolerant black pepper (*Piper nigrum* var. Karimunda) should be trailed on support trees from the second year of tree planting. The trees should be subjected to annual lopping (70 %) during May. Both the tree species showed better response to pruning. The trees are usually free from serious pest and disease infestation.

Economics

Acacia auriculiformis based production system:

Black pepper yield: Annual dry pepper yield of 2.56 Mg/ha. Returns from black pepper: A conservative estimate suggests that the annual income from pepper was around Rs 7.68 lakh per ha (@ Rs 300 per kg dried pepper.

Returns from the sale of support tree wood at final tree harvest at 22 years of age: 33 lakh per ha (considering 20% casualty)

Artocarpus heterophyllus based production system:

Black pepper yield: Annual dry pepper yield of 1.91 Mg/ha

Returns from black pepper: Approximately 5.73 lakh per ha (@ Rs 300 per kg dried pepper)

Returns from the sale of support tree wood at final tree harvest at 22 years of age: 30 lakh per ha (considering 20% casualty).

Orientation: Block planting in the field preferably in North-South orientation

Suitable intercrops: Black pepper (*Piper nigrum* L. var. Karimunda)

Environmental Benefits

A. auriculiformis and *A. heterophyllus* have high potential for carbon sequestration with average total C storage in the vegetation and soil at 20 years of tree growth was at the rate of 226.06 and 198.5 Mg/ha, respectively. Apart from the high carbon stocks in the biomass, both the species registered substantial improvement in soil carbon stocks to the tune of 71.39 and 64.42 Mg/ha as compared to the contiguous treeless open soil--38.17 Mg/ha (Kunhamu et al. 2018).

Utilization

Black pepper is in high demand as a potential spices crop both in the domestic and international market. It is used in medicinal preparations. Both the support trees are excellent timber species and hence claim good price in the wood market at the final rotation. Jack fruit is of high demand in the domestic market, however, the fruit yields are limited due to extensive pruning for pepper production.

Improved varieties/accessions: Black pepper traditional variety Karimunda is preferred on account of its tolerance to pests and diseases. Other promising verities are Panniyoor- 4 and Panniyoor-5 (KAU).

Source of planting material: Pepper Research Station, Panniyur, Kannur, Kerala Agricultural University (KAU), Kerala; AICRP on Agroforestry, Kerala Agricultural University, Thrissur, Kerala

Benefits Accrued to Farmers/Public

The technology is well accepted by the farmers of Kerala. As against other conventional pepper production systems that involve staggered cultivation of pepper on miscellaneous trees in the farm

lands, this block cultivation offers excellent returns for the farmer with low input costs. Good returns from the trees at final rotation age are an additional feature of this system. This technology may be suitable for the warm humid tropical climate with mean annual rainfall of more than 2000 mm and temperature ranges such as 38 ^{o}C (mean maximum) and 19.5 ^{o}C (mean minimum).

Way Forward

The land-use pattern in the humid tropical regions of India such as Kerala is undergoing paradigm shifts towards non-agricultural practices on account of the intense demographic pressure on land and undesirable socio-economic changes. Tree based high output systems such as black pepper production system is an excellent option for the revival of agricultural land use in such regions. The enormous potential of integrating high value bamboo species in the agricultural landscape is yet another strategy that needs to be explored in these regions.

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19.4. Agroforestry Model: Mulberry and *Calliandra* based Silvi-pastural System

Area of adoption: Tropical regions of Kerala that enjoy rain fall >2000 mm

Tree Component 1: *Morus indica* L.
Common name: Mulberry
Family: Moraceae

Habit and Habitat
Medium-sized tree, adapted to a wide range of climates and soils.

Distribution
Widely distributed in Asia, Africa and Americas.

Propagation: Stem cuttings

Tree Component 2: *Calliandra calothyrsus*
Common name: Calliandra
Family: Fabaceae

Habit and Habitat
Calliandra is a medium- to large-size shrub tree (2-12 m high), with a trunk diameter of up to 30 cm

Distribution
Calliandra is distributed all over tropical regions.

Propagation: Seeds

Package of Practices
Intensive silvi-pasture system comprises trees and shrubs grown in dense planting (> 10,000 trees/ha^{-}) in multiple rows along with high-yielding grasses, to produce high-quality forage from a limited area (Murgueitio et al. 2011). A recent study conducted in Kerala revealed that 2-tier silvo-pasture systems with hybrid Napier (variety CO-4) + trees (mulberry + calliandra; @ 11111 trees/ha),

planted in 3:2 ratio area wise under intensively managed cut and carry systems showed good potential to provide higher dry fodder (31.5 Mg/ha) and crude protein (4.75 Mg/ha on dry matter basis) for ruminants as against conventional grass monoculture (30.18 tons of dry yield and 2.83 tons of crude protein/ha)--(Raj et al. 2016). Trees are planted at closer spacing of 60 cm x 60 cm and pruned at 1 m height and at 3-month intervals.

Economics

Net income over a two-year period: Rs 5.4 lakh
Benefit: cost ratio- 4.07

Environmental Benefits

Intensive silvi-pasture systems have higher potential for carbon sequestration, with carbon capture of 40 Mg/ha^{-} in plant biomass over a 2- year period. Appreciable increment in soil carbon stocks was also noticed.

Utilization

The above system has greater potential for quality forage production and can reduce the feed cost by 30 to 40 %.

Improved varieties/accessions: Mulberry variety V1 is preferred due to higher biomass and foliage yield. Hybrid Napier CO5 and CO4 are the preferred ones due to higher yields.

Source of planting material:

- AICRP on Agroforestry, Kerala Agricultural University (KAU), Thrissur, Kerala
- Kerala Livestock Development Board, Dhoni Farm.

Benefits Accrued to Farmers/Public

The technology is well accepted by the farmers of Kerala. As against the conventional practice of fodder grass monoculture, this system yields more proteinaceous fodder which can reduce farmer's dependence on commercial concentrate feeds, thereby providing more net returns.

Way Forward

Intensive fodder production strategies in small holder sector in the humid tropics need substantial revival in land crunch humid regions like Kerala. There is need to develop such fodder based production systems suitable for integration in the traditional home gardens of Kerala. The need is being addressed by the Kerala Agricultural University under its AICRP on Agroforestry scheme.

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Agro-Ecological Region 20

Islands of Andaman Nicobar and Lakshadweep

20.1. Agroforestry Model: Coconut based Horti-pastural System

Area of adoption: Tropical regions in Kerala, Islands of Lakshadweep and Andaman and Nicobar and other states in India that enjoy a rain fall >2000 mm

Tree Component 1: *Calliandra calothyrsus*
Common name: Calliandra
Family: Fabaceae

Habit and Habitat

Shrub or a small tree (2-12 m high), with a trunk diameter of up to 30 cm.

Distribution

Distributed all over tropical regions.

Tree Component 2: ***Cocos nucifera***
Common name: Coconut
Family: Arecaceae

Habit and Habitat

Coconut grows with a single unbranched trunk up to 30 m in height and 50 cm in diameter and the base gets thicker. Its habitats range from areas of human habitation to sandy beaches.

Distribution

Coconut is distributed in the states of Kerala, Tamil Nadu, Karnataka, Andhra Pradesh, Orissa, West Bengal, Pondicherry, Maharashtra and Islands of Lakshadweep and Andaman and Nicobar in India. Four southern states account for 92% of the total production in the country (Kerala 45.22%, Tamil Nadu 26.56%, Karnataka 10.85%, Andhra Pradesh 8.93% and other states 8.44%).

Phenology

The primordial of the inflorescence is reported to develop in the leaf axils about 32 months before the opening of the inflorescence. The primordia of the branches of florescence develop in about 16 months and male and female flowers in about 11 and 12 months, respectively, before the opening of the inflorescence. The ovary is first differentiated about 6-7 months before the opening of the inflorescence. Seasonal factors prevailing during the developmental stages during the period of 32 months before the inflorescence opens do affect the yield of nut. The number of nuts harvested per palm during April-May (second half of summer) is significantly high and distinct, but low during the first half of southwest monsoon (May-June).

Package of Practices

Integrating Calliandra hedgerows in the interspaces of mature coconut gardens provides protein rich quality forage thereby reducing the need to buy costly concentrate feeds. Management factors such as plant spacing, pruning height and pruning frequency not only affect fodder yield per unit area but also the total long-term productivity and quality of the forage, under hedgerow fodder production systems. Maximum yield and quality can be attained by planting trees at close spacing of 60 cm x 60 cm, harvesting at an interval of 12 weeks at a pruning height of 100 cm, and with intensive management. Annual fresh fodder yield of 50-60 tons/ha can be harvested from second year onwards. Economic yield expected extends up to 10 years.

Propagation material: Seeds

Economics

Net income over a three-year period from coconut-calliandra system: Rs 5.5 lakh/ha
Benefit cost ratio: 2.71

Environmental Benefits

Integrating Calliandra in coconut plantation offers multiple ecosystem services like carbon storage and associated climate change mitigation. Intercropping Calliandra in a coconut garden with tree density of 27,777 trees/ha and harvesting fodder at an interval of 12 weeks yielded maximum dry forage of 35.16 Mg/ha, apart from an additional carbon capture of 90 Mg/ha against coconut monoculture, over a three-year period (Joy, 2017).

Utilization

Establishment and management of Calliandra fodder banks in the unutilized interspaces of existing coconut gardens is a promising practice to enhance quality forage production and carbon sequestration in land crunch humid tropical areas.

Source of planting material: Kerala Livestock Development Board, Dhoni Farm; AICRP on Agroforestry, KAU, Thrissur, Kerala, India

Benefits Accrued to Farmers/Public

The technology is well accepted by the farmers of Kerala. Integration of Calliandra fodder banks in coconut gardens can partially address fodder as well as crude protein deficit in livestock farms.

Way Forward

Despite the humid climate that offers good scope for the production of fodder grasses in Kerala, there exists a genuine scarcity of fodder during the lean seasons especially the summer months. Integration of fodder trees with high nutritive value that ensure fodder availability during such lean seasons is to be promoted in prominent land use systems such as coconut in humid tropics. Also, there is genuine need for trials involving integration of suitable fodder trees in other plantation crops such as rubber, cashew and spice plantations in Kerala which represent the major land use systems in such regions.

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Annexture I

Consortium of Industrial Agroforestry: A Value Chain System for Sustaining Agroforestry in India

The National Forest Policy of 1988 directed wood based industries to generate their own raw material resources instead of depending on the forest department for their wood requirements. However, the policy guidelines were not taken seriously by most of the wood-based industries except a few paper industries. Subsequently, the Government of India announced an exclusive National Agroforestry Policy (NAP) in 2014, which identified ten strategies to promote agroforestry in the country. To address all the issues envisaged in the National policies, Tamil Nadu Agricultural University (TNAU), Coimbatore pioneered by establishing a "Consortium of Industrial Agroforestry (CIAF)" on 21 March 2015 which has successfully linked various stakeholders in the Industrial Agroforestry value chain and has been carrying out multifarious activities for the past three years in Tamil Nadu.

Objectives and Activities of the Consortium

The consortium aims to create sustainable and value-added agroforestry initiatives with the following objectives:

- Network and establish linkages with all stakeholders to augment the Production to Consumption System (PCS) in Industrial Agroforestry.
- Promote effective collaboration among public agencies, private industries and organizations engaged in Industrial Agroforestry.
- Develop suitable research and development mechanism for industrial agroforestry in consultation with the consortium partners.
- Ensure self-reliance in raw material supply and augment associated socio-economic and environmental issues.
- Formulate and recommend policy guidelines for promotion of Industrial Agroforestry.

CIAF primarily aims to resolve the issues in production to consumption system in agroforestry through systematic Research and Development mechanism. This approach has made several stakeholders across the country enroll as members of the consortium whose present strength is 208. The details of the members are furnished in Fig. 1.

Fig. 1. Composition of CIAF

Institutions for Production of Quality Planting Materials (QPM)

The CIAF has created 12 decentralized institutions, *viz.* nurseries and clonal production centres who mass multiply over 18 million plants annually which ensure availability of quality planting material in a decentralized manner as envisaged in National Agroforestry policy.

Organized Plantation Developers

One of the major problems faced by farmers and tree growers is the shortage of labour coupled with timely plantation establishment. This practical constraint was resolved by establishing eleven such plantation developers groomed by CIAF and are involved in establishing over 5000 acres of agroforestry plantations annually. Plantation developers of the consortium ensure availability of skilled

labour for manual planting as well as machines for mechanized planting which has created significant positive impact among farmers/tree growers of Tamil Nadu.

Harvesting and Marketing Institutions

The major problem faced by farmers and tree growers include harvesting, transportation and marketing of farm grown trees. To resolve this issue and to reduce logging related wood loss, the consortium conceived the idea of creating felling institutions from among its members. Over 10 felling institutions were established and these establishments have enabled decentralized availability of felling groups which harvest over 1 lakh tonnes of industrial wood per annum in Tamil Nadu. Many of these groups also undertake transportation and marketing of harvested wood thereby providing the farmers with economic returns at the farm itself.

Organized Wood-based Industries for Marketing

Success of agroforestry has been widely questioned for lack of marketing facilities which is cited to be the key reason. To overcome this constraint, the CIAF has identified 18 wood based industries and has created market base for a wide range of farm grown trees. These industries are linked in the consortium and facilitate the marketing issues in tree cultivation.

Development of Price Supportive Mechanism

Unlike agriculture and horticulture, there has been a lack of price supportive mechanism for farm grown trees. This issue was earnestly addressed by establishing a price support system in the "organized contract farming mode" for farm grown trees. Wood price for various industrial wood species has been fixed based on mutual consultations besides taking a cue from the prevailing local wood market prices which attracted several towards agroforestry.

Value Addition Technologies

It is estimated that from 1 ha of *Casuarina* plantation, 5 tonnes of plantation residues and in *Eucalyptus*, for every ton of wood, nearly 200 - 300 kg of wood bark residue is produced. These residues are value added in the form of briquettes, pellets, charcoal etc.

Institutional Credit and Insurance

Bankable projects were presented to the financial institution for extending institutional credit to agroforestry. The CIAF has implemented insurance scheme for 7 major agroforestry trees which attracted farmers towards tree husbandry.

Framework for Implementing Aroforestry Policy in Tamil Nadu

The CIAF organized an exclusive workshop to prioritize the strategies and guidelines provided in the National Agroforestry Policy in order to develop a framework for adopting and implementing an exclusive Agroforestry policy for Tamil Nadu and the recommendations of the workshop were submitted to the Government of Tamil Nadu for adoption and implementation.

Creation of Database

Development of a sound database on the extent and distribution of farm grown tree species (districtwise and specieswise data), intercrops suitable for cultivation, monthly market prices are also being undertaken by the consortium which is being shared among the members of consortium.

Research Initiatives

The CIAF also conducts a wide range of research initiatives to resolve the issues in Production to Consumption System. One of the major research initiatives is to inventorize and domesticate new tree species amenable for agroforestry. The consortium has prioritized 30 tree species suitable for agroforestry and efforts are being taken to develop High Yielding Short Rotation clones/varieties (HYSR), designing Multi Functional Agroforestry Models (MFAM) and ensure adoption of new, emerging technologies by the farmers and stakeholders.

Brief Achievements

The Consortium:

--Identified 30 important tree species suitable for agroforestry in Tamil Nadu

--Created micro institutions like plantation developers, felling/ harvesting groups, marketing groups and value addition groups

--Facilitates a balanced price supporting system for farm grown industrial tree species through partnership with wood-based biomass power and packaging industries

--Helps to increase tree cover, meet industrial wood requirement improving profitability of agroforestry practicing farmers besides developing clean development mechanism processes

Impact of CIAF Activities

The activities of the CIAF have created significant impact in terms of increase in area under agroforestry coupled with improvement in productivity and profitability. It is estimated that these agroforestry initiatives have created 300 mandays/ha of employment and augmented productivity to the tune of over 25m^3/ha/annum from the baseline level of less than 10m^3/ha/annum. It is also estimated that one ton of wood is equivalent to 0.5 tonnes of carbon sequestered and thus expansion of agroforestry in Tamil Nadu through CIAF's initiatives will help to reduce the carbon load in the atmosphere and help address the growing concerns on climate change besides opening up a new vista of carbon trading for the farmers of the state in future.

Establishment of Agroforestry Business Incubator

CIAF has further strengthened the agroforestry promotional activities in the form of business enterprise by establishing an exclusive "Agroforestry Business Incubator. This institution is now involved in transforming the farmers, unemployed youth, members of men and women self help group, tribal communities etc. into agroforestry based business entrepreneurs and thus ensures successful implementation of agroforestry.

Way Forward

The consortium activities are spearheaded by TNAU whose present reach has expanded outside Tamil Nadu to Karnataka, Kerala, Maharashtra, Telangana, Andhra Pradesh, Madhya Pradesh, Gujarat and Uttar Pradesh. In near future, the activities of CIAF are expected to extend to other states of the country as well. By 2023, the CIAF proposes to raise a corpus fund of Rs.1,00,00,000 (INR 10 million) for sustaining research and development activities and may

grow into a self-sustaining institution for promoting and sustaining agroforestry in India.

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Annexture II

Agroforestry-based Industrial Hub at Yamuna Nagar

Agroforestry: A Major Source of Raw Materials for Industries

The Indian Paper Industry accounts for about 1.6% of the world's production of paper and paperboard. The estimated turnover of the industry is Rs 35,000 crore. The industry provides employment to more than 0.37 million people directly and 1.3 million people indirectly. The mills use a variety of raw material, viz. wood, bamboo, recycled fibre, bagasse, wheat straw, rice husk, etc. India is the fastest growing market for paper globally and it presents an exciting scenario; paper consumption is poised for a big leap forward in sync with the economic growth and it touched about 13.95 million tons by 2015-16. India being one of the major consumers in the Asia Pacific region, it is estimated that the country would need 152 million m^3 of wood by 2020 (FAO, 2009). It means that industry will require a large amount of raw material to achieve these targets.

In order to meet the industrial demand, a number of fast growing species such as Eucalyptus, which constitutes a large share of the world economy in relation to pulpwood, plywood and solid wood production (Dhakad et al. 2018) are planted every year. India has about 10% of the world's Eucalyptus plantation. Every year around 150,000 ha of Eucalyptus plantation is grown in India, creating employment in rural areas (Juhari, 2017). Presently, it is estimated to be grown in over 3 million ha, about 80% of which is under agro/farm forestry.

In spite of these initiatives, presently most of the paper industries are facing acute shortage of the raw material and not operating at their full capacity. The paper industries are now banking on agroforestry to meet the rising demand of wood pulp. Major paper industries have taken significant initiatives in this regard and paper major ITC, covered a large area under the agroforestry in areas such as Khammam, West Godavari, Prakasam and Nizamabad districts of Andhra Pradesh. In these areas, Eucalyptus is planted along with agricultural crops such as cotton, chili, sunflower and maize.

Eucalyptus trees are planted on the bunds in between agricultural crops. With an investment of Rs. 22,000 an acre over a four-year period for growing eucalyptus, farmers have been getting a pulp yield of 40 to 60 tonne per acre, resulting in an income ranging from Rs 60,000 to Rs 1 lakh in the four-year time span besides regular income from growing other crops. The paper industry gets its key raw material – wood pulp — through agroforestry/social forestry efforts with local communities. The way forward will be to reclaim the degraded land available in the country through agroforestry. It is all the more critical now to augment wood production since import of wood and wood pulp will increasingly become difficult in the coming years as the wood exporting countries are in the process of strengthening value-addition in their own countries. Thus agroforestry will be the only way to meet the increased wood pulp demand of paper industries.

Agroforestry in Haryana

Agroforestry in Haryana started in 1976 when state forest department planted Eucalypts on field bunds on large scale. However, it was introduction of Poplar buy back scheme by WIMCO in 1984 which brought revolution for agroforestry in Haryana and since then it is gaining importance and spreading in new areas of Haryana. Introduction of clonal eucalypts, *Melia composita* and *Ailanthus excelsa* has further increased the areas under Agroforestry. As per the latest data Haryana has 0.0158 million ha area under State Forests and 0.0141 million ha area under tree cover. Out of the tree cover, about 70,000 ha area is under poplar, 25,000 ha under eucalypts and 45,000 ha under other agroforestry tree species like *Prosopis cineraria, Melia, Ailanthus, Acacia, Dalbergia,* neem, etc.

Agroforestry can Sustain Economy of a Region: An Example of Yamunanagar (Haryana)

More than 70 % of the population of the Yamuna Nagar District in Haryana, depends upon agriculture for its livelihood. Average land holding in the district is 8.53 ha. There are two main crops in the year namely *Kharif* and *Rabi*. Maize and Rice are grown during *Kharif*

and wheat, Gram and Potato in *Rabi*. Large-scale crop of sugarcane is also raised during recent years. Eucalyptus has been grown in association with agricultural crops since sixties, as wind break, as avenue tree on farmers houses, cattle shed and as roadside avenue on farm approach road. Planting eucalyptus on field boundaries is a common practice adopted by farmers. It is worth mentioning here that present tree cover of Yamuna Nagar district is 24.6% whereas the forest land is just 12.1% of the total geographical area.

Availability of wood from agroforestry plantations particularly from Poplar since 1990 has resulted in establishment of number of wood based industries especially Plywood industries in Yamunanagar. The registration of wood based industries in Haryana started only in 2002 after the directions of Hon'ble High Court. At present there are 1012 wood based registered industries (having license from state forest department) in Haryana. Out of these units, 205 plywood industrial units are in Yamunanagar alone which meet about 60% plywood demand of the country. Presently Haryana is meeting only 30% wood demand of the plywood industries and rest is being met by adjoining states of Punjab (15%), U.P (40%) and H.P and Uttarakhand (15%). Therefore, there is a large gap between the demand and supply of raw material for plywood industries and more farmers will have to be encouraged to adopt poplar/eucalypts based agroforestry system to meet the demand of raw material.

The twin cities of Yamuna Nagar and Jagadhari are the most important timber markets in Haryana in terms of volume traded. Of a large number of species, Eucalyptus and Poplar, however, constitute the largest chunk of the market. It is one of the biggest timber markets of North India. Agroforestry based industries at Yamuna Nagar are paper mills; saw mills, hard board, plywood and straw board factories, sugar mills, packing case industries and furniture making providing employment to about 41000 persons. Demand for timber comes from varied sources. It is used as an important input for the production of furniture, doors, windows, their frames, pulpwood, packaging materials and now many other industrial uses as well.

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