Refresher Training Program on Agroforestry and Opportunities in Value Addition for Established Agripreneurs Under AC&ABC Scheme

TRAINING MANUAL 2023

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AGROFORESTRY AND OPPORTUNITIES IN VALUE ADDITION

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2023

AN OVERVIEW OF AGROFORESTRY: POLICY ISSUES

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INTRODUCTION

Agroforestry: -

Land use system which integrates trees and shrubs on farmlands and rural landscapes to enhance productivity, profitability, diversity and ecosystem sustainability. It is a dynamic, ecologically based, natural resource management system that, through integration of woody perennials on farms and in the agricultural landscape, diversifies and sustains production and builds social institutions.

Benefit of Agroforestry

- Trees provide food, fodder, wood, fuel and fertilizers.
- Biomass, Biodiesel, Biochar and Biogas production.
- India's 65% timber needs met through farm grown trees. Hence Agroforestry perhaps the only alternative to achieve 33% tree cover as per National Forest policy 1988.
- Above extra incomes provide one type of 'backup/insurance' against crop failure, poor monsoon.
- Thus, given the shrinking size of farm-holdings, agroforestry is essential to increase farm income.
- Moderates Microclimate
- Conserves natural resources. (because villagers cutting less trees in jungle)
- Carbon sequestration (storage of carbon as a biomass)
- Because tree-species of agroforestry- sequester as much carbon as primary forest trees and far greater than grass and crops.
- Agriculture land can withstand extreme weather conditions, soil erosion.
- Prevents deforestation, promotes Soil and water conservation, Nutrition recycling

- Supplies raw material to wood-based industries
- Food production increased
- Greenhouse gases decreased
- Climate change averted

Major Policy Initiatives in Agroforestry: -

- National Forest Policy 1988
- National Agriculture Policy 2000
- Planning Commission Task Force on Greening India 2001
- National Bamboo Mission 2002
- National Policy on Farmers, 2007
- Green India Mission 2010

Role of Agroforestry for efficient nutrient cycling, organic matter addition for sustainable agriculture and for improving vegetation cover. However, agroforestry has not gained the desired importance as a resource development tool due to various factor.

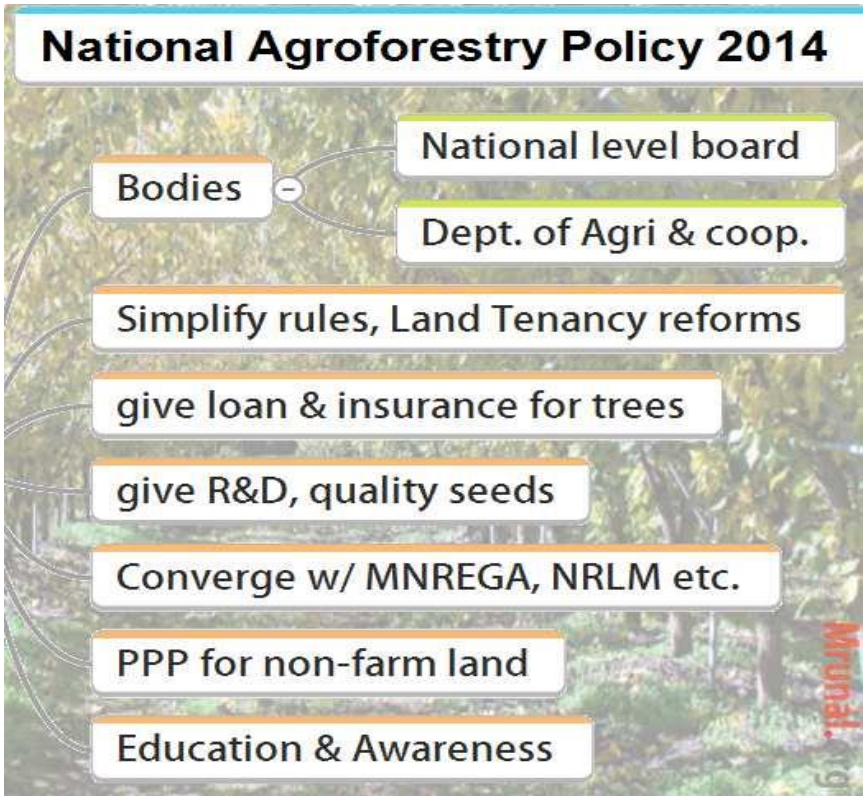
National Agroforestry Policy 2014

A policy which deals with problems faced by agroforestry sector, including adverse policies, weak markets and a dearth of institutional finance was approved by the Cabinet February

- **India became the world's first country to adopt a comprehensive Agroforestry policy**

OBJECTIVES

- Encourage and expand tree plantation in complementarily and integrated manner with crops and livestock to improve productivity, employment, income and livelihoods of rural households.
- Protect and stabilize ecosystems, and promote resilient cropping and farming systems to minimize the risk during extreme climatic events.
- Meet the raw material requirements of wood-based industries and reduce import of wood and wood products to save foreign exchange.
- Supplement the availability of agroforestry products (AFPs), such as the fuel-wood, fodder, non-timber forest produces and small timber of the rural and tribal populations, thereby reducing the pressure on existing forests.
- Increasing forest/tree cover to promote ecological stability, especially in the vulnerable regions.
- Develop capacity and strengthen research in agroforestry and create a massive people's movement for achieving these objectives and to minimize pressure on existing forests.



STRATEGY

Establishment of Institutional Setup at National level to promote Agroforestry: -

- An institutional mechanism, such as a Mission or Board is to be established for implementing the agroforestry policy. It will provide the platform for the multi-stakeholders to jointly plan and identify the priorities and strategies, for inter-ministerial coordination, programmatic convergence, financial resources mobilization and leveraging, capacity building facilitation, and technical and management support.
- The Ministry of Agriculture has the mandate for agroforestry. Agroforestry Mission / Board will be located in the Department of Agriculture and Cooperation (DAC) in the Ministry of Agriculture (MoA).
- The actual implementation may involve convergence and dovetailing with a number of programmes.
- Agroforestry research and development (R&D), including capacity development and pilot studies / testing and action research should be the responsibility of the ICAR

In the proposed institutional arrangement, the current stakes of the key ministries are to be respected and utilized.

Simple regulatory mechanism: -

- There is a need to create simple mechanisms / procedures to regulate the harvesting and transit of agroforestry produce within the State, as well as in various States forming an ecological region.
- There is also the need to simplify procedures, with permissions extended on automatic route as well as approval mode through a transparent system within a given time schedule.
- There are regulations imposed by multiple agencies of State governments (viz. Department of Forest, land revenue, other local bodies) on harvesting and transit which have negative implications on the 8 growths of agroforestry. All these restricting regulations need to be identified and aligned with the proposed simplified mechanism.
- Development of a sound database & information system
- Investing in research, extension and capacity building and related services
- Improving famers' access to quality planting material
- Providing institutional credit and insurance cover for agroforestry
- Facilitating increased participation of industries dealing with agroforestry produce

- Strengthening farmer access to markets for tree products.
- Incentives to farmers for adopting agroforestry
- Promoting sustainable agroforestry for renewable biomass-based energy

Agroforestry Status After the Implementation of the policy

As per the latest Forest Survey of India (FSI) report, there is an increase of 110.34 million m3 in total growing stock of the country as compared to the last assessment (ISFR, 2013).
Awareness of PPP through the creation of an enabling environment, such as process patenting, branding and incentives to both producers and industry, is the need of the hour to promote agroforestry in the region.

CHALLENGES in Agroforestry practices: -

- Undeveloped market
- Unfamiliarity with technologies
- Less of awareness
- Inter Competition between trees, crops and animals
- Lack of fiscal resources
- Lesser profit potential
- Expense of additional management
- Unavailability of training or expertise
- Lack of marketing knowledge for such products
- Adoption cost
- Apparent inconvenience

INDUSTRIAL AGROFORESTRY: BUSINESS MODELS OF TAMIL NADU STATE

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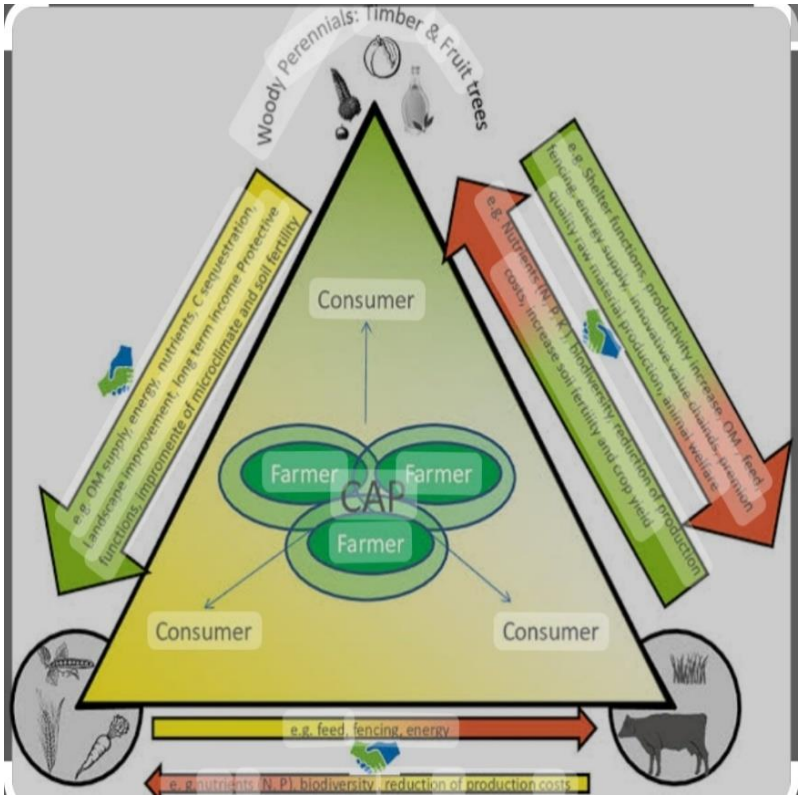


Prior to the enactment of the forest conservation act and national forest policy 1988, most wood industries were deriving their raw material predominantly from forests. But now the forest conservation act and national forest policy 1988 has directed the wood-based industries to establish their own plantations through direct relationship with farmers and individuals by providing necessary inputs, technologies, credit facilities and assuring price supportive mechanisms.

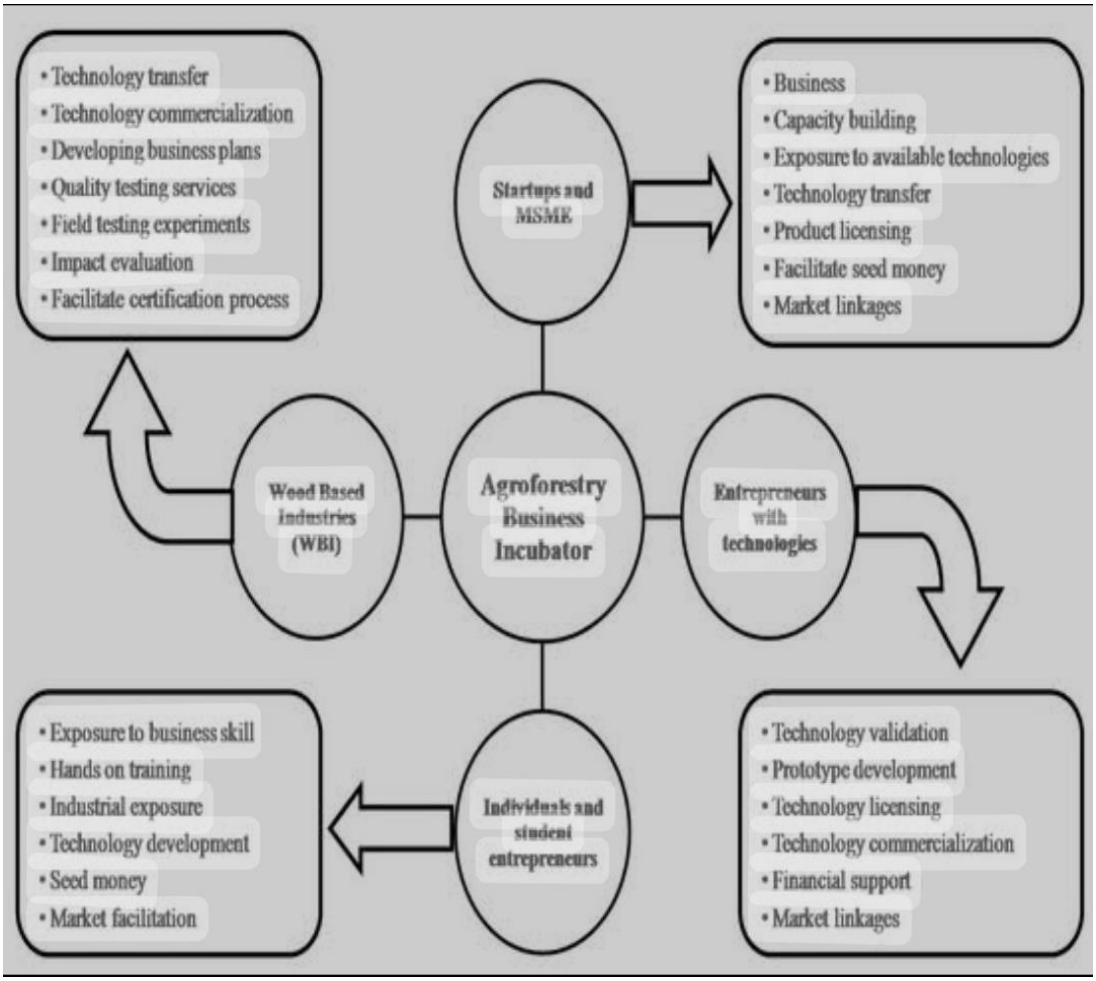
Farmers all over India appreciate the multifarious benefits from trees and they have for decades maintained sporadic naturally grown trees on their farms.

Mostly land owners prefer to lease their lands on annual basis.

To take positive decision in favour of Farm- forestry as a preferred land use option are high productivity /and far better returns compared to agricultural crops.

Tree farming with eucalyptus has now become so popular that irrigated and fertile land of the farmers Paper unit- CPM is producing high productive, disease resistant and site-specific clones of *Eucalyptus*, *Leucaena* and *Casuarina* to the tune of 10 million per

annum
provides technical guidance for planting and maintenance and provides assured buy back of wood at prevailing market price.
industries based on NTFPs such as beedi (country cigarette), lacquerware, brooms, essential oils, katha and cutch, tannins, resin and rosin, cane and bamboo furniture, herbal medicines and cosmetics, etc.
It is estimated that NTFPs worth Rs. 350 billion are used annually in India and the government revenue from NTFPs is around Rs. 20 billion, nearly 50% of the total forest revenue.
Total NTFP exports (raw material as well as finished products) were estimated to be US$ 480 million
Globally paper Industry is one of the high priority industries having a bearing on the socio-economic development.
In India too this industry plays a vital role in the overall industrial growth.
Indian paper industry is one of the world's fastest growing industries. It grew at a compounded annual growth rate of 6.7% over FY 06-11. Among the top producers of paper, India.



Major Wood Based Industries in India:

Major Wood Based Industries in India are Paper and paper board, News print, Construction Industry, Furniture, Packaging, Rayon grade pulp Automobiles, Agriculture implements, Railway sleeper, sports goods, handicraft, plywood, veneer particle board, MDF board, match box, mining, catchment, pencil industry, etc.

The demand of wood for these industries is increasing at alarming rate but there is no concomitant development of plantations which resulted in massive imports.
The total industrial wood demand for the year 2020 has been projected to 153 million m^3 which will increase from 58 million m^3).

The demand for wood has been categorized into short rotation species and long rotation species. The short rotation species are primarily used for pulp and paper industries, packaging, sports goods plywood, match and other miscellaneous industries. In general, most of the short rotation species are softwoods used in wood industry, growth in the production volume of wood products ranged between one to eight percent.

Production of forest products has been healthiest in Asia-Pacific and North America due to a growing housing market

Other important factors in the wood products outlook include a decline in harvesting from natural forests and the emergence of planted forests.
Major source of wood supply and technological developments such as increased plantation productivity through tree improvement, reduced wood requirements owing to expanded recycling, higher recovery, wider use of new composite products and production of cellulosic bio fuel.

Year	Demand (million m3)	Percentage increase average per annum
2000	58.00	-
2005	74.00	5.52
2010	95.00	5.68
2015	123.00	5.89
2020	153.00	4.88

Number of mills	**759**
Installed capacity, Mt	**12.7**
Capacity utilization, %	**~ 90**
Production of Paper, Paperboard and Newsprint, Mtpa	**10.9**
Per capita Consumption (kg)	**9.3**
Annual Turnover, Rs. Crores	**30,000**
Contribution to Exchequer, Rs. Crores	**3000**
Employment Direct, million people	**0.37**
Indirect Employment, million people	**1.2**
Indian Share in World's Production, %	**2.6**

PRODUCTION FROM DIFFERENT RAW MATERIALS: -

Raw materials	No. of Mills	Production, Mtpa	Production Share (%)
Wood based (Large Integrated)	30	3.40	31
Agro based (Medium Scale)	150	2.42	22
Recycle Fibre based (Medium and Small Scale)	579	5.10	47
Total	759	10.92	100

Variety	Raw Material	Production (Mtpa)	Total production (Mtpa)	% Contribution
Writing Printing grade	Wood based	2.53	4.18	38
	Agro based	0.78		
	Recycled fibre based	0.87		
Packaging grade	Wood based	0.84	5.90	54
	Agro based	1.64		
	Recycled fibre based	3.43		
Newsprint grade	Wood based	0.03	0.84	8
	Agro based	Nil		
	Recycled fibre based	0.81		
Total Production			10.92	100

Indian paper Industry: -

- The average annual turnover of the Indian paper industry is approximately Rs. 30,000 crores, which accounts for approximately 0.37% of the national GDP.
- It contributes Rs. 3000 crores to exchequer and provides direct employment opportunities to about 3.7lakh people and indirect employment of over 12lakh people.
- The industry employs wood, agro residues and recycled/ waste paper as the major raw material for manufacture.
- Indian paper industry ranks sixth among the energy intensive industries with an energy requirement of about 10 Mtpa of coal and 10.6 GWh of electricity. Table 2 shows the current status of Indian paper Industry.
- The medium sized Agro based paper mills have the capacity from 30-350 tpd with a production share of 22% whereas the small waste paper-based paper mills operate in the range10-500 tpd contributing to 47% of total country's production.

The yearly production and consumption in Indian paper industry are presented: -

Year	Capacity, Mt	Production, Mt	Export, Mt	Import, Mt
2005-06	7.32	6.80	0.312	0.981
2006-07	7.99	7.16	0.343	1.138
2007-08	8.32	7.33	0.329	1.341
2008-09	8.83	7.64	0.340	1.407
2009-10	9.34	8.02	0.382	1.464
2010-11	12.7	10.1	0.527	1.582
2011-12	13.55	10.9	0.545	2.336

Natural fiber Industry: -

Natural fibers are extracted from plants and are classified into three categories, depending on the part of the plant they are extracted from fruit fibers, Bast fibers and leaf fibers. Cotton, is world- wide one of the most important
fruit fibers used in the textile industry. Cotton is applied for the manufacturing of clothes, carpets, blankets, mobs and medical cotton wool. Coir (Coconut fiber) Coconut fiber is obtained from the husk of the fruit of the coconut palm, is used for brushes and mattresses.

Stem Fibre

Jute; *Corchorus capsularis* and *Corchorus olitorius* are the main source of jute. The fibers are extracted from the ribbon of the stem

Ramie: obtained from *Boehmeria nivea can* easily grow in tropical agroclimatic regions, is an expensive and durable fiber and can be dyed very easily, and is used in decorative fabrics than as construction material like in curtains, wallpaper, sewing thread and furniture covers.

Hemp: *Cannabis sativa* is used for the production of rope, fishing nets, paper, sacks, fire hoses and textile. Leaf fibers Sisal obtained from *Agave sisalana* is mainly used for ropes, mats, carpets and cement reinforcement

In India many companies and industries are taking lands from small to large farmers for plantation of these fiber species and paying them money in return.

Role of Small-Scale Industries in Promoting Agroforestry

- It is estimated that each million rupees of investment in fixed assets in the small-scale sector leads to production of goods and/or services worth Rs.4.62 million annually, with an approximate value addition of ten percentage points.
- This sector also creates the largest employment opportunities outside agriculture. It is estimated that Rs.100,000 of investment in fixed assets in the small-scale sector generates employment for four
- Though it is quite difficult to get an accurate overall picture of the total number of forestry enterprises in the country or their output due to lack of adequate information.
- The ICFRE has estimated that there are 4,235 wood-based factories in India Different small-scale industries which are promoting industrial plantation by taking lands from the farmers for plantation and generating employment are:
- Sawmilling: It is estimated that there are around 23,000 sawmills in the country and 98% of these are in the small category with annual log intake up to 3,000m^3. Annual production capacity is estimated at 27.12 million m^3.
- Safety matches: There are approximately 12,000 safety match making units in the country, and all except five are in the small-scale and cottage industries category. Over two-thirds of India's matches are produced in just two districts
- Main raw material used are *Bombax ceiba, Evodia roxburghiana Ailanthus malabarica, Hevea brazilensis.*
- Sports goods: The main raw materials used are willow, cane, mulberry, maple, ash and rosewood (Tewari, 1995). According to projections made by the Forest Survey of India, the total wood demand for the sports goods industry was estimated to be 101,000 $m^{3.}$
- Katha and cutch: Katha and cutch are products made from the heartwood of *Acacia catechu* tree. Katha is used as an ingredient of paan (betel) and paan masala.
- Chewing confectionery in India. Cutch is used for dying canvas and tanning leather. According to an estimate made a few years ago, 3,000 tons of katha was produced annually in India, of which 2,000 tons was produced in the factory sector, which also produced 4,500 tons of cutch. The total consumption of wood was estimated to be around 200,000m3
- Lac: Lac is produced from the secretions of a tiny insect *Lacciferlacca*Kerr., which is a parasite on a number of wild and cultivated plants. India is an important producer of lac and lac products. The present production of lac is about 15,000 metric tons, which

is much less than the peak production of 91,199 metric tons.

- Lacquerware and lac turnery is a traditional industry based on lac. It is estimated that in Channapatna Taluka of Karnataka, over 35% of the workforce is engaged in lacquer work
- Bamboo and rattan products: There are a number of SSFEs manufacturing bamboo and rattan-based products. The main products manufactured from bamboo are handicraft items such as table mats, trays, lampshades and other household articles. Reed bamboo based traditional industries, such as mat and basket weaving, play a crucial role in the rural economy. Many tribes and ethnic groups (Banjaras, Bansforias, Kamars, Kotwalias, etc.) earn their living through bamboo handicraft work. Recently some bamboo mat board manufacturing units have also been established. It has been estimated that bamboo based SSFEs provide livelihoods more than 300,000 village people in Kerala state alone.
- Rattan (cane): Rattan extraction and utilization in India is, by and large, a cottage industry. It is estimated that there are around 2,000 small to medium sized rattan-based industrial units in India, employing over 200,000 people, some in the manufacture of a variety of handicraft items and furniture, and the rest predominantly in the rural areas in extraction, cleaning, processing and transportation. The rattan furniture industry produces goods worth Rs.50 million annually. About 10% of the goods are exported (Bhatnagar, 2007).

Biofuel Industry in India

India's share of crude oil production is about 1 per cent of global crude oil production, whereas consumption amounts to 3.1 per cent of global consumption

A number of private and Government organizations are involved in production and distribution of biofuel in India. The leaders in biofuel processing in India are, D1 Oil Plc, Reliance Industries Ltd, Godrej Agrovet, Emami Group, Aatmiya Biofuels Pvt Ltd., Gujarat Oelo Chem Limited (GOCL), Jain Irrigation System Ltd., Nova Bio Fuels Pvt. Ltd.

Sagar *Jatropha* Oil Extractions Private Limited etc. It is wise to consider the oil yield potential of different edible and non-edible crops before selecting the crop as suitable source of biodiesel production (Tuli, 2011).

Considering the food grain scarcity in developing countries like India, edible major crops may be spared as a potential source for bio-diesel production.

Typical feed stocks for biodiesel production are soybean, canola/rapeseed, sunflower, cottonseed, palm seed and palm kernel, corn and mustard seed oil.

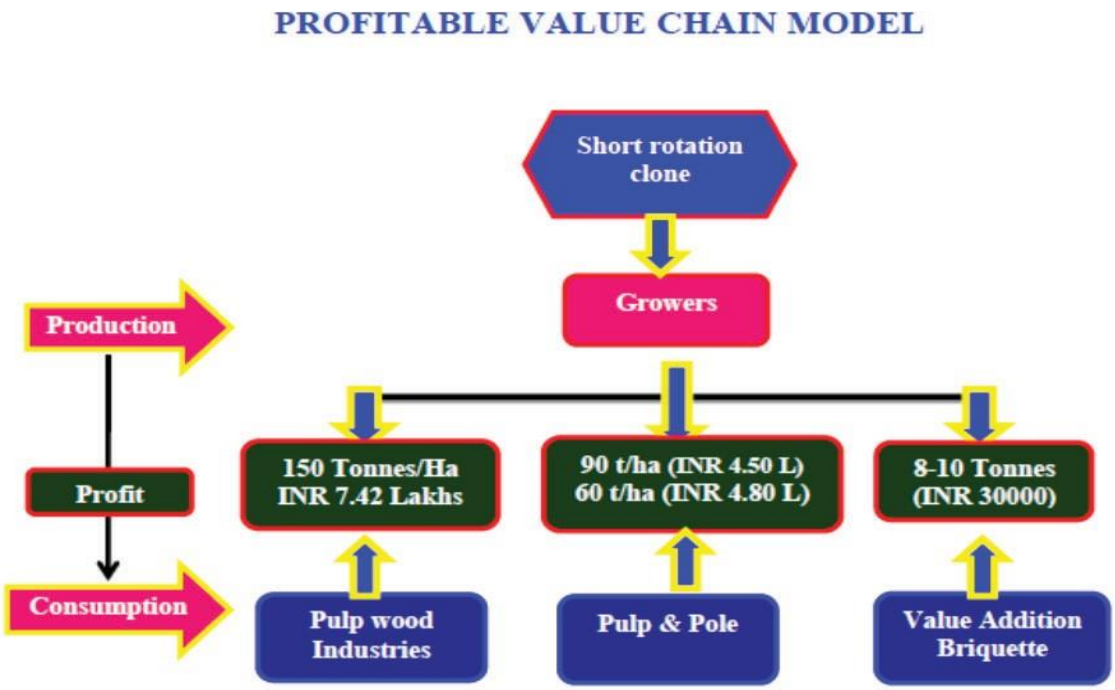
Pork, beef and poultry fat and grease can also be converted to biodiesel. Palm oil and animal fat may have a high free fatty acid content, which causes soap formation that has adverse effects

BIOFUEL POTENTIAL FROM AGRICULTURAL CROPS IN INDIA.

Crop	Residue type	Prod. (tons)	RPR	Res. (dry wt.) (tons)	Sustain. Res. (20%)	Biochem. EtoH-low (litre)	BiochemEtoH-high (litre)
Rice	Straw/husk	9.60E+07	1.8	1.73E+08	3.46E+07	3.80E+09	1.04E+10
Wheat	Straw	8.70E+07	1.6	1.39E+08	2.78E+07	3.10E+09	8.30E+09
Jawar	Stalk	7.00E+06	2.0	1.40E+07	2.80E+06	3.00E+08	8.00E+08
Sugarcane	Bagasse/ leaves	3.42E+08	0.4	1.37E+08	2.74E+07	3.00E+09	8.20E+09
Bajra	Straw	1.04E+07	2.0	2.07E+07	4.10E+06	5.00E+08	1.20E+09
Maize	Stalk/cob	2.17E+07	2.5	5.43E+07	1.09E+07	1.20E+09	3.30E+09
Gram	Waste	8.20E+06	1.6	1.32E+07	2.60E+06	3.00E+08	8.00E+08
Tur (Arhar)	Shell/ waste	2.90E+06	2.9	8.30E+06	1.70E+06	2.00E+08	5.00E+08
Other cereal	Stalk	4.60E+06	2	9.10E+06	1.80E+06	2.00E+08	5.00E+08
Total					1.36E+08	1.50E+10	4.10E+10

Profitable value chain model: -

An organized value chain model which eliminated the middle men and benefitted both the farmers and industries. The industries have been benefitted through quality and assured raw material which resulted in the industries venturing into certified wood thereby help to achieve forest certification resulting in global expert of paper from NAIP partner industries.



Challenges for Agroforestry

Although the advantages of agroforestry are gaining attention internationally.
Emphasis on commercial agriculture: Agricultural policies often offer incentives for agriculture that promote certain agricultural models, such as monoculture systems, and tax exemptions are usually aimed at industrial agricultural production. Agricultural price supports or favourable credit terms which are granted for certain agricultural activities but hardly ever for trees, are also discouraging agroforestry adoption.

Limited awareness of the advantages of agroforestry:
Overdependence on conventional agricultural methods and inadequate knowledge of sustainable approaches restrict the interested of policy-makers in agroforestry development. This in turn influences negatively the number of resources dedicated for research, dissemination, market information and propagation of quality germplasm, which are all crucial for wide adoption of agroforestry practices.

CONCLUSION:

Industrial agroforestry is a practice of agroforestry to meet the industrial requirement. The basic consideration in agroforestry is productivity, sustainability and adaptability. In many states of India many pulp and paper industries are approaching the farmers to cultivate pulp wood species with buy back agreement tomeet the requirement of pulp and paper industry.

- In India mirrors global trends in small and medium enterprises, which indicate that small and medium enterprises represent one of the fastest growing industrial sectors in the world.
- The SSI sector accounts for around 95 per cent of the industrial units, 40 per cent of the manufacturing sector output, 45-50 per cent of exports (directly and through export houses etc), and provides direct employment to more than 19 million people in around 3.4 million registered SSI units.
- There is need for research to increase the system (trees and crops) productivity through low-cost interventions and better techniques. Quality planting material, assured market and higher and assured returns well established industry-farmer government linkage is the prime consideration for the rapid increase in industrial agroforestry. The government need to take confidence building measures and clearly formulate its policy and explain to farmers that their role is vitally important in the success of any agro industrialprogram.

ADAPTATION AND MITIGATION TO CLIMATE CHANGE THROUGH AGROFORESTRY

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INTRODUCTION

Climate change is linked to internal variability of the climatic system and external natural factors but much more to human activities. The potential fallout Softhis phenomenon have been identified to include rise in temperature, much more erratic rainfall regimes, increased frequency and intensity of extreme events, and general unpredictability of agricultural operations among other effects. These have grave economic, social, and ecological consequences for agriculture and food security in many countries particularly, where agriculture is largely rain-fed. Climate change will affect developing countries more severely because of their low capacity for adaptation (IPCC,2001). Within these countries, the agricultural sector is particularly vulnerable, putting rural populations at risk. Furthermore, climate change is an additional threat that might affect a country's ability to meet urgent rural development demands including the improvement of food security, poverty y reduction, and provision of an adequate standard of living for growing populations. In the quest to provide food and fibre to an expanding human population, the provision of agriculture-based ecosystem services that help to moderate climate change is increasingly under threat (FAO,2007). There is a real risk of losing the gain Softhis Green Revolution, which has largely eliminated the danger of famines such as those seen in the1950sand1960s.

The discussion on the potential synergies between adaptation and mitigation measures is just starting and is all too often reduced to a discussion of the costs of global adaptation vs global mitigation. A practical understanding of the link between adaptation and mitigation measures, particularly with respect to land use and management does not yet exist. Yet agricultural research in the last few decades has been addressing the need to cope with adverse and irregular climatic conditions including rainfall variability or shifting weather patterns. Similarly, there has been a major emphasis on improving the productivity of agricultural systems, leading to the understanding that increasing soil carbon stocks in degraded lands is essential for enhanced productivity. Agroforestry provides a unique opportunity to reconcile the objectives of mitigation and adaptation to climate change. A wide range of studies (Albrecht and Kandji, 2003; IPCC, 2000; Palm et al. 2005) have substantiated the fact that agroforestry systems, even if they are not primarily designed for carbon sequestration, present a unique opportunity to increase carbon stocks in the terrestrial biosphere (Table1).

Potential carbon(C)storage for agroforestry systems in different ecoregions of the world

Region	Ecoregion	System	$MgCha^{-1}$
Africa	Humid tropical high	Agri silvicultural	29–53
South America	Humid tropical low dry lowlands	Agri silvicultural	39–10239–195
South east Asia	Humid tropical dry lowlands	Agri silvicultural	12–22868–81
Australia	Humid tropical low	Silvi pastoral	28–51
North America	Humid tropical high humid	Silvi pastoral	133–15
Tropical low	Silvi pastoral	4104–198	
Dry lowlands	Silvi pastoral	90–175	

Based on assessments of national and global terrestrial carbons inks, two primary beneficial attributes of agroforestry can be identified. The first is direct near-term carbon storage in trees and soils through accumulation of carbon stocks in the form of live tree biomass, wood products, soil organic matter and protection of existing products. The second involves potential to offset greenhouse gas emissions through energy substitution (e.g. fuelwood from woodlots) and fertilizer substitution (through biological nitrogen fixation and biomass production). Agroforestry can also have an indirect effect on carbon sequestration when it helps decrease pressure on natural forests, which are the natural sink so terrestrial carbon. Carbon is particularly useful in agricultural systems, making agroforestry a quantitatively important carbon sink. Agroforestry systems in the humid tropics are part of a continuum of landscapes ranging from primary forests and managed forests to row crops or grasslands.

They are mostly perennial systems such as home gardens and agroforests in which the tree component can stay in the field for more than 20 years. While agroforestry systems contain less carbon than primary or managed forests, the fact that they contain significantly higher carbon stocks than row crops or pastures suggests that the introduction and proper management of trees in crop lands has a great potential for carbon sequestration, in addition to rehabilitating degraded land. Unlike simultaneous systems, improved fallows are tree–crop rotation systems where fast growing, often leguminous, trees are cultivated for a period of 8 months to 3 years to enhance nutrient depleted soils and degraded lands in the sub-humid tropics. However, several studies on soil carbon dynamics have indicated that soil organic matter increases after a few seasons of tree planting on degraded soils.

Enhancing farmer adaptive capacity through agroforestry

As adaptation emerges as a science, the role of agroforestry in reducing the vulnerability of agricultural systems (and the rural communities that depend on them for their livelihood) to climate change or climate variability needs to be assessed more

effectively (Verchot et al., 2007). Rainfall variability is a major constraint in the semi-arid regions and to the upland farms in Southeast Asia that do not have access to irrigation. However, the effects of variable rainfall are often exacerbated by local environmental degradation. Therefore, curbing land degradation can play an important role in mitigating the negative impacts of climate change and variability, and that is where agroforestry can be a relevant practice. Successful and well-managed integration of trees on farms and in agricultural landscapes often results in diversified and sustainable crop production, in addition to providing a wide range of environmental benefits such as erosion control and water shed services. Optimizing the use of increasingly scarce rain water through agroforestry practices such as improved fallow could be one way of effectively improving the capacity of farmers to adapt to drier and more variable conditions. Under many of the different farmer practices in Africa, crops still fail completely or yield very little in drought years. Results from improved fallow trials were used to model these various systems. The model suggested that it would be possible to produce an acceptable amount of food in low rainfall years if practices such as improved fallows were pursued. In low-rainfall years, water availability to crops is paramount and seems to be the dividing factor between absolute crop failure and reasonable food production. Buffering agricultural crops against water deficiencies is, therefore, an important function agroforestry would have to play in the adaptation battle. There are other mechanisms such as improved micro climate and reduced evapotranspiration through which agroforestry practices may improve the adaptive capacity of farmers. In the African drylands, where climate variability is common place, farmers have learned to appreciate the role of trees in buffering against production risk (Ong and Leakey, 1999). The parkland farming system, in which trees are encouraged to grow in a scattered distribution on agricultural land, is one example. One of the most valued (and probably most intriguing) trees in the Sahelis *Faidherbia albida*. Thanks to its reversed phenology (the tree shed sits leaves during the rainy season), *F. albida*significantly contributes to maintaining crop yield through biological nitrogen fixation and provision of a favourable microclimate while minimizing tree–crop competition. A study on an *F. albida*–millet park land system in Niger demonstrated that shade-induced reduction of soil temperatures ,particularly at the time of crop establishment ,is critical for good millet growth (Vanden beldt and Williams,1992).This type of reversed phenology is not observed in other parkland trees such as the shea butter tree (*Vitellaria paradoxa*)and néré (*Parkia biglobosa*), which have a negative shading effect that may reduce millet yield under the tree by 50 to 80 percent in some cases (Kater et al., 1992). Farmers are well aware of this loss in yield, but do not mind it since the economic benefits from harvesting marketable tree products largely compensate for the loss of crop yield. However, in extremely hot conditions (which we may have to face in the future), the shading effect of the sever green trees could compensate for the yield losses due to excess heat in the open areas of the field. Such a hypothesis has been validated by the work of Jonsson et al., (1999), who measured variables including temperature, photosynthetically active radiation (PAR is the light in

the 400–700 nm waveband of the electromagnetic spectrum that is useful for photosynthesis) and millet biomass under and away from tree canopies in a parkland system. The results showed that despite the heavy shading, similar amounts of millet biomass were obtained from the area sunder these tree sand in the open. This absence of yield penalty under trees was, to a great extent, explained by the fact that millet seedling sunder tree canopies experienced only1–9 hours per week of supra- optimal temperatures (> 40°C) compared with 27 hours per week in the open. In other words, the shorter exposure to extreme temperatures compensated for the millet biomass loss that would otherwise have occurred as a result of shading. This underscores the important role trees could play in mitigating the negative effects of extreme temperatures on crops, especially in semi-arid regions. Pests, diseases and weeds already stand as major obstacles to crop production in many tropical agro ecosystems and there are strong reasons to believe that their prevalence and deleterious effects on crops may increase with a warmer climate (Rosenz weigetal.,2000). It is strongly believed, yet not sufficiently tested, that enhancing plant biodiversity and mixing tree and herbaceous species in agricultural landscapes can produce positive interactions that could contribute towards controlling pest and disease out breaks. The potential of agroforestry to control both ordinary weeds and parasitic weeds such as *Striga hermonthicahas* also been demonstrated.

Income generation through tree products

Besides the bio physical resilience, which allows the various component so the agro forestry systems to with stand shocks related to climate variability, the presence of trees in agricultural croplands can provide farmers with alternative or additional sources of income, so strengthening the socio-economic resilience of rural populations. Tree products (including timber, fodder, resins and fruits) are normally of higher value than maize or hard grains such as millet and sorghum, and can buffer against income risks in cases of crop failure. The Sahelian Eco-Farm (SEF) provides aneloquent example of how an agroforestry-based integrated natural resource management regime can help to improve the livelihood of the rural poor in vulnerable regions such as the Sahel (Pasternak et al.,2005). The SEF is an integrated land-use system that incorporates high-value multi-purpose trees /shrubs with soil and water conservation structures. The value produced is in the form of food, fuel wood and forage (which can all be converted into cash), plant nutrients biomass for mulch (which contributes to increased infiltration of rainfall, and addition of organic matter to the soil), and protection from wind erosion. The first on-station test of theSEF took place at the Sahelian Center of the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) in Niger during 2002. The estimated income from a 1-hafarm was US$ 600, some 12 times the value of a typical millet crop. The estimated costs of establishing the SEF are not high; the plant material costs about US$60 per ha, and the one-time application of fertilizer about US$10. The labor requirements for land preparation and tree planting are met by farmers and their families.

In the semi-arid zone of Kenya, the park-land system is showing similar success. The fast-growing indigenous species *Melia volkensii* is highly compatible with crops and can provide high-value timber in 5–10 years. A study by Ongetal (2002) in the Kitui district of Kenya showed that in an 11-year rotation period, the accumulated income from tree products exceeds the accumulated value of crop yield lost through competition. This income difference is worth US$10 or 42 percent during average years, and US$22 or 180 percent if a 50 percent rate of crop failure owing to drought (reasonable for Kitui) is assumed. In such a hostile environment, where crops normally fail every other year, good and secure financial returns from *M. volkensii* even in drought years can provide significant relief for farmers. This will be all the more necessary as extreme climate events (droughts and floods) are likely to increase in frequency and in magnitude in the near future.

Conclusions

The impact of climate change will be felt at several levels in the agricultural sector. Most of the effects will hit the rural poor in developing countries, who are the most vulnerable because of their poor ability to adapt. The adaptive capacity of farmers in developing countries is severely restricted by their heavy reliance on natural factors and a lack of complementary inputs and institutional support systems. The concepts of resilience and sustainable productivity are well established in agriculture and can be linked directly to the discussions about adaptation and mitigation to climate change. Thus, policy maker scan draw upon a substantial body of knowledge in this respect. However, the adaptation and mitigation synergies of agroforestry management systems warrant further investigation. Within international fora, there is much talk about bringing adaptation into the main stream of planning processes. We have shown above, through the specific case of agroforestry, that some mitigation measures simultaneously provide opportunities to increase the resilience of agricultural systems. It is suggested that such synergies ought to be promoted more intensively through the channels of the UNFCCC such as the CDM. However, if agroforestry is to be used in carbon sequestrations schemes including the CDM, several areas need to improve, for example, we need better methods of assessing carbon stocks and non-CO emissions. Furthermore, the debate on durable wood products is ongoing, but what is known is that farmers will need provisions to allow them to market wood products from their agroforestry systems, and we should develop methods to account for the life time of the carbon sequestered in agroforestry products. As small-scale farmers are enrolled in carbon-offset projects, we will need to develop a better understanding of the implications of these for carbon sequestration by agroforestry and what it means to lively hoods. Finally, the CDM has very stringent rules for participation that may be beyond the reach of small-scale farmers to understand or to provide evidence of compliance. There is a need for institutional

support by national, regional and international centres of excellence to facilitate effective participation of small-scale farmers in the CDM. In their attempts to develop adaptation strategies for the agricultural sector, scientists and policy makers must consider the complex interactions of constraint created by changing climates in the light of other stress factors. Government and international support in terms of research, education, and extension will be required to help farmers in developing countries scope with the additional stresses created by climate change and increased climate variability. Agroforestry can very likely contribute to increasing the resilience of tropical farming systems. However, our understanding of the potential of agroforestry to contribute to adaptation to climate change is rudimentary at best. Better information is required on the role of agroforestry in buffering against floods and droughts from both the biophysical (e.g. hydraulic lift or soil fertility) and financial (e.g. diversification and income risk) points of view. Agroforestry promises to create synergies between efforts to mitigate climate change and efforts to help vulnerable populations adapt to the negative consequences of climate change. The research agenda in this area is fairly well defined; much is already known and putting these ideas into practice on the ground with small-scale farmers will allow us to learn important lessons.

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SCOPE OF MEDICINAL PLANTS IN AGRO- FORESTRY AND LIVELIHOOD OPPORTUNITIES THROUGH VALUE ADDITION

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INTRODUCTION

About 80% of the population of most developing countries still use traditional medicines derived from plants for treating human diseases. In India, 9,500 species have been reported to be of medicinal value, of which 2,500 species provide raw material to herbal industry. The Ayurveda (900 species), Siddha (800 species) and Unani (700species) systems are the main users and about 1,000 species are reported to have trade potential.

In recent years, the growing demand for herbal products has led to a quantum jump in volume of plant material traded within and outside the country. Further, growing demand is putting a heavy strain on the existing resources causing a number of species to be either threatened or endangered category. Lately, medicinal and aromatic plants are looked upon as a source of income. The recent study indicated that herbal drug market continues to grow at the rate of 7-30 % annually. Maiti (2013) reported that the export of raw material and finished herbal products is valued at about US$ 100-114 million per year. A never increasing demand of medicinal plants- based medicines warrants the mass propagation. The 54 top most traded medicinal plants are still being collected from the wild. Only few commercially valuable medicinal plants are under cultivation. Many national organizations-Indian Council of Agricultural Research (ICAR), Council of Scientific and Industrial Research (CSIR), National Medicinal Plant Board (NMPB), Indian Council of Forestry Research and Education (ICFRE) and different State Forest Departments are working on different aspects viz., conservation, propagation, varietal development etc. of medicinal and aromatic plants (MAP). Some large private manufacturing units like Dabur, Zhandu, Himalayan Drug, Hamdard, etc. are big traders or manufacturers of medicinal plants-based drugs. National Medicinal Plant Board, New Delhi under Ministry of AYUSH, GOI has been working to promote and support cultivation of medicinal plants in a Mission mode approach under Centrally Sponsored Scheme of “National Mission on Medicinal Plants (NMMP)” since 2008-09 in the country through State Government designated agencies to reduce pressure on the collection from wild habitat in forests and to meet the demand of MAPs in National and international market.

The potential returns to the farmer from cultivation of medicinal and aromatic plants are reported to be quite high, cultivated in different parts of the country.

The congenial climate available indifferent plantations offer great scope for cultivation of medicinal and aromatic plants, which in turn would increase resource use efficiency and generate supplemental income. Several medicinal plants require (or

tolerate) partial shade, moist soils high inorganic matter, high relative humidity, and mild temperatures. Indigenous people living in the different parts in forests or forest margins in India, are known to have conserved and cultivated several medicinal species for centuries. However, several medicinal plants have not been tried so far as intercrops in plantation and require standardization of agro-techniques under different agroforestry systems.

Integration of medicinal plants in different agroforestry systems as upper story or under story are recognized as the most productive, remunerative, environmentally sound and ecologically sustainable alternative land use systems.

Keeping in view, the high demand of medicinal plants and to increase livelihood opportunities through sustainable farming, Agroforestry can be utilized as a key instrument to provide livelihoods for farmers while protecting and preserving forest reserves and biodiversity as well.

Cultivation of such plants can be taken up in thinned forests and cleared forest patches and as intercrops in new plantations in Silvi-medicinal systems. Two types of intercropping systems with medicinal plants can be adopted-

(1) Medicinal plants (Trees) as upper story

(2) Medicinal plants as under story

Some important medicinal plants as upper story and under story for different agroforestry systems are summarized below:

IMPORTANT MEDICINAL TREES & BAMBOO AS UPPER STORY UNDER SILVI/MEDI/AGRI /AGROFORESTRYSYSTEM

Botanical Name &Common name Family/Maturity Period	**Active ingredients (useful parts)**	**Varieties available /Source**	**Gross production /Income**	**Major Medicinal properties/Uses**	**Photographs**
Aeglemarmelous (Bael) Fam.-Rutaceae Maturity period-After 4-5year	Carotenoids, Phenolics, alkaloids, Coumarins, flavonoids, terpenoids, and Other antioxidants (Fruit, Bark)	Goma Yashi (Source-ICAR-CIAH, Bikaner) NarendraBael(NB-5, NarendraBael-7, NarendraBael-9, NarendraBael-16and NarendraBael-17 (Source-N.D. University of Agriculture and Technology, Kumarganj, Faizabad, U.P.) Pant Aparna, Pant	Dhar Divya-Average yield/plant is85.20 kg in9th year. Thar Neelkand-Yield: 70-75 kg per plant(8thYear) Yield:58.58 kg/plant(7thyear) and124.36kg/plant (12thyear) NB-5-28.78 kg per plant(6thyear) NB-9-56kg/plant (6thyear) NB-7- (starts fruiting inthe4th year, 32.10kg/plant (6th year)	Diarrhea, dysentery, constipation.	

		Sujata, Pant Urvashi and Pant Shivani (Source-G. B. Pant University of Agriculture and Technology, Pant Nagar, Uttarakhand) CISHB-1andCISHB-2(Source:Central Institute For Sub- tropical Horticulture, Lucknow, UttarPradesh) Thar Divya, Thar Neelkanth, Thar Gaurav And Thar Srishi (ICAR-CIAH, Bikaner)	Pant Aparna- 40.25 kg/plant(6th year) CISHB-1-42.64 kg/plant (6th year And fruiting starts in the4th year) CISHB-2-3845kg/plant (6th year) Goma Yashi-51kg/plant(6th year)		
Azadirachta indica (Neem) Fam.MeliaceaeMaturityperiod-After 3-5years,	Azadirachtin, Nimbolinin, Nimbin, Nimbidin, Nimbidol, Salannin and Quercetin. (Leaf Seed)	6 cultivers - FRI-IFFCO-1,FRI-IFFCO-2,FRI-IFFCO-3, FRI-IFFCO-4,FRI-IFFCO-5 ,FRI-IFFCO-6 Recommended for eastern plateau (Bundelkhand Uphill), Northern plains (Rajasthan) then upland and Gujrat plains) and Deccan plateau hot semiarid region.	Seeds 10-12kg/tree/yr	Various skin disorders, diabetes, Ulcer, Dandruff/ring worm	
Annona reticulata (custard apple) Fam.-Annonaceae Maturity period-5th year	Tannins, alkaloids, phenols, glycosides, flavonoids and steroids. (Fruit)	Arka Neelanchal Vikramand Arka Sahan (Source: SVRC, Govt. of Odisha) Arka Sahan-IIHR Bangalore	Arka Neelanchal Vikram-69fruits/plant); fruit weight (211g) Arka Sahan - 45Kg/tree (5th yearand Fruits starts at 3rd year)	As anthelmintic, analgesic, Anti-inflammatory, Antipyretic, wound Healing and cytotoxic effects.	
Buchnanialanzan (Chironji) Fam.-Anacardiaceae Maturity period-After10 years	Fatty oil, Seed cake contains fibres, carbohydrates, mineral, fats, vitaminB_1, B_2, B_3, C, calcium, chlorine copper, iron, magnesium, phosphorus, potassium, sodium, sulfur, fatty oil, β-amyrin	*Buchnanialanzan* var. Palodensis (Source-Kumar *et al*.,2020) Thar Priya (Source: ICAR, CIAH, Bikaner, Rajasthan)	TharPriya-11.90kg /plant (Start bearing in 4th year of planting)	Useful in the treatment of diarrhoea, leaves are used in the treatment of skin diseases and Fruits are used in treating coughs and asthma.	
Emblica officinalis (Amla) Fam.-EuphorbiaceaeMaturity period-After 4th year	Vitamin–C (Fruit)	Banarasi, Chakaiya, Francis, NA-4(Krishna), NA-5(Kanchan), NA-6, NA-7(Promising	NA-7-51 kg/tree Chakaiya-34Kg/tree NA-628 Kg/tree	Cough, diabetes, cold, laxative, hyper acidity.	

		variety), NA-10, BSR-1 (Bhavanisagar). (Source) Goma Aishwarya (ICAR-CIAH, CIAH, Bikaner, Rajasthan)			
*Citrus aurantifolia (Kanjinemuor*acid lime*)* Fam.-*Rutaceae* Maturity period-Starts bearing from 3rd year after planting	Flavonoids including apigenin, hesperetin, kaempferol, nobiletin, quercetin, and rutin, (Fruit)	PKM1, Vikram, Pramalini, Chakradhar, seedless lime, Balaji and Rasraj Balaji [Tirupati (Andhra Pradesh)] PDKV Lime [Akola (Maharashtra)] Phule-Sharbati [Rahuri (Maharashtra)]	25kg/ha/yr(6m*3mand 5m*5m spacingapprox.45-62.5kg/plant)	Antibacterial, anticancer, Antidiabetic, antifungal, Anti-hypertensive, Anti-inflammation, Anti-lipidemia.	
Citrus limon (Nimbu) **Fam.**-*Rutaceae* Maturity period-Starts bearing from 3rd year after planting	Flavonoids, limonoids, phenolic acids, carboxylic acids, coumarins, vitamins and their sec. metabolites (Fruit)	Eureka, Allen, Cascade, Cook, Meek, Thorton, Lisbon, Bradbury, Cavors, Deavor, Hall, Jameson, Ledig, Limoneira, -8A, Monore, Prior, Prospect, Strong, Femminelo, Oval, Genoa, Brena	50-60 fruit/tree (after3rd yr) 1000-1500 fruit/tree(after8th yr)	Meniere's disease, Kidney stones, Treating scurvy, The common cold and flu. Decreasing swelling. Increasing urine.	 
Moringa oleifera (Sahajan) Fam.-Moringaceae. Maturity period-9 months	Flavonoids. alkaloids, phenols, vitamins, minerals, proteins, glycosides, glucosinolates, Isothiocyanates, terpenes, saponins, and tannins (Fruit ,Leaf)	Periyakulam 1and2(PKM 1andPKM2) (Source-Horticulture Research Station of Tamil Nadu Agricultural University (TNAU) Thar Harsha (Source: ICAR-CIAH, Bikaner, Rajasthan)	Average yield200-220kg fruits/tree/yr138 tonn/ha (Spacing1.2m*1.2 m, approx. 19.87kg/tree) Thar Harsha-45-48kg/plant	Arthritis and other joint pain (rheumatism), asthma, cancer, constipation, diabetes, diarrhea, stomach and intestinal ulcers.	
Morus alba (*Sehtut*, white mulberry) Fam.-*M*oraceae Maturity period-after 3rd year	Rutin(293.5µg/g), chlorogenic acid (226.9µg/g), caffeic acid (17.2µg/g), quercetin(15.2µg/g), gallic acid(8.9µg/g), kaempferol (5.8 µg/g), andapigenin (3.5 µg/g), Rutin, chlorogenic acid, caffeic acid,	Kanva-2, S-36, S-54, Victory-1, S-13, S-34, MR-2 (Source: CSRTI, Mysore) Anantha (Source: Regional Sericulture Research Stationin	Fruit yield Thar Lohit-12.4 kg to26.5kg/tree/yrThar Harit-32.6kg /tree/yr plant	The treatment of dizziness, insomnia, premature aging, atherosclerosis, liver and kidney disorders, and inflammation.	

	quercetin, gallic acid, kaempferol, and apigenin	Andhra Pradesh) Vishala (Source: Central Silk Board, Bangalore) Thar Lohit and Thar Harit (Source: ICAR-CIAH, Bikaner, Rajasthan)			
Punica granatum (pomegranate) Fam.-Punicaceae Maturity period-	Flavonoids, Ellagitannin, Punicalagin, Eellagic acid, vitamins and minerals. (Fruit)	Ganesh, Mardula, Bhagwa, Phule Bhagwa Super, Phule Araktaand G 137(Source: MPKV, Rahuri) CO-1 and Yercaud-1(TNAU, Coimbatore), Rubya nd Amlidana (Source: IIHR, Bengaluru) YCD-1 Pomegranate- (Source: Horticultural Research Station, Yercaud) Goma Khatta (Source: ICAR-CIAH, Bikaner, Rajasthan) CAZRI Vishal (Source: SinghandMeghwal,2020) Jyoti (UAS, Dharwad)	Goma Khatta -6.59kg/tree and anardana yieldis1.18kg/tree CAZRI Vishal -12-15 t/ha (3.5m*4m, approx.16.8-21 kg/tree) YCD-1-60–70 fruits/plant/yr	Treatment for Cancer, Osteoarthritis and Other Diseases. The pomegranate has been used in natural and holistic medicine to treat sore throats, coughs, urinary infections, digestive disorders, skin disorders, arthritis, and to expel tapeworms.	
Syzygiumcumini (Jamun) Fam.-Myrtaceae Maturity period- Fruitbearingstartin3rdyear	Phenolicacids, Flavonoids and Anthocyaninsetc. (Fruits)	Ram Jamun Jamun GJ-2, JamunGJ-8, CISH J-37, CISHJ-42 (Source: Central Institute for Subtropical Horticulture, Lucknow) Konkan Bahadoli (RFRS, Vengurla) Goma	Thar Kranti-65.00 kg/tree/yr Goma Priyanka-30kg/tree/yr	Antihyperglycemic, Hyperlipemia, Anti-inflammatory, Cardioprotective, and Antioxidant activities.	 

		Priyanka-(ICAR-CIAH, Bikaner) Narendra Jamun 6-Narendra dev University of Agriculture and Technology, Faizabad, U.P. Rajendra Jamun-1– Bihar Agriculture Collage Bhagalpur Thar Kranti and Goma Priyanka (Source: ICAR-CIAH, Bikaner, Rajasthan)			
Terminaliachebula(Harad)Fam.-Combretaceae Maturityperiod-After6 years	Glycosides, Gallic acids, Ellagic acid, Chebulinc acid, Tannic acid (Fruits)	*Vijaya, Rohini, Putana, Amrita, Abhaya, Jivanti*and *Chetaki* (ChattopadhyayandBhattacharyya,2007)	Approximately40–50 kg/tree/yr dry fruits	Ingredient of Triphala, Laxative.	
Tamar indus indica (Tamarind,Tamarindo, Tamarin, Sampalok) Fam.- Fabaceae Maturity period-within three to four years	β-amyrin, compesterol, β-sitosterol and seven hydrocarbons. (Fruits)	Goma Prateek (Source: ICAR-CIAH, Bikaner,Rajasthan)PKM1 (Source: Tamilnadu University(HCRI, Periakulam) Tumkur Parthithan (Source: FRS, Aurangabad, Maharashtra) Urigam DTS-1 (Source: UAs, Dharwad) Yogeshwar (Source: Forest Deptt. Karnataka)	Average yield –150-200 kg/tree/yrPKM1 Yield – 250 kg from9thyear	It is used In wound healing, abdominal pain, diarrhea, dysentery, parasitic infestation, fever, malaria and respiratory problems.	
Zizyphusmauritiana(Ber)Fam.-Rhamnaceae Maturity period-	Proteins & amino acids, flavonoids, alkaloids, glycosides, terpenoides, saponins, fibers, tannins andphenolic	Thar Sevika, Thar Bhubharaj, Goma Kirti and Thar Malti (Source: ICAR-CIAH,	Thar Sevika -30-32 kg/tree. Thar Bhubharaj-Thar Malti-30-36kg/tree Thar Malti -65-70 kg/treeGomaKeerthi-35.6kg/tree	Eye diseases, leukorrhea, asana string enttonictothehearbrain. These edsalsohelptoreli evethirst, and	

	compounds. (Seed)	Bikaner, Rajasthan) Goma Keerthi (Source: ICAR-IIHR, Bengaluru)		have asedative and hypnotic effect, which is helpful in insomnia, pain, physical weakness, and rheumatic symptomol ogy.	
Cassia augustifolia (Senna) Fam.- Liliaceae Maturity period- Within1year	Sennosides (Dry tubers)	Sona CSIR-CIMAP's (Source: CSIR-CIMAP Lucknow Uttar Pradesh)	Sona CSIR-Dry leafyield:11q/ha, seedyield:4-5 q/ha. Net profit- 27,000-30,000Rs/ha. /yr.	Rheumatis m, general debility tonic, aphrodisiac .	

About 80% of the population of most developing countries still use traditional medicines derived from plants for treating human diseases. In India, 9,500 species have been reported to be of medicinal value, of which 2,500 species provide raw material to herbal industry. The Ayurveda (900 species), Siddha (800 species) and Unani (700 species) systems are the main users and about 1,000 species are reported to have trade potential.

In recent years, the growing demand for herbal products has led to a quantum jump in volume of plant material traded within and outside the country. Further, growing demand is putting a heavy strain on the existing resources causing a number of species to be either threatened or endangered category. Of late, medicinal and aromatic plants are looked upon as a source of income. The recent study indicated that herbal drug market continues to grow at the rate of 7-30 % annually. Maiti (2013) reported that the export of raw material and finished herbal products is valued at about US $ 100-114 million per year. An ever-increasing demand of medicinal plants-based medicines warrants their mass propagation. The 54 top most traded medicinal plants are still being collected from the wild. Only few commercially valuable medicinal plants are under cultivation. Many national organizations-Indian Council of Agricultural Research (ICAR), Council of Scientific and Industrial Research (CSIR), National Medicinal Plant Board (NMPB), Indian Council of Forestry Research and Education (ICFRE) and different State Forest Departments are working on different aspects viz., conservation, propagation, varietal development etc. of medicinal and aromatic plants (MAP). Some large private manufacturing units like Dabur, Zhandu, Himalayan Drug, Hamdard, etc. are big traders or manufacturers of medicinal plants-based drugs. National Medicinal Plant Board, New Delhi under Ministry of AYUSH, GoI has been working to promote and support cultivation of medicinal plants in a Mission mode approach under

Centrally Sponsored Scheme of "National Mission on Medicinal Plants (NMMP)" since2008-09inthecountry through State Government designated agencies to reduce pressure on the collection from wild habitat in forests and to meet the demand of MAPs in National and international market.

The potential returns to the farmer from cultivation of medicinal and aromatic plants are reported to be quite high, cultivated in different parts of the country.

MEDICINAL HERBS & SHRUBS AS UNDERSTORY COMPONENT(S) UNDER SIVI-MEDI AGROFORESTRY SYSTEMS IN FOREST OR PLANTATION

Botanical Name &Common name Family/Maturity Period	**Active ingredients (useful parts)**	**Varieties available /Source**	**Gross production /Income**	**Major Medicinal properties/Uses**	**Photographs**
Andrographi spaniculata(Kalmegh/ Bhuineem) Fam.- Acanthaceae Maturity period- Within one year	Andrographolide (Whole Plant)	CIM-Megha (Source: CSIR-CIMAP Lucknow Uttar Pradesh)	CIM-Megha- 2.5-3.0 t/ha. Of dried herb Net Income-45,000/ha (from 3rdmonth) (Bahl*etal*.,2018)	Fever, weakness, gastric problems	
Aloevera (Grit-kumari) Fam.-Liliaceae Maturity period- 2nd-5thyr	Aloin (Leaves)	CIM-Sheetal (Source: CSIR-CIMAP Lucknow Uttar Pradesh) IC11127 IC111269 IC111280 IC111273(Source-NBPGR, ICAR, Delhi)	CIM-Sheetal-50t/ha. Net return-1,25,000 Rs. /Ha. Approx (Bahl*et al*.,2018) Cost of cultivation (Rs/ha)-1,30,000 Leaf yield (ton/ha)-50-60 Leaf Rate/qt-5000 Gross return (Rs. /ha)-2,50,000 Net return (Rs. /ha)-1,20,000	Laxative, Wound Healing, &Skin burns	
Acoruscalamus (Buch) Fam.- Acoraceae Maturity period- Within one year	β-asaron, Flavonoid, monoterpene, quinone, sesquiterpene, and phenylpropanoid (Root)	Jor LabAC-1 (Source: CSIR-NEIST Jorhat, Assamandlaletal.,2019)	Rs-36602.5/ha/yr50-70gram/plant	Depression, Mental ailments, Asanins ecticide, Paediatric cough and colicky problems.	
Bacopamonnieri (Brahmi) Fam.- Scrophulariaceae Maturity period- Oneyear	Bacoside A&B (Whole plant)	Subodhak, Pragyashakti, and CIM-Jagriti. (Source: CSIR-CIMAP Lucknow Uttar Pradesh)	Asapurecrop, fresh yieldis22.5 tonnes/ hectare, reduced to approximately 5.5 tonnes / hectare on drying.	Memory enhancer, mental disorders.	
Cassia augustifolia	Sennosides (Dry	Sona CSIR-	Sona CSIR-Dry	Rheumatism,	

(Senna) Fam.- Liliaceae Maturity period- Within1year	tubers)	CIMAP's (Source: CSIR- CIMAP Lucknow Uttar Pradesh)	leafyield:11q/ha, seedyield:4-5 q/ha. Net profit- 27,000-30,000Rs/ha. /yr.	general debility tonic, aphrodisiac.	
Coleus barbatus (Pashan Bheda /Pathar Chur) Fam.- Lamiaceae Maturity Period-One year	Bergenin, and Afzelechin (Root)	**Manganiperu**(commercially cultivated in Tamil Nadu). **Garmai**(cultivated in Gujarat state). **Maimul**	Fresh tubers: 15 – 20 t/ha Dry tubers: 2000 – 2200kg/ha	Kidney stone, Calculus.	
Cymbopogonflexuosus(Cochin grass, East-Indian lemon grass) Fam.- Poaceae Maturity period- after4to6months	Myrcene, limonene, citral, geraniol, citronellol, geranyl acetate, neral, terpenes, alcohols, ketones, aldehyde andesters. (leaves)	Cim –Pragti, Nima, Chirharit, Krishna, CIM-Swarna and CIM –Shikhar, which gives more herb and oil yield. (Source: CSIR-CIMAP Lucknow Uttar Pradesh)	Krishna- 230-250kgoil /ha. Nima-25-260 Kg/ha essential oil CIM – Shikhar,- More280kg/ ha.oilyieldNet profit of about Rs60,000 and1,00,000 /ha./yrdepenonirrigation(Bahl*etal*.,2018)	Antispasmodic, Hypotensive, Anticonvulsant, Analgesic, Antiemetic, Antitussive, Antirheumatic, Antiseptic and treatment for Nervous and Gastrointestinal disorders and Fevers.	
Cymbopogonmartini(Palmarosa) Fam.- PoaceaeMaturity period- after4to6months	Motia (palmarosa oil), Menthaxpiperita(peppermint) and Eugeniacaryophyllus (clove). (Flower)	PRC-I, Trishna, Tripta , Vaishnavi, CIM-Harsh. (Source : CSIR-CIMAP Lucknow Uttar Pradesh)	PRC-I-125-150kgoil/ha.Net Return-60,000-1,00,000/ha. yr CIM-Harsh-175-200 kg/ha. (Bahl*et al*.,2018)	Aromatherapy as a skin tonic due to its antimicrobial properties. It has also used in Ayurvedic medicine in problems and to relieve nerve pain.	
Cymbopogonwinterianus(java citronella) Fam.- PoaceaeMaturity period-After4month	Citronellol, citronellal, and geraniol. (leaves)	Source: CSIR-CIMAP Lucknow Uttar Pradesh)	20 -30t/ha/year (spacingof60x45cm) Citronellal 38.61%(Manjusha)	Anti-Inflammatory, Antinociceptive, and central Nervous system (CNS)disorders.	
Curcuma longa(turmeric)Fam.- Zingiberaceae Maturity period-7-9 months after planting	Three curcuminoids; curcumin (diferuloylmethane, the primary constituent responsible for yellow color of turmeric)	Suvarna. Suguna, Sudarsana, IISR Prabha, IISR Prathibha., Co-1, BSR-1, Krishna, Sugandham, Roma ,Suroma , Ranga, Rasmi, Rajendra, Sonia, SRK edaram, Sobha, Sona, Varna, Kanthi. (Source:	CIM-Pitamber60–65 tonnesfresh rhizomes/ha Netprofit- 1.25–1.50 lakhs/ha (1.25–1.50lakhs/ha (Bahl *et al*.,2018)	A cough, diabetes, dermatological conditions, respiratory problems, cardiovascular and hepatobiliary diseases, arthritis, irritable bowel disease (IBS), pepticulcers, psoriasis, and atherosclerosis.	

		Department of spices and plantation crops, faculty of horticulture , Tamil Nadu Agricu lture univer sity, Coimb atore, Tamilnadu.) CIM-Pitamber (Source-CSIR-CIMAP)			
Desmodiu mgangetic um(salpar ni.) Fam.-Fabaceae Maturity period-six to seven months	Gallic, protocatechui c,salicylic, chlorogenic, caffeic acids, rutin, quercetin and kaempferol in both parts of plant. (Root, whole plant	Source: CSIR-CIMAP Lucknow Uttar Pradesh)	The total herb yield perhectareisestimate dtobe50–55quintals dry weight, while the dry weight yield of roots is estimated to be 11–15quintals/hectare.	Febrifuge, aphrodisiac, analgesic, diuretic, anti-inflammatory, and haemorrhagic properties. It is used in postnatal complaints, diarrhoea, chronic fever, biliousness, cough, vomiting, and asthma. It is an important ingredient of dasmoolarishta and chyavanprash.	
Embeliaribes (Vidanga) Fam.- Primulaceae Maturity period-After 5-6months	• Embel in;quer citol, fatty ingredients and alkaloids christembine, a resinoid, tannins (Seed)			Relieving Headache, Rhinitis, Haemorrha ge, Epilepsy Insomnia.	 
Gloriosasuperba (Kalihari) Fam.- Liliaceae Maturity Period-Five years	Cholchicin,Alkalo idgloriocine (Seed, tuber)		Seeds200-250kg/ha. tubers300 kg /ha.	Skin Diseases, Abortion, General debility.	
Mentha pipertia(Pippermint)F am.- Lamiaceae Maturity Period-Perennial	Menthol, Essential oil (Leaves, Flower, Oil)	Menthone, mentholrich**:** Kukrail: menthol (34.5%), menthone (27.9%), Tushar: menthol (33.3%), menthone (27.3%) Pranjal menthol (52%), menthone (13.5%) CIM-madhuras:	Tushar-85-90 kg/ha (Bahl*etal*., 2018) Oil yield (kg/ha) -120 Cost of cultivati on (Rs. /ha)-	Carminativ, Antiseptic and Gastro-stimulant	

		menthol31.2%, menthone 24.3%.Menthofuran rich: -VCIM-indus; menthofuran (27%) and pulegone (15%) CIMAP-patra: mentho furancontent:35-46%. (Source: CSIR-CIMAP Lucknow Uttar Pradesh)	75,000 Value@Rs.2 400/kg-2,88,000 Net Return Rs. /ha-2,13,000 CIM Madhuras-High oil yielding(120-125kg/ha)		

AGROFORESTRY MODELS FOR INCOME GENERATION: A SCENARIO OF UTTARAKHAND

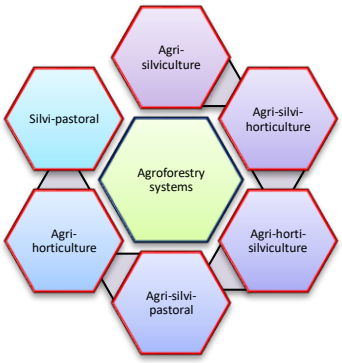
Mr. Vaibhav Gupta PhD scholar (DBU University) Dehradun Uttarakhand

Agroforestry models for income generation: scenario of Uttarakhand

Agroforestry is the term that affords an immense potential for sustaining the mankind with its multifarious outputs. Though this terminology is new to the world, but the main ideology behind is decade old addressing the human needs. In north-western Himalayas (Uttarakhand, Himachal Pradesh and Jammu and Kashmir) (accounting for 16 per cent of country's geographic area), the arable land is scarce with undulating topography, owing to which raising of trees on farmlands and/or bunds is vital to farmers for obtaining food, fodder and fuelwood in pinch period of the year. The viability of the conservation efforts aiming sustainability, productivity and adoptability can be met only by better application of agroforestry practices.

Important agroforestry systems in North-western Himalaya

The agroforestry systems are made of of two kinds of componentsPrimary components being more important and occupying larger area, however secondary components being of less



importance and occupying less area.

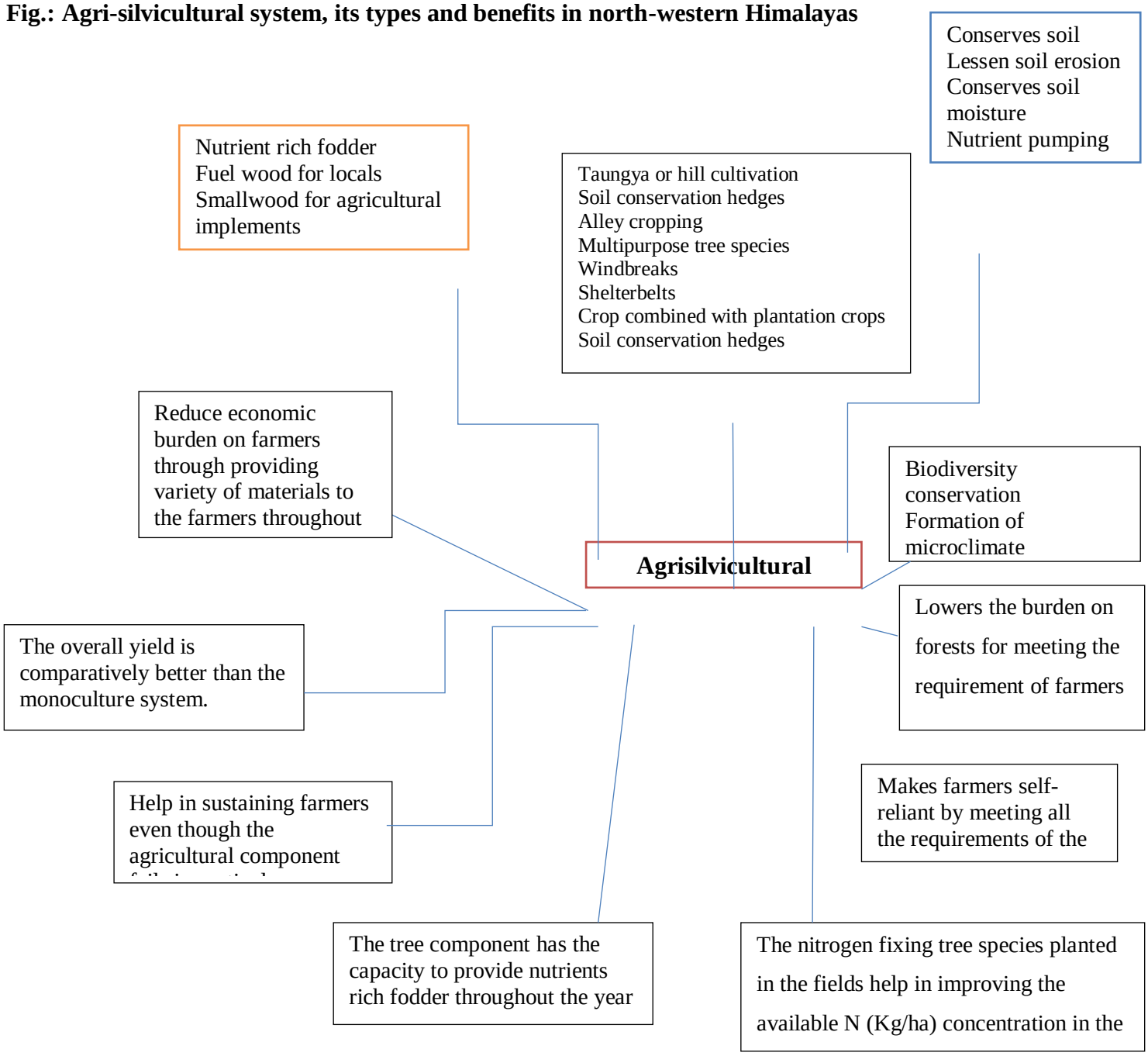
Fig.: The silvicultural systems based on nature of components commonly employed in north-western Himalaya

AGRI-SILVICULTURAL SYSTEM

The term is made up of Agri + silviculture. Here agriculture is the dominant/primary

component and trees are planted in the agricultural field. The system is widespread in north-western Himalayas as farmers are actively raising trees on their field bunds. In the region fields are made on steep slopes as terraces. Here, space optimization is necessary through the cultivation of crop on fields and multipurpose tree species on farm bunds. Further, the land scarcity is an important factor, because with growing populations the land has been divided among the family successors, leaving very small fraction with the individuals with time, making it difficult to all to sustain merely on agriculture. Also, varying fertility gradient, soil type, erosion and landslides are the concerns that are addressed with agroforestry in the area (Kumar *et al*., 2009). Further, the fields in mountains are generally away from the homes, making it difficult to the farmers to go multiple times for fodder for livestock and then for fuel wood to such farther places. Anticipation to that, farmer in the fodder and fuelwood scarcity areas tend to grow multipurpose tree species that serves as both fodders as well fuel wood e.g., *Quercus leucotrichophora*. This helps them to get quality fodder during the pinch period of the year and the twigs left over after the livestock ate fodder serves as fuelwood. In this way, the agri-silviculture system is playing a very important role in sustaining livelihood in the north-western Himalayas.

Fig.: Agri-silvicultural system, its types and benefits in north-western Himalayas



AGRI-HORTICULTURE/HORTI-AGRICULTURE SYSTEM

The system consists of combination of agricultural crops i.e., cereal crops along with the fruit trees e.g., apple, peach, plum and pomegranate. The system is very important as being the main cash earner systems for mountainous states along with acting as main source of food for farmers. The system can be employed by farmers either for subsistence or on large scale. The system has a crucial role also for meeting the fodder requirement of the livestock. Similarly, the system is also commanding on the mountainous state for conserving soil, water retention and moisture (Dollinger et al., 2018, Silva et al., 2022). Further planting nitrogenous crop below the tree species improves the available soil nitrogen status of soil along with acting as mulch material if planted as a mulch crop in fields with main crop.

SILVI-PASTORAL SYSTEM

It is the combination of forest trees and grasslands in the mountainous regions. The system is very unique in its aesthetic value along with its functional traits. This consist of grasses with sparse trees of different species in between. The system is very characteristic for providing fodder for livestock in the lean period of the year, where animals either graze directly or farmers take fodder from these systems to their farmstead. Mainly these systems are present on higher altitudes, where the nomads move during the summer period because during winter the area is either covered with snow or devoid of vegetations. Farmers move with their livestock along these systems for grazing and browsing. These are also a very important tourism attraction for their rich diversity and scenic beauty. Many medicinally important herbs and plants are also endemic to these regions. Further, in mountainous areas, besides the natural silvi-pastoral systems, a large portion of farmer's own land is under this system due to limiting factors such as steep slopes, rocky terrains and low moisture etc. which is called as Ghasnis in local dialect. The system has many environment advantages besides providing the fodder and fuelwood.

AGRI-SILVI-PASTORAL OR SILVI-AGRI-PASTORAL SYSTEM

The system is a complex combination of crops, multipurpose tree species and grasslands in a close combination with each other. The system doesn't always infer a clear-cut boundary between all the components, however is very common in dry localities with steep terrains (mainly towards the southern or western aspects) having limited moisture and water retention. The system is very important in its ability to meet the farmers need for fodder, fuelwood and subsistence for food materials. Even, the system has a lot more environmental benefits of biodiversity conservation, habitat generation and soil protection.

AGRI-SILVI-HORTICULTURE

The system is a complex combination of agricultural crops, fruit trees and forest/multipurpose tree species. It is commonly employed in north-western Himalayas due to their multiplicity of outputs and associated environmental benefits, affording as one of the most resilient systems providing multiple output such as food, fodder, fruits and agricultural crops. This system matches very well with the farmers tendency to accommodate all the different resources on their farms for gaining maximum outputs and benefits associated. Further the different components of the system serve as backup to the other if any of them fails. The system sustains the farmer throughout the year and reduces his dependence on the outside world or markets. This in turn relieves his economic burden and stabilize his farm income. The system if managed scientifically, can help farmers in a systematized way by providing fuel wood and fodder from the forest tree component, meanwhile food sustenance from agricultural crops along with fodder, however fruit trees acting as robust economic source besides proving fodder and subsistence. On future prospects, this system is very important as limited land shall be allocated in such a way as to protect and conserve all the component of the nature along with sustainability in the production. The system is worthy enough for reducing pressure on nature.

PROMISING AGROFORESTRY MODELS FOR CENTRAL INDIA DEVELOPED BY TFRI

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INTRODUCTION

Agroforestry, a time-honored agricultural practice rooted in the ancient wisdom of farmers, has undergone a transformative evolution, emerging as a dynamic science and a pivotal strategy in contemporary sustainable land use. The term maybe relatively new, coined only in recent decades, but its essence lies in the age-old tradition of integrating trees with crops and livestock to meet diverse household needs. From its humble origins, agroforestry has matured into a recognized field of study, garnering attention in the late 20th century for its potential to enhance rural livelihoods, mitigate environmental risks, and optimize overall productivity. This evolution traces a journey from intuitive farming practices to asophisticatedsciencethatnowholdspromiseinaddressingmodernchallengesin agriculture, making agroforestry a beacon for achieving productivity, profitability, and sustainability in land management. This introduction explores the historical and conceptual evolution of agroforestry, capturing its transition from a traditional practice to a globally recognized solution for the complex interplay between human needs and ecological resilience.

NEED AND SCOPE OF AGRO-FORESTRY

The imperative for agroforestry transcends geographical, regional, and agro-climatic boundaries, positioning itself as a universal and indispensable solution for contemporary agricultural challenges. Recognized as a pressing need of the day, agroforestry extends far beyond a mere land-use practice; it embodies a versatile approach with the potential to address the complex interplay between rural development and environmental conservation. This paradigm encompasses a spectrum

of products and services pivotal for sustainable development. From essential food and fruit production to the provision of fuel, fibers, and wood, agroforestry emerges as a multifaceted strategy capable of meeting diverse needs. Importantly, it has proven instrumental in providing employment and income generation avenues for marginalized farmers and women's self-help groups. By contributing to food and nutritional security, as well as fostering increased rural income and employment opportunities, agroforestry stands as a catalyst for holistic development. Its dual nature—productive and protective—renders it a key player in enhancing land productivity, crucial for meeting the escalating demands of a growing human and livestock population. As we confront the challenges of the present and future, agroforestry stands as a beacon of sustainable, inclusive, and resilient agricultural practices.

PROTECTIVE FUNCTIONS OF AGROFORESTRY SYSTEMS:

FOOD:

1. Agroforestryenhancescroppingsystemsustainabilitybypreventingsoilerosionthroughstrategically placed trees.
2. Increased food and feed production is achieved through nitrogen fixation, improved access to soil nutrients from deep tree roots, and enhanced nutrient availability through organic matter and mycorrhizal associations.
3. Agroforestry provides a direct source of food for humans, including fruits, seeds, cereal substitutes, and fodder for livestock.
4. Micro-climate improvements, especially from shelter-belt sand wind- breaks, contribute to the overall resilience of food production systems.

Water:

1. Improvedsoil-moistureretentioninrainfedcroplandsandpasturesisfacilitatedby enhanced soil structure and the micro-climate effects of trees.
2. Regulationofstreamflowreducesfloodhazardsandensuresamoreconsistentwatersu

pplyby decreasing run-off and improving water interception and storage.

3. Agroforestry systems assist in drainage improvement for waterlogged or saline soils by introducing trees with high water requirements.

Energy:

1. Agroforestry serves as adverse source of energy, providing fuel-wood for direct combustion.
2. Pyrolytic conversion products, including charcoal, oil, and gas, offer alternative energy resources.
3. Ethanolproductionfromthefermentationofhigh-carbohydratefruitscontributestorenewable energy sources.
4. Oils, latex, and combustible saps and resins further expand the range of available energy resources.

Shelter:

1. Agroforestry systems provide essential building materials for construction.
2. Shade trees cater to the needs of people, livestock, and shade-loving crops.
3. Wind-break sand shelter-belts protect settlements, croplands, pastures, and roadways.
4. Livefencesandfencepostsderivedfromagroforestryproductsmeetfencingrequirements.

Raw Material for Industries:

1. Agroforestry contributes raw materials for the pulp and paper industry.
2. Tannins, essential oils, medicinal ingredients, wood for agricultural implements, and various crafts are sourced from agroforestry.
3. Fiberforweavingisanothervaluableproductderivedfromagroforestrysystems.

Cash:

1. Agroforestry yields direct cash benefits through multiple products.

2. Indirecteconomicgainsarerealizedthroughincreasedsoilproductivityandthemaint enanceof fertility.

CATEGORIZATION OF AGROFORESTRY SYSTEMS:

Agroforestry demonstrates its adaptability in a number of different systems, including agri- silviculture, alley cropping, boundary, block, and energy plantations; agri-horticulture; agri-silvi- horticulture; agri-silvi pasture; horti-pasture; horti-olericulture; horti-pasture; livefence; forage forestry; shelter-belts; windbreaks; live fence; silvi or horti-sericulture; and homestead. This thorough classification highlights how adaptable agroforestry is to India's various agro-ecological zones, making it a highly useful and essential tool for rural development and sustainable land management. Categorization of Systems in Agroforestry

The following are typical agro-forestry systems that exist in various agro-ecological zones of India, based on the composition of their constituent parts:

1. Agri-silviculture(trees+crops)
2. Boundary plantation (tree on boundary +crops)
3. Block plantation (block of tree+block of crops)
4. Energy plantation (trees+crops during initial years)
5. Alley cropping(hedges+crops)
6. Agri-horticulture (fruit trees+crops)
7. Agri-silvi-horticulture (trees+fruittrees+crops)
8. Agri-silvipasture (trees+crops+pasture or animals)
9. Silvi-olericulture(tree+vegetables)
10. Horti-pasture (fruit trees+pasture or animals)
11. Horti-olericulture (fruit tree+vegetables)
12. Silvi-pasture(trees+pasture/animals)
13. Forage forestry (for age trees+pasture)
14. Shelter-belts(trees+crops)

15. Wind-breaks(trees+crops)
16. Live fence (shrubs and under-trees on boundary)
17. Silvi or Horti-sericulture (trees or fruit trees+sericulture)
18. Horti-apiculture (fruit trees+honeybee)
19. Aqua-forestry (trees +fishes)
20. Home stead (multiple combination of trees, fruit trees, vegetable etc).

CRITERIA FOR SELECTION OF TREE IN AGROFORESTRY SYSTEM

The selection of tree species in agroforestry systems is a critical decision that directly impacts the success and sustainability of the farming system. Several criteria guide this selection process, with a primary focus on the tree's ability to generate higher cash income. Considering the strong ties farmers maintain with their socio-cultural traditions, changes in farming systems are gradual, often aligning with increased income levels and a shift towards cash generation. The chosen tree species should possess the following essential characteristics:

SUITABILITY FOR AGRO-CLIMATIC CONDITIONS:

The tree species should be well-suited to the specific agro-climatic conditions of the region, ensuring optimal growth and productivity.

MULTIPURPOSE FUNCTIONALITY:

The selected tree should serve multiple purposes, addressing various needs of farmers. These may include providing timber, fodder, fuel, fruit, and fiber, contributing to a diversified income stream.

FAST-GROWING WITH SHORT ROTATION AND NARROW CROWN:

A desirable tree species should exhibit fast growth, facilitating short rotation cycles. Additionally, an arrow crown is preferred to minimize interference with arable crops, ensuring an efficient use of available land.

NITROGEN-FIXING CAPABILITY:

The tree species should have nitrogen-fixing abilities, promoting soil fertility and supporting the growth of companion crops.

NON-INTERFERENCE WITH ARABLE CROPS:

The selected tree should not adversely affect the growth and yield of arable crops, allowing for successful intercropping.

EASE OF ESTABLISHMENT:

The tree species should be easy to establish, minimizing the challenges associated with initial growth phases.

EASY DECOMPOSITION OF LEAF LITTER:

The leaf litter of the tree should decompose easily, contributing to nutrient cycling in the agroforestry system.

ABILITY TO WITH STAND LOPPING:

The tree should be resilient to lopping, ensuring sustainable harvesting practices without compromising its overall health.

EASY MARKET ABLE PRODUCE AND EMPLOYMENT GENERATION:

The tree's produce should be easily marketable, contributing to income generation. Additionally, the cultivation of these trees should create employment opportunities for local communities.

FAMILIAR IT WITH POLICIES:

Knowledge of policies related to land use, soil, vegetation, and socioeconomics, including trade and market policies, is crucial. This ensures alignment with regulatory frameworks and promotes sustainable agroforestry practices.

In essence, the selection of tree species in agroforestry systems involves a holistic consideration of ecological, economic, and sociocultural factors, aiming to create a

harmonious and sustainable farming environment.

CRITERIAFOR GOODAGROFORESTRY DESIGN:

Productivity:

A fundamental criterion is enhanced productivity. Agroforestry designs should result in increased output of tree products and improved yields of associated crops. This can be achieved through the reduction of inputs in the cropping system, enhanced labor efficiency, diversification of production, and the fulfillment of basic needs.

Sustainability:

The sustainability of production systems is paramount. Agroforestry designs should strive for long-term sustainability, not only achieving conservation goals but also aligning with the motivations of low-income farmers. Connecting with the economic interests of farmers enhances the likelihood of sustained adoption, making conservation a practical and beneficial goal.

Regardless of technical brilliance or environmental soundness, the effectiveness of an agroforestry design hinges on its adoption by intended users. Practical success relies on the alignment of technology with both the social and environmental characteristics of the specific land-use system for which it is intended. An agroforestry design must be adaptable to the needs, preferences, and practices of local communities, ensuring seamless integration into existing agricultural systems.

In essence, a good agroforestry design goes beyond the or ethical efficacy; it should demonstrably enhance productivity, promote sustainability, and, crucially, be readily adopted by the communities it seeks to benefit. This holistic approach ensures that agroforestry serves as a practical and impactful solution, aligning with the needs and aspirations of farmers while contributing to environmental conservation.

Understanding the intricate interactions among trees, crops, and soil is crucial for

those delving into the realm of agroforestry. In simultaneous agroforestry systems, trees and crops coexist, sharing both above-ground and below-ground spaces. The interactions between trees and crops can result in positive effects, known as facilitation, or negative effects, referred to as interference, impacting the growth of both components. These interactions, influenced by factors such as light, water, nutrients, and wind, are complex and extend to the soil. Indirect interactions also play a role, including those related to pests and diseases. Central to comprehending these interactions are the cycling processes of soil organic matter, nutrients, and water.

Positive Interactions (Below and Above-Ground):

Nutrient and Water Recycling:
Trees and crops mutually benefit from there cycling of nutrients and water within the system.

Role of Tree Root Systems:
Act as a 'safety-net' for leached nutrients below crop roots and function as a 'nutrient pump' for minerals in deep soil layers.

Improvement of Water Infiltration:

Old tree-root channels enhance water in filtration and reduces oil erosion.

Nitrogen Supply:

Tree roots contribute nitrogen through root decay or nitrogen fixation.

Mycorrhizal Associations:
Enhance phosphorus availability.

Litter Production and Soil Organic Matter:

Influences oil quality and maintain organic matter content.

Mulching:
Affects soil moisture and biological activity.

Shading and Micro climate Improvement:

Impact temperature, humidity, and other micro climatic factors, vital for certain crops like coffee.

Negative Interactions (Below and Above-Ground):

Competition for Light, Water, and Nutrients:

Above-ground competition for light and below-ground competition for water and

nutrients can occur.

1. **Pests and Diseases:**
   Inter cropping may introduce pests or diseases, impacting the overall health of the system.
2. **Allopathic Effects:**

Certain tree species may release all elopathic substances that hinder the growth of associated crops.

Management Strategies for Complex Agroforestry Systems:

Management options to manipulate component growth include:

Micro climate Amelioration:
Adjusting the local climate to optimize conditions for plant growth.

Fertilization:
Applying fertilizers to enhance nutrient availability.

Mulching or Manure Application:

Using mulch or organic manure to improve soil structure and fertility.

Irrigation:
Providing supplemental water to meet the water needs of the system.

Soil Tillage:

Cultivating the soil to improve aeration and nutrient availability.

Adapted Species:
Selecting tree and crop species that are well-adapted to the specific agroforestry system.

Supplemental Feeding:
Providing additional nutrients or supplements to enhance growth.

For Decreased Growth:

1. **Pruning:**
   Removing specific parts of trees or crops to control growth.
2. **Pollarding:**
   Systematically cutting back the upper branches of trees.
3. **Root Pruning:**
   Trimming or cutting tree roots to control growth.
4. **Trenching:**
   Creating trenches to limit root expansion.

5. **Excessive Shading:**

   Managing tree can opines to prevent excessive shading.

6. **Herbicide:**

   Using herbicides to control unwanted plant growth.

7. **Grazing or Browsing:**

   Allowing animals to graze or browse selectively to manage vegetation.

In navigating the complexities of tree-crops-soil interactions, understanding this principal sand implementing effective management strategies are vital for optimizing the benefits of agroforestry systems.

Innovative Agroforestry Systems for Enhanced Income:

Bamboo-Based Enterprises:

Establish bamboo plantations for sustainable harvesting, supporting industries such as bamboo crafts, construction, and furniture.

Paper and Pulp Industry:

Plant fast-growing trees suitable for paper and pulp production, fostering a sustainable source for the paper industry.

Fruit Processing Unit:

Integrate fruit-bearing trees into agroforestry to support a fruit processing unit, creating value-added products like jams, juices, and dried fruits.

Plywood Mills:

Incorporate species with high-quality wood suitable for plywood production, contributing to the timber industry.

Leaf Cup-Plate Units:

Explore the use of leaves from specific tree species for eco-friendly disposable cup and plate production, contributing to the emerging market for sustainable alternatives.

Fuel Wood Depots:

Designate areas for the sustainable cultivation of fast-growing trees for fuel wood, meeting the demand for cooking and heating.

Lac Processing Units:

Integrate lac-producing trees to support lac processing units, tapping into the demand for natural resin products.

Fiber Extractions and Rope Making Unit:

Cultivate fiber-producing plants for rope-making units, catering to various industries requiring natural fibers.

SUCCESSFUL AGROFORESTRY SYSTEMS IN INDIA

Adoption of Multipurpose Tree Species (MPTs):

Large-scale plantation of Eucalyptus, Casuarina, Poplar, Leucaena by companies like ITC and Wimco covering 5 million hectares.

West Coast Paper Mills:

Successful use of *AcaciaMangium* and *A.auriculiformis* for paper production.Hindustan Paper Mills:

Bamboo plantation with a preference for short rotation species.

Poplar Plantation sin Northern States:

Thirtymillionpoplartreesannuallyproducing1.125millionm3ofindustrialwood inUttar Pradesh, Haryana, and Punjab, integrated with traditional wheat-paddy crops

Agri-Silviculture Systems:

Poplar in 25,000 hectares and Eucalyptus in 5,000 hectares in Andhra Pradesh under agri-silvi systems with 6-8 years rotation.

Silvi-Pastoral Systems:

Integration of Dalbergiasissoo, Albizia with Cenchurusciliaris, ginni, Dinanath grass, generating 120-man days/ha/year employment over a 10-year period.

CONSTRAINTS IN AGROFORESTRY IMPLEMENTATION

Limited Regional Technologies:

Proven agroforestry technologies are available only for specific regions, limiting widespread adoption.

Limited Knowledge About Tree Species:

Farmers may lack knowledge about the selection of suitable tree species for agroforestry.

LegalRestrictions:

Rigid legal laws restrict the harvesting, transporting, and sale of trees, creating barriers to agroforestry operations.

Quality Planting Material:

Availability of quality planting material maybe limited, hindering successful agroforestry establishment.

Irrigation Shortages: Shortage of adequate irrigation facilities poses a challenge for agroforestry practices.

Lack of Fencing:

The absence of proper fencing leads to theft and harm to agroforest produce and livestock, posing additional challenges.

Overcoming these constraints requires a collaborative effort involving farmers, policy makers, and industry stakeholders to create an enabling environment for sustainable agroforestry practices.

AGROFORESTRY SYSTEMS DEVELOPED BY TFRI FOR CENTRAL INDIA

Teak-Turmeric Silvi-Medicinal System:

Integration of teak trees with turmeric, emphasizing medicinal plant cultivation.

Sissoo-Maize Silvi-Agri System:

Combining sissoo trees with maize crops to create a symbiotic silvi-agricultural system.

Lac Culture Model Silvo-Entomo System:

Implementation of a model integrating lac culture with silvo-entomology practices.

Bamboo-Based Silvi-Agri System:

Development of a system centered on bamboo cultivation in conjunction with agricultural practices.

MPTs Based Silvi-Olericulture System:

In corporation Multipurpose Tree Species (MPTs) into a silvi-olericulture system for diversified yields.

Teak-Safed Musli Silvi-Medicinal Systems:

Creating a silvi-medicinal system by combining teak trees with the cultivation of safed

musli.

Paddy-Babul Model:

Introducing a model that integrates paddy cultivation with babul trees, promoting sustainability.

Paddy-Bach Model:

Development of a model combining paddy cultivation with bach trees for optimized land use.

Different Tree-Farming Systems Adopted by Farmers in Maharashtra:

1. **Traditional Forestry:**
   Incorporating traditional tree species such as Teak, Khamer, Arjun, Babul, Neem, Albizia odoratissima, and Palas, along with fruit plants like mango, Ber, Bahera, Jamun, and Sitaphal.
2. **Farm Forestry:**
   Promoting farm forestry with the cultivation of Karanj, Babul, Sissoo, Su babool, Eucalyptus, Acacia mangium, Casurina, siris, and various bamboo species for both industrial and domestic uses.
3. **Block Plantations:**
   Implementing block plantations with trees like teak, sissoo (suitable for semi-waterlogged conditions), Eucalyptus, Su-babul (for paper and pulp), A. mangium (in the Konkan region), Casurina (in the Konkan and foothills of the Western Ghats), and various bamboo species for industrial and domestic purposes.
4. **Agri-Silvi System:**

Introducing agri-silvi systems, such as teak with crops, at spacingof2x2mor 3x3m.

5. **Horti–Agri System:**
   Integrating horticulture with agriculture, such as planting oranges with oleri crops, banana with oleri crops, sapota with oleri, and mango with oleri.
6. **Konkan Region-Horti-Floriculture:**
   Implementing horti-floriculture systems, involving grapes, banana, alphonso mango, cashew, and floriculture, spices, and medicinal plants under irrigated

conditions.

The development of these agroforestry systems showcases the versatility and adaptability of integrated tree-crop systems to the agro climatic conditions and farmer requirements in Central India and Maharashtra.

BAMBOO BASED SILVI-AGRI MODEL

Edaphic and environmental requirements of Model	This model will perform better in well drained Sandy loam soil condition with optimum irrigation during its early period (first 1 -2 years). Bamboo can grow in river and gullies to control the soil erosion and conserve moisture. The system is not suitable underclay, black cotton soil and water-logged areas which affect teak growth. Usually comes well in 15- 40^{o}C with annual rainfall range of 800-2500mm and prefers sea-level to an altitude of 1200m.
Significance of the model	Generally, farmers are not aware about the high yielding bamboo species thornless bamboo species as well as quality planting materials (seedlings and clones) and also for technical inputs on bamboo farming especially unsustainable harvesting methods. They are adopting desi lathi bamboo (*Dendrocalamusstrictus*) in field bunds not much knowledge about different bamboo species suitability in different soil condition along with crop combinations.
Improved technique	Research institutions and SFDs are developing quality planting materials (seedlings from CSO, SSO and SPAs and clones from plus trees). Farmers can grow various inter crops *viz.* urad, wheat, etc. up to 5 years, till the bamboo canopy closes. Bamboo farming will provide income till 40 years of its age at one planting. Weeding should be done three times during each cropping period to get maximum production from annual crops Further, turmeric is partial shade loving crop and require moist condition which favors more yield. Introduction of teak with turmeric will give additional income to farmers by Using the natural recourses in an optimum way.

 	preferred for best survival and easy establishment. High yielding thorn less bamboo species *viz. Bambusa nutans,* *B.balcooa, B.tulda, B.vulgaris,* etc. are highly suitable for this model. Vegetative propagated seedlings of bamboos should be preferred for best survival and easy establishment in the main field. Bamboo seedlings (400 seedlings ha^{-1}) should be planted @ spacing of 5 x 5 m after making pits size of 45 cm^3 during the onset of monsoon. Bamboos are managed by timely pruning of the culms from II^{nd} year onwards to avoid the congestion within the culm/clump and to maintain a healthy growth to fetch better growth and returns. Lateral roots of bamboo should be pruned at 2.5 m away from the periphery of the clump to reduce root competition within associate intercrops. Variety306ofwheat (average yield0.16tha^{-1}) and Jawahar Urad(averageyield0.10tha^{-1}) should be preferred. Further, farmers can grow various inter crops *viz.* urad, wheat, etc. up to 5 years, till the canopy closes. Weeding should be done three times during each cropping period to get maximum production from annual crops. Application of Chlorpyriphos 20 EC @ 2 ml l^{-1} soon after first monsoon showers kills the adults of termites and white grub and reduces the infestation level. Timely pruning of lateral branches of bamboo is required to get straight culm (stem)and to avoid conjunction within the clump. Yearly Two times weeding is necessary.

Rotation period &Yield   	Bamboo culms can be harvest from 4th year onwards. Generally, bamboo is ready to harvest from 5th year onwards under monoculture but in Agroforestry, it is ready to harvest after 4th year due to its fast growth and benefited from the various inputs given to annual crops. Bamboo harvest should be start during March-Aprilmonth i.e. before on set of monsoon @ 6 -7 culms per clump (average height 11m and 15cm diameter, @ Rs.100 per culm) may be obtained subject to growth and maintenance of the system. Agriculture crops-wheat (average yield 0.16 t ha^{-1}) and Urad (average yield 0.10 t ha^{-1}) can be obtained from the system.

- **BACH-PADDY AGRI-MEDICINAL MODEL**

 	preferred for best survival and easy establishment. High yielding thorn less bamboo species *viz. Bambusa nutans, B.balcooa, B.tulda, B.vulgaris,* etc. are highly suitable for this model. Vegetative propagated seedlings of bamboos should be preferred for best survival and easy establishment in the main field. Bamboo seedlings (400 seedlings ha^{-1}) should be planted @ spacing of 5 x 5 m after making pits size of 45 cm^3 during the onset of monsoon. Bamboos are managed by timely pruning of the culms from II^{nd} year onwards to avoid the congestion within the culm/clump and to maintain a healthy growth to fetch better growth and returns. Lateral roots of bamboo should be pruned at 2.5 m away from the periphery of the clump to reduce root competition within associate intercrops. Variety306ofwheat (average yield0.16tha^{-1}) and Jawahar Urad(averageyield0.10tha^{-1}) should be preferred. Further, farmers can grow various inter crops *viz.* urad, wheat, etc. Up to 5 years, till the canopy closes. Weeding should be done three times during each cropping period to get maximum production from annual crops. Application of Chlorpyriphos 20 EC @ 2 ml l^{-1} soon after first monsoon showers kills the adults of termites and white grub and reduces the infestation level. Timely pruning of lateral branches of bamboo is required to get straight culm (stem)and to avoid conjunction within the clump. Yearly two times weeding is necessary.

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Economics of the model	**TotalExpenditure**-Rs.96,000ha^{-1}(inclusive of field operations) **Income from Urad and Wheat**- 1) Rs. 40,000 ha^{-1}, 2) Rs. 70,000 ha^{-1} **Income from bamboo poles**-Rs.2lakhsha^{-1}@Rs.100per culm = 2000 culm (first harvest after 4 years **Net Income**–Rs2.17lakhs
Impact and up scaling	Bamboo – Urad /Wheat Agroforestry model has potential to provide additional income in a sustainable manner and this model will fulfill the government goal of ‘Doubling the farm income’ from its intercrops within short rotation period of 5 years. Further the model generates rural and women employment opportunities throughout the year. In addition, this model improves soil fertility and increase the overall productivity.

	In the rice field during IInd week of July–August at the spacement of 30 cm X 30 cm. **Farm Yard Manure**:15trolleytha^{-1}ofFYMis necessary for the Bach-paddy system It shouldbeapplied1/4thofquantity (3.5) as basal dressing, half of the quantity (7) after two months of planting and remaining 1/4th quantity (3.5) after6th month of crop. Further, farmers can grow bacha long with paddy up to 5 years, till its lateral roots will spread. Weeding should be done three times during each cropping period to get maximum production from annual crops. bach is highly sensitive to salinity. The crop is free from grazing. The crop is resistant to insect-pests and fungal attacks. The first yearcropprovidesplantingmaterialfornextseasonatleastforonehectareareabesides Marketable produce.
Rotation period & Yield 	**Best time for harvesting**: Approximately 10 months after planting in rice field. **Yield**: 3.5 t. ha^{-1} of dried rhizome (Rs70 - 80kg^{-1}) or planting material (fresh rhizomes 1 lakh propagules @ Rs.1.00) for 1 ha.

Economics of the model 	**Total Expenditure: Rs.1,20,000** (inclusive of field operations cost of planting material, preparation of field, FYM, Wages) **Income from paddy:** Rs. 50,000 **Income from Bach plants**: Rs. 2 lakhs (market rate) **Net Income**: Rs1.30 lakhs
Impact and up scaling	Bach-paddy Agroforestry model having the potential to provide additional net farm in comet farmers' and will one of the best models for Doubling the farm income' in short rotation period of years. In addition, this model can Utilize the water logged are an efficiently and

- **FLEMINGIA BASED SILVI-AGRI-LAC MODEL**

Edaphic and environmental Requirements of Model	This System will perform better under well drained sandy loam soil condition. Since the *Flemingia* plants are fast growing in nature and having narrow crown, hence farmers' can utilize its interspaces by growing traditional agriculture crop Like *Cajanuscajan* for their regular income. Usuallycomeswellin15-40^{o}Cwithannual rainfallrangeof800-2500mmandpreferssea level to an altitude of 1200 m.

Existing practice	Lac growing farmers are not aware of quality planting materials (seedlings and brood lac) and also technical know how about the species on lac farming on Flemingia. Lac Farming – Usually farmers are practicing lac farming on old traditional host existing on their field bunds unscientific manner without using high yielding improved varieties.
Improved technique	Research institutions and SFDs are engaged to develop quality planting materials (seedlings from CSO, SSO and SPAs and clones from plus trees). Further, lac farming require moisture for its maximum yield. Introduction of lac cultivation of Flemingia under Agroforestry system will provide additional income to farmers by using the natural Recourses in an optimum way.
Significance of the model	This model is beneficial for the Lac growers especially farmers' who are not having traditional Lac host trees like (*B.monosperma*) or Kusum (*S. oleosa*) in their field bunds. *Flemingiasemialata* Roxb. is a bushyleguminous plant and proved as a good host to kusumi strain of Lac. This *F.semialata* plants are ready to inoculate Brood lac within a year after its planting and framers' can Maintain this model and get lac up to8years.

Establishment and management of model

Seeds of *F.semialata* should be sown during April month in the poly bags with 1:1:1 ratio of soil, sand and FYM mixture and the seedlings will be ready for the transplantation during rainy season. Healthy seedlings should be preferred for best survival and easy establishment. Land should be ploughed and FYM may be applied (10 t ha^{-1}) as basal dressing in the month of May. *Flemingia* seedlings (625 plants ha^{-1}) should be planted @ spacing of 4 x 4 m after making pits size of 45 cm^3duringtheonsetofmonsoon.Soilsurfacealongthe pit should be treated with chlorpyriphos (2g in one lit solution) to control termite attack before rainy season. After one Year of planting, plants are ready to raise good quality of brood lac during rabi season is the best time for its cultivation. **Cajanus cajan cultivation**-Ashavarietyof*cajan*av erage yield 0.10 t ha^{-1}) July @ 75cm x 75 cm spacing after transplanting of *Flemingia* plants to manage the field activity. Weeding should be done three times to get maximum production.

Lac farming- Farmers are not much aware about the scientific cultivation of Lac. Good quality Brood lac should be selected by the farmer to get maximum yield. Farmers' can select healthy, soft, disease-free shoots for the infestation of Brood lac (@ 40 g plant $^{-1}$). Research institutions are developing quality planting materials (seedlings and Brood lac from good quality seeds from plus trees). *Fsemialata* plants should be pruned from its up to maintain certain height(upto1.5) for easy Cultural operations like weeding, ploughing, etc.

Rotation period & Yield 	Flemingia seedlings is ready for lac cultivation after one year of its planting. The plant is a shrub and needs to maintain certain height (2.5m) and more branches for management of lac crop. The lac crop will be ready to harvest within a year.
Economics of the model	**Economics of the model:** **Total Expenditure- Rs. 75,000** ha^{-1} (inclusive of field operations) **IncomefromLacandArhar**-1) Rs.1,00,000ha^{-1} 2)Rs. 1,00,000ha^{-1} *F. semialata* based silvi-agri-lac model has potential to generate Rs. 1.25 lakhs yr^{-1} ha^{-1} than monoculture of conventional crops like Lac (Rs. 1,00,000 ha^{-1}) orarhar (Rs.1,00,000 ha^{-1}).
Impact and upscaling	The *Flemingia* plant is so easy to maintain even by the women and within their small piece of land. TFRI has introduced first time of this Lac host species in tropical region of Madhya Pradesh to explore the possibilities of Lac culture on *Fleminga* under Agroforestry model with agriculture crop *Cajanus cajan* and become popular among the Lac growers due to its short period of maturity (i.e. two years). This model is able to generate income as well as employment throughout the year as compared to traditional farming also improves soil fertility and provide additional income. Training and demonstrations are most important component to popularize this model among the farmers 'especially for rural women with one time investment.

SILVICULTURE IN AGROFORESTRY

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INTRODUCTION

The theory and practice of controlling establishment, composition and growth of the forest". In other words, Silviculture is that branch of forestry which deals with the establishment, development, care, and reproduction of stands of timber or forests. In general, Silviculture may be defined as art and science of growing and reproducing timber stands on permanent or regular basis.

Silviculture has been defined variously authors. According to Toumey and Korstian, 'silviculture is that branch of forestry which deals with the establishment, development, care and reproduction of stands of timber'. Indian Forest and Forest Products Terminology, published by the Forest Research Institute and Colleges, Dehra Dun, defines silviculture as, 'the art and science of cultivating forest crops. According to Champion and Seth, 'the term silviculture in English commonly refers only to certain aspects of theory and practice of raising forest crops. Though from the above definitions, there appears to be some diversity in views about the scope of silviculture, yet, in a broad sense, silviculture may be taken to include both silvics and its practical application. According to Indian Forest and Forest Products Terminology, silvicsis 'the study of life history and general characteristics of forest trees and crops with particular reference to environmental factors, as the basis for the practice of silviculture'. Thus, silvics implies the study of trees and forests as biological units, the laws of their growth and development and the effect of environment on them. It explains the natural laws of their growth and development and their behaviour in a given set of environmental conditions. It deals obtaining natural regeneration under the various silvicultural systems, artificial regeneration of various species, and methods often ding young crops, whether natural or artificial to help them to grow into forests of quality timbers and great economic value. Silviculture is not a purely biological science which has no relation with economics. The foresters raise the forests and tend them for the service of the people, but this is not to be done at prohibitive cost. If forests are to be grown for the public good, the methods of raising and tending them, developed on the basis of knowledge of silvics, will to be modified in practice by economic considerations. Silviculture has been rightly described as an art and in this art, intuition plays an important part. In our own country as well as in the European countries, there have been foresters who have advocated that, in case of doubt, the trees should be approached for answer. Even today, the local flora is regarded to be the best guide about the suitability of a species for a particular site. This is so because in nature there are so many complex factors at play that it is only the vegetation that can give an indication of the possible solution. But in order to understand the indication of the vegetation or answer of the trees, it is necessary for the forester to be conversant with their language and proficiency in this art comes by close continuous observation and experience.

AIMS AND OBJECTIVES OF SILVICULTURAL PRACTICES

The objectives of silviculture may be one or more of the following:
To yield produce of a definite description, for instance trees and shrubs of special beauty, or trees giving a certain kind of timber, or other produce fit for particular purposes, such as grass, turpentine, etc.
To produce greatest quantity of wood or other produce per acre and per year.
To produce the highest possible money return on the invested capital.
To produce certain indirect effects, for instance, influence on climate, to regulate the 'drainage of the country, to prevent landslips or avalanches, to arrest shifting sands.

OBJECTS OF STUDY OF SILVICULTURE

The forests are as old as the universe; naturally they must have been growing and renewing themselves. It is a well-known fact that forest preceded civilization in every part of the world. Management of the forests by the Forest Departments is a very recent phenomenon. Even today, there are virgin forests in many parts of our country. The N question naturally arises as to what use is the study and practice of silviculture and why should a forester take upon himself the work that the nature had been doing all these years. The answer to this question is purely economic. The object study and practice of silviculture is to produce more useful and valuable forests to meet our multifarious requirements, than nature would do and that too, in a shorter time. The objective with which nature produces vegetation are not identical with that of man. The former produces a ‘jungle’, the latter forest. The study of silviculture helps in:

1) Production of species of economic value–In the virgin forests, many of the species are generally neither very valuable nor useful. Therefore, the production of timber of species of economic value per unit area is low. If the forests have to produce timber of industrial and economic importance, it is necessary to study and practice silviculture so that we can produce only the desired species.

2) Production of larger volume per unit area – In the virgin forests, the crop is generally either very dense or very open. Both the se extremes are unsuitable for quantitative production. If the crop is very dense, the growth of the individual trees is adversely affected resulting in lesser timber volume production per unit area. On the other hand, if the crop is very open, the number of trees, and consequently volume, per unit area would be less. Besides this, a large number of trees die out as a result of competition before reaching maturity. In the unmanaged forest, they are not utilized and that volume of timber is lost. The study and practice of silviculture helps in raising sufficienttreesperunitsarearightfromthebeginningtofullyutilizethesoilandasthey grow up, gradually reduce the number so that the requirement of light and food of the remaining trees is met. In this way, while by raising sufficient number of trees, the volume production per unit area is increased, the utilization of the excess trees as the crop grows in age, prevents the loss and consequently further increases that volume.

3) Production of quality timber – In the unmanaged forests, because of intense competition, a large number of trees become crooked, malformed, diseased and defective. This results in the deterioration of the quality of timber produced. If the production of quality timber is to be ensured, knowledge of silviculture will be essential so that the trees can be grown in disease free condition without adverse competition.

4) Reduction of rotation–In the virgin forests because of intense competition in the dense parts, the rate of growth of the individual tree is retarded with the result that it takes longer time to reach the size at which it can be exploited. This increases the cost of production of timber. With the knowledge and practical application of silviculture, the density of the crop can be properly regulated and consequently the rate of growth increased and rotation reduced.

5) Raising forests in blank areas – In nature, a large number of areas, potentially suitable for tree growth, occasionally remain blank due to certain adverse factors inhibiting growth of trees. Silvicultural skills and techniques help in raising forest in such areas.

6) Creation of manmade forests in place of natural forests – There may be areas in natural forests which may not regenerate or reproduce themselves naturally or where natural regeneration may be extremely slow and uncertain. In such areas, it becomes necessary for the forester to take up the work of nature in his hand and raise manmade forests in such areas. Success in this endeavour can be achieved only when he has a good knowledge of the science and art of raising forest crops artificially.

7) Introduction of exotics – The indigenous species may not be able to meet the commercial and/or industrial demands. In such areas, efforts are made to introduce exotics which can grow in that particular locality and can supply the timber required by industries, etc., in time. For example, the demand of paper is increasing very fast. There is no indigenous species which may grow in a variety of sites easily and very fast so that the demand of the paper pulp industry may be met.

FORESTRY, ITS SCOPE AND CLASSIFICATION

Forestry is defined as the theory and practice of all that constitutes the creation, conservation and scientific management of forests and the utilization of their resources. It is an applied science which is concerned with not only the raising or cultivation of forest crops but their protection, perpetuation, mensuration, management, valuation and finance as well utilization of the forest products for the service of the nation. In favorable localities, this science is applied to get maximum return and so it is called intensive forestry which is defined as the practice of forestry with the object of obtaining the maximum in volume and quality of products per unit are through the application of the best techniques of silviculture and management. When forestry is practiced to achieve more than one purpose, it is called multiple-use forestry which is defined as the practice of forestry for the simultaneous use of a forest are for two or more purposes, often in some measure conflicting, e.g., the production of wood with forest grazing and/or wildlife conservation. Based on the objectives, forestry is classified as under: a)

Protection forestry–Protection forestry is the practice of forestry with the primary object of

(1) protecting lands whether those upon which the forest is situated or those at a distance from it, against wind and water erosion,

(2) conserving water supplies for human consumption, fish culture, etc.,

(3) reducing hazards from flood damage to human life and property and

(4) amelioration of adverse climatic effects.

b) Commercial forestry –Commercial forestry is the practice of forestry with the object of producing timber and other forest products as a business enterprise. A specialized aspect of commercial forestry is to meet the requirement of a particular industry and in that case, it is called industrial forestry which is defined as the practice of forestry to sustain a given industrial enterprise, such as a sawmill, pulp mill, chemical plant or a combination of these.

c) social forestry – Social forestry is the practice of forestry on lands outside the conventional forest area for the benefit of the rural and urban communities. Supply of fuel wood to divert cow dung from village hearths to village fields, small timber for rural housing and agricultural implements, fodder for the cattle of the rural population living far away from the forest areas, protection of agriculture by creation of diverse ecosystem and arresting wind and water erosion and creation of recreational forests for the benefit of the rural as well as urban population are the basic economic and cultural needs of the community without which there can be no improvement in the conditions of their living. The application of forestry technology to achieve this social objective is known as social forestry.

SILVICULTURE AND FOREST MENSURATION

Forest mensuration is defined as that branch of forestry which deals with the determination of dimensions, form, volume, age and increment of logs, single trees, stands or whole woods. Thus, while silviculture deals with raising of forest crop, forest mensuration deals with measurement of diameter and heights of crop so produced, calculation of its volume, age, etc., for sale and research to decide the best treatment to be given to the crop while it is being raised. Silviculture and Forest Utilization Forest utilization is defined as the branch of forestry concerned with the harvesting, conversion, disposal and use of the forest produce. Thus, while silviculture is concerned with the cultivation of forest crops, forest utilization is concerned with the harvesting and disposal of crops so produced.

SILVICULTURE AND FOREST ECONOMICS

Forest economics is defined as those aspects of forestry that deal with the forest as a productive asset, subject to economic laws. Thus, while silviculture is concerned with the cultivation of forest crop, forest economics works out the cost of production including rental of land and compound interest on capital spent in raising the crop, and compares it with the sale proceeds to decide whether raising of the crop is economically profitable or not. It is also the function of the forest economist to compare the cost of production of a particular crop by different methods and then decide the most profitable method of raising that crop.

SILVICULTURE AND FOREST MANAGEMENT

Forest management has been defined as the practical application of the scientific, technical and economic principles of forestry. Thus, while silviculture deals with the cultivation of forest crop, forest management manages that crop according to the dictates of the forest policy. Silviculture deals with the techniques and operations which result in the development of a forest. Forest management prescribes the time and place where the silvicultural techniques and operations should be carried out so that the objects of management are achieved. The various branches of forestry are so closely related that the considerations of one branch influence the techniques of the other branches. For example, silvicultural techniques and operations are governed by the consideration of cost and modified to suit the requirement of protection. Similarly, even the most profitable method of exploitation or harvestings has to be given up if it is not compatible with silvicultural techniques or the protective considerations.

SILVICULTURE AND FORESTRY

From the definition of forestry given earlier, it is clear that forestry has a very wide scope and silviculture is only one of its branches. It has the same relation with forestry as agronomy has with agriculture. While agronomy and silviculture deal with cultivation of crops, agriculture and forestry deal not only with the cultivation of crops but also with their protection, management, mensuration, marketing, etc. In short, forestry is an applied science which has many branches. It may be compared to a wheel. Silviculture is the hub of the wheel; it is neither the whole wheel nor is it the only essential part. But, just as a cartwheel composed of several sections is supported on its hub, similarly forestry and its other branches are supported on silviculture without which there would be neither forestry nor its branches.

THE TREE AND THE FOREST

THETREE

Tree is essentially a plant. Plants may be classified into the following three categories: i) Herb, ii) Shrub and iii) Tree i) Herb is defined as plant whose stem is always green and tender and height is usually not more than one metre. According to the span of life, it is called annual, biennia or perennial. ii) Shrub is defined as a woody perennial plant differing from a perennial herb in its persistent and woody stem and less definitely from a tree in its low stature and its habit of branching from the bare. A shrub is usually not more than 6 metres in height. Both these categories of plants supply, if at all, economic minor forest products only. As they are very small in size, they do not produce timber but shrubs are used as firewood. iii) Tree is defined as a large woody perennial plant having a single well-defined stem (bole or trunk) and a more or less definite crown. A tree is usually more than 6 metres in height which can, according to species, be up to 127 metres. For example, height of a Pseudosugataxifolia tree in British Columbia has been measured to be 127.1 m and that of a Sequoia sempervirens tree in California has been found to be 112.1 m. In India, the maximum height so far recorded is not more than 75 m. A scrutiny of the record of heights of trees reveals that the conifers are taller than the broad-leaved trees. For example, while the maximum height of deodar has so far been recorded to be 73.2 m, those of teak and sal have been found to be only 58.5 m and 51.2 m respectively. From the point of view of girth also, the Sequoia of California and the Eucalyptus of Australia are the biggest because they have attained girths of 3574 cm and 2438 cm respectively. In India the maximum girth so far recorded is 1646 cm, of a deodar in kulu (Himachal Pradesh). The maximum girths of teak and sal are even less; these have beenrecordedtobeonly625cm and782cmrespectively. Even from the point of view of age, tree has very much more longevity than the shrubs and the herbs. For example, age of a Sequoia sempervirens of California has been estimated to be more than 4000 years. In India, the age of a deodar tree, whose section is preserved in the F.R.I. was found to be 704 years. Of the other Indian species, maximum ages of teak and Dalbergialatifolia have been estimated to be 500 years and 600 years respectively. All trees provide timber from their stem and thick branches while the thinner branches and hollow portions of stem are used a fire wood.

The tree can be divided into three parts: TREE THE CROWN Above the ground (i) The crown (ii)The stem Below the Ground –(iii) Theron

Silviculture and quality of forests and woodlands to meet the diverse needs and values of landowners and society such as wildlife habitat, timber, water resources, restoration, and recreation on a sustainable basis. This is accomplished by applying different types of silvicultural treatments such as thinning, harvesting, planting, pruning, prescribed burning and site preparation. Intermediate treatments (thinning) are designed to enhance growth, quality, Vigor, and composition of the stand after establishment or regeneration

and prior to final harvest. Regeneration treatments (harvesting) are applied to mature stands in order to establish a new age class of trees. Regeneration methods are grouped into four categories: coppice, even-aged, two-aged, and uneven-aged.

All vegetation activities, including prescribed fire, wildlife habitat improvement, timber harvesting and cutting trees in campgrounds for human safety must have a silvicultural prescription. A silvicultural prescription is a document which has a planned series of treatments designed to change current stand structure and composition of a stand to one that meets management goals. The prescription normally considers ecological, economic, and societal objectives and constraints. In the Forest Service, silvicultural prescriptions are prepared or reviewed by a certified silviculturist prior to implementing the project or treatment.

DIFFERENT TYPES OF SILVICULTURE SYSTEM IN AGROFORESTRY

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SILVICULTURE SYSTEMS

The origin of forestry in German-speaking Europe has defined silvicultural systems broadly as high forest (*Hochwald*), coppice with standards (*Mittelwald*) and compound coppice, short rotation coppice, and coppice (*Niederwald*). There are other systems as well. These varied silvicultural systems include several harvesting methods, which are often wrongly said to be a silvicultural system, but may also be called rejuvenating or regenerating method depending on the purpose.

REGENERATIONS

Regeneration is basic to the continuation of forested, as well as to the afforestation of treeless land. Regeneration can take place through self-sown seed ("natural regeneration"), by artificially sown seed, or by planted seedlings. In whichever case, the performance of regeneration depends on its growth potential and the degree to which its environment allows the potential to be expressed Seed, of course, is needed for all regeneration modes, both for natural or artificial sowing and for raising planting stock in a nursery.

The process of natural regeneration involves the renewal of forests by means of self-sown seeds, root suckers, or coppicing. In natural forests, conifers rely almost entirely on regeneration through seed. Most of the broadleaves, however, are able to regenerate by the means of emergence of shoots from stumps (coppice) and broken stems

FOREST TREE PLANTATIONS

Plantation establishment criteria

Plantations may be considered successful when outplant performance satisfies certain criteria. The term "free growing" is applied in some jurisdictions. Ontario's "Free-to-Grow" (FTG) equivalent relates to a forest stand that meets a minimum stocking standard and height requirement, and is essentially free of competition from surrounding vegetation that might impede growth. The FTG concept was introduced with the advent of the Forest Management Agreement program in Ontario in 1980 and became applicable. to all management units in 1986. Policy, procedures, and methodologies readily applicable by forest unit managers to assess the effectiveness of regeneration programs were still under development during the Class Environmental Assessment hearings.

In British Columbia, the Forest Practices Code (1995) governs performance criteria. To minimize the subjectivity of assessing deciduous competition as to whether or not a

plantation is established, minimum specifications of number, health, height, and competition have been specified in British Columbia. However, minimum specifications are still subjectively set and may need to be fine-tuned in order to avoid unwarranted delay in according established status to a plantation. For example, a vigorous white spruce with a strong, multi-budded leading shoot and its crown fully exposed to light on 3 sides would not qualify as free-growing in the current British Columbia Code but would hardly warrant description as unestablished.

TENDING

Tending is the term applied to pre-harvest silvicultural treatment of forest crop trees at any stage after initial planting or seeding. The treatment can be of the crop itself (e.g., spacing, pruning, thinning, and improvement cutting) or of competing vegetation (e.g., weeding, cleaning).

PLANTING

How many trees per unit area (spacing) that should be planted is not an easily answered question. Establishment density targets or regeneration standards have commonly been based on traditional practice, with the implicit aim of getting the stand quickly to the free-to-grow stage. Money is wasted if more trees are planted than are needed to achieve desired stocking rates, and the chance to establish other plantations is proportionately diminished. Ingress (natural regeneration) on a site is difficult to predict and often becomes surprisingly evident only some years after planting has been carried out. Early stand development after harvesting or other disturbance undoubtedly varies greatly among sites, each of which has its own peculiar characteristics.

For all practical purposes, the total volume produced by a stand on a given site is constant and optimum for a wide range of density or stocking. It can be decreased, but not increased, by altering the amount of growing stock to levels outside this range. Initial density affects stand development in that close spacing leads to full site utilization more quickly than wider spacing. Economic operability can be advanced by wide spacing even if total production is less than in closely spaced stands.

GROWTH AND YIELD

In discussing yields that might be expected from the Canadian spruce forests, Haddock (1961)[6] noted that Wright's (1959) quotation of spruce yields in the British Isles of 220 cubic feet per acre (15.4 m^3/ha) per year and in Germany of 175 cubic feet per acre (12.25 m^3/ha) per year was misleading, at least if it was meant to imply that such yields might be approached in the Boreal Forest Region of Canada. Haddock thought that

Wright's suggestion of 20 to 40 (average 30) cubic feet per acre (1.4 m^3/ha to 2.8 m^3/ha (average 2.1 m^3/ha) per year was more reasonable, but still somewhat optimistic.

The principal way forest resource managers influence growth and yield is to manipulate the mixture of species and number (density) and distribution (stocking) of individuals

that form the canopy of the stand. Species composition of much of the boreal forest in North America already differs greatly from its pre-exploitation state. There is less spruce and more hardwoods in the second-growth forest than in the original forest; Hearn den et al. (1996) calculated that the spruce cover type had declined from 18% to only 4% of the total forested area in Ontario. Mixed wood occupies a greater proportion of Ontario's second-growth forest (41%) than in the original (36%), but its component of white spruce is certainly much diminished.

Growth performance is certainly influenced by site conditions and thus by the kind and degree of site preparation in relation to the nature of the site. It is important to avoid the assumption that site preparation of a particular designation will have a particular silvicultural outcome. Scarification, for instance, not only covers a wide range of operations that scarify, but also any given way of scarifying can have significantly different results depending on site conditions at the time of treatment. In point of fact, the term is commonly misapplied. *Scarification* is defined[2] as "loosening the top soil of open areas, or breaking up the forest floor, in preparation for regenerating by direct seeding or natural seed fall", but the term is often misapplied to practices that include scalping, screefing, and blading, which pare off low and surface vegetation, together with most off its roots to expose a weed-free surface, generally in preparation for sowing or planting thereon.

Thus, it is not surprising that literature can be used to support the view that the growth of seedlings on scarified sites is much superior to that of growth on similar sites that have not been scarified, while other evidence supports the contrary view that scarification can reduce growth. Detrimental results can be expected from scarification that impoverishes the rooting zone or exacerbates edaphic or climatic constraints.

Burning site preparation has enhanced spruce seedling growth, but it must be supposed that burning could be detrimental if the nutrient capital is significantly depleted. An obvious factor greatly influencing regeneration is competition from other vegetation. In a pure stand of Norway spruce, for instance, Roussel (1948) found the following relationships:

Percent cover (%)	**Vegetation Description**
Below 1	No vegetation
1-3	Moss carpet with a few fir seedlings
4-10	Herbaceous plants appear
10-25	Bramble, herbs, fairly vigorous spruce seedlings
>25	Herbs, brambles very dense, vigorous, no moss

A factor of some importance in solar radiation–reproduction relationships is excess heating of the soil surface by radiation. This is especially important for seedlings, such as spruce, whose first leaves do not shade the base of the stem at the soil surface. Surface temperatures in sandy soils on occasion reach lethal temperatures of 50 °C to 60 °C.

GIS APPLICATION FOR MAPPING OF AGROFORESTRY TRESS

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MAPPING AGROFORESTRY EXTENT

Remote sensing data effectively captures various characteristics of the earth's surface with distinctive reflectance values enabling for the discrimination of classes (AFS, forestry, agriculture) based on their spectral signatures.

However, it needs the interpreter's knowledge about:

- shape, texture, patterns, and site context to derive information
- about land use activities from information about the land cover
- Especially, mapping the AFS extent requires a thoughtful and systematic approach as well as skill and mainly depends on various parameters:

  - Definition of AFS
  - Scale
  - Spatial dataset
  - Type of analysis (classifier)
  - The timing of dataset
  - A good sample of ground control points (training points) to be considered

Definition of AFS

It is a land use system that cultivates woody perennials in monoculture (plantation) or polyculture on agricultural lands, regardless of animals or crops.

Types of imagery and resolution

The spatial and spectral resolution has a critical role in the analysis of AFS resources, as it increases the efficiency, accuracy, as well as detailed mapping of the AFS patches over the larger areas and influences the selection of the image classification technique. The delineation of the AFS class and species categorization using the **multispectral data** is limited due to lack of the spectral variance that discriminates the species through modest spectral differences.
Hyperspectral datasets have the potential to collect the reflectance of AFS class or trees in over a hundred (typically 64–425) abundant and continuous narrow bands that can distinguish discriminately between spectrally similar objects due to their capability to address vegetation chemistry.
Thus, **hyperspectral datasets** on their own may be used well for developing spectral

signatures and categorizing land use or tree species

Simultaneously, the recent advancements and increased availability of the space-borne **SAR data**, like Sentinel-1 (C band), also expand the possibilities for monitoring AFS cover change and above-ground biomass.

Timing of Spatial Dataset

The timing of image acquisition in tree species mapping has a critical role in optimizing the classification accuracy. Each tree species has a distinct spectral signature during a particular period of the year owing to the phenological and seasonal behavior of tree which has an enormous potential for accurate tree species identification and improvement in crop classification.
Notably, for AFS patch delineation, multi-seasonal images, ideally from two critical periods, should be acquired. First is during the starting of Kharif season (June to August) and second is during ending of Kharif season (September–October).

Image classification technique (Classifier)

The choice of appropriate image classification techniques (ICT) also plays a substantial effect on the mapping of AFS patches.

The selection of the ICT depends on the user's need, the spatial resolution of product, and time constraints. Several approaches of image classification exist, although for AFS, class identification can be broadly classified into **unsupervised, supervised,** and **algorithmic.**

Unsupervised classification (clustering-based algorithm) entails the generation of several spectral classes from the partition of the spectral image from the statistical information inherent in the imagery.

In Supervised classification, prior knowledge, i.e., reference data for each spectral or land use class from the region, is utilized to train the classifier and generate the individual spectral class.

Machine learning algorithms (MLAs) particularly nonparametric-based classification have gained significant attention in the recent years due to their high potential for effectively and efficiently classifying satellite imagery, besides handling the high dimensionality data and map spectral classes with very complex characteristics like AFS.

Ground control points and accuracy assessment

Accuracy assessment and validation of the classification is an integral part of the mapping and monitoring resources. However, the quantity and distribution of ground control points (GCP), as well as sampling techniques, play a crucial role in assessing the accuracy of the classified image.

CARBON SEQUESTRATION (CS) ASSESSMENT OF AFS

AFS has immense potential in the mitigation of atmospheric accumulation of greenhouse gases especially the carbon dioxide through CS and is widely recognized. The AFS acts like a carbon sink, and its potential depends on the species composition and their age, geographical location, local climatic condition, and management intensities.
In recent times, RS-GIS provided the essential inputs for effective and efficient estimation as well as monitoring of biomass, productivity, C stock, and flux at any scale. Primarily, the AGB production through the variation in the spectral attributes as the vegetation absorbs the red energy and reflects near-infrared (NIR) energy indicates the differences in biophysical attributes related to biomass accumulation. Despite above, C stocks of AFS can be assessed using the different models or species or region-specific allometric equation.
Different models like CO2fix model, CENTURY, Roth C, PROCOMPAC, and DNDC have the potential to determine the CSP in AFS at a broader scale.
Among the various models, the carbon accounting model named “CO2fix” is commonly used.

AFS SUITABILITY MAPPING

Until now, the majority of AFS suitability assessment carried out are actual land suitability type but lack a defined approach.

The majority of AFS suitability mapping conducted in the last decade are multi-criterion based, viz., biophysical variables of land, soil, climate, and topography for the identification of potential land patches for the AFS
.
FAO methodology is the most common methodology used in AFS suitability mapping for at district, country (India and Nepal) and South Asian region scale.

Moreover, recently, the multi-criteria decision analysis approach such as analytical hierarchy process (AHP) which deals with complex decision-making is also used in the AFS suitability evaluation.

Spatial Decision Support System (SDSS)

Furthermore, spatial decision support system (SDSS) for the AFS is also carried out by

combining GIS, a plant database with the soil and climate datasets to provide the decision-making for the selection of AFS tree species in specific scenarios. The ancillary data from various sources plays a crucial role to delineate the AFS suitable lands even at the village level.

Simultaneously, the environmental risk parameters, viz., flood hazard, erosion hazard, soil erosion, nitrogen leaching, landscape diversity, wind erosion, hardiness zone, environmental indicators such as GHG farm emission, wind emission in addition to the market access, and profitability to local people and vulnerability to the insect, disease, and weeds, should also be taken into consideration.

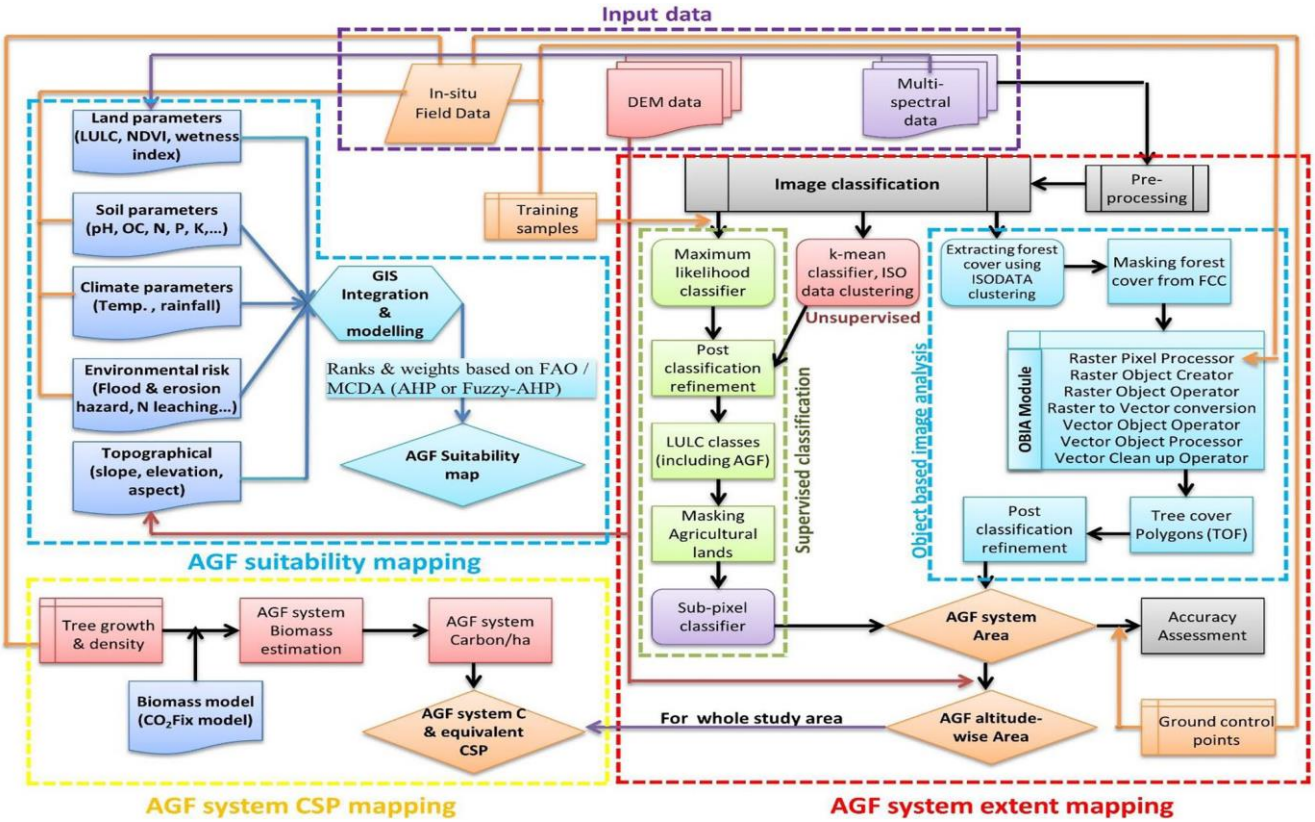


Fig: Flowchart of methodologies for agroforestry extent, suitability and carbon sequestration potential (CSP) mapping.

UNMANNED AERIAL VEHICLES (UAVS)

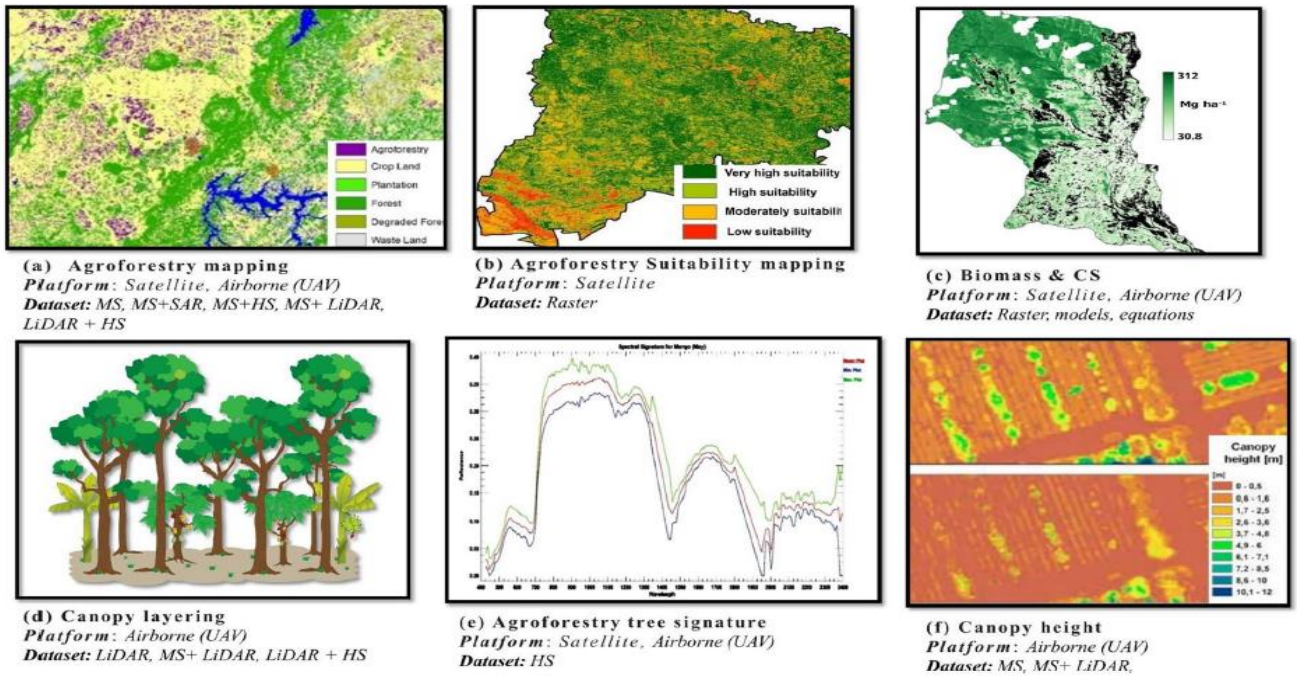
In recent years, UAV-equipped sensors emerged as one of the innovative tools offering the advantages of utilizing superior reach and dexterity in data collection.

The significant advantage of the UAVs includes the high spatial (about 1 cm) and temporal resolution, low operation cost, flexibility, and little or no effect of the cloud cover on the image.

Additionally, UAVs complement the existing techniques and fill the void left by satellite-based RS. This frontier technology in recent years emerged as one of the finest data sources for AFS mapping due to better resolution that allows detection of cropping systems and individual plants, which is not possible with noncommercial satellite

imagery.
Various types of UAV [fixed wing (large areas) or multirotor (small area)] equipped with a variety of sensors (RGB, infrared, multispectral, thermal, LiDAR, or hyperspectral) and data processing techniques can be used for the AFS mapping and monitoring
Despite the paucity of research, light detection and ranging (LiDAR) sensors are the most commonly equipped UAV sensors which can accurately delineate the individual tree crowns in addition to AGB, height determination and tree physiological parameters like leaf area index.

The height derived from the LiDAR can be used to determine the AGB through the species-specific or regional-specific allometric equations.
Apart from the airborne, terrestrial LiDAR is also used to determine the tree as well as stand-level ABG estimation, tree height, tree diameter, tree biomass equation and crown canopy in order to provide highly accurate information over a small spatial extent.
Furthermore, UAVs equipped with hyperspectral sensors are used for tree characterization, while the multispectral sensor for extent mapping and height mapping.
Additionally, the micro-hyperspectral imagers and thermal camera equipped on UAV platforms are now extensively used for the detection of the canopy temperature stress such as water stress in plants.



(a) Agroforestry mapping
Platform: *Satellite, Airborne (UAV)*
Dataset: *MS, MS+SAR, MS+HS, MS+ LiDAR, LiDAR + HS*

(b) Agroforestry Suitability mapping
Platform: *Satellite*
Dataset: *Raster*

(c) Biomass & CS
Platform: *Satellite, Airborne (UAV)*
Dataset: *Raster, models, equations*

(d) Canopy layering
Platform: *Airborne (UAV)*
Dataset: *LiDAR, MS+ LiDAR, LiDAR + HS*

(e) Agroforestry tree signature
Platform: *Satellite, Airborne (UAV)*
Dataset: *HS*

(f) Canopy height
Platform: *Airborne (UAV)*
Dataset: *MS, MS+ LiDAR,*

Overview of remote sensing & GIS application in Agroforestry mapping and monitoring. **A.** agroforestry mapping, **B.** agroforestry suitability mapping, **C.** biomass and carbon sequestration estimation in agroforestry, **D.** canopy layering in agroforestry, **E.** tree spatial signature, **F.** agroforestry canopy height.
Geographic Information Systems (GIS) play a crucial role in the field of agroforestry by

providing a powerful tool for spatial analysis, planning, and decision-making. Here are some specific applications of GIS in agroforestry:

Site Selection and Planning:

Land Suitability Analysis: GIS can be used to assess the suitability of different areas for agroforestry practices based on various factors such as soil type, topography, climate, and water availability.

Multi-Criteria Decision Analysis (MCDA): GIS can integrate multiple criteria, allowing stakeholders to make informed decisions about the most suitable locations for agroforestry projects.

Tree Species Selection:

Biodiversity Mapping: GIS can assist in mapping existing vegetation and biodiversity, helping in the selection of tree species that are well-suited to the local environment.
Climate Modeling: GIS can be used to model climate patterns and predict future changes, helping in the selection of tree species that are resilient to climate variations.

Resource Management:

Water Resource Management: GIS can be used to analyze and manage water resources for agroforestry, optimizing irrigation practices and water use efficiency.

Soil Health Monitoring: GIS helps in monitoring soil health and nutrient levels, enabling farmers to make informed decisions about fertilization and soil conservation practices.

Land Use Planning:

Land Cover Change Detection: GIS can monitor changes in land cover over time, helping to identify trends and assess the impact of agroforestry practices on the landscape.

Zoning and Land Allocation: GIS can assist in developing land use plans and zoning regulations to ensure sustainable agroforestry practices.

Erosion Control and Watershed Management:

Slope Analysis: GIS can analyze slope characteristics to identify areas prone to erosion, aiding in the implementation of erosion control measures.

Watershed Modeling: GIS helps in modeling and managing watersheds, optimizing water flow and reducing the risk of soil erosion.

Monitoring and Evaluation:

Remote Sensing Integration: GIS can be integrated with remote sensing data to monitor the health and growth of trees, providing valuable information for ongoing evaluation and management.

Yield Prediction: GIS can contribute to predicting agroforestry yield by analyzing various spatial factors that affect crop and tree growth.

Policy and Planning:

Land Tenure Mapping: GIS can assist in mapping land tenure and ownership, helping policymakers in developing effective policies for agroforestry management.

Impact Assessment: GIS enables the assessment of the socio-economic and environmental impact of agroforestry projects, supporting evidence-based policy decisions.

In summary, GIS is a versatile tool that enhances the planning, implementation, and management of agroforestry practices by providing spatial insights and facilitating informed decision-making.

Summing up, geospatial technologies offer enormous potential for effectively and efficiently mapping, monitoring, and intrinsic spatial complexity of the AFS at any landscape while also providing new insight for planning and decision making.

Melia dubia AS A PROMISING TREE SPECIES IN AGROFORESTRY

Mr. Adarsh Jha
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Kingdom: Plantae
Order: Sapindales
Family: Meliaceae
Genus: Melia
Species: *Meliadubia*

Agroforestry is a sustainable land management system that increases the overall yield of the lands by combining the trees and shrubs with crops and livestock on the same unit of land, either simultaneously or sequentially. Besides enhanced yields per unit area, agroforestry also helps in the conservation of natural resources, increases farm income and also makes the agricultural system climate-resilient.

Agroforestry or trees outside forests are vital for ensuring environmental resilience in terrestrial landscapes. In this regard, growing trees on farmlands i.e. agroforestry ensures livelihood security to the farming communities.
Nonetheless, there are a few bottlenecks in the farmers' adoption process of agroforestry trees as they ought to be

- fast-growing
- deciduous
- straight bole
- high market value
- assured buyback
- low maintenance cost, etc.

On these counts, and based on tree ideotypes for agroforestry, *Melia dubia*has both structural and functional traits for agroforestry, and essentially has market value as well.
*Melia dubia*is a fast-growing, deciduous tree with stout, straight, tall bole and wide-spreading branches. The block planting of 300–400 Melia trees per acre can ensure a minimum profit of 1 lakh per year.
Hence, *Melia dubia*is considered highly suitable for farm forestry and agroforestry to generate higher income per unit area besides increasing green cover.
It is one of the fastest-growing tree species in the world and is considered a money-spinning tree of short rotation due to its high demand in pulpwood, plywood, and timber industries. A few reports reveal the fuel, fodder, and medicinal values of *Melia dubia*as well.
Melia dubia owing to its short gestation period, assured buyback, and low maintenance cost is a commercially viable tree species for agroforestry

Tree Ideotype for Agroforestry System:

- It should not interfere with soil moisture
- It should have very little water requirement
- It should not compete with crops for resources/nutrients
- It should not be nutrients exhaustive
- It should help in building soil fertility
- It should have a tap root system and root growth characteristics
- It should have a light branching pattern
- It should withstand pruning operations
- It should have a high survival rate
- It should have fast-growing habit and easy management
- It should have a short rotation
- It should have wider adaptability

- It should have high palatability as fodder
- It should have capability to withstand management practices.
- It should have nutrient cycling and nitrogen fixation attributes.
- It should be free from chemical exudations.
- It should have easily decomposable leaves.
- It should have multiple uses.
- It should have high yield potential.

*Melia dubia*has all positive characteristics that makes it an ideal tree species for agroforestry. Among them few important characteristics have been described in the next few slides.

A. Root

The roots of *Melia dubia*are reported to have less interference with crop in agroforestry systems and are mostly concentrated below the crop root zone with minimal lateral expansion.

It has been stated that the root distribution of woody components grown with annual crops in agroforestry systems should be below 40 cm soil layers and have little lateral expansion because most of the roots of annual crops are concentrated in the upper 30–40 cm soil layer only

The dissimilar root distribution pattern of tree and crop components in agroforestry systems avoids competition for nutrients and water and helps in soil working.

B. Crown:

- *Melia dubia* is a large tree that attains a height of 20 meters with a spreading crown and a cylindrical straight trunk (9 m length × 1.2–1.5 m girth) after 10–12 years plantation.
- It has a thin to moderate crown that passes enough light to understory crops. It has been established that a tree with dense crown does not pass enough light on the understory crops canopy in agroforestry systems which adversely affect its photosynthesis process and ultimately results in low yield of the understory crops.
- Therefore, light crown tree species are considered suitable for the agroforestry system as these tree species pass enough light to the understory crops for their photosynthesis activity.

C. Bole

- Generally, tree species with straight, clean, and long bole are preferred for agroforestry.

- In addition, the chosen tree species should also have either self-pruning characteristics or tolerate a high incidence of artificial pruning because it helps in developing a clear bole and enhances timber quality.
- *Melia dubia* has rounded, cylindrical knot-free, clean and straight bole of up to 9 m length. Besides, it also has inbuilt self-pruning, termite resistant, frost and drought resistant qualities.
- Altogether, these characteristics make *Melia dubia* an ideal and farmer-friendly agroforestry tree species.

C. Phenology

Phenological characteristics namely leaf fall and emergence of the new leaf are considered important for the selection of a tree species for the agroforestry system.

The deciduous nature of trees allows their leaves to avoid competition for light, nutrients and moisture with crops are preferred for agroforestry systems. Therefore, better crop growth is observed with trees that have a longer period of leaflessness.

Furthermore, leaf litter of deciduous trees adds organic matter to the soil which ultimately helps to improve the health and productivity of the soil.

In this context, *Melia dubia* being a deciduous tree species sheds leaves in winter (December-January) and new flushing occurs in February-March along with flowers.

This short leafless period provides enough light, nutrients, and moisture for winter crops to flourish well. The litterfall of Melia also adds organic matter to the soil which enhances fertility and productivity of the soil.

D. Fast Growth

- *Melia dubia* is a fast-growing tree and can be managed through short rotation.

- It achieves up to 40 feet height within two years of planting. It is reported that a 10-yearold plantation of *Melia dubia* has the potential to yield on an average up to 40 tonnes of biomass per acre per year.

- Being a short rotational industrial tree, its cultivation period generally ranges between 6–12 years for a good economic yield.

E. Allelopathic effect

- *Melia dubia* either has ephemeral or no allelopathic effect on crops at early

stages.

- Hence, *Melia dubia* fits well to the criteria of agroforestry ideotypes and is considered an ideal tree species for agroforestry.

F. Phenology

- Phenological characteristics namely leaf fall and emergence of the new leaf are considered important for the selection of a tree species for the agroforestry system.
- The deciduous nature of trees allows their leaves to avoid competition for light, nutrients and moisture with crops are preferred for agroforestry systems. Therefore, better crop growth is observed with trees that have a longer period of leaflessness.
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Yield:

- The tree attains a volume of 15 cu. ft. at the end of 15 years and earns revenue of Rs. 350 per cubic foot from the 5th year onwards.
- Growth rate ranges from 20-25 cm per year when intensively managed and 6 to 8 cm per year in unmanaged plantations.
- It is expected to produce 12 to 15 Cuft. (0.4 - 0.5 cu.m) of timber in 5 years' time. Presently Melia fetches Rs. 7300/- per tonne for billets of girth 50-120 cm girth and above Rs.370 per CFT (0.02 cu.m.) for trees which have attained a girth > 120 cm.

Uses:

- It is a good secondary timber and the most preferred species for plywood industry. The wood is also used for packing cases, ceiling planks, building purposes, agricultural implements, pencils, match boxes, splints, catamarans, musical instruments and tea boxes as the wood is anti-termite by itself. Thus, the species has a ready and assured market due to its multipurpose utilities. The species is also highly adaptable. The species is in high demand by the plywood industries.

Crop combinations:
Intercropping with Legumes:

Leguminous cover crops: Planting leguminous cover crops such as clover or peas between *Melia dubia*rows can provide nitrogen fixation, enhancing soil fertility.
Pigeon pea (*Cajanus cajan*): Pigeon pea is a leguminous crop that can be intercropped with *Melia dubia*, providing both food and fodder for animals.

Fruit and Vegetable Crops:

Banana or Plantain: *Melia dubia*'s canopy can provide shade for shade-tolerant crops like bananas. This combination utilizes vertical space effectively.
Vegetable crops (e.g., tomatoes, beans): Intercropping *Melia dubia* with vegetables can provide short-term income while the tree matures.

Medicinal Plants and Herbs:

Aloe vera or medicinal herbs: Growing medicinal plants underneath *Melia dubia* can provide additional income and contribute to diversified agroforestry products**.**

Silvo pastoral Systems:

Grasses and forage crops: Combining *Melia dubia* with pasture or forage crops can create a silvo pastoral system, allowing for livestock grazing while the tree provides timber and shade.

Beekeeping:

Flowering crops: *Melia dubia* produces flowers that attract pollinators. Integrating beehives and flowering crops can support beekeeping, promoting biodiversity and providing additional income through honey production.

Nutrient-Rich Crops:

Crops with deep root systems (e.g., yams, sweet potatoes): These crops can benefit from the nutrient-rich layers of decomposing *Melia dubia* leaves.

Agricultural Residues and Mulching:

Mulching with Melia leaves: *Melia dubia* leaves can be used as mulch, contributing organic matter to the soil and suppressing weed growth in agricultural crops.

Timber Agroforestry:

Other timber species: Integrating *Melia dubia* with other timber species diversifies the agroforestry system and provides options for different market demands.

Spice Crops:

Black pepper or vanilla: These crops can be cultivated on the supporting poles of young *Melia dubia*trees, utilizing the vertical space and providing additional income.

Water Management:

Water-loving crops (e.g., rice): In areas with waterlogged conditions, *Melia dubia*can be used to improve water management by absorbing excess water, and rice or other water-loving crops can be grown in combination.

*Melia dubia*is a promising tree highly suitable for farm forestry and agroforestry. This is a fast-growing tree whose wood is readily used in plywood industries. This timber species has gained a lot of interest among farmers in India as it is known to fetch a good income with minimal investment and maintenance due to its positives such as straight stem without much branching, less shade effect, not being susceptible to insect attack and its ability to grow in all types of soil and even in areas of low rainfall.

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SEED COLLECTION, PROCESSING AND STORAGE OF AGROFORESTRY TREES

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SEED SOURCE

A seed source is where seed is collected. This may be an identified or established number of trees in a landscape; farmland, natural forest or a group of trees from which you obtain seeds.

THE BEST TREE SEED SOURCES

Seed sources for particular tree species should be in a suitable agroecological zone for good seed production. Choose seed sources from areas which share the same climatic conditions (in terms of average annual rainfall and altitude) as one where the seed collected will be planted. This ensures that trees will be well adapted to that environment. Seed trees from lowlands fit well in lowlands, while seeds from highlands fit well in highlands. If seeds collected in highlands are planted in lowlands the trees grow poorly. The same applies if seeds collected from lowlands are planted in highlands.

A good seed source should provide fast growing, healthy and high-quality planting material. Choose sources with trees with desirable traits such as fast growth, pest resistance, healthy and quality products.

Use seed sources that have more than 30 trees to ensure good inherited (genetic) quality, as trees grow to be like their mother trees. Collect seed from adjacent farms in case you have less than 30 mother trees in your farm.

Avoid identifying isolated mother trees since they normally have self-pollination. Normally many of their seed may be empty due to poor pollination.
In natural forest, select mother trees of same species which are spaced 50-100m from each other. For exotic tree species, ensure that trees of same species are spaced at least 10-14 meters from each other. This prevents pollination between closely related individual trees (inbreeding) and allows good crown development.
Note: Selection of mother trees is related to the intended use of the trees to be grown. All seed trees should be trees growing vigorously and should be mature trees that produce ample quantities of seed.

THE MAIN CATEGORIES OF SEED SOURCES?

A tree seed source category is determined by the tree species, where the source is

located and the seed source design. The four main seed source categories used for provision of planting material (seeds, cuttings and scions) are:

Farmland seed source refers to trees on-farm and in urban areas e.g. on roadside which have been planted, or indigenous trees retained, for provision of services and other end-products e.g. fodder, timber apart from providing seed.

Natural forest seed source refers to trees identified in natural forests (government forests), that are selected and managed for seed provision.

Plantation seed source refers to superior tree stands planted in blocks of minimum one hectare. They primarily provide services or products but are also selected for seed provision due to the tree superiority. For example, some stands have been selected by national institutions to provide seeds of pine and cypress.

Seed orchard source refers to trees that are planted from high quality seed or grafted plant material in blocks of minimum half hectare. They are specifically planted for seed or scion production, e.g. mango (Mangifera indica)

MANAGEMENT OF FARMLAND RESOURCES

Seed sources should be managed well to increase seed production while maintaining seed quality. Record the altitude, average annual rainfall of seed source locality in a book.

Seed production trees establishment should be managed by groups of farmers who occupy adjacent farms. Each farmer should have at least 4-10 trees of the same species for seed production. The seed should always be bulked before use by subdividing it according to how much seed each farmer had contributed to the bulked seed lot.

Note: Good seeds can be bought or acquired from authorized seed suppliers such as, Kenya Forestry Seed Centre (KFSC), Tanzania National Tree Seed Agency (TTSA), Uganda National Tree Seed Centre (NFA Uganda), Rwanda National Tree Seed Centre, Forest Department in Rwanda, Non-Governmental Organizations (NGOs), World Agroforestry Centre (ICRAF), Community-Based Organizations (CBOs), Farmers' associations, Farmers' cooperatives or authorized seed dealers. Avoid procuring seeds from market as the seed source is often unknown.

TREE SEED COLLECTION

What are the main tools and materials used in seed collection?

The major seed collection tools and materials are hooks or pruning shear, ladders, ropes, baskets, buckets, bags, crates, plastic sheets, netting sheet, notebooks, labels to be put in seed containers and a pen.

Note: Ask for permission to collect from the landowner or land manager. This is important if you are collecting seed from private land, industrial forests or government seed sources. Collect fleshy fruit seeds only when you have an order or when you want to plant since they are difficult to store.

How do I tell when the seeds are mature?

- Different tree species flower at different times. It is important to carry out a flower and seed survey to enable you to find out when majority of trees have mature seeds or the best harvesting time.
- Harvest when at least 30 trees have fruits or pods ready for harvesting.
- A mature fruit or pod can be confirmed by checking the size, colour and vigour of the fruit or pod. A mature fruit/pod is expected to be of optimal size as per the species.
- Seed shall be whole and firm inside - this is confirmed through cutting test. Pick a total of 100 seeds or fruits from various trees at random and carry out a cutting test using a knife or fingernail clipper. When you cut the seed in a cross-section, you get a firm-white sap if the seed is mature. If you get a moist sap or an empty seed then the seed is not mature.
- Check if there are pests or diseases.
- Observe if the fruits or pods' colour changes from green to yellow, red, orange brown, black and/or purplish. Observe when fresh fruits start falling from the crown

VARIOUS WAYS OF COLLECTING TREE SEEDS

Tree seeds can be collected using various methods. The choice of collection method depends on growth form of the tree and the height. The major seed collection methods are:

Collection from the crown of cut down trees: This method is used mostly on tall trees like silky oak (Grevillea robusta), elgon teak (Olea capensis) that have been cut for e.g. timber when seed is mature.

Collection of fallen fruits: This method is used for large fruits like of mango (Mangifera indica), water-berry (Syzygium cordatum), avocado (Persea americana) or Musine (Croton megalocarpus). Remove the weeds under the tree or spread a polythene sheet, so that fruits can fall on a clean place.

Collection of seed by climbing the tree without using any equipment: Climb the tree, pick seeds by hand and put in a bag.

Collecting directly from a tree without climbing: This is done using a hook, a pruning shear or hands. The method is used for short trees such as fish bean (Tephrosia vogeli) and calliandra (Calliandra calothyrsus).

Collection from the crown by climbing the tree using a ladder: After climbing you collect fruits or pods from the crown by pulling twigs or small branches with your hand. This method is used for tall trees like musizi (Maesopsis eminii). Safety measures must be taken into consideration.

Seed processing

Steps in seed processing from legumes and coniferous (orthodox seeds)

Examples: Calliandra (Calliandra calothyrsus), sesbania (Sesbania Sesban).

1. Orthodoxy seeds from pods, capsules, cones or samara can be sun-dried by spreading them in direct sun for 1-2 days.
2. Put them in a sack or spread on a polythene sheet and thresh by beating them with a

stick. This is followed by seed cleaning (blowing or winnowing) to remove inert material, damaged seeds or infected seeds.
3. Sort out the left inert material and bad seeds by hand.
4. Dry the clean seeds to the right moisture. See table in appendix.

Steps in removing pulp from fruits (berries and drupes)

Examples: Red Stinkwood (Prunus Africana), Black water-berry (Syzygium cordatum), East African greenheart (Warburgia ugandensis) and Mango (Mangifera indica).
1. Soak fruits in water at a ratio of 1 part fruit to 2 parts water. Leave them for 1-2 days. Clean, rinse and sort the seeds.
2. Put the clean seeds in open trays and spread them in thin layers to maximize aeration and allow them to dry slowly under shade.

Note: Always maintain seed lot identity by putting a label with species name, collection dates, weight of extracted seeds and date of extraction.

Enable farmers understand tree seed processes and seed quality testing procedures with the aim of improving seed quality. This chapter should be taught as a theory lesson mixed with hands on demonstrations on pre-sowing treatments and simple moisture content testing. Each farmer should have a copy of the table in the appendix on pre-sowing treatment methods of various species.

At the end of the training, farmers should be able to: Know how to carry out various pre-sowing treatments to break seed dormancy of different tree species and how to test for the quality of seed before storage or distribution. Duration: 1.5 hour

SEED DORMANCY

Seed dormancy is a state in which viable seed show no or only little germination within a certain time, although all environmental conditions (moisture, light, air) are adequate for germination. Seed dormancy prevents seed germination until a pre-sowing treatment is done.

What causes seed dormancy?

Dormancy of seed can be caused by the special quality of the seed coat such as hard layers of cells or water in-permeability of the coat or the existence of germination inhibiting substances in the seed coat such as oil. Some dormancy is also caused by undeveloped seed.

Pre-sowing treatment methods to break seed dormancy

What is a pre-sowing treatment?

Pre-sowing treatment is a treatment of the seed before sowing to break seed dormancy, accelerate germination or to enhance rapid and uniform germination. The best method depends on type of seed and the species you would like to plant.

Why should you carry out pre-sowing treatments?

Necessary for some species to break seed dormancy.
To obtain a rapid and uniform germination and to increase germination percentage.
Save high quality and expensive seeds.
Enables you to predict transplanting period and shorten the period the seedlings need in the nursery – thus conserving space.

COMMON PRE-SOWING TREATMENT METHODS

Below are some of the most comment pre-sowing treatments methods. For detailed description per species – see table in the appendix.

Soaking seeds in cold water: Seeds are put in cold water (1-part seeds to 4 parts water). **Examples:** Fish bean (Tephrosia vogelii) and sesbania (Sesbania sesban).

Soaking seed in hot water overnight: This is used for seeds with a thick seed coat. Boil water which is 4 times the seed volume. Remove from the heat source and pour the water in the container with the seeds. The container should be made of glass or metal to resist heat.

Example: Acacia (Acacia mangium).

Seed coat nicking or cutting: This is used for species with a hard seed coat. Make a small cutting in the seed coat to allow water enter. The seed coat is cut or nicked using a knife, fingernail clipper, file or by piercing with a hot wire.

Cracking large seeds: Seeds with a very hard seed coat are cracked to break the seed coat and allow water to penetrate inside the seed. This is done using a stone or a hammer. Crack seeds with great care not to damage the seed. Examples: Melia (Melia volkensii) and podo (Podocarpus falcatus).

Removal of seed coat by having goats feed on fruits (biological treatment): Animals such as goats can feed on seeds. The seeds go through the digestion system of the animal and clean seeds are then released which germinate well. The eaten seeds are exposed to the hydrochloric acid in the stomach of the animal, and this breaks the dormancy without damaging the seed. Example: Desert date (Balanites aegyptiaca).

Seed testing to verify seed value:- Seed test are used to verify seed quality and monitor seed conditions. These tests should be done immediately after processing or before storage or distribution. These tests include; seed cleanness, germination percentage testing, viability test and moisture content test (water in the seed).

Seed cleanness test Seed lots contain debris including seeds of other species, pieces of fruits, twigs, leaves and dirt. Pure seed refers exclusively to clean seed of the specified species. This is a test to measure seed cleanness (purity) percentage.

1. Measure the total weight of the sample before removing all other matter. The sample size should be approximately one handful.
2. Separate the sample into two components: 1) Pure seed, and 2) All other matter.
3. Calculate seed cleanness percentage as follows: Cleanness (%) = Weight of pure seeds (g) x 100/Total weight of the sample (g)

Germination test

1. Pick a sample of seeds at random. The sample size should be two samples of 100 seeds per replication. If seed quantity is limited, 50 seeds can be used.
2. Sow the seeds in open trays or in nursery in sand or soil.
3. Count all germinating seeds and record the number in a form. Germination period is 4-90 days depending on the species. (Germinating seeds can then be discarded or transplanted in the nursery).
4. Calculate germination % as follows:

Germination (%) = No. of germinated seeds (g) x 100/Total seed sown

Viability test

Seed viability can easily be tested by sampling 100 seeds from a seed lot. Pick the seeds at random and use a knife or sharp object to do cutting test. Observations: seeds with firm white sap are viable while the empty or dark or black are not viable and may be dead. Count the viable seeds to get viability percentage.

Moisture content testing

The amount of moisture in a seed can easily be tested for dry seeds like all orthodox seeds such as legumes (calliandra (Calliandra calothyrsus) and coniferous). This is done by:

1. Filling one quarter of a glass jar with salt.
2. Adding the seed sample enough to fill half of the jar.
3. And then closing the lid tightly and shaking the jar well for some minutes.
4. Observation: If damp salt sticks on the sides of the jar, then the seeds are too moist for storage (moisture is above 13-15 %). If the jar is still dry and no salt is stuck on its sides then the seeds have less than 15% moisture content and can be stored safely.

Note: Tree seed quality can be best monitored and maintained by appropriate certification (e.g. Quality Declared Seed and Truth in Labelling schemes). It is very important for the seed dealer to declare the exact number of trees the seed is collected from and the real germination percentage or viability test for any seed lot.

SEED STORAGE

Objectives of the chapter: - Equip the farmers with good seed storage practices with the aim of maintaining good seed quality and avoid losses. This chapter should be taught as a theory lesson.

After the end of the training, farmers should be able to: Know different ways of storing and preserving seeds for different tree species. Duration: 20 minutes

Why should I store seeds: - To keep them in good conditions until they are planted.
To plant seeds in later years when trees produce few seed.
In preparation for distribution.
To protect them from pests or diseases.
To prolong their life span and wait for increased demand from customers.
For conservation purpose.

Where should I store my seeds: -The ideal seed storage room should have modified atmosphere with regulated temperature and humidity. However, it's also possible to use a simple storage structure such as a charcoal storage cooler. This is made of a grass roof and charcoal walls to keep it cool. The charcoal is enclosed in a mesh wire on both sides including the door. It is kept cool by pouring cold water on it to keep it moist. Seeds can be stored for different periods, depending on moisture content in seed and temperature during storage.

How do I store legume and coniferous seeds (orthodox seeds): - Orthodox seeds are seeds from pods, samara, cones and capsules and also from some drupes which can be dried to low moisture and stored for a long period at low temperature.

Examples: Calliandra (Calliandra calothyrsus), guava (Psidium guajava), croton (Croton megalocarpus), acacia (Acacia aneura), whistling pine (Casuarina equisetifolia), and mukumari (Cordia africana).

1. Dry the seeds to the right moisture (water in seed) and test it to ensure that the moisture is 7-15 %.
2. Put the seeds in clean, dry and airtight containers. Ideal containers are thick polythene bags that are tightly sealed, plastic containers such as drums, aluminum packets, glass jars that have a rubber lining and screw lid or glass bottles that have a screw lid. You can also store dry seed in gourds, clay pots or bottles.
3. Store the containers in cool (room temperature), dark, dry and well-ventilated place. Do not place containers directly on the floor. These seeds can be stored for 1-2 years.

Note: Avoid storing seeds directly on floors to avoid water absorption and rotting.

How do I store intermediate seeds (e.g. papaya, passion)? Intermediate seeds are sensitive to low temperatures.

Examples: Papaya (Carica papaya) and passion fruit (Passiflora edulis).

1. Dry the seeds under shade to an appropriate moisture level.
2. Put the seeds in clean, dry and airtight containers.
3. Store the containers in room temperature but with little moisture. You can store them for 4-6 weeks under ideal conditions.

How do I store seeds from fleshy fruits with a lot of water? Fleshy fruit seeds (recalcitrant) must retain high moisture to remain viable. They cannot tolerate low moisture or high temperatures. Examples: Red stinkwood (Prunus africana) and east African greenheart (Warburgia ugandensis).

1. To maintain moisture, put the fresh seeds in a media that are slightly moistened, for example moist sawdust with a ratio of 1 part seed to 2 parts saw dust.
2. Store the seeds in room temperature, protected from high temperatures.
3. Seeds in moist sawdust can be stored for 1-2 weeks when the moisture content is maintained at 30-40%.

Note: Instead of storing, you can sow fresh seeds in the nursery as soon as possible and sell them as seedlings. For more information on storage for various species see table in the appendix.

HI TECH NURSERY FOR SHORT ROTATION SPECIES

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MEANING OF NURSERY

Nursery is an area where plants are raised for eventual planting out. It comprises nursery beds, paths, irrigation channels, shade house, mist chambers etc.
Classification of major methods of propagation:

- Through Seed
- Through Vegetative Parts
  - Cutting Layering
  - Budding
  - Grafting
  - Tissue Culture

TYPES OF NURSERIES

A permanent nursery is centrally and conveniently located and has permanent residential buildings for staff, stores for equipment's and machinery, fencing, water arrangements etc. It is meant for supplying plants for planting on a long-term basis. When planting programme is short (five years or less) a temporary nursery is sufficient which has just the most essential low-cost facilities and structures to produce plants for meeting the specific planting target. Temporary nursery is generally much smaller than permanent one, and is also referred to as site nursery, field nursery, or flying nursery. In a continuing programme that is likely to go on for more than five years, it is desirable to have at least a few permanent nurseries with proper infrastructure. However, in case of afforestation projects lasting five years or less, temporary or semi-permanent nurseries can be established in which the cost can be reduced by dispensing with some of the infrastructure elements such as permanent structures for green houses, nursery sheds, fencing with angle iron posts and modern irrigation facilities.

FACTORS TO BE CONSIDERED FOR SELECTING A SITE FOR NURSERY

It is very important to critically consider all factors while selecting the site for a nursery. One should consider not only the physical aspects for the selection of the site but also the end use of the seedlings. Following points may be kept in mind while selecting a site for the nursery, however, in reality, a decision of compromise is often made in many situations based on nursery manager's priorities.

Location: The site should be centrally located with easy access for transportation of seedlings. It should be close to the area where seedlings are to be utilized. The site should be as square as possible. Sites used earlier for agriculture may be avoided and preference be given to former forest sites where weed problems will be less and beneficial mycorrhizae forming fungi are often endemic.

Water: Enough water should be available especially during the dry season. A natural source of water, at a higher level, will be operationally cheaper, as it can be tapped by gravity. If no natural source of water is available, ground water may be used. It is estimated that the water requirement for a semi-arid area is a minimum of 25,000 litter per day during summer, for every 1,00,000 seedlings. Requirement of water will be somewhat less for moist or cold areas.

Topography and Drainage: The area should be nearly flat with good drainage. This can be managed by providing gentle slope (<5 degrees) and channels should be dug to drain out excess water from the nursery. In the hills northern aspect is desirable up to 1,200m elevation, Western or South Western aspect is best for moist areas and Northern for dry areas. Nursery site should not be selected close to the edge of a high forest or in the middle of the grassland. Frost pool should be avoided.
Soil: The ideal forest nursery should have sandy loam to loamy texture. Sandy soils may be given preference over heavy soils. Soil should have pH 5.5 to 7.5, moderate fertility, with a minimum of 2 per cent organic matter.

SIZE AND SHAPE

As far as possible the nursery should be of a rectangular shape; so that it can be divided into smaller nursery beds of rectangular shape, leaving space for roads, inspection paths, heaping of manure, hut for mali and space for people working in the nursery to rest or take shelter during periods of rain. In bigger nursery (one ha and above), a road of a minimum width of 3 m should be constructed to facilitate transport of sand and manure inside the nursery and to carry the plants from the nursery, leaving space for turning of the vehicle. The requirement of the total area for the nursery can be calculated by adding together the area required for mother beds, containers, entire plant/root shoot cuttings and beds required for rooted cuttings. Another 40% area may be added for making the paths. Area will also increase if seedlings are kept in the nursery for more than one year, especially for raising tall plants. Area required for sheds, water tank, storage of seed, manure etc. should also be kept in mind. Bags of size 18 2 2 cm x 5.5 cm need 1 m for keeping 772 bags and slightly larger bags 18 cm x 7.5 cm need 1 m for keeping 400 bags. 2 Accordingly 1,00,000 bags will require 250 m area plus 40% for paths. Thus, for raising 1,00,000 polypot seedlings, a 2 area of 350 m may be sufficient.

SITE PREPARATION

The site should be cleared properly by removing all stumps, roots, lops and tops. Stones collected from the site may be used for metaling the main nursery road. Thorough ploughing or hoeing to a depth of 30 cm should be done, especially in places where plants are to be raised in the nursery beds. The soil should be levelled to form an even slope or, if a site is flat, should be slightly domed. As far as possible, removing of top soil must be avoided. Drainage channel should be dug as early as possible to avoid soil erosion. Drains should be dug on both sides of the paths and connected to main drain. In plains, drain should be adequately sloped and steps should be used in hills to check the flow of water.

Size of Beds

Beds are prepared to germinate seeds, keep polypots and transplant pricked out seedlings. In the plains, beds of 10 x 1 m or 12 m x 1.20 m size are made. In the hills smaller beds such as of 2 m x 1 m size are generally prepared.

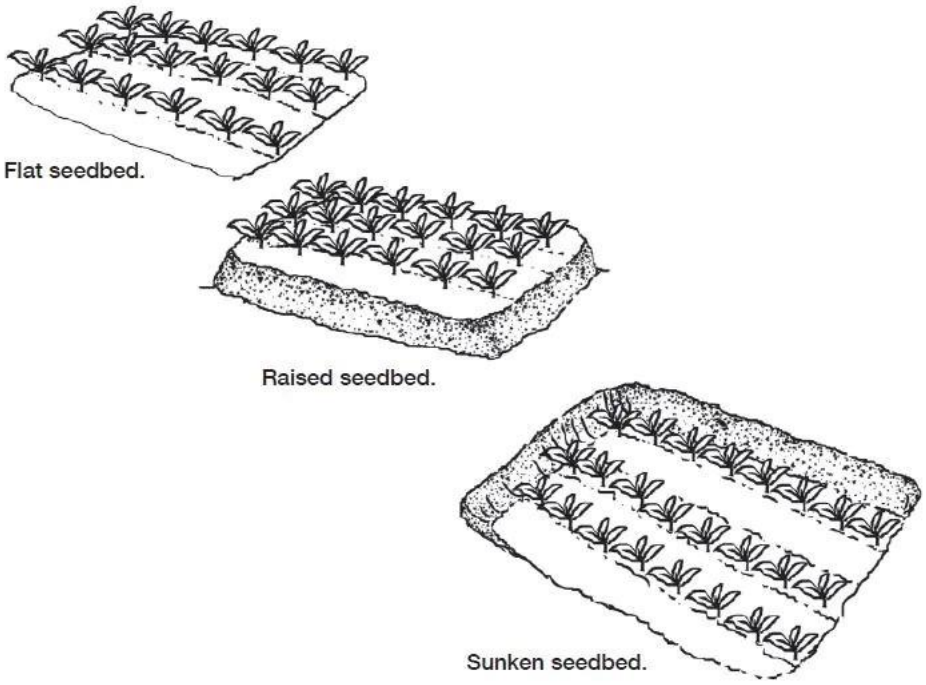
Types of Beds

On basis of Vertical Level

On the basis of vertical level with respect to the ground, the following types of beds are prepared in the nursery.

Sunken Beds: These nursery beds are about 15 cm deep and used in arid areas and hot places to maximize the use of rain water, protect young seedlings from hot winds, and also to reduce the rate of evaporation, thus reducing the consumption of water. Sunken beds are also used to keep small flexible bags in an upright position.

Raised Beds: These types of beds are generally used in moist areas. The beds are raised 15 cm above the ground to increase drainage and promote warming of seedbed. Beds are given side supports of bamboos, twigs, bricks or other locally available materials. Seedbeds (germination beds) are generally raised beds and should be located in shade and close to beds of polythene bags where seedlings will be transplanted.



On the basis of purpose

Seedbeds: The plot where seedbeds are to be prepared must be ploughed and levelled and sloped (1 to 3%), depending upon the texture of soil (less slope for sandy soils). It should be ascertained that the soil in the seedbed is light. If necessary, sand and soil (1:1) may be mixed so that the seedlings can break through when germinate, and this will also be helpful when plants are lifted for pricking out.

Transplant Beds:
Seedlings after pricking out from germination beds are transplanted into transplant beds. Planting is done at the prescribed bed spacing to give enough space to all individuals. Such beds are used for producing naked root plants (e.g. Quercus, deciduous plants for winter planting) and root-shoot cuttings of teak.

Beds for Normal Sowing of Seeds/Planting of Cuttings:

In species with bold seed and good germination (more than 70% germination), sowing is directly done in beds e.g. Celtisaustralis (khirak), Sapindusmukorossi (ritha), Bauhinia variegata (kachnar) etc. for winter planting. This is also used for direct planting of cuttings in species where rooting is above 80% in the open and planting can be done without earth ball e.g. poplar.

Beds for Polythene Bags:
These beds are the most common types of beds used in the present-day nurseries. Raising of nursery plants in polythene bags is the commonest method and is suited to

almost all species e.g. Eucalyptus, Casuarina, Acacia (khair, babool), Albizia, Leucaena (subabul), Gmelina arborea (gamhar or sivan), Tamarindusindica (imili), Azadirachtaindica (neem), bamboo, shisham etc. It is recommended to spread plastic sheet spread over the bed on which bags are put to check penetration of roots into the ground.

Important Propagation Structures

The following table summarises the main propagation structures in the nursery:

Structure	**Main Functions**
Shade House	Provides shade to plant to reduce illumination and temperature.
Mist Chamber	It provides high humidity (>85% RH) for rooting of cuttings
Green House	It provides controlled temperature, irrigation, humidity, light conditions for better plant growth.
Net House	Its main purpose is to grow plants protected from birds, large insects, animals and human beings.
Growth Chamber	It provides precise control on temperature, humidity, light conditions, carbon dioxide/oxygen, etc. for study of plant growth during experiments. Plants are raised in pots inside growth chamber.

BAMBOO PRODUCTION

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INTRODUCTION

Bamboo is a tall fast-growing grass and belongs to the grass family Poaceae (Gramineae). Though it is a grass, it is a woody grass. We see this grass growing around very commonly. We use bamboo in our daily life for many uses. We use it to furnish our homes and various articles like baskets, mats etc. made of bamboo. With over1500 documented uses for bamboo in the country, it may be said that there is a bamboo for every reason and region. In fact, bamboo is integral to the lives of 1.5 billion people, or around one fourth of the present world's population

India has a rich bamboo resource-the second largest in the world. There are about 29 genera of bamboos among 148 species in India. The North East India has the largest stock and diversity of bamboos. Next to the North East, the Western Ghats have the second largest diversity of bamboos. They cover around 10 million hectares of forestland alone. In addition to this, bamboo is grown in private plantations and on community land. Indian bamboos grow in a wide range of habitats, and at altitudes ranging from sea level to over 3,000 meters though, we have vast bamboo resources but most of us are not aware of the huge potential for these fast-growing plants to provide a sustainable way out of poverty and a stable source of income through small and medium-sized enterprises. It is a resource that can generate income and employment, especially in backward areas and amongst disadvantaged communities. In recent years there is a growing interest in the cultivation of bamboo, due to several factors. There is an increasing demand for good-quality bamboo culms for industrial and commercial applications, along with demand for traditional uses and crafts. Organized cultivation of bamboo shoot has found new markets from processors. Ecological awareness too has contributed to the recognition of bamboo as an environment-friendly material. Bamboo is renewable, versatile in application and has other qualities like strength, durability etc. Due to these, there has been increased commercial interest in the development and manufacture of bamboo-based materials

This self-learning material is aimed to provide you an easy guide to the cultivation and management of commercially useful species of Indian bamboo. It tells you about the economic benefits of raising bamboo as a managed plantation crop. It is hoped that the manual will encourage you to set up commercial bamboo plantations, especially on marginal agricultural and degraded lands.

OBJECTIVES

After reading this lesson, you will be able to:

differentiate different forms of bamboo present in India;

- identify different parts of the bamboo plant;
- understand the importance and use of each part;
- list out overall diversity present in India
-

BAMBOO PLANT FAMILY

If you see a bamboo plant carefully, it will look like a large form of the grass that you see commonly in the parks or gardens. Actually, bamboo belongs to the same grass family which is called Gramineae (also called Poaceae, it is the fifth largest flowering plant family. Most of the cereals that you eat like rice, wheat, oats, barley and maize belong to this family. Bamboos are perennial (everlasting) tall grasses.

FORMS OF BAMBOO PLANT

The bamboo plant can grow in many forms as follows:

Tree Forms

These are bamboos up to 35 meters in height, and with large or medium sized, usually thick-walled, culms. Examples: *Bambusa balcooa, Dendrocalamus hamiltonii, Dendrocalamus strictus, Dendrocalamus giganteus.* Most bamboos in India are tree (woody) forms.

Reed Forms

These are medium sized bamboo, which commonly grow as reed brakes. They have thin-walled culms up to 9 meters in height with long internodes. Example: *Ochlandratra vencorica*. Reed bamboos are common in Kerala and adjacent parts in southern India.

Straggler Form

These are medium-sized bamboos up to 15 meters tall, with the tip of the culm arching or drooping down or climbing on adjacent trees Example: *Meloacalamus compactiflorus* (climbing bamboo). Straggler forms are rare in India.

Shrub Form

These are erect, short forms of bamboo found as temperate species. They mainly occur at high altitudes, and have thin culms that rise to a height of up to 5 meters. Examples: *Arundinaria racemosa, Sinarundinaria falcata*. Shrub forms are widespread in India's Himalayan regions, nearer the snowline in Arunachal Pradesh, Uttarakhand, Himachal Pradesh and Sikkim. They also occur in the ghat areas of Kerala and Karnataka

PARTS OF A BAMBOO PLANT

The bamboo plant is a complex system. It consists of two sets of similar vegetative axes: one above the ground and the other below the ground.

- The above ground axis consists of jointed, tall, cylindrical stems. They are called culms The branches coming out from the culms laterally, form the secondary above ground axis.
- The underground axis is a solid rhizome (modified stem) system with roots and buds on it.

  Now, let us learn the structure of different parts of the bamboo plant in a little detail. We will also understand what these parts do for the plant.

  Rhizome

  You must be using many rhizomes in your daily life like ginger, turmeric (haldi) etc. The rhizome is the underground portion (stem) of a plant. In bamboo, the rhizome grows laterally under the soil surface and is branched. It helps the plant to spread its area of growing. It contributes to growth and vegetative reproduction of the plant and also holds the food reserve

The rhizome consists of nodes from which roots emerge (comes out). Buds come from it and develops into more rhizomes under the ground. On rhizome, nodes are very close to each other and are protected by sheaths (covering).

There are usually two broad types of rhizomes in bamboo:
Pachymorph (sympodial): Clump-forming, that is, many bamboo stems (culms) come out close to each other from the rhizome.

Leptomorph (monopodial): Non-clump-forming, that is, the bamboo stems (culms) coming out from rhizome are not very close to each other

Most Indian bamboos have sympodial rhizomes and are therefore clump-forming.

Some bamboos have both sympodial and monopodial rhizomes. They have characters common to both types. These are called amphipodial rhizomes

Clump

You must have observed that bamboo usually doesn't grow alone but mostly grows in a group. The group of bamboos is called a clump. A bamboo clump can develop from a seed or from another clump that has been cut away. Bamboo clumps take 4–6 years to mature. Each year, culms of larger height and girth (diameter) are produced. Clumps can be tightly packed (as in *Dendrocalamus hamiltonii*, *Bambusa tulda*, *Bambusa*

bambos) with many closely spaced culms or they may be loosely spaced but still in a cluster (as in *Bambusa vulgaris*, *Oxytenanthera stoksii*

Culm

The stem of the bamboo is called culm. It is like a hollow cylinder that becomes narrow towards the top. It is the most easily seen part of the plant. It is also the most widely used part. There are many uses of culm that range from basket making, furniture to timber etc. These have high demand in the market The culm emerges (comes out) from the ground as a shoot. It then grows fast and turns woody. It reaches its full height and girth within 80–110 days. In the fourth year its strength is highest. After the fifth year, it becomes increasingly weak and brittle (easily breakable).

Most bamboo culms are green in colour but some can be yellow, black, or even purple-black. Some bamboos are striped also, in yellow or green. In many species, the color changes as the culm matures

UTILIZATION OF BAMBOO

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BAMBOO: USE AND POTENTIAL

After going through the previous lesson, you must have developed an understanding about the different bamboo species and various parts of the bamboo plant. As you know now that bamboo is a woody grass, itcan be the perfect alternative for hardwood. It is light weight, strong, durable and flexible. These qualities are suitable enough to make composites, furniture, decors, flooring, roofing, cloths, paper and even a complete building from bamboo. About 2.5 billion people in the world depend economically on bamboo (INBAR, 1999), and international trade in bamboo amounts to about US$2.5 million (INBAR, 2005). Though India has the largest area under bamboo, which is estimated to be around 13.96 million hectares. It has low yield of around 0.4 tonnes per ha (Internationally it is as high as 50 tonnes per ha.). It is very low in comparison to other countries like China, Malaysia, Costa Rica etc. The annual turnover of the bamboo sector in India is estimated to be around Rs. 2400 crores. Still, this is a largely unorganized sector and bamboo has always been considered from the craft point of view and if otherwise for pulp making only. In this lesson, you will learn the various uses of bamboo in different fields. You will find that they have their innumerable uses as food, shelter, clothing, decorative articles, flooring etc. They can even be a source of renewable energy and also help in sustainable development. You will also come to know about the various initiatives taken by the Govt. in India to encourage bamboo cultivation on a commercial scale.

OBJECTIVES

After reading this lesson, you will be able to:

- list the use of bamboo in various fields.
- demonstrate use of bamboo in housing construction, flooring etc.
- extract charcoal, oil and gas from bamboo
- estimate the importance of bamboo in sustainable development.
- explain the potential for bamboo industry in India.
- analyze the public initiatives for bamboo industry.

USES AND APPLICATIONS OF THE BAMBOO PLANT

Bamboo is an important resource in the India with over1500 recorded uses. It is a fast growing, widespread, renewable, low-or-no cost, environment-friendly resource. It has potential to provide livelihood in the years to come, in both rural and urban areas. Apart from its traditional uses, bamboo has various new applications as an alternative to wood and other more expensive materials like steel, iron etc. It is widely used in construction, either in its natural form or as a reconstituted material, laminated boards and panels composite of bamboo and plastic.

Let us see some of the uses of bamboo that we see in our surroundings. They can be used:

- as a composite and wood substitute
- as fabric for making clothes
- as food for people and animals
- as fuel
- as a wind break and fence
- as soil binder
- for building normal and air-conditioned houses, schools, hospitals, etc.
- for making furniture
- for medicinal purposes
- for scaffolding
- for making paper
- for making handicraft items
- to make accessories and utility items.
- to make durable utensils

ENGINEERED BAMBOO

Bamboo can be processed into modern products (engineered bamboo) that may successfully compete with wood products in price and performance. Use of bamboo in making composite panels and boards greatly improves quality of the culms and allows the production of homogeneous products. Bamboo composites come under Green Materials category. The constructions based on bamboo

material provide excellent alternate of wood, cement concrete and other high-cost material.

BAMBOO HOUSING

There are three main types of bamboo housing:

1. **Traditional houses:** They use bamboo culms as a primary building material. According to reports, over one billion people live in traditional bamboo houses.

2. **Traditional (bahareque) houses:** In these houses a bamboo frame is plastered with cement or clay.

3. **Modern prefabricated houses**: Houses made of laminated boards, veneers and panels: These buildings are usually cheaper than wooden houses. They are light, strong and earthquake resistant as compared to brick or cement constructions. They are environment friendly too. Bamboo based materials are widely available and can be cultivated at a low cost. Bamboo based structures are low on maintenance, fire resistant, and have thermal protection and most importantly suitable for constructions in earthquake prone zone. They are important due to ease of construction and cost- effectiveness of bamboo. They also play an important role in disaster mitigation and post-disaster rehabilitation.

BAMBOO PANELS/ BOARDS AND TIMBER

Bamboo panel/board consists of multiple layers of bamboo, available in many variations with respect to size, thickness, configuration, style and color at present more than 20 different types of panels are produced theses are Bamboo Mat board, Scrimber (processed board from low quality or old bamboo). The process and the product are called Scrimber. Veneer panel, bamboo jute composite board, flattened board, Bamboo timber etc. For example, Bamboo Mat Panel is made by hot pressing of hand-woven bamboo mats. Mat boards are durable, stable and resistant to pest attack, fire etc. They can be used as wall panels, ceilings, assembled structures and household utensils etc

BAMBOO FLOORING

It is a quality product that can be commonly used and has a large global market. It

has certain advantages over wooden floors due to its smoothness, brightness, stability, high resistance, insulation qualities and flexibility More and more furniture, flooring, and even homes are being built with bamboo. It is becoming a popular wood alternate. The smooth floors hold up well in kitchens and other rooms.

BAMBOO FURNITURE

Traditional bamboo furniture uses natural round or split bamboo. Anew type of 'pack-flat,' 'knockdown' furniture uses glue-laminated bamboo panels. Unlike the traditional design, this furniture may be shipped in compact flat packs, to be assembled on the spot. The furniture, bound attractively with rattan or leather, gives any room a modern look.

BAMBOO CRAFTS AND WOVEN MATS

They are traditional products in India, China, Malaysia, the Philippines and Thailand. The technique has been known for several thousand years. There are nearly 20 categories of woven bamboo products in Asia, including fruit baskets, trays, bottles, jars, boxes, cases, bowls, fans, screens, curtains, cushions, lampshades and lanterns. Several bamboo-producing countries, such as China and India, use bamboo in pulp, paper and more recently cloth. Bamboo paper has practically the same quality as paper made from wood.

BAMBOO FIBRE

Bamboo clothes are a fabulous trend right now as bamboo fibers being used in fabrics and clothing. Bedding made of bamboo fibers is as soft as or softer than most cotton beddings. They have the look of silk without being expensive. It is becoming a mainstream trend to have bamboo fabric products or clothing, populating many major chains retail stores.

BAMBOO CHARCOAL, OIL AND GAS

Through a process called pyrolysis, bamboo can be converted into three valuable products: bamboo charcoal, oil and gas. Bamboo can be used in machines called gasifiers as a source of fuel. They are also used in thermal applications, replacing furnace and diesel oils. Gasification of bamboo (waste and low-quality bamboo) can produce energy and a range of valuable byproducts. This can be used to produce clean and renewable electricity and thermal energy. Gasification is a thermo-chemical conversion, carried out through process of oxidation and reduction with limited air supply (Fig. 2.9). It generates a combustible gas called producer gas and active charcoal as a by-product. The producer gas obtained can be used either for thermal

application or for mechanical/electrical power generation. It provides smokeless combustion and is thus an environment friendly operation. Whole process has lower operating cost than other methods. A 100 KW gasifier would require only about 1000 tonnes of bamboo per annum. Gasification process does not depend on quality, species, and maturity of bamboo hence the waste bamboo can also be used as fuel for the gasifiers Bamboo waste generated during the production of different products can be used in charcoal and briquette production. Bamboo Waste Charcoal is produced by heating bamboo with a controlled supply of air. Carbonization in a brick kiln produces uniform quality charcoal with a good yield and with minimum investment. This not only serves the heating needs of people but also reduce burden in the ecosystem by reducing cutting of trees. Bamboo charcoal has much higher calorific value (7000Kcal/ kg) than wood. Bamboo charcoal could be used as solid fuels by hotels, *dhobis* (washer-men) and for cooking in rural areas. It can further value added by pulverizing (for use in Agarbatti making) and briquette forming (for heating). Bamboo vinegar is a byproduct of charcoal which can be prepared by condensing the gases coming out of bamboo charcoal. Bamboo can also be used in the manufacture of charcoal, which is superior to charcoal from other sources in terms of calorific value. Bamboo charcoal is traditionally used as a substitute for wood charcoal or mineral coal. It can serve as a fuel, absorbent and conductor Bamboo extracts also contain valuable elements and can be used in pharmaceuticals, creams and beverages. Activated bamboo charcoal can be used for cleaning the environment, absorbing excess moisture, producing medicines, water filtration, cosmetics, fuel etc.

BAMBOO SHOOTS

Bamboo shoot is a young culm harvested shortly after it appears above the ground. Bamboo shoots have high nutritional value and low fat, and are a good source of fiber, vitamins, cellulose and amino acids. About 200 species of bamboo can provide edible and palatable (tasty) bamboo shoots. Fresh bamboo shoots are delicious and healthy, with high fiber content. Bamboo vegetables can be found in high end grocery stores and restaurants worldwide. After cooking, the shoots still remain crisp, because cooking does not destroy their texture. Cooked bamboo shoots can be stored in containers and shipped worldwide

Cooking with bamboo is nothing new in Asia. But introduction of new food process technologies has led to the shift from home scale processing to industrial scale. The bamboo shoots are processed using these technologies

which help not only in increasing shelf life, improving the product quality and sales, providing employment but also increase the marketability of product under hygienic conditions. These finished and processed bamboo shoots are finding higher demand in the market due to their taste and health benefits.

BAMBOO FOR SUSTAINABLE DEVELOPMENT

The importance of Bamboo industry for sustainable development is evident from the fact that it is the best source for the restoration of forests and landscapes. It is to be noted that around 47 percent of the world's potential forest area has been cleared or degraded to make way for crops, cattle, cities, and roads. As a native species across tropical, sub-tropical, and some temperate areas, bamboo could contribute significantly to restoring degraded landscapes. By planting bamboo in parts of landscapes, degraded lands could be restored to some productive use Bamboo Forest ecosystem has a higher potential in fixing Carbon from the atmosphere relative to other forest species (Fig. 2.15). It is one of the prominent ecosystems which plays an important role in the carbon cycle and carbon balance on the earth in fixing the CO_2 from the atmosphere through the process of photosynthesis and release it through respiration and decomposition process. Bamboo sequestersCO_2 and generates up to 35% more oxygen than an equivalent stand of trees. They are also fast growing and have high production and rapid maturation from shoot to culm.

THE POTENTIAL FOR THE BAMBOO INDUSTRY IN INDIA

The world bamboo market is currently worth US$ 8 billion/year, of which China's share is US$ 5.5 billion. Traditional markets cover handicrafts, blinds, bamboo shoots, chopsticks and traditional bamboo furniture, which explain 95 per cent of the market to date. New market products include modern/laminated furniture, flooring and panels cover the remainder five percent of the bamboo sector The bamboo and rattan industry of India is worth Rs. 28,005 Crores. During 2015- 16 and 2016-17 the export of bamboo and bamboo products was Rs. 0.11 Crores and Rs. 0.32 Crores respectively while the import was Rs 148.63 Crores and Rs213.65 Crores. Hence, despite the growing stock both within and outside forests, India is a net importer of bamboo. It means that there are greater opportunities to harness the market potential by increasing its production and ensuring establishment of a proper value chain system. In most of the hilly states of the country, bamboo is used as building /construction material, besides, having a potential niche market in other countries as well with various traditional and an ever-increasing range

of modern uses/applications in industries like construction, furniture, textile, food, energy production, herbal medicine etc. This is especially important from the potential of bamboo-based livelihoods and employment for rejuvenating the rural economy and doubling of farmers' income (NBM 2019)

PUBLIC INITIATIVES FOR BAMBOO INDUSTRY

Keeping in view the vast untapped potential of the bamboo sector government of India realized an urgent need to widen the dimension of bamboo sector and give due attention to the unorganized market and provide for high level technology application for manufacture of value-added products in the industrial and artisanal sector. National Mission on Bamboo Technology and Trade Development formulated an Action Plan to upgrade the bamboo economy by according bamboo development a strategic role in rural development, poverty alleviation and bamboo-based handicrafts and industrial development. This is to be achieved under an integrated programme of expansion of plantation, of bamboo species on selective basis, with a view to reaching the markets and utilization centers, scientific management with the involvement of expert committees, Self Help Croups (SHGs), and assisting the industry to access and apply modern technology for producing globally competitive new generation bamboo products.

National Bamboo Mission (NBM)

With a view to using the potential of bamboo crop, Department of Agriculture and Cooperation (DAC), Ministry of Agriculture and Farmers Welfare implements a 100% Centrally Sponsored Scheme called National Mission on Sustainable Agriculture (NMSA) under the umbrella scheme Krishonnati Yojana of which National Bamboo Mission (NBM) is being implemented as a sub scheme.

The Mission plans to promote the holistic growth of bamboo sector by adopting area-based, regionally differentiated strategy and to increase the area under bamboo cultivation and marketing. Under the Mission, steps have been taken to increase the availability of quality planting material by supporting the setting up of new nurseries and strengthening of existing ones. To address forward integration, the Mission is taking steps to strengthen marketing of bamboo products, especially those of handicraft items

Objectives

To increase the area under bamboo plantation in non-forest Government and private lands to supplement farm income and contribute towards resilience to climate change as well as improve availability of quality raw material

requirement of industries. The bamboo plantations will be promoted predominantly in farmers' fields, homesteads, community lands, arable wastelands, and along irrigation canals, water bodies etc

(i) To improve post-harvest management through establishment of innovative primary processing units near the source of production, primary treatment and seasoning plants, preservation technologies and market infrastructure.

(ii) To promote product development keeping in view market demand, by assisting R and D, entrepreneurship and business models at micro, small and medium levels and feed bigger industry.

(iii) To rejuvenate the underdeveloped bamboo industry in India.

(iv) To promote skill development, capacity building, awareness generation for development of bamboo sector from production to market demand.

To realign efforts to reduce dependency on import of bamboo and bamboo products by way of improved productivity and suitability of domestic raw material for industry, to increase income of the primary producers

Coverage

The Mission will focus on development of bamboo in limited States where it has social, commercial and economical advantage, particularly in the North Eastern region and 13 other States including Andhra Pradesh, Bihar, Chhattisgarh, Gujarat, Jharkhand, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Odisha, Tamil Nadu, Telangana and Uttarakhand, The Mission is expected to establish about 4000 treatment/ product development units and bring more than 100000 ha area under bamboo plantation during the period 2018-19 and 2019-20

National Mission on Bamboo Application (NMBA), now North East Centre for Technology Application and Reach (NECTAR).

National Mission on Bamboo Applications (NMBA), a Technology Mission was established by he Department of Science and Technology during the 10th five-year plan period. NMBA has now joined North East Centre for Technology Application and Reach (NECTAR) an autonomous organization under Department of Science and Technology, Govt. of India.

The primary objective of the mission was to support the up gradation and

enlargement of the bamboo sector with special emphasis on value added products and applications. It supported the efforts of the government towards better economic opportunity especially in areas and amongst people who are relatively disadvantaged

The Mission was multi-disciplinary in its approach with focus on value addition and commercialization, developing, testing and disseminating technologies, creating knowledge and technology network in action.

The core application and thrust areas of the NMBA include wood substitutes and composite, structural Applications, machinery and process technologies; Agro Processing; Industrial Products and Bamboo for energy.

The NMBA has played an important role in skills training to almost 2,50,000 persons in primary processing and related activity who were integrated with the industry/ economy for supply of mats. It has set up more than 42 lakh sq.ft. of public utility structures with just socio-economic objectives in many states and union territories and also contributed towards rehabilitation construction after the tsunami in Andaman and Nicobar is lands in the year 2004 and the 2005 Uri earthquake disaster in J and K and in Sikkim in the year 2011.

AGROFORESTRY ORGANIC FARMING

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INTRODUCTION

Conservative agriculture efforts around augmenting harvests of a selected produce. It's upheld a simple assumption: crop yields are raised by supplement inputs and by predominant vermin, illnesses and weeds. Natural agribusiness might be an all-encompassing methodology of cultivating: other than creation of results of top quality, an imperative point is that the preservation of normal assets likes fruitful soil, clean water and affluent assortment. The craft of natural cultivating is to frame the least difficult utilization of biological standards and cycles. Natural ranchers will take in a phenomenal arrangement from learning the connections in common biological systems like forests. Trees and various plants take up supplements from the dirt and join them in their biomass. The supplements go to the dirt once leaves or branches fall or plants pass on. A piece of the biomass is devoured by various creatures (counting creepy crawlies), and their waste matter returns the supplements to the dirt. Inside the dirt, a huge assortment of soil living beings are worried inside the decay of natural material that makes supplements available to plant roots again. The thick root arrangement of woods plants gathers the free supplements basically completely. Backwoods have a high variety of plant sorts of entirely unexpected size, root frameworks and necessities. Creatures are a piece of the framework. In an exceptionally sound, different frame work, in the event that one organic entity exits, it's immediately supplanted by another that fills the hole. Along these lines space, light, water and supplements region unit utilized close ideally. The outcome's an outrageously steady framework. Agroforestry is one in everything about easiest employments of agro-biodiversity that moreover produces different benefits, along with disintegration the executives and wetness maintenance. Expound examples of vertical striation give an assortment of radiant and cooler conditions for different species. In a few tropical nations, guaranteed natural items are made with accomplishment in agroforestry frameworks. Frameworks epitomize variety of money and means crops (for example bananas, espresso, cocoa, pineapple, sweet potatoes, beans) yet as stock. Cows and pigs are solid in pens ("zero eating") and furthermore the compost is reused, giving fruitfulness. Home nurseries are intended to amplify variety.

AGROFORESTRY BENEFITS FOR ORGANIC FARMING

Agroforestry is extremely adaptable and applicable among a large vary of physical and social conditions because it enhances stability and productivity of agro-ecosystems and

alleviate environmental stresses. Thus, this practice shows substantial ecological and socioeconomic roles in farmer's resource. Orthodox fields were found to be less numerous with reduced density leading to low annual gross financial gain. So, it's less ecological and socioeconomic benefits, as compared to organic fields. Coverage on the sector edges and bounds, shading effects and delightful natural scenery are the most causes for the adoption of agroforestry among organic farmers, whereas undermining agroforestry importance, ignorance, lack of awareness furthermore as land shortage are the foremost factors of non-adoption of agro biology among standard farmers. there's an important ought to raise recognition and awareness at the agricultural grassroots level to in still information regarding the values of agroforestry and assist in applicable tree management techniques and inter-cropping regimes furthermore as guaranteeing accessibility to markets among the farmers so as to boost the ecological and socioeconomic sustainability of agro-ecosystems.

Current standard agribusiness is considered impractical and lacking to manage pleasant gathering of people difficulties like temperature change, ecological contamination, food security, reliance on fossil energy moreover on the grounds that the decay of common assets and assortment. A few of those issues are related with horticultural specialization (for example monoculture) and in this manner the subsequent improvement of the agro-biological system. during this regard, endeavours pointed toward up singular science strategies and at expanding the utilization effectiveness of outside inputs (for example fake data sources, petroleum products), while not altering the construction and elements of the total framework, appear to be light to acknowledge reasonable in generally regular and concentrated cultivating frameworks. Current natural cultivating frameworks embracing the supposed info replacement approach stay concentrated and incredibly specific and not basically ready to extensively improve their supportability. This may require framework broadening and plan of the agro-environment to expand the spatial and transient enhancement of every one of its parts and advance positive natural connections between them. Agroforestry is an agrarian methodology upheld the enhancement of the agro-biological system creation parts (woody perennials, similar to trees or bushes, and crops and additionally animals) and on the increase of the agro-natural connections between these parts. Thusly, it's extraordinary potential, giving an opportunity to expanding the property of natural cultivating.

BENEFITS AND OPPORTUNITIES FOR ORGANIC AGRICULTURE

- Diminished synthetic deposits in food and the climate.
- Hardly any unequivocally negative natural effects.
- Monetary execution is regularly identical to customary cultivating.
- Elevated requirements of creature government assistance.
- Dependable and sound standard-setting cycles and certificate plans.
- Dynamic review of strategies and norms.
- Solid consumer interest and brand acknowledgment.
- Native information is esteemed.
- Potential for agreeable provincial and territorial turn of events.

OPPORTUNITIES AND CHALLENGES

Organic farming has pulled in impressive consideration from the individuals who consider it to be a panacea to the individuals who consider it to be philosophical jabber. A more unassuming duty regarding the natural development might be to fill in as good example for a cultivating framework in which esteems other than monetary are developed. Natural cultivating asks how we should identify with one another and our common habitat. The estimations of the natural development are not exclusive, but rather depend on perception and good judgment: treat domesticated animals well, use assets sparingly, utilize the most un-unsafe technique; nature is inalienably significant, etc. Food security relies on close to home connections of honesty and trust among ranchers, ranch labourers, providers, buyers and others all over the horticultural inventory network, and respectability and trust have been key to natural agribusiness' prosperity. There are numerous other good examples across the range of agrarian frameworks, like protection culturing, permaculture and customary cultivating frameworks, yet natural cultivating has arisen as outstanding amongst other realized elective cultivating frameworks created in light of the weaknesses of standard horticulture. A considerable lot of the key advantages and openings for natural horticulture are appropriate regions for the natural development to show administration and advancement, including confirmation and evaluating methodology, provincial and local turn of events and ease agrarian frameworks depending on organic and environmental cycles.

DIFFICULTIES FOR ORGANIC FARMING

Maintaining global economic prosperity requires matching organic values with commercial imperatives.

Keeping organic standards and certification procedures flexible to fix issues like:

- Environmental protection and regeneration;
- Qualification programmes that are available, affordable, and flexible;
- Capable work relations and land residency plans;
- Creature government assistance;
- New sources of info, for example, 'normal' biocides, soil alterations and gmos; and
- Deficient or informal reason for including/barring materials from natural guidelines.
- Seeking after worldwide harmonization of guidelines and confirmation.
- Growing locally appropriate agronomic answers for creation requirements, like weeds, creature wellbeing andsoil richness.
- Extending research exercises in numerous controls (especially past Europe and North America) and cultivatethe joining of information.

- Safeguarding food quality while attempting to expand efficiency. Teaching and preparing at all levels toassemble limit, framework and organizations.
- Deficiencies in administrative and showcasing structures (for example naming).
- Unreasonable purchaser costs and conflicting quality and accessibility.
- Setting up and keeping up validity and polished skill.

CHALLENGES TO AGROFORESTRY ADOPTION

The chances for agroforestry are energizing, yet not deprived of difficulties. Agroforestry selection has been shockingly short, seeing the all-around reported advantages. Obstructions have incorporated the cost of foundation, landowner's absence of involvement in tree, and the time and information needed for the executives. Numerous ranchers find out about new horticultural practices through expansion faculty or agrarian item vendors, and these experts ordinarily don't have preparing or experience with agroforestry. Also, nonattendance of set up display plots makes it hard for landowners to see these structures, in actuality. Since an enormous number of the significant outcomes from agroforestry are less indisputable or longer-term, it may be difficult for landowners to envision them. For agroforestry structures that produce palatable things, for instance, verdant food varieties, the coordination of accumulate can be trying. For agroforestry frameworks to be monetarily serious, motorization might be needed for bigger plantings. This can be muddled if different organic product or nut species are developed. Non-customary business sectors and postponed benefits might be another impediment. The monetary achievability of some agroforestry frameworks, for example, silvopasture have been demonstrated to be beneficial, though different practices like biomass plantings or riparian cushions may require the advancement of business sectors that offer remuneration for the environment administrations gave to bode well. Social change and systems administration will likewise assume a part as mentalities advance to incorporateoptions in contrast to the standard.