SOCIAL FORESTRY AND AGROFORESTRY:

PAST TRIUMPHS AND FUTURE HORIZONS

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“THE EARTH, THE AIR, THE LAND AND THE WATER ARE NOT AN INHERITANCE FROM OUR FORE FATHERS BUT ON LOAN FROM OUR CHILDREN. SO WE HAVE TO HANDOVER TO THEM AT LEAST AS IT WAS HANDED OVER TO US”

-Mahatma Gandhi

Preface

'*Trees are the Lungs and Streams are the Blood Vessels of the Mother Earth*'

Serving mankind since time immemorial with its shade and cover, food and livelihood resources, trees play a vital role in sustaining life on the planet. As the population grows at an uncontrollable rate, the need for more infrastructure and living spaces continues to engorge whatever remains of the forest cover in the country. However significant positive effects can only be expected when about 33 per cent of land is covered with vegetation. To achieve this goal, a long term planning on planting of appropriate multipurpose tree species in agroecosystems has to be necessary. This mission is very difficult until and unless resource poor people's are provided with fuelwood for cooking, small timber for construction and fodder to their animals. It requires scientific management and sincere efforts of all the stakeholders. The importance of promoting environmental friendly management practices in surrounding ecosystems that provide local community with their day-to-day needs for food, cash, shelter, medicine, *etc*.

Social forestry and agroforestry are one of the components of sustainable agroecosystem development for protecting the forests and helping to sustain the rural livelihood as well as environmental stability. It is an integral part of the Gandhian philosophy of economic growth and community development. Agroforestry, deliberate introduction or retention of trees on farmlands, is widely recognized as a sustainable land-use management practice for all agricultural landscapes. It not only creates greater economic value, enhances biodiversity and improve soil, water, and air quality on many sites and also generated the additional resources in stepping stones towards self-sufficiency and sustainable ecosystem development.

Despite rapid developments in social /agroforestry practices, many research activities and emerging issues have become prominent in the ecosystem sustainability agenda of recent years. Therefore, there is a need to make available up-to-date information for referring the society in social /agroforestry programs. The book '*Social Forestry and Agroforestry: Past Triumphs and Future Horizons*' is designed to obtain a systematic knowledge on the components of agroforestry practices, and methodologies to bring more area under tree cover outside the conventional forests. This textbook is intended for as a focused material to undergraduate and postgraduate students, research scholars, extension workers in agriculture, horticulture, forestry, environmental science, NGO's, KVK's, rural institutes and other allied sciences.

As this is the first edition of the textbook, errors and omissions are unavoidable. The authors would greatly welcome feedback from valuable readers and students who use this textbook for their references.

The Authors

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The Authors

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Chapter - 1

INTRODUCTION

"Trees means water, Water means bread and Bread is life"

The continued existence of the human race wouldn't have been feasible without trees in our biosphere. Trees are the dominant component in the terrestrial ecosystem of the biosphere as primary producers and a major life supporting ecosystem. The forests are Earth's most precious renewable natural resource, supports directly or indirectly and with various degrees to the terrestrial biological diversity of the planet earth. Forests are found at diverse latitudes and elevations form distinctly different ecological zones *viz.*, tropical forests near the equator, temperate forests at mid latitudes and boreal forests near the poles. Higher elevation areas tend to sustain forests analogous to those present in higher latitudes and quantity of precipitation also affects forest composition.

Forests has to keep the balance between three main stakes *viz.*, ecological, economic and socio-cultural. For millennia ahead of the industrial revolution, forests and trees were the source of land for settlement and cultivation, goods and materials for construction, biomass for fuel and energy and indeed, directly for food and nutrition as well. The extend of agricultural revolution depended on the conversion of forests into cultivable land. The lifelong contributions of forests to global biodiversity, to the fertility of agricultural lands and to the wellbeing of those who depend on them mean that forests are immensely precious for sustainability.

Globally, around 25 per cent of the world's population relies on forests for their livelihoods, many of whom are the poorest. Forests provide US$ 75–100 billion per year in goods and services such as clean water and healthy soils. Forests are home to 80 per cent of the world's terrestrial biodiversity. Forests account about 75 per cent of the gross primary production of the Earth's biosphere and contain about 80 per cent of the Earth's plant biomass. Net primary production is estimated at 21.9 gigatonnes of carbon per year for tropical forests, 8.1 for temperate forests and 2.6 for boreal forests. Trees use the natural resources like sunlight, soil, water and air to grow, and that is the basis for renewability.

India faces a critical imbalance in its natural resources base with about 18 per cent human and 15 per cent livestock population of the world being supported only on 2.4 per cent geographical area, 1.5 per cent forests and pasture lands and 4.2 per cent water resources. In the mean time India is the motherland of wide diversity lying at the juncture of the big geographic regions of Afro-Eurasia and the Orient because of diversified climatic and physiographic factors. India is blessed with all form of vegetation like tropical, subtropical, temperate and alpine. India is one of the world's top 12 "megadiversity" nations with two hot spots. Of the nearly 425 families of flowering plants in the planet, 328 families with 21,000 species are occurred in India. From this varied emporium, commercially important non-timber forest products (NTFPs) are derived from over 3,000 species.

Lowering the loss and degradation of forest ecosystems and promoting their restoration have the prospective to contribute over one-third of the total climate change mitigation by 2030 to meet the objectives of the Paris Agreement. Successfully achieving sustainable forest management will provide integrated benefits to the community and ecosystem, ranging from safeguarding livelihoods to protecting the biodiversity and environment provided by forests, dropping rural poverty and mitigating the ill effects of climate change.

Managing forests increases the benefits, meets society's needs and maintains its sustainable services for the benefit of present and future generations. Many of the world's forests and agricultural lands, especially in the tropics and subtropics are still not managed sustainably and scientifically. A number of countries lack in appropriate forest policies, legislation and institutional frameworks to uphold sustainable forest management, while others may have inadequate funding and lack of technical knowledge. Forest management plans subsist to make sure the sustained production of wood, without paying consideration to the many other products and services that forests/trees offer.

Realization of the significance of forests led to the emergence of organizations such as the International Union of Forestry Research Organization (IUFRO), United Nations Conference on Environment and Development (UNCED) and Intergovernmental Panel on Climate Change (IPCC), but also the signing of various multilateral environmental agreements, including the Convention on Biological Diversity (CBD), United Nations Framework Convention on Climate Change (UNFCCC) and Kyoto Protocol. Changes in

forest and tree cover have been made one of the 48 indicators of the Millennium Development Goals (MDGs) under Goal 7 (ensuring environmental sustainability).

The world stands at a critical juncture in the second decade of the 21st century to overcome the impacts of climate change, it comprise of shifting seasons that affect planting and growing periods such as extreme heat, droughts, increased aridity and water shortages that reduce or wipe out productivity, erratic rainfall that makes farm planning extremely difficult; storms, floods and landslides also devastate crops, livestock and habitats; rising sea levels that salanize farm land; increased human, plant and livestock diseases; and lowered productivity of farm, livestock and fisheries.

Global policy makers have begun to face the unspeakable possibility of the people running out of food stuffs and the land to grow it. An innovative way of thinking is essential when we are going to meet the demands for future needs. Trees along with agricultural crops play a significant function in Earth's ecosystems and provide a wide range of benefits to the dependent communities. At present social and agroforestry practices have become sustainable modes of forest and tree cover management; empowering dependent stakeholders and hence, allowing integration of diverse practices that supports the sustainability of the ecosystem. About 30 per cent of the world's rural populations are already using trees, and that trees are present on 46 per cent of all agricultural land.

The world stands at a crucial juncture in the second decade of the 21 century. Staggeringly, there is necessitate to grow as much food in the next two decades as we have done in the past 800 decades. Meanwhile, the worldwide population continues to raise and demanding more food. A new approach of doing crop production is essential to meet the demands for food tomorrow, let alone in 2025, when urban populations become the majority in developing countries or by 2050, when it could be expect 9.7 billion mouths to feed. Two thirds of agricultural lands in world face degradation or deteriorate and about 140 million hectares of forest land have been lost worldwide since 1990.

Forestry activities along with other kinds of tree management in agroecosystems are essentially economic undertakings. Most of the wide range of forest products, including timber, fuelwood and non wood forest products (NWFPs) are tradable in markets. Environmental and recreational services such as water and soil protection, biodiversity conservation, carbon sequestration and ecotourism are equally imperative for subsistence.

The scientific forestry management system has been practiced for the last 150 years. However, this system is incapable to sustain the quantity and quality of India's forests to meet the demands of the rising population for wood and non wood forest products. This also in turn has encouraged soil degradation, declining of productivity and loss of biodiversity. Forestry outside the conventional forests has been an integral element of development strategies since the early development decades after independence. Its objectives and related approaches have changed over the years. During the 1970s, erosion protection, local forest related goods supply and generating rural incomes were the dominant goals. During the 1980s, an important shift towards promoting natural forest management occurred to achieve development and forest conservation objectives. Since the 1990s, forestry practices support initiatives have clearly focused on both poverty alleviation and forest conservation, with emphasis on legal and regulatory reforms, small and medium enterprise development and capacity building.

There are four components of scientific forest management system that seem to have played the major roles are i) forest exploitation under different silvicultural systems for commercial purposes and revenue generation, ii) planting of industrial fast growing species, iii) conservation of some areas for biodiversity and iv) attempts to protect selected forests for soil and water conservation. To carry out these tasks, the Indian government was entrusted with the custodianship of 90 per cent of the total forest area (20 per cent of the land area of the country).

The goal of Nationa1 Forest Policy (1988) emphasized that a minimum of one third of the total land area of the country to be under forests or tree cover. It is hard to extend forest area but tree cover can increase substantially through sustainable people's forestry programmes. It is necessary to strengthen the research activity in order to evolve innovative methodology in implementation of tree planting programmes needed by the people in their everyday life and also for generation of income. Social/farm/agro forestry being a

people's programme is different from traditiona1 forestry. The productivity has to be increased per unit of area per unit time. It can increase the relative share of forest in the total land use pattern in the country. It must aim a need basis and time bound programme of afforestation and tree planting. India's social forestry effort is among the largest in the world. It is essential that social forestry should increasingly become a people's enterprise where the government has a supporting and non-implementing role. Largely with the assistance of international bodies such as the World Bank, SIDA and USAID more than 14 million hectares of relatively small parcels of land were afforested during the 1980s.

In recent decades, in a series of familiar responses to deforestation, the Government of India replaced the contractor system of tree harvesting by parastatals to reduce corruption. It also banned all green felling in the forest lands, prohibit clear cutting in the silvicultural management system, brought more areas under biological conservation (4.4% of the total land mass of India) and made forestry subject to erstwhile state control. It has also changed policies to involve local people in forest management which includes social/ farm forestry in non government areas and joint forest management.

The number of trees planted by the farmers in social forestry is not accurately recorded but it runs into billions. Nevertheless, the overall forestry situation has been dismal. The closed forests have become open forests, the open ones have degenerated and the degraded portions have been deforested. Over 1500 plant and animal species are endangered. Corruption has not decreased, local poor people in most areas near the forests have continued to damage and disturb both the old forests and new plantations with the exception of trees on farms. The local poor also collect subsistence products from the forest to add their meager income. The quality of trees in farm planting is unsatisfactory because they were raised from poor quality seeds. Encroachment into the forest areas continues unabated in many areas.

The most glaring deficiency in the scientific management is great concern about satisfying the local needs in theory and ignorance to it in practice. In other words, the scientific management system and the adhoc corrections failed to sustain the forests and induce positive development. Unless the local people voluntarily take actions to protect the forest from all forms of destruction, there is no prospect of a genuinely sustainable forestry development.

The increasing global concern regarding the production of adequate food to sustain the growing human population has been reinforcing the magnitude of sustainable intensification of plant production. Agroforestry as a traditional land use adaptation may potentially maintain the livelihood improvement through simultaneous production of food, fodder and firewood as well as help to reduce farmer's vulnerability and increases their ability to adapt the impact of climate change. It plays a major role in bringing the desired level of diversification along with sustainability. It is expected that by 2050 there will be considerable increase in area under tree cover *i.e*. the trees outside forest and a large portion of it will be developed to agroforestry. Various models of agroforestry systems are practiced in different agro-ecological regions of India which reflects biophysical and social variations. The systems and practices, in response to local conditions and traditions, vary enormously in structural complexity, species diversity, productive and protective attributes and socioeconomic benefits. The farm - industry linkages have also helped the systems to be more sustainable than the traditional cropping systems.

Agroforestry provides a larger contribution of the total income of farmers per year. This contribution is obtained from agricultural crops, forestry and livestock production. Many households keep cattle that are regularly sold or redeemed for cash and food as part of their normal activities yearly. Agroforestry based land use system provides better overall productivity, soil fertility enhancement, nutrient cycling, soil conservation, microclimate modification and carbon sequestration potential are usually superior than that of an annual system. Understanding this dynamism, replicating the most successful agroforestry systems and matching them to specific socio-cultural-ecological circumstances is crucial for helping farmers adapt to climate change. However, yet, wide scale agroforestry adoption remains inadequate due to numerous obstacles and challenges, remarkably, the lack of institutional and precise policy support for agroforestry.

Enhanced economic and environmental contributions from the forestry sector in the future will depend on the extent to which stakeholders are capable effectively to address the parental issues. The foremost of these concerns efforts to better understand and capture forest benefits that are currently neither recognized nor,

consequently, being captured. Secondly, the deployment of new technologies in the forestory sector for improved value added in processing, manufacturing and exchange are key intervention areas. Thirdly, equal importance is the need to understand the contributions of forests to other sectors, in particular soil and water conservation, agriculture, industry, tourism and health. Finally, efforts to address the legality of harvesting of forest products are likely to develop considerably the extent to which governments and peoples are able to benefit from forest related activities.

More recent shifts in thinking about forestry practices and the benefits they provide have used the lens of ecosystem services. Scientists and decision makers recognize the significant role of economic incentives from local to national levels in reducing deforestation. They argue for the need to compensate producers of tree based ecosystem services. The possibility of mitigating climate change through terrestrial carbon sequestration has thus led to the development of new regulatory and economic strategies to protect and improve forest and tree cover through payments for ecosystem services in programs such as REDD+ (reduce emissions from deforestation and forest degradation and foster conservation, sustainable management of forests and enhancement of forest carbon stocks). Sustainability of agroecosystems, their biodiversity, and their flows of goods and services will require innovative emphases on areas of value added that create alliances beyond forests, cross sector and multi scale governance strategies, effective financing that counts the contributions of a range of stakeholders and greater emphasis on coordination and communication among stakeholders.

Chapter - 2

FOREST

The word forest is derived from the Latin word '*foris*' meaning outside, the reference being a village boundary or wild land set aside for hunting or fence and it must have included all uncultivated and uninhabited land. All around the world roughly 800 definitions to define the forests and wooded areas are in use. Forest is a stand of trees growing close together with associated plants of various kinds. Ecologically a forest is "an ecosystem or assemblage of ecosystems dominated by trees and other woody vegetation". Technically, forest is "an area managed for the production of timber and other forest products, or maintained as woody vegetation for certain indirect benefits which it provides".

Food and Agriculture Organization (FAO) of United Nations defines "forest as a land having a tree canopy cover of more than 10 per cent and over an area of more than 0.5 ha with forestry as the principal land use". India defined forest during the Kyoto Protocol by adopting the definition of United Nations Framework Convention on Climate Change (UNFCCC). Accordingly, forest is a land area having at least 0.05 ha land area and 15 per cent tree cover with at least 2 m tree height. As per UNFCCC this definition includes the closed (tree cover more than 40 %) as well as open forests (tree cover between 10 to 40 %). United Nations Environment Programme (UNEP) follows 40 per cent criteria of tree cover to define the forest.

People began life on this Planet earth as forest dwellers, even today forests provides livelihood for more than 1.6 billion people worldwide and rely on forests for their basic necessities such as food, fodder, fuel, medicines, etc. Forests make available a wide range of wood and non-wood products as well as environmental and social services. The role of forest is classified into three broad categories *viz*., productive, protective and socio-economic.

Role of forest

A. Productive role of forests

Forests fabricate various commodities that are either directly consumed by the households without going to the formal market or traded in a market for monetary income. Wood and wood products and Non-wood forest products (NWFPs) / Non-timber forest products (NTFPs) are obtained from the forests and involved in an essential part of development and livelihood of people.

i. Wood and wood products

Wood and wood products are the main commercial products of forests. They include wood, fuel wood and charcoal, raw materials for industries *etc*. The world demand for wood and wood products has been growing from 2 to 3 per cent per year over the past decade.

a. Wood

Wood is a most versatile and miraculous resource and has played a major role in the development of civilizations in the world for thousands of years. The world's forests and tree plantations are thought to include 400 billion m^3 of wood. In 2017, the global industrial round wood production amounted to 1.9 billion m^3 which is 13 per cent increase compared to the level in 2000. In 2016, global sawnwood production totalled 468 million m^3, which was 16 percent higher than in 2012 (405 million m^3). Likewise, global wood-based panel production reached 416 million m^3 and a 24 percent increase over the observed period (2012).

In 1995, the United States accounted for nearly 24 per cent of the hardwood lumber produced worldwide. Other major lumber producers were India, Brazil, China and Malaysia. Between 1995 and 2002, global hardwood lumber production declined with the greatest declines occurring in India. About 77 per cent decline in Indian hardwood lumber production during this period appears to be the result of a ban on most logging that was instituted in the late 1990s to stop serious depletion of the country's forest resources. According to FAO, in 2017, India ranks 8^{th} place in industrial round wood production (United States of America (19%), Russian Federation (10%), China (9%), Canada (8%), Brazil (8%), Indonesia (4%), Sweden (4%), India (3%) and Finland (3%)).

The indigenous production was sufficient to meet most of the domestic timber demand till the 1980s. However, with the enactment of the Forest Conservation Act, 1980 and subsequently the formulation of the National Forest Policy, 1988 there has been additional emphasis on conservation than timber production. India cannot meet its own demand for wood products with domestic supply and currently, about 50 per cent of the wood supply in the country comes from non forest sources, that is, imports and from outside of the conventional forests mainly from public forests and plantations. According to ITTO (2017) the wood

industry of India produced 50 million m^3 of logs in 2015. Although India is one of the world's top producers of tropical logs, it is also one of the world's largest consumers of wood products and as a result currently it becomes the 2nd largest importer of tropical logs.

b. Fuel wood and charcoal

Fuel wood, in the form of firewood or processed into charcoal, would continue to be used in all parts of world as fuel, because it is the least expensive fuel and is reliable with the cultural patterns and living habits of the rural population. The charcoal is man's first industrial fuel which has assumed for over four thousand years (Fig 2.1). Fuel wood can only be considered a renewable form of energy so long as forest resources are kept at a level to sustain needed supplies. The efficient usage of wood fuel is much more eco-friendly than fuels such as kerosene and natural gas (LPG). Generally the LPG emits 15 times more CO_2 (carbon dioxide) than wood and kerosene nearly 10 times as much. India has been estimated about four million man years are engaged to collect their fuel wood.

Global fuel wood production is 1.89 billion m^3. International Energy Agency predicted that population growth will render 2.7 billion people still relying on plant based energy forms in the year 2030. According to FAO, in 2017, India ranks first in wood fuel production (16%) followed by China (9%), Brazil (6%), Ethiopia (6%) and Democratic Republic of Congo (4%). The household segment is one of the largest users of energy in India, accounting for about 30 per cent of final energy consumption reflecting the significance of that sector in total national energy scenario. As per the results of the household consumer expenditure survey conducted by National Sample Survey Office (NSSO) in the year 2007-08, over 77 per cent of households in the country continued to depend on firewood and chips for cooking, with 9 per cent using LPG.

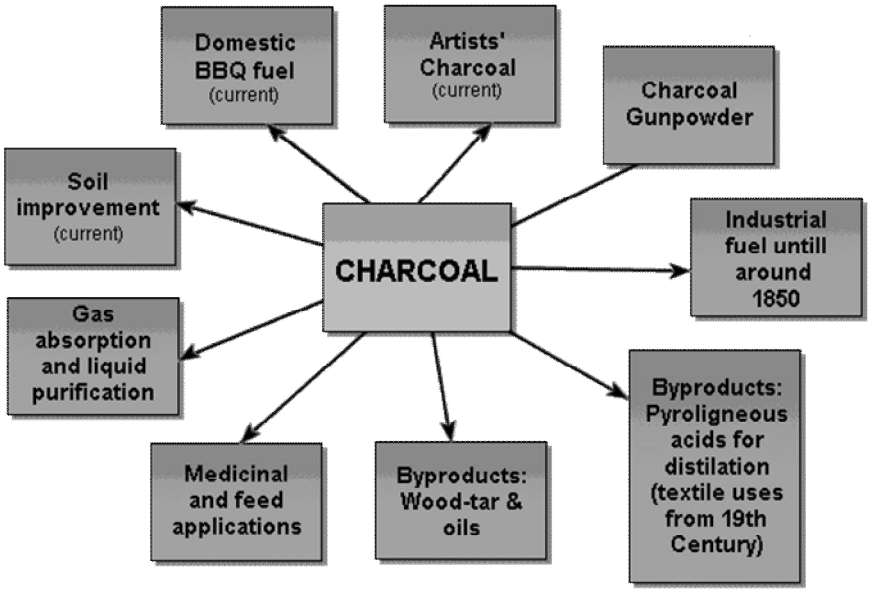


Fig-2.1: Utilizations of charcoal

According to one report the total annual fuel wood consumption in India roughly estimated between 250 and 310 million m^3. Most of the 225 million m^3 of fuel wood is consumed domestically by the forest especially the poor's and tribal's. About 30 million m^3 of fuel wood are used for industrial purposes, including production of charcoal. However, only about 17 million m^3 of fuel wood are recorded to be derived from India's forest. Fuel wood collection (head loading) from forests is traditionally uncontrolled and unmonitored practice, which constitutes a large part of consumption leaving a staggering gap of more than 90 per cent of the total consumption. Based on per capita fuel wood consumption, the Forest Survey of India (FSI) has estimated the annual consumption of fuel wood in rural areas in the neighborhood of forests and non-forest areas at 78 million tonnes and 74 million tonnes, respectively. Average per capita consumption was 424 kg and 144 kg per annum, respectively.

c. Raw materials for industries

Forests play a most important role as a source of raw material to the domestic wood based industries. Any industry which depends on forests for their raw material requirement is considered to be forest or wood based industry. The growing demand of wood and wood based industries will create a wood deficit of 20-70 million m^3 by 2025. The following are the major forest based industries which depend heavily on forest plantation to meet the raw material requirement.

i. Wood pulp and paper

Pulp is a lignocellulosic fibrous material prepared by chemically or mechanically separating cellulose fibres from wood. Among the wood based industries, pulp and paper industries have unique position in the economic growth as the paper is the very basic need of the civilization. Many kinds of paper are made from wood, includes printing and writing paper, packaging paper, coated paper and some speciality paper. Varieties under printing and writing paper are creame wove paper, super printing paper, maplitho paper (non-surface and surface size), copier paper, bond paper and coating base paper and others. The varieties under packaging paper are kraft paper, boards, poster paper, *etc*. The other varieties under coated paper are art paper/board, chromo paper/board and others such as filter paper, tea bags, tissue paper, medical grade coated paper, *etc*.

The world wood pulp production is 184 million tonnes and the paper and paper board is about 413 million tonnes. India produces 2.3 million tonnes of wood pulp and 4.2 million tonnes of paper and paper board. The domestic demand in India grew from 9.3 million tonnes in 2008-09 to 15.3 million tonnes in 2016-17 at a compound annual growth rate of 6.4 per cent and is expected to grow to 22.0 million tonnes by 2025. In spite of the sustained growth witnessed by the paper industry, the per capita paper consumption in India stands at a little over 13 kg which is well below the global average of 57 kg and significantly below 229 kg in USA. As per Indian Paper Mills Association's (IPMA) estimates, this industry provides employment to over 5 lakh people across approximately 750 paper mills. The demand for wood based products in Tamil Nadu is 8 to10 lakh tonnes of wood pulp per year, which is greater than the 4 lakh tonnes that are currently available.

Types of wood pulps

- Kraft pulp: wood free pulp or free sheet (all lignin removed by sulphate process), consists of pure cellulose fibres used for fine papers, packaging
- Semi-chemical pulp: lignin removed are used as corrugated medium
- Dissolving (sulfite) pulp: used for acetate, film and rayon making
- Gumwood pulp: wood is ground off of logs and used for newsprint
- Pressure ground wood pulp: logs ground under pressure and steam, used for newsprint.
- Thermo-mechanical pulp (TMP): chips ground under pressure and superheated steam, used for newsprint, fibre board, hardboard, *etc*.
- Chemi-thermo-mechanical pulp: used like TMP (uses chips, superheated steam & some caustic soda)

The raw material pattern of pulp industries in India is hardwood including bamboo (30-35 %), recycled material (45-50 %) and agricultural residues (20-22 %). *Acacia mangium, Bamboo, Eucalyptus, Casuarina equisetifolia, Pinus radiate, etc.,* are mainly used for producing wood pulp. It is projected that in 2025 the demand for wood for the production of pulp in India is 45.86 million m^3. After the enunciation of National Forest Policy, 1988, all wood based industries have been directed to obtain raw materials on their own preferably by establishment of direct relationship between the factory and the individuals who can grow the raw material by supporting the individuals. However, the industries have to rely on imported wood pulp and recycled paper to meet the part of India's raw material needs.

ii. Match Industries

Match wood industry is one of the oldest wood based industries in India. India makes four crore matchboxes per day and these are the cheapest in the world. Every third matchbox used in the world is Indian. Yet, India's per capita consumption of matches at 2.9 sticks per head per day is perhaps the lowest in the developing world. About 75 per cent of the total match wood industries in the country are located in the state

of Tamil Nadu which comprises nearly 6,000 match industries with mechanized, semi mechanized and as cottage industry.

The increasing demand for the matches coupled with declining wood resources is a major bottle neck faced by the entire match industries in India including the ancillary splint and veneer industries. The veneer quality wood for match boxes, which accounts for 44 per cent of match wood used, is also in short supply. The major matchwood species are *Ailanthus excelsa, Alianthus triphysa, Albizia falcataria, Albizia lebbeck, Anthocephalus cadamba, Bombax ceiba, Erythrina indica, Populus spp*., etc.

iii. Plywood industries

One of the fastest growing wood based industries in India is the plywood industry. The industrialization and urbanization and the increased interest on interior decorations have made great usage of plywood in the country. Wide range of species have been found amenable for making face, core and inner veneers resulted in establishment of more than 2,562 large and small scale industries involved in plywood manufacture. The Indian plywood market reached a value of US$ 4 Billion in 2016, growing at a CAGR of nearly 5 per cent during 2009-2016 and the market is further expected to reach a value of nearly US$ 15 Billion by 2022. Major plywood species are *Ailanthus, Eucalyptus, Melia, Populus*, etc.

iv. Particle board industries

Particle board is reconstituted constructional panel particularly developed as a substitute for natural constructional wood and is made from low grade waste woods or from ligneous agricultural residues. These particle boards are principally used for wall panelling and interior decorations in domestic and industrial wood sector. The major raw materials are all types of wood waste, pine needles, Casuarina needles and ligneous agriculture residues

v. Fibre board industries

Fibre board is constituted using sheet materials of widely varying diversities manufactured from refined or partially refined wood fibers or other vegetable fibers.

vi. Wood veneer industries

Wood veneer is a versatile material that has grown in popularity in recent years, as interior designers and discerning consumers are attracted to natural materials. Veneers use wood, a valuable raw material, to its optimum, by slicing it into thin veneer leaves. It is both economical and ecological to use veneer instead of solid wood boards as these thin leaves produced using the same raw material can surface thousands of square feet of area. These slices of wood are glued onto core panels of real wood to produce flat panels such as doors, tops and panels for cabinets, parquet floors and parts of furniture. Thus, wood veneer production caters to endless design possibilities and creative uses of wood across interior infrastructure industry.

vii. Tree biomass power generation industries

Biomass is an important fuel source in overall energy scenario. This biomass include plantation that produces energy crops, natural vegetable growth and other organic waste and residues. Among all these biomass, the role of tree biomass is very significant due to their higher calorific value and increased fuel efficiency. Hence, large number of tree biomass based power plants has been established across the country to generate electricity. Major energy crops are Acacia's, *Prosopis, Albizia, Casuarina equisetifolia, Eucalyptus, Leucaena leucocephala*, etc.

Some other industrial raw materials obtained from forests are as follows:

- Packing cases: *Pinus* sp, *Grevillea robusta*
- Toys: *Pterocarpus santalinus, Dalbergia sissoo*
- Clothing: Manufactured, regenerated cellulosic fibres such as rayon and its variants *viz.*, nitrocellulose, modal, lyocell, *etc*. are produced from cellulose rich timbers.

d. Non-Timber Forest Products (NTFPs)/ Non-Wood Forest Products (NWFPs)

Non-wood forest products play an important role in the social and traditional life of millions of forest dependent populations, particularly the tribal and landless people, women and other rural poor. Nearly 400 million people living in and around forests in India depend on NWFPs for sustenance and supplemental

income. NWFPs contribute significantly to the income of about 30 per cent of rural people. More than 80 per cent of forest dwellers depend on NWFP's for essential necessities. The collection of NWFPs comprises the most important source of wage labour for 17 per cent of landless labourers and 39 per cent more are involved in NWFP collection as a subsidiary occupation. NWFP's are primarily consumed at the local or national level, although about 150 are traded internationally in significant quantities and contribute over 75 per cent of total forest export revenue in India.

i. Food and value added products

Natural forests supplement the food supply for human beings. Several forest fruits and seeds, flowers, rhizomes, tubers, roots, barks, etc. are consumed by people.

a) Fruits/Berries: Aegle marmelos, Anacardium occidentale, Anona squamosa, Artocarpus heterophyllus, Borassus flabellifer, Emblica officinalis, Ferronia elephantum, Morus alba, Zizyphus spp

b) Flowers: Madhuca latifolia, Bambax ceiba, Tamarindus indica

c) Seeds / nuts: Anacardium occidentale, Bamboo spp., Pinus gerardiana, Tamarindus indica, Terminalia catapa

d) Rhizome : Amarphous campanulatum

e) Tuber : Dioscorea belophylla, D. oppositifolia, Manihot esculenta

f) Root : Asparagus racemosus (satavar) and Chlorophytum borivilliana

g) Sap / Syrups: Borassus flabellifer, Cissus rapanda, Phoenix spp.

h) Shoots : Bamboo spp.

i) Green leafy vegetables: Tamarindus indica, Moringa oleifera, Sesbania grandiflora

j) Mushrooms: Mushrooms grown on wood/monocot stub: Amylosporus campbellii, Coprinus disseminatoides, Filoboletus manipularis, Gyrodontium sacchari, Hericium cirrhatum, Lentinus squarrosulus, Pleurotus cornucopiae, P. eous, Polyporus arcularius and Royoporus spathulatus. Mushrooms grown on soil: Astraeus hygrometricus, Boletinellus merulioides, Boletus edulis, Lactarius volemus, Lycoperdon utriforme, Phlebopus marginatus, P. portentosus, Schizophllum commune, Scleroderma citrinum, Termitomyces clypeatus, Termitomyces eurhizus, T. fuliginosus, T. heimii, T. indicus, T. microcarpus and Volvariella bombycina.

k) Honey/Nectar: Acacia nilotica, Acacia leucophloea, Azadirachta indica, Bombax ceiba, Emblica officinalis, Eucalyptus spp., Lagerstroemia speciosa, Madhuca latifolia, Melia azedarach, Pongamia pinnata, Prosopis juliflora, Holoptelea integrifolia, Syzygium cumini, Tamarindus indica

ii. Fodder for animals

Forests contribute about 30 per cent to the fodder requirement of the country in the form of 178 million tonnes of green fodder and 145 million tonnes of dry fodder per annum.

iii. Minor forest products

a. Construction materials

Poles, palm leaves *etc*. used for the construction of shelters.

b. Fibres and flosses

Fibres fall into three categories *viz.*, soft (obtained from stem of plants), hard (from leaf) and surface (borne on the surfaces of stems, leaves, seeds, *etc*.). Based on their general use, they are classified as textile fibres, brush fibres, plaiting and weaving fibres, natural fabrics, *etc*. Fibres obtained from *Agave sisalana* and *Sterculia villosa* have commercial importance and used in making ropes, mats, twines, nets, *etc*. *A. sisalana* yields 1 to 2.5 tonnes of fibre ha^{-1} while in *S. villosa* the yield ranges from 4.5 to 5.5 t ha^{-1}. The information based on demand of planting materials, availability of sisal fibre, interactions with different sisal producing agencies it may be estimated that the sisal area in India will be between 1800 and 2400 ha with a production of 1080-1440 tonnes.

Flosses obtained from capsules of *Bombax ceiba* and *Ceiba pentandra* is known as "Indian Kapak"**.** The floss is soft and strong and used in life-saving devices for boats, stuffing for cushions, pillows and mattresses, thermal insulation, sound proof covers and walls, padded surgical dressings, *etc*. About 300 tonnes of kapak are produced annually in India.

c. Oil seeds

Indian forests have about 86 different oil seed tree species. A substantial amount of oil seed is collected and marketed on a commercial scale from *Shorea robusta, Madhuca latifolia, Garcinia indica, Azadirachta indica, Pongamia pinnata, Schleichera trijuga, Salvadora oleoides, S. persica* and *Actinidaphne hookeri*. *Shorea robusta* seed is collected and marketed on a commercial scale. The potential production is estimated at 5.5 million tonnes but current collection is less than 10,000 kg per annum. *Madhuca latifolia* also has a potential kernel production of 1.1 million tonnes but the annual collection is around 2500 kg per annum.

d. Essential oils

India produced more than 3000 tonnes of essential oils per annum and utilized for making soaps, detergents, cosmetics, chemicals *etc*. Among them Indian sandal wood oil (35 tonnes) mostly from Tamil Nadu and Karnataka contributes over 89 per cent of its total world production. The other forest related tree based essential oils *viz*., Deoder (*Cedrus deodara*) wood oil (200 tonnes annum^{-1}), Eucalyptus (*Eucalyptus citriodora and E. globulus*) oil (60 tonnes annum^{-1}) are produced in significant amounts. Apart from that lemon grass oil, palmarosa oil, ginger grass oil, citronella oil and vetiver oil *etc*., are mostly obtained from tropical grasses rich in aromatic essential oil.

e. **Tannins and dyes**

Tannins are polyphenolic compounds and occur in varying concentrations in all plant material, but only certain plants contain concentrations permitting commercial exploitation. Important tannins are extracted from bark of wattles (*Acacia mearnsii, A. decurrens, A. dealbata*) and *Cassia auriculata,* leaves of *Embelica officinalis* and *Anogeissus latifolia,* bark of *Cleistanthus collinus,* fruits of *Ziziphus xylopyrus, Cassia fistula, Terminalia alata, T. arjuna, T. chebula etc*.. About 90 per cent of the total tannins produce from plants in the world are used by the leather industry.

India has the largest livestock population (> 400 million head) in the world therefore prospects for the leather industries are bright. Around 78,000 to 100,000 tonnes of *Terminalia chebula* nuts are estimated to be produced annually with a value at Rs. 15 to 20 million. Over 23,000 tonnes of wattle bark is harvested every year (valued at Rs. 38 million). An average 15 year old plantation yields about 12.5 tonnes of bark. About 22,000 tonnes of *Acacia nilotica* bark is produced annually (valued at Rs. 55 million). Annual production of *Cassia auriculata* bark is estimated at 23,000 tonnes with a value of about Rs. 35 million. At present about 78,000 to 100,000 tonnes of *T. chebula* nuts, 25,000 tonnes of wattle, 25,000 tonnes of babul and 23,000 tonnes *Cassia auriculata* bark are harvested every year and valued more than Rs. 200 million. In the forest scenario over 2,000 plant pigments are known, of which only a few are of a commercial importance. Among them the following are important species.

(i) **Wood dyes**: obtained from *Acacia catechu, Artocarpus heterophyllus, A. lakoocha, Pterocarpus santalinus* and *Caesalpinia sappan.*

(ii) **Bark dyes:** obtained from *Acacia concinna, A. farnesiana, A. leucophloea, Alnus* spp. *Casuarina equisetifolia, Manilkara littoralis, Myrica esculenta, Terminalia tomentosa,* and *Ventilago madraspatana.*

(iii) **Flower and fruit dyes:** This is one of the most important group of natural dyes. Flower and fruit dyes are commonly obtained from *Mallouts philippensis, Woodfordia floribunda, Bixa orellana, Butea monosperma, Toona ciliata, Nyctanthes arbour-tristis, Mammea longifolia, Wrightia tinctoria,* and *Carocus stativus.*

(iv) **Root dyes:** Root dyes are obtained from *Berberis aristata, Datisca cannabina, Morinda tinctoria, Punica granatum,* and *Rubia cordifolia.*

(v) **Leaf dyes:** obtained from *Indigofera tinctoria* and *Lawsonia inermis*.

f. Gums and resins

Gums and resins form an important group of non-wood forest products which are exuded by trees as a result of injury to the bark or wood (Table 2.1). They are used in many unrelated industries such as paper, textile, petroleum, pharmaceutical, cosmetics, food, varnishes, lacquers and soaps. Indonesia, India, China and Sudan are the major producers of gums and resins. India annually produces about 0.28 m.t. which includes about 0.22 m.t. of gums, 0.05 m.t. of resins and 1,500 t of gum-resins. Even though gum and resins is produced by a large number of plants, their commercial exploitation is restricted to members of the Leguminosae, Sterculiaceae, Combretaceae, Pinaceae, Dipterocarpaceae, Burseraceae and Umbelliferae.

Table-2.1: Classification of Indian resins and gums

Category	Name of the product	Source
True gums	Gum Arabic	*Acacia nilotica* spp. *indica*
	Gum tragacanth	*A. catechu*
		A. senegal
		Bauhinia retusa
		Lannea coromandelica
		Pterocarpus marsupium
		Sterculia urens and S. villosa
Hard resins	Copal Dammar	*Canarium strictum*
		Hopea odorata
		Shorea robusta
		Vateria indica
Oleo-resins	Balsam	*Dipterocarpus turbinatus*
	Turpentines	*Pinus roxburghii*
	Copaiba	*Kingiodendron pinnatum*
Gum resins	Gamboge	*Garcinia morella*
	Olibanum	*Commiphora mukul*

g. Phyto-pharmaceuticals

Herbal medicines in use today are derived from nearly 8,200 species of medicinal plants. A great wealth of medicinal plants is found in Indian forests. Important species yielding drugs are *Acorus calamus*, *Cinchona* sp., *Emblica officinalis, Rauvolfia serpentina, Hemidesmus indicus*, *Piper longum*, *Terminalia chebula, Terminalia bellerica, Withania somnifera,* etc,

h. Spices

Seeds of *Carum carvi*, barks of *Cinnomomum zeylanicum*, dried capsules of *Elettaria cardomomum* are used as spices.

i. Biopesticides

Pyrethrum and neem (*Azadirachta indica*) are used for the preparation of biopesticides.

j. Leaf based materials

Among the NWFPs, tendu leaves (*Diospyros melanoxylon*) used as wrappers for making country cigarettes (beedi) and leaves of *Bauhinia spp*, *Butea spp* used for making plates, dona, *etc*. In India, annually around 3 lakh tonnes of tendu leaves are produced and sold in the market with an average price of Rs 16,000 tonne^{-1}.

k. Cane

Canes or rattans are the stems of a climber plants and are used for a large number of household things *viz*. sofa, furniture, walking sticks, polo sticks, baskets, picture frames, screens, mats etc.

l. Lac and other products

Lac, wax, silk, horns, ivory, etc. are some products that are obtained from forests. Of these, the former three are most important. India is the largest producer of lac in the world. The mean lac production in the country had been estimated at 20,640 tonnes (2003 – 08).

Lac is a resinous secretion from the insect *Laccifer lacca*, which feeds on the plant sap. Lac is presently used for various purposes in plastics, electricals, adhesives, leather, wood finishing, printing, polish and varnish, ink and other industries. It is also the principal ingredient of sealing wax. The rangeeni strain of lac insect is raised on several host plants, the important being *Butea monosperma* and *Zizyphus mauritiana*. The kusumi strain strain of lac insect is raised on *Schleichera oleosa*.

The silk worm *Bombyx mori* is fed on mulberry leaves cultivated in plantations. There are other silk worms which are found wild on forest trees; the best known of these is *Antheraea paphia*, which produces the famous "tassar" silk of India. It feeds on several trees such as *Anogeissus latifolia, Terminalia tomentosa, T. arjuna, Lagerstroemia parviflora,* and *Madhuca indica*. Other wild silk worms are *Antheraea assamensis,* producing "muga" silk, and *Philosamia cynthia ricini,* producing "eri" silk. In some areas silk worms are introduced on host plants to enhance the production of silk. Estimated annual production of tassar silk is 130 tonnes per annum.

In India about 250 tonnes of rock bee honey is produced annually. After the extraction of honey, bee's wax is used in the manufacture of furniture and floor polishes, dressing and water proofing of leather goods. It is also an ingredient of shoe polish, cosmetics, lipstick, and face cream. About 64,000 tons of beeswax were produced in the world, Asia (mainly India) being the major producer with 31,000 tonnes.

B. Protective role of forest

The forests have many protective functions, they are as follows

i. Creates conducive macro and micro climate

Forests provide shade and absorb heat energy, producing a cooling effect and lowered the temperature up to 8^{o} C compared to the adjoining open areas under changing climatic condition.

ii. Enhancing precipitation

Forests capture horizontally moving clouds and create favourable condition for the condensation which increases local precipitation.

iii. Source of carbon sink (carbon sequestration)

Forests form an effective sink for the carbon dioxide produced as a result of animal respiration, burning of fossil fuels, volcanoes and other natural and human induced phenomenon. The world's forests and forest soils store more than one trillion tons of carbon- twice the amount found floating free in atmosphere. According to global Forest Resource Assessment report, 2010, the total carbon stock of the world is 652 Giga tonnes (161.8 t ha^{-1}). Out of this the forest biomass contains 289 Giga tonnes (71.6 t ha^{-1}); the dead organic matter contains 72 Giga tonnes (17.8 t ha^{-1}) and forest soil organic carbon (to a soil depth of 30 cm) contains 293 Giga tonnes (72.3 t ha^{-1}) of carbon. The forests spread over nation's geographical area act as a sink to sequester and store 138.15 million tonnes of CO_2 every year and this annual removal by forests is enough to neutralize 9.31 per cent of the country's total GHG emission levels of the year 2000. According to India State of Forest Report (ISFR), 2017, carbon stocks stored in India's forests has been estimated to be 7083 million tonnes. The annual increase of carbon stock is worked out to be 19.5 million tonnes which is 71.5 million tonnes of CO_2 equivalent. Among the states Arunachal Pradesh has maximum carbon stock of 994.5 million tonnes. The per ha carbon stock among different states/ UTs indicated that Andaman Nicobar is contributing the maximum of 170.68 tonnes. Tamilnadu has recorded total carbon stock of 229.3 million tonnes and per ha carbon stock of 87.26 tonnes.

iv. Forests as Earth's air purifiers

Forests act as an important factor for oxygen production. Forests perform a valuable role in intercepting and trapping windborne particulate matter *viz*., dust, ash, chemical, pollen and smoke that adversely affect human health, then washed to the ground by rainfall or snow.

v. Sustain the productivity of the soil

Forests sustain the productivity of the soil through adding a large quantity of organic matter and involved in recycling of nutrients through litter fall and biomass addition.

vi. Reservoir of water
Forests retain large quantities of water, slowly releasing it over time. This mitigates flooding during heavy rains and preserves water supplies for drier times.

vii. Warehouse of biological diversity
Forests are complex ecosystems that cover 30 percent of the global land area, providing habitat for innumerable terrestrial species viz., trees, shrubs, herbs, insects, animals, birds, etc.

viii. Act as soil and water conservator
Forest act as windbreaks and shelterbelts, which protects the young plants from destruction by wind within their zone of influence. Forests reduce soil erosion caused by rain and floods, and therefore decrease sedimentation rates in irrigation canals, rivers, and reservoirs. Forests also protect water by filtering water pollutants, moderating floods and mitigating salinity.

ix. Coastal protection
Coastal forests, particularly mangroves, reduce shoreline erosion and siltation and the impacts of storm, surges and tsunamis.

C. Socio-economic role of forest
Forests have been offering different social services, creates employment and income-generating possibilities and providing substantial support to rural economy.

i. Contribution to GDP
The FAO estimated that forest industries contribute more than US$ 450 billion to national incomes, contributing nearly one percent of the global GDP in 2008.

In 2002, forestry industry contributed 1.7 per cent to India's GDP. In 2010, the contribution to GDP dropped to 0.9 per cent, largely because of rapid growth of the economy in other sectors and the government's decision to reform and reduces import tariffs to let imports satisfy the growing Indian demand for wood products. During the above period the gross value of goods and services provided by the forestry sector was estimated at an average of Rs. 26,330 crores, of this about 60 per cent revenue comes from minor forest products.

ii. Income-generating possibilities
Nearly 350 million people living in and around forests in India depend on Non wood forest products (NWFP's) for their sustenance and supplemental income which is worth of Rs.400 billion annually. The leaf based cottage industry alone supports more than 10 million people.

iii. Employment generation
In general, one hectare of forest plantation creates nearly 630 man days, from the raising of nurseries to the stage of harvesting. The total reported level of employment in forestry in 2000 is 11.0 million people, of which over half (6.0 million) are employed in the primary production of goods. The reported level of employment is highest in Asia (8.3 million), with India accounting for over half of this and China a further one quarter (2.0 million). Of the total wage employment in the forestry sector, NWFPs account for more than 70 per cent (about 1.6 million man-days) of the opportunities for self-employment for the forest dwellers. Rural women use 70-80 per cent of the man days in collection of NWFPs, fuel and fodder.

iv. Habitat for indigenous peoples
More than 88 million tribal people representing over 250 tribal communities, approximately 94 per cent reside in and around forests and form a part of the culture and natural way of life.

v. Protection of natural and cultural heritage
Forests protect and maintain forest-related cultural and spiritual knowledge and values.

vi. Recreational opportunities
Forest ecosystems serve as natural recreational place to the millions of people. Recently forest related ecotourism popularized among the communities. Nature-based tourism, which aims to turn biodiversity into a marketable commodity creates new revenue streams for conservation management and benefits for local people.

vii. Educational services

Forest is an outdoor education delivery model in which students visit natural spaces of forests to learn personal, social and technical skills. It is an inspirational process that offers children, young people and adult's regular opportunities to achieve and develop confidence through hands-on learning in a woodland environment. Annually more than 60,000 students are graduated out in forestry. Among them one-third are female.

Forest Scenario

Global Forest Scenario

- Geographical area:14.89 billion ha
- Total forest area: 4 billion hectares (ha) *i.e.* 27 % of total land area,
  - Primary forests 36 %, but about 6 million ha lost or modified each year.
  - Other naturally regenerated forests 57 %
  - Planted forests 7 %
- The average productivity of forests: 2.1 m^3 ha^{-1} $year^{-1}$
- Average per capita availability: 0.64 ha.
- The seven countries *viz*., Russian Federation, Brazil, Canada, USA, China, Australia and Congo account more than 60 per cent of the total forest area.
- Deforestation continues: about 13 million ha per year.
- 80 per cent of the world's forests are publicly owned.

Indian forest Scenario

- Geographical area: 328. 75 million ha
- Forest cover: 70.83 million ha (21.54 % of India's geographical area)
  - Very dense forest: 9.82 million ha (2.99 %)
  - Moderately dense forest: 30.83 million ha (9.38 %)
  - Open forest: 30.17 million ha (9.18 %)
  - Scrub area: 4.60 million ha
- Tree cover outside the forests: 9.38 million ha (2.85 %)
- Total forest and tree cover: 80.21 million ha (24.39 %)
- Actual dense forest and tree cover (Tree canopy cover more than 40 per cent): 50.33 million ha (15.21 % of countries geographical area). Thus, in total, 29.88 million ha of forests in India are degraded or open forest or scrub area (9.1 % of countries geographical area).
- The volume of growing stock in India's forest (4,499 million m^3) and trees outside forest (1,599 million m^3) is 6,098 million m^3.
- The average productivity of Indian forests: 1.34 m^3 ha^{-1} $year^{-1}$
- Per capita forest and tree cover: 0.064 ha
- Major commercial tree species (in the forests as well as outside forests): *Acacia catechu, A. nilotica A. mollissima, A. auriculiformis, A. mangium, Azadirachta indica, Anogeissus latifolia, Abies pindrow, Bamboo, Cedrus deodara, Casuarina equisetifolia, Dalbergia sissoo, Eucalyptus spp., Picea smithiana, Pinus roxburghii, Quercus spp., Prosopis juliflora, Shorea robusta, Tectona grandis, Terminalia spp, Toona ciliata, etc*
- In forests, *Shorea robusta* has recorded the maximum contribution in total volume (8.53 %).

- In trees other than forests, *Mangifera indica* contributes the maximum volume of 10.36 %.
- Madhya Pradesh recorded the maximum forest cover (7.74 million ha) in India.

Tamil Nadu Forest Scenario

- Geographical area: 13 million ha (4 % of countries geographical area)
- Forest cover: 2.63 million ha (0.80 % of countries forest area & 20.23 % of states geographical area)
  - Very dense forest: 0.35 million ha (2.69 % of states geographical area)
  - Moderately dense forest: 1.10 million ha (8.46 % of states geographical area)
  - Open forest: 1.16 million ha (8.92 % of states geographical area)
  - Scrub area: 0.12 million hectares
- Tree cover: 0.47 million ha (3.62 % of states geographical area)
- Total Forest and tree cover: 3.10 million ha (23.85 % of states geographical area & 3.86 % of countries forest and tree cover)
  - Actual dense forest and tree cover (canopy cover more than 40 per cent): 1.92 million hectares (14.76 % of states geographical area). Thus, in total, 1.28 million ha forests in Tamil Nadu are degraded or open forest or scrub area (9.84 % of states geographical area).
- Per capita Forest and Tree cover: 0.04 ha
- The volume of growing stock in Tamil Nadu's forest (142.38 million m^3) and trees outside forest (73.36 million m^3) is 215.73 million m^3.
- The district of Nilgiris recorded the maximum forest cover of 0.2 million ha.

CLASSIFICATION OF FORESTS

Forests have been classified on the basis of: age, method of regeneration, composition, ownership, object of management and growing stock.

1. Classification based on age

a) Even aged forest

Even-aged forests, also called regular forests are those consisting of even aged woods or approximately the same age. True even aged forests can be only man made forests. Which regenerate naturally, and differences up to 25 per cent of the rotation are usually allowed in cases where forest is not harvested for 100 years or more.

b) Un-even aged forests

A forest is called uneven - aged or irregular when trees vary widely in age. In the case of forests which regenerates naturally and age difference occurs

2. Classification based on regeneration

a) High forest: When regeneration is obtained from seed

b) Coppice forest: When regeneration is through coppice or some vegetative part of the tree.

c) Natural forest: When the regeneration is obtained naturally.

d) Manmade forest or forest plantations: When it is obtained artificially.

3. Classification based on composition

a) Pure forests: Pure forests are composed almost entirely of one species, usually to the extent of not less than 50 per cent.

b) Mixed forests: Mixed forests are composed of trees of two or more species intermingled in the same canopy.

4. Classification based on management

a) Protection forests: It is managed primarily for ameliorating climate, checking soil erosion and floods, conserving soil and water, regulating stream flow and increasing water yields and exerting other beneficial influences.

b) Production forests: Production forests are those which are managed primarily for their produce or economic value.

c) Social forests: Social forests where the produce is utilised by neighbouring society.

5. Classification based on ownership

a) Government forests

On the basis of Legal status, Government forests are further classified into:

i) Reserved forests: A Reserved forest is an area with complete protection, constituted according to chapter II of the Indian Forests Act. 1927.

ii) Protected forests: A Protected forest is an area subject to limited degree of protection constituted under the provisions of chapter IV of the Indian Forest Act., 1927.

iii) Village forests: A Village forest is a state forest assigned to a village community under the provisions of chapter III of Indian Forest Act.

b) Private forests: A forest which is not owned by the Government.

c) Forests owned by Corporations, Panchayats, Societies and other Agencies.

6. Classification based on Growing Stock

a) Normal forest: A Normal forest is an ideal forest with regard to growing stock, age class distribution and increment and from which the annual or periodic removal of produce equals to the increment and can be continued indefinitely without endangering future yields.

b) Abnormal forest: Abnormal forest is one which is not normal, i.e. growing stock, age, class, distribution of stems, increment, etc. are either in excess or more usually in deficit than the normal forest.

Types of forests India

The forest types of India were classified in the year 1936 by Sir H.G. Champion which was later on revised in the year 1968 by Sir H.G. Champion and S.K. Seth as 'A Revised Survey of Forest Types of India'. They have used temperature and rainfall data for classifying the Indian forest into five major groups and 16 type groups (climatic types) and >200 subgroup types. The Champion and Seth's classification is still in use for classifying Indian forests and a brief description is given below

I. Tropical forest

A great majority of the forests found in India are Tropical forests viz., A) Tropical moist forests and B) Tropical dry forests

A. Tropical moist forests

These are further classified into the following types on the basis of relative degree of wetness:

(i) Tropical moist evergreen forests

It is also called as tropical rain forests and found in very wet regions receiving more than 2500 mm average annual rainfall. These are climatic forests; number of species per hectare has been estimated in a range of 40 to 100. Evergreen trees are the climax vegetation and there is well developed stratification, having 4-5 strata that having luxuriantly growing lofty trees which are more than 45 metres in height. The shrubs, lianas (woody climbers) and epiphytes are abundant because of high rainfall. In India it is found in Andaman and Nicobar Islands, Western coasts and parts of Karnataka, Annamalai hills (Koorj), and throughout North East.

The major species are *Artocarpus chaplasa, Dipterocarpus grandiflorum, D. costatus, Hoppea odorata, Shorea assmica, etc*.

(ii) Tropical moist semi evergreen forests

It is found along the western coasts, eastern Odisha and Upper Assam where annual rainfall is between 2000 and 2500 mm. In these forests top stories are dominated by the deciduous species while middle and lower stories are dominated by the evergreen species. The plants in these forests are the species of *Albizzia, Bambusa, Bombax, Calamus, Cinnamomum, Dipterocarpus, Garcinia, Mallotus, Olea dioica, Shorea, Sterculia, Syzygium cumini, Tectona grandis, Terminalia* and *Xylia xylocarpa*.

(iii) Tropical moist deciduous forests

These cover an extensive area of the country receiving sufficiently high rainfall (1200 to 2500 mm) spread over most of the year. The dry periods are of short duration. Many plants of such forests show leaf fall in hot summer. The forests are found along the wet western side of the Deccan plateau, Andhra, Gangetic plains and in some Himalayan tracts extending from Punjab in west to Assam valley in the east. These forests produce some of the most important timbers of India. In north, they are dominated by *Shorea robusta* and in Southern India are dominated by *Tectona grandis, Terminalia paniculata, T. bellerica, Pterocarpus marsupium, Grewia tilliaefolia, Dalbergia latifolia, Lagerstroemia, Adina cordifolia*, *Pongamia*, etc.

(iv) Littoral and swamp forests

Littoral and Swamp forests are further grouped in to 3 categories viz., beach forests, tidal or mangrove forests and fresh water swamp forests.

a) Beach forests

The beach forests are found all along the sea beaches and river deltas. The soil is sandy with large amount of lime and salts but poor in mineral nutrients. Ground water is brackish, water table is only a few metres deep and rainfall varies from 750 mm to 5000 mm depending upon the area. The temperature is moderate. The common plants of these forests are *Casuarina equisetifolia, Borassus, Phoenix, Manilkara littoralis, Callophyllum innophyllum, Thespesia, Barringtonia, Pongamia*, etc.

b) Tidal or mangrove forests

Tidal forests grow near the estuaries or the deltas of rivers, swampy margins of Islands and along sea coasts. Mangroves receive rainfall between 1000 to 3000 mm and temperature between 26 and 35 °C. The plants are typical halophytes which are characterised by presence of prop roots with well developed knees for support and pneumatophores and viviparous germination of seeds.

Tidal forests one distinguished into the following four types with overlapping constituent species viz., Tree mangrove forests, Low mangrove forests, Salt water forests and Brackish water forests.

i) Tree mangrove forests

These forests occur on both east and west sea coasts. The best development occurs in Sundarbans. The forest floor is flooded with salt water daily. Plants may attain a height 10-15 metres and form an almost closed evergreen forest. The common trees of these forests are *Rhizophora mucronata, R. conjugata, Avicennia alba, Bruguiera conjugata, B. parviflora, B. caryophylloides, Kandelia candel, Xylocarpus molluccensis, X. granatuns, Ceriops tagal, Avicennia officinalis, Excoecaria agallocha, Sonneratia acida, Lumnitzera racemosa, L. littorea, Aegiceras carniculatum* and two most frequently occurring palms are *Nipafruticans* and *Phoenix paludosa*.

ii) Low mangrove forests

Low mangrove forests are more developed on east sea coast than on west coast. These forests grow on soft tidal mud near estuaries, which is flooded by salt water. Forest is dense but the trees with leathery leaves attain maximum height of 3-6 m. The vegetation consists of a few species which show gregarious growth habit. Important tree species are *Ceriops decandra, Avicennia alba, Aegialitis rotundifolia* and *Excoecaria agallocha*.

iii) Salt water mangrove forests

It occurs beyond tree mangrove forests in big river deltas where the ground is flooded with tidal water. Silt deposition and salt content in soil are low. Tree height is upto 20 m or so but girth is not large. Forests are

dense. Pneumatophores are common. The common plants are *Heritiera minor, Excoecaria agallocha, Ceriops decandra, Xylocarpus molluccensis, Bruguiera conjugata, Avicennia officinalis,* etc.

iv) Brackish water mangrove forests

They grow near the river deltas where forest floor is flooded with water at least for some times daily. Water is brackish (salty) but during rains it is nearly fresh. Tree height may reach 30 m. Forest is dense. Common species of the forests are *Heritiera minor, Xylocarpus molluccensis, Bruguiera conjugata, Avicennia officinalis, Sonneratia caseolaris, S. acida, Excoecaria agallocha, Ceriops decandra Cynometra ramiflora, Amoora cuculata, Pandanus* and *Phoenix paludosa*.

v) Fresh water swamp forests

These forests grow in low lying areas where rain or swollen river water is collected for some time. Water table is near the surface. Important plants include *Salix tetrasperma, Acer, Putranjiva, Holoptelia, Cephalanthus, Barringtonia, Olea, Phoebe, Ficus, Murraya, Adhatoda, Canna,* etc.

B. Tropical dry forests

These are classified into the following types

(i) Tropical dry evergreen forests,

(ii) Tropical dry deciduous forests, and

(iii) Tropical thorn forests.

(i) Tropical dry evergreen forests

It is found in the areas where rainfall is in plenty but dry season is comparatively longer (4-6 months). The trees are dense, evergreen and short (about 10 to 15 metres high). These forests are found in eastern part of Tamil Nadu, in east and west coasts. The common plant species are much the same as in tropical moist evergreen forests like *Albizzia amara, Canthium decoccum, Chloroxylon swietenia, Dalbergia paniculata, Dispyros ebenum, Drypetes, Feronia, Manilkara, Memecylon, Mimusops, Syzygium mentanum, Zizyphus,* etc. are most common.

(ii) Tropical dry deciduous forests

These forests are distributed in the areas where annual rainfall is usually low, ranging between 800 and 1200 mm, such as, Punjab, Uttar Pradesh, Bihar, Odisha, Madhya Pradesh and large part of Indian peninsula. The largest area of the country's forest land is occupied by tropical dry deciduous forests. The dry season is long (6-8 months) and most of the trees remain leafless during that season. The forest trees are not dense, 10 to 15 m in height and undergrowth is abundant. In north, the forests are dominated by *Shorea robusta* and in south by *Tectona grandis*. The common constituents of these forests in are *Acacia, Butea monosperma, Chloroxylon, Dalbergia, Dendrocalamus, Dillenia, Diospyros melanoxylon, Gymnosporia, Hardwickia, Lannea coromandelica, Pterospermum, Terminalia, Zizyphus,* etc.

(iii) Tropical thorn forests

It is also known as xeric forests due to occurrence of very less rainfall which lies in a range of 200-800mm. The dry season is hot and very long (7-10 months) and found in South Punjab, most of Rajasthan and part of Gujarat, Maharashtra, Andhra, Karnataka, Madhya Pradesh and Uttar Pradesh. The vegetation is of open type consisting of small trees (8 to 10 m high) and thorny or spiny shrubs of stunted growth. The forests remain leafless for most part of the year and are sometimes called thorn scrub or scrub jungles. There is luxuriant growth of ephemeral herbs and grasses during the rainy season. Towards the desert region the vegetation diminishes and in arid parts there is almost no vegetation. The species of *Acacia catechu, A. leucopholea, A. arabica, Anogeissus latifolia, Albizzia amara, Canthium decoccum, Capparis deciduas, Chloroxylon swietenia, Hardwikia binata, Prosopis spicigera, Pterocarpus santalinus, Wrightia tinctoria, Zizyphus mauritiana, Z. nummularia,* etc. are common.

II. Subtropical montane forests

These forests are found in the region of fairly high rainfall but where temperature differences between winter and summer are less marked. Winter generally goes without rains. They are found up to the altitude of about 1500 metre in south and up to 1800 metre in the north. In composition, subtropical forests are almost

intermediate between tropical forests and temperate forests and a sharp demarcation can seldom be made between tropical and subtropical or subtropical and temperate forests.

These forests have been grouped into the following three types
(i) Subtropical broadleaved hill forests,

(ii) Subtropical dry evergreen forests and

(iii) Subtropical pine forests

(i) Subtropical broadleaved hill forests

The vegetation is composed of mainly broadleaved and evergreen with high forest trees. Such forests are usually seen on western and central Himalayas and on the hills of south India. The rainfall ranges from 1000-3000 mm with 4-7 months dry period. The important trees found in the sub-tropical broad-leaved hill forests are *Alnus nepalensis, Callicarpa arborea, Acacia auriculiformis, Albizzia spp., Castanopsis tribuloides, C. indica, Euginia wightiana, Memecylon sp, Quercus vercus, Q. serrata,* etc.

(ii) Subtropical dry evergreen forests
They occupy the Shiwalik hills, Western Himalaya, Jammu and Punjab. The rainfall ranges from 500-1000 mm. The common constituents of tree vegetation are *Acacia modesta, Dondonaea viscose, Olea cuspidata,* etc.

(iii) Subtropical pine forests
It mainly occur on hills and largely Pine forests extend in the western and central Himalayas between 1000 to 2000m. The rainfall varies from 1000-3000 mm with 3-7 months of dry period. The forests are dominated by *Pinus khasya, P. roxburghii, Quercus leucotrichophora, Rhododendron arboretum, Shorea robusta* etc.

III. Temperate montane forests
These forests occur in the Himalayas at the altitude from 1800 to 3800 metres where humidity and temperature are comparatively low. Montane forests have been classified into the following three types on the basis of moisture regime

(i) Montane wet temperate forest,

(ii) Himalayan moist temperate forest and

(iii) Himalayan dry temperate forest

(i) Montane wet temperate forests

They are broadleaved and dense with closed evergreen forests. The rainfall varies from 1500-5000 mm with 2-5 months dry period. These are found in Himalayas extending from Nepal to Assam at the altitude from 1800 to 3000 m, as well as in some parts of South India (Nilgiris). The forests in south are evergreen and are called sholas. The forests are dense with closed canopy and the trees may be 15 to 20 m high. Important trees constituting the vegetation are *Alnus nepalensis, Eugenias calophyllifolia, Rhododendron nilagiricum, Quercus lamellosa, Q. pachphylla, Machilus edulis, Meliosma wightii, Symplocos theaefolia, Ternstroemia gymnanthera, etc.*

(ii) Himalayan moist temperate forests
These forests develop in the areas of 1000-2500 mm of rainfall with 2-5 months dry period. In general, these forests occur all along Himalaya at 1500- 3300 m altitude in the regions of Jammu and Kashmir, Punjab, Himanchal Pradesh, Uttrakhand, West Bengal, Assam and Eastern Himalayas. The trees are high, sometimes up to 45 metres tall. The dominant elements of vegetation are *Abies spp., Cedrus spp, Picea spinulosa, Pinus roxburghii, P. excels, P. wallichiana, Quercus dilate, Q. lamellose, Rhododendron arboretum, Tsuga dumosa, etc.*

(iii) Himalayan dry temperate forests
It found in the narrow belt at the altitude from 3000 to 4000 m in the western Himalayas extending from a part of Uttaranchal through Himachal Pradesh and Punjab to Kashmir. The regions experiencing less than 1000 mm of rainfall with 4-42 months dry period. These forests dominated by *Abies spectabilis, Acer*

pentapomicum , Betula utilis, Cedrus deodara, Juniperus wallichina, Pinus spp., Prunus cornata, Quercus semecarpifolia, etc.

IV. Sub alpine forests

The sub alpine forests are found throughout Himalayas from Ladakh in the west to Arunachal in the east at the altitude from 2800 m to 3800 m. Annual rainfall is less than 650 mm 6-12 months dry periods but snowfall occurs for several weeks in a year. Strong winds and below 0°C temperature prevail for greater part of the year. The dominant tree species are *Abies spp, Betula utilis, Rhododendron companulatum, Pinus wallichiana, Quercus semecapifolia, etc.*

V. Alpine forests

Plants growing at the altitude from 2900 to 6000 m are called alpine plants. At lower level in Himalayas, alpine forests consist of dwarf trees with or without conifers and at higher level scrubs and only scattered xerophytic shrubs are left to merge with alpine meadows. Alpine vegetation has been classified into the following two types:

(a) Moist alpine scrubs and

(b) Dry alpine scrubs

(a) Moist alpine scrubs

They occur throughout the Himalaya, above timberline to 5500 m altitude, particularly in the regions of Kashmir, Uttrakhand, Sikkim, Manipur, Western and Eastern Himalayas. The dominant vegetations are *Rhododendron companulatum, R.wightii, R. molle, Betula utilis, Sorbus foliolosa, etc*.

(b) Dry alpine scrubs

The forests are alpine xerophytic, occur in very low rainfall (< 370mm) areas at up to 5500 m altitude in the regions of Himanchal Pradesh, Kashmir and Uttrakhand. Species belonging to *Artimisa maritima, A. sacrorum, Eurotia ceratoides, Juniperus wallichiana, J. communis, Lonicera spp.* and *Potentilla spp.* are dominant.

Chapter - 3

FOREST MANAGEMENT IN INDIA

Historically too, India's forest resources have been accorded due importance since 2500 BC, such that forests in India have been viewed as a source of limitless product. Historical forest management practices in India given the diversity of culture, forest types and administrative systems. However, the role of communities, their rights over the forests and the relationship have seen a transition from the pre-colonial era, to colonial period and thereafter since independence.

Forest management during pre-colonial era

'Independent village republics' existed that regulated the use and preservation of forests through decentralized community control system before the advent of the British and their rule over India. From the age of Vedas, protection of forests was emphasized for ecological balance. Kautilya in his Artha Sastra (321-296 BC) mentioned that superintendent of forests had to collect forest produce through the forest guards. Documentation of trees, creepers, fibrous plants, drugs and poisons, skins of various animals, etc., that come under the purview of this officer. Sangam literature (200 BC to 100 AD) of Tamils (Tholkappiyam) in Southern India provides information on forest land (Mullai), its resources and managerial people's.

Until the first forest policies and acts were introduced in the 1860's during the British rule, the forests in India were principally used by the then rulers and indigenous peoples. The emperors, kings, their local vassals and the local chieftains set aside forests for hunting, some revenue gathering from the sale of forest products, collection of non wood forest products and, when necessary, used the forest wilderness for hiding and warfare. The indigenous people considered forests as a common resource, different portions of which belonged to different villages or communities. They used the forests for subsistence. Usage mainly consisted of shifting cultivation with a 20-year fallow period gathering, hunting and cattle grazing. However, a great deal of documentation regarding forest management regimes is available from the British administration era.

Forest Management under British Rule

India is one of the first countries in the world started scientific management of forests. In 1806, Captain Watson appointed as first conservator of forest by government of Madras. He establishes timber monopoly in Malabar and Travancore region. In 1843, afforestation work started and Champell introduces *Eucalyptus pinnata* at Wellington, Madras Province. In 1855, Cleghron was appointed as first regular conservator of forest. During the year 1864 the then British India Government established the Imperial Forest Department. Sir Dietrich Brandis, a German Forester, was appointed as the Inspector General of Forests in India from 1st April, 1864 and served up to 1883, is regarded as the father not only of modern scientific forestry in India, but also as the father of tropical forestry. The Indian Forest Act of 1865 extended the British colonialism in India and claimed over forests in India.

Having recognized the need to have a premier forest service to manage the varied natural resources of the vast country and to organize the affairs of the Imperial Forest Department, Imperial Forest Service was constituted in 1867. In 1875, Badan Powel and Dr. Schlich issued the first copy of The Indian Forester Journal. Forest school at Dehradun is started in 1878. In 1878 Indian Forest Act was revised. Elephant preservation act passed in the year 1879 likewise Madras Forest Act was passed in 1882. In 1898, Vedanthangal declared as first wildlife sanctuary in India. Administration in the federal and provincial Governments realized the importance of a multi-tier forest for effective management of forest resources. British India Government constituted Provincial Forest Service and Executive and Subordinate Services, which were fairly comparable to the present day forest administrative hierarchy.

The officers appointed to the Imperial Forest Service from 1867 to 1885 were trained in France and Germany. Thereafter, until 1905 they were trained at Coopers Hill, London, which had been one of the prestigious professional colleges of Forestry at that time. From 1905 to 1926 the Universities of Oxford, Cambridge and Edinburgh had undertaken the task of training the officers of the Imperial Forest Service. The Imperial Forest Research Institute, Dehradun, presently and popularly known all over the world as Forest Research Institute (FRI) was established at Dehradun in the year 1906. The baton to train the IFS officers was passed on to Forest Research Institute, which it did successfully from 1927 to 1932. Subsequently the Indian Forest College (IFC) was established in the year 1938 at Dehradun and the trained officers were recruited to the Superior Forest Service by the provinces/states.

However, British rulers interested in forest resources for commercial purposes affected not only the rights of the local communities to resource-use, but also the local community institutions that managed the resources. Forest dependent communities were kept away from the management of the resource and were accorded limited use rights on it.

Table-3.1: Chronology of forest policies, acts and orders in India

Period	Years	Event	Features
Pre-independence	1865	Forest Act of 1865	Generates revenue by selling timber and forest produce
	1878	Forest Act of 1878	Divides forests into reserve and protected forests; reserve forests meant for timber production and ecological stability
	1894	Forest Policy of 1894	Facilitates conversion of forest lands for agriculture and timber logging
	1927	Forest Act of 1927	Controls timber and other forest products in transit, as well as the implementation of fines and penalties related to forest offences; provides extensive powers to state governments to formulate and implement forest laws
Post-independence	1952	National Forest Policy (NFP)	Complementary land use; management of forests for sustained production of timber
	1972	Wildlife Protection Act (WPA)	Constitutes protected areas where human occupation or resource exploitation would be limited
	1976	National Commission on Agriculture (NCA)	Maximizes forest products through the creation of forest corporations
	1980	Forest Conservation Act (FCA)	Governs the diversion of forest land for non-forest purposes
	1988	National Forest Policy (NFP)	Ensures environmental stability and maintenance of ecological balance
	1996	Hon. Supreme Court Order	Bans harvesting in government forests without an approved working plan

National Forest Policy, 1894

The British administration directed its forest policy towards commercial interests and the development of agriculture, which was a major source of revenue. National Forest Policy 1894, or Circular F 22 of 1894, was the first formal forest policy statement of India, and was based on the Voelcker Report in 1893 on Improvement of Indian Agriculture. The main stated objective of this policy was to manage the State Forests for public benefit and specified that 'forests which are the reservoirs of valuable timbers should be managed

on commercial lines as a source of revenue to the States'. However, the policy also provided for regulation of rights and restriction of privileges of users in the forest area. This regulation and restriction was justified only when the advantage to be gained by the public was great, the cardinal principle being that the rights and privileges of individuals must be limited, otherwise than for their own benefit, only to the degree as was absolutely necessary to secure that advantage. The Forest Policy did not accord due recognition to forestry, and placed it below the agricultural needs of the country, especially as far as land use was concerned.

The policy provided for four important classes of forests, viz. forests for preservation, forests for commercial purposes, minor forests and pasturelands. The first class of forests was generally situated on hill slopes and was deemed essential for the protection of cultivated plains from damage caused by landslides and hill torrents. It served a conservation role for the benefit of agriculture in the plains. Driven by commercial interests, forest management measures were developed to promote natural regeneration of *Cedrus deodara*, *Shorea robusta* and artificial regeneration of *Tectona grandis*. People's requirements were to be met by the third class of forests that yielded only inferior timber, fuelwood or fodder and by the fourth class of forests pastures and grazing grounds to which certain restrictions were applied.

Although the 1894 policy laid a way on the satisfaction of the needs of the local people over riding the considerations of revenue, beyond this realization of maximum revenue was the guiding factor. The general perception remains that the 1894 Forest Policy aimed at State monopoly over the forest resources with revenue earning through timber harvesting the prime motive, and with agriculture given precedence over forestry

Indian Forest Act, 1927

The implementation of the Indian Forest Act, 1927 by the British Administration had an impact on people's dependent on forests. The Indian Forest Act was drafted for the first instance in 1865, placing most forests under state ownership. It was further revised in 1878 and consolidated in 1927. It was an Act to strengthen the law relating to forests, the transit of forest produce and the duty leviable on timber and other forest produce.

Weakness of Forest Management under British Rule

An analysis of the National Forest Policy, 1894 and the Indian Forests Act, 1927 suggests that the rights of people to forests under erstwhile rulers in the pre-colonial era were further limited. It is also evident that many of the informal forest management institutions that functioned at the grassroots level collapsed after the takeover of the forests by the British administration, leading to an erosion of social capital. However, in some cases people actively opposed the State take over and demonstrated against the curtailment of public rights. Further British forest management policy and rules not restricted the shifting cultivation and no mention about scientific management of forest, wild life conservation, women involvement, tribal development, forestry research and education, *etc*.

Forest management of independent India

Forest policy of independent India, 1952

The first forest policy, 1894 was revised after independence in 1952 on the basis of six dominant needs of the country viz., the need for balanced and complementary land use, checking of soil erosion, denudation in the catchments areas for soil and water conservation, establishing tree lands for public use, ensuring the increased supplies of grazing, small wood for agricultural implements and sustained supply of timber for defense, communities and industry.

Features of forest policy, 1952

Based on Forest policy, 1952 the forest areas are classified in to four major categories *viz*., Protection forests (physical, climatic considerations), National forests (Defense, communications, industry), Village forests (local requirements) and Tree lands (Public use). It visualizes that maintaining one-third of its total land area under forests is necessary to the promotion of forest areas and two-third of its total land area under forests in mountains and hilly regions and 20 per cent forests in the plains.

The forest departments establish the need extreme species of commercial importance with nurseries and supply through seed stores, to supervise the planting of trees and conduct tree awareness programmes among the people through publicity by celebrating the festivals. In order to arrest the destruction of forests

excessive, exploitation of forests for personal use was restricted. To minimize the grazing in protected forests, continuous grazing in the same area should be controlled and regulated through grazing rate. Shifting cultivation is converted in to Taungya systems. Sustained forest operations and Afforestation schemes implemented to replace inferior trees in order to obtained sustained yields. Forestry courses are conducted for Forest Rangers, Superior officers at the FRI, Dehradun to enhance forest education.

Weakness of Forest Policy, 1952

Weakness of Forest Policy, 1952 focus on intensification of commercial forestry to meets industrial demand from natural forest by logging and conversion and that leads to degradation of forests. Further it was not mention about people's participation in forest management such as women involvement**,** tribal development**,** *etc.*

NATIONAL FOREST POLICY, 1988

The serious depletion of forest resources due to biotic and industrial pressure and other reasons made the policy makers review the situation in the late eighties and evolve a new strategy for conservation of forests. The National Forest Policy was once again revised in 1988, which envisaged community involvement in the protection and regeneration of forests with the highest priority to sustainable management of the forest resource.

Basic objectives

- To ensure environmental stability and maintenance of ecological balance
- Conserving the natural heritage of the country by preserving the remaining natural forests
- Checking soil erosion and denudation in the catchment areas of rivers
- Increasing sustainability through afforestation and social forestry programmes
- Meeting the requirements of fuel wood, fodder of the rural and tribal populations
- Increasing the productivity of forests to meet the essential national needs.
- Creating a peoples movement with the involvement of women.

Important features of National Forest Policy, 1988

a. Forest area classified into

i. Reserved forest

ii. Protected forest

iii. Un-classified forest

b. Area under forests

Scope of the National Forest Policy, 1988 emphasizes a minimum of one-third of the total land area of the country to be bring under forest or tree cover.

c. Tribal development

i. Symbiotic relationship between the tribal people and forests

ii. Forest development corporation should be associated the tribal people

iii. Employment to people living in and around the forest

d. Diversion of forest land for non-forest purposes

Diversion of forest lands to non-forest purposes like construction of dams, reservoirs, mining and industrial development compensatory by afforestation.

e. Wildlife Conservation

i. Forest management should take special care of the needs of wildlife conservation

ii. Necessary to provide for "corridors" linking the protected areas

iii. Maintain genetic continuity between artificially separated sub-sections of migrant wildlife

f. Special attention in forestry programmes

i. Contractors should be replaced by tribal cooperatives

ii. Protection, regeneration and optimum collection of minor forest produce

iii. Family oriented schemes for improving the tribal status

iv. Development programmes to meet the needs of the tribal, economy in and around the forest areas.

g. Shifting cultivation management

Shifting cultivation is affecting the environment and productivity of land. It should be rehabilitated through social forestry and energy plantations.

h. Regulation of grazing

Grazing and browsing in forest areas need to be controlled. It is regulated with the involvement of the local people

i. Promotion of forest based industries

Forest based industry should raise their own raw material. Industry should be encouraged to use alternative raw materials. Provide employment to local people in raising trees and raw material.

j. Forestry research and education

Forestry research focused on identifying the strategies to increase the productivity of wood and other forest produce per unit of area per unit time. Research also related to social forestry for rural/tribal development, and development of substitutes to replace wood and wood products. Forestry education related to wildlife and management of natural parks and sanctuaries.

INDIAN FOREST FESTIVALS

i. Chipko movement

In India during 1970s, an organized resistance to the destruction of forests spread throughout the country and came to be known as the Chipko movement. The name of the movement comes from the word 'embrace', as the villagers hugged the trees, and prevented the contractor's from felling them.

The original 'Chipko movement' was started in the early part of the 18th century in Rajasthan by '*Bishnoi*' community. A large group of them from 84 villages led by a lady called Amrita Devi laid down their lives in an effort to protect the trees from being felled on the orders of the king of Jodhpur. After this incident, the king gave a strong royal decree preventing the cutting of trees in all Bishnoi villages.

In the 20th century, it began in the hills where the forests are the main source of livelihood, since agricultural activities cannot be carried out easily. The Chipko movement of 1973 was one of the most famous among these. The first Chipko action took place spontaneously in April 1973 in the village of Mandal in the upper Alakananda valley and over the next five years spread to many districts of the Himalayas in Uttar Pradesh. It was sparked off by the government's decision to allot a plot of forest area in the Alaknanda valley to a sports goods company. This angered the villagers because their similar demand to use wood for making agricultural tools had been earlier denied. With encouragement from a local NGO, Dasoli Gram Swarajya Sangh, the women of the area, under the leadership of an activist, Chandi Prasad Bhatt, went into the forest and formed a circle around the trees preventing the men from cutting them down.

The success achieved by this protest led to similar protests in other parts of the country. From their origins as a spontaneous protest against logging abuses in Uttar Pradesh in the Himalayas, supporters of the Chipko movement, mainly village women, have successfully banned the felling of trees in a number of regions and influenced natural resource policy in India. Dhoom Singh Negi, Bachni Devi and many other village women, were the first to save trees by hugging them. They coined the slogan: 'What do the forests bear? Soil, water and pure air'. The success of the Chipko movement in the hills saved thousands of trees from being felled.

One of environmentalist Sunderlal Bahuguna's notable contributions to that cause was his creation of the Chipko's slogan "Ecology is permanent economy." Sunderlal Bahuguna helped bring the movement to prominence through about 5,000 kilometer trans-Himalaya march undertaken from 1981 to 1983, travelling from village to village, gathering support for the movement. He had an appointment with the then Indian

Prime Minister Srimathi Indira Gandhi and that meeting is credited with resulting in Mrs. Gandhi's subsequent 15-year ban on cutting of green trees in 1980. Later, the movement has stopped felling in the Western Ghats and the Vindhyas and has generated pressure for a natural resource policy that is more sensitive to people's needs and ecological requirements.

Fig-3.1: Women in Chipko movement

ii. Van Mahotsav

'Van' means 'forest' and 'mahotsav' means 'festival'. The name Van Mahotsav means “FESTIVAL OF FORESTS". It is now a week long program celebrated on different days in different parts of India, but usually between 1st July to 7th July. Van Mahotsav – the festival of tree planting owes its origin to the great visionary late K.M. Munshi, the then Union Minister for Food and Agriculture who launched the programme in 1950 with the slogan “Tree means water, water means bread and bread is life”. This event creates enthusiasm among masses for forest conservation and planting trees.

According to the forest department, for every tree fallen ten tree saplings should be planted to make up the long time problem of the constant falling of trees. Van Mahotsav is important in creating awareness of the issues. It has gained significant national importance and millions of saplings are planted every year across India with energetic participation of students, volunteers, local people and various agencies like the forest department and observed as Van Mahotsav week.

Fig-3.2 & 3.3. Van Mahotsav festival celebration

PARTICIPATORY/ JOINT FOREST MANAGEMENT (JFM)

India’s national forest policy of 1988 was a landmark policy for local people’s rights over forest resources. The policy recognized people’s participation in using and protecting forests and suggested the forest communities should develop and conserve forests together with the state forest departments. This reform in forest policy has begun to transform how forests are protected and used in India.

The Joint Forest Management (JFM) is the generic term in India for partnership in forest management involving the state forest department and the local communities. In 1972, the forest department realised the

reasons of forest degradation in Arabari forest range, Mindnapore district of West Bengal. The earlier methods of policing and surveillance were rooted frequent classes with local people and led to alienation of people from the conservation programme. Then came and rescue was a forest officer named Dr. Ajith Kumar Banerjee (Father of JFM in India) who was allowed to seek participation of villagers in regeneration of 1,272 hectares of forest on employment cumulative share basis i.e. a scheme to boost the regenerative efforts or a project to make the forest public again. Within a few years, by 1983, Arabari forest had been revived.

Communities that were historically perceived to be encroachers and illegal users of forests by the state were invited to partner with the state in protecting forests. This understanding with forest department and communities is popularly known as Joint Forest Management (JFM). Buoyed by this success, the Government of India introduced the concept of Joint Forest Management (JFM) in the early 1980s. The local village committees and the forest department enter into a MoU to manage the forest area jointly with forest department and are entitled to the legal right benefits from the forest area managed under JFM as long as the forest property is not damaged.

Concepts of JFM

Institution building, micro planning and benefit sharing with the involvement of community people are the main concepts of JFM.

Managerial Plan

Village Forest Institutions (VFI) or Village Forest Council (VFC) is given conditional access to specified forest products in accordance with the guidelines laid by the forest department under the terms of JFM. The products usually include fuelwood, fodder and non-timber forest products. Forest departments also provide VFI's with information, training and wage employment related to forest management. Initial community funds may also be provided. In many states, JFM resolutions mandate that villagers be solicited to make micro-plans for forests.

Organizing into a VFI can result in access to wage employment and fuelwood through forest management activities such as lopping, clearing of debris, and cutting. In return, VFIs agree to certain conditions such as collective protection of the forest against encroachment, poaching or timber smuggling and monitoring of restrictions on some types of use. After a period of protection (5 to 10 years or more), the VFI and its members are entitled to 25 to 100 per cent of the net income from the sale of major forest produce, timber, etc.

The organization structure and membership rules of VFIs differ in each state. In Tamil Nadu the unit of management under Joint Forest Management is a hamlet/group of hamlets/entire village, the abuttant degraded forest, community and private lands. In each of the identified Management unit, the people's representative body called Village Forest Council (VFC) is formed, which is fully involved in the planning, execution of works, and protecting the forests. The Forest Ranger concerned initiates the process of formation of Village Forest Council. Each Village Forest Council elects an "Executive Committee" in such a manner that one hamlet elects at least two and maximum of fifteen members. The Village Forest Council meets at least once in three months. Sharing the benefits with the members of Village Forest Council is the most important component of Joint Forest Management. The guiding principle of this benefit sharing is equitable distribution and the Executive Committee decides the individual beneficiaries. District/Divisional Forest officers conduct sample survey of the unit of management and decide about the quantity of firewood available for supply to poor households.

Fodder and green leaf manure are given at free of cost to the members of Village Forest Council except big farmers, subject to availability. Grazing is regulated and allowed free of cost depending on the carrying capacity except in regeneration areas, where grazing will be closed for 3 years.

All Non-wood Forest produces (Minor Forest Produce) for domestic consumption is given free of cost to the members of Village Forest Council subject to availability. Executive Committee sells any surplus quantity. District/Divisional Forest Officer decides sustainable Non-wood Forest Produce (NWFP) available. The Executive Committee as decided by District/ Divisional Forest officer sells any other sustainable yield from the management unit. The Executive Committee distributes the sale proceeds to received equally among the members of Village Forest Council after remitting 25 per cent to Village Forest Development Fund.

A joint account in the name of Village Forest Council is opened in local or nearest bank or post office with the President and Member Secretary as signatories. All the Village Forest Council Funds are kept in this account. The President and Member Secretary are responsible and accountable to the Village Forest Committee for all financial transactions.

Impact of JFM

According to the principles of community participation in the management of natural resources and biodiversity guidelines in 1990, various state governments began implementing their own Participatory/Joint Forest Management strategies. It caught on very quickly and by March 2011, there were 118,213 JFMCs covering about 170,000 villages on forest fringes were protecting more than 22.94 million hectares of forest areas.

Chapter - 4

SOCIAL FORESTRY

Forests have been providing substantial support to the rural economy. Historically, the local communities managed their forests for the supply of fuel, fodder, fibre, timber, food and herbal medicines while maintaining an ecological balance. In our country the concept of social forestry is not new. It is found in the preachings of Lord Buddha about 2500 years ago. Buddha preached that every good Buddhist should plant one tree and look after it over five years so that it grows to a full tree and in this way he should plant about five trees in his life time. The Great Emperor Ashoka is credited to have got planted shady trees and fruit trees along the roadsides for the benefit of travellers.

However, with the biotic pressure from growing human and livestock populations, lack of technical skills, poor investments and change in the ownership, forests in India have depleted rapidly. Apart from biotic pressure, the factors *viz.* Inadequate scientific and technical inputs, inadequate skills and training of the staff to play their expected new roles, poor investment on forest development, damage caused by mining, irrigation projects, industries, roads and shifting cultivation which contributed to the denudation of forest resources. This led to introducing new concepts in forestry development during the early 1970s. Thus social forestry programmes included a wide range of activities such as growing trees on farm bunds and roadsides, developing woodlots on common properties and collection, processing and management of forest products by involving local communities.

Origin of the term and its popularization

The word social forestry was coined by Jack Westoby and used in the ninth Commonwealth Forestry Congress held in Delhi during 1968. The term remained unused and unnoticed till the National Commission on Agriculture (NCA) revitalize it in its interim report on "production forestry and man-made forestry" during 1973. Thus, social forestry also called as "forestry of the people, by the people and for the people" record a great movement throughout the world. During 1976, the National Commission on Agriculture in India popularised the concept of social forestry to encourage those who were dependent on fuelwood, fodder and other forest products, to meet their own needs through various activities in order to reduce the burden on the forests. This concept was further refined by FAO in 1978, by defining community forestry as the programme which intimately involved local people in afforestation, irrespective of the pattern of land ownership.

Definition

"Social forestry as a forestry which aims at producing flow of protection and recreation benefits for the community" (Westoby, 1968). Social forestry is defined as "Forestry outside the conventional forests which primarily aim at providing services for the benefit of people". Conceptually, social forestry deals with poor people to produce goods such needs of the local community particularly underprivileged section.

It is a programme of activities to encourage those who depended on fuelwood and other forest products to produce their own supplies in order to lighten the burden on production forestry. It is the science and art of growing trees and/or other vegetation on all available land in and outside forest areas and managing the existing forest with intimate involvement of the people and integrated into other operations, resulting in balanced and complementary land use with a view to provide a wide range of goods and services to the individuals as well as to the society".

Social forestry refers to the promotion and self-help management and use of trees and perennials to sustainably improve the livelihoods of local people, especially the poor, generally using participatory methodologies. Between 1970s and 1990s, almost all countries that were or remain in the developing world experienced the introduction of one kind of social forestry or another, either by their government or by non-government organizations at varying scales of implementation and incorporating a mix of practices.

Social forestry is 'social' in the sense of being socially configured, that is, adaptable, dynamic and responsive to the context and social environment. Social forestry projects take varying forms depending on the particular (political, economic, cultural, ecological) environment and remain flexible because of the social creativity of the participating interest groups shaping this forest management.

Social forestry, community for rural forestry or peoples forestry are synonym and involve the people (society or community) individually or collectively in forestry operations for the creation, management, maintenance, protection and utilization of forests for their mutual benefit. It is a programme of land transformation aimed

at multiple use of lands and environmental rehabilitation in which the community is voluntarily involved as the prime beneficiary to harvest subsidiary gains other than conventional industrial raw material and in the process improved land, landscape, environment and quality of life at large is ensured

Simply it is the practice of 'forestry of the people, forestry by the people and forestry for the people'.

Components of social forestry

Social forestry programmes usually have the following major components *viz*., (a) farm forestry, (b) community forestry (c) Extension Forestry, (d) Recreation Forestry and (e) rehabilitation of degraded forest area.

a) **Farm forestry:** Plantation and management of trees on private lands, purely by private efforts, with or without government support.

b) **Community forestry:** It is a practice of forestry on community lands, Panchayat lands, government vacant lands, degraded lands *etc*., to be managed by the community.

c) **Extension forestry:** Practice of forestry in areas devoid of tree growth and other vegetation situated in places away from the conventional forest areas with the object of increasing the area under tree growth. It includes the following.

i) Shelterbelts

Shelterbelt is a belt of trees and or shrubs maintained for the purpose of protecting crops and animals from wind, scorching sun, snow drift, etc.

ii) Linear strip plantations

These are the plantations of fast growing species on linear strips of avenues, river and canal banks, tank bunds etc.

d) **Recreation forestry**: Practice of forestry with the object of raising flowering trees and shrubs mainly to serve as recreation forests for the urban and rural population.

e) **Rehabilitation of degraded forest area:** It includes afforestation of degraded forests with a view to meeting the requirements of fuel wood and fodder for the local population.

Objectives of social forestry

The objectives of Social forestry adopted by the Commission (1976) were based on the economic needs of the community aimed at improving the conditions of living. They are:

(i) To *fulfil the basic requirements* such as fuel, fodder, small timber, supplementary food and income from surplus forest products to the rural area and replacement of cow dung as a fuel.

(ii) To *provide employment opportunities* and to increase family income considerably to alleviate poverty.

(iii) To *develop cottage industries* in rural areas.

(iv) To organize them in their struggle for *socioeconomic development* and to integrate economic gains in the distribution of their benefits to the rural society.

(v) To provide *congenial environment* and preserve their cultural identity as their life related to forest.

(vi) To indoctrinate the value of village level *self sufficiency and self management* in the production as well as distribution of forest products with social justice.

(vii) To form the villagers into a well knit community and an *effective functional unit of society* which can shape its own destiny.

(viii) To play a vital role in the *reclamation of degraded lands*, conservation of soil and moisture, improvement of agricultural production and prevention of environmental deterioration.

(ix) To increase the *natural beauty of the landscape*, create recreational forests for the benefit of rural and urban population.

(x) To *protection of agricultural fields* against wind speed and natural calamity.

(xi) To *solve the food problem* of the rural area to a great extent.

(xii) To *utilize the available land* according to its carrying capacity.

(xiii) To help *restore ecological* balance.

Social forestry mission

Social Forestry Mission aimed to carry out a need based and time bound programme of afforestation with special emphasis on fuel wood and fodder development on all degraded and denuded lands and forests. Afforestation could be in abandoned jhum lands and mined areas, linear strip plantation of fast growing species on sides of public roads, rivers, streams and irrigation canals. Afforestation on underutilized lands in the state, institutional or private ownership also considered. Green belts to be created in urban and industrial areas. Shelter belt (generally more extensive than the wind breaks) could be planted for the purpose of shelter from wind and sun covering areas larger than a single farm on a planned pattern.

Farm forestry in the form of raising rows of trees on bund or boundaries of fields and individual trees in private agricultural land as well as creation of wind breaks round a farm or orchard by raising one or two lines of trees. Raise flowering trees and shrubs mainly to serve as recreation forests for the urban and rural population could be encouraged. Elicit people's participation involving women and young people in conservation of forests, wildlife and environment. Environmental awareness generation and celebration of vanamahotsava, environment day, wildlife week etc. could be encouraged.

Strengthening the social forestry

Social forestry programmes were strengthened almost everywhere in the country along the lines of the recommendations of National Commission on Agriculture (NCA), 1976. The programme has received sufficient budgetary allocations since 6^{th} five-year plan. The Ministry of Environment and Forests, Government of India is committed to achieve the goal of 33 per cent of the land under forest and tree cover as per National Forest Policy, 1988.

Social forestry programmes have been further strengthened by procuring assistance from different international donor agencies, such as the World Bank, Swedish International Development Authority (SIDA), Canadian International Development Authority (CIDA), Danish International Development Agency (DANIDA), French Development Agency (AFD), Japan Bank for International Cooperation (JBIC) now it is Japan International Cooperation Agency (JICA), United States Agency for International Development (USAID), etc. Externally Aided Projects (EAP) Division assists the state governments in preparation of externally aided forestry projects, negotiations with donor and funding agencies and monitoring and evaluation of the sanctioned projects.

Expected prosperity through social forestry

a) Enhance food availability

Superior food availability via, supplementary food for tribal and other people; availability of fruits, protein rich seeds and seeds at lower cost; improvement in health of rural living**;** growth of subsidiary fruit based industries and help in solving national food crises.

b) Increase supply of Fodder

Easy availability of nutritious fodder; improvement in cattle wealth; progress in human health through the availability of animal based food products and enhancement of soil health through additional manures

c) Increase supply of fuel wood

Augment supply of fuel wood through easier availability of fuel, cheaper substitute for commercial fuel, release cowdung for manure**,** lesser presser on Govt. forests and renewable sources of energy.

d) Promotion of small and cottage industries

Regular supply of tree based raw materials; growth of cottage industries and development of cooperative societies; and rural financing agencies.

e) Rural employment opportunities
Generate employment; check on the migration of rural population; job opportunities for landless; multifarious economic activities; additional income to the village population; and rise in rural per-capita income.

f) Environmental and ecological balance
Relieve pressures from natural forests; rational land use; optimization of use of renewable resources; development of water resources; conservation of soil and water; control of water, air and noise pollutants; creation of oxygen bank; bio-aesthetic development and better health.

Social forestry and afforestation projects/ schemes implemented in India
Up to the mid 1970s most development projects in India were funded with internal resources. After that time, because of the global attention on "the fuel crisis" and deforestation, forestry was one of the first among many development sectors in India to attract international funding on a large scale. A number of donor agencies are active in funding forestry related projects. The Government of India and other donor agencies have launched various promotional schemes all over the country for social forestry, afforestation and fresh plantations to increase the forest cover with the participation of local people during the first half of the 1980's onwards. There are provisions under the National Forest Policy, 1988 to encourage a need based and time bound programme of afforestation and tree planting through afforestation and social forestry with involvement of local communities. The policy encourages planting of trees alongside roads, railway lines, rivers and streams and canals and on other unutilized lands under State/corporate, institutional or private ownership including creation of green belts in urban and industrial areas as well as in arid and semiarid tracts.

Rural Fuel wood Plantation Scheme
Rural fuelwood plantation Scheme was initiated under the scheme of social forestry as a Centrally Sponsored Scheme during the Sixth Plan period (1980-85), 101 fuelwood deficit districts spread over all the States and three Union Territories of Arunachal Pradesh, Delhi and Mizoram were taken up. The objective of this scheme was to augment fuel wood production and make it available to the rural poor near their habitation. Later, in 1982-83 it was extended to cover 157 chronically fuel wood deficit districts of the country against about 460 districts existing at that time. The scheme envisaged the raising of 2,60,000 hectares of fuelwood plantation and supply of about 580 million seedlings at free of cost to the public and also to the children under the "A Tree for Every Child Programme". During the end of sixth five year plan, about 0.31 million ha were planted with the total expenditure of Rs.499 million.

It continued during seventh five year plan (1985 – '90) and about 0.47 million ha were planted with the payment of 1643.6 million (GOI, 1992). The scheme has sustained since then, with modifications, as the Fuel wood and fodder scheme. The number of fuel wood deficit districts covered increased to 299 (out of 590 districts) in the eighth five year plan (1992 – 1997) with a budget of 1542 million. The number of districts covered under the programme has been increased to 241 in the ninth fiver plan (1997 – 2002).

Operation Soil Watch
The operation 'soil watch' centrally sponsored scheme was introduced in 1977-78 for treatment of selected catchments in micro watersheds of Himalayan region. The objective of the scheme is to treat the micro-watersheds with soil and water conservation measures.

Afforestation and pasture development form essential components of the scheme. The treatment given under this scheme has helped in reducing soil erosion. In the sixth plan, about 0.11 million ha have been covered with an expenditure of Rs.264.2 million. During the first three years of the 7^{th} plan about 0.12 million ha have been covered.

Grants-in-Aid to Voluntary Agencies
This scheme was initiate in the seventh five year plan with the philosophy of eliciting and nurturing people's participation, the National Afforestation and Eco-Development Board (NAEB) provides financial assistance to Non-Governmental Organisations (NGOs)/ Voluntary Agencies (VAs), tree growers co-operatives for afforestation, tree planting and eco-development. These agencies can approach people and function in a flexible manner for obtaining people's participation in afforestation programmes *viz.*, nursery establishment,

planting, soil and moisture conservation, awareness enhancement, training and extension and regeneration of degraded forests. Species covered under planting / afforestation should include fuelwood, fodder, small timber, fruit, and other species, which provide food and income to the local people while also improving the status of the land. In all, 289 projects had been funded up to April 1989, involving a financial commitment of Rs. 225 million.

Decentralized Nurseries Programmes

With the formation of National Wastelands Development Board in 1985, and made a declaration to bring 5 million ha of wastelands under afforestation every year. This created a demand for 10-15 billion plants per year. Accordingly, several attractive schemes were launched by the government and other donor agencies to produce the maximum possible seedlings. The scheme of decentralized nurseries was introduced in 1986-87 with a view to involve people in production of nursery stock and afforestation programmes. Seedlings could be established in nurseries managed by the small farmers (Kishan nursery), schools, women groups, voluntary agencies and co-operatives.

Promotion of decentralised nurseries through credit in the rural areas will lead to identify the local needs for specific tree species; easy and timely availability of planting material, Supply of healthy plants in the vicinity of 2-3 km from plantation sites and in the process lead to creation of employment opportunities and income generation in the rural areas. The cost of production of seedlings at the rate of Rs. 0.45 per seedling is paid in instalments in cash and kind to the farmer by the forest department or donor agencies. The seedlings are supplied to needy people either free or at subsidized price. The seedlings produced during 1986 to 1989 were more than 900 millions. However, poor performance of many decentralized nurseries had a set back on the National Afforestation Movement during the last two decades. Although a small number of Kisan Nurseries were successful in the past to continue their activity for income generation, there is good scope for promotion of decentralised nurseries throughout the country.

Silvopasture Scheme

The silvopasture scheme was started in 1986-87 to augment the production of grass and fodder and to improve the degraded lands. The scheme envisages raising of fodder trees, shrubs, legumes and grasses on degraded and marginal lands of the farmers. About Rs. 1250 per ha was provided as central assistance. The assistance is available to nongovernmental organizations, cooperatives, milk unions, *etc*. The scheme is also being implemented in government wastelands and degraded forest areas.

Margin Money Assistance Scheme

The margin money assistance scheme has been taken up with the objective of raising fuel wood, fodder, small timber and commercial timer plantations with the help of institutional finance. The scheme is for private lands and lands belonging to public sector undertakings. Assistance up to 25 per cent of the total project cost is available, provided at least 50 per cent of the project cost is met from loans from financial institutions. The scheme will increase the flow of institutional finance for wasteland development.

Tree Patta Scheme

The tree patta scheme (also known as 2C Patta) envisages giving usufruct rights in trees planted and grown on earmarked land. The rights would include collection of deadwood, lopping, tree produce such as fruits, flowers, *etc.* The patta would be for a period equivalent to the normal silvicultural life of trees. The patta would be granted on government land to beneficiaries selected from the landless poor with emphasis on scheduled caste and scheduled tribe.

The beneficiary has to raise a certain number of trees (but not agricultural crops) on the land within 2 years. The stress is on fuelwood, fodder and fruit tree species and the land is either government wasteland, panchayat or village community land, or areas along roads and canals. The idea is to produce goods for the under privileged family and there is a right to sell any surplus. The unit of land should be sufficient to provide full time employment to the family members. In general the average size of tree patta land is two hectare.

Promotion of Co-operatives

The co-operatives are formed in the vicinity of operational areas to manage the wastelands, ultimately converting them into productive lands with regard to fodder and fuel. Three major types of co-operatives

have been promoted with a view to increasing people's participation in social forestry programme. Tree growers' co-operatives on the Anand pattern or model have been created in five states *viz*., Gujarat, Andhra Pradesh, Rajasthan, Odisha and Karnataka. The village wastelands are taken on a long lease and trees and fodder crops are planted by the members of cooperatives. Farm forestry co-operatives aim at establishing integrated farming systems including agroforestry and animal husbandry livestock, poultry, piggery, etc., the main objectives of these co-operatives are to develop farm forestry on a large scale on wastelands to bring ecological balance and to conserve soil and moisture. The national dairy development board's concern is to produce enough fodder for milch animals. Hence, dairy co-operatives are functioning in many areas and helped to produce fodder on community wastelands.

Donor assisted social forestry projects in India

External assistance in the social forestry sector remained as a major source of funding, and 15 projects have been completed in 14 states from 1980 to 1998. The total expenditure of these projects were about 18,375 million with a plantation activity coverage of 2.64 million ha and other services. The thrust of external assistance is now on implementing projects geared towards overall development of the forest sector.

Table-4.1: Donor assisted for forestry projects

Name of project and state	Donor agency	Project period
National Social Forestry Project, Uttar Pradesh	World Bank, USAID	1985-86 to 1989-90
National Social Forestry Project, Gujarat	World Bank, USAID	1985-86 to 1989-90
National Social Forestry Project, Himachal Pradesh	World Bank, USAID	1985-86 to 1989-90
National Social Forestry Project, Rajasthan	World Bank, USAID	1985-86 to 1989-90
Haryana Social Forestry Project	World Bank, DANIDA	1982-83 to 1986-87 extended to 1989-90
Jammu & Kashmir Social Forestry Project	World Bank, DANIDA	1982-83 to 1986-87 extended to 1989-90
Karnataka Social Forestry Project	World Bank, ODA (UK)	1983-84 to 1987-88
Kerala Social Forestry Project	World Bank	1984-85 to 1989-90
West Bengal Social Forestry Project	World Bank	1981-82 to 1986-87 extended to 1989-90
Bihar Social Forestry Project	SIDA	1985-86 to 1990-91
Orissa Social Forestry Project	Phase I SIDA	1983-84 to 1987-88
	Phase II SIDA	1988-89 to 1992-93
Tamil Nadu Social Forestry Project	Phase I SIDA	1981-82 to 1985-86 extended to 1987-88
	Phase II SIDA	1988-89 to 1992-93
Andhra Pradesh Social Forestry Project	CIDA	1983-84 to 1987-88 extended to 1989-90
Maharashtra Social Forestry Project	USAID	1982-83 to 1989-90

Recent afforestation/ reforestation projects

The projects which were designed by the Government of India and proposed from 1991 to 1997 for Japanese Official Development Assistance Loans, which are called first generation forestry projects in India, were primarily focused on afforestation and included components such as soil and water conservation, training, extension and procurement of equipment. The funds are utilized for rehabilitation of forest land with the aim to increase forest cover, improve the quality of life of the villagers adjoining forests, ensure people's participations, strengthening joint forest management institutions, augment availability of fuel wood and fodder, promote farm forestry, agro forestry, water and soil conservation measures, encourage tree growing on private land and greening of the urban areas in accordance to the objectives envisaged in various projects under implementation.

The projects which began from 2003 to 2012 were the second generation projects, aimed at striking equilibrium between afforestation and sustainable livelihood improvement of local communities through

JFM. The projects also included institutional capacity building of state forest departments, soil and water conservation measures, improvement of infrastructure, introduction of technology based planning and monitoring, research and extension and involvement of NGOs/community development officers in project implementation. From 2002 to 2009 ten State Sector Forestry Projects with an investment of about Rs. 52,870 million are being implemented in ten States and one Central Sector Project on Capacity Building in Forestry Sector with an outlay of Rs. 2,250 million is being implemented Directorate of Forest Education (DFE), Dehradun and 10 States (Assam, Bihar, Chhattisgarh, Jharkhand, Kerala, Madhya Pradesh, Maharashtra, Sikkim, Uttarakhand and West Bengal) with major funds from Japan International Cooperation Agency (JICA).

Table-4.2: Recent afforestation/ reforestation projects in India

S. No	Name of the Project	Cost (in Rs. Million)	Project Period
1.	Uttar Pradesh Participatory Forest Management and Poverty Alleviation Project	5750	2008-09 To 2015-16
2.	Gujarat Forestry Development Project - Phase II	8300	2007-08 To 2015-16
3.	Tripura Forest Environmental and Poverty Alleviation Project	3660	2007-08 To 2014-15
4.	Swan River Integrated Watershed Management Project (Himachal Pradesh)	1620	2006-07 To 2013-14
5.	Orissa Forestry Sector Development Project	6600	2006-07 To 2012-13
6.	Karnataka Sustainable Forests Management & Bio-diversity Conservation	7450	2005-06 To 2012-13
7.	Tamil Nadu Afforestation project phase-II	5670	2005-06 To 2012-13
8.	Integrated Natural Resources Management and Poverty Reduction Project in Haryana	2860	2004-05 To 2010-11
9.	Rajasthan Forestry and Biodiversity Project	4420	2003-04 To 2007-08 (extended upto 31st July, 2010)
10.	Andhra Pradesh Community Forests Management Project (Funded by World Bank)	6540	2002-03 To Sept. 2009 (extended upto 31st March, 2010)
11.	Capacity Development for Forest Management and Training of Personnel	2250	2008-09 To2013-14 (5 years and 3 months)
	Total	**55,120**	

Source: MOEF, 2011

From 2013 onwards, the third generation projects have come into being, with the inclusion of several other components like afforestation (village based cluster approach on watershed basis), agro-forestry/farm forestry, water and soil conservation, training and extension, biodiversity conservation and ecotourism, community development activities, income generation activities through SHGs, involvement of NGOs as facilitators for micro planning, training, etc., training of all stakeholders, dovetailing of project activities with other government departments schemes (inter-sectoral convergence), technology-based planning and monitoring, monitoring and evaluation and impact analysis after project completion. JICA is also exploring the possibilities of considering preparedness for Reducing Emissions from Deforestation and Forest Degradation (REDD+) mechanism under the ongoing and future forestry projects which would lead to flow of monetary benefits in future directly to forest dependent communities and putting into effect mechanisms for achieving sustainability of project impacts.

Samanavit Gram Vanikaran Samridhi Yojana (SGVSY)

Ministry of Environment and Forests (MoEF) was operating four centrally sponsored afforestation schemes during the 9th Plan, *i.e.* Integrated Afforestation and Eco-development Project Scheme (IAEPS), Area Oriented Fuel wood and Fodder Project Scheme (AOFFPS), Conservation of Non-Timber Forest Produce including Medicinal Plants (NTFPS) and Association of ST and Rural Poor in Regeneration of Degraded Forests (ASTRPS). The Mid-Term evaluation of the projects under these schemes recommended a

decentralized approach and speedy fund transfer mechanism. Taking cue from these recommendations, a Pilot Scheme, Samnavit Gram Vanikaran Samridhi Yojana (SGVSY) was launched in 2000-01 utilising the delivery mechanism of Forest Development Agency (FDA) and Joint Forest Management Committee (JFMC). Under this scheme 47 FDA projects were sanctioned in 19 States during the 9th Five Year Plan (1998-2002).

The objectives of the Schemes were to

- arrest and reverse the trend of forest degradation due to the unsustainable removal of forest products by communities living in and near the forest areas by making the community responsible for monitoring removals from the forest
- provide sustainable and assured employment opportunities to the tribals and other weaker sections of the rural populations in such areas all round the year;
- create durable community assets for such populations, which would contribute to overall eco-development in the target areas.
- to involve the village community in the execution of the scheme and make the exercise as fully participatory.
- create an effective mechanism in order to ensure that the medium of the FDA is used to reach the beneficiaries by other government departments also.

All Pilot projects launched during 9th Plan were highly successful in terms of achievement of the set objectives. Hence the SGVSY Scheme has merged with National Afforestation Programme (NAP) in 10th Plan (2002 – 07), and funding to the SGVSY-FDA projects is continuing under NAP.

The National Afforestation Programme (NAP)

As per 10th five year Plan (2002-07) document of Planning Commission relating to the Forests and Environment sector, the National Afforestation Programme (NAP) Scheme was initiated by scaling-up the SGVSY project experience and converging all afforestation schemes of the 9th Plan period to avoid duplicity or redundancy, and at the same time keeping in focus the decentralization agenda of the government. NAP is being operated as a 100 per cent Central Sector Scheme.

Objectives

The overall objective of the scheme is to develop the forest resources with people's participation, with focus on improvement in livelihoods of the forest-fringe communities, especially the poor.

NAP Scheme aims to support and accelerate the ongoing process of devolving forest protection, management and development functions to decentralized institutions of Joint Forest Management Committee (JFMC) at the village level, and Forest Development Agency (FDA) at the forest division level.

Components

Financial support under NAP Scheme is available for:

a) Mobilisation of village JFMC, and Micro-planning in project villages

b) Afforestation – with the following components:

- Aided Natural Regeneration,
- Artificial Regeneration,
- Bamboo plantation,
- Cane plantation,
- Mixed plantation of trees having minor forest produce and medicinal value,
- Regeneration of perennial herbs and shrubs of medicine value
- Pasture/ silvipasture development

c) Soil and moisture conservation

d) Entry Point Activity (for village development; average assistance Rs. 1.6 lakh per village)

e) Fencing, monitoring and evaluation, training, awareness raising, overheads, etc.

Activities and Achievements

Under NAP wherein plantation of 200 plants per ha is prescribed along with cost provisions for soil moisture conservation works, micro planning, awareness raising and Entry Point Activities (EPA). Bamboo plantation, medicinal plants and Jatropha have been given adequate focus under NAP. State Governments have been advised to earmark 10% of the project area under NAP, as per feasibility, for Jatropha plantation. Rehabilitation of jhum-lands (shifting cultivation) also have been given specific focus under the programme.

The flagship afforestation program of Government of India has covered a total area of 1.69 million ha over a decade 2000 - 2010 spreading over 42,535 JFMCs in 800 Forest Development Agencies (FDA), at a cost of Rs.22,374 million (MoEF, 2011).

Assisted or Aided Natural Regeneration Projects

Assisted/Aided Natural Regeneration (ANR) forms the major strategy of treating degraded forest through Joint Forest Management (JFM) approach under the National Afforestation Plan (NAP) and Externally Aided forestry Projects (EAP). It is the dominant plantation model of forest-treatment in India. ANR is based on the principles of secondary succession is fast gaining acceptance as the key strategy for rehabilitation of degraded tropical forest landscapes. It uses the natural regeneration of forest trees (wildlings and sprouts) and promotes natural regeneration to grow faster through tending and silvicultural operations supplemented with traditional knowledge and involvement of local community.

ANR technique is aimed to reduce bias in favor of a few forest species in a forest community, instead favouring plant community growth with increasing number of species adjudged usefull for livelihood and conservation locally, and for productivity in terms of growing density, canopy cover and biodiversity with passage of years. ANR suggest models as per number of plants to be planted per ha; the models being used are Artificial Regeneration (1100 plants/ha); Silvi-pasture Developments (400 plants/ha); Bamboo Plantation (625 plants/ha); and Mixed Plantations of trees having minor forest products and medicinal values (1100 plants/ha). As on 2011, ANR forms the major strategy for rehabilitation of forest land under externally aided projects being operated in 11 states of India at an investment of Rs 57,180 million.

Green India Mission (GIM)

National Mission for a Green India or the commonly called Green India Mission (GIM) is one of the eight missions (solar energy, enhanced energy efficiency, sustainable habitat, water, sustaining the Himalayan eco-system, Green India, sustainable agriculture and strategic knowledge for climate change) outlined under India's action plan for addressing the challenge of climate change in the National Action Plan on Climate Change (NAPCC). GIM was launched in February 2014, is aimed at protecting, restoring and enhancing India's diminishing forest cover and responding to climate change by a combination of adaptation and mitigation measures.

The mission has the broad objective of both increasing the forest and tree cover by 5 million ha as well as increasing the quality of the existing forest and tree cover in another 5 million ha of forest and non forest lands in 10 years. The mission proposes a holistic view of greening and focuses not on carbon sequestration targets alone, but also, on multiple ecosystem services, especially, biodiversity, water, biomass etc., along with provisioning services like fuel, fodder, timber and non-timber forest produces. It will also increase options of forest based livelihood of households living in the fringe of those landscapes where the mission is implemented.

GIM Goals

The Mission goals are as listed below:

- To increase forest/tree cover to the extent of 5 million hectares (mha) and improve quality of forest/tree cover on another 5 mha of forest/non-forest lands; Separate sub-targets exists for different forest types and ecosystems (eg. Wetland, grassland, dense forest etc.). For instance, GIM aims at:

- ❖ Improvement in quality of forest cover and ecosystem services of forests /non-forests, including moderately dense, open forests, degraded grassland and wetlands (5 m ha). The sub-targets are:
  - ➢ Moderately dense forest cover, but showing degradation: 1.5 m ha
  - ➢ Eco-restoration of degraded open forests: 3 m ha
  - ➢ Restoration of Grasslands: 0.4 m ha
  - ➢ Restoration of Wetlands: 0.10 m ha
- ❖ Eco-restoration/afforestation of scrub, shifting cultivation areas, cold deserts, mangroves, ravines and abandoned mining areas (1.8 m ha) with separate sub –targets for each one of those.
- ❖ Improvement in forest and tree cover in urban/peri-urban lands (0.20 m ha)
- ❖ Improvement in forest and tree cover on marginal agricultural lands/fallows and other non-forest lands under agro-forestry / social forestry (3 m ha)
- ❖ To improve/enhance eco-system services like carbon sequestration and storage (in forests and other ecosystems), hydrological services and biodiversity; along with provisioning services like fuel, fodder, and timber and non-timber forest produces (Minor forest produces or MFPs) etc which are expected to result from the treatment of 10 m ha;
- ❖ To increase forest based livelihood income for about 3 million households in and around these forest areas; and
- ❖ Enhanced annual CO_2 sequestration by 50 to 60 million tonnes in the year 2020.

The National Afforestation Programme (NAP) and National Mission for a Green India (GIM) schemes are implemented in participatory mode under Joint Forest Management (JFM) approach. NAP is aimed at afforestation and eco-restoration of degraded forests and adjoining areas whereas GIM aims at increasing the forest cover of country along with improving its quality. There is a component under GIM to support forestry on farm lands for taking up Agro-forestry and Social forestry.

SOCIAL FORESTRY PROJECTS IN TAMIL NADU

Tamil Nadu is the pioneer state initiated afforestation programme in community lands, village commons and degraded lands outside the Reserve forests.

- ❖ In 1956, afforestation by planting teak was taken up on river bank and canals of Cauvery irrigation system.
- ❖ During 1960, farm forestry was implemented.
- ❖ In 1970's, extension forestry, mixed plantations and village forests were implemented to develop forest on Govt. lands.
- ❖ In the two decades ending 1980 – 81 about 1.33 lakhs ha of lands outside the reserve forests were engaged.
- ❖ It provided about 10 lakh tonnes of fuel wood annually from tank bed plantations alone at 10 years rotation.

The above favourable results encouraged the Tamil Nadu Govt. to intensify the social forestry activities in the state.

Social forestry project – Phase I (1981 – 88)

In the phase I two major social forestry projects were undertaken in Tamil Nadu. They are,

1. Externally aided social forestry programme
2. Centrally sponsored social forestry scheme for Rural Fuel Wood Plantation

1. Externally aided social forestry programme

A massive social forestry project was launched with the aid from Swedish International Development Authority (SIDA) in the year 1981 – 82. This programme was originally considered for the period of five

years from 1981-82 to 1985-86, but it was extended for two more years *i.e.* up to 1987-88. The outlay of the project was Rs. 450 millions with 70 per cent of SIDA aid. But the total expenditure for seven year period was Rs. 570 millions.

Objectives

- To ensure supply of fuel wood in rural areas
- To provide fruit, small timber, fodder and other non-timber forest products.
- To establish, wherever possible, plantations on long-term basis which satisfy the requirement of wood of the villages and generating employment through establishing, maintaining and felling of plantations.
- To shift gradually the responsibility for establishment, maintenance, protection and harvesting of woodlots, raised outside forest lands from the forest department to village panchayats.
- To help economically weaker sections to raise plantations in their land holdings which are unsuitable for agriculture.

Aim/ Goal

- Creation of land based asserts in the form of forests to fulfill the rural requirements.
- Ensure equitable distribution of the commodity flows on an even and sustained basis.
- Utilize nontraditional lands such as tank foreshore, Govt. vacant lands, road side, railway and canal side lands, private marginal and sub marginal agricultural lands etc., for creating such forest asserts and for maintaining the environment.
- Obtain the full and equal participation of the rural communities including women and children and the panchayats in activities involving the planting.
- Providing employment opportunities particularly to the economically weaker sections.

Table-4.3: Components, Targets and Achievements of Externally aided social forestry programme (SIDA) Phase I

S. No	Component	Target	Achievement
I	**Farm Forestry** (Distribution of Seedlings)		
a	Tree cultivation Incentive Programme (TCIP)(In Millions)	**42.56**	**44.52**
b	Tree cultivation Extension Programme (TCEP) (In Millions)	**117.65**	**121.54**
II	**Community forestry**		
a	**Block planting (in ha)**		
i	Tank foreshores		1,13,962.00
ii	Promboke plains		7,253.00
iii	Promboke hills		17,756.00
iv	Fodder plantations		1,392.00
	Total	**1,56,910.00**	**1,40,363.00**
b	**Strip planting (in km)**		
i	Road avenues		4,140.00
ii	Railway lines		1,935.00
iii	River/Canal Bund		2,216.00
iv	Tank Bund		528.00
	Total	**7,715.00**	**8819.00**
III	**Recreation Forestry (Distribution of Seedlings)** (In Millions)	**---**	**48.00**

2. Rural Fuel Wood Plantation

The centrally sponsored social forestry scheme for rural fuelwood plantation scheme was introduced by planning commission of India in the 6th five-year plan (1980-85). Its aim was to establish plantation of fuelwood in chronically fuel wood deficit districts of the country.

In Tamil Nadu it was implemented in Chengelpattu, Dharmapuri and Trichy districts.

Table-4.4: Components, Targets and Achievements of Rural Fuel Wood Plantation scheme

S. No	Component	Target	Achievement
1	Farm Forestry (Distribution of Seedlings in millions)	76.20	70.42
2	Block planting (in ha)	36,100.00	34,177.00
3	Strip planting (in km)	1,163.50	1,365.00

First phase of social forestry projects to bring an extent of 0.18 million ha of area under forest and tree cover and also strip planting of over 10,184 km along road sides, railway lines and canals and to distribute 236.48 million seedlings to the people. A minimum of 70 per cent success of this first phase of social forestry at least increase one per cent of forest and tree cover to the total geographical area of Tamil Nadu.

Social Forestry Project (SFP) Phase – II

Encouraged by the success of phase – I, the SIDA aided social forestry project of Tamil Nadu was extended for another eight years under phase - II (1988 – 89 to 1992 – 93; extended up to 1995-96) with total out lay of Rs. 850.00 millions. Based on the experience gained during phase – I, SFP phase - II identified the following major policy issues.

i. To create a dynamic market orientation of social forestry products those are being increasingly sold in the market.

ii. To shift the emphasis from fuelwood to multiple use / Non Timber Forest Produce species.

iii. To improve the quality and productivity of the plantation.

iv. To have proper target group orientation.

In the case of Phase - I the forest department remains as the nodal agency, but Phase - II was implemented as a multi departmental venture (Forest, Rural and Agricultural Department).

The implementation strategy of phase II project was slightly modified with the following programmes.

a) The community woodlot development action continued with more intensive efforts towards transferring the responsibility of management of the community woodlots to panchayats.

b) Interface Forestry Programme (IFF) was launched with the aim of reforesting the degraded Reserve Forests abutting the habitations on watershed basis.

c) Joint Forest Management (JFM) or Participatory Forest Management (PFM) was introduced to involve the people of the villages enlisting their participation and co-operation and to meet out the immediate needs.

d) Biological up graduation of degraded forests which are rich in biodiversity potential.

e) To obtain sustained water yield in the command area through physiographic and biological development of the upstream side of forest land in the water-shed.

Major objectives of Social Forestry Project - phase II

i. To increase the efficiencies of the villagers in raising plantation.
ii. To implement agro-forestry among farmers for increase agricultural production.
iii. To meet the basic needs of village population.
iv. To provide self employment for villagers.
v. To extend the activities of community forests, thereby helping the economically backward people in rural areas.
vi. To improve the environment by afforestation.

Components of Social Forestry Project phase II

i. "Tree patta" scheme

ii. Agroforestry in dry lands

iii. Community wasteland development

iv. Interface forestry

v. Research, development and extension

i) Tree Patta Scheme

Tree Patta Scheme was implemented by Rural Development Department. The objective was to ensure better survival of seedlings in community lands with involvement of local landless women. Tree patta's for one ha area for block planting or one km for strip planting will be issued to each beneficiary consisting of at least 50 per cent of SC and ST families. The patta holder entitled to the trees only responsible for protection and tending works. SIDA provides professional support through training of staff and beneficiaries of the scheme for raising quality seedlings and advice on silviculture aspects.

ii) Agroforestry in dry lands

This scheme was implemented by Agricultural Department with two programme activities *viz.,* a) Main programme and b) Development programme

a) Main programme

This programme was implemented throughout the state with small and marginal farmers in low rainfall area were motivated and supplied free seedlings of agro-forestry importance along with incentives.

b) Development programme

The development programme was concentrated on degraded barren lands and aim at developing agro-forestry or the tree husbandry models. It was implemented on a trial basis in 4 or 5 districts.

iii) Community Wasteland Development programme

The main trust of this component was to establish a system of self sustaining and improved assets. Under this programme, plantation activities are carried out in fresh areas and older plantation areas of tank beds which need up-gradations either by gap planting or replanting. Strip planting was carried for three years *i.e.* from 1988 – 89 to 1990 – 91 and it was phased out after 1990 – 91. More than 78,448 ha of block plantations were tackled under this component. In addition, strip plantations along avenues, rivers and on the canal and tank bunds of 1,687.0km were also raised.

iv) Interface Forestry Project (IFP) - 1988 -96

Interface Forestry Project was evolved, and during 1988 it was launched in Tamil Nadu as a component of SIDA aided Social Forestry Project Phase II. It is considered as an evolutionary stage in the implementation of joint forest management (JFM) or participatory forestry management (PFM). This programme aimed at restoration of degraded forests close to habitations, on watershed basis, with active cooperation of abutter villagers. An Interface Forest is a part of the degraded Reserved Forest, which has a border with adjoining village and it provides direct and indirect benefits to rural communities who living in that adjoining village.

In Tamil Nadu about 6.10 lakh hectares of Reserve Forests lying adjacent to about 3000 villages are under various stages of degradation due to excessive grazing, browsing, illicit felling and recurrent forests fires in summer. The Forest Department has become conscious of the fact that unless the user communities are made to obtain from overuse and misuse of forests, and cooperate with the Government in developing and protecting the forests especially those neighboring the villages it would be almost impossible to maintain the forest lands as a natural resource.

Concepts

Interface forestry was

- ❖ Degraded forest based
- ❖ Participatory Rural Appraisal (PRA) based micro planning

- ❖ Institution building in the form of Village Forest Council
- ❖ Structured benefit sharing

Objectives of IFP

1. To upgrade the degraded forest resources by promoting natural regeneration and adopting artificial regeneration with the active involvement of abutter village communities.
2. To augment the water resources, particularly for increasing the ground water potential of the selected micro watershed by adopting water harvesting measures.
3. To develop the human resources of the target village communities through employment generation and providing training on various skills.
4. To meet the forest based needs of the abutter village communities with regard to fuel, fodder, minor forest produce, small timber and other forest produces.
5. To identify the prioritised needs of the villagers in the buffer zone and to create the necessary infra-structural facilities to satisfy their prioritised needs.
6. To promote agro-forestry by way of supply of fruit seedlings and other seedlings of their choice to plant in their farm lands.
7. To facilitate and ensure peoples participation of the adjoining communities in planning, implementation and maintenance of the programme through PRA based approach in forest based watershed management for ensuring sustainability by creating stake for the local people in the management of forests.

Management Plan

Watershed is considered as the unit of management and the project area is divided into macro and micro watersheds. Potential areas for development at micro watershed level are identified after consultation with the abutting user communities. The Interface Forests at micro watershed level includes forest-ecosystem, agro-ecosystem and other common property eco-systems. The rural people living in the micro watershed level are considered as eco-system people and they are the primary stake holders in the management of the forest at micro watershed level. Action plans are drawn up by the implementing officers after conducting Participatory Rural Appraisal (PRA) exercises and ascertaining the needs of the communities and matching it with the physical conditions of the area to be treated and also the funds available. Village Forest Councils (VFC) and Executive Committees are formed in the programme villages for planning and implementing the programme.

People's participation was sought for from the initial planning stage onwards up to benefit sharing and to some extent for the management and protection of forests. The modes of benefit sharing of various produces by dependent communities are given below

i. Fuel wood

The produce obtain by pruning in Interface Forestry Area would be supplied to the head loaders and landless poor at free of cost. Head load permits for free removal will be issued by the Executive committee.

ii. Fodder and green leaf manure

Collection of fodder and green leaf manure will be allowed under cut and carry system from the lower slopes of the forests at free of cost.

iii. Grazing

The number of animals (except goats) which each household entitled for grazing will be decided by the Forester in consultation with the Executive Committee. Forests under Interface Forestry Programme (IFP) will be close for grazing at least for three years. The executive committee will issue annual grazing permits to the members every year.

iv. Non- Timber Forest Produce (NTFP)

The non-timber forest produce is classified under two categories *viz.*, A and B.

Category A
The poor people of the respective interface villages are allowed to collect category A like usil leaves, neem fruit, medicinal herbs, curry leaves, Agave etc., at free of cost. However, these forest produces and beneficiaries will be identified by the Executive Committee and permits will be for removal.

Category B
This includes items like gallnut, stone and tree masses. This will be allowed only after collecting 25 per cent value of the fair price fixed by the Forest Department. However, the beneficiaries will be identified by the Executive Committee.

(v) Bamboo / Small Timber
All the members of village Forest Committee are entitled to get this produces at 50 per cent of the fair price fixed by the Forest Department.

Benefits of IFP

i. Every year 2000 – 2500 ha of forestland, Govt. lands, community lands and patta lands of the villages adjoining the degraded forests were treated on watershed basis.
ii. About 20% of the lands outside the Reserve Forests lying within the watershed were also treated.
iii. More importance was given to the soil and moisture conservation measures.
iv. Besides afforestation works check dams, percolation ponds, gully plugs, contour walls etc. were formed to conserve the soil and water.
v. Employment to the village of the watershed on one family one person basis was provided throughout the year.
vi. The interface areas were tackled on the principles of eco-restoration (upper zones), asset creation (middle slopes) and interface zone (lower slopes).
vii. Mainly fodder, fuel, fruit and small timber tree spp. were planted in village common lands and in the interface lower slopes for catering to their needs.
viii. Seedlings of fruits and fodder spp. were distributed at free of cost to villagers for planting in their lands.

Apart from forestry programmes the following other developmental activities have also been carried out under this programme for the benefit of the villagers. It includes development of infrastructural facilities like drinking water facility, threshing floors, bus shelters were provided; income generation activities like tailoring, basket making, gem cutting, palm graph oriented cottage industries etc., have been commenced to earn additional income; various production oriented activities like milk producers co-operatives societies, basket making societies, sheep co-operative societies have been set up; women welfare organisations have been formed in all the villages to ensure the involvement of the women; health camps, veterinary campus, eco-awareness camps, rallies have been conducted by involving the voluntary organization / non – governmental organisations and local school children in collaboration with villagers; adult education programmes have been undertaken by utilizing the services of the local educated youths to improve the literacy level among the villagers; creches have been constructed in all the command areas to accommodate the children of the working groups; and Fuel economic smokeless chulas have been distributed to the needy villagers.

With the above benefits and developments IFP has come to close in the year 1996. However, it has developed into Japanese Overseas Economic Cooperation Fund (OECF) Aided Micro Watershed based Comprehensive Forestry Project in Tamil Nadu from 1997 onwards.

vi) Research, Development and Extension
The change in the concept of social forestry from a mere plantation system to a life supporting system necessitated an evolution of new knowledge within the framework of sustainability and in this regard the Society for Social Forestry Research and Development of Tamil Nadu (SSFRDT) was formed during 1989.

Selection and launching of research projects, monitoring and evaluation of such project and the dissemination strategies, and to manage the activities of the society a committee was formed. The secretary Agricultural Department and the Principal Chief Conservator of Forests are ex-officio members from the Government of Tamil Nadu. Planning, implementation and dissemination of the programme are the duties of the society.

Programme planning consisted of identifying the priority areas for research to be funded by the society. After the identification of the priority areas for research, the society encourages the development of project proposals in two ways.

i. The society approaches the institutions and individuals for specific projects and

ii. Informs scientists, NGO's and research institutions through brouchers, seminars and workshops regarding the objectives of the society and its priority areas of research.

The proposals are discussed by a committee of the society for their relevance vis-à-vis the objectives of the society, feasibility and cost effectiveness. The proposals are also sent to expert in the relevant field for their comments. After the approval of the committee, the proposals are launched as projects.

The projects are monitored through a Management Information System (MIS). Once a project is completed, it is evaluated by experts and is refined according to the suggestions of the experts and disseminated to the target groups.

Research Projects

The research projects of the society can be classified into five broad categories as mentioned below

i. Germplasms

ii. Growth promoters

iii. Fodder research

iv. Agroforestry models

v. Studies for policies and planning

Participatory research is an important tool for testing the knowledge in the field and it defines the social viability of the new technology. Society emphasis participatory research and this approach are being externally used in Agro-forestry models and fodder research.

Achievements in SFP Phase II

i. Forestry Recovery

About 27,284 ha (1.2%) of degraded Reserve Forests have been tackled under IFF programme.

ii. Linkages with other departments

Positive linkages have been established with several NGO's operating in the Interface Forest Areas and linkages to other departments and village communities have been strengthened.

iii. People's involvement

In realizing the benefits obtained from the forests, villagers have come forward to assist the Forest Department in protecting forests. Over grazing has been reduced considerably. The villagers have voluntarily sold their goats and purchase sheep to avoid goat browsing. The villagers through Forests councils undertake to impose fines on the illicit cultures in the forests.

iv. Soil and water conservation

Soil and water conservation measures undertaken by this programme have increased the percolation and availability of water substantially in the treated watersheds. The water level was increased in many of wells from 3 m to as high as 9 m in the project area.

Sustainability of the project

This programme also attempts to improve the quality of life of the user communities. Alternative employments through developmental activities and income generation activities implemented in the project

area gave immediate benefit to the local villages. About 558 lakh man-days are generated in the IFP village area alone. Since, Interface Forestry Project is an integrated project consisting of bio-physical, social and economic aspects, it has got a very good potential for sustainability. The Swedish mission has conducted that "The Interface Forestry component is impressive in both concept and practice and its activities have produced strong signs of recovery in degraded natural forests".

The social forestry programme was launched on 01.04.1981 and came to an end on 31.03.1996.

TAMIL NADU AFFORESTATION PROJECTS (TAP)
TAMIL NADU AFFORESTATION PROJECT (PHASE – I)

In order to uplift the quality of life of villagers abutting the forest areas and to restore the degraded forests in Tamil Nadu through their participation, a massive Joint Forest Management based "*Tamil Nadu Afforestation Project"* Phase-I was implemented from 1997-98 to 2004-05. The project was originally conceived for 5 years from 1997-98 to 2001-2002 at a base cost (cost at the time of project preparation) of Rs.499.20 crore for 1000 villages and an area of 3, 36,106 ha. This project achieved all the physical targets without time or cost over run in 2001-2002. Due to savings in the loan amount and also exchange fluctuation, the project was extended to two more years *i.e.*, 2002- 2003 and 2003-2004 benefiting 258 more villages and 82,400 ha. The project was carried out during 2004-2005 with State Government funds. The overall outlay of the project was Rs.688 crore with a soft loan of Rs. 483 crore from Japan Bank of International Cooperation (JBIC) and State Government funds of Rs.205 crore.

Objectives
General Objectives

- To launch a massive tree plantation programme in the State of Tamilnadu, for bring a balanced ecological up-gradation, and
- To meet the requirements of the local people with respect to wood and non-wood forest products.

Specific Objectives

- Improving the forest productivity by creating heterogeneity of tree species and through intensive soil conservation and water harvesting measures.
- Preserve areas which are rich in biodiversity.
- Optimize use of land resources on scientific basis and provide employment opportunities in rural areas.
- Enhancing the capabilities of the Tamil Nadu Forest Department by establishing Geographic Information system, various training programmes, and re-orientation in the management of natural resources through Joint Forest Planning and Management.

Implementation
TAP Field Zonation

In this component every year 200 programme villages are identified and work will be taken up on watershed basis following the Joint Forest Management (JFM) concept. The watershed improvement work will consist of both planting and soil and moisture conservation work. The improvement treatment of each watershed will be done zone -wise (Lower, Middle, Upper and buffer) based on the character of terrain and existing vegetation cover.

Lower Zone

The lower zone will be planted with the species to meet the immediate needs of the village community and also for long term benefits. It also includes soil and moisture conservation measures like gully plugging. Totally 500 seedlings distributed per hectare. Out of these, 450 seedlings of miscellaneous species which can meet the need of the local villagers for fruit and fodder (*Syzygium cumini, Anacardium occidentale, Annona squmosa, Emblica officinalis, Mangifera indica, Azardirachta indica, Hardwikia binata, Thespesia populnea, Dalbergia sissoo,* Bamboo*, Albizia lebbeck, Albizia amara, Ailanthus excelsa, Ceiba pentandra,* etc.) are planted. Twenty five good quality tamarind seedlings and 25 vegetative propagated cuttings are also planted.

Middle Zone

In middle zone (asset creation zone) species to meet the long term needs of the village community will be planted. Soil and moisture conservation measures *viz.,* gully plugging, check dams, contour trenches, vegetative barriers are formed. Out of 300 seedlings distributed per hectare, 250 seedlings of miscellaneous species like Bamboo, *Madhuca latifolia*, *Syzygium cumini*, *Emblica officinalis*, *Dalbergia sissoo*, *Albizia lebbeck*, *Hardwikia binata*, *Thespesia populnea etc.*, 25 good quality tamarind seedlings and 25 vegetative propagated cuttings are to be planted. The rate of financial allocation per hectare for planting work and soil and moisture conservation measures should be 55: 45 respectively.

Upper Zone

The upper zone will be known as zone of eco-restoration. The existing natural growth of this area will be totally protected as such and the genetic bio-diversity will be enhanced by planting the pioneering species available in this area. Soil and moisture conservation measures *viz.,* gully plugging, check dams, contour trenches, vegetative barriers etc. formed. Totally 100 seedlings were distributed per hectare. The ratio of financial allocation per hectare for planting work and soil and moisture conservation measures in upper zone should be 35: 65, respectively.

Buffer Zone

This zone comprises both the patta lands and community poramboke waste lands falling within 2- 3 kms radius of forest boundary selected to be treated under TAP project. Soil and moisture conservation works and planting along the field bunds will be taken up based on the demand of the local villagers as planned in micro plan. Developmental activities in the programme villages should be done in an integrated manner with the involvement of all other sister departments and local NGOs. Asset creation works which are of priorities are identified in consultation with Village Forest Council (VFC) and included in the micro - plan before execution.

Institution building

Institution building was done based on the JFM practices.

Table-4.5: Tamil Nadu Afforestation Project (TAP) Phase-I (1997-98 to 2004-05) Achievements

Activities	Achievements
Afforestation	❖ An extent of 4.80 lakh ha. of degraded forests and community lands has been covered.
People's participation	❖ 1367 Village Forest Councils formed with 4.66 lakh villagers as members.
Water harvesting	❖ 23,454 check dams and 2,201 percolation ponds were constructed for rainwater harvesting. ❖ A combined storage of more than 800 million cubic feet of water created. ❖ Forest fringe villages had a rise in water table ranging from 5 per cent to 10 per cent despite severe drought. This also helped augmenting agricultural production.
Technological thrust	❖ Introduction of Geographical Information System (GIS) in implementation and monitoring of the project. ❖ Computerization down to the level of the Forest Range Office.
Integrated village development	❖ Community assets like overhead tanks, bore wells, hand pumps, VFC buildings, etc. provided to improve the quality of life in all project villages. ❖ 4722 rural development works implemented by 22 line departments by cross sectoral linkage.Rs.41.30 crores worth of works benefitted 946 project villages spread over 27 districts except Chennai, Nagapattinam and Thiruvarur.
Growth in employment	❖ 1,75,000 forest dependents and villagers benefitted through alternate employment. ❖ 60 million man days of employment generated.

Micro-credit	❖ Rs.53 crores of micro-credit distributed to villagers. ❖ Fund will revolve and rejuvenate village economy.
Active participation of women	❖ 3,891 Self Help Groups (SHG) benefitting around 60,000 women formed.

TAMIL NADU AFFORESTATION PROJECT - PHASE II (TAP II)

To consolidate the gains of TAP-I, Tamil Nadu Afforestation Project phase II (TAP II) was initiated from 01.04.2005 with an outlay of Rs.567.42 crores with a soft loan from JBIC, which includes Rs 158.34 crores as State Government share. The TAP II will be implemented over a period of 8 years from 2005 -2006 to 2012-2013.

Objectives

- ❖ To bring about ecological restoration of the degraded forests.
- ❖ To facilitate livelihood improvement of the inhabitants of the project villages by afforestation through Joint Forest Management.
- ❖ To contribute towards poverty reduction in the area.

Components

- ❖ Afforestation
- ❖ Buffer zone activities
- ❖ Improvement to infrastructure
- ❖ Supporting activities

Afforestation

The Afforestation programme has two sub components *viz.*

i. Integrated Watershed Development Programme (IWDP)

ii. Integrated Tribal Development Programme (ITDP)

i. Integrated Watershed Development Programme (IWDP)

Degraded forests upto a density of 0.4 and degrading forests upto a density of 0.6 will be treated for their ecological restoration under the project. JFM will be the main strategy for people's participation. The NGOs will be involved in social mobilization, awareness creation and institution building. About 1,25,000 ha of degraded forests having less than 0.4 density abutting 500 villages will be restored. Degrading forests to a wide of 37,500 ha having a density of 0.4 - 0.6 abutting 150 villages will be brought under JFM.

The entire watershed of each programme village will be divided into two zones *viz.*, upper zone (Eco-restoration zone) and lower zone (Asset creation zone). Soil and moisture conservation works such as check dams and percolation ponds are constructed to improve the ground water table.

ii. Integrated Tribal Development Programme (ITDP)

Tribals are the integral part of the forest eco-system and their economy depends on the forest resources. Tribal villages are mostly enclosures located within the forest area. In order to improve the productivity of the forests close to the tribal settlements, afforestation works over an extent of 15,000 ha were undertaken to plant useful tree species yielding Minor Forest Produce (MFP), bamboo, small timber and poles.

Buffer zone activities

Buffer Zone is a essential zone interfacing the village and the forests. In order to improve the quality of life of the villagers, Buffer Zone Activities (BZA) will be implemented in 800 IWDP and ITDP villages for five years. BZA consist of Income Generation Activities (IGA) and Community Development Works (CDW). IGA will be allotted 67 per cent of the total BZA budget for the village, while CDW will get the balance 33 per cent to undertake infrastructure development in the village such as providing drinking water supply, roads, etc. The SHGs and individuals will be given loan to take up alternate employment. The activities to be undertaken in each village by identifying by the villagers themselves in the PRA exercise and documented in the micro-plan.

Assessment of social forestry project outcomes

The origin of large scale tree plantations on non forest lands (social forestry) can be traced to the report of the National Commission on Agriculture (NCA), 1976. Initially, the main focus was on common land plantations and farm forestry targets were kept modest. This was because the planners believed that farmers would plant only a few trees on homesteads or farm boundaries. But, in terms of simply amount of planting of new trees, the social forestry programme has been immensely successful. Between 1980 and 1987, the Government claims to have grown 18,865 million trees. If the estimate of survival of 60 per cent is taken as correct, and taking the number of villages as 580,000, the average number of surviving new trees per village comes to nearly 19,500.

Many success stories from social forestry projects were recorded at micro-level which were good for replication and motivation of the rural people on a larger scale. It generates a lot of awareness among the local people. However, this success was due to the popularity of farm forestry in commercial regions. Tree planting on village lands, with some exceptions, failed throughout the country. There were shortcomings in the way the programme was conceptualised and implemented, leading to marked divergence between the stated objectives of social forestry and the actual outcomes. The acceptance of farm forestry was not uniform throughout the country. The difference between these regions manifest themselves in the number of farmers involved in tree plantation, total trees planted, survival rate and the place and purpose of planting. For instance, in subsistence areas, trees were mainly grown for household use and to complement or supplement food crops. Consequently, a majority of the trees were planted on homesteads or farm bunds. In some subsistence areas, the government subsidies offered rather than the returns from the tree produce were the main motivation for planting them. On the other hand, the main motivation for farmers in commercialised regions was increased income through sale of tree produce.

However, the drawbacks of various social forestry schemes launched in different parts of the country became noticeable. The social forestry departments had great difficulty in mobilizing local participation due to wide gap between the assumed problems and actual realities in the field. Moreover, the work plans were not based on specific ground data and ecological conditions, the proposed models of social forestry were often found to be inappropriate. However, modifications in the project designs and implementation plans could not be carried out because of rigid rules and regulations. These schemes could not register the anticipated success because of the following reasons:

a) Perception of the problem

As deforestation was analysed by the NCA to be due to fuelwood and fodder demands of the people, it was assumed by the policy makers that, given government help, people would willingly invest their labour and capital in raising fuelwood and fodder trees. However, as fuel and fodder were often collected free, farmers (at least in the commercial areas where farm forestry had greatest impact), as well as panchayats, preferred income generating trees, and continued to collect branches, twigs, leaves and grasses from forests as before. Thus the assumption in social forestry about how village farmers would react to a given opportunity was untenable. Producers were interested in increasing their incomes, and not in the national objective of providing fuelwood and fodder to the poor.

The extent and magnitude of rural fuel shortages was often over estimated and the role of other gatherable biomass fuels (woody shrubs, agricultural residues, animal dung) underestimated. Shortages of fuel are often severe and bear particularly heavily on women. However, village studies have shown that when confronted with shortages of fuelwood, the landless and poor shift to other gatherable fuels rather than to purchased fuelwood. As they need regular supplies of small quantities, sources which produce only at infrequent intervals provided by the harvesting of woodlots are likely to be of only limited value to subsistence users. In general, the woodlot planting has therefore created a resource which is unlikely to make a significant contribution towards meeting local needs of the poor.

b) Convergence of people's and panchayat's interests

Foresters and foreign experts who designed the projects did not fully grasp the complexity of the rural power structure and assumed that the village panchayat's represented the interests of all concerned in the village. In actual practice, village panchayat's often tended to be indifferent to the poor. They perceived the woodlots primarily as significant sources of communal income, rather than as sources of produce to meet village

needs. For this reason there was usually a preference for auctioning the output, rather than selling it at preferential rates or distributing it. The evaluation of the second phase of the Tamil Nadu Social Forestry Project in 1992 concluded that "community planting has had little social impact, a large proportion of the benefit from community plantation goes to the town and cities to middlemen, fuelwood using industries and retailers. The distribution of benefits has thus been different from what was intended in the project". Fuelwood which is to be sold, as is the case with most woodlot projects, is therefore unlikely to be accessible to the poor even at concessionary prices.

c) Willingness of panchayat's for management

In most communal woodlot activities planting and management was undertaken by the forest department on village lands transferred to the department for this purpose. It was assumed that panchayat's would take over responsibility for management, which did not happen. Evaluation reports of social forestry schemes in India (which were "for the community" but not "by the community"), such as those of Odisha (SIDA 1987), Tamil Nadu (SIDA 1988), Uttar Pradesh, Rajasthan, Gujarat and Himachal Pradesh (World Bank 1988), Andhra Pradesh (CIDA 1988) and Maharashtra (USAID 1991) have in general found little evidence of communal interest or of management capabilities of the panchayat's. It remained a departmental activity on land transferred to the forest department, alienating and disempowering local management and participation.

d) Limited land availability

The area under village lands which could be made available for afforestation was highly exaggerated when the social forestry programme started, just as the area under private lands was grossly under-estimated, under a mistaken notion that the entire amount of private land is cultivated. Social forestry programmes in several states encountered shortages of actually available plantable land due to the encroachment, competition from other government programmes (including competition between the social forestry programmes of different departments), competition from grazing and other existing local uses and poor productivity (additional land could be brought under trees, but only at a per hectare cost well in excess of what was budgeted and made available). As a result, the area of woodlots available to a community was usually small; liable neither to satisfy the fuelwood needs of the village, nor to promise sufficient non-monetary returns to village leaders who were expected to devote their time and energy to raising the woodlots.

e) Tenure on village lands

Throughout the Social Forestry phase it was not clear whether village lands belonged to the forest department, the revenue department or the village body. Such uncertainty about ownership and legal rights impeded community action. It was also difficult for the forest department to remove encroachments on such lands. Further, non forestry laws often conflict with social forestry.

f) Technical issues

Species selection and silvicultural issues were considered technical questions to be settled in the field and hence were not examined carefully at the project stage. Benefits which could flow to the poor from species yielding intermediate products were not properly appreciated. The value of a tree was linked, in the minds of planners, with the final product obtained through felling. Thus production of grasses, legumes, leaf fodder, fruit and NTFPs were neglected. Thinning and pruning, which could have produced intermediate yields of grass and tree products for the people were not undertaken. Technology with which the foresters were familiar for large scale plantations for markets within forest areas was applied to small scale village woodlots, where the need was more for fodder and subsistence than for timber. As projects were designed around the ultimate felling of the planted trees, degradation often set in after the trees were harvested.

g) Policy for forest lands

The small size of village woodlots also had implications for policy on forest lands. People continued to depend on nearby forest areas, which were however being used by the forest Corporation for timber and cash crops like teak and cashew, thereby depleting the availability of fuelwood which could be gathered by the people. People's pressure however endangered the success of commercial plantations. It was ironic that millions of rupees were being spent to create new fuelwood resources through small woodlots, whereas the existing much larger potential fuelwood areas on forest lands were being diverted for non-fuelwood commercial plantations. It would have been cheaper to rehabilitate the existing forests for the purpose of meeting people's demands. Unless creation of woodlots and rehabilitation of nearby forests were both

undertaken in an integrated manner with the specific objective of satisfying people's needs, the long-term viability of village woodlots was in doubt.

h) Neglect of forest lands

Funding availability for forest lands became quite precarious during the social forestry phase. As state funds were reserved to meet the matching contributions required for external assistance for projects on non forest lands, forest lands were starved of funds, with several adverse effects. The neglect of forest lands hurt forest dwellers and tribals. It reduced timber supplies to the markets, resulting in price escalation, which further increased smuggling from forest lands.

i) Rights and distribution policy

Another key reason for the poor performance of community plantations has been the failure to define, establish and publicise the rights to the trees and the procedures for marketing and allocating benefits. For instance, the mid-term evaluation report (CIDA 1988: 51) of Andhra Pradesh observed, 'Final benefit sharing agreements are neither finalised nor formalised, which obviously causes uncertainties in the minds of beneficiaries.' Even forestry officials disagreed with each other about the rules. The shares which would go to the individuals, village, panchayat and the forest department were not clearly laid down.

j) Community woodlots

Development of fuelwood plantations on community wastelands was a major programme to generate employment for the local poor and the landless, while augmenting the fuel and forage shortfall faced by the community. However, this scheme could cover only 9 per cent of the villages either due to non-availability of wastelands or unwillingness of the Village Panchayats and public institutions to spare their wastelands for community plantations. Certain projects had failed to progress in terms of plant survival, growth and income generation. In the absence of effective local organisations, the programme heavily depended on the Village Panchayats, who had bare minimum staff to manage these plantations. As the area available for plantations was very small, and realised that the problems of fuelwood and fodder shortages could not be solved simply by promoting the cultivation of these species, as these commodities were of least value as compared to timber wood. Therefore, despite the shortage of fuelwood, the farmers preferred to grow timber and fruit species.

In some successful community plantations, inspite of the offer to collect grass free of cost, the response from farmers was very poor. The villagers felt that feeding such fodder to poor quality animals would not improve the productivity except in a few locations where they had maintained livestock of improved breeds. As the community plantation activities could not motivate the local people, most of these plantations were destroyed within a short period after completion of the project.

k) Strip plantations

Saplings of tall growing tree species were established in multiple lines along the railway tracks, canal bunds and roadsides and the landless families were involved in protecting them. This was fairly successful but the incentives offered by the project implementing agency were not adequate for the beneficiaries to devote sufficient time for protection. Thus some of these trees were stolen. In the absence of clear directives from the government regarding the sharing of benefits, the participants were not allowed to cut the trees.

l) Farm forestry

Farm forestry was the most successful scheme wherein farmers established plantations of eucalyptus, casuarina, poplar, teak, etc., on their agricultural lands using necessary inputs like irrigation and fertilisers with the hope of finding a suitable market and attractive price for the produce. Many of these farmers located near the wood based industries could sell wood at remunerative prices. However, in the absence of any marketing infrastructure it was difficult for them to find attractive buyers in remote areas. Obsolete Tree Acts imposed by the government created further obstacles in felling, transporting and sawing of timber by the growers. This forced them to either sell it to the middlemen or delay the harvest.

The 'community forestry programme' also included a component of planting fruit species on marginal lands owned by poor families belonging to scheduled castes and scheduled tribes. However, the project could not get adequate response at the initial stage as most of the illiterate target families feared that the government would acquire their lands, after the establishment of trees. Subsequently, even the limited number of

participants in the programme could not maintain the plants due to inadequate resources to provide irrigation and protection.

It was also observed that while promoting farm forestry, farmers were not informed about the profitability of various tree species which could be grown under local agro-climatic conditions. As a result, the farmers preferred only a few species such as eucalyptus, which they thought to be most profitable, while many other fruit and non-timber forest product species which could have provided higher income were neglected.

m) Decentralised nurseries

The primary objective is to build up the local capacity for assured supply of planting materials of popular tree species. The programme had the following drawbacks.

i. The seedlings raised in these nurseries were based on the advice of the donor agencies to promote fodder and fuelwood cultivation, while most of the farmers were interested in fruit and timber species.

ii. Many agencies and people selected for raising nurseries did not have adequate land and water resources or the experience to manage the nursery.

iii. The nursery participants were assured assistance only for one season and hence they had no special interest in acquiring necessary skills or making adequate investments.

iv. Due to delayed selection of participants for receiving support, the nurserymen were not able to mobilize necessary inputs well in time.

v. In the absence of superior quality seed, the nurserymen collected seeds from unknown sources which resulted in the production of inferior quality seedlings.

vi. Delayed nursery operations could not produce tall and healthy seedlings, by the onset of monsoon. Hence whatever seedlings were available were distributed to the farmers. As it was freely supplied, the farmers often had no voice to demand good quality planting material. Such poor seedlings had a high rate of mortality which resulted in failure of many afforestation schemes.

Hence, the local people could not take maximum advantage of these facilities. Although a small number of Kisan nurseries were successful in the past to continue their activity for income generation, there is good scope for promotion of decentralised nurseries throughout the country.

n) Energy conservation

Although biomass was the major source of fuel for cooking, the supply was not critical. Energy conservation measures like promotion of improved wood stoves and biogas plants did not achieve the expected results due to poor publicity and awareness. The poor response was also because of unsuitable designs of smokeless wood stoves which failed to save wood.

o) Financial strategies

There are three important financial problems. First relates to the untimely allocation of funds from government, the second to inadequate financial delegation and the third to unrealistic yardsticks. There appears to be uncertainty about both availability of funds and its timing. Sanctions (budgetary approvals) are issued in the month of August or even later, although the financial year starts in April. Ideally, financial allocations should be decided for a period of five years, so that nursery, planting and protection activities can be better planned, but in practice even monthly releases of funds were not certain.

The Divisional Forest Officer (DFO) is the key person in the execution of a project, and to take almost all operational decisions. However, when a budget allocation is made by the government, the actual withdrawal still requires the Conservator's authority. These administrative matters take a lot of field staff time, leaving little energy for extension or establishing contacts with farmers.

The budget for protection is available only for three years, although based on field conditions it should be for five years. The bulk of funds are earmarked for planting schemes, which have a low rate of survival, as actual field constraints are not taken into account. Many field officers felt that the way they spend money, especially on village lands, neither creates assets nor helps the people beyond giving them wages.

Strategies for popularization

Social/community/farm forestry projects has been a unexcited response to these activities in the past, mainly because of lack of awareness, inadequate benefits and lack of trust between the local communities and government agencies who own these lands. Hence, to increase the tree cover the new strategy should find a suitable solution for these problems. They are

i. Development of forest lands

Rehabilitation of denuded forest lands and protection of natural forests are essential to conserve biodiversity. The forests influence the climate and soil moisture conditions and improve agricultural production. This aspect needs wider publicity in rural areas and the local people should be motivated to take active part in Joint Forest Management. The Village Forest Committees willing to protect the natural forests should be encouraged to share the benefits in the form of fodder, fuel, timber and NWFP.

ii. Improvement of community lands

Lack of people's initiative was a serious problem in developing community wastelands, mainly due to lack of direct benefits. Earlier efforts to establish woodlots could not generate substantial income. Establishment of NWFP species such as *Tamarindus indica*, *Emblica officinalis*, *Azadirachta indica*, *Pongamia pinnata*, *Madhuca latifolia* and a wide range of medicinal species can generate substantial income, regularly for over 50-100 years.

iii. Development of mined areas

Rehabilitation of mined areas is another cause of serious concern especially it causes soil erosion, etc. Although the industries are obliged to establish a green cover after mining the area, the outcome has been very poor. Lack of commitment, inadequate expertise in selection of plant species and their management has been the main reasons for failure. These activities can be entrusted to voluntary organisations and local communities, with research support to raise healthy plantations. Preference should be given to NWFP and timber species which have long gestation period is sufficient to enrich the mined lands.

iv. CO_2 Sinks

There are opportunities for environmental protection by establishing industrial greenbelts, recycling treated effluent for tree growing and developing carbon sinks are necessary. The polluting industries can be compelled to establish greenery through the involvement of voluntary organisations and local people.

v. Environmental awareness and eco-tourism

Lack of awareness among the common public is a cause for environmental pollution in the developing countries. Hence, continuous efforts are needed to motivate the common public to plant more trees and protect the environment. School children and literate urban population are fairly receptive to participate in environmental protection. This can be undertaken through school based plant nurseries, development of arboretum, botanical gardens and greenbelts around the schools, public places and industries.

While developing industrial greenbelts and afforestation on river banks, special efforts can be made to promote eco-tourism. It includes creating water bodies through plugging of gullies, developing nature trails, shady grounds for resting, selecting suitable plant species to attract wildlife and providing adequate eco-tourism. Environmental exhibitions also can help in motivating the public to take active part in community forestry and environmental protection.

Organisational Development

Development of local organisations is the key factor to ensure people's participation and to sustain the benefits of investments and efforts made in community forestry.

i. Tree grower's organisations

The initial need is to provide leadership to organise local people in afforestation. This can be carried out through formation of local Selp Help Groups (SHG), village level farmers' associations and forest groups. This activity should receive priority during the next decade.

ii. Capacity building

Training of local farmers, supply of critical inputs, credit and technical advisory services to improve the profitability and developing market networks are the critical inputs which have to be introduced in the field to support tree growers.

iii. Networking of tree growers and user groups

There is an urgent need to set up networks of tree growers, forestry users and concerned scientists in these fields. Such networks should identify the opportunities for tree growers. It also promote processing and marketing of forestry products and protect the interests of tree growers.

iv. Forestry information service

Setting up of information centres to identify the priority of the industries and farmers and provide necessary information to enhance the economic viability of community forestry would help to sustain the interest of tree growers. Forestry Extension Units should closely associate with Information Service Centres to identify appropriate technologies for transferring to the field.

v. Forestry research

The networks should identify the problems affecting the production and marketing of the produce and encourage the Forestry Research Institutions to take up relevant scientific studies to solve the problems. The researchers should closely associate with the network and Information Centres to disseminate new technologies to solve field problems and enhance the production.

Forestry research should focus on the following topics:

- Conservation of biodiversity;
- Improving the productivity of wastelands, tree plantations and natural forests;
- Exploring the utility of multipurpose tree species and NWFP;
- Developing of alternatives for conserving wood;
- Selecting various organisational systems to manage social forestry.

The outcome of these research topics can further strengthen the social forestry programme in the country.

Chapter - 5

AGROFORESTRY

To feed the world an innovative and exclusively different agricultural revolution is needed, where farm production is intensified and sustained by maintaining and enhancing the productive capability of land rather than destroying it in search of short term growth. In this glow, trees have to be the fundamental part of the future landscape. Almost half of the world's farmland already has more than 10 per cent tree cover. But that is not enough to supply the goods and ecological services needed today. As natural vegetation is cleared for agriculture and other types of development, however, trees necessitate to be integrated into agriculturally productive landscapes.

India has a long historical tradition of growing trees on farms and around homes and play an important role in the ethos of people. Across the diversified agro-climatic regions there are different region based culturally and religiously attached traditional agroforestry systems oriented with livelihood activities of local people. These are natural ecosystems which are efficient in conservation of local resources. Of the 118 million farmers in India, over 80 per cent are rainfed smallholders and dependence on monsoonal rainfall as well as the small size of landholdings makes them highly vulnerable to climate change impacts. Agroforestry can become a significant tool to build resilience of farmers and rural people against threats of natural calamities and climate change.

Definition

Many general definitions of agroforestry can be found in the literatures. Agroforestry refers to integration of forest components such as trees and shrubs as an essential element of agricultural and other land use systems with an idea of increasing the productivity and fertility of the soil.

Agroforestry is any sustainable land use system that maintains or increases total yields by combining food crops (annuals) with tree crops (perennials) and/or livestock on the same unit of land, either alternately or at the same time, using management practices that suit the social and cultural characteristics of the local people and the economic and ecological conditions of the area.

Agroforestry is a collective name for a land use system and technology whereby woody perennials are deliberately used on the same land management unit as agricultural crops and/or animals in some form of spatial arrangement or temporal sequence.

World Agroforestry Centre, Nairobi, Kenya (known as the International Centre for Research in Agroforestry (ICRAF) before 2002) defined as '*Agroforestry is a dynamic, ecologically based, natural resources management system that, through the integration of trees on farms and in the agricultural landscape, diversifies and sustains production for increased social, economic and environmental benefits for land users at all levels'*.

On the other hand, the Association for Temperate Agroforestry describes it as 'an intensive land management system that optimizes the benefits from the biological interactions created when trees and/or shrubs are deliberately combined with crops and/or livestock'.

Essentially, agroforestry refers to 'the practice of deliberate growing of trees in conjunction with crops or livestock for benefits and services'.

These definitions imply that:

- Agroforestry normally involves two or more species of plants (or plants and animals), at least one of which is woody perennial;
- An Agroforestry system always has two or more outputs;
- The cycle of an agroforestry system is always more than one year;
- Even the simplest Agroforestry system is more complex.

Aim of agroforestry system

The aim of agroforestry systems are to optimize positive interaction between the component themselves (trees/shrubs and crops/animals) and the environment. This will lead to higher total, more diversified and /or more sustainable production both from agriculture and forestry

Table -5.1: Similarities and dissimilarities between different forestry practices

S No	Conventional forestry	Social forestry	Agroforestry
1	Deals with only forest tree species	Deals with both forest and fruit tree species	Deals with combination of trees and agricultural crops and /or animals
2	Minimal peoples participation	Peoples directly participated and execute the programme in community places	Peoples practiced in their own farm lands
3	Peoples are not direct beneficiary of the produce from the forest.	Peoples are the direct beneficiary	The produce is individual farmers own property
4	Activities is limited only to the Govt. forest land	It extends throughout the community places including Govt. forest land.	Activities limited only to the farmers own land
5	It provides raw materials to big industries (controlled basis)	Provide raw materials to small and cottage industries.	It supplies food, fuel, fodder, small timber *etc*. depending on the need of the individual farmers.

Genesis of Agroforestry

The prominent traditional farming systems like shifting cultivation, taungya and homegardens have evolved long ago. The shifting cultivation, *i.e*. sequential agroforestry system, believed to have originated in the Neolithic period around 7000 BC, is still extensively practiced in the North Eastern hill region and other humid and hilly parts of the Indian subcontinent. The taungya system, a method of establishing forest tree species in temporary association with agricultural crops was attempted in the Indian subcontinent soon after its first introduction by Brandis in Burma in 1856.

The World Agroforestry Centre (International Centre for Research in Agroforestry - ICRAF) (with six regional offices located in Cameroon, China, India, Indonesia, Kenya and Peru) is an international institute headquartered in Nairobi, Kenya and founded in 1978 as International Council for Research in Agroforestry, generates science based knowledge about the diverse benefits both direct and indirect of agroforestry, or trees in farming systems and agricultural landscapes, and disseminates this knowledge to develop policy options and promote practices that improve livelihoods and benefit the environment. In recent years, the Kenyan Government, under its Ministry of Agriculture has framed new rules and regulations that at least 10 per cent of all farms and agricultural lands are to be covered with trees.

The organized efforts in agroforestry research in India began in 1983 by the Indian Council of Agricultural Research (ICAR) with the establishment of All-India Coordinated Research Project on Agroforestry (AICRP-AF) and later the establishment of the National Research Centre for Agroforestry (NRCAF, 1988), which has now been upgraded as the Central Agroforestry Research Institute (CAFRI, 2014), Jhansi. These efforts are resulted in collection and evaluation of germplasm of multipurpose tree species and development of location specific agroforestry technology for different agro-climatic zones of the country.

Agroforestry finds a place in the National Agricultural Policy, 2000, wherein it is underlined that farmers will be encouraged to take up farm/agroforestry for higher income generation by evolving technology, extension, credit support packages and removing constraints to development of agroforestry. The Government of India has launched several schemes/projects like the National Bamboo Mission (NBM), Rashtriya Krishi Vikas Yojana (RKVY), National Horticulture Mission (NHM), National Biofuel Policy, etc. wherein integrating forestry components on farmlands has been given the much needed thrust. Similarly, the National Medicinal Plants Board (NMPB) under Ayurveda, Yunani, Siddha and Homeopathy (AYUSH), has laid emphasis on integrating medicinal plants and trees along with agricultural crops. Establishment of silvi pastoral systems and fodder banks has been envisaged in various schemes operated by the department of Animal Husbandry. The National Afforestation and Eco-development Board (NAEB) under the Ministry of Environment, Forests and Climate Change, is also promoting agroforestry practices on farm and wastelands. In addition to these schemes, State Governments also have schemes/projects that promote agroforestry.

Area under agroforestry

The land area of the World is 14.89 billion ha of which 4.89 billion ha are classified as agricultural area (32.84% of the land area includes: arable land 28%; permanent crops 3%; and permanent meadows and pastures 69%). As per the World Bank 2004 report, almost 10 per cent of the world's agricultural area is under agroforestry. About 1.2 billion rural people currently practise agroforestry on their farms and in their communities and depend upon its products.

In India, agroforestry perhaps the only alternative to meeting the target of increasing forest or tree cover to 33 per cent from the present level of less than 24 per cent, as envisaged in the National Forest Policy (1988). The current approximate area under agroforestry is estimated to be 25.32 m ha (8.2 per cent of the total geographical area of the country). However, Forest Survey of India estimated the same as 11.54 m ha (3.39 per cent of the geographical area of the country). Based on data from Central Agroforestry Research Institute (CAFRI, Jhansi) and Bhuvan Accuracy of Land Use Land Cover (LULC) data, the area under agroforestry in India was estimated to be 14.46 m ha when fallow land was not included. Potential area under agroforestry was estimated to be about 17.45 m ha, when fallow land was included. Among all the states, Uttar Pradesh, Maharashtra and Rajasthan is ranked first, second and third in terms of area under agroforestry (1.86, 1.61 and 1.55 m ha, respectively). The area under agroforestry in Tamilnadu was 0.65 m ha.

Benefits of agroforestry

Agroforestry combines the attributes of both forestry and agriculture; it is thought to provide a number of advantages to the sustainability of agroecosystem and the environment. Traditionally, people resorted to agroforestry practices for the inter dependent benefits of the three components, *viz*. trees, crops and livestock in addition to the 5 F's, *i.e.* food, fodder, fuel, fertilizer and fibre. In modern aspect, environmental sustainability also included. There are a considerable number of researches from different parts of the country suggesting that agroforestry is more profitable to farmers than agriculture or forestry alone for a particular area of land. A comprehensive analysis indicated economic viability with internal rate of return (IRR) ranging from 25 to 68 and B: C ratio of 1.01 to 4.17 for 24 agroforestry systems from different agro-climatic regions of the country.

A) Economic benefits

- Increment in an output of food, fuel wood, fodder, fertilizer, timber, non-timber forest products (NTFP) etc.
- Reduction in occurrence of complete crop failure, which is common to single cropping or monoculture systems
- Increase in level of farm income due to enhanced and sustained productivity

B) Social benefits

- Enhancement in rural living standards from sustained employment generation and attaining higher income
- Improvement in nutrition and health due to augmented quality and diversity of food outputs

C) Environmental / Ecological benefits

- Reduction of pressure on forest
- Effective utilization of natural resources viz. solar radiation, land and water in a sustainable way
- More capable recycling of nutrients by deep rooted trees on the field
- Improved protection of ecological systems
- Reduction of surface run off, nutrient leaching and soil erosion through impeding effect of tree roots and leaf litter on these processes
- Enhancement of microclimate, such as lessening of soil surface temperature and reduction of evaporation of soil moisture through a combination of mulching and shading effect

- ❖ Increment in soil nutrients through addition and decomposition of litter fall.
- ❖ Improvement of soil structure through the constant addition of organic matter from decomposed litter.
- ❖ Reducing the extreme effects of soil acidity, salinity and alkalinity.
- ❖ Effective utilization of degraded/waste and marginal lands.
- ❖ Reduced the adverse effects of natural disasters.

Functions of Agroforestry

An agroforestry system provides tree products which can supplement diets as well as generate additional sources of income. Using fertilizer trees can improve soil fertility and generate productivity gains. In modern times, the intangible benefits often referred to as ecosystem services rendered by the agroforestry systems have been generally recognized. It is a well known fact that agroforestry is mentioned by The Intergovernmental Panel on Climate Change (IPCC) as one of the instruments to fight climate change. Agroforestry systems have the potential for being an effective tool in climate change mitigation and adaptation steps. In the short run, agroforestry can diminish the effects of climate change through microclimate moderation and the preservation of natural resources. In the long term, agroforestry practices helps to augment the resilience of the agroecosystems and retain the sustained flow of ecosystems services. Agroforestry act as a fundamental source of carbon sequestration. Compared to crop and grass land ecosystems, agroforestry species provide far more carbon sequestration potential and on par with primary forests.

Provisioning Functions

Provisioning functions are the products obtained from ecosystems, including genetic resources, food, fodder, medicines, energy, fibre, fresh water etc.

Food products

Seeds, fruits, green leafy vegetables, mushrooms, honey, *etc*. from the agroforestry systems are fundamental to the livelihoods of both rural and urban inhabitants.

Fodder

The majority of the smallholder farmers keep livestock under rangeland conditions. However, farmers face green fodder shortages especially during the dry season when most pastures have dried up. The fodder trees and shrubs are grown along boundaries, pathways, field bunds and across contours have real potential to alleviate livestock feed shortages; reverse the negative effects of over-grazing and improving the livelihoods of small farmers. This also allowed for controlled browsing or feeding to animals in an enclosure in a cut-and carry system which perform either as a supplement or a substitute to the more expensive dairy concentrate.

Energy

More than 75 per cent of the people in the rural depend on fuel wood for their energy needs. Adoption of Agroforestry systems are the only option to meet a major share of the fuel wood demand and can significantly reduce deforestation. Trees grown in home gardens, contour strips, rotational woodlots and fallows can generate large quantities of fuel wood. The fuel wood production in the home gardens of certain locations is estimated at 1.5-3.0 m^3 ha^{-1} $year^{-1}$. Assuming the minimum consumption rate of 1.0 m^3 $adult^{-1}$ $year^{-1}$ and each family requires 4-6 m^3 $year^{-1}$, a home garden supplies 25 – 33 per cent of the household fuel wood requirements.

Manures

Manure is commonly used as household fuel in many parts of India. On farm production of fuelwood can have the supplementary benefit of allowing farmers to shift to composting of animal manures and recycling of nutrients into the soil. Incorporating farm manure into the soil, while improving fertility and soil structure, can also reduce the need for chemical fertilizers and significantly increase organic matter and soil carbon.

Wood and non wood products

Current estimates show that about 65 per cent of the country's timber requirement is met from the trees grown on farms. Agroforestry plantations established on arable land permit the development of a quality wood and non wood resources that complements, rather than competes with, the products from traditionally

exploited forests. It is especially significant to produce wood that can substitute for tropical saw logs, which will soon decline in availability and quality.

Medicinal products

Over 80 per cent of the rural community in the world depends on medicinal plants for many of their primary health needs. The leaf, seed, bark and root extract of certain agroforestry trees are used for the treatment of common diseases such as diabetics, malaria, dysentery, diarrhoea, rheumatism, *etc*.

Supporting functions

Supporting ecosystem services are those that are necessary for the production of all other ecosystem services *viz*., enhancing crop yields, production of atmospheric oxygen, biomass production, soil formation and retention, nutrient cycling, water cycling, *etc*.

Enhancing crop yields

Trees in agroecosystems may directly enhance the crop yields. For instance, studies conducted in the arid region of Haryana, integration of agroforestry tree species positively enhanced the productivity of *Hordeum vulgare* (barley). In this system, *Prosophis cineraria* enhanced the grain yield by 86.0 per cent, *Tecomell undulata* by 48.8 per cent, *Acacia albida* by 57.9 per cent and *Azadirachta indica* by16.8 per cent over the crop planted in open area. It must be pointed out that although agroforestry systems may decrease crop yield for a variety of reasons, there may be a trade off. For case, studies on traditional agroforestry system in central India found that the effect of residual nitrogen on the yield of rice crop after removal of 15-year old *Acacia nilotica* trees resulted in increase in the crop yield (12.5 t ha^{-1}) that was almost equal to the reduction in the crop yield suffered during 15 years of the tree growth in agroforestry system. Yield reductions may also be compensated in the long run by microclimate modification.

Soil and nutrient conservation

The main conceptual basics of agroforestry is that trees reduce surface runoff, control soil erosion and nutrient leaching through imminent effect of tree roots and organic matter. Trees in agroecosystems can enhance soil nitrogen (N) through biological nitrogen fixation by legume trees. Even the trees that do not fix nitrogen can enhance physical, chemical and biological properties of soils by adding significant amount of above and belowground organic matter as well as releasing and recycling nutrients in tree bearing farm lands.

Tree roots can form a dense network that prevents ion mobilization from being washed out into deeper soil layers or carried downhill by lateral water flow, where they are not available to plants anymore. Trees perform as a nutrient pump, because the deeper soil layers can be easily reached by deep rooting trees, mobilized the nutrients, taken up into the root and stored in different plant organs.

A considerable share of these minerals is later released from the tree via litter fall and root turnover and deposited on the upper soil layers, where shallow-rooting plants like associated annual crops can make use of them. For example, in the dry regions of India, the mean annual litter fall by neem trees can be 6059 kg ha^{-1} at the density of 400 trees ha^{-1} with potential return of 98, 2.25, 32 and 131 kg ha^{-1} of available nitrogen, phosphorous, potassium and calcium, respectively. These improvements in soil quality in turn result in improved agricultural productivity and increased yields of food crops.

Microclimate modification

Agroforestry can be considered an adaptive strategy in areas with increasing climate variability. Trees and shrubs in agroforestry systems can contribute to superior microclimate by providing shade and windbreak. The tree leaf litter and canopy have been documented to influence the microclimate in terms of improved rainfall infiltration, soil structure and micro-fauna, reduced evapo-transpiration and temperature extremes and increased relative humidity.

Reduce pollutants and improved ground water quality

The deep root system of trees efficiently improved ground water quality by taking up the excess nutrients that have been leached below the rooting zone of agricultural crops. Agroforestry trees lower saline water tables to prevent salinization of agricultural land. Agroforestry can also be useful for utilization of sewage contaminated waste water from urban systems and acted as an efficient bio drainage system to prevent water logging in canal irrigated areas.

Enhanced soil aeration
During the drought, deep root systems of trees are able to explore a larger soil volume for water and nutrients. It increased the evapotranspiration rates and can thus maintain aerated soil conditions by pumping excess water out of the soil profile more rapidly than other production systems.

Improvement in water retention capacity to mitigate moisture stress
Agroforestry has the potential for improving water use efficiency by reducing the unproductive components of the water balance *viz*., run-off, evaporation, etc. The repeated accumulation of tree biomass to the soil increases soil organic matter, which leads to mprovement of soil structure, increased water infiltration and enhanced water retention in the soil profile which can reduce moisture stress during succeeding drought period.

Enhancing soil biological activity
Significant improvement in soil biological activity has been reported under different tree based agroforestry systems. For instance, in Rajasthan, soil microbial biomass with C, N and P under agroforestry varied between 262–320, 32.1–42.4 and 11.6–15.6 μg g^{-1} soil, respectively, with corresponding microbial biomass C, N and P of 186, 23.2 and 8.4 μg g^{-1} soil under a no tree control.

Biological pest control
Agroforestry systems generate landscape structure that is important for the biological pest control. In small scale, subsistence agriculture in the tropics, traditional farming practices have evolved that provide a sustainable means of reducing the incidence and damage caused by pests including nematodes.

Providing habitat for beneficial insects
Agricultural intensification affects functionally important pollinator species excessively. Restoring pollination services in areas of greatest agricultural intensity would necessitate both reducing insecticide use and restoring native or substitute vegetation to provide nesting habitat and floral resources for bees when they are not using crops. Agroforestry can improve bee keeping as well as pollination services, because most of trees used in agroforestry systems produce abundant nectar and pollen during the offseason, which significantly increased in both diversity and total abundance of native bees.

Biodiversity conservation
Agroforestry offers farmers the opportunity to exploit nature's principle of diversity on their farms and provided ecological resilience and contributed to the maintenance of beneficial ecological functions. The major roles of agroforestry in conserving biodiversity are

- Agroforestry provides habitat for species that can withstand a certain level of disturbance in agroecosystems
- Agroforestry helps preserve germplasm of socially useful and associated species
- Agroforestry helps reduce the rates of conversion of natural habitat by providing goods and services alternative to traditional agricultural systems that may involve clearing natural habitats
- Agroforestry provides connectivity and acts as stepping stone by creating corridors between habitat remnants and thereby conservation of area-sensitive plant and animal species and
- Agroforestry helps conserve biological diversity by providing other ecosystem services such as erosion control and water recharge, thereby preventing the degradation and loss of surrounding habitat.

Carbon sinks
Conversion of woodland to agricultural land depletes terrestrial C stocks by drastically reducing the vegetation C and soil organic carbon pools. Introduction of trees in agricultural arrangements serve as viable carbon sinks because they capture and store carbon in soils and biota, reduce deforestation and produce low-carbon bio-solids that serve as substitutes for high carbon fossil fuels.

Agroforestry for carbon sequestration is attractive because (i) it reduces green house gas emissions and enhances the uptake of CO_2 from the atmosphere, (ii) the sequestered carbon is locked through non destructive use of such tree based products, (iii) the more intensive use of the land for agricultural production

reduces the need for slash and burn or shifting cultivation, (iv) the wood products produced under agroforestry serve as substitute for similar products unsustainably harvested from the natural forest etc. The potential of agroforestry systems as carbon sink varies depending upon the species composition, age of trees and shrubs, geographic location, local climatic factors, and management regimes.

Based on assessments of global terrestrial C sinks two primary mitigating effects of agroforestry on CO_2 emissions. The first direct near term effect is C storage in trees and soils through accumulation in live tree biomass (3 - 60 t ha^{-1}), wood products (1 - 100 t ha^{-1}), and soil organic matter (10 - 50 t ha^{-1}), and through protection of existing forests (up to 1000 t ha^{-1}). Secondly, agroforestry has the potential to offset greenhouse gas emissions through energy and material substitution, and lessening of fertilizer C foot print. About 360 t ha^{-1} of greenhouse gas emissions are offset through energy substitution, up to 100 t ha^{-1} through material substitution and 1 - 5 t ha^{-1} through reduction of fertilizer inputs. For smallholder agroforestry systems in the tropics, potential C sequestration rates range from 1.5 to 3.5 t C ha^{-1} $year^{-1}$. Coppicing fallows of *Gliricidia sepium, Senna siamea, Acacia* and *Leucaena* spp. store more carbon. For example, two to 12 year old trees in *Leucaena* woodlots stored up to 74 t ha^{-1} in aboveground biomass and 140 t ha^{-1} in the soil.

Socio-economic functions

Breaking the poverty

Trees in agroforestry systems can provide host to globally valued products, and thus, support livelihoods locally. Trees provide a variety of products including fuelwood (30 kg $tree^{-1}$), brushwood for fencing (4 kg $tree^{-1}$), small timber for farm implements and furniture (0.2 m^3), and non-timber forest products such as gum and seeds from 20 *Acacia nilotica* trees ha^{-1} of 1 to 12 years of age. Trees account for nearly 10 per cent of the annual farm income, distributed equally throughout the year than in rice monoculture of smallholder farmers with less than two ha farm holding.

Breaking the food insecurity

Domestication of forest fruit trees and other species grown in agroforestry systems offer significant opportunity for livelihoods improvement through the nutritional security of poor people in tropics by providing quality and diversified food outputs. The wild edible plants with high carbohydrate content form an important constituent of traditional diets in the Sikkim Himalaya where about 190 species are eaten and almost 47 species are traded in local market.

Augmentation of rural living standards

Enhancement of rural living standards through sustained employment and provide higher income. In North East India, trees in agroecosystems are particularly valued as host to insects that yield marketable products such as silk, lac products, honey, etc. Wood carving industry is emerging as an important source of income to local artisans worldwide. Promotion of species used in woodcarving industry facilitates long term locking-up of carbon in carved wood and supports local knowledge, therefore, strengthens livelihoods.

Cultural services

Cultural services are the non material benefits people obtain from ecosystems through spiritual enrichment, cognitive development, recreation and aesthetic experience, enriching knowledge systems, social relations, etc.

Traditionally, trees play a crucial role in the cultural and spiritual lives of local communities. In some communities certain trees are considered as a sacred tree and it is never cut when clearing lands. In India *Azardirachta indica* is well known to be of great importance due to their cultural value. Agroforestry appropriately places the traditional values given by local communities to such trees in the context of conservation and production.

Creation of original landscapes in agroecosystems is attractive due to its aesthetic nature and favours recreational activities. Agroforestry plots have a truly innovative landscaping potential, and would improve the public image of farmers to society.

The opportunities and benefit offered by agroforestry can only be getting with the help of substantial investments and coordinated efforts in research, education, extension services and appropriate national policies.

Chapter - 6

AGROFORESTRY POLICY OF INDIA

National Agroforestry Policy

India became the first nation in the world to adopt a comprehensive agroforestry plan named National Agroforestry Policy (NAFP) at the World Agroforestry Congress with the theme 'Trees for Life' was organized in February 2014, by the World Agroforestry Centre (ICRAF) and partners. The policy recognises the potential of agroforestry to alleviate poverty, augment productivity, while also making agricultural landscapes more resilient to the danger of climate change.

Necessity for Agroforestry Policy in India

Absence of a dedicated and persistent national policy

Major policy initiatives, including the National Forest Policy 1988, the National Agriculture Policy 2000, Planning Commission Task Force on Greening India 2001, National Bamboo Mission 2002, National Policy on Farmers 2007 and Green India Mission 2010, highlights the role of agroforestry for efficient nutrient cycling, organic matter addition, sustainability of agriculture and enhancing vegetation cover. However, agroforestry has not gained the required importance as a resource development tool.

Lack of an integrated farming system approach

Farming enterprises of marginal and small farmers necessitate to be understood and developed as a portfolio of activities rather than as permanent single type of cropping system. Development along this direction involves a convergent programme which integrates trees, crops, livestock and other livelihood initiatives. This perspective of integration seems to be missing in the national agroforestry initiatives in whatever form it may currently be. Survival of trees is one of the major challenging tasks in the establishment phase of the trees. The enthusiasm of farmers diminishing substantially with the higher mortality rate as experienced from various programmes in the past.

Restrictive regulatory regime

There are restrictions enforced by the government authorities on harvesting and transportation of agroforestry produce, especially those species which are found growing in the nearby forests. These restrictions were fundamentally designed to prevent pilferage from conventional forests. However, the rationale for such restriction is not very convincing as the species grown in the forest are to be most excellently grown in the nearby agroecosystems because of their suitability to that agroclimatic condition. Obtaining permits for harvesting and transportation are unmanageable, costly and frustrating, and hence, discourage farmers from undertaking tree planting on agricultural lands. Similarly, tax is imposed at various stages of the processing by multiple agencies. These restrictions also negatively impact the insitu or onfarm primary processing, jeopardize local employment in these operations and increase transport cost because of the transportation of the entire bulk raw material to the processing centers. As a result, the domestic agroforestry produce is progressively more and more losing grounds against the imported materials, which are cheaper and of superior quality. The states taking steps for liberalization of above restrictions, such as, exempting agroforestry species from the harvesting and transit, but this has not been uniformly done by all the states. Also the coverage of liberalization is not commonly known to the farmers and thus, their problem continues. In this regard, Arun Kumar Bansal Committee (2011) appointed by the MoEF has reported the regulatory bottlenecks associated with the growth of agroforestry and the necessitate for acting on those issues.

Inadequate research, extension and capacity building

Research results on agroforestry promotion do not reach down to the farmers due to the shortfall dedicated extension system and institutional mechanisms.

Unavailability of quality planting material

Planting materials such as seeds, seedlings, saplings, clones and hybrids were not easily accessible to the farmers particularly in resource poor regions. Additionally, only around 10 per cent of the planting materials were found to be of possessing high quality and meeting the quality standards.

Institutional finance and insurance coverage

Institutional finance in agroforestry was deficient due to lack of awareness of technical and economic data required by financial institutions to evaluate finance needs and viability of projects.

Weak market access

Marketing infrastructure including price discovery mechanisms for agroforestry was not accessible in the country except few states. As a result, the middlemen profited more than the growers.

Industry operations at a suboptimal level

The wood based industries have played a significant role in the encouragement of agroforestry and economy. However, the regulations governing this industry have become stringent. The procedure for setting up new units or fulfilling of compliance by existing units is troublesome and time consuming, and not very encouraging to insstil confidence in industries. The restrictions on primary processing at production sites after harvesting leads to higher cost for transportation of entire stock to the factory. This also results in lessening supply of raw material, forcing the wood based industries to operate at sub-optimal level. The low import tariff for raw materials and finished goods, cumbersome procedures for sourcing raw materials domestically are some of the major reasons for the slow or negative growth of the wood based industries in India.

Objectives

- Encourage and expand tree plantation in complementarity and integrated manner with crops and livestock to improve productivity, employment oppurtunity, source of income and livelihoods of rural households, especially the small and marginal farm holdings
- Protect and stabilize ecosystems and promote resilient cropping and farming systems to reduce the threat during extreme climatic events
- Meet the raw material requirements of wood based industries and decrease the import of wood and wood products to save foreign exchange
- Supplement the availability of agroforestry products, such as the timber, fuel wood, fodder and non timber forest produce of the rural and tribal populations, thereby reducing the pressure on existing forests
- Complement achieving the goal of increasing forest and 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

Salient futures of National Agroforestry Policy (NAFP)

The comprehensive policy intends to address the increasing demand for timber, food, fuel, fodder, fertiliser and fibre, while at the same time providing employment opportunities and generating income. The NAFP will help to increase area under agroforestry from 25 million hectares to 53.23 million hectares. NAFP, 2014 is a path breaker in creating agroforestry as a land management mechanism for transforming the lives of the rural farming population, protecting ecosystem and ensuring food security through sustainable means. The major highlights of the policy are i) establishment of institutional setup at the national level to promote agroforestry under the mandate of the Ministry of Agriculture, GoI; ii) simplify regulations related to harvesting, felling and transportation of trees grown on farmlands; iii) ensuring security of land tenure and creating a sound base of land records and data for developing an market information system for agroforestry; iv) investing in research, extension and capacity building and related services; v) access to quality planting material; vi) institutional credit and insurance cover to agroforestry practitioners and vii) increased participation of industries dealing with agroforestry produce, and strengthening marketing information system for tree products.

One of the objectives of NAFP, 2014 is to bring together various programmes, schemes, missions among the elements of agroforestry under one platform functioning in various departments of agriculture, forestry and rural sectors of the government. It is proposed to be achieved through setting up of a National Agroforestry Mission/ Board under the Department of Agriculture and Co-operation (DAC), Ministry of Agriculture, GoI and upgrading of National Research Centre for Agroforestry (NRCAF), Jhansi (now CAFRI) as a nodal centre with agroecology based regional centres in different parts of the country. This step will encourage

value chain, climate resilient technology development and pave the way for region based marketing linkages in agroforestry.

Sub-mission on agroforestry

The National Agroforestry Policy in 2014 recommends for setting up of a Mission or Board to address development of agroforestry sector in an organised manner. The Sub-Mission on Agroforestry (SMAF) under National Mission on Sustainable Agriculture (NMSA) is an initiative to this end. The mission is purposeful to achieve the quantifiable benefits *viz*., increase tree cover to enhance carbon sequestration, enrichment of soil organic matter, availability of quality planting material, employment opportunities, improvement in livelihood, income generation and livelihoods of rural households, productivity enhancement of crops and cropping systems, development of an information system, etc.

Objectives of SMAF

- To encourage and expand tree plantation in complementary and integrated manner with crops and livestock
- To ensure availability of quality planting material like seeds, seedlings, clones/ hybrids, improved varieties, etc.
- To popularise various agroforestry practices or models suitable to different agro ecological regions and land use conditions
- To create database, information and knowledge support in the area of agroforestry
- To provide extension and capacity building support to agroforestry sector

Mission interventions

Nursery development for quality planting material

Assistance shall be given for nurseries (small, big and hitech precission nurseries) for producing quality planting material to meet the requirement of planting material.

Peripheral and boundary plantations

To make potential use of the area occupied by the bunds around the periphery of the agricultural fields, tree species can be grown as peripheral/ or boundary plantations to add more income to the farmers' basket.

Low density plantations on farm lands

Low density block plantation ranging from 100 to 500 plants ha^{-1} without sacrificing the yield of the existing crops/cropping systems shall be incentivized at the proportionate rates as applicable to per plant expenditure.

High density plantations on farm lands

High density block plantations on agricultural lands will be supported as a complementary source of income to the farmers. Differential planting densities ranging from more than 500 to 1500 plants ha^{-1} as intermediate blocks / strip plantations /wind breaks would be supported. For sustaining all the plantation activities, the assistance will be provided in a phased manner spread across four years in the proportion of 40:20:20:20.

Capacity building and trainings

Activities like training of farmers and field workers with a view to ensure growing quality planting material, skill development, awareness campaign, publications, information sharing, exposure visits at national and international levels, seminars/workshops at national/international levels *etc*. would be supported.

Demonstration of agroforestry models

Specific projects for demonstration to bridge the yield gap and for extension purposes on area specific innovative agroforestry models by SAUs / ICAR Institutes/ CAUs/ CSIR/ ICFRE institutes / State Government/ other National and International level agencies and organizations will be supported particularly in the field of climate resilient agroforestry system and studies on carbon foot print, carbon sequestration, nitrogen fixation *etc*., with the approval of project sanctioning committee on case to case basis.

Mission implementation plan

- States will prepare action plan for development on cluster basis indicating the year wise activities and corresponding fund requirement spread across four years.

- Soil Health Cards (SHC) is to be made a pre-requisite for farmers in getting the benefit of the programme.
- In order to motivate the farmers to take up tree plantation on farm land, relaxation of existing policy and regulatory frame work need to be finalized by the states concerned.
- States are given the flexibility to implement the programme at field level by using the services of existing extension system. However, states may engage additional human resources purely on contractual basis as per guidelines of NMSA.
- Any procurement / purchases / auctions etc will strictly be through eprocurement process following general financial rules. Wherever feasible, during transfer of assistance particularly for farmer centric activities, direct benefit transfer may be adopted. Farmers benefitted under the programme may be linked with the AADHAR based information system.

Funding pattern and pattern of assistance

The Sub-Mission on Agroforestry will be operational under the umbrella of NMSA and funding pattern 60:40 as GoI: State Govts basis for all states excepting for 8 states of NE Region, the hilly states of Himachal Pradesh, Uttarakhand and Jammu & Kashmir where it would be 90:10 fund sharing. For UTs, the assistance will be 100 per cent from GoI. Farmers would be supported financial assistance to the extent of 50 per cent of the actual cost of the interventions for the respective interventions. Farmers groups/ Cooperatives/ Farmer Producers Organization can also avail the benefit of the programme but the assistance can be accessed as per norms and provisions applicable to the individual farmers.

Monitoring and Evaluation of SMAF

Monitoring and evaluation will be the essential and integral part of the sub-mission to assess the implementation and progress of the programme in harmony with the set norms and guidelines. Apart from coverage of area under plantation, the performance of the scheme will be monitored based on a few quantifiable success indicators *viz*., number of plants in area/ periphery, soil carbon sequestration, soil organic matter, improvement in livelihood, productivity enhancement of crop and cropping systems, *etc*. Mechanism for monitoring information system and periodical assessment using GIS technologies would be adopted for ensuring effective implementation of the programme. The digital location of the cluster with the attributes of interventions like plantation area, number of plants, name of beneficiaries, details of nurseries, project cost *etc* need to be uploaded in the Bhuvan Platform.

Expected Outcome

The implementation of the sub-mission will result in the following quantifiable benefits

- Provides additional income/savings opportunities for farmers and will also serve as a cushion to crop damage
- Increase in tree cover through agroforestry will lead to higher carbon sequestration and compliment the National initiatives on climate change adaptation and mitigation efforts
- Trees grown in farm land will help in enriching soil organic matter and will enhance nutrient uptake of the crops measurable under different time interval. This can be periodically assessed from the soil health status depicted on the soil health card to be issued to the farmers from time to time
- Contribute in availability of agroforestry produce to meet the increasing demand of raw materials for wood based industries which will result in saving of foreign exchange being used for impost of wood and wood based products
- Development of information system and database on agroforestry
- Income and livelihood generation of the farmers

Chapter - 7

CLASSIFICATION OF AGROFORESTRY SYSTEMS

A variety of systems and designs can be subsumed under the term of agroforestry and they can be classified in a number of different ways depending on the criteria employed. In order to get clear and absolute understanding on agroforestry and its different systems as well as for their future improvement, it is necessary to classify them according to some modern criteria. Agroforestry systems refer distinct agroforestry practices in which agriculture/ horticulture, forestry (trees) and pastures (animals) are combined either temporally or spatially. However, one system differs from the other in respect of structure, composition, age, intensity, technologies, inputs, *etc*. The key principle of classification should be providing a practical framework for the synthesis and analysis of information about existing systems and the development of new and promising ones.

Criteria for classification

Criteria include a logical way of grouping the major factors on which productions of the system will depends. It consists of how the system is managed, offer flexibility in regrouping the information and be easily understood and readily handled.

Basis of the classification

Among the attempts to classify the different systems, the proposal of Nair (1987) considers the i) structure (composition and arrangements), ii) function (role and output of components), iii) ecological spread (ecological zone where the system exists) and iv) the socio-economic scale and level of management

Further on Dwivedi (1992) reorganizes this basis in to seven classification as follows:

A. Structure

B. Function

C. Ecological

D. Socio-economic

E. Physiognomic

F. Floristic

G. History

Later based on the utilization of land also consider for the classification.

A. Structural classification

Structure refers to composition, stratification and dimension of crops. Based on the structure the system is further classified into 1) Based on the nature of composition, 2) Based on dominance of composition and 3) Based on the arrangement of components

1. Classification based on the nature of composition

a) Agro-silvicultural system

This system involves the conscious and deliberate use of land for the production of agricultural and forest crops, either simultaneously or alternatively.

Based on the nature of the components this system can be sub-grouped into various forms.

(i) Improved fallow species: In shifting cultivation areas woody species of fast-growing preferably leguminous are planted and left to grow during the 'fallow phase'.

(ii) Taungya system: Combined stand of woody and agricultural species during early stages of establishment of forest plantations.

(iii) Multispecies tree gardens: Multispecies, multilayer dense plant associations with no organized planting arrangements

(iv) Alley cropping (Hedgerow intercropping): Woody species of fast growing legumes, that coppice vigorously in hedges; agricultural species in alleys in between hedges; microzonal or strip arrangement.

(v) Multipurpose trees and shrubs on farmland: Trees scattered randomly or according to some systematic patterns on bunds, terraces or plot/field boundaries.

(vi) Crop combinations with plantation crops: It includes integrated multistorey (mixed, dense) mixtures of plantation crops; mixtures of plantation crops in alternate or other regular arrangement; shade trees for plantation crops, and shade trees scattered and intercropping with agricultural crops

(vii) Agroforestry fuelwood production: Inter planting firewood species on or around agricultural lands.

(viii) Shelter belts and wind breaks: Trees around farmland/plots in wind prone areas

(x) Trees in soil conservation and reclamation: In sloping areas, degraded lands and sand dunes.

(xi) Riparian buffer: A riparian buffer or stream buffer is a vegetated area near a stream, usually forested, which helps shade and partially protect the stream from the impact of adjacent land uses.

b) Silvo-pastoral systems

Silvo-pastoral system refers to a land management system in which forests are managed for the production of wood, as well as, for rearing of domestic animals. It does not include the growing fodder crops that are harvested and fed to stalled animals, which is silviculture.

This system consisted into three major categories:

(i) Protein bank: Production of protein-rich tree fodder on farm/rangelands for cut-and-carry fodder production

(ii) Plantation crops with pastures and animals and

(iii)Trees and shrubs on pasture lands: Trees scattered irregularly or arranged according to some systematic pattern in extensive grazing areas.

c) Agro-silvo-pastoral system

Agrosilvopastoral system is the combination of agrosilvicultural and silvopastoral system and it integrate trees, forage crops and livestock on the same unit of land.

(i) Food, fodder and timber trees on agricultural/ grazing lands.

(ii) Home gardens involving animals: Intimate, multi-storey combination of various trees and crops, and animals, around homesteads

d) Other systems

i) Multipurpose tree lots

All trees are said to be multipurpose; some, however, are more multipurpose than others. In the agroforestry context, multipurpose trees are understood as those trees and shrubs which are deliberately kept and managed for more than one preferred use, product, and/or service; the retention or cultivation of these trees is usually economically but also sometimes ecologically motivated, in a multiple-output land-use system. Multipurpose tree lots, location specific multipurpose forest trees are regenerated and managed to the production of fuel wood, timber, fodder, fruits, medicine etc.

e.g. *Madhuca latifolia, Shorea robusta*

ii) Aqua-agroforestry

In this system, various trees and shrubs preferred by fish are planted on the boundary and around fish-ponds. Tree leaves are used as feed for fish. The main or primary role of this system includes augment fish production and bund stabilization around fish-ponds.

iii) Entomo-agroforestry

Apiculture combined with woody plant species

In this system, various pollen and nectar producing tree species frequently visited by honey bees are planted on the boundaries or mixed with agricultural crops. E.g. *Acacia nilotica, Pongamia pinnata*

Lac and sericulture with woody plant species
In this system, culturing of these lac insects and silk worms are attractive in terms economic returns as well as suitable for the rural communities and also form excellent components for agroforestry. Conventional tree hosts of lac like *viz*., *Albizia procera, Zizyphus mauritiana* and *Butea monosperma* and silk worm host *viz*. *Morus alba, M. indica, M. serrata* and *M. latifolia* and *Terminalia arjuna* can easily be integrated in bunds of cropped fields and in strips at the periphery of uplands.

2. Classification based on dominance of composition
On the basis of dominance of components, the system is further classified in to the following categories:

a) Silvoagricultural
Trees constitute the major component while agricultural crops are integrated with them. e.g. Shifting cultivation, Taungya cultivation.

b) Agrosilviculture
Agriculture is the principal component and the trees are secondary. e.g. MPT's on farm bunds, alley cropping.

c) Silvopasture
Trees constitute the primary component of land use with pastures as secondary. e.g. grazing lands in forests.

d) Pastoral silviculture
Pasture is a primary component while the tree is secondary, e.g. grazing lands.

e) Agrosilvopasture
Agricultural crops and trees are dominant over pasture.

f) Silvoagropasture
Trees are dominant over other components.

3. Based on the arrangement of components
Arrangement of components can involve the dimensions of space and time. Based on it, agroforestry system can be classified as:

a) In space or spatial arrangement

b) In time or temporal arrangement

c) Vertical stratification of components

a) Classification on the basis of in space or spatial arrangement
i) Mixed dense
Different components are arranged together with high density, e.g. home garden.

ii) Mixed sparse
Different components are arranged together with low density, e.g., scattered trees on agricultural lands.

iii) Strip plantation
The width of strip to be more than one tree, e.g. alley cropping.

iv) Boundary plantations
Trees grown on the edges of plots or fields.

b) Classification on the basis of in time or temporal sequence
i) Coincident
It occurs when different crops occupy the land together, e.g. coffee/ tea under shade trees.

ii) Concomitant
Different crop components are stay together for certain period, e.g. Taungya system.

iii) Intermittent (space dominant)
Annual crops are grown with perennial ones, e.g. shade loving agricultural crops under coconut or other MPT's and seasonal grazing of cattle in pastures under trees

iv) Interpolated (space and time dominant)
Different components occupy the space during different times, e.g. Home garden

v) Separate (time-dominant)
Trees or crop components occupy space at different times, e.g. improved fallow in shifting cultivation.

4. Classification based on stratification
a) Classification based on vertical stratification
i) Single layered
The major components usually grown in one layer/ storey, e.g. tree garden.

ii) Double layered
The components are grown in two layers, e.g. tea / coffee under shade tree.

iii) Multilayered
Different components are grown in different layers, e.g. homestead agroforestry.

B. Functional classification
On the basis of role and output of various components agroforestry systems are classified into followings:

i. Productive agroforestry system
This system refers to the production of essential commodities (food, fodder, fuelwood, minor forest products, *etc*.), required to meet the basic needs of the society. It includes intercropping of trees, home gardens, production of animals and fishes in association with trees *etc*.

ii. Protective agroforestry system
This system primarily aims at ameliorating the land to improve climate resilient, reduce soil erosion, moisture conservation, provide shelter, shade, etc. e.g. wind breaks.

iii. Multipurpose agroforestry system
Multipurpose agroforestry system ensures multipurpose production through optimizing both productive and protective functions, e.g. hedge row intercropping.

C. Ecological classification
The agroforestry system is related to various ecological factors *viz*., climatic, edaphic and physiographic ones. On the basis of ecological parameters, it can be classified as:

i) Tropical
Vegetation in extreme climate such as high temperature, low humidity, and scarcity of water *etc*., e.g. Tropical silvopasture.

ii) Sub-tropical
Agroforestry system in optimal climatic condition, *e.g*. agroforestry in sub-tropical regions

iii) Temperate
Agroforestry system in low temperature regions.

iv) Sub-Alpine
Agroforestry systems in low and medium mountainous regions.

v) Alpine
Agroforestry system in high mountainous regions.

D. Socio-economic classification
Based on socio-economic consideration, the agroforestry systems are classified based on cost / benefit relations, management options and technology used

1. On the basis of cost / benefit relations
i) Subsistence agroforestry system
This system aims at meeting the basis needs of small family having less holding and very little capacity for an investment. They may be some marginal surplus production for sale, e.g., shifting cultivation, scattered trees in the farms, homestead agroforestry.

ii) Commercial agroforestry system
This system refers to large scale production on commercial basis. The main consideration is to sale the products, e.g., tea/coffee/cocoa plantations under shade trees. This system is managed by individuals, companies, industries, corporate bodies or government.

iii) Intermediate agroforestry systems
This system is an intermediate between commercial and subsistence systems. It is practiced on small medium sized farms. The system aims at production of sufficient food, wood, fodder and other beneficial products, which are not enough to meet the needs of the family, but to earn money the surplus can be sold.

e.g. fruit trees with agricultural crops.

2. On the basis of management
i) Intensively managed agroforestry system
Agroforestry systems are intensively managed for more production per unit area. This system usually characterised by higher inputs in labour, higher diversity of plant species and higher structural diversity compared to the other systems. *e.g.,* Home gardens and multi-storey systems.

ii) Extensively managed agroforestry system
In this system area under management is more but productivity is less. It includes shifting cultivation, silvopasture, *etc.*

3. On the basis of technology
i) Low technology system
The technology used in this system is primitive as in shifting cultivation.

ii) High technology system
This system depends on modern technology for production of forest and agricultural crops, *e.g.,* Use of tissue culture in tree/ crop management.

iii) Intermediate technology system
This system is intermediate between low and high technology system, *e.g.,* Agrosilviculture.

E. Physiognomic classification
Physiognomic classification is based on the characteristics of vegetation in relation to water. This classification includes the following system.

i) Hydromorphic agroforestry system
It refers to agroforestry in wet lands or in waterlogged areas, *e.g.* aqua forestry in coastal wet lands.

ii) Xeromorphic agroforestry system
It is the dry land agroforestry in arid and semiarid areas.

iii) Mesomorphic agroforestry system
It is the agroforestry system where water is available in optimal quantity.

F. Floristic classification
The tree species composition along with their component crop species are also considered for classifying agroforestry systems. For instance maize, sorghum, pearl millet, finger millet, pulses and cotton along with *Acacia nilotica, Acacia planifrons, Acacia senegal, Azadirachta indica, Zizyphus spp etc.* are common in Arid ad semi Arid regions of India. In humid regions tea, coffee, cocoa, banana, black pepper, pineapple along with *Artocarpus spp., Areca catechu Erythrina spp., Gliricidia sepium, Grevilia robusta*, etc. are frequently widespread.

G. Historical classification
Historically cultivation of crops started about 10,000 years ago in the form of Shifting cultivation or Swidden agriculture (oldest known agroforestry system). Then the land is directed towards satisfying basic needs and managed by a farmer occurs in the name of subsistence agroforestry systems. Over the years due to the advancement of knowledge on cultivation practices with improved technologies, sedentary farming systems came in to existence. Most recently intensive agroforestry systems are practiced with the mixture of companionable crops along with multipurpose trees.

H. Others

1. Classification based on utilization of land

i) Homestead agroforestry

It refers to production of multipurpose trees along with agricultural crops in homestead garden.

ii) Forest land agroforestry

Production of crops in the vacant spaces of the forest.

iii) Crop-farm-forestry

Production of crops and trees in the cropping land.

iv) Fish-farm-Forestry

Production of fishes and trees in the fish farm.

v) Animal-farm-forestry

Production of animals with protein/fodder banks (These are blocks of highly nutritious leguminous tree species planted to provide fodder to range of livestock on the farm. The trees used in a fodder bank are usually selected tree species of high leaf protein content. Fodder banks act as important resource during drought and offseason). For instance the examples of animal based farm-forestry are as follows. Poultry-farm-forestry: Farming of poultry birds and trees; Dairy-farm-forestry: Farming of milch cattle and trees; Beef-cattle-farm-forestry: Farming of beef cattle and trees and Goat-farm-forestry: Farming of goats and trees.

vi) Integrated-farm-forestry

Production of crops, animals, fishes along with trees.

vi) Avenue agroforestry

Production of deep rooted, tall trees with narrow canopies and soil building grasses or crops along the sides of roads, highways, railways and embankments.

vii) Public place agroforestry

Production of suitable trees singly or along with decorative herbs and vegetables in places likes premises of school, college, university, *etc.*

2. Special multi-storied agroforestry systems

Multi storied agroforestry systems are characterized by randomly mixing various, mostly multi-purpose species that create at least two layers of canopy. The upper canopy is composed of light-demanding species, while the understory is made up of shade-tolerant species. The special category of multi storied agroforestry systems are distinct here under.

i) Successional agroforestry

Successional agroforestry systems are designed to mimic the entire course of natural succession in an accelerated way. It starts with pioneers, contravene several intermediary stages and reaches relatively stable site-specific high point vegetation. Pioneer stages are characterised by low standing biomass, fast growth and low species diversity, climax vegetation at potential forest sites has high standing biomass, slow net growth and high biodiversity. e.g. improved fallow

ii) Permaculture

Permaculture is sustainable land use design based on ecological and biological principles, stressing the harmonious interrelationship of humans, plants, animals and the Earth. The word permaculture comes from ‘permanent agriculture’ and ‘permanent culture’. Permaculture as a systematic method was first practised by Austrian farmer Sepp Holzer in the 1960s and then scientifically developed by Australians Bill Mollison and David Holmgren and their associates during the 1970s. According to Bill Mollison, permaculture is a "conscious design and maintenance of agriculturally productive ecosystems which have the diversity, stability and resilience of natural ecosystems. It is the harmonious integration of landscape and people providing their food, energy, shelter and other material and non-material needs in a sustainable way". An ideal permacultural system possesses the following structural features:

- Large trees dominate but not saturate the area, i.e. there exist patches barren of trees.

- ❖ Edges that create special favorable conditions exist.
- ❖ Initially the system is in a state of controlled -possibly ongoing- succession.

iii) Forest gardening

Forest gardening is a food production and land management system based on replicating woodland ecosystems, but substituting trees (such as fruit or nut trees), bushes, shrubs, herbs and vegetables which have yields directly useful to humans. Making use of companion planting, these can be intermixed to grow on multiple levels in the same area, as do the plants in a forest. Forest gardening was pioneered by the Robert Hart during 1960's by using the model of the Kerala home gardens. It is consisted the following dimensions;

- ❖ A canopy layer consisting of the original mature fruit trees.
- ❖ A low-tree layer of smaller nut and fruit trees on dwarfing root stocks.
- ❖ A shrub layer of fruit bushes such as currants and berries.
- ❖ A herbaceous layer of perennial vegetables and herbs.
- ❖ A ground cover layer of edible plants that spread horizontally.
- ❖ A rhizosphere or underground dimension of plants grown for their roots and tubers.
- ❖ A vertical layer of vines and climbers
- ❖ At present an eighth layer, mycosphere (fungi), is often included.

iv) Rainforestation

Rainforestation assumes that imitating the natural climax vegetation in physical structure and species composition leads to the most resilient possible land use. Basic principles of rainforestation are the at least 3 storey structure and focus on native species. It is recommended to plant representatives of four associations of plants *viz*., lumber, fruit trees, climbers and shade-tolerant tuber crops. A standardized planting pattern has deliberately not been proposed; concerning planting distances and choice of species, the scheme may be modified with respect to farmers' preferences, site characteristics and availability of seedlings. Initially, exotic fast growing 'miracle trees' like *Gmelina arborea, Acacia mangium*, *Swietenia macrophylla*, *Eucalyptus spp*. etc. are used in rainforestation. Due to reports of higher resistance to local conditions and pests and diseases, focus shifted more and more towards native high value species.

v) Analogue forestry

Analogue forestry arose in Sri Lanka around 1981 as an alternative to monocultures of *Pinus spp*. and *Eucalyptus spp*. and at present it has spread throughout the world. Analogue agroforestry considered as sub-climax of a forest ecosystem. Analogue forestry systems may contain exclusively native but also exotic species. It represent complex and holistic forms of agroforestry that seek to maintain a functioning tree-dominated ecosystem while providing broad range of marketable commodities that may include fruit, nuts, herbs, cut flowers and cut foliage, pharmaceuticals and timber. The production system is built up in layers over successive years while offsetting the establishment costs for the next layer (e.g. shrub) by the sale of commodities from harvests of the previous layer.

AGROFORESTRY SUBSYSTEMS

A. SHIFTING CULTIVATION

Shifting cultivation or Swidden agriculture is a pattern of land use and a system of production of crops in which land are cleared (normally by fire), cultivated for a few years for raising one, two or three crops for a few years and then abandoned for a new area until its fertility has been naturally restored.

The slash and burn method (fire fallow cultivation) differs from a much more ancient system of shifting cultivation. The major difference between the slash and burn system and shifting cultivation is in the length of time for which the land is used for agriculture. In the slash and burn system, the conversion is long term, often permanent. Shifting cultivation is a more ephemeral use of the land for cultivation.

Shifting cultivation has long been used by humans for subsistence agriculture in tropical forests worldwide. In India this system is practised extensively in the north-eastern hill region comprising the states of Assam,

Meghalaya, Manipur, Nagaland and Tripura and the two Union territories of Arunachal Pradesh and Mizoram and to some extent Andhra Pradesh, Bihar, Madhya Pradesh, Odisha and Karnataka states. It is reffered as 'jhum' in the north-eastern hill region and 'podu' in Andhra Pradesh and Odisha states and considered most destructive for forest areas.

Shifting cultivation considerably accelerate land degradation due to the cropland left without crops for periods ranging from one season to several years. Now shifting cultivation is upgraded with improved fallow system of agroforestry. The objective of improved fallow system is to recover depleted soil nutrients. Once the soil has recovered, crops are reintroduced for one or more seasons and the fallow periods becoming shorter due to an increasingly acute land shortage.

Selection of species

The main function of the fallow is to sustain or restore soil fertility and reduce soil erosion, while some plants are introduced primarily for their economic value. Choice of species should not be exclusively confined to 'soil improvers' and plants with marketable products should also be considered. Plants included in improved fallows should be compatible with future crops, free of any negative physical or chemical effects on the soil and not in competition with the crops to be planted later on the same site.

Improved fallows can be established with variety of ways at various stages of the fallow and it might includes i) direct seeding of clean tilled, harvested plots, ii) selective cutting of bush, followed by enrichment planting with tall seedlings, iii) introducing tall seedlings and cuttings into poor quality fallows on degraded land and iv) Planting tree seedlings in closely spaced, deep planting holes or furrows within blocks of cleared cropland. The exact techniques differ with the previous land use, value of the fallow vegetation condition of the land and expected duration of the fallow.

B. TAUNGYA SYSTEM

The Taungya (taung - hill, ya - cultivation) is a Burmese word coined in Burma in 1850s. The taungya system was introduced into India by Brandis in 1890 and the first taungya plantation was raised in 1896 in North Bengal. It is practiced in the states of Kerala, West Bengal and Uttar Pradesh and to a lesser extent in Tamil Nadu, Andhra Pradesh, Odisha, Karnataka and the north-eastern hill region. In southern India, the system is reffered as 'kumri'. It is mostly practiced in humid and subhumid region.

The taungya is a system is a modified form of shifting cultivation in which local people are given the right to cultivate agricultural crops during the early stages of forest plantation establishment. The practice consists of land preparation, tree planting, growing agricultural crops for 1-3 years, until canopy cover becomes too dense, and then moving on to repeat the cycle in a different area. In some cases crops may be grown one year before the trees are planted. A large variety of crops and trees are grown depending on the soil and climatic conditions.

Trees and associated Crops

a) Trees

Acacia nilotica, Anacardium occidentale, Bamboo spp. Ceiba pentandra, Hevea brasiliensis, Tamarindus indica, Tectona grandis, etc.

b) Crops

Millets, pulses, oilseeds, cotton, tapioca, banana, vegetables, *etc.*

Types of Taungya systems

Taungya systems are of three types:

i) Departmental taungya

Agricultural crops and plantation are raised by the forest department by employing a number of labourers on daily wages. The main aim of raising crops in departmental Taungya is to reduce the weed growth, provide additional income and maximum utilization of land.

ii) Leased taungya

The plantation land is given on lease to the person who offers the highest money for raising crops for a specified number of years and ensures care of tree plantation.

iii) Village taungya

This is the most successful of the three taungya systems. In this, crops are raised by the people who have settled down in a village inside the forest for this purpose. Usually each family has about less than two hectares of land to raise trees and cultivate crops for 3 to 4 years.

Advantages offered by the Taungya system are:

- Artificial regeneration of the forest is obtained cheaply
- Problems of unemployment are solved
- Helps towards maximum utilisation of the land
- Low cost method of forest plantation establishment
- In every case highly remunerative to the forest departments
- Provision of food crops from forest land
- Weed growth is eliminated.

Disadvantages of the Taungya system

- Loss of soil fertility and exposure of soil
- Danger of epidemics
- Legal problems created
- Susceptibility of land to accelerated erosion increases
- It is a form of exploitation of human labour.

The Taungya farmers are given the following concessions as a part and parcel of success of the system

- Free grazing for animals
- Free small timber for house construction and agricultural implements
- Schooling facilities for children
- Monitory loan at nominal interest
- Water supply through excavation of wells and construction of ponds.

C. ALLEY CROPPING

Alley cropping or hedgerow intercropping is the practice of farming annual crops in the spaces or ‘alleys’ between rows of multipurpose woody perennials. It is a promising alternative to the traditional tree fallow system. The woody crops are harvest regularly and leaves and twigs are used as mulch on the cropped alleys in order to minimize evaporation from the soil surface, suppress weed growth and add required nutrients and organic matter to the soil. Where nitrogen is essential for crop production, nitrogen fixing plants are the major components of the hedgerows.

The primary rationale of alley cropping is to stabilize or increase crop yields by enhancement of the soil fertility status, optimizing microclimate and weed smothering. Farmers may also obtain tree products from the hedgerows, including food, fodder, fuelwood, construction poles, medicine, etc. On sloping lands the hedgerows and pruning with mulching help to manage soil erosion. Alley cropping generally works better in places where people feel a need to intensify crop production but face soil fertility problems.

The primary products and services provided by tree hedgerows includes nutrient cycling from deeper soil layers, green manure and mulch benefit companion food crops, mulch and shade suppress weeds, favorable conditions for beneficial soil organisms, barrier to control soil erosion, act as a wind break and shelter belt, green animal fodder, prunings for firewood and construction poles and supply biologically fixed nitrogen to system.

Alley cropping model

Woody plants are established as hedgerows in farm lands to maximise the positive and diminish the negative effects of trees on crop management and yields. Without suspicion, trees compete with farm crops for soil nutrients, soil moisture and light. However, the selection of right kind of trees at the right spacing, with appropriate crop management essentially produces a net increase in productivity from croplands.

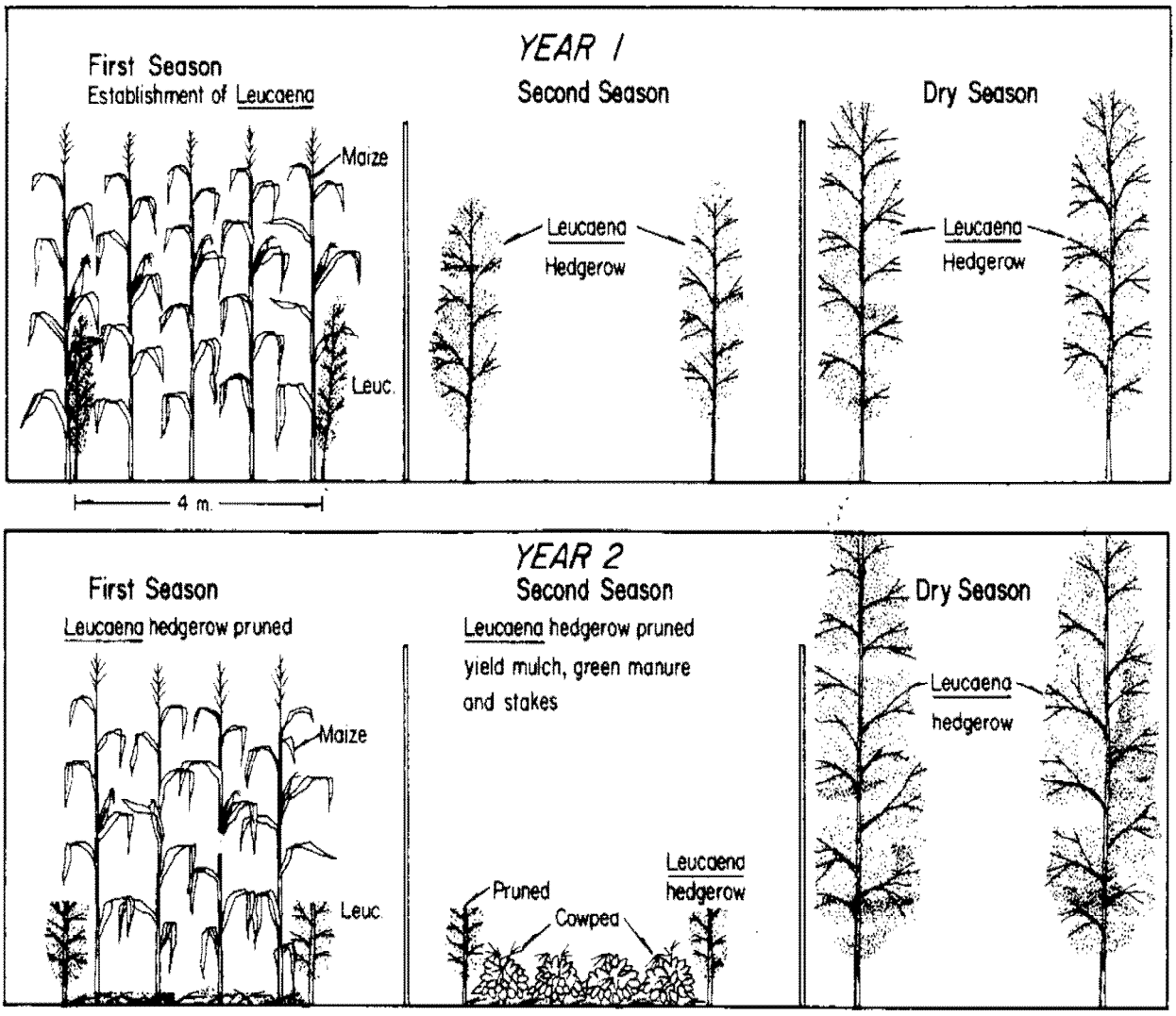


Fig-7.1: Leucaena alley cropping model

The position and spacing of hedgerow and crop plants in an alley cropping system depend on climate, slope, soil conditions, plant species and the space required for conducting intercultural operations. Ideally, hedgerows should be positioned in an east-west direction, perpendicular to prevailing winds and parallel to slope contour. This orientation provides maximum 'alley' (crop) sun exposure and maximum erosion control. The position and spacing of hedgerows are diverse depending on the slope and the placement and design of soil and water conservation structures. On sloping land, hedgerows should always be placed on the contour and that they do not have desirable east west orientation, then they may need regular thinning to prevent excessive shading of adjacent crops.

The most important high intensive hedge row system design decision is alley width. Alley width will determine the ratio of tree products/services to crop product and the degree of competition between the root of crops and trees. If alleys are too narrow, crop yields win drop off dramatically as tree hedges grow. If alleys are too wide, the soil improving role of trees is reduced. Based on tried systems, a 4 to 8 meter width are recommended.

Fig-7.2: Well managed timber based alley cropping system

For the production of fodder or biomass/mulch material the recommended hedge consists of two lines of trees 0.5 m apart. Trees within the lines should be at 0.5 m spacings. Timber based alley cropping system trees within the lines should be at 1 to 3 m spacings. Close spacings encourage more leaf and smaller branch production. The closer spacing is generally followed in humid regions and the wider spacing in sub-humid or semi-arid regions.

Selection of species

An ideal alley cropping tree or shrub species should have following characteristics

- Bushy form: Multi stemmed woody perennials typically produce more biomass of a higher leaf: stem ratio than larger, single stemmed species.
- Fast growth and biomass production: Additional leafy biomass and small branchs production reflects surplus litter/mulch accumulation, additional fodder and/or more fuelwood.
- Easy to establish: Trees are uncomplicated to raise from seed either directly field planted or in containers.
- Easily re-establishing: Stems and leaves grow back again and again quickly after pruning, coppicing, pollarding or lopping.
- Nitrogen fixing: N fixing trees are able to fix atmospheric N and contribute to the system.
- Deep rooting: It should form a deep taproot system with few lateral root branches near the surface so as not to compete with crops and take up nutrients and water out of reach of crops.
- Easily manageable: It should have shallow lateral roots that are easily pruned by ploughing along the hedgerow, without serious damage to the crop plants.
- Easily decomposable: The leaf litter or some portion of it should decompose at rapid rate that makes nutrients available when they are needed in the cropping cycle.
- Multipurpose: Alley cropping should produce wood, food, fodder, medicine or other products used by farmers or dependent local community.

- ❖ Widely adaptable and stress tolerant: The species selected should grow well under the specific limitations of the site such as saline or acid soils, drought, flooding, heavy winds, etc.
- ❖ Free from pests and diseases: Trees should not be hosts to crop damaging insect or fungus pests.

Some of the suitable alley crops are *Gliricidia sepium, Leucaena leucocephala, Senna siamea, Sesbania grandiflora, Sesbania sesban, etc.*

Hedge management

Periodic hedge pruning is necessary to prevent trees from shading out agricultural crops. The amount/frequency of pruning required will depend on the shade tolerance of a particular root crop at a particular stage in development. A tump rule is to maintain a hedge height equal to the distance between the hedge and nearest crop row. Pruning frequencies also depend on the produce mix desired. More frequent pruning adds additional green manure to the soil or fodder. Fewer frequent pruning will produce more fuelwood diameter twigs. The timing of prunings is most important in tropical environments where decomposition leaf and organic matter mineralization occurs rapidly. Prunings should be timed so that applied litter is releasing nutrients when the crops are most demanding.

D. HOMEGARDENS / HOMESTEAD FORESTRY

Globally, home gardens have been documented as a significant supplemental source contributing to food and nutritional security and livelihoods. Homegardens may have originated in prehistoric periods when hunters and gatherers were deliberately or accidentally dispersed seeds of highly valuable food yielding trees in the vicinity of their camp sites. Food production on small plots neighbouring to human settlements is the oldest and most enduring form of cultivation. For centuries, home gardens have been an integral constituent of family farming and local food production systems.

Generally, home gardening refers to the cultivation of a small portion of land which may be nearer to the household or within walking distance from the home. The home garden is a small scale food production system supplying plant and animal consumption and serviceable items either not obtainable, affordable or readily available through hunting, gathering, fishing, field cultivation, retail markets and wage earning. Household gardens have a tendency to be located nearer to dwelling for security, convenience and special care. They occupy land marginal to field production and labor marginal to main household economic activities. Featuring ecologically adapted and complementary species, home gardens are marked by less capital input and simple operational technology.

Homegarden as a well defined, multi storied and multi use area near the family dwelling that serves as a small scale complementary food production system preserved by the household members and one that encompasses a diverse collection of plant and animal species that mimics the natural ecosystem. The interest in homegardens has principally been focused on their purpose of producing subsistence things and generating additional income. They are known for their stable yields, very varied products, continuous or repeated harvests during the year and low inputs. Food, fodder and timber production is primary function of contemporary home gardens. Homegardens can be described as a mixed cropping system that includes vegetables, fruits, spices, plantation crops, medicinal herbs and ornamental plants as well as livestock that can serve as a supplementary source of food and income.

In the modern era this system is found extensively in high rainfall areas in tropical regions. The first International workshop on Tropical Homegardens held at the Institute of Ecology in Bandung in December 1985, such systems were reported from tropical regions of various countries. Homegardens symbolize land use systems involving deliberate management of multipurpose trees and shrubs in intimate association with annual and perennial agricultural crops and livestock within the compounds of individual houses. The exact size of a homegarden differs from household to household and normally, their average size is less than that of the arable land owned by the household. In India, most of the homestead has around 0.20 to 0.50 ha of land indicating the subsistence of the practice. Homegardens find a typical expression in the state of Kerala. For example, homestead farming in Kerala covers about 88 per cent of the total landholding and about 41 per cent of the total cultivable area.

An outstanding structural characteristic of the homegarden is the vast diversity of species with numerous life forms. Many species of trees, shrubs, vegetables and other herbaceous plants are grown in dense and in random or spatial and temporal arrangements. Depending on the nature, type of components, most homegardens in the tropics can be classified as agro silvopastoral system consisting of herbaceous crops, woody perennials and animals. However, some homegardens represent agrisilvicultural system consisting only of the first two components. The whole tree crop animal units are being intensively managed by family members. Hence, homegardens are highly productive, sustainable and incredibly practicable.

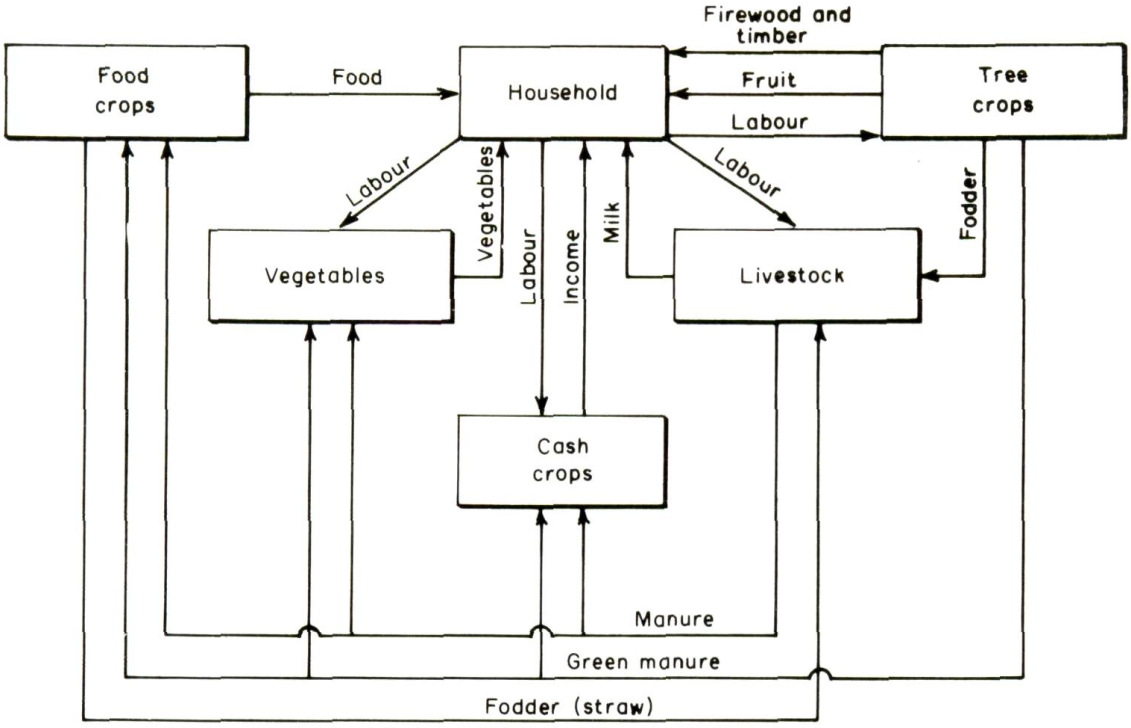


Fig-7.3: Resource flow in intensively managed homegardens

Species diversity in homegardens

Species diversity and plant density vary from place to place, influenced by ecological and socio-economic factors. A classification based on the production systems and species diversity ranked homegardens pinnacle with its highest biological diversity among all manmade agroecosystems. For instance, one of the recent reports pointed out on agrobiodiversity, structural compositions and species utilization of homegardens in humid tropics (from 330 homegardens in Thrissur, Kerala) has highest 525 plant species, represented 320 genera and 102 families, of which 237 were trees (> 20 cm GBH) (140 genera and 49 families), 100 shrubs (62 genera and 32 families) and 187 herbs (138 genera and 54 families). Homegardens represent a genetic backstop, preserving species and varieties that are not economic in field production and are planted in small scale for reasons of taste preference, tradition, or availability of planting materials. Hence, it is reasonable to assume that much of insitu domestication has taken place in homegardens.

Structure and composition of home gardens

The layered arrangement and companionable species admixture are the most prominent characteristics of all homegardens. Homegardens seem to lack structure as trees, shrubs and herbaceous plants grow in a complex mixture without any clear pattern. The forest like structure is also derived from the lack of a noticeable planting pattern; usually there are no rows, blocks or specific planting distances among the components. However, a closer look at the vegetation shows that plants do seem to be organized in different patterns or layers. Thus, homegardens is also called as ‘multi-tier system’ as it consists of different canopy strata.

The schematic presentations on the structure of different homegardens from various geographical locations exposed that the canopies of most homegardens consisted of two to five vertical canopy strata (Fig. 7.4). For instance, five canopy strata have been identified in the homegardens of Kerala. Generally all homegardens

consists of herbaceous layer near the ground (first layer), an intermediate layer and a tree layer at the upper levels. The lower layer can be partitioned in to two, the lowermost being at less than 1.0 m in height, dominated by different herbs and the second layer of 1.0 -3.0 m height comprising food crops. The intermediate layer of 5-10 m height is dominated by different fruit and spices trees. The upper tree layer can also be divided into two, consisting of emergent, full grown timber and fruit trees occupying the upper most layers of 25 m height and medium size trees of 10-20 m occupying the next lower layer.

The upper most canopy layer is formed by *Anacardium occidentale, Anona squamosa, Averrhoa carambola, Cocus nucifera, Areca catecheu, Artocarpus heterophyllus, Citrus spp, Psiduim guajava, Phyllanthus emblica, Mangifera indica, Swietenia macrophylla, Tamarindus indica, Tectona grandis* and other tall trees. The middle layer is dominated by banana, papaya, pepper, coffee, cocoa, spices, etc. The lower layer is constituted by amaranthus, arrowroot, bhendi, brinjal, beans, cowpea, ginger, onion, pumpkin, pineapple, tapioca, turmeric, sweet potato, yams, *etc*. The animal components includes are cow, goat, poultry and rabbit.

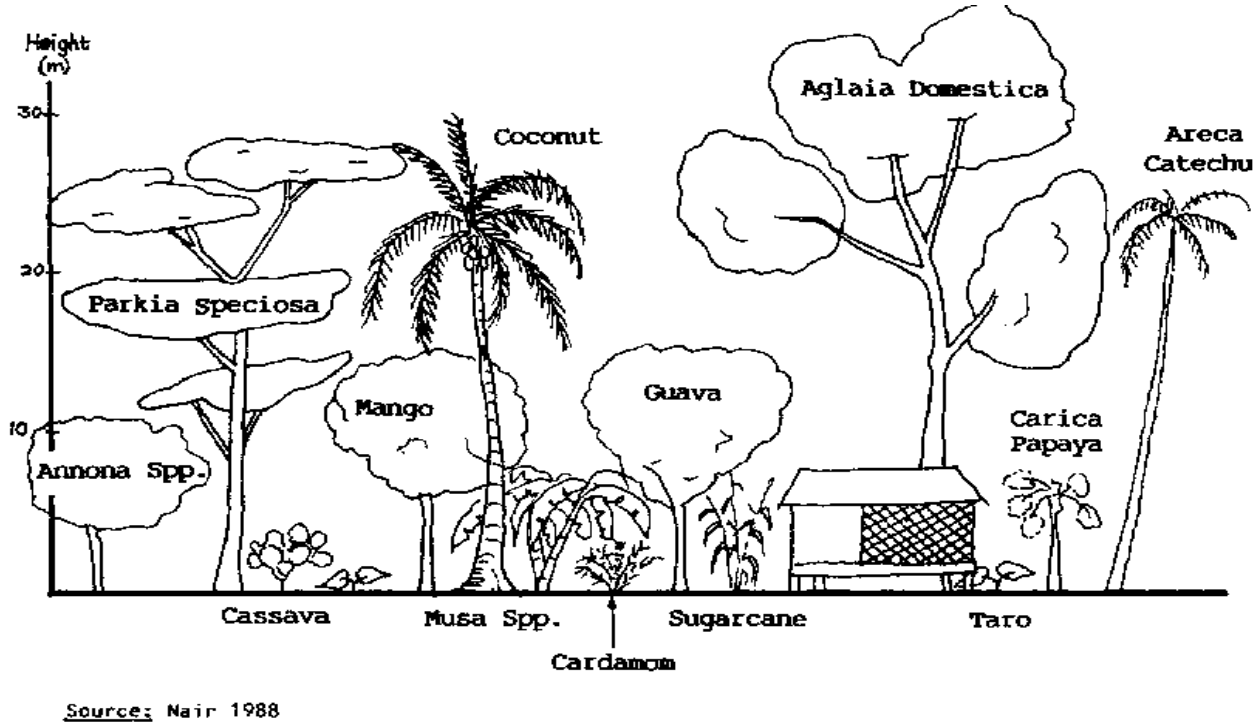


Fig-7.4: Structure of homegarden

Significance of homegarden agroforestry system

Sustained food and nutritional security

The homegardens play a major role in food production directly by providing edible products such as fruits, and indirectly by supporting food production through enhancing the soil's ability to support agriculture. The homegardens seldom meet the entire basic-staple-food needs of the family. However, they are complementary to other crop lands. Thus, homegardens are a component of the larger farming system of the household. Indeed, if the home garden is the only land available to the household, food crops such as cassava, yams, vegetables, banana, moringa, etc. will dominate the species composition of the homegarden.

Household energy requirement

The traditional homegardens constitute a principal source of bio-fuels for the rural households. For example 51 per cent of the fuel wood collected in various geographical regions is derived from homegardens.

Supply of Wood

Homesteads provide 74 to 84 per cent of wood requirements in Kerala. For instance, analysis of supply and demand of bamboo in Kerala State indicated that during the year 1993-94 the estimated demand for bamboo was 1,69,000 metric tons. Of the total supply of bamboo in State, homegardens contributed 63 per cent and forests the remaining 37 per cent.

Employment opportunity
It is estimated that about 94 per cent of the total female labour days was constituted by family labour. This female labour (family labour) forms 41 per cent of the total labour employed in the homestead farm in a year.

Increased economy
Homegardens are recognized as repositories of non-timber products such as medicinal and aromatic plants, ornamentals, gums, resins, chemical extractives and green leaf manure. In addition, several crops of homegardens are often instrumental to link heterogeneous communities in the village ecosystem. For instance, the bamboo weaving communities obtain suitable bamboo poles from the homegardens and weave items such as bamboo mats, baskets, fish nets, etc. While some of these items are offered to those supplied the raw materials, rest will be sold by the weavers. Like homestead bamboo, many other crops is one element in a complex system of rural relationships where human beings are the main actors.

Carbon sequestration
Homegardens has high carbon storage (sequestration) potential in their multiple plant species, especially in woody perennials and soil. They help in conservation of C stock in existing forests by alleviating the pressure on natural forest.

Ecosystem services
The intimate association between the annual and perennial components enhances nutrient recycling and reduces vulnerability to soil erosion through nutrient pumping mechanism. Nutrient turnover is strongly influenced by the species composition and biomass of the tree components. Unlike monoculture or dual component systems, the multi-species, multi-strata composition of homegardens permits the enhancement in resource acquisition efficiency.

Preservation of traditional knowledge
Local people have more knowledge about the flora and fauna in their homegardens, its utility, its interactions, the seasonal variations in the ecosystem, skills in managing and sustainable use of plants and other such details of the functioning of the ecosystems through experience and observation. This traditional knowledge can be preserved for the benefit of future generation.

E. WINDBREAKS AND SHELTERBELTS
Windbreaks or shelterbelts are linear plantings (strips) of single or multiple rows of trees or shrubs or sets of linear plantings, which obstruct the flow of the wind and decrease the velocity of the air currents in the lower layers of the atmosphere and produce a sheltered zone in the vicinity of the belts. Properly designed and maintained windbreaks provides the following benefits

- ❖ reduce the velocity of the wind
- ❖ shelter crops and pastures from hot and drying winds
- ❖ improve the microclimate for growing crops
- ❖ reduce evaporation from water surfaces, such as irrigation ponds, canals or streams
- ❖ decrease water evaporation from soil and plants
- ❖ shelter people and livestock
- ❖ protect livestock from cold winds
- ❖ reduce/prevent soil erosion
- ❖ provide habitat for wildlife
- ❖ reduce evaporation from farmlands
- ❖ act as fencing and boundary demarcation

In addition, wind breaks can provide wide range of useful products, from poles and fuelwood to fruit, fodder, fiber and mulch.

Designing windbreaks

i) Permeability

A wind break works by filtering and breaking the force of the wind and allow some wind to pass through are the most suitable. The movement of air through the wind breaks form a cushion of slow moving air on both upwind and downwind sides. This deflects the major volume of wind upwards and prevents it from descending for some distance. Thus, the wind velocity in the protected area may be reduced to between 25 and 75 per cent of the wind speed.

Dense wind breaks produce a little area of still air in a narrow strip behind the trees, but further downwind there may be substantial turbulence. However, dense wind breaks are desirable when a high level of protection is needed for small areas such as around homesteads and work areas or for vulnerable livestock such as newborn calves, lambs, *etc*. The desired permeability can be acquired by carefull selection of tree /shrub species.

ii) Orientation

Windbreaks should be planted at right angles to winds from which protection is needed to obtain best results. However, shelter belts may be raised in quadrangles if the wind direction tends to change very often.

Fig-7.5: A well designed wind break

iii) Height

The height of wind break determines the size of the sheltered area. The taller the wind break, the greater the area it protects. On level ground, a windbreak will reduce the speed of wind for about 20 times the tree height on downwind side.

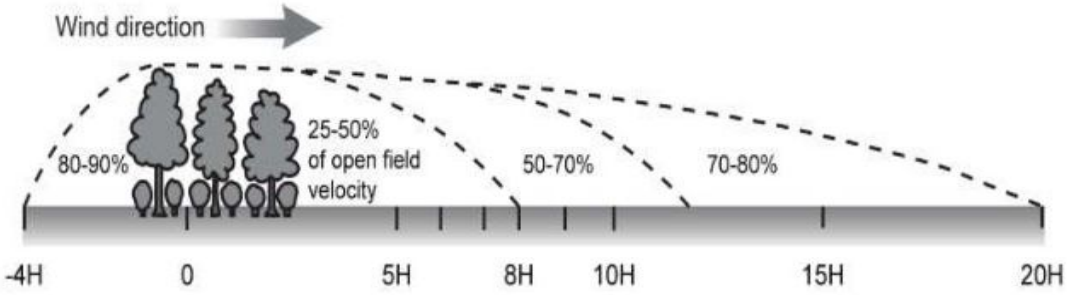


Fig-7.6: Zones of reduced wind velocity downwind of barrier as percentage of open field velocity for a wind break with height H

iv) Length and width

Windbreaks are largely effective when they stretch without major gaps for distances exceeding 25 times the mature height of the trees. The ratio of height and width should be roughly 1: 10; however, it may differ with local conditions. Shelterbelts upto 50 m width are considered ideal under Indian conditions.

v) Number of rows

Windbreaks of three to five rows are more effective for majority of the farm situations and are less affected by gaps caused by mission trees. Tall growing tree species should be planted in the middle rows and small shrub species in the outside rows.

vi) Tree spacing

Distance between trees differs with the relative importance of the protective versus productive purposes of the wind break. Where the produce of wind breaks have a high priority, and then farmers may favor greater

number of shorter strips, and a higher proportion of small trees and shrubs which provide products such as fodder and fuelwood. If the produce is timber, the spacing of wind breaks and the intervals between them can be increased.

vii) Gaps

Gaps are required for gates and tracks; however, because of the funneling effect through gaps, wind velocity in these areas can be considerably increased. In multi row wind breaks this can be eliminated by angling the gap at about 45^{o} to the prevailing wind direction. Alternatively, a few trees or shrubs can be used on either side of the gate or track to broaden the gap and reduce the funneling effect. Other solutions are to plant five or six trees at an angle to the main belt as a wing or to plant a second short row to cover the gaps.

viii) Choice of species

The selection of trees and shrubs for the establishment of windbreak should be based on the features of species *viz*., hardiness, good form and foliage, fairly fast growth, longevity, deep root system which does not spread into nearby fields, resistance to drought, low maintenance, pest and disease resistance and suitable for planting site and that fit to windbreak design. An ideal windbreak should consist of a central core of a double-row planting of fast and tall growing species such as *Acacia auriculiformis, Eucalyptus* spp., *Casuarina* spp., *Dalbergia Grevillea, Syzygium, Tamarix articulata, Parkinsonia aculeate, etc.* and two rows each of shorter spreading species such as *Cassia* spp., or *Leucaena* spp. on both sides of the central core.

Since the trees alter their shapes as they grow, it is habitually necessary to mix several species of diverse growth rates, shapes and sizes in multiple rows. Some fast growing multipurpose species should be used to establish the desired effect as rapidly as possible. In addition, some of the trees selected may not be as long-lived as others. Fast and slow growing species as well as trees with longer and shorter life spans should thus be mixed to extend the useful life of the windbreak. Mixing species also provides protection against attack from diseases or insects that can easily destroy single species stands.

Features of windbreak design examples

a) Single row windbreak

A single row wind break should be used only where land is so valuable that only a little amount of space can be available for tree planting. It is used for field crop or orchard protection. Dense plantation provides maximum effect. Use shrubs and dense evergreens that retain lower limbs and foliage like junipers, spruces and densely branched deciduous trees, preferably with narrow crowns. The main disadvantage of a single row wind break is that if one tree is vanished by pest and diseases, gap is created, which reduces the efficiency of the entire wind break.

b) Two row windbreak

Two row windbreaks are used for field or orchard protection, outdoor storage place, urban setting and also for few wildlife values. They are densely planted as in single row system.

Plants are alternately planted with a space in one row filled by the tree in the other row and rows are close together. Standard two row wind break uses two rows of dense evergreens, or one evergreen and one shrub or deciduous tree row; standard between row spacing.

Fig-7.7: A single row windbreak

c) Three row windbreak

Three row windbreak is for field protection of bigger area, farmstead and feedlot protection; wildlife conservation with the row of food bearing shrubs. It consists of at least one row of dense evergreens and other two rows of deciduous trees, shrubs or pines.

d) Four row (or more) windbreak

Four row windbreaks are established for farmstead and feedlot protection and is excellent for wildlife. It uses mix of shrubs, deciduous trees and at least one row of dense evergreen trees.

It can alternate similar species within rows. Greater design flexibility can uses a large area of land.

In general wind breaks of three to five rows are more effective for most farm situations and are less affected by gaps caused by missing trees.

F) Industrial agroforestry

Forests are playing a considerable function in the economic prosperity and ecological stability of the country. The Indian forests faces vigorous biotic and abiotic pressure leads to shrinking of its geographical distribution and the forest dependent industries are at the cross roads. The speed of deforestation at an alarming rate of 1.5 million ha $year^{-1}$ and has fortunately come down quickly with the enactment of the Forest Conservation Act, 1980. Currently, the forest area in the country is around 24.39 per cent and in Tamil Nadu, it is around 23.85 per cent which is much low against the mandated requirement of 33.0 per cent. Not only is the forest wealth of the country very poor but also its productivity in terms of mean annual increment is also lowest.

The country imported six million cubic metres of timber and round woods and spent about Rs 18,000/- crore during 2014. National Research Centre for Agroforestry (NCRA) data suggests that India has 23,220 saw mills, 2,562 large and small plywood mills and 750 pulp and paper mills. Wood based industries are producing only 40 per cent of their total capacity because more than 70 per cent of wood industries are small, which are dependent on wood from small farmers who are not encouraged to produce. The least forest area coupled with the lower productivity of Indian forest has accompanied in a total mismatch between the demand and supply of both domestic and industrial wood requirement.

Industrial agroforestry is one of the practices which partly solve the demand and supply of wood based industries. Industrial agroforestry comprises the supply of raw materials to various wood based industries like pulp and paper, plywood, matchwood, dendro power, biofuel, *etc*., and the associated supply chain management. It have been recognized as an integrated part of Indian forestry in the recent past to meet the growing needs of industries, besides satisfying domestic demands. The forests as well as agricultural policies of the country have recommended strong farmer linked industrial wood plantation through benefit-sharing mechanism.

Several initiatives were made by popularizing industrial agroforestry practices at grass root level. For example in Tamilnadu, a Value Chain on Industrial Agroforestry in Tamil Nadu funded by National Agricultural Innovation Project (NAIP), ICAR through a consortium mode involving research organizations, wood based industries, nursery entrepreneurs, forest department, tree grower societies, NGOs, tree growing farmers and financial institutions popularizing industrial agroforestry. Through this consortium approach high yielding short rotation varieties in *Casuarina, Eucalyptus, Melia, Subabul, Gmelina, Ailanthus* and *Dalbergia sissoo* have been promoted and this has witnessed increased wood production (150 t ha^{-1}) and reduction in rotation (3-5 years). These activities have attracted several farmers towards tree husbandry and several hectares of plantations are established in association with all stake holders. Further, tree insurance model, an effective tool for legal security, through the participation of all stake holders are popularised which will ensure protection of farm grown trees against all abiotic and biotic damages and also ensured the farmer's economic benefits.

Agroforestry systems of India

In general, the common agroforestry systems being practised in different agro-ecological regions of India are, agri-silviculture, Boundary plantation, block plantation, energy plantation (trees + crops during initial years), alley cropping (hedges + crops), agri-horticulture (fruit trees + crops), Agri-silvi-horticulture (trees +

fruit trees + crops), agri-silvi-pasture (trees + crops + pasture or animals), silvi-olericulture (tree + vegetables), horti-pasture (fruit trees + pasture or animals), horti-olericulture (fruit tree + vegetables), silvi-pasture (trees + pasture/ animals), forage forestry (forage trees + pasture), Shelter belts (trees + crops), wind breaks (trees + crops), live fence (shrubs and under- trees on boundary), silvi or horti-sericulture (trees or fruit trees + sericulture), horti-apiculture (fruit trees + honeybee), aqua-forestry (trees + fishes) and homestead (multiple combinations of timber/ fruit/ fodder trees, vegetable and animals).

CONSTRAINTS IN ADOPTION OF AGROFORESTRY

Despite the remarkable potentials of food-tree-animal farming system is an effective land use option, relative to those of monocultures, the level of institutionalization and farmer adoption has generally lagged due to certain negative challenges.

i) Technical and economic knowledge gaps related to agroforestry systems

Many small and marginal farmers do not have the knowledge and skills to manage agroforestry. The use of trees for soil fertility or other benefits involves quite new concepts and therefore farmers need some basic trainings.

ii) Lack of secure land tenure

Land tenure has long been considered a critical factor by farmers to relocate food crops with trees and long term maintenance of agroforestry practices. Agroforestry reduced arable land in that it too long for benefits of the trees to be realized.

iii) Property rights to trees

On the one hand smallholder systems in India supply about 50% of wood and fuelwood demand, on the other here are still many restrictive regulations that potentially deter farmers from growing trees in agroecosystems and selling these in markets hinder agroforestry adoption of high value trees.

iv) Delayed liquidation

Delayed liquidation of planting investments is generally experienced due to long gestation period.

v) Biased cultivation aspects of trees

Past research and extension efforts are biased towards cultivation of exotic tree species and neglected indigenous species. The debate on the effect of reforestation on water availability and flood control has also contributed to some misconceptions about agroforestry and tree planting in general. For example, there has been gross simplification and generalization that trees consume too much water. This was essentially based on biased geographical data and monoculture plantation of exotic species. This has been further exaggerated in the popular press, with headlines like “Down with Trees” in the Economist.

vi) Lack of quality planting material

Genetically improved trees may provide more biomass and other products valued by the society, but presently research results in this field mostly remain in the laboratory or available in only few locations. A full mechanism starting from developing and registration of clones, decentralized certification and mass multiplication of suitable stock to ensure availability to farmers is required.

vii) Yield reduction due to interference effects

Although some traditional agroforestry systems increased crops yields near trees, there are instances where fast growing trees have reduced crop yields in the short term due to competition and allelopathic effects with the associated food crops. Possible competition of trees with food crops for space, sunlight, moisture and nutrients and allelopathic effects reduce crop yields.

a) Competition for light

Intercropping of food crops with the trees in their early years will help in better utilization of the resource. Reduction in crop yield form succeeding years of tree growth under agroforestry systems has been reported.

b) Competition for moisture

One of the primary assure of agroforestry, high water use by fast growing species and therefore alleged groundwater depletion is a common concern in dry regions that remains unresolved.

c) Competition for nutrients

The proportional abundance of fine roots of agricultural crops, grasses and trees suggests that there is a huge competition for nutrients between the crops and trees when grown in mixture.

d) Allelopathic effect

Allelopathy is considered as one of the major determining factors in tree-crop-soil interactions. The decaying litter and residues from the trees are reported to be effective source of phytotoxic phenolics that interfere with the growth of associated plants.

viii) Damage due to birds

It is generally believed that planting of trees in the agricultural land will attract the birds and thereby increase the risk of damage for annual crops.

ix) Trees act as alternate hosts

Some trees act as alternate hosts for insect pests. For instance, the sorghum hopper migrates to *Azardirachta indica* tree after harvest of crop and returns to the crop after completing its life cycle on the woody perennial.

x) Invasiveness of trees

Exotic tree species used in agroforestry can also become invasive and affect ecosystem functions and biodiversity. Some trees such as *Prosopis juliflora* have the potential to become invasive in new agroecosystems.

Chapter - 8

COMPONENT INTERACTIONS IN AGROFORESTRY SYSTEMS

An agroforestry component interaction is the influence of one component of a system on the performance of the other components as well as the system as a whole. Studying interactions helps to know how the components of agroforestry effectively share and utilize the available resources of the environment, and how the growth and development of any of the components will influence the others. In general, interaction occurs both below and above-ground and is used to describe interactions between components for growth factors absorbed through roots (nutrients and water), and those absorbed/intercepted through leaves (radiation exchange). However, it is suitable to consider these interactions based on their net results as positive, negative and or neutral. Interactions are usually termed as complementary (when the interaction is positive), supplementary (complementary force = competitive force) and competitive (when the interaction is negative). Fig. 8.1 shows schematically the relationships between two agroforestry components according to the type of interactions between them.

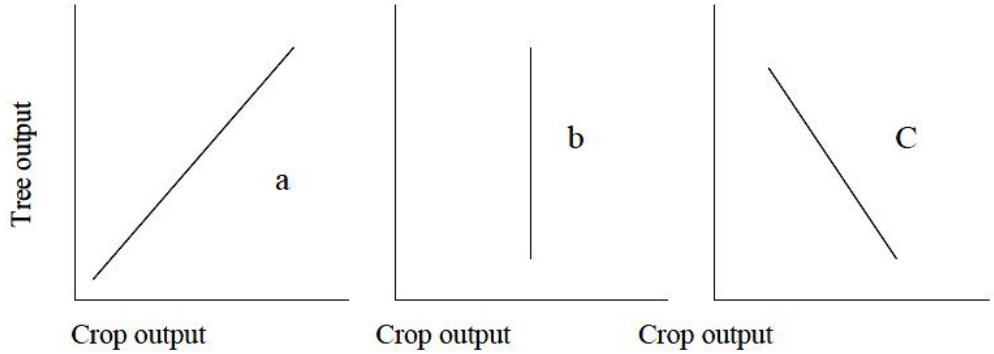


Fig-8.1: Complementary (a), supplementary (b) and competitive (c) interactions (Nair, 1993)

ICRAF have developed a tree-soil-crop interaction equation for quantifying tree-crop interaction (I), considering positive effects of tree and crop yield through soil fertility enrichment (F) and negative effects through competition (C) for growth resources between tree and crop. Where, I = F – C. If F > C, interaction is positive *i.e.*, agroforestry system is beneficial or productive; if F < C interaction is negative *i.e.*, agroforestry system is harmful or not productive; and if F = C, interaction is neutral. Positive, neutral or negative interactions leads to subdivision of interactions as presented in Table 8.1.

Table-8.1: Analysis of interactions between two populations A and B.

Type of interaction	**Effect of the interaction on the population**		**Nature of the interaction**	**Agroforestry example**
	A	B		
Mutualism	+	+	Interaction favourable to the two populations	Mycorrhizae, Rhizobium - legume
Facilitation	+	0	Interaction favourable for A but not obligatory; B not affected	Windbreaks, shade Trees, Alley cropping (well managed)
Commensalism	+	0	Interaction obligatory for A; B not affected	Support trees for vines; Improved fallows
Neutralism	0	0	None of the populations affects the other in crop land	Scattered trees
Parasitism/predation	+	–	Interaction obligatory for A; B is inhibited	Pest and disease
Amensalism	–	0	A inhibited; B not affected	Allelopathy
Competition and interference	–	–	Each population is inhibited by the others use of (above or below ground) growth resources	Alley cropping (poorly managed)

(0: No significant interaction; +: Advantage for the population in question (growth, survival, reproduction etc.); –: disadvantage for the population in question)

Complementary interactions

i) The tree-crop interactions

In agroforestry systems, microclimate amelioration involving soil moisture and soil temperature relations results primarily from the use of trees for shade or as live supports, live fences or windbreaks and shelterbelts. The provision of shade causes a net effect of complex interactions, which extend far beyond the mere reduction of heat and light. Temperature, humidity and movement of air as well as temperature and moisture of the soil, directly affect photosynthesis, transpiration and the energy balance of associated crops; the net effect of which may translate into increased yields.

In general, shading causes a reduction of temperature and temperature fluctuations as well as the vapor pressure deficit under tropical conditions. For example, comparing shaded versus open grown coffee plantations under the shade of *Inga jinicuil* (205 trees/ha with the average tree height of 14 m), the average maximum temperature was 5.4°C lower, the minimum temperature was 1.5°C higher and vapor pressure deficit was substantially reduced as compared to open grown coffee. The smaller temperature fluctuations under shade were attributed to reduced radiation load on the coffee plants during the day and to reduced heat loss during the night. Similar results, indicating a buffering effect of the trees on the microclimate beneath them, were also reported for a combination of coconut and cacao and for an alley cropping system of millet and Leucaena. A reduction of vapor pressure deficit will cause a corresponding reduction in transpiration and, hence, less likelihood of water stress for the shaded crop. This could be especially beneficial during short periods of drought and may result in production increases, as in the case of increased tea yields under shade. Similarly, bean plants associated with *Grevillea robusta* trees showed no signs of wilting in hot afternoons, whereas those grown on a field without trees exhibit wilting symptoms. Soil temperature will generally be affected in the same manner as air temperature *i.e.*, shading tends to exert a buffering effect on temperature fluctuations and extremes.

The presence of trees may have both positive and negative overall effects on the water budget of the soil and the crops growing in between or beneath them. Generally, a mulch or litter layer under shade trees acted as a barrier to moisture flow, since it increases the infiltration of rain water while simultaneously reducing evaporation of moisture from the soil. However, in some situations, especially in semiarid regions, the transpiration of the shade trees may actually increase water stress to the associated crops.

In nutrient recycling, nutrients can be taken up while leaching down to a deeper layer with tree roots acting as a safety net. It also taken up from weathered minerals in deeper layer, with deep tree roots acting as nutrient pump. Nutrient supply in the rhizosphere soil either by direct transfer if nodulated roots are in close contact with crop roots and root decay following tree pruning. The high quality litter (low C/N ratio, low lignin and polyphenolic content) will decompose rapidly and make nutrients available to the crops and the trees. Litter of low quality (high C/N ratio, high lignin and polyphenolic content) decomposes slowly and is suitable as mulch and maintains soil moisture during the dry season. The soil fertility improvement was mostly noted in the topsoil (0–20 cm). Generally, there is a fertility gradient with fertility decreasing from a tree's base to the edge of its crown or beyond. Higher SOM and organic forms of nutrients nearer the tree increased mineralization and greater availability of plant available nutrients under trees than in the open areas during the cropping season. Soil changes under trees influenced by species specific, size and age of the trees and site conditions and the magnitude of changes in the soil properties under trees was generally greater in light soils than in heavy soils.

Trees can improves soil physical conditions under their crowns, compared with open areas. Improvements are reflected through lower bulk density, lower surface resistance to penetration, increased porosity and greater aggregate stability. These changes would lead to higher rain water infiltration into the soil and higher availability of water to crops. Improvement in soil physical conditions is closely associated with increased SOM, as old tree roots decay; they leave channels that increase water infiltration, highly effective in controlling soil erosion; even within periods as short as 18 months with fast growing trees. Woody hedgerows provide a semi permeable barrier to surface movement of water, while mulch from the trees reduces the impact of raindrops on the soil and minimizes splash and sheet erosion. Current emphasis is on selection of tree species that provide effective physical barriers to erosion and produce mulch that offers a longer lasting protective role.

Another potentially positive interaction in agroforestry systems is related to suppression of weeds. The effect of shade is more severe for light demanding plants than for shade tolerant plants and could be an avenue to suppress light demanding weeds. For example, in alley cropping systems weed yield was positively correlated with available radiation. *Senna siamea* was reported to control weeds better than *Gliricidia sepium*. Similarly, weed reduction under closely spaced Leucaena alleys due to shading, pruning's in alley cropping was related to mulch quality, for instance slowly decomposing mulches suppressed weeds more effectively than mulches that decomposed more rapidly.

Allelopathy is a natural ecological phenomenon and it also positively and negatively interacts in agroforestry systems. Allelopathy was first used in 1937 by Molish to describe biochemical interactions that inhibit the growth of neighbouring plants, by another plant. The term was refined by Rice (1984) to define any direct or indirect harmful or beneficial effect by one plant (including microorganisms) on another through production of chemical compounds that escape into the environment. All tree species produce a good amount of leaf, litter and debris are rich in secondary metabolites like allelochemicals, which influences the pattern and distribution of adjoining flora and also regulates the nitrification, nitrogen fixation and ecosystem balance. Allelochemicals often imparts resistance to plants from pathogens, insects, nematodes and also reduces weeds. The leachates and purified compounds are eco-friendly alternatives to synthetic pesticides. For instance, aqueous extract from bark and leaf of *Eucalytus citriodora* showed allelopathic effect on the growth of weeds such as *Bidens pilosa, Digitaria pertenuis, Eragrostis cilianensis, Setaria geniculata.*

Reduced pest problems in agroforestry systems have been recorded due to greater niche diversity and complexity than in monoculture systems. This can be attributed to a number of mechanisms *viz.*, variable distribution of host plants makes it more difficult for pests to find the plants; a plant species which is highly attractive to pests can act as a 'trap-crop', protecting nearby economically valuable species from herbivore attack; a plant species which is repellent to pest herbivores may also deter them from other, more palatable, species in the vicinity; higher predator and parasitoid densities due to higher plant diversity increases pressure from natural enemies; and increased interspecific competition between pest and non-pest species limits the spread of pests. In certain cases, a toxic or deterrent compound can be extracted from trees and used for pest control, for instance azadirachtin in the *Azadirachta indica.* The leaves, oil, and cake as well as a water extract of crushed seeds, provide a cheap and effective means of pest management.

ii) The tree-animal interactions

The tree-animal interface influence overall system productivity animal production systems (grazing, semi-intensive and stall- feeding or zero grazing) in various ways. Most obviously, some part of the autotrophic production that is of no direct use to the farmer (such as weeds or tree fodder) can be transformed into animal biomass with high nutritional and monetary value. The productivity of the individual system components also increased through the transfer of manure as a fertilizer source and thus reduced the use of purchased fertilizers. For example, about 15 months of grazing sheep in a rubber plantation increased soil fertility and decreased weed competition, thereby resulting in larger diameter growth of the trees. The slight compaction of the soil due to trampling and treading was not sufficiently pronounced to affect tree growth.

The shade of trees reduced air temperature by 1-5°C which, in turn, contributed to a more favorable environment for cattle, goat, sheep and poultry production especially in tropics. To reduce heat stress, which is one of the main constraints to animal production in the tropics, animals (particularly high grade, non-indigenous animals) tend to seek shade; this tendency may significantly reduce the time spent grazing in the open. Consequently, depending on the degree of climatic stress, the breed and the type of animal and the quantity and quality of available pasture, total feed intake also reduced. However, except in extreme situations, this may be balanced by the reduced energy expenditure of the animal for thermoregulation, which may be the main reason that animals in shade generally show higher feed conversion ratio and ultimately higher weight gain or milk production.

Shade provided by agroforestry trees has a complementary interaction effect on animal reproduction. The performance becomes more significant for exotic livestock in tropical climates. It was reported that 0.9 per cent reduced calving rate for every 0.1 °C increase above 30.0°C in the rectal temperature of cows. Calving rate depressions in British breeds and Brahman crossbreds were 10 per cent and 10 to 25 per cent, respectively. Milk production differences were also noticeable, with increased mean yields of 2 kg per cow

compared to animals without shade, concurrent with a reduced rectal temperature of 39.4°C compared with 40.0°C for animals in open sunlight. The decreased lamb mortality and better protection of sheared sheep have been recorded as benefits of grazing under Pinus shade.

Additionally, good quality feed is essential for higher milk yield; if the feed is high in fiber and low in energy, which is the case in most tropical environments, milk production will suffer considerably. Despite the high variability in the nutritive value of shrub and tree fodder as livestock feed, they are very valuable especially in extensive systems involving small ruminants in arid and semiarid regions. In humid regions, leguminous fodder trees appear to be the most promising protein supplement.

Agroforestry systems potentially involve the management and use of the natural resources (crops, animals, land and water) in which these sub-systems and their synergistic interactions have a significant positive and greater total effect than the sum of their individual effects. For instance, integration of trees with complementary advantages include the presence of ponds under coconuts or fruit trees or crop growing ecosystems which further enable the integration of fish, vegetable crops and ducks. This diversification and effective use of the available natural resources presents the most important means to sustain livelihoods of small and marginal farmers, as well as maximize farm productivity.

Competitive interactions

The tree crop interactions

The major yield decreasing effects at the tree-crop interaction arise from competition for light, water and nutrients, as well as from interactions *via* allelopathy.

Competition for light

Shading was found to be more important than below ground competition in an intercropping study with pearl millet and groundnut in India. Competition for light was a more critical factor than root competition in agroforestry systems. The low yields from maize rows adjacent to Leucaena hedgerows and *Tectona grandis* due to shade. The availability of light may be the most limiting factor in many situations, particularly those with relatively fertile soils and adequate water availability, the relative importance of light will decrease in semiarid conditions as well as on sites with low fertility soils.

Crops differ in their responses to poor nutrition, competition for light or water may either be reduced or amplified by a shortage of nutrients. A good example of such an interaction between light and nutrients is recorded in the case of cocoa (Fig 8.2). The pod production of cocoa is maximum under conditions of high soil fertility and low shade, plants under nutrient stress yield more under shade than in the open; hence the importance of shade trees under low soil-fertility conditions.

The shade tolerance of crop plants depends on the photosynthetic pathway and the product to be harvested. In comparison to leaf yielding plants, fruit and seed yielding crops are relatively shade intolerant and should grown in open spaces. Crops such as coffee, cacao, vanilla and black pepper, which are traditionally grown under partial tree shade, can be expected to exhibit depressed yields as the intensity of shade increases unless they are subjected to nutrient or water stress. Further, in humid and subhumid environments, where adequate rainfall favours rapid tree growth, competition is primarily for light, resulting in significant negative effects (crop shading) on the intercrops. The shade of trees may have no effect or beneficial effect on shade tolerant and short-duration crops, while it may generally have negative interaction effect on other short-statured and longer duration crops.

Crop yield are noted mostly under the canopies of large, evergreen and unmanaged trees over open and treeless field. In India, wheat yields were reduced by up to 60 per cent and mustard (*Brassica* sp.) yields by up to 65 per cent under *A. nilotica* trees. The reduction of crop yields under trees is mainly due to reduced light.

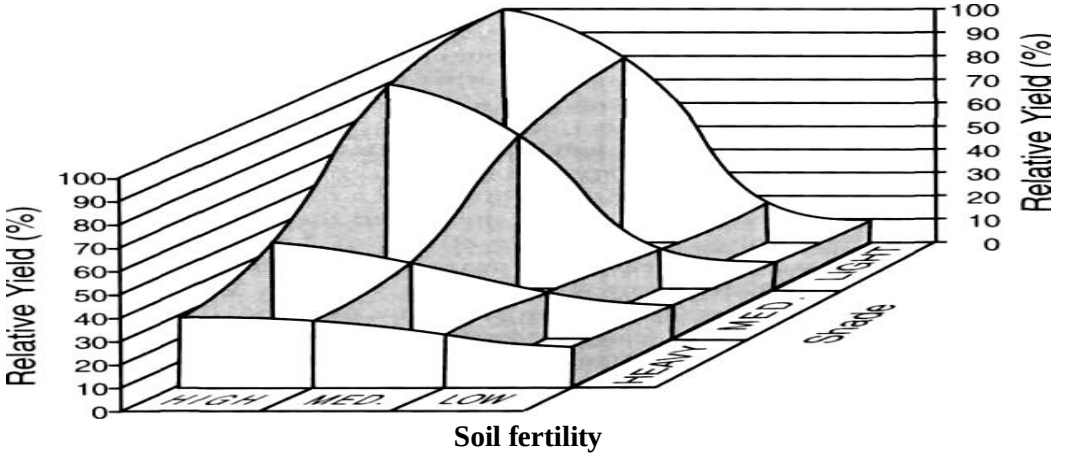


Fig.8.2 Interacting effects of shade and soil fertility on the yield of crops in agroforestry systems (Nair, 1993)

Competition for nutrients

Competition for nutrients in intercropping systems is one of the main reasons leading to the reduction of crop yield and the competition for soil nutrients and has a negative interaction in trees and crops intercropping. The hedgerows of *Inga edulis* reduced the yield of rice in rows closest to the hedgerows by up to 50 per cent by one year; root pruning of hedgerows at 25 cm from the hedgerow base, to 20 cm soil depth, significantly increased the rice yield by 20 per cent when compared to yields from alleys without root pruning. On alluvial soils at the same location, crop yield reductions were noted up to 1.5 m from hedgerows, for three different tree species.

Competition for water

Competition of water is depends on the rainfall pattern, availability of below ground water, severity of the water deficit situation and the drought tolerance of the plants. Substantial reduction of crop yields even when crops were fertilized at recommended rates confirms that the inadequacy of water to meet the demands of hedgerows and crops is the principal factor determining crop yields in semiarid climates. Thus, despite the use of drought adapted plants, water competition is likely to play a major role in the productivity of agroforestry systems, especially in dry areas. In the semiarid tropics, the competition of hedgerow trees with crops is primarily for water. In alley cropping trials of *Leucaena* sp. with cowpea, castor and sorghum under semiarid conditions in India, competition for water appeared more important than shading effects. Likewise, the soil moisture effects of 3.5 year old *Eucalyptus tereticornis* on mustard and wheat yields next to the tree line reduces over 30 per cent for the crops growing at a distance of less than 10 m from the tree line.

Similarly, on Alfisols with 600 to 700 mm of rainfall during the main cropping season, yields of a number of crops with leucaena were severely reduced (up to 90%) as compared with the crop only control. Installation of a root barrier, up to 0.5 m depth, between leucaena hedges and crop rows removed the effect of belowground competition and restored crop yields almost to the level in sole cropping. In the same way, detailed measurements of soil water in the 165 cm soil profile during three consecutive seasons under hedgerow intercropping with *Senna* spp. (*S. siamea* and *S. spectabilis*) and a maize–cowpea annual crop system highlighted the importance of competition of hedgerows for water in semiarid environments. Soil water under both hedgerow intercropping systems was lower than in the annual crop system throughout the study period and the differences were greater in periods of water stress.

Allelopathy

Allelopathic substance was first detected by Davis (1928) in black walnut tree (*Juglans nigra*) whose foliar leachate containing Juglone damaged germination and seedling growth of crops beneath the tree. Leaf leachates of *Acacia auriculiformis, Casuarina equisetifolia, Bambusa arundinacea* and *Tectona grandis* significantly inhibited germination percentage and growth of vegetable crops like tomato, brinjal and chilli.

Allelochemicals like terpenoids volatalize from the tree foliage is enhanced in hot weather especially in arid regions. Volatile terpenes present in Eucalyptus exert maximum allelopathic potential of the tree. Eucalyptus

oil vapours get absorbed on the soil surface, thus adversely affected the germination, shoot and root growth of surface feeding plants.

Leached substances from plants during rain, dew, mist, snow and fog reach the soil beneath, or aerial parts of ground vegetation beneath the trees intercepts or absorbed through roots causes adverse effects in receiver species. At times, the phytotoxic allelochemicals of leaves and barks of the tree dissolved in the leachates may cause injury to the donor plants.

Varieties of compounds are also exuded from the roots and influence the growth of microorganisms and associated plants. The rhizosphere of some of the trees is rich in allelochemicals which are injurious to underneath or neighbourhood vegetation. For example, the allelochemicals found in the Eucalyptus rhizosphere are injurious to the nearby vegetation. In agroforestry, the largest sources of the allelochemicals are added to the rhizosphere through death and decay of fallen plant parts, mainly the leaves and crop residues.

Higher concentrations of leaf and bark leachates showed inhibitory effects on the radical and plumule growth of most agricultural crops. Even though certain trees may release harmful chemicals into soil through leaf litter or root secretion, they may have only temporary or no effect on crops under field conditions because of rapid elimination of chemicals by soil microorganisms and/or leaching, particularly in the humid environments. The practical significance of allelopathy cannot be ascertained unless the effect of allelochemicals on crop yields is demonstrated under field conditions, independent of the competition of trees for water and nutrients, and independent of the temporary immobilization of plant nutrients due to the addition of low quality tree litter.

Microclimatic modification for pests/diseases

The effect of plant associations on pest and disease incidence is a potentially important but rather unexplored area. Bacterial and fungal diseases may increase in shaded, more humid environments like the incidence of *Phytophthora palmivora* on cocoa increases greatly under conditions of heavy shading. The main reasons for this are probably greater relative humidity, which is tending to favor fungal growth. This situation is likely to apply to other crop plants susceptible to Phytophthora.

The tree-animal interaction

The most important negative interactions between animals and plants can be classified as direct effects. The mechanical damage of trees or deterioration of soil properties through compaction have a negative impact on crops. Among ruminants, cattle and sheep are well suited to integration with tree crops. Goats are more selective in their feeding habits because they are browsers, and are therefore only more suited when both browse and forages are available in agroforestry systems. Goat, sheep, cattle and buffaloes are damages trees, especially during early or young stage and the bark of a tree.

On the other hand, the toxic components and low quality of tree fodder can adversely affect livestock production. While tree fodder holds great promise, particularly as a dry season supplement in semiarid areas, its value should not be overestimated. Many species contain secondary compounds that reduce the feed value. The presence of high levels of phenolic compounds (tannins) or strong odors found in the leaves of species such as *Senna siamea* and *Gliricidia sepium* may reduce palatability or acceptability of the fodder. In addition, digestibility can be low and the leaves may contain toxins or toxic concentrations of certain micronutrients. For instance, the toxic compound mimosine found in Leucaena fodder and cyanogenic glucosides in Acacia species.

COMPONENT MANAGEMENT IN AGROFORESTRY SYSTEMS

Agroforestry systems are designed to optimise resource capture by maximising positive interactions and minimising negative ones. Appropriate selection of the woody and crop or livestock species of the system to meet site and farm production requirements is necessary, as well as careful consideration of the potential interactions between the different species. Ideal tree species for agroforestry systems should maximise niche differentiation between the tree and crop; deep roots are key to access nutrients and water unavailable to the crop and either a crown that is in leaf outside the crop's main growing period or that casts a light even shade. The spatial design of the system will also influence productivity by determining the zone of interactions between the trees and crops, and therefore, the relative potential benefits. For example, trees distributed

evenly will have a larger zone of interaction with the adjacent crop or pasture when compared to a clumped distribution and in tropical regions, orientating tree rows in east west direction is generally accepted as the most efficient orientation to optimise direct sunlight penetration to the crop/pasture.

The selection of suitable tree species for agroforestry is important. However, it is not always possible to select tree species having all the desirable characteristics for agroforestry, because of different production and protection goals. It is stated that in such cases, agroforestry systems have to be managed through planting optimum density of trees, proper spatial arrangement, and pruning and thinning of tree crowns and roots to reduce the negative effects of trees.

In the agroforestry systems, productivity of each component can be manipulated by management practices including pruning, weed control and protection from animal damage. Controlling the density of the tree canopy through pruning will determine the amount of sunlight reaching the crop or pasture, and is particularly important in hardwood systems to ensure good quality timber. Below ground pruning of tree roots through management practices such as trenching, disking or subsoiling, etc., aims to minimise belowground competition and consequently prolong profitable crop production.

Manipulating densities and arrangements is probably the most powerful method for capitalizing on beneficial effects of trees while reducing negative ones. However, in some cases, for example, when trees are used as supports for crop plants, the planting density of the trees is determined by the planting density of the crops. Therefore, in these cases, choosing wider plant spacing for trees with larger crowns may not be a valid option. Hence, theknowledge of the light transmission characteristics of the tree crowns and of the options for tree management will become important.

Several characteristics could be identified as desirable attributes for trees in agroforestry systems; but often it is not possible to choose trees with all these characteristics, either because other plants are already established, or because production or protection goals favor the choice of other. Whenever a tree species with all the desired characteristics is not available, tree crowns and roots can be manipulated through management operations, mainly by pruning and thinning. Other common management operations such as fertilization, application of mulch and manure, cut-and-carry fodder systems and confinement or rotation of the animals also are employed.

The goals of management practices should be to increase the production of the desired products and to decrease growth and competition of undesired components. In many cases, one cultural treatment will accomplish both goals simultaneously *e.g.*, in the case of pruning trees in alley cropping and applying the biomass to the soil. While the removal of parts, or the entire crown will obviously reduce the tree's competitive ability and it will automatically increase the growth of the associated intercrop by allowing more light to penetrate to the crop.

Below ground competition may also be reduced as a result of pruning induced root die-back. These observations also apply to pruning or pollarding operations on trees grown for shade or as live supports, such as legumes of the genera *Erythrina* or *Gliricidia*. Species which have large thick leaves and high rates of biomass production when grown as a shade tree, will require more intensive pruning than trees with a less dense canopy *e.g. Gliricidia sepium*.

Root pruning operations or trenching may eliminate, or at least strongly reduce, the negative effects or below ground competition of the trees on the intercrop. To ensure compatibility between livestock and trees, appropriate choice of species, control of grazing, covering the stem of trees with wire mesh up to a reachable height and also the optimum age of trees when the canopy is out of reach of the animal are important considerations.

Chapter - 9

AFFORESTATION OF WASTELANDS AND DEGRADED LANDS

The pressure on the soil is often beyond its carrying capacity and the productivity of lands. In India constant progression of various degrees of degradation cause fast turning of fertile lands into wastelands. In the last six decades, India's blossoming green forests and woodlots have been deforested to the upper limit. At present, approximately 63.87 million ha area of the land is lying as wastelands/ degraded lands in India. Out of these lands, roughly 50 per cent is unproductive non forest lands, which can be made fertile again if managed properly.

The non technical definition of wasteland is 'An empty area of land, which is not used to grow crops or built on, or used in any way and/or a place, time or situation containing nothing positive or productive, or completely without a particular quality or activity'. The technical task group report of the national wastelands development board defines 'the wasteland as a land which is presently lying unutilized due to different constraints'.

ICAR proposed that 'wastelands are lands which due to neglect or due to degradation are not being utilized to their full potential. This can result from inherent or imposed disabilities or both, such as location, environment, chemical and physical properties and even suffer from management conditions'. According to Integrated Wasteland Development Programme, 'wasteland is a degraded land which can be brought under vegetative cover, with reasonable effort and which is currently under utilized and land which is deteriorating for lack of appropriate water and soil management or on account of natural causes'.

National Wastelands Development Board (NWDB) defined wasteland as that land which is degraded and is presently lying unutilized (except as current fallow) due to different constraints.' NWDB also suggested that any land which is not producing green biomass consistent with the status of soil and water must be treated as wasteland. Although no consensus have yet been arrived at definition of wasteland but it is largely accepted that wastelands are the areas which are underutilized and which produce less than 20 per cent of its biological productivity.

Classification of wastelands

Wastelands are broadly classified in to two categories namely culturable and unculturable.

I. Culturable wasteland

Culturable wastelands are those lands which have the ability for the development of vegetative cover or may be reclaimed at later stage. These lands includes gullies and or ravinous lands, undulating upland surface, water logged and marshy areas, salt affected land, shifting cultivation area, degraded forest land, sandy area, mining and industrial wasteland, strip land, pasture and grazing land.

II. Unculturable wasteland

The land that cannot be developed for vegetative cover like the barren rocky areas and snow covered glacier areas.

Currently National Remote Sensing Centre (NRSC) and Ministry of Rural Development (MoRD), 2010 classified the wastelands/ degraded lands into 12 major groups.

1) Gullied and/or ravinous land

Gully is a narrow channel when surface water flow increases in response to clearing and excessive use of land. The factors involved in gully initiation are the type of landscape, geology, soil texture, rainfall, hill slope length and seasonal climatic extremes. The intricate network of gullies is referred to as ravines. The word 'ravine' means a deep gorge and represents the last stage of water erosion. Ravines are the systems of gullies running almost parallel to each other and draining into a river after a short distance with the development of deep gorges. Two categories of ravines viz., medium ravines and deep ravines could be delineated based on their depth.

a) Medium ravines

These are the ravine lands with a depth of gullies ranging between 2.5 and 5 meters. Generally, these are seen confined to the head region of the stream close to agricultural land.

b) Deep ravines

The depth of ravines is more than 5 meters. Deep ravines, generally, occur along the higher order stream areas that are close to the main river.

2) Scrubland

Scrubland includes topographically high locations, excluding hilly/mountainous terrain. Scrubland is generally prone to deterioration due to erosion. Based on the occurrence of vegetation cover, two sub classes could be delineated *i.e.,* land with dense scrub and land with open scrub.

a) Land with dense scrub

These lands have shallow and skeletal soils, extremes of slopes, chemically degraded, severely eroded and are subjected to excessive aridity with scrubs dominating the landscape. They have a tendency for intermixing with croplands.

b) Land with open scrub

This category is same as pointed out in the previous category except that it has sparse vegetative cover or is devoid of scrub and has a thin soil covers.

3) Waterlogged / marshy land

Waterlogged land is that low lying land where the water is at/or near the surface and the water stands for most part of the year. Depending on duration of waterlogging, two sub classes viz., permanently waterlogged and seasonally waterlogged areas.

a) Permanent

Permanently waterlogged areas are those where the waterlogging conditions prevail during most part of the year. These areas are mostly located in low lying areas, with impervious substratum along the canals/ river banks, coastal inlands, etc.

b) Seasonal

Seasonally waterlogged areas are those where the waterlogging condition prevails generally during the monsoon period. These lands are mostly located in plain regions associated with the drainage impediment.

4) Land affected by salinity and alkalinity

Land affected by salinity and alkalinity have excess soluble salts (saline) or high exchangeable sodium. Salinity is caused due to capillary movement of water, during extreme weather circumstances leaving salt encrustation on the surface. Alkali soils have exchangeable sodium percentage (ESP) values of more than 15. The predominant salts in alkali soils are carbonates and bicarbonates of sodium. Considering the degree of salinity and or alkalinity, the following two sub classes *viz*., moderately saline / alkali and strongly saline / alkali areas could be delineated.

a) Moderately saline/alkali land

These are the areas located in the fluvial plains with the degree of salinity (ECe) ranging from 8 to 30 (dSm^{-1}), pH between 9.0 – 9.8 and the Exchangeable Sodium Percentage (ESP) values ranging between 15 – 40.

b) Strongly saline/alkali land

These are the salt affected lands with ECe values greater than 30 dSm^{-1}, pH values more than 9.8 and ESP values of > 40.

5) Shifting cultivation areas

Shifting cultivation is a traditional practice of growing crops on forested/ vegetated hill slope by the slash and burn method. This region is classified in to two catagories.

a) Current

The areas that are currently used for cultivation by the slash and burn practices and are clearly perceptible on the satellite image in a pre burnt and post burnt conditions.

b) Abandoned

Areas that are earlier under shifting cultivation however subsequently leave idle for more than one year but less than 5 years, thereby giving a scope for the regeneration of secondary vegetation. This category has a tendency to get mixed with forests.

6) Scrub forest

Two sub classes *viz*., scrub dominated degraded forest land and agriculture land inside notified forest area have been delineated.

a) Scrub dominated
Land, as notified under the Forest Act and those lands with various types of forest cover with less than 20 per cent of vegetative cover are classified as degraded forest. These lands are generally confined to the fringe areas of notified forest.

b) Agricultural land inside notified forest land
This category refers to land that have been notified under the Forest Act, in which agriculture is being practiced (except for the de-notified forest areas).

7) Degraded pastures and grazing land
These are the lands in non-forest areas that are either under permanent pastures or meadows, which have degraded due to lack of proper soil and water conservation and drainage development measures.

8) Degraded land under plantation crop
The degraded lands that have been brought under plantation crops after reclamation, and are located outside the notified forest areas.

9) Sandy areas
This category refers to land with accumulation of sand, in coastal, riverine or inland areas. Generally, these lands vary in size, occur in various shapes with contiguous to linear pattern. These lands are mostly found in deserts, riverbeds and along the sea shores.

a) Coastal sand
Coastal sands are the sands that are accumulated as a strip along the sea coast due to action of seawater. These are not being used for any purpose like coastal plantation, recreation, etc.

b) Desertic sand
Desertic sands are confined in arid environment where the rainfall is scanty and characterized by accumulation of sand in the form of varying size of sand dunes and height that have developed as a result of transportation of soil through aeolian processes. There are two categories of desert sands could be identified based on their vertical approximate heights *viz*., semi stabilized to stabilized dunes with >40 m height and semi stabilized to stabilized moderately high dunes with heights ranging between 15 and 40 m.

c) Riverine sand
Riverine sands are accumulated in the flood plain of the river as sheets, or sand bars. It also includes inland sand which was accumulated along the abandoned river courses or by reworking of sand deposits by wind action leading to long stretches of sand dunes or sand cover areas.

10) Mining /Industrial wastelands
a) Mine dumps
These are those lands where waste debris is accumulated after extraction of minerals. Included in this category is the mine / quarry areas subject to removal of different earth material (both surface and sub-surface) by manual and mechanized operations. Large scale quarrying and mechanical operations result in creation of mine dumps. It includes surface rocks and stone quarries, coal mine, sand and gravel pits, soil excavation for brick kilns, etc.

b) Industrial
These are areas of stockpile of storage dump of industrial raw material or slag/effluents or waste material or quarried/mixed debris from earth's surface.

11) Barren Rocky Area
The rock exposures of varying lithology often barren and devoid of soil and vegetative cover. It occurs amidst hill forests as openings or as isolated exposures on plateau and plains. Barren rocky areas occur on steep isolated hillocks/hill slopes, crests, plateau and eroded plains associated with barren and exposed rocky/stony wastes, lateritic out crops, mining and quarrying sites. The category also includes steep sloping areas devoid of vegetation cover.

12) Snow covered and / or glacial area

The lands are under perpetual snow cover and are confined to the Himalayan region. The mountain peaks and slopes and high relief areas are the places where snow/glacial areas occurs.

Wastelands/ degraded lands of India

The estimates on wastelands/ degraded lands/soil degradation are available from various national organisations like NCA, National Bureau of Soil Survey and Land Use Planning (NBSS & LUP) of Indian Council of Agricultural Research (ICAR), National Remote Sensing Centre (NRSC) (erstwhile NRSA) of Department of Space, *etc*. The area statistics of degraded lands/ wastelands reported by these organisations vary from 11.34 to 187.7 million ha (Table 9.1). These variations are essentially because of the differences in objectives, class definitions, approach/ methodology, scale of mapping, *etc*.

Table-9.1: Land degradation assessment by different organizations

Agency	Estimated Area (m ha)
National Commission on Agriculture (NCA, 1976)	148.09
Ministry of Agriculture (1978) (Soil and Water Conservation Division)	175.00
Society for Promotion of Wastelands Development (SPWD) (Bhumbla and Khare, 1984)	129.58
NRSA (1985)	53.28
Ministry of Agriculture (MOA, 1985)	173.64
Ministry of Agriculture (MOA, 1994)	107.43
NBSS & LUP (1994)	187.70
Department of Environment (Vohra, 1980)	95.00
National Wasteland Development Board (1985)	123.00
NRSA (Wasteland Map) (1986–2000)	11.34
NBSS & LUP (Soil degradation map) (1986–1995)	34.65
NRSA and MoRD (2000)	63.85
NBSS&LUP (2004) (revised)	147.75
ICAR – NASS (2010) (Preliminary Assessment) (Trivedi, 2010)	114.01
ICAR – NASS (2010) (Harmonized data) (Trivedi, 2010)	120.72
NRSC and MoRD (2010)	47.21

The recent classification scheme adopted for monitoring of wasteland on 1: 50,000 scales are presented in Table 9.2.

Table-9.2: Categories of wastelands in India

Particulars	Area (m ha)
Gullied and/ or ravinous land (Medium)	0.70
Gullied and/ or ravinous land (Deep)	0.17
Land with Dense Scrub	9.34
Land with Open Scrub	9.16
Waterlogged and Marshy land (Permanent)	0.25
Waterlogged and Marshy land (Seasonal)	0.30
Land affected by salinity/alkalinity (Medium)	0.54
Land affected by salinity/alkalinity (Strong)	0.17
Shifting Cultivation - Current Jhum	0.56
Shifting Cultivation - Abandoned Jhum	0.46
Under-utilised/degraded forest (Scrub domin)	8.58
Under-utilised/degraded forest (Agriculture)	1.64
Degraded pastures/ grazing land	0.72
Degraded land under plantation crop	0.03
Sands-Riverine	0.24
Sands-Coastal	0.07
Sands-Desertic	0.53

Sands-Semi Stabilized: Stab > 40m	1.12
Sands-Semi Stab.-Stab 15-40m	1.56
Mining Wastelands	0.05
Industrial wastelands	0.01
Barren Rocky/Stony waste	6.94
Snow covered /Glacial area	4.07
Total	47.21

NRSC and MoRD. 2010

According to harmonized area statistics, total degraded area comes to 120.8 m ha out of which 73.3 million ha is estimated to suffer from water erosion, 12.4 m ha from wind erosion, 17.4 m ha from chemical degradation, and 1.1 m ha from physical degradation (Table 9.3).

Table-9.3: Spatial distribution of degraded and wastelands of India

Degradation type	Arable land (M ha)	Open forest (< 40 % canopy) (M ha)
Water erosion (>10 tonnes/ha/yr)	73.27	9.30
Wind erosion	12.40	-
Sub total	85.67	9.30
Chemical degradation		
Exclusively salt-affected soils	5.44	-
Salt-affected and water eroded soils	1.20	0.10
Exclusively acidic soils (pH< 5.5)	5.09	-
Acidic (pH < 5.5) and water eroded soils	5.72	7.13
Sub total	17.45	7.23
Physical degradation		
Mining and industrial waste	0.19	-
Water logging (permanent surface inundation)	0.88	-
Sub total	1.07	-
Total	104.19	16.53
Grand total (Arable land and open forest)	120.72	

(Trivedi, 2010)

Management of wastelands and degraded lands with tree planting

Ever increasing global population and pressure on agricultural land for industrial and other infrastructural projects, waste land reclamation has become a priority to ensure sustainable food production and environmental conservation. Degraded lands can be suitably reclaimed for agriculture or some alternate uses through afforestation and agroforestry. Till the sixth five year plan, no specific programme of wasteland development was taken up. In 1985 with establishment of National Wastelands Development Board (NWDB) under the Ministry of Environment and Forests, the problem of wasteland development received a new thrust. With the setting up of NWDB, a number of new schemes were initiated to secure people‘s participation, besides continuation of ongoing afforestation schemes.

- Decentralized people’s nurseries
- Silvipasture farms
- Seed development
- Area oriented fuel wood and fodder projects
- Ariel seeding programme
- Plantation of minor forest produce
- Margin money schemes
- Rural employment scheme

Wasteland and degraded land development programme have to consider the following *viz*., identification of nature, extent and location of wastelands and their availability for agricultural uses and identification of technology and management practices suitable for specific type of wasteland, taking into account the availability of resources for their care after planting or introduction.

Components of wasteland development plan

The design and construction of physical structures (check dam, gully plugs, contour bund and percolation pond); the types of vegetative cover or trees to be introduced in different segments of the wasteland; and measures to augment the productivity of arable and non-arable land by making use of the improved soil moisture conditions.

Choice of species

Reclamation with vegetation helps in ameliorating microclimatic conditions and has a marked catalytic effect on succession on severely degraded sites. It plays a critical role in restoring productivity, ecosystem stability and biological diversity through numerous processes, including maintenance or increase of soil organic matter, biological nitrogen fixation, uptake of nutrients from deep soil layer, increase water infiltration and storage, reduce loss of nutrients by erosion and leaching, improve soil physical properties, reduce soil acidity and improve soil biological activity.

Plant species chosen should be preferably native of that place and should be fast growing so that it can provide quick and immediate vegetative cover and accumulate biomass rapidly on degraded sites to avoid further damage. Local species are most suitable, better adapted as well as economically and ecologically viable for reclamation. Choice of species based on seed and seedling availability, local uses for the species, economic aspects represent lower successional stages, maintains itself indefinitely without attention, having higher root soil binding characteristics and high esthetic, economic and ecological values, nitrogen fixing, improving the soil fertility such as the soil organic matter, available soil nutrients and soil microbial biomass.

Reclamation of ravines

Optimum utilization of ravines a detailed classification was proposed in which gullies have been classified into six reclaimability classes.

Class 1: Shallow gullies which require minor leveling work on gently sloping sides on bed for reclamation for agriculture. They have favorable soil texture for most of the crops. The bed may be wide enough to be converted into agricultural fields with minor shaping. Good management practices are required.

Class 2: Gullies which require moderate leveling work for reclamation for agriculture. The gullies are 1.5–3 m deep and sides are more sloping than in Class 1.

Class 3: It has got more limitations than Class 2 of reclaimability class gullies. Soil texture may be lighter or heavier than loam and the gully may be deeper, presenting more limitation for reclamation and management of reclaimed gully for cropping.

Class 4: It has severe limitations for reclamation for agriculture in the soil texture or gully dimensions. Steeper side slopes and more gully depth constitute a borderline case for reclamation for cropping. Such gullies may be put under agri-horticulture after constructing narrow terraces

Class 5: This category includes gullies described in Classes 1–4, but they cannot be gainfully reclaimed for agriculture as they are prone to seasonal back flows from a nearby river or have developed water logging, salinity problems, etc., due to irrigation of the adjoining table land or any other adverse factors. Under such very adverse conditions, gullies may be put under perennial vegetation like suitable fuel and fodder trees and grasses (silvipasture).

Class 6: Gullies presenting limitations more severe than Class 4 in soil characteristics like texture and gully features like depth and side slopes are included in this category and put under perennial vegetation.

Measures for checking extension of gullies

- Protection of the soil by good crop canopy during rains.
- Control of sheet and rill erosion through proper land and tillage management practices.

- ❖ Immediate stabilization of sheet or rill erosion through specific slope treatment measures such as stone bunds, construction of drop structures, terraces and inter-bund land surface configurations.
- ❖ Maintenance of organic matter in the soil and soil fertility through proper inputs, crop rotation and control of land degradation.
- ❖ Revegetation or maintaining remnant vegetation in drainage lines and eliminating grazing from these areas.
- ❖ Control of grazing and revegetation of community land and grassed waterways in general.
- ❖ Reducing the slopes of the gullies by levelling and diverting the surface flow are essential pre-requisites for any successful afforestation programme.

Agroforestry approach

In the gullies belonging to reclaimability Classes 1, 2, 3; all local crops are grown in gully beds and on bench terraces made on gully sides. Class 4 may be put under arable crops along with fruit trees at required spacing in agriculture crops in gully beds. Classes 5 and 6 may be planted under perennial vegetation like fuel and fodder producing trees and grasses. For instance by planting and protection of grasses, good green fodder yield is achieved in 2–5 years. *Cenchrus ciliaris* and *Cenchrus setigerus* grasses could provide 5–7 t ha^{-1} yr^{-1} air dry fodder which is equivalent to 18–20 t ha^{-1} yr^{-1} of green fodder. This practice also reduces runoff and soil loss considerably to the tune of 6–10 t ha^{-1} yr^{-1}. In most ravenous tracts, the secondary succession takes 10–15 years to reach a stable tree stage while in ravine bottom it takes 6–7 years only.

Trees: *Acacia nilotica, Acacia catechu, Azadirachta indica, Albizia lebbeck, Citrus limon, Dendrocalamus stricuts, Dalbergia sissoo, Emblica officinalis, Eucalyptus sp., Prosopis chillensis, Mangifera indica, Ziziphus mauritiana*

Live hedges: *Agave americana, Arundo donax, Impomea carnea, Vitex negundo.*

Grassess and legumes: *Cynodon dactylon, Cenchrus ciliaris, Cenchrus setigerus, Dicanthium annulatum, Heteropogon contortus, Panicum maximum, Pennisetum pedicllatum, Saccharum spontaneum, Stylosanthes, Vetiveria zizanioides*.

Management strategies for waterlogged and marshy lands

Waterlogged and marshy land vegetation plays a major role in erosion control, which in turn contributes to shoreline stabilization and storm protection. Proper drainage, ridge and furrow or/ mound methods of planting with waterlogging tolerant species are important to reclaim these areas. Tree species suitable for the waterlogged areas are: *Acacia nilotica, Eucalyptus robusta, E. camaldulensis, E. globules, Populus nigra, Syzygium cumini, Salix spp., Terminalia arjuna* etc. In marshy places, trees species best adopted are: *Baringtonia spp, Bischofia javania, Eucalyptus robusta, E. rudis, Lagerstroemia flosreginea*.

Reclamation of salt affected soils

Crop production in saline and sodic soils is neither feasible nor economically profitable. This is due to the specific soil and water related constraints of these soils. Saline soils have excessive amounts of soluble salts which adversely affect the growth of most crop plants. Similarly, the high exchangeable sodium present in sodic soils is injurious to most crop plants. The soils are characterized by high pH, low organic matter, excessive exchangeable sodium, high clay dispersion, hard pan formation and salt accumulation in the root zone (Table 9.4). Several factors contribute to the development of salinity and alkalinity *viz*., Arid and semi-arid climate (low rainfall and high evaporative demand), high water table and impeded drainage, salt bearing substrata or use of brackish water, impervious hard subsoil due to kankar pan *etc*. Saline soils are however, not confined to the arid and semiarid regions. They are also found extensively in sub-humid and humid climates, particularly in the coastal regions. Developmental techniques such as leaching of soluble salts, breaking of kanker pan, use of soil amendments (FYM/ compost, gypsum) etc., helps in mitigating adverse effects of salts on plants.

Table-9.4: Characteristics of salt affected soils

Characteristics	Saline	Sodic	Alkaline
Other names	**White & Brown alkali, Solanchak, Reh, Kari, Pokkati, Thur**	**Usarsoil**	**Black alkali, Solonetz, Rakkar, Bara-bari**
EC (dSm) at 25^{o} C	> 4	> 4	< 4
ESP (%)	< 15	> 15	> 15
pH	< 8.5	> 8.5	8.5- 10.0
Sodium Absorption Rate (SAR)	< 13	>13	>13
Dominants salts	SO_4^{-2}, Cl^- and NO_3^- of Na, Mg and K	-	Na_2CO_3
Soil colour	White	-	Black
Formation process	Salinization	Salinization and Alkalinization	Alkalinization
Physical Condition	Flocculated	Both condition	Deflocculated

Agrisilvipastoral system for salt affected soil amelioration

Biosaline agroforestry has the potential to address climate change mitigation and adaptation needs on salt-affected wastelands. In this system economically important multipurpose trees (MPTs) such as *Acacia nilotica, Acacia auriculiformis, Azadirachta indica, Casuarina equisetifolia, Eucalyptus tereticornis, Leucaena leucocephala* and *Pongamia pinnata* along with grasses are raised first for some periods then agricultural crops are planted in the inter space available. Fruit species are generally sensitive to salt stress; however, some of the species *viz., Zizyphus mauritiana, Punica granatum, Syzygium cumini, Emblica officinalis* and *Tamarindus indica* showed good performance on saline soils. Extended growth of trees on salt affected soils ameliorates by decreasing the pH and EC along with build up of organic matter, improving soil fertility through nutrient cycling and enhanced microbial activity.

Table-9.5: Tolerance/sensitive of tree crops for varying pH

Highly tolerant (>10.0)	Tolerant (9.5-10.0)	Moderately tolerant (9.0-9.5)	Sensitive (< 9.0)
Acacia nilotica, Casuarina equisetifolia, Prosopis juliflora, Tamarix articulata,	*Acacia catechu, Albizia lebbeck, Butea monosperma, Cordia rothii, Emblica officinalis, Eucalyptus tereticornis, Pithecellobium dulce, Pongamia pinnata, Prosopis cineraria, Psidium guajava, Tamarindus indica, Terminalia arjuna, Zizyphus mauritiana*	*Acacia auriculiformis, Albizia procera, Azadirachta indica, Bambusa spp., Dalbergia sissoo, Grevillea robusta, Kigelia pinnata, Leucaena leucocephala, Melia azedarach, Moringa oleifera, Morus alba, Senna siamea, Sesbania sesban*	*Aegle marmelos, Bauhinia variegata, Bombax ceiba, Cedrela toona, Ficus virens, Hardwickia binata, Manigifera indica , Melia azedarach, Morus alba, Populus deltoids, Tectona grandis, Thespesia populnea*

Table-9.6: Tree species suitable for soil with varying EC

Tolerant (EC 25-35 dSm^{-1})	Moderately tolerant (EC 15-25 dSm^{-1})	Moderately sensitive (EC 10-15 dSm^{-1})	Sensitive (EC 7-10 dSm^{-1})
Acacia farnesiana, Parkinsonia aculeata, Pithecellobium dulce, Prosopis juliflora, Tamarix articulata, Tamarix troupii	*Acacia pennatula, Acacia tortilis, Acacia nilotica, Casuarina equisetifolia, Casuarina obesa, Casuarina glauca, Callistemon lanceolatus, Eucalyptus*	*Acacia auriculiformis, Albizia caribaea, Albizia saman, Casuarina cunninghamiana, Eucalyptus tereticornis, Leucaena shannoni,*	*Acacia deamii, Albizia guachapele, Alelia herbertsmithite, Caesalpinia eriostachya, Caesalpinia velutina, Haematoxylon*

	camaldulensis, Leucaena leucocephala	*Pongamia pinnata, Terminalia arjuna*	*brasiletto, Salix spp, Syzygium cumini, Syzygium fruticosum, Tamarindus indica*

Rehabilitation of mined areas

Rehabilitation measures aim at returning the damaged ecosystem to productive use which is environmentally and socially acceptable. Establishment of vegetation in these areas is very difficult due to lack of top soil, altered pH, lack of organic matter, coarse rock fragments, high runoff or debris movement during monsoon and many other adverse biological and chemical factors. It takes about 50–100 years to attain a satisfactory vegetation cover. Redevelopment of advanced communities may even take a millennium or more. Mechanical measures are important before starting any plantation create conditions favorable to plant growth by arresting fine soil, and improving soil moisture status. These measures are followed by vegetative measures so that both of them act in union as bio-engineering measures, supporting and supplementing each other. Selection of plant species for revegetation of over burden dumps depends on various parameters such as climate, physical and chemical properties of dump materials, topography, viability, and surrounding vegetation. Trees and shrubs suitable for rehabilitation of different mined areas is given in Table 9.7.

Table-9.7: Plant species suitable for revegetation of mine spoils

Mine spoil category	Plant species
Bauxite mine spoil	*Eucalyptus camaldulensis, Grevillea pteridifolia, Pinus spp, Shorea robusta*
Coal mine spoil	*Acacia auriculaeformis, Acacia nilotica, Bamboo, Dalbergia sissoo, Eucalyptus camaldulensis, Eucalyptus hybrid, Pongamia pinnata*
Lime stone mine spoil	*Acacia catechu, Agave americana, Arundo donax, Bauhinia retusa, Buddleja asiatica Chrysopogon fulvus, Dalbergia sissoo, Erythrina suberosa, Eulaliopsis binata, Ipomoea carnea, Leucaena leucocephala, Mimosa himalayana, Pennisetum purpureum, Rumex hastatus, Salix tetrasperma, Vitex negundo*
Rock phosphate mine spoil	*Acacia catechu, Buddleja asiatica, Dalbergia sissoo, Leucaena leucocephala, Mimosa himalayana, Pennisetum purpureum, Rumex hastatus, Saccharum spontaneum, Salix tetrasperma, Vitex negundo*
Mica, copper, tungeston, marble, dolomite, limestone minespoil	*Acacia tortilis, Acacia senegal, Cenchrus setigerus, Cymbopogon spp, Cynodon dactylon, Dichanthium annulatum, Grewia tenax, Prosopis juliflora, Salvadora oleoides, Sporobolus marginatus, Tamarix articulata, Ziziphus nummularia*
Iron ore mine	*Dalbergia sissoo, Eucalyptus, Bamboo, Pongamia, Albizia, Emblica officinalis*

Coastal sand dune reclamation

Coastal areas are important and most preferred human settlement sites since ancient time and half of the world's population live within a distance of less than 200 km from the coast. Indian Peninsula has over 6000 km of coastal line. An eco-friendly measure for the protection and restoration of coastal habitats is now regarded as an effective response to reduce and reverse the negative effects of habitat loss, degradation and fragmentation on native biological diversity and ecological processes. A rapid environmental survey carried

out soon after the 2004 tsunami, indicated beyond doubt that vegetations and sand dunes, wherever they had been left undisturbed from anthropogenic interventions, formed the best natural barrier. The massive strip of vegetation (*Casuarina equisetifolia*) in the coastal areas of Nagapattinam district, Tamilnadu can be considered as a proven model. Rising of this vegetation started in 1978, immediately after a severe cyclone hit this coastal stretch in 1977. During the recent tsunami, the vegetation in sand dunes/ coastal regions played a critical role in mitigating the ill effects and protecting the adjoining agricultural lands.

Coastal sand dune reclamation requires three important processes *viz*., sand dune fixation, dune stabilization and afforestation. Sand dune fixation is based on the principle of reducing the threshold velocity of wind at the dune surface by establishing a pre planting mechanical system. The sand fixation can be achieved by erecting low fences or vertical mulching with locally available living or dead vegetative materials *viz*., twigs from trees, palm leaves in parallel lines. The distance between the parallel lines are three to five meters, which gradually built upon each other on the sand accumulated by the preceding fence.

After fixation, dunes can be stabilized with salt tolerant grasses and creepers which colonize them once they grow abundantly. The efficient vegetative species for the sand dune stabilization in the coastal Tamil Nadu are *Spinifex littoreus* and *Ipomea pescaperae*. Grasses and creepers baffle winds thus causing sand and sediment deposition. The initially formed incipient dunes then coalesce to form fore dunes which with further accretion result in large dune ridges that run parallel to the shoreline due to binding of sand particles, soil crust formation and addition of organic matter and also the presence of surface cover.

The stabilized sand dunes are afforested with the help of Multi Purpose Tree species (MPT's). Choice and mix of species can be decided based on the ecological and economical importance of species and the biophysical condition of the location. The criteria's *viz*., deep and well-spread root system, wind resistant, saline tolerant, easy to propagate and maintain and provide economic benefits to local communities are taken in to consideration. The tree species *viz*., *Anacardium occidentale*, *Azardirachta indica*, *Borassus flabellifer*, *Calophyllum inophyllum*, *Cocos nucifera*, *Casuarina equisetifolia*, *Eucalyptus tereticornis*, *Pongamia pinnata* and *Thespesia populnea* are most suitable for afforestation of sand dunes. The seedlings performed better when planted in pits / auger holes filled with the mixture of composted coir pith at the rate of 10 t ha^{-1} along with gypsum at the rate of 200 kg ha^{-1}, $ZnSO_4$ at the rate of 25 kg ha^{-1} and microbial consortia as sub-surface moisture barrier and source of nutrients for the initial growth and development. Once trees established agricultural/ horticultural crops are intercropped between the tree species. In Tamilnadu, the crops such as groundnut, pearl millet, finger millet, sesame, watermelon (*Citrullus lanatus*), *Vetiveria zizanioides, etc*., are successfully cultivated by the farmers.

Nitrogen fixing trees (NFTs) in reclamation of waste/degraded lands

Nitrogen is often referred to as a primary limiting nutrient in plant growth *i.e.* when nitrogen (N) is not available, plants stop growing. Although deficiency of N is often viewed as a severe problem, nature has an massive reserve of N everywhere plants grow. Atmosphere consists of approximately 78 per cent of nitrogen gas (N_2), representing approximately 6400 kg of N above every hectare of land. However, plant life is not capable to derive vital N from its gaseous form.

Biological N fixation, a process by which certain plants 'fix' or gather atmospheric N_2 and make it biologically available. This pattern of nutrient cycling has successfully been used in agriculture for millennia. Symbiotic association of microbes (rhizobium/ actinomycetes) with root nodules of trees are capable of transforming the atmospheric N_2 gas into more usable forms mainly ammonium (NH_4). Specifically, nitrogen fixing trees (NFTs) are principally valuable in tropical and subtropical agroforestry systems. They can be integrated into an agroforestry system or waste lands/ degraded lands to restore nutrient cycling and soil fertility self reliance.

The necessitate for sustainable agricultural practices is revitalizing the interest in biological N fixation, particularly those involving economically important tree crops. Trees with the capacity to convert the atmospheric N into usable compounds such as ammonia are NFTs. A limited number of plants in nature have this rare ability to use atmospheric nitrogen for their own purpose and to add it to the soil. These NFTs pull the element out of the atmosphere and build a storehouse of the gas through their nodule root formation.

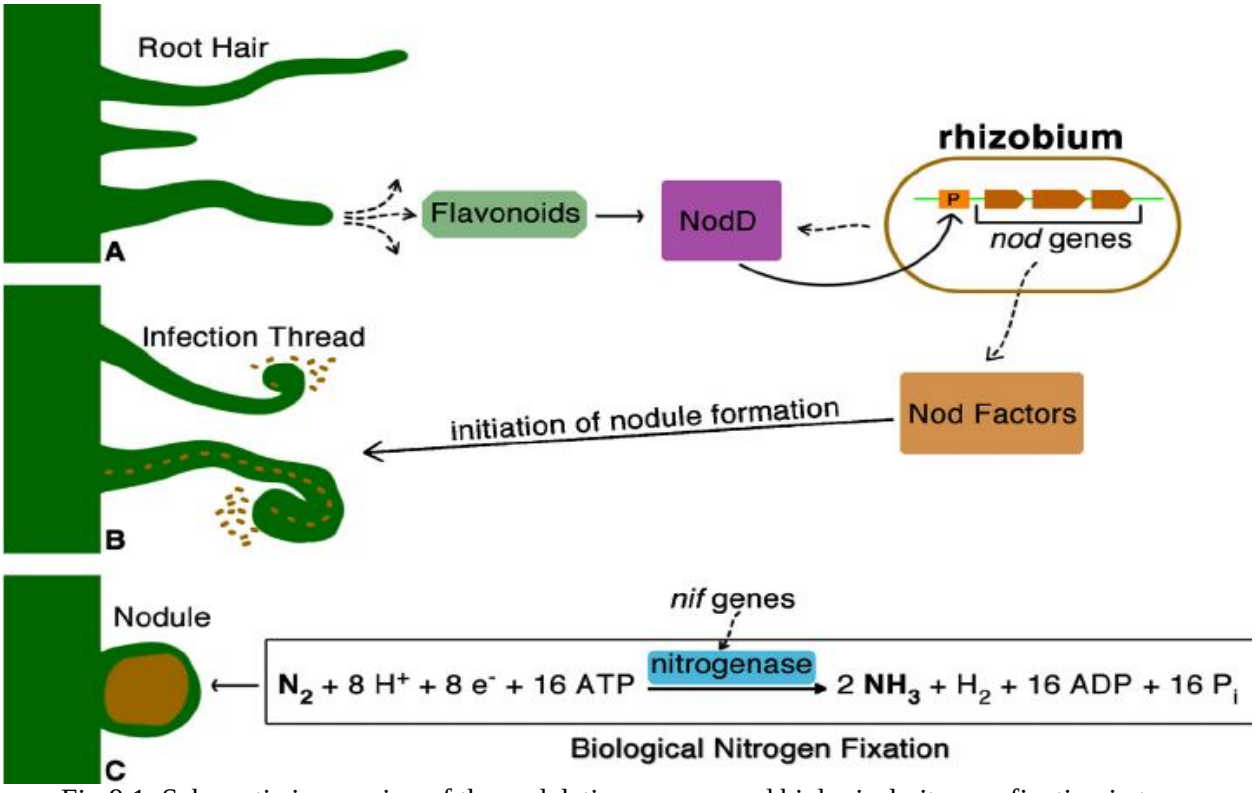


Fig-9.1: Schematic impression of the nodulation process and biological nitrogen fixation in trees

NFTs are often deep rooted, which allows them to gain access to nutrients in subsoil layers. The extensive root system stabilizes soil, while constantly growing, adding organic matter to the soil while creating channels for aeration. There are numerous species of NFTs that can also provide several useful products and functions including food production, wind protection, shade, animal fodder, fuel wood, living fence, timber, etc. in addition to providing N to the system.

Bacteria reside within the nodules (the warehouses of nitrogen) of NFTs, making the nodes their single most important feature. N fixation and ammonia production are the work of these microorganisms that labor intensively inside these knobs of varying size. In this symbiotic interaction, the trees provide carbohydrates (succinate and malate) to the rhizobia, obtaining the ammonia needed to form amino acids. The nodules hold the majority of the nitrogen, enabling host plants to grow. The morphology of nodules varies widely based upon the characteristics of the host plant. Nodules also differ in their size and number. Most are small, usually less than 0.5 cm in diameter or length; some others are as large as a baseball. Plants and trees with more nodules tend to have smaller nodes and are less efficient in fixation. Successful nodules are greaterin size and demonstrate superior efficacy in fixing higher amounts of N. Young nodules are generally white or grey inside and are incapable of N fixation. Mature and larger nodules are identifiable by their pink or reddish internal color due to the presence of leghemoglobin, a nitrogen and oxygen carrier.

Fig-9.2: Legume root nodule

Fig-9.3: Root nodule formed by Frankia in Alnus

Among N fixing trees, many legume species are nodulated by *Rhizobium*. Rates of N_2 fixation by legume trees can differ significantly by species as well as soil N status and can range from 5 to greater than 300 kg N ha^{-1} yr^{-1}. Actinorhizal trees play vital role as woody perennials in agroforestry systems. Actinorhizal - *Frankia* symbiosis has the potential to fix up to 320 kg N ha^{-1} yr^{-1}. In an average *Alnus* and *Casuarina* adds about 61.5 to 157 kg N ha^{-1} yr^{-1} and 60 kg N ha^{-1} yr^{-1}, respectively. In Egypt, a nitrogen fixing potential of 288 kg N ha^{-1} yr^{-1} has been reported for *Casuarina*. In India it is estimated that the average number of NFTs was 1.5 trees ha^{-1}, fixing about 11.18 kg N ha^{-1} yr^{-1}. Therefore, NFTs in an area of 17.45 m ha (estimated agroforestry in India) can fix N up to 0.195 Tg $year^{-1}$. This biologically 'fixed' N_2 becomes available to crop plants when nodules or plant tissues decompose. Though the entire amount of fixed N_2 is not readily crop available instantaneously, the amount that is can equal or exceed that needed by associated crop plants.

Choice of species

Over 650 multipurpose tree species have been reported as biological N fixing and integration of these trees can reduce resource competition among different components of agroforestry. As a consequence, these plants are able to grow in poor and disturbed soils and are significant elements in associated plant communities worldwide. Tree species such as *Acacia auriculiformis, Acacia ferruginea, Acacia leucophloea, Acacia mangium, Acacia nilotica, Albizia chinensis, Albizia lebbeck, Dalbergia sissoo, Erythrina variegate, Gliricidia sepium, Leucaena leucocephala, Peltophorum pterocarpum, Pithecellobium dulce, Pongamia pinnata, Prosopis chilensis, Prosopis cineraria, Prosopis juliflora, Pterocarpus santalinoides, Sesbania grandiflora, etc.* (leguminous N fixing trees) and *Alnus acuminate, Alnus nepalensis, Casuarina cunninghamiana, Casuarina equisetifolia, Casuarina junghuhniana, etc.* (non-leguminous N fixing trees) are some of the suitable NFTs for degraded agroecosystems. The integration of NFTs into agricultural systems offers an alternative strategy to increase N availability in cropping systems without increasing mineral N additions.

The amount of nitrogen fixed by any NFTs is related to its N fixing potential, i.e., its ability to fix N in the absence of any limiting factor. The N fixing potential is directly conditioned by the genotypes of both the host plant and the associated symbiont. Consequently, to get the maximum N input into an agroforestry system, the first essential characteristic is to use a NFT with a high N fixing potential. The second essential characteristic is that a NFT should be maximally tolerant of environmental stresses, be they physical (e.g. excessive temperature, drought), chemical (e.g. excess of combined N) or biological. Because of these stresses, however, even the most tolerant NFT cannot attain its full potential in the field. The amount of N that is fixed under field conditions is called the actual N fixation. The actual N fixation of stress sensitive NFTs is expected to be much lower than their N fixing potential; conversely the actual N fixation of stress tolerant species is expected to be much closer to their N fixing potential. Special mention must be made of the inhibitory effect of high levels of combined (mineral) soil N, especially nitrate, on nitrogen fixation. This implies that NFTs in agroforestry systems should be engineered to continue fixing significant amounts of N even when the intercrop receives N fertilizers.

TREE PLANTING TECHNIQUES

a) Direct seeding

Direct seeding is cost effective and easier. Artificial seeding of quick growing grasses with short life cycle, legumes and forage crops accelerate development of vegetation and helps in improving site fertility, moisture retention capacity, stabilizing sloping areas and encourage natural invasion of tree and shrub seedlings. Plantation of mixed species of economic importance should be done after 2–3 years of growing annuals. In severely degraded soils direct seeding of tree species for 3 years with grasses and leguminous species has been found to be useful.

Depending on the tree architecture, species and objective of seedling planting spacing may vary from 1.5 x 1.5 m to 8 x 8 m. Overtime self organizing biotic communities develop to optimize the flow of nutrients and energy within the ecosystem.

b) Direct seeding with seed balls or seed bombing

Seed balls or seed bombing is another form of artificial seed dispersal and afforestation by embedding organic seed balls in the ground. In seed ball a seed that has been wrapped in soil materials, usually a mixture of clay and compost, and then dried. Essentially, the seed is pre-planted and can be sown by

depositing the seed ball anywhere suitable for the species, keeping the seed safely until the proper germination environment arises. The compost offers nutrients for the seeds to germinate and grow strong during their infancy and the clay binds the seed ball, making it hard enough not to break when it hits the ground.

Seed balls may have been used by the Ancient Egyptians to seed the receding banks of The Nile after annual floods. They have been used in Asia and elsewhere, especially in arid regions, because of their ability to keep the seeds safe until conditions are favourable for germination and the ease at which they can be distributed. A new book called Seed bombs: Going Wild with Flowers by Josie Jeffery introduces this concept to modern users, but the idea of seed bombing first germinated in Japan with the ancient practice of tsuchi dango, which translates as "earth dumpling". The idea was again popularised in the 20th century by Masanobu Fukuoka, an advocate of "Do Nothing Farming". His research and outreach efforts have brought the seed ball back into the green minded modern era of 21st century.

Seeds are scarified if necessary prior to placing in the seed ball. Mix 3/4th clay and 1/4th compost and microbial inoculants and insert the tree seeds and makes them into small but firm balls. Depending on the size and requirements of the plants, seeds are either mixed in with the soil before the seed balls are made or placed individually within the moist seed ball. Then hand rolls each seed ball until its just right and make into one inch in diameter. The seed balls are then air-dried, providing a safe shelter for its contents until germination.

Characteristics that make a particular species appropriate for seed ball/ bombing are

- small or medium sized seed,
- frequent and prolific seed availability,
- ability of the seed to germinate on the soil surface,
- fast germination and rapid seedling growth,
- ability to withstand temperature extremes and prolonged dry periods (orthodox seed),
- ability to tolerate a wide range of soil conditions,
- high light tolerance,
- seed that is easy to collect in large quantities and to store for long periods,
- rapid development of a deep taproot by seedlings to enable them to withstand adverse climatic conditions in the period following germination.


Fig-9.4 and 9.5. Seed balls

Throw and grow mechanism of seed balls

Seed balls are an easy and sustainable way to cultivate plants in a way that provides a larger period of time. Seed bombing enable them to be launched in areas that are physically challenging to access, like wastelands. Because of their size and strength they can simply be thrown along the wastelands before the onset of monsoon. In wastelands, the ball gives enough room to hold and conserve moisture. When the seeds begin to germinate and the ball breaks apart. The small pile of crumbles provides the start for the root system, but is still heavy enough to anchor the emerging seeds to the ground.

This unique method not only makes planting faster but it is also more cost effective than traditional tree planting methods. The seed is sown on top of the soil where it may be baked dry by the sun, blown away by the wind, washed away by heavy rains, or nibbled away by birds or other wildlife. Very little is left to germinate and grow. Throw and grow mechanism making of seed balls addresses all of these problems. These clay balls protect the seed from the heat of the sun, heavy enough to be unaffected by the wind or heavy rains and the hard clay casing deters animal nibblers as well.

c) Transplanting of seedlings

Soil working techniques

Proper soil working methods of planting tree seedlings is important for the establishment of vegetation and reclamation of degraded lands.

a) Simple pits

Pits of 45–60 cm^3 have been found optimum for planting tree seedlings. Loosen the soil in the bottom, to make it easier for the roots to grow out and down. The seedlings are planted in pits after filling 2/3 depth with the mixture of red /native soil, FYM/ compost and sand.

b) Ridge furrow

Ridge furrow method is applicable where water depth is less than one meter. Height of ridge is depending on water depth. Furrow on the sides of the ridge help to drain excessive water. Planting is done on the ridges. Furrows should be about 0.45 m deep and the ridges were prepared with 0.75 m height. The size of this method was varied depending on the spacing of the species. The seedlings were planted on the side of ridge about 0.60 cm above the ground level. For this a slit was formed, seedlings were placed on it and backfilled with soil amendment mixture.

c) Trench-cum-pit

Trench-cum-pit type is suitable for gently sloping areas with stony surface. If fruit trees are used for increase the productivity of wasteland, pits of 60 × 60 × 75-100 cm sizes are dug up and are filled with mix of soil, fine textured silt and compost. Planting is completed soon after the onset of monsoons.

d) Mound method

The pits were formed with a dimension of 0.30 m deep and 0.30 m at the base of sides slanting with top 0.45 cm. The pit is filled back with the dug up or borrowed earth soil and formed a raised mound with 0.60, 0.75 and 1.00 m wide at the top, middle and bottom, respectively with 0.60 m height from the original soil surface. A slit in the side of the mound and the tall seedlings are planted with amendment mixture.

e) Auger hole technique

A tractor mounted auger is used to make holes of 20-25 cm diameter by piercing the hard kankar layer at 1.2-1.8 m depth. Auger holes are refilled with mixture of original soil, 3 kg gypsum, 10 kg FYM/ pressmud/ composted coirpith, 10 g $ZnSO_4$ and microbial consortia. The seedling is placed in the center of the hole.

f) Pit auger-hole method

Although the auger hole method has been found to yield good results, feeder roots are confined to the diameter of the auger hole in upper soil layer. Consequently, plants may face nutritional problems during later stages of growth. To overcome this problem, a pit and auger-hole method was designed. In this technique 60-75 cm^3 pits are prepared then mechanical auger is used to make holes of dimensions 20-25 cm diameter and 1.2-1.8 m deep. This technique recognizes that in trees, owing to their deep root systems, management of the root zone by modifying the soil environment to greater soil depths using a limited quantity of amendments would be vital.

g) Pit-auger hole and furrow method

This planting method is similar to the previous method except that a furrow is made running across the slope. Furrows (20 cm deep and 50-60 cm wide at top) are first made at specified intervals cutting across the slope and are then used to make pit-holes. Furrows can be made by tractor-driven furrow maker. The additional advantage of this method is in providing sufficient moisture to the plants in furrows by preventing erosion losses. This is important in such soils, which often show moisture deficiency.

h) Staggered contour trenches

In areas having low rainfall, staggered contour trenches should be made to enhance the survival and growth of the seedlings. Trenches should be designed to store 60–70 per cent of runoff and accordingly the number and size of trenches should be decided. The numbers of trenches are usually equal to number of trees to be planted in a unit area according to its spacing adapted. Sizes of trenches are usually 3 x 0.30 x 0.30 m. However, if trees are to be closely spaced, size of trench should be reduced. The dug up soil is placed on the downhill slope along the trench. The seeds are either sown or seedlings are planted on bream of the trenches or in diagonally half filled trenches. The successive lines of contour trenches are kept at 2–4.5 m depending on slope.

i) Saucer pits/ crescent shaped ridges

Growing of trees around the perimeter of the saucer with the diameter of 3 meter and 15 cm mid depth can impounded 1000 litre of water per saucer for 5 cm rainfall. Likewise the pits provided with saucer shaped depressions around the plants in plains or crescent shaped ridges of 15 cm high are formed across the slope to arrest the runoff water during monsoons also significantly increase the yield of trees.

Fig-9.6: Rectangular shaped with sloping side

Fig-9.7: Saucer shaped depressions

j) Subsurface planting and furrow irrigation system

In saline or waterlogged soils the special technique called subsurface planting and furrow irrigation system was followed. In this technique furrows (15-20 cm deep and 50- 60 cm wide) are created at 3-5 m intervals with a tractor drawn furrow maker. Augerholes (0.2 m diameter and 1.2 m deep) are dug at the sill of these furrows spaced at 2-3 m intervals. These are re-filled with the mixture of original soil plus 8 kg of farmyard manure/ compost, 30 g superphosphate, 15 g zinc sulphate, 15 g of iron sulphate and microbial consortia. Six months old tree seedlings are transplanted during rainy season at sites where auger holes are dug. The irrigation with saline water is given in furrows only. The irrigation may be provided for initial three years (4-6 times in a year). Salt storage in soil profile may increase during irrigation period but the added salts get distributed in soil profile as a consequence of seasonal rainfall during monsoon and some episodic events.

Chapter - 10

AGROFORESTRY AS ALTERNATE LAND USE PLANNING FOR SUSTAINING LIVELIHOODS

Land use planning (LUP) is the systematic assessment of physical, social and economic factors to encourage and assist land users in selecting land use options that is an interactive and continuous process of development; requires flexibility does not have a clear end-product; is problem oriented; is area specific; and involves all stakeholders. Land use planning is not just crop/farm planning on a different scale, but it has a further dimension i.e. the interest of the whole community.

Land use planning means diverse thing to different people; for researchers it is the systematic assessment of land and water potential for alternative land use under existing economic and social conditions in order to select and adopt the best options. For small farmers it is the efficient utilization of land and water resources for crop production in order to minimize crop failures and risks and to sustain family needs. The farmers anticipate family sufficiency and profit with or without sustained use of natural resources. For big farmers it is an effective utilization of resources to maximize profit from the whole farm, based on principle of comparative advantage.

Alternate landuse system

Alternate landuse system refers to a perennial system or practice which is adopted to replace or modify the traditional landuse. Its main aim and objective is to match the land capability classes for generating more assured income with minimum risk through efficient utilization of available resources. Such systems have more potentiality and flexibility than the traditional crop production systems.

Success or failure of crop diversification can depend on a number of factors. Before tumbling into new, costly ventures, the following advice is worth heeding. Anticipated benefits of crop diversification are alternative crops may enhance profitability; diversified rotations can reduce pests, labour may be spread out more evenly; different planting and harvesting times can reduce risks from weather and new crops can be renewable resources of high value products.

Land capability classification

Land Capability Classification (LCC) is an interpretative groupings of soils based on inherent soil characteristics, land features and environmental factors that limit land use or impose risk of erosion. Soils are grouped in 8 capability classes on the basis of their ability to produce commonly cultivated crops. The risk of soil degradation progressively increases from Class I to Class VIII. Arable lands are placed in Class I to IV and the non arable in Class V to VIII. There is a provision to assign subclass on the basis of kind of predominant hazard, limitation or conservation problem (erosion and run off, excess water, root zone limitation, climatic limitations, etc.). A sub class may be further divided into land capability units according to similarity in potential and response to management. While LCC system is useful for relatively broad level planning it needs to be supplemented by more precise evaluation for micro level planning. Further, the LCC is conservation oriented which considers the negative aspects. Yet this system is still widely used because of its simplicity and ease of comprehension. The capability classification gives common idea about the capability of the soils but does not explain specific crop performance unless supplemented by additional information. This method could be followed efficiently for highlighting the conservation oriented limitations which need immediate attention and for broad grouping of soils into agricultural and non agricultural lands.

Table-10.1: Appropriate alternate land use system for different LCC

LCC	ALU
Class I	Intensive crop cultivation
Class II & III	Moderately intensive cultivation with alley cropping, agrisilviculture, agrihorticulture, etc.
Class IV	Restricited cultivation – ley farming
Class V &VI	Silvi/ Horti pastoral system
Class VII	Tree plantations
Class VIII	Watershed protection, recreation, wildlife

Micro level land use planning in relation to agroforestry systems

Productive Farming Systems Matrix Approach model indicated by All India Coordinated Research Project for Dry land Agriculture (AICARDIA) is the typical example for alternate land use planning for agroforestry systems (Fig.10.1). It is aimed to optimize of resources through the principle of recycling, internalize the input production. Micro level highly diversified farming systems are practicable due to resilience in adoption of diversification from crop through tree to animal.

Crop diversification in agroecosystems aims to make agriculture achieving nutritional security (human and animal and crops), more employment and income generating, eco-friendly, poverty alleviation and comparative advantage in the trade.

In agricultural production systems, based upon diversification index and severity of soil degradation horizontal and vertical diversifications were suggested. Horizontal diversification focuses on the multiple cropping, *i.e.*, intensification of cropping in time and space dimensions under a given land degradation status in a particular zone/region in a crop(s) based production system. This has special significance in small farm diversification. Horizontal diversification aims at is advantageous in effective utilization for natural resources, *viz.*, soil, light water and conservation, employment generation, and risk minimization.

Vertical diversification aims at reducing the soil loss, high biomass production, high income and employment generation through year round activity and addition of organic matter to soil, organic linkage between agriculture and industry wherein the scope is widened for post harvest value addition by practicing the enterprises like agroforestry (silviculture, silvipasture, agri-silvi-horticulture and agri-silvi-pastoral system, alley cropping,), sericulture, rainfed horticulture, silvi-olericulture, medicinal aromatic plants, other economic shrubs like dye yielding plants and most importantly animal component for diary, poultry, apiary, rabbit rearing, *etc*.

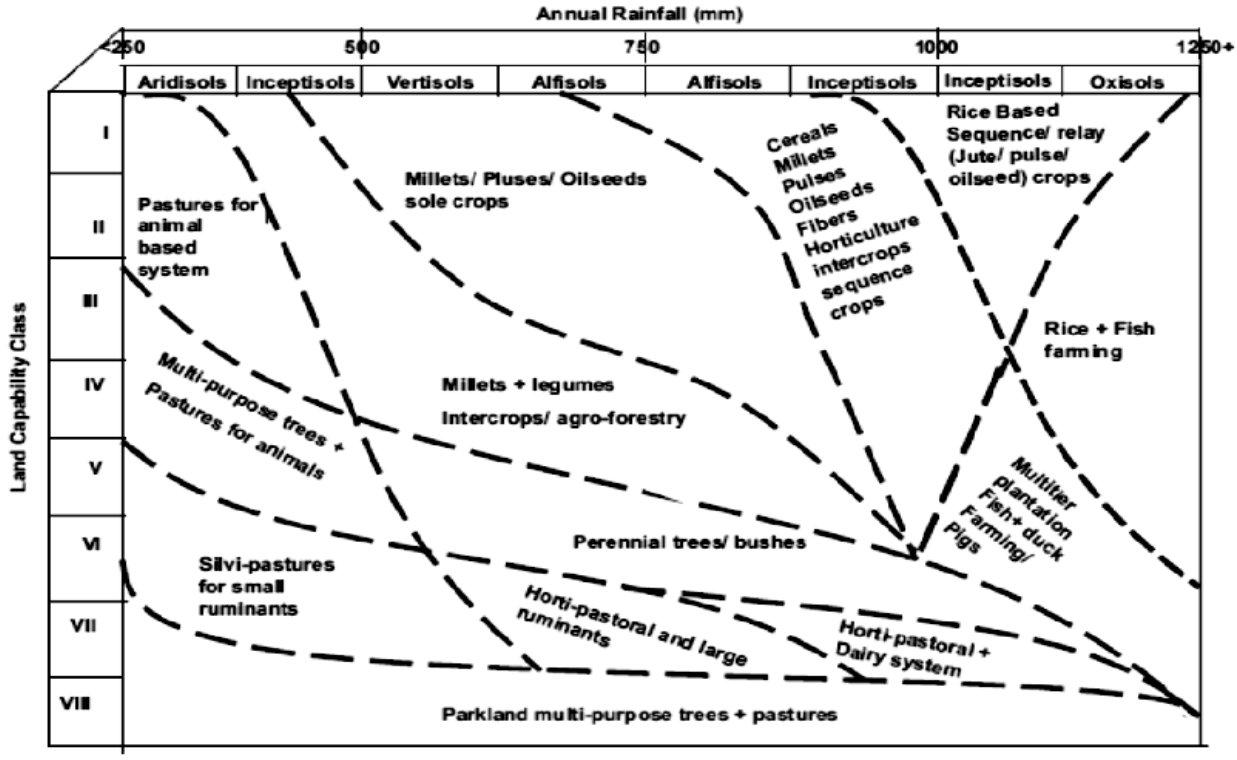


Fig-10.1: Productive farming system matrix

The complementary ALU enterprises with multiple objectives for some of the regions of India are given below.

Domain I: Nalgonda District, Telangana State

Soils: Deep loamy, clayey mixed red and black soils; Rainfall: 763 mm

Length of growing period: 120 – 150 days

1. Horizontal diversification

Castor + Pigeon pea, Castor + Sorghum, Castor + Greengram/Blackgram, Castor + Pigeonpea (2:1), Intercropping one row of cluster bean between 90 cm castor rows, Blackgram + Castor (6:1), Castor + Setaria and Castor + Cowpea.

2. Vertical diversification

Parkland systems: *Azadirachta indica, Acacia nilotica, Tamarindus indica*

Trees on bunds: *Acacia nilotica, Borassus flabellifer, Cocos nucifera, Leucaena leucocephala, Tectona grandis, etc.*

Silvipastoral system: *Leucaena leucocephala* + *Stylosanthes hamata, Leucaena leucocephala* + *Cenchrus ciliaris*

Alley cropping: *Leucaena leucocephala* + sorghum/ Pearlmillet, *Gliricidia sepium* + sorghum/pearlmillet

Agri-Horti system: Mango, Ber, Custard apple, Guava, Pomegranate, Amla+ short duration pulses

Fodder/green biomass: *Azadirachta indica, Albizzia amara, Albizzia lebbeck, Albizzia procera, Bauhinia purpurea, Butea monosperma, Dalbergia sissoo, Luecaena leucocephala.*

Medicinal and Aromatic Plants: *Aloe barbadensis, Catharanthus roseus, Cassia angustifolia, Cymbopogan martini, Cymbopogan flexuosus, Psoralea corylifolia, Vetiveria zyzanoides, Withia somnifera*

Domain II: Chitradurga District, Karnataka

Soils: Medium to deep red loamy soils; Rainfall: 654 mm

Length of growing period: 120-150 days

1. Horizontal diversification

Pigeonpea paired rows + groundnut (10:2); Groundnut + castor (8:1)

Medicinaland aromatic plants: *Catharanthus roseus, Cassia angustifolia, Salanum viarum, Dioscrorea, Geranium, Pogostemon patchouli*, Jasmine

Vegetables: Tomato, chillies, okra watermelon, bitter gourd, drum stick, brinjal, bitter gourd.

2. Vertical diversification

Gravelly shallow soils – *Stylosanthes scabra*

High gradient non-arable lands with shallow soils – Amla

Deep soils: Neem, Pongamia and *Albizzia lebbek*

Fodder/ green biomass: *Cassuarina*, Silver oak, *Glyricidia, Calliandra, Faidherbia albida* on bunds

Forage crops: *Pennisetum pedicallatum* / *Cenchrus ciliaris, Microtaliem axillaries*

Fruit: Mango, Pomegranate, Sapota, Guava, Custard apple, Jamun

Wastelands: Jackfruit, Custard apple, Tamarind

Animal Component: Male/female cattle, female buffaloes, poultry, sheep, goat

Other enterprises: Muhsroom cultivation, sericulture, piggery, apiary, rabbit rearing

Domain III: Rayalaseema (Anantapur, Kurnool and Chittoor districts)

Soil type: Arid shallow alfisols with 616 mm annual rainfall,

LGP: 60-90 days

1. Horizontal diversification

Groundnut + Pigeonepa (11:1)

2. Vertical diversification

Boundary plantation – *Azardiracta indica, Eucalyptus camaldulensis, Acacia nilotica*

Live fence Outer layer: Eucalyptus, Agave

Inner layer: Glyricidia

Trees on crop lands:

Fodder production : *Dalbergia sissoo*, Glyricidia

Fruit trees: Ber, Custard apple, Pomegranate, Amla + Kharif spreading crops

Wood (Commercial/farm use/fuel wood): *Acacia auriculiformis/Acacia nilotica*

Livestock: Cattle, buffaloes, sheep, goat, poultry

Domain IV: North Saurashtra agro-climatic zone, Gujarat

Arid deep vertic/vertisols, with 350 to 670 mm rainfall.

LGP 60 to 120 days.

1. Horizontal diversification

Subabul (paired row) + sorghum (5-6), subabul + groundnut, perennial pigoenpea (alleys) + groundnut

2. Vertical diversification

Fodder /Biomass on sloppy fallow lands: *Dicanthium annulatum, Leucaena* and *Pongamia*

Fruit crops: Custard apple, mango, pomegranate, phalsa, fig, jamun and tamarind

Boundary plantation: *Prosopis cineraria, Acacia nilotica*

Live fence- Outer layer: Lawsonia alba,

Inner layer: *Prosopis cineraria*

Trees on crop lands:

Fodder/Green biomass: *Dichrostachys cineraria*

Fruit: Custard apple, Fig, Mango

Wood (commercial/farm use/fuel wood): *Acacia senegal, Acacia nilotica*

Livestock: Cattle, Buffalo, Sheep, Goat

Domain V: Bijapur, Bagalkot and Gulbarga, eastern parts of Belgaum, Lingsugur of Raichur of Karnataka and Southern parts of Maharshtra

Soils: Semi-arid medium/ deep vertisols with 680 mm of rainfall

Horizontal and vertical diversification

Agri-horti system of rabi sorghum + ber, subabul *Acacia nilotica* and *Dalberja sissoo*

Pigeonpea + aswagandha / sunflower + aswagandha

Amla/custard apple + henna + castor/ pearlmillet /foxtailmillet

Sapota + pearlmillet/castor

Guava + henna + Seemarisba + greengram

Boundary Plantation – *Eucalyptus camaldulensis, Tectona grandis*

Live fence

Outer layer: *Agave sisalana, Cactus*

Inner layer: *Leucaena leucocephala, Carrissa carundus*

Trees on crop lands

Fodder/green biomass: *Dalbergia sissoo, Glyricidia, Albizzia lebbeck, Hardwickia binata*

Fruit: Mango, Pomegranate

Wood (Commercial/farm use/fuel wood): Eucalyptus hybrid, *Acacia auriculiformis*

Domain VI: Agra, Aligarh, Hathras, Mathura, Etah, Mainpuri and Firozabad districts of Uttar Pradesh

Soils: Semi Arid Inceptisols covering having mean annual rainfall of 665 mm.

Horizontal and vertical diversification

Pearlmillet + pigoenpea (2:1)

Ber + green gram/cluster bean/cowpea in between rows of fruit crops

Ber+ pearlmillet for fodder

Amla + mustard / Chickpea/barley/lentil

Ber+mustard

Sarpagandha /Mehandi/ Rajanigandha/Awagandha

Boundary Plantation: *Azadirachta indica, Albizzia lebbeck, Pongamia*

Live fence

Outer layer: *Agave sisalana*

Inner layer: *Lawsonia alba*, Agave, *Carissa carundus*

Trees on crop lands

Fodder/green biomass: *Azadirachta indica, Leucaena leucocephala, Albizzia lebbeck*

Fruit: Mango, Guava, Amla, Phalsa

Wood (Commercial/farm use/fuel wood): *Eucalyptus, Acacia nilotica*

Domain VII: Mandsaur, Rajgarh, Ujjain, Indore, Dewas, Shajapur, Ratlam, part of Dhar (Badnawar and Sardarpur tehsil), Jhabua (Petlawad Tehsil) and part of Sehore district of Madhya Pradesh.

Soils: Semi-arid medium to deep vertisols.

1. Horizontal diversification

Soybean + pigeonpea (4:2); Soybean + chickpea/Soybean + Pigeonpea (4:2)/Cowpea + chickpea

Fodder system- Sorghum /Maize green /Sorghum green fodder

2. Vertical Diversification

Boundary Plantation – Gliricidia / Jatropha

Live fence:

Outer layer: Lawsonia

Inner layer: Glyricidia, sesbania, Leucaena

Trees on crop lands:

Fodder/green biomass: *Hardwickia binata, Leucaena*

Fruit trees: Ber (*Zizyphus* sp.)/ Aonla (*Phyllanthus emblica*)/ Pomegranate/ drum stick (*Moringa oleifera*)

Wood (Commercial/farm use/fuel wood) : eucalyptus,

Medicinal and aromatic plants: *Rauvolfia serpentina*, *Vetiver zyzanoides*, Palma rosa

Livestock: Cattle, Buffaloes, Goat, Poultry

Domain VIII: Entire plateau of Jharkhand state, parts of Rohtas, Gay, Jamui in Monghyr district, Banka sub-division of Bhagalpur district in Bhir and Purulia and Bankura districts of West Bengal

Soils: Sub-Humid Alfisols with annual rainfall between 900- 1500 mm.

1. Horizontal diversification

Rice + pigeonpea (3:1) and groundnut + pigeonpea (2:1) in uplands

2. Vertical diversification

Agri horticulture: Fruit crops (Nungo /citrus /sapota /pomegranate /custard apple /litchi/jack fruit jamun) +field crops (pulses/oilseeds)

Alley cropping: Leucaena + turmeric/ginger

Boundary Plantation: Eucalyptus

Live fence:

Outer layer: *Lawsonia*

Inner layer: *Leuceana, Tectonia grandis*

Trees on crop lands:

Fodder/green biomass: *Leucaena*

Fruit: Mango, Ber

Wood (Commercial/farm use/fuel wood): *Tectona grandis, Eucalyptus*

Medicinal and aromatic plants: Vetivera, Palmrosa

Livestock: Cattle, Buffaloes, Sheep, Poultry, Duckery, Piggery

Domain IX: North-eastern zone of Tamil Nadu (Chennai, Kanchipuram, Thiruvallur, Cudallore, Vellore, Thiruvannamalai, Vilupuram)

Soils: Red loam, red sandy loam, black clayey and black clay loam to limited extent, saline alluvial in sea coast;

Rainfall: 1054 mm

Length of growing period: 90 – 120 days

1. Horizontal diversification

Rice, groundnut, black gram, green gram, sesame, pearl millet, finger millet and sugarcane

2. Vertical diversification

Intercropping groundnut, pulses and millets with *Casuarina equisetifolia* and *Anacardium occidentale*

Parkland systems: *Azadirachta indica, Borassus flabellifer, Tectona grandis*

Trees on bunds: *Borassus flabellifer, Cocos nucifera, Lannea coromandalica, Leucaena leucocephala, Tectona grandis, Thespesia populnea*

Wood lots: *Casuarina equisetifolia, Eucalyptus tereticornis, Acacia auriculiformis*

Agri-Horti system: Mango + short duration pulses

Fruit: Mango, Guava, Indian goose berry

Medicinal and Aromatic Plants: *Catharanthus roseus, Vetiveria zyzanoides*

Livestock: Cattle, sheep, goat, poultry

Domain X.: Southern zone of Tamil Nadu (Ramanathapuram, Tirunelveli, Madurai, Pudukottai (part), Sivagangai, Virudhunagar and Thoothukudi)

Soils: Black clayey (mid zone), saline coastal alluvium or river alluvium (eastern region), red sandy soil (north eastern side), deep red soil (western region)

Annual Rainfall: 776 mm

1. Horizontal diversification

Rice, pearl millet, cotton, sorghum, fodder sorghum, minor millets, groundnut, senna, chilli and vegetables

2. Vertical diversification

Silvipasture consists of *Acacia nilotica, Acacia leucophloea, Leucaena leucocephala*

Parkland systems: *Acacia planifrons, Azadirachta indica, Borassus flabellifer, Tamarindus indica, Tectona grandis*

Trees on bunds: *Borassus flabellifer, Lannea coromandalica, Leucaena leucocephala, Tectona grandis, Thespesia populnea*

Wood lots: *Eucalyptus tereticornis, Tamarindus indica, Azadirachta indica*

Medicinal and Aromatic Plants: *Aloe vera*

Livestock: Cattle, sheep, goat

Chapter - 11

AGROFORESTRY IN WATERSHED MANAGEMENT

The phrase 'watershed' was introduced in 1920 and used for the water parting boundaries. Watersheds are an area of land with streams and rivers that all drain into or contribute runoff to a common outlet such as a larger body of water, such as a bigger river, a lake or an ocean. Hence, it is a geo-hydrological unit draining to a common point by a system of drains. Watersheds supply water for a multitude of ecological and cultural services, including water for irrigation, habitats for biodiversity, industry, shelter and sources of livelihoods. All lands on earth are part of one watershed or other. A watershed is an ecosystem with complex interacting natural components (biotic and abiotic).

Watershed is not simply the hydrological unit but also socio-political ecological entity which plays crucial role in determining food, economical and social security and provides life support services to rural people. Management of natural resources at watershed basis produces multiple benefits in terms of increasing food production, improving livelihoods, protecting environment, addressing gender and equity issues along with biodiversity concerns.

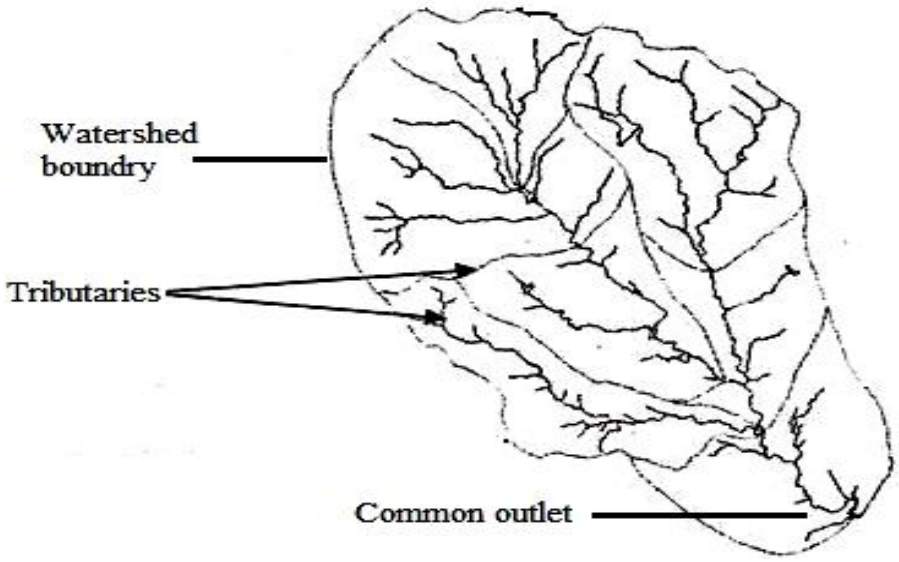


Fig-11.1: A typical watershed

The watershed is the product of the interactions between land and water, particularly its underlying geology, rainfall patterns, slope, soils, vegetative cover and land use. The availability of water and its flow (watershed hydrology) is a critical determinant in the various production functions in a landscape, especially since it is open to interference by human agency.

Principles of watershed management

The principles of watershed management based on resource conservation, generation and utilization are

- Utilizing the land based on its capability
- Protecting the fertile top soil
- Minimizing silting up of tanks, reservoirs and lower fertile lands
- Maintaining vegetative cover round the year
- In situ conservation of rain water
- Safe diversion of gullies and construction of check dams for increasing ground water recharge
- Increasing cropping intensity through inter and sequence cropping
- Alternate land use systems for efficient use of marginal lands
- Water harvesting for supplemental irrigation
- Maximizing farm income through integrated agricultural activities such as dairy, sheep, goat and poultry forming

- Improving infrastructural facilities for storage, transport and agricultural marketing
- Improving socio - economic status of resourse poor farmers

Objectives of watershed management

- Production of food, fodder, fuel, timber and non wood forest products.
- Pollution control
- Over exploitation of natural resources should be minimized
- Water storage, flood control and checking sedimentation.
- Wild life preservation
- Maintaining ecological biodiversity
- Erosion control and prevention of soil from degradation and conservation of soil and water.
- Employment generation through industrial development, livestock and fishery production.
- Recharging of ground water to provide regular good quality water supply for consumption and industry as well as irrigation.
- Recreational facility.

Watershed problem causes

Asian watersheds are in rapid disturbances and heading for an impending crisis. The rates of sediment deposition in the reservoirs are much higher in Asia than anywhere else in the world. Nearly 130 million people who live in upper watershed areas throughout Asia face poverty and other discouraging constraints. It is very important for watershed management that the physical, biological and socioeconomic conditions that lead these watershed problems put into proper perspective. The underlying causes of watershed ecosystem degradation and resulting upland and downstream impacts can be due to natural phenomena and human activities; often it is a combination of the two. The causes of watershed ecosystem degradation include i) natural causes such as geologic instability, erodibility of soil, drought hazard, high intensity rainfall, strong wind, fire, etc. and ii) human causes such as deforestation (unwise and poorly logging, fuelwood cutting due to fuel shortages, conversion of forests to grazing lands or cultivated croplands and forest fire set by inhabitants), inappropriate collection, transportation and use of water resources, Inappropriate use of land resources, unwise farming or cultivation practices, overgrazing by livestock, road construction on fragile lands, system of land ownership, inadequate policy and legislative support, lack of unified planning and extension for integrated watershed management. Early in the watershed management project formulation stage, it should be assess the existing situation and identify the causes of watershed problem.

Types of watershed

The criteria for selecting watershed size depend on the objectives of the development and terrain slope. Watershed is classified depending upon the size, drainage, shape and land use pattern. The usually accepted five levels of watershed delineation based on geographical area of the watershed are the following

i) Macro watershed : > 50,000 ha

ii) Sub watershed : 10,000 to 50,000 ha

iii) Milli watershed : 1000 to10000 ha

iv) Micro watershed : 100 to 1000 ha

v) Mini watershed : 1-100 ha

A large watershed can be managed in plain valley areas or where forest or pasture development is the main objective. In hilly areas or where intensive agriculture development is planned, the size of watershed relatively preferred is small.

Components of watershed

Watershed management must be integrated and address both water and the related land resources that affected by water. Water includes floods and droughts, surface water and groundwater, water supply and water quality. Related land resources include streams, wetlands, forests, soil, fisheries, flora and fauna. The principle that 'everything is connected to everything else' lies at the heart of watershed management.

The main components in watershed management are land management, water management and biomass management.

i) Land management

Land characteristics like terrain, slope, formation, depth, texture, moisture, infiltration rate and soil capability are the major determinants of land management activities in a watershed. The broad category of land management interventions are as follows

a) Structural measures

Structural measure include interventions like contour bunds, stone bunds, earthen bunds, graded bunds, compartmentnal bunds, contour terrace walls, contour trenches, bench terracing, broad based terraces, centripetal terraces, field bunds, channel walls, etc.

b) Vegetative measures

Vegetative measures include vegetative cover, plant cover, mulching, vegetative hedges, grass land management, agroforestry, etc.

c) Production measures

The production measures include interventions aimed at increasing the productivity of land like mixed cropping, strip cropping, cover cropping, crop rotations, cultivation of shrubs and herbs, ridges and furrows, contour cultivation, conservation tillage, land levelling, use of improved verity of seeds, horticulture, agroforestry, etc.

d) Protection measures

Protective measures like landslide control, gully plugging, runoff collection, etc are adopted. Adoption of all the interventions mentioned above should be done strictly in accordance with the characteristics of the land taken for management.

ii) Water management

Water characteristics like inflows (precipitation, surface water inflow and ground water inflow), water use (evaporation, evapotranspiration, irrigation and drinking water), outflows (surface water outflow and ground water out flow) and storage (surface storage, ground water storage and root zone storage) are the principal factors taken care in sustainable water management. The broad interventions for water management are rain water harvesting, ground water recharge, maintenance of water balance, preventing water pollution and economic use of water.

Rainwater harvesting forms the major component of water management. The rainwater collected is recharged into the ground. Roof top water harvesting, diversion of perennial springs and streams in to storage structures, farm ponds etc are the methods widely used for rainwater harvesting. Some simple and cost effective rainwater harvesting structures are percolation pits/tanks, recharge trenches/rain pits, recharge wells, farm ponds, V ditch, bench terracing, etc.

iii) Biomass management

Major intervention areas for biomass management are agroforestry, farm/ community forestry, eco-preservation, biomass regeneration, forest management and conservation, plant protection and increased productivity of farm animals.

Unified watershed management planning

The very important step in the entire watershed management planning process is to clearly define the goals and objectives of the project. Specific objectives associated with watershed management projects typically involve one or more of the following:

- Reduce the erosion modulus to an acceptable level
- Reduce the sediment yield to an acceptable level
- Provide the water yield which needed by downstream
- Food security
- Increase the income of inhabitants
- Safety of life and property

Watershed management programmes implemented in India

(i) Drought Prone Area Programme (DPAP) - 1970-71

Objectives: Area development programme through restoration of ecological balance and optimum utilization of land, water, livestock and human resources to mitigate the effect of drought.

(ii) Desert Development Programme (DDP) - 1977-78

Objectives: Mitigate the effect of drought in the desert area and restore ecological balance.

(iii) National Watershed Development Programme for Rainfed Agriculture (NWDPRA) - 1986-87

Objectives: To conserve and utilize rain water from both arable and non arable lands on watershed basis and to increase the productivity of crops and to increase the fuel, fodder and fruit resources through appropriate alternate land use system.

(iv) Control of Shifting Cultivation - 1986-87

Objectives: Restoring ecological balance in hilly areas and improving socio-economic conditions.

(v) World Bank Assisted Integrated Watershed Development Project - 1990

Objectives: To arrest the problems of environmental degradation and promote sustainable increase in agriculture production and to enhance vegetative technology of soil and water conservation for rain water conservation and for increasing crop, forage, fuel wood and timber yield of the area.

(vi) Integrated Watershed Management Programme (IWMP) - 2009-10

The objective of IWMP is to restore ecological balance by harnessing, conserving and developing degraded natural resources such as soil, vegetative cover and water principally the rainfed portions of net cultivated area and culturable wastelands in rainfed area. The activities undertaken inter alia include ridge area treatment, drainage line treatment, soil and moisture conservation, rain water harvesting, nursery raising, afforestation, horticulture, pasture development, livelihoods for asset less persons, *etc*. In the year 2015 onwards, IWMP is implemented as Watershed Development Component of Pradhan Mantri Krishi Sinchai Yojana (WDC-PMKSY).

Watershed and Agroforestry systems

Agroforestry combined with land and water management practices help to increase agricultural productivity and save watersheds from degradation. Agroforestry systems evolved over centuries through farmer experimentation and changing conditions. Today, agroforestry is an integral component of community forestry, watershed management and natural resource management efforts throughout Asia. People's participation is the key to sustainability of agroforestry in watersheds. An emerging trend in agroforestry research and development underpin the potential contributions of agroforestry to watershed management as well as to sustainable development for households and communities.

For instance, watershed management (870 ha) for fuel wood and fodder security in a traditional agroforestry system of arid western Rajasthan was revealed that the initiation of runoff was delayed by 15 to 30 minutes in block plantation of forest and silvi-pastures. It helps to reduction in 60 per cent silt load and conserves the rain water. The dry fuel wood collection from tree and shrub resources on farmers' field was 650 kg/ ha/ year. No household purchased fuel wood for cooking and heating needs. Total dry dung production (1800 t/ year) was transferred directly to crop fields which helps farm productivity enhancement. The trees and

shrubs in the watershed yields highly nutritious fodder (0.65 t/ ha/ year) helping in income generation from livestock. Improved silvi-pasture grows the *Acacia tortilis* (5 m × 5 m) as a woody and *Cenchrus ciliaris* as a noon-woody component. The average yield from grass was 2 t/ ha which helps to meet fodder requirements.

Central Arid Zone Research Institute (CAZRI) developed an arid watershed at Jhanwar, covering an area of 1200 ha, as a model watershed. About 60 ha of community land was developed as an ideal pastureland for animal grazing. Besides 6 to 7 q of grass seed $year^{-1}$, the previously barren land could yield good quality dry forage of 2 to 3 t ha^{-1}. Improved dry farming technologies were widely adopted by the farmers. The rocky and gullied catchments were treated with physical and biological measures, which resulted in 8 fold increase in biodiversity. The water conservation structures resulted in a rise in ground water recharge at the rate of 0.70 m $year^{-1}$ in the watershed. An additional 3240 m^3 of surface water potential was generated in the watershed by farm ponds of 271 m^3 capacity, which was found to be economical (B: C=1.66) in raising agro-horticulture system. This resulted in overall resource conservation and in the process increased crop productivity by 25-30 per cent with a sustained socio-economic development. This watershed was recognized by the UNEP for outstanding contribution in combating desertification and controlling land degradation in dry land environments.

Another study was carried out by ICAR. They constructed eight check dams, marginal bunds and mechanical measures were supplemented through vegetative measures by plantation of about 6,000 MPTs along the nallah, 12 different agroforestry models were introduced at the farmer's field (6.5 ha) along with suitable crop demonstration for dissemination of technologies. During that year when rainfall was below normal (24%), there was sufficient surface (24,000 m^3) and subsurface water (all 107 open wells are filled with water) harvested in the watershed, whereas more than 90 per cent wells are dry outside the watershed in nearby villages. Watershed development programme increased the cropping intensity (96–116 %), productivity and generated employment for 7,500 man days which helps to improve livelihood of local people.

In general agroforestry is increasingly adopted by farmers because of the crucial role of biomass derived from perennials as well as the changing patterns of availability and access to tree products. Successful watershed management must be built on two pillars *viz*., sound, practical, suitable technical innovation, and participatory institutional innovation. Agroforestry has a role in both. Two key strategies for agroforestry in watershed management are emerging *viz*., the adoption of a problem solving approach and the promotion of a suite of agroforestry practices that provide the service functions of watersheds, which are of greatest concern to outside stakeholders, as well as the productivity functions that are of most urgent concern to local people living in the watersheds.

Chapter - 12

MODELLING AGROFORESTRY SYSTEMS

Models are the tools that have been developed to make research, management or teaching more effective. In this context models were generally used by three types of end users *viz*., researchers, decision makers, teachers/ trainers. The objectives for using models is identifying knowledge gaps and testing interactions through virtual experiments, to the provision of decision support and teaching (and also research) in terms of using models to synthesise existing knowledge and to share that knowledge with others.

Crop models are widely available, and for many crops they are probably sufficiently accurate for inclusion in agroforestry models without much modification. In fact agroforestry models are used to compare land use decisions across a range of land uses that include both agriculture and forestry. Agroforestry modelling has gain importance due to the following reasons. Models of agroforestry systems have the possible to advance ecological understanding while providing greater guidance for future experimentation. Synthesize and integrate experimental and conceptual information as current understanding of how trees and crop component interact in complex systems, the model as a representation of the agroforestry system; to provide a reasonable null hypothesis about and extrapolate the results of tree-soil-crop-climate management interaction that can be tested with field experiment; and to save money, energy, and time in looking for appropriate agroforestry design for a location, *etc*.

Worldwide several models with updated versions have already been developed and used in the evaluation of agroforestry systems.

i) WaNuLCAS

WaNuLCAS is a process-based model of the Water, Nutrient, and Light Capture in Agroforestry Systems developed by Van Noordwijk in 1998 mainly for tropical region. The WaNuLCAS model was used to determine the complementary effects of trees and crops in the agroforestry systems to improve crop yields. WaNuLCAS is organized around a set of inputs that define initial conditions of the soil and tree properties plus dynamic inputs such as rainfall. It includes a management scheduling calendar, spatial definition of the agroforestry system, core modules that keep track of water, nitrogen, phosphorus, crop and tree roots in four vertical soil layers by four horizontal zones defined in terms of their distance from the tree, as well as crop and tree growth. This leads to a primary set of outputs in terms of the water and nutrient balances, standing stock of vegetation, harvested products and profitability (as Net Present Value). It enables evaluation of the choice of tree species, their spacing and pattern and possible intercrop. In an alley cropping context, whilst the two-dimensional WaNuLCAS model is used to determine the effect of distance from a tree on crop yields, this particular version of the model assumes that light interception in a West-East direction will be the same as in a North-South alignment.

ii) APSIM

The main motivation behind the development of the Agricultural Production Systems Simulator (APSIM) modelling framework was to provide the capacity to simulate biophysical processes in farming systems, in order to predict the economic and environmental outcomes of management practices and policy measures. The APSIM framework was initiated in 1994 and a 'next generation' of APSIM was released in October 2014. APSIM is not primarily an agroforestry modeling framework, but its modular structure has enabled some forestry and agroforestry applications including

- the hydrology and salt balance of eucalyptus woodlots grown in pasture systems to assist in the discharge of water from areas with shallow saline water tables,
- the economic viability of windbreaks in low rainfall areas, considering the trade off between competition for water and improved crop shelter provided by trees,
- soil conditions required to minimize seedling mortality in variable rainfall conditions,
- timber production and nutrient cycling in effluent-irrigated woodlots,
- fodder production and water use of saltbush alley systems, and
- habitat value of eucalypt woodlots of varying design.

iii) Hi-sAFe

The Hi-sAFe (Silvoarable Agroforestry for Europe) models are designed in response to the need for a process-based model that could simulate tree-crop interaction and management options in a temperate region. Hi-sAFe is an example of a three-dimensional agroforestry model. Hi-sAFe model has a switchable toric symmetry module that replicates the simulated scene, allowing it to simulate isolated trees, tree, alley cropping agroforestry and forest edges, as well as crop and forest monocropping. The typical agroforestry systems to be simulated by the model are walnut (*Juglans* spp.), wild cherry (*Prunus avium*), poplar (*Populus* spp.) or Mediterranean oaks (*Quercus* spp.) with winter and summer annual crops. Simulated management options include tree stem pruning and canopy thinning, tree stand thinning, tree root pruning, tree-crop distance adaptation, and precision crop management.

iv) Yield-sAFe

Yield- sAFe is a daily-time-step model which can describe the yields of crops and trees in agricultural, agroforestry and forestry systems. The Yield- sAFe model comprises of two above-ground zones (crop and no crop) and one below-ground zone (soil depth).

v) Farm-sAFe

The Farm-sAFe model developed during the SAFE project is an example of a financial model, developed to evaluate the profitability, practicality and feasibility of silvoarable systems from a farmer perspective. It used annual tree and crop yield data on arable, forestry and agroforestry systems, derived from the Yield-sAFe model, which was then used to compare the financial benefits and costs. As it is a farm-scale model, it can be used to model different arable, forestry and agroforestry systems across a farm reflecting the contrasting levels of soil fertility.

vi) SCUAF

Soil Changes under Agroforestry (SCUAF) is an easy-to-use computer model which predicts the effects of specific land use systems under given environmental conditions. Development of the model to estimate soil changes under agriculture, agroforestry and forestry was initiated in the 1980's, with a primary focus on the tree effects on soil conservation and soil carbon content. It also aimed to predict the effects of land use under defined climate conditions on soil loss and medium-term productivity. SCUAF focuses on the ability of trees to improve soil fertility in the humid tropics.

vii) HyPAR

The HyPAR model combines the Hybrid tree growth model with the PARCH (Predicting Arable Resource Capture in Hostile environments) model for grain crops and legumes. In the Hybrid model, trees are modelled using a 'gap model' that simulates competition between individual trees of different physiological types and determines nutrient fluxes at different canopy heights and soil depths for each tree. The PARCH crop model simulates growth of crops based on light, water, nitrogen and phosphorus availabilities, which are converted into growth efficiency factors. PARCH also adds additional stress factors that can account for adverse effects of high or low temperature. HyPAR provides a tool for examining alternative agroforestry options over a range of soil types, climatic conditions and management practices. It can run with either growing trees, or with trees of fixed age and structure, and runs with a daily time step.

viii) Other models

Besides the SCUAF, WaNuLCAS, HyPAR, HyCAS and APSIM, several other models such as COMP8, WIMISA (WIndbreak MIllet SAhel), CropSys, Almanac (Agricultural Land Management Alternatives with Numerical Assessment Criteria) and GAPS (General-purpose Atmosphere-Plant-Soil Simulator) are adequately simulate below ground processes of supply, uptake and competition for water, carbon, nitrogen or other nutrients for particular applications. However, these models were primarily research tools and not always well linked to other parts of the ecosystem such as food and/ or wood production.

Chapter - 13

FUTURE SCENARIO

Forests, being an inherent component of earth's ecosystem and needs a sustainable way of management. Issues involving the forests, the environment and the wildlife have become critical in deciding the future of our developmental activities. As far as environmental conservation is concerned, on the one hand, India is on the threshold of getting affected by the vagaries of climate change and biodiversity is getting depleted slowly yet massively due to over exploitation, poor management of natural resources and subsequent degradation of the forest and agricultural ecosystems. Even after the implementation of the joint forest management programme, natural regeneration of the flagship species of Indian forests is either scanty or deficient. Further, India's forests are shifting towards drier conditions resulting in huge reduction in environmental stability.

On the other hand, developmental progression is moving slowly due to environmental log jam. There was a time, when there was widespread diversion of the forest land for non forestry use till the Forest (Conservation) Act, 1980 was enacted. The diversion was reduced from 1,50,000 ha per annum in 1980 to around 30,000 per year until now. According to Ban Ki-moon (2015), to build a sustainable, climate resilient future for all, one must invest in forestry related activities. In this aspect the management of forests and conservation of environment has to be decided. Instruments created are for the management of our natural heritage and environment must satisfy all the stakeholders in order to ensure sustainable development, attaining the status of a developed country and for the realisation of millennium development goals of eradication of poverty, hunger, education, health and to ensure environmental sustainability.

While promoting forestry it must be clear that tree plantations should not be established on fertile agricultural lands at the expense of food production. There are only two options for growing trees like the first option is to grow on the wastelands, degraded lands and common grazing grounds which are mostly under the ownership of the government, public institutions and community. The second option is to grow on agricultural fields, under farm, homestead or agro forestry systems. For afforestation on wastelands, only a part of the society *i.e.* poor, landless labourers or marginal farmers are participate. On the other hand farm, agro, and homestead forestry can involve each and every landholder in the country involved in establishing trees. Thus the scope of forestry programme would include both social/community forestry and agroforestry.

Perennial tree crops in social forestry or community forestry and agroforestry systems play a fundamental role in the economies of many developed and underdeveloped countries in the tropics where they occupy millions of hectares and few alternative agricultural enterprises exist. They can be a major factor in local poverty alleviation and global demand for non timber forest products. Today smallholders produce 80-95 per cent of tree products. As perennial landscape features tree crops can impact land tenure and provide many of the biodiversity and soil protection functions of natural forests. They rarely compete with food crops and by incorporating valuable intercropped annual or perennial species they can provide the basis for productive agroforestry systems.

Programme priorities for the future

The community based forestry or agroforestry programmes during the next three decades should focus on the following aspects

- Enhancing the productivity of natural resources, while augmenting the basic needs of the community and
- Empowering the local communities to initiate the process of planning and programme implementation at the micro level to promote afforestation for income generation and ecological conservation.

The programme during the next three decades may be divided into two phases. During the first phase of 15 years, importance should be given to enhance the productivity, while conserving biodiversity and the environment. The second phase should strengthen the programme by promoting micro and macro level enterprises, involving the local people and the business interests to sustain the development and optimise the opportunities for employment and income generation.

i) Trees outside the forests

Number of methodologies has been framed for ecosystem services at the international and national level for pure forests or forest plantations. The Government of India has already sponsored programmes like a 'tree

for every child', 'a tree for every house', eco-development camps involving school and college students in tree planting and free distribution of seedlings to stakeholders. State sponsored Agroforestry schemes also have resulted in plantation of trees with commercial values.

a) Commercial plantations

Wood production should continue to be the priority under community forestry. However, fuelwood being a low value commodity, farmers prefer to grow superior quality wood suitable for timber and industrial use. Therefore the priority should be to promote cultivation of timber and industrial wood on degraded agricultural lands and community wastelands, which are not suitable for cultivation of fruit and NWFP species. The wood based industrial sectors which are dependent on natural forests can associate with farmers to procure their raw materials. This programme can be managed with least financial support from the government, as commercial banks and industries are prepared to provide necessary finance.

b) Mixed plantations

While the industries utilise the wood of a certain minimum diameter, almost 40-50 per cent biomass in the form of branches and twigs can be available for fodder, manure and fuel, almost free of cost. Apart from producing fuelwood as a by product in commercial plantations, fast growing fuelwood species of short gestation can be introduced on field bunds and as mixed crops with commercial wood species. This will augment the fuelwood supply to a great extent.

ii) Non-timber forest produces

To maximize economic benefits to the communities with sustainable forest use, the available mechanisms for dealing with NTFP will be reviewed. As the large volume NTFPs require dealing and trading at higher scale, professional services can be organized through the marketing federations of NTFP gatherers/processors. Nationalized system of collection through corporations and contracts will be dealt with in the light of the settled policy and legal position. Improving livelihood through gainful employment opportunities will be encouraged by organizing value addition of NTFP at community level. For capacity building and technology assistance, linkages with voluntary organizations and programmes such as National Bamboo Mission, National Mission on Bamboo Applications, Village and Small Scale Industries, and institutes of rural development and technologies will be established.

iii) Energy saving devices

Biomass being a renewable form of energy, in future it can be an excellent source for generating electricity in wood surplus countries. Efforts are also needed to introduce various energy conservation measures. These may include the development of fuel efficient, low cost wood stoves, promotion of improved cooking vessels and introduction of efficient models of biogas to substitute wood fuel for cooking.

iv) Agroforestry

National Agroforestry Policy, 2014 has written a new chapter in the development of the agroforestry in India by addressing most of the disputes faced by farmers and rural people but the major challenge left is to move forward the National agroforestry policy from paper to the ground level. To facilitate use of agroforestry systems as a significant option for livelihoods improvement, climate change mitigation and adaptation and sustainable development in India, research, policy and decentralized planning will have to needed to the implementation. They are i) effective communication with people in order to enhance the agroforestry practices with primacy to multifunctional values, (ii) maintenance of the traditional agroforestry systems and strategic creation of new systems, iii) enhancing the size and diversity of agroforestry systems by selectively growing trees more useful for livelihoods improvement, iv) designing context specific silvicultural and farming systems to optimize food production, carbon sequestration, biodiversity conservation, v) maintaining a continuous cycle of regeneration-harvest-regeneration as well as locking the wood in non emitting uses such as woodcarving and durable furniture, vi) participatory domestication of useful fruit tree species currently growing in the wilderness to provide more options for livelihoods improvement, vii) strengthening the markets for nontimber forest products and viii) addressing the research needs and policy for linking knowledge to action. Prevalence of a variety of traditional agroforestry systems in India offers opportunity worth reconsidering for carbon sequestration, livelihoods improvement, biodiversity conservation, soil fertility enhancement and poverty reduction.

Contribution of agroforestry to various commodities during 2050

Recent agricultural census data showed that there are more than 570 million farms worldwide are small and family operated. The small farms (less than 2 ha) operate about 12 per cent and family farms about 75 per cent of the world's agricultural land. If trees are planted as a part of climate resilient farming in their farm lands, enhances the sustainability of livelihoods in the same time protect environment from degradation. According to CAFRI (2015) by 2050, there is a scope of increasing the area under agroforestry by another 28.0 mha and thus a total of 53.23 mha or 17.5 percent of country reported area under agroforestry. Therefore, raising plantation on non-forest areas including farm forestry and agroforestry has bright prospects in enhancing the green cover outside the forests. It was also estimated that during 2050 the contribution of agroforestry includes 41.14 mt of food grains, 47.74 mt of fruits, 154.50 mt of fodder, 308 mt of fuel wood and 295 mt of timber.

Table 13.1 Domestic demand for various commodities and agroforestry contribution in 2025 and 2050 (CAFRI, 2015)

Particulars	2010-11	Projected for 2025	Projected for 2050	Contribution from Agroforestry in 2050
Food grains (m t)*	218.20	320.00	457.10	41.14
Fruits (m t)*	71.20	106.00	305.30	47.74
Fodder (m t)	1061.00	1170.00	1545.00	154.50
Fuel wood (m t)	308.00	479.00	629.00	308.00
Timber (m t)	120.00	171.00	347.00	295.00
Bio-oil required for 20 % blending with diesel (m t)	12.94	22.21	37.92	30.34
Area (m ha) required for TBO's	12.32	15.86	21.67	17.34
Agroforestry (m ha)	25.32		53.32	

(*Food-grains/fruits production from systematic agroforestry systems *viz.* agri-silviculture/ agri-horticulture only considered)

Agroforestry for improving productivity of agroecosystems

As over 70 per cent of the agricultural lands in India are dependent on rainfall, the crop yields are comparatively low. In such a situation, promotion of tree based farming system has good potential to improve the land equivalent ratio (LER) as well as crop yields. The selection of a suitable farming system will be based on the soil fertility and moisture availability. The system of combining agricultural and horticultural crops with timber, fodder, fuel and NWFP producing trees can ensure the supply of essential commodities while generating cash surplus. In this system the income from fruit and NWFP plantation are generally higher than timber and industrial wood plantation, because of substantial annual income without cutting the trees.

The world herbal trade has grown to $120 billion and is expected to reach $7 trillion by 2050. India is the second largest exporter of medicinal plants in the world. With 6,600 medicinal plants, India is second to China in this ranking and together they produce over 70 per cent of the herbal medicine's demand across the globe. Along with trees, cultivation of medicinal plants will be an excellent opportunity for the Indian farmers to enhance their income through integrated cultivation of these species on community lands as well as agricultural lands.

The silvihorticultural systems are ideal for deep soils having some water resources to protect the plants, while agrisilviculture and farm forestry are suitable for marginal lands. With introduction of fruit species, farmers can be motivated to intensify their farming operations and improve the soil productivity. Such tree based farming systems have been highly effective in supporting livestock husbandry to enhance their income by 35-40 per cent and preventing migration of rural families.

Government of India has already launched a massive programme of watershed development with linkage of agroforestry as an integral part of this programme will not only provide an opportunity to enhance biomass production, but also improve the profitability. The development of tree based farming systems on the watershed basis has the potential to improve water supply, food production, employment generation apart

from supplying fuel and forage. This programme can help in recharging the ground water table to provide water for human beings, livestock and crops.

Dissemination of information on tree-crop-livestock interactions

Tree-crop-livestock interactions in agroforestry systems are potentially significant, but have not been adequately developed. The nature of livestock tree interactions are variable and the extent, especially of the more positive effects, economic and environmental impacts, are inadequately understood. Most of the research has been undertaken in Africa and South-east Asia with demonstration of successful benefits; however, much more dissemination of information is necessary about the impacts of the interactions.

Another aspect that has not received adequate attention is the time and spatial dimension of biophysical interactions in agroforestry. The interactions of systems at farm and landscape level should receive attention in the future because the lateral flow of resources (water and nutrients) becomes important at such spatial scales and because trees can exploit resources from larger areas than. Knowledge of the larger scale interactions is important in order to realistically assess the community and global benefits of agroforestry.

Contribution of bio-fuel from tree born oil seeds (TBOs)

The major source of biofuels in India is non-edible oil seeds *i.e.* tree borne oilseeds (TBOs). The requirement for TBOs in the country as per the National Oilseeds and Vegetable Oils Development Board, Gurgaon (India) exceeds 5 million tonnes. However, only 0.8-1.0 million tonnes are being collected from various TOBs. National policy on bio-fuel (2009) has proposed target of 20 per cent blending of biofuels, both for biodiesel and bio-ethanol by 2017, which needs approximately 13 mha afforestation with oil seed plants, however so for it was not achieved. Proposed plantation and processing involves huge business opportunities (13 mha area to be brought under biofuel plantations which is 30 times than the presently available) and employment generation. According to CAFRI (2015) it was projected that during 2050, agroforestry contributes 30.34 mt (80 %) of bio-oil from 17.34 mha of agroforestry land with TBOs. Some of the TBOs species can be grown in wasteland under relatively unfavorable environmental conditions and such species should be promoted. They meet the triple objectives of rehabilitating wasteland, providing an energy substitute and increasing the area under green cover. However, there is still a need for research on genetic improvement for increasing seed and oil yield.

Carbon sequestration potential

The global carbon sequestration potential is 1.9 Pg C over 50 years on 1023 m ha under agroforestry with median sequestration of 94 Mg ha^{-1}. Considering the large extent of degraded crop lands and pasture lands and the potential to improve them using agroforestry, there is enormous potential to sequester additional carbon in such systems. According to an estimate by IPCC (2000), improving current management practices in existing agroforestry practices could sequester an additional 17 Gg C ha^{-1} $year^{-1}$ by 2040. Additionally, 630 million ha of unproductive crop lands and grass lands could be converted to agroforestry, representing a carbon sequestration potential of 586 Pg C $year^{-1}$ by 2040. Recently, according to the Nationally Determined Contribution (NDC), India has a target to sequester 2.523 billion tonnes of carbon by 2020-30. Our current forest and tree cover is 75 million hectare and to meet our target of carbon sequestration, 30 million hectares of additional land would be required for forests. However, comprehensive data on C distributions in agroforestry systems for many countries is lacking; therefore, documentation of such data is needed. This will help design better farm/agroforestry systems for agricultural landscape to enhance carbon sequestration potential.

Approaches for recuperating the agroecosystem conservation

i) Agroforestry at watershed level

Conservation and optimal utilization of natural resources (soil, water and vegetation) are the principal objectives of the watershed management. Agroforestry is a useful approach in watershed management to promote sustainable use of various resources and to improve the economic well being of the local people. In future, properly designed and sustainably managed agroforestry systems at watershed level can provide benefits to the society and has potential to meet environmental and socioeconomic requirements.

ii) Modelling approaches in tree planting

Agroforestry is sustain its place in the mainstream discourse on agricultural development and food security, it is immensely important that reliable predictions of tree and crop performance can be made for a wide range of agroforestry practices and across a wide range of environmental conditions. Modular modelling approach should allow combining appropriate tree, crop and other components to obtain new system configurations and to simulate all relevant aspects of their performance under the set of environmental conditions of interest. Extending such frameworks to include capabilities to model trees and their interactions with crops is an efficient strategy towards achieving reliable yield prediction in agroforestry that builds on, rather than replaces, past modelling efforts.

iii) Establishment of user friendly databases

User friendly scientific databases for the forestry and agriculture sector will be strengthened to ensure greater reliability of estimates and forecasting the process of planning and policy making with the areas like improvement of rural livelihoods, policy, social and institutional issues, carbon sequestration, biodiversity, public/private partnerships, water issues, agroforestry for health and nutrition, management genetic diversity, medicinal and aromatic plants, scaling up of agroforestry benefits, short rotation woody crops, phyto-remediation, small farm soil fertility management strategies, tree domestication, trees in fragmented landscapes, tropical home gardens, valuation of environmental benefits *etc*. with the ultimate goal of sustainable uses.

iv) Linking social/community and agroforestry practices with REDD+

Reducing emissions from deforestation and forest degradation, and the role of conservation, sustainable forest management, and enhancement of forest carbon stocks (REDD+) proposes to deliver multiple outcomes, including emissions reduction, livelihood support, and sustainable forest management. Forestry outside the conventional forests and REDD+ share the objectives of maintaining forest cover by reducing forest conversion to other land uses and maintaining forest integrity by reducing unsustainable resource extraction while securing essential ecosystem services. Social/community forestry was developed principally to protect forests and support the subsistence and income generating extractive activities such as fuel wood and fodder production and sale of non-timber forest product exploitation by forest dependent communities. In contrast, REDD+ was developed principally to mitigate climate change. However, for REDD+ to succeed, buy-in, engagement and meaningful participation of local communities, as well as enhancement of people's livelihoods, have proven to be critical. Therefore, over the years, social/ community forestry became popular in the global REDD+ discourse compared to other forest protection approaches such as protected areas that may feature high social costs because of exclusion or restriction of local communities' access and use. Hence, the policy makers and the scientific community have explored possible ways of linking social/ community forestry and agroforestry to REDD+.

v) Eco-tourism

Eco-tourism, including farm and homestead tourism, offers excellent possibilities of taking the benefits of nature conservation to local communities in many ways. The protected areas and the adjoining terrestrial and wetland ecosystems have the potential to contribute to the rural economy and community development. The programmes should be taken up with the tourism sector and build on community ownership to promote equitable distribution of the net benefits.

vi) Imbursement for ecosystem services

Tree crops currently face numerous problems including product price instability, increased industrial concentration within certain commodity chains, withdrawal of state support and weak research efforts. Neither past attempts to regulate trade nor more recent market liberalization has stabilized prices for their products. Producers now need to focus more on diversifying and increasing product quality to ensure more stable income and sustainability. There is a need to focus on methodologies for quantification and payment of ecosystem services in agroforestry system, which will link consumers of environmental services with suppliers. Uniform guidelines for exemption of agroforestry tree species from restrictive regulatory regimes in all states are required with uniformity in tree and land tenure laws across the country.

vii) Facilitative policy environment

The policy measures are recommended by analysts to boost tree growing are i) there is a need for a nationwide review of all laws and procedures constraining farm forestry, ii) rules and procedures for felling, transport and sale of major tree species should be totally liberalised and the local *Panchayat raj* institutions should be given powers to issue necessary passes, iii) existing policy of state monopoly on trade of most commercially important non-timber forest products should be reviewed, iv) laws governing the management of private forests need to be liberalised, v) incentives for tree farming, such as nationally tradable afforestation credits, should be introduced, vi) industry may be given some concessions in excise or sales tax, vii) policies such as state monopoly over certain forest products and supply of forest products at concessional rates to various users should be reviewed and viii) whether the government should continue to raise tree species on forest lands that can be more easily and efficiently grown by the farmers on their farm lands should be reconsidered.

viii) Gender perspective

Women are the principal stakeholders in natural resource use and management. It is crucial to ensure equal representation of women in the decision making and implementation processes in participatory planning and development programmes. The participation of women should be ensured in all community activities and the decisions should be based on their considered opinions. This should hold good for processes such as afforestation through Panchayats, protected area management, planning, and use of common property resources management. Thus gender perspective should be a visible component of any community based programme.

ix) Research and development efforts

Research support for farm or agro forestry could expand the range of commercially tradable species, identify species appropriate for particular environments and extend the option of farm or agro forestry to those for whom it has not been viable to date. The following research initiatives are recommended by the scientists are i) suitable tree species for different areas should be identified and tree improvement work on promising indigenous species should be initiated, ii) new uses for produce from popular multipurpose tree species should be developed, iii) environmental impacts of taking up farm/agro forestry on a large scale in a region should be studied by an independent body and iv) research on producing better and higher yielding clones should be needed.

Chapter - 14

SILVICULTURAL PRACTICES FOR ECONOMICALLY IMPORTANT TREE SPECIES

Forests in India cannot meet national demand for firewood, timber and wood-based products on a sustainable basis, because of low growing stock, poor increments, inadequate financial and technological inputs, severe biotic pressures and serious degradation of forest resources. To sustain the productivity of forest based resources, farmers have maintained sporadic naturally grown trees on their farms and homesteads. However, as land holdings are marginal and farmers are generally very poor and prefered to grow short-rotation seasonal or annual crops for their livelihood and for regular income to meet family needs.

Many farmers planted a few trees along farm boundaries or roads as shelterbelts and for production of small timber or fuelwood. It provides a good hedge against risks of crop failures and generated lump sum incomes in times of need. Now, wood based industries have promoted farm forestry and agroforestry plantations through supply of planting stock, technical extension services and buy back arrangements, with varying degrees of success. Exploration of the potential indigenous plants as alternate sources of industrial raw materials support its conservation by contributing to genetic diversity and safeguarding native species from the threat to become endangered thus promoting their sustainability in that region.

Silviculture typically associated with various aspects of tree planting, such as tree selection, genetic improvement, site selection, regeneration methods, seedling production, site preparation, tree density management, fertilisation, pest management, thinning and pruning. Formally, the role of silviculture is to manage forests scientifically for continuous production of goods and services while meeting biological and economic requirements. However, new paradigms emphasising ecological values such as the biological diversity of forests have evolved recently. Managing conventional forests and trees outside the forests to meet social aspirations and ecological requirements is now in the realm of silviculture.

Acacia spp. (Australian Acacias) (Leguminosae – Mimosoideae)

Australian acacias are the extremely diverse and found in habitats from rainforest to arid lands. The generic name of acacia comes from the Greek word 'akis' meaning a point or a barb. Of the 1380 species of acacia in the world, Australia has about 985. Collectively Australian acacias are known as "Wattles". It ranges in size from mat like creepers to tall forest trees. Australian acacias have been spread to over 70 countries due to their wide adaptability and suitability for multipurpose uses, including timber, pulpwood, tannin, fuelwood, erosion control, windbreaks, stabilization of moving sand, animal fodder, edible seed. By the 1840s, three Acacia species were planted in India to supply fuel for the army.

As natural forests in our country disappear and utilization technologies adapt to small diameter logs from plantations, fast growing exotic *Acacias* are playing a major growing role in supplying large scale demand. *Acacias* fix nitrogen after nodulating with a range of *Rhizobium* and *Bradyrhizobium* strains. It also has associations with both ecto and endo mycorrhizal fungi. It's spreading, superficial and densely matted root system makes *Acacias* suitable for stabilizing degraded lands. In this section, the four significant wattles *viz.*, *A. auriculiformis*, *A. holosericea A. mangium* and *A. auriculiformis x mangium* hybrids are discussed.

Acacia auriculiformis Benth.

Common name: Earleaf acacia (Engilish), Kathivel (Tamil)

Acacia auriculiformis is a small to medium sized evergreen tree. The species name *auriculiformis* comes from the Latin 'auricula'- external ear of animals and 'forma- form, figure or shape, in mention to the shape of the pod. It is widely planted for fuelwood, erosion control, shade, shelter, amenity and it has great potential to provide timber and other industrial wood products. It is a dense wood with high energy (4500-4900 kcal kg^{-1}) contribute to its popularity. It provides very good charcoal that glows well with little smoke and does not spark. The wood is extensively used for paper pulp. The bark contains sufficient tannin (13-25%) for commercial exploitation and contains 6-14 per cent of a natural dye.

Distribution

A. auriculiformis has been an important exotic in many tropical countries for more than half a century. It was introduced in India during 1946 in West Bengal and has since become popular social forestry species throughout the country because it tolerates long dry spells and alkaline soils.

Biophysical limits

A. auriculiformis occurs from near sea level to 500 m, but is most common at elevation less than 80 m. It is predominantly found in the seasonally dry tropical lowlands in the humid and sub humid zones. The mean annual rainfall in its natural range varies from 700-2000 mm, and the dry season may be 7 months.

The mean maximum temperature of the hottest month is 32-34^0 C and the mean minimum of the coolest month is 17-22^0 C. Most commonly suited soil is clay soils and exhibits the ability to grow in a variety of soils including calcareous sands and black cracking clays, seasonally waterlogged soils, sandy loams and coral rag. It can also tolerate highly alkaline and saline soils with pH ranging between 4.3 and 9.

Reproductive Biology

A. auriculiformis is hermaphroditic and pollinated by insects. Flowering season is September-October and fruiting season is March April and seeds are available for collection from April to May in Tamilnadu.

Germplasm management

Seed storage behavior is orthodox; seeds retain viability for several years. There are approximately 38,000-55,000 seeds kg^{-1}. Germination is 55 per cent with the viability 3 years at 8 per cent moisture content.

Propagation

By seeds

Immersion of seed in adequate boiling water for 1-2 minutes is suitable to break dormancy. Pretreated seeds at the rate of 5g m^2 are broad cast or line sowed or dibbled at 1 cm depth with 5 x 5 cm spacing in nursery beds. Germination starts in 15 – 20 days and completed in 30 – 35 days depending on temperature. Seedlings pricked out in polybags at two leaf stage.

Newly emerged seedlings should receive 50 per cent shade. Once they are established, 70 per cent sunlight is optimal. Inoculation with appropriate rhizobia may be beneficial, especially when seedlings are raised in sterilized soil. In general, 3-4 months are needed to raise seedlings to a plantable size, 25 cm in height.

By vegetative propagules

The soft wood cuttings are soaked in IAA solution (100 ppm) for 24 hrs before planting had a rooting rate of 82 per cent and survival rate of 95 per cent with well established bare root.

Planting

The most successful method is transplanting polybag grown seedlings. Plantings are spaced at 2-4 x 2-4 m, the closer spacing being more suitable for firewood and pulp wood plantations.

Manuring and fertilization

Application of NPK fertilizer in the first year helps to improve initial growth. Fertilization rates depend on site quality.

Pruning

Removal of lower branches and of young plants has been suggested as a means of improving stem form and of reducing the incidence of multiple stems.

Thinning

One or two thinnings are required with longer rotations, depending on initial spacing, site quality and tree growth.

Growth

Under favourable conditions, trees may reach a height of 15 m in 5 years and produce an annual wood increment of 8-20 m^3 ha^{-1} over 10-12 years. An increment in height of 2-4 m per year in the first few years is common even on soils of low fertility.

Rotation period

Recommended rotation is 4-5 years for fuelwood, 8-10 years for pulp and 12-15 years for timber.

Yield

Yields recorded higher than 20 m^3 ha^{-1} yr^{-1} on 10–20 year rotation. On poor soils, yields drop to 8–12 m^3 ha^{-1} yr^{-1}.

Acacia holosericea G.Don

Common names: Silver leaf wattle (English), Maankaadhu karuvel (Tamil)

Acacia holosericea attains an average height of less than 8 m, with numerous branches beginning from the base, giving it a multi stemmed appearance. This shrubby acacia is little used in its native Australia, yet it promises to be an outstanding multipurpose tree for the dry tropics. The species name is derived from the Greek 'holo' (entire/whole) and the Latin 'sericeus' (silky, with long straight close pressed glossy hairs).

A. holosericea has an excellent potential for fuel, charcoal, land rehabilitation and as an ornamental is now being realized in the Indian subcontinent. The rapid early growth rate makes it a highly productive fuelwood source (wood and charcoal, 4670 Kcal kg^{-1} and 7535 Kcal kg^{-1}, respectively). The large, dense crown of this shrubby nature enables it to form a screen and act as multi storey windbreak with other trees.

Biophysical limits

A. holosericea grown well with an altitude of up to 600 m, mean annual temperature of 19-40^0 C, the mean annual rainfall of 600-1200 mm. it grows on a wide range of soils from shallow acidic sandy lithosols, shallow loams, etc.

Reproductive biology

A. holosericea relies on sexual reproduction. It produces a large number of flowers, a small proportion of which develops into fruit. It is pollinated by the activity of insects. Seed dispersal is prompted by propulsion from drying dehiscent pods. In Tamilnadu the flowering season is October to November and fruiting occurs in December – February.

Germplasm Management

There are 1,00,000 - 1,75,000 seeds kg^{-1}. Seed storage behaviour is orthodox and 11 per cent viability lost after 14 years storage at room temperature.

Tree management

Coppicing is generally regarded as poor.

Yield

Trees of 4 years old can yield up to 13 t/ha.

Acacia mangium Willd.

Common names: Black wattle (English), Maan sevi varuvai (Tamil)

A. mangium is a single stemmed evergreen tree or shrub that grows to 25-35 m in height. The specific name is a suggestion that this tree resembled 'mangge' (mangroves in Indonesia). *A. mangium* have become major plantation tree species in Southeast Asia in recent decades. It provides good quality charcoal and suitable for the manufacture of charcoal briquettes and artificial carbon. It is mostly used for pulp production, but its wood can also be used for general construction, furniture making, particle board as well as plywood. The pulp is readily bleached to high brightness levels and is excellent for papermaking. It has high tannin content (18-39%), justifying commercial exploitation of tannins. With its dense foliage, retained throughout the year, *A. mangium* makes a useful shade tree, screening and soil cover crop.

Distribution

Its native habitat is tropical rainforests of Queensland, Australia. In India it was introduced in 1980’s and farmers started to planting in farm fields in the early 1990’s.

Biophysical limits

A. mangium is a species of the humid, tropical lowland climatic zones characterized by a short dry season. Altitude range is from sea level to 800 m, mean annual temperature is 13 - 32^0 C and can grow a minimum annual rainfall of 1000 mm. Soil type is deeply weathered or alluvial soils and tolerates pH levels between 4.5 and 6.5. The productivity of *Acacia mangium* is good in wet zone where soil depth is moderate and soil fertility is good.

Reproductive biology

A. mangium starts to flower and produce seeds 18-20 months after planting. Flowering months varies greatly

with regions. The tree is a hermaphrodite and generally outcrosses, with a tendency towards selfing. From the onset of flower buds to pod maturity is about 6-7 months. Pods and seeds should not be left long to dry in the sun, as temperatures exceeding 43^0 C reduce viability.

Germplasm management
There are about 66,000-120,000 seeds kg^{-1}. Seed storage behaviour is orthodox. There is little loss in viability (6%) after 1-2 years storage at $4\text{-}5^0$ C.

Propagation and nursery management
By seeds
The dormancy of seeds is caused by the hard and water impermeable seed coat. It gives seed longevity, makes germination slow, unpredictable and difficult. To obtain even and quick germination in the nursery, seeds are pretreated before sowing by immersing them in boiling water for 30 seconds then soaking them in cold water for 24 hours; alternatively, they may be manually scarified. The seeds are sown in sunken or raised beds. The germination rate is high, generally 55-88 per cent and germination is rapid, occurring within one month.

The germinated seedlings in the beds are prickled in to polybags at two leaf stage. The seedlings are maintained in the nursery for 9-16 weeks.

By vegetative propagules
Plants can also be propagated vegetatively through single node stem cuttings 4-5 cm long and 0.5-1.5 cm in diameter, leaving 0.5-1 phyllodes.

Planting
The appropriate height for transplanting of seedling is 25-40 cm.

Silvicultural characters and tree management
Acacia species are pioneers that demand full light for good development; in shade, *A. mangium* growth is stunted and spindly. The ectomycorhizal fungus *Thelephora ramaroides* has been identified in association with *A. mangium*. However, it is more susceptible to pests, diseases and damage due to wind. Its productivity reduces considerably under degraded lands in dry areas.

Growth
A. mangium is a very fast growing species. It can achieve a mean annual diameter increment of up to 5 cm and a height of up to 5 m in the first 4-5 years and it attaining 15 m height and 40 cm diameter at breast height (DBH) in three years. Plantation canopy cover occurs after 9 months to 3 years, depending on soil fertility, weediness and initial spacing. However, growth declines rapidly after 7 or 8 years. Except under ideal conditions or over periods of more than 20 years, the tree will probably not exceed 35 cm in diameter and 35 m in height.

Pruning
Pruning is done twice; the 2^{nd} time the branches are pruned out farther up the trunk, often to a height of 6 m. Pruning out branches with diameter of 2 cm or more makes the tree susceptible to infections, especially heart rot.

Thinning
Trees are very responsive to extra growing space. The thinning carried out in plantations for pulpwood production is aimed at achieving a final stock of 600-700 stems ha^{-1} from the 1,250 trees ha^{-1} planted. It is executed after 18 months. In certain locations, plantations grown on a 7-8 year rotation for pulpwood are not thinned.

In plantations producing quality logs, the initial number of trees is generally thinned, reducing them from 900 ha to 100 ha^{-1} in 2 or 3 thinning's. The 1^{st} thinning is done when trees are 9 m tall, that is, before 2 years of age. The rotation is 15-20 years.

Felling cycle
A. mangium trees are clear cut for pulpwood 6-8 years after planting whereas, for sawn timber the rotation is 15-20 years.

Yields
In 4 year old commercial plantations, yields as high as 44 m^3 ha^{-1} $year^{-1}$, but 8 m^3 has been reported on poor sites. In general on an average, *A. mangium* often yields 25 m^3 ha^{-1} $year^{-1}$.

***Acacia* hybrids**
The Acacia hybrid is a medium sized tree that is similar in appearance to *A. mangium*. *A. mangium* x *A. auriculiformis* hybrids often occur spontaneously in places where both parental species have been introduced in the same vicinity. The morphological traits of these hybrids (flower colour, pod aspect, leaf shape and size, bark aspect and colour, wood density) are generally intermediate between those of the *A. mangium* and *A. auriculiformis* pure parent species. When Acacia hybrid is young, the bark is greenish white, similar to the bark of *Acacia auriculiformis*. As it ages, the bark turns greenish brown or brown, eventually becoming as smooth as the bark of *A. mangium* with slightly scaly, shallow furrows at the foot of the tree. In the late 1970s, natural hybridisation between *Acacia mangium* and *Acacia auriculiformis* was first reported in Malaysia. *Acacia mangium* was identified as the female parent and *Acacia auriculiformis* as the male parent of the natural Acacia hybrid. *Acacia* hybrid has a promising potential for plantation use since it was shown to be more vigorous and adaptable than both parental species. The establishment of Acacia hybrid plantations in rural areas creates employment opportunities for poor households, which had hitherto only been possible on large scale forestry plantations.

Acacia hybrid is found where mean annual temperatures are 12– 35°C, annual precipitation is 1200–1850 mm and elevation is 50–350 m. The species grows on sandy loam or sandy clay soil; however, it also thrives on lateritic crude soils.

Propagation
The main advantage of mass vegetative propagation compared to propagation by seeds is that higher yield planting materials with uniform characteristics can be obtained within a minimum time period. Vegetative propagation of superior mature selected trees avoids the long selection cycles associated with genetic improvement strategies using sexual propagation. Acacia species are generally propagated by seeds for large-scale reforestation programs. However, in the case of

A. mangium x *A. auriculiformis* hybrids, vegetative propagation remains the only means of multiplication because of the very limited capacity for producing interspecific hybrid seeds from bispecific orchards. Besides, tissue culture technologies and especially micropropagation are faster than horticultural vegetative propagation methods to rejuvenate and mass multiply true-to-type adult selected trees. From an economic standpoint, tissue culture technologies could be even more cost effective than conventional methods for large scale cloning, since several years could be saved through rapid mobilization of genetically superior materials.

Growth
The tree is capable of reaching a height of 8–10 m and a diameter at breast height (DBH) of 7.5–9.0 cm within 2 years. Stem volume of acacia hybrids is 2-3 times greater than that of *A. mangium* and 3-4 times greater than that of *A. auriculiformis* of the same age.

***Acacia nilotica* (L.) Delile** (Mimosoideae)

Common names
Indian gum Arabic or Black Babul (English), karuvelum (Tamil), Babul (Hindi)

Trade name: Babul acacia

Acacia nilotica a multipurpose tree with 5 to 20 m high is native to the arid and semi-arid regions of Africa and western Asia and the Indian sub continent. The generic name ‘acacia’ comes from the Greek word ‘akis’, meaning a point or a barb. The typical *A. nilotica* is native to the Nile countries, hence the specific name. *Acacia nilotica* is a complex species and has number of sub-species. Presently, 9 sub species are known. These sub-species have been differentiated mainly on the basis of the shape, size and degree of pubescence of the branches, characteristics of pods, the habitat of the tree and the shape of the crown. *A. nilotica* subsp. *nilotica* and *A. nilotica* subsp. *cupressiformis* are commonly occurring species in India.

A. nilotica is truly a multipurpose tree and extensively used in traditional agroforestry systems. The tree has a special significance to resource poor farmers, who have a long tradition of growing it on their farms along with crops. It is reported to be well nodulated with Rhizobium species. This nodulation behavior helps in biological nitrogen fixation which helps to meet the nitrogen requirement in nutrient poor soils and application of nitrogen. In addition, this species form symbiotic associations with naturally occurring soil fungi called vesicular arbuscular mycorrhizae (VAM). This association assists the roots to exploit more soil volume and to gain improved access to available nutrients especially phosphorus under stress and also makes the unavailable forms of nutrients into utilizable forms. *A. nilotica* leaf litter decomposes easily and cycles organic matter in the soils where planted, qualifying the species for its suitability in agroforestry systems. *A. nilotica* appears to be the most important species for rehabilitation of saline, alkaline, ravine and waterlogged areas.

The wood is strong, tough and heavy, with a density of 650–830 kg/m^3 at 15 per cent moisture content. The wood has a high content of silica which rapidly blunts cutting tools but is very durable if seasoned well. The wood is an excellent fuel, the energy value of moisture free heartwood being 4800 kcal/kg. It yields a high grade charcoal with an energy value of 6700 kcal/kg. This valuable source of firewood and charcoal has been used in small industries. The crude protein content of the leaves is 14-20 per cent, and 11-16 per cent for the highly palatable pods. It constitutes a chief diet for goats and sheep and seeds are a valuable cattle food. The fragrant flowers of *A. nilotica ssp. nilotica* are popular bee forage and yield a honey of good quality. The bark of slender branches yields a fibre which is made into coarse ropes in India. Trees have been managed on a 20-30 year rotation producing termite resistant timber.

A. nilotica ssp. nilotica is probably the earliest source of gum arabic (Indian Gum Arabic), although this now comes mainly from *A. senegal*. The gum tapped from the bark is used in manufacturing matches, inks, paints and confectionery. The pods have been used for tanning in Egypt for over 6000 years. The whole pod of babul contains about 12-19 per cent tannin and that removed of seeds 18-27 per cent tannin. The bark is obtained mainly as a byproduct when trees are felled for timber or fuel. It is separated by beating the logs with wooden mallets and the strips obtained are dried in the open chipped into pieces and sent to tanneries without grading. The inner bark tannin is used for tanning and dyeing leather black. Young pods produce a very pale tint in leather, notably goat hides. Dye stuffs with varying colours are prepared by boiling the pods, leaves, bark in different proportion and occasional additions of wood extract.

Natural Habitat

A. nilotica ssp. nilotica has requires a strong light requirement. Severe frost affects small seedlings as well as large trees. It is drought resistant and occurs in plain, flat or gently undulating ground and ravines. Trees grow best on alluvial soils in ravine areas subject to periodic inundation.

Biophysical limits

The altitude ranges from 0-1340 m with mean annual temperature of 4-47^o C and mean annual rainfall of 200-1500 mm. It grows on a wide variety of soils, seemingly thriving on alluvial soils, black cotton soils, heavy clay soils, and can tolerate poorer soils.

Reproductive Biology

Flowers began between March and June, with pods forming between July and December. Most leaf fall corresponds to this dry period between June and November. Pods drop from October to January. Most flowers are functionally male with a few hermaphrodites.

Germplasm Management

Seed storage behaviour is orthodox. Viability can be maintained for several years in airtight, moisture-proof conditions at 10^o C. with 8-9 per cent moisture content. Seed weight varies from 6,600–7,500 seeds per kg. Germination capacity is varies from 30-50 per cent.

Propagation and management

Natural regeneration

Trees produce seed in abundance from around 5–7 years old. It can be easily propagated by seed. Seeds germinate following rainfall in the wet season. Natural germination is aided when seeds are disturbed, *e.g.* by fire or by passing through the digestive system of animals. The latter seeds germinate easily due to fermentation and moistening.

Propagation and planting

Pre-sowing treatment

Seeds are extracted from the pods. Pre-sowing treatment is required once seed exhibits dormancy as the seed coat is very hard. Seed may be immersed in hot water (80°C) for about 30 minutes or in boiling water for 10–15 seconds and then soaked for 24 hours in cold water before sowing. Germination can also be improved by soaking in concentrated sulphuric acid (90%) for 10–30 minutes followed by rinsing in cold water and by also fermentation in moist cow dung for 48 hours. Seed mixed with companion Rhizobium strains/ microbial consortium in a slurry and then sown in polybags has shown significant increase in seedling growth.

The treated seeds are sown in raised nursery beds about 5 months before transplanting in the field. Germination starts 1–3 weeks after sowing and is mostly complete in one month. Seedlings are transplanted in to containers at 4^{th} leaf stage. Growths are rapid and when planted in polytubes seedlings reach a height of 25–30 cm in 4 months.

Planting

Direct sowing in the field is the most common method of planting. The successful ones are by broadcast sowing (seed rate 2.5 – 3 kg/ha) or dibbling in lines/ patches during the onset of monsoon (seed rate 1 kg/ha). For transplanted seedlings are planted at a spacing of 3 × 3 m. Plantation for the production of tannin and gum, a spacing of 4 × 4 m is recommended.

Tree management

Young seedlings are required full sunlight. To assist the seedlings to develop into a vigorous and healthy, it is necessary to carry out proper espacement, cleanings and thinnings for the first five years especially when regeneration is form direct seeding. Plantations of *A. nilotica* for timber, tannin or gum production require regular weeding and thinning to maintain maximum growth. Thinning begins from 4–5 years and continues in 3 year cycles. An ideal stocking density at 30 years is 100 trees ha^{-1} for 28 m tall trees and 400 trees ha^{-1} for 14 m tall ones. For fuel wood extraction, there is evidence of adequate natural thinning and additional thinning seems not justified. Plantations are irrigated at 3–7 day intervals after sowing, and 2–3 weedings are sufficient to control weed growth. Spot sowings with 10–15 seeds per hole did not require weeding, but needed early thinning and then thinning at 5 yearly intervals and to maintain a stand density of 1200 trees ha^{-1}. Trees pollard well and can be freely lopped for thorn fences; however heavy lopping reduces tree growth.

Harvesting

Timber and fuel wood production are usually harvested on a 10–20 year rotation with the bark as a useful byproduct. The bark is separated from the logs by beating them with mallets. The strips are then sun dried, chopped into small chips before being sent to tanneries. Bark from trees up to 10 years old yields lighter tannin. Pods are also collected for tanning, preferably from the tree and soon after turning black. Pods can be harvested at different ages to vary the colour of the tanned leather. Pods have been lightly ground to remove seeds and fibrous matter, yield up to 60 per cent tannin. For harvesting the gum, strips of bark 5–7.5 cm wide are removed from the trunk in the dry season, the bark around the cut is bruised with a hammer and gum nodules form where the trunk has been damaged. Gum dries on contact with air and is collected a few days later.

Yield

Growth rate is relatively fast, with average timber yields for plantations on dry sites of 3–5 m^3 ha^{-1} $year^{-1}$ using a 15–20 year rotation with 700–1000 trees ha^{-1} (10–12 m tall). Maximum yields up to 9 m^3 ha^{-1} $year^{-1}$ were collected from 10–15 years old tree in Rajasthan and Uttar Pradesh. In riverine forests a maximum mean annual increment of 13 m^3 ha^{-1} at 20 years and 10.5 m^3 ha^{-1} at 30 years has been recorded. Estimates of standing biomass ranged from 36 t ha^{-1} for 5 year old plantations to 307 t ha^{-1} for 17 year old plantations in Haryana. Likewise, 10 year old trees yield about 35–40 kg bark, or about 6 t ha^{-1} and plantations of about 600 trees ha^{-1} produces 12 t bark from 15 years old plantation. Average annual pod yield is 8–10 t ha^{-1}. The yield of 18 kg pods per tree per year also recorded in certain locations. Young trees yield annually 0.1–0.6 kg gum per tree whereas, older trees yield less. In India annual production of babul acacia bark for tannin was estimated in 1994 at 22,000 tonnes. The proportion of bark to wood is roughly 1:5 by weight. A 15 year old plantation of about 620 trees per hectare may yield about 5 tonnes of bark per hectare.

Ailanthus excelsa Roxb. **(**Simaroubaceae)

Common names: The tree of heaven, Match splint tree **(**English), Perumaran (Tamil), Ardu (Hindi)

Trade name: Maharukh

Ailanthus excelsa is a fast growing deciduous tree commonly found in mixed deciduous forests and rare in moist areas with high monsoons. The generic name '*Ailanthus*' comes from ailanthos means tree of heaven while in Latin *excelsa* means tall. The tree is native to central, western and southern India, but is now being spread to other semi-arid and subtropical areas. *A. excelsa* grows well in semi-arid and semi-moist regions and has been found suitable for planting in dry areas.

The leaves are rated as highly palatable and protein rich nutritious fodder for sheep and goats and are reported to augment milk production. However sheep do not readily browse the plants because of the offensive smell in young leaves. The wood is easily worked but is perishable and subject to pest attack and stain. The pulp is obtained from debarked wood is used in paper industry. Wood is extensively used for making packing cases, matchwood boxes and match splints. It is also used as manufacturing of Grade III and Grade IV plywood.

Biophysical limits

It grown an altitude of up to 1500 m with mean annual temperature around 0-45^{o} C and mean annual rainfall distribution varies from 500-2500 mm. Grows in a wide variety of soils, but thrives best in porous sandy loams. Clayey soils with poor drainage and waterlogged areas are sensitive. It is a relatively salt tolerant species. Its growth is poor on shallow dry soils.

Reproductive biology

The flowers appear in large open clusters among the leaves towards the end of the cold season. Male, female and bisexual flowers are intermingled on the same tree. The fruits ripen just before the onset of the monsoon. The seeds are very light and are dispersed far and wide by the wind.

Silvicultural characteristics

A. excelsa is a strong light demander. The leaves are shed during the cold season and the new leaves appear in summer. It is sensitive to drought and is moderately frost tender, being killed by frost in exposed situations. The prolonged droughts kill the seedlings, though the poles and trees are drought resistant. In places, where winters are damp as well as cold, seedlings do not easily grow. The tree coppices well and produces root suckers freely. It is easily broken by wind due to the brittleness of the stem and branches. It can attain a height of 18 to 25 m and girth of 0.8-2.5 m and has a cylindrical bole.

Germplasm management

Samaras are usually picked before maturity since fully mature fruits are liable to lose most of their seeds through wind dispersal as soon as attempts are made to collect them. Seed storage behaviour is probably orthodox and viability is maintained for one year in open storage with 7 per cent moisture content. There are about 9,500 – 12,500 seeds/kg with 30 per cent germination.

Propagation and management

Propagation methods

Natural reproduction occurs through seed and coppice. Natural regeneration through coppice and root suckers is adequate for healthily harvested. Artificial regeneration is through direct seeding or planting pre germinated seed.

Nursery techniques

Pre treatment is not required. The seeds are small and hence mixed with sand to ensure uniform sowing. Seeds are sown in primary beds and covered with fine soil. About 15-20 g of seeds are required for sowing per square meter. Germination starts in a week and takes about one month time to complete. Seedlings are prickled out and planted in polybag containers at four leaf stage. Seedlings are liable for damping off. Hence, care should be taken during watering.

Planting
Pits having a size of 45 cm^3 or auger holes are dug in advance to allow weathering of soil. The recommended spacing is 6 x 6 m for agroforestry and 3 x 3 m in block plantations. Planting is done during monsoon rains.

After cultivation
Soil working for moisture management and weeding are done up to second year.

Harvest and yield
In Tamil Nadu, about 50-75 t/ha at a rotation of 5-6 years was realized through seed raised plantations with rainfed conditions. In the irrigated conditions the yield is 120-135 t/ha in 5-6 years rotation.

***Azadirachta indica* A. Juss. (**Meliaceae)

Common names: Neem, Indian lilac (English), Vembu (Tamil), Balnimb (Hindi)

Trade Name: Neem

Azadirachta indica has been introduced and established throughout the tropics and subtropics due to its multifarious significance. Although the exact origin is unknown, it is thought to have originated in Upper Myanmar in Burma and/ in the forest of Siwaliks and naturally distributed throughout the Indian subcontinent. Now it is one of the fastest spreading trees in the world and has become pan-tropic. Old Indian literature *viz*. Atharava Veda, Upanishda, Amarkosha, Ghrayasutra, Ayurveda *etc*. mention neem tree as "Sarva Roga Nivarini" means medicine to cure all the diseases and United Nations declared it as "Tree of 21^{st} century".

The leaves, though very bitter and used as a dry season fodder. *A. indica* leaves and small twigs are used as wonderful green leaf manure. Farmers use neem cake as an organic manure and soil amendment. It enhance the efficiency of nitrogen fertilizers by reducing the rate of nitrification and inhibiting soil pests including nematodes, fungi and insects. *A. indica* fruit is an important source of food for wildlife, especially birds and bats, although they digest only the pulp. The density of the wood is 720-930 kg/m^3 at 12 per cent moisture content. The timber of the tree is widely used to make furniture's and termite resistant materials. An exudate can be tapped from the trunk by wounding the bark. This high protein material has potential as a food additive and is widely used in Southeast Asia as 'neem glue'. Tree bark contains 12-14 per cent tannins.

The seed oil yield is as high as 50 per cent of the weight of the kernel. Oil has long been used as an industrial scale for soaps, cosmetics, pharmaceuticals and other non-edible products. Neem based pesticides contains 'Azadirachtin' and acts as an insect repellant, inhibiting feeding and disrupting insect growth, metamorphosis and reproduction. A traditional agricultural practice involves the production of 'neem tea'. The seeds are dried, crushed and soaked in water overnight to produce a liquid pesticide that can be applied directly to crops. It played a significant role in India's traditional herbal medicinal systems and considered as a 'pharmacy in the backyard'.

Intercropping with neem like sorghum, black gram, wheat, chickpea, groundnut, pearl millet, cotton, horsegram, mungbean, cowpea, vegetables, grasses etc. under agri-silviculture, agri-silvi-horticulture, silvipastoral system and shelter belts/wind breaks etc. are most successful. It also promoted for afforestation in farm and social forestry plantations and for non edible seed oil mission.

Ecology and distribution
Natural Habitat
A. indica is said to grow 'almost anywhere' in the lowland tropics. Under natural conditions, it does not grow gregariously. Adult *A. indica* tolerates some frost, but seedlings are more sensitive. It quickly dies in waterlogged soils. *A. indica* requires large amounts of light, but it tolerates fairly heavy shade during the first few years.

Biophysical limits
A. indica grow well at elevations from sea level to perhaps 1,500 m near the equator. It thrives under the hottest conditions, where maximum shade temperature may soar past 50°C, but it will not withstand freezing or extended cold. The tree is said to grow almost anywhere in the lowland tropics. However, it generally performs best in areas with annual rainfalls of 400-1,200 mm. It grows on a wide variety of neutral to

alkaline soils and performs better than most species on shallow, stony, sandy soils, or in places where there is a hard calcareous or clay pan not far below the surface.

Reproductive Biology
A. indica trees may start flowering and fruiting at the age of 4-5 years. The economic quantities of seed are produced only after 10-12 years. The flowering and fruiting seasons largely depend on location and habitat. In general, flowering occurs during February–March in South and March–April in North India. Pollination is by insects such as honeybees. Fruits ripen in about 12 weeks from anthesis (May-June in South and June-July in North India) and are eaten by bats and birds, which distribute the seed.

Germplasm Management
There are about 4,000-4,500 seeds/kg. Viability is reduced under hermetic air-dry storage at room temperature. Germination rate of fresh seed is 90 per cent which would drop to 40 per cent in 30 days and less than 5 per cent in 60 days.

Propagation and management
A. indica is easily raised in the nursery and planted out as potted plants or seedlings. Direct sowing of fresh seeds in the shelter of existing vegetation has also proved successful.

Seed treatment
No seed pretreatment is required, although depulping and cleaning of seeds considerably improves the germination rate.

Ripe seeds are collected from the tree and the pulp is removed then seeds are washed clean. Seeds are air dried for 3-7 days in the shade and stored for up to four months if kept at 15°C. Seed will remain viable even longer at 6-7 per cent moisture content and refrigerated in sealed containers at 4° C.

Sowing and nursery management
The recommend sowing seed in nursery beds in rows 15-25 cm apart and 2.5-5 cm spacing within the rows. Seeds should be sown horizontally at a depth of one cm. Mature seeds germinate within a week, with a germination percentage of 75-90 per cent.

Seedlings can be pricked out when two pairs of leaves have developed, or the rows should be thinned to 15 cm x 15 cm spacing. Plastic pots are commonly used to produce neem seedlings, although rigid container systems are used. Both bare-root and containerized seedlings should be raised under partial shade for the first 1-2 months or until about 30 cm tall, then gradually exposed to full sunlight.

Bare-rooted seedlings are usually kept in the nursery for 1-2 years before out planting. The roots and shoots of seedlings lifted from nursery beds should be pruned before transplanting. Bare-rooted seedlings can also be prepared for stump planting. Stumps are made from 1-2 year old seedlings by trimming the root to 20-22 cm root and the shoot to 5 cm. Containerized seedlings should be out planted after 3-4 months in the nursery, when they reach 30-50 cm.

Planting
Plantations are laid out at 2.5 x 2.5 m spacing and then later thinned to 5 m x 5 m. The recommended spacing for windbreaks is 4 x 2 m. Neem trees managed to maximize fruit yield should be more widely spaced to allow the crown to develop fully.

Tree Management
Weeding in dry areas is essential, as the tree cannot withstand competition, especially from grasses. In general, two weedings per year up to second year and one weeding in the third year are recommended. Otherwise intercropping may considerably reduce the weed population. It responds well to organic and chemical fertilizers. Trees coppice freely, and early growth from coppice is faster than growth from seedlings. *A. indica* withstands pollarding well, but seed production is adversely affected when trees are lopped for fodder and green leaf manure.

Harvesting
Naturally Ripened fruits drop on the ground are to be collected within 1-2 days for further processing. These fruits should not be mixed up with semi dried fruits collected through sweepings. These fruits may be kept in

water for 12-24 hours to soften the pulp. Water soaked fruits should be macerated with the help of gunny bags or mechanised scrubbers, macerators and washers can also be used for larger quantities. Moisture content of commercial neem fruits are 6–9 per cent and after drying 5 per cent.

Yield

About 10-12 years old tree yield 5-8 kg seed, in an average 20 years and above yield 20-30 kg every year. Yield depends on rainfall of previous year, and well drained deep soils with adequate moisture enhance tree growth and fruit yield. With about 150-200 trees per ha the annual yield may goes up to 4-5 tonnes. It has been estimated that 10 year old tree can yield a timber of 5-6 ft^3 / tree.

BAMBOO (Poaceae - Bambusoideae)

Bamboos are fastest growing woody grass (up to 3–4 feet day^{-1}) and rated as strongest in the plant kingdom. Bamboo grows very densely, its clumping nature enables a lot of it to be grown in a comparatively small area, easing pressure on land use. In many parts of the tropics and particularly in Asia, bamboo is considered, next to rice, as the staff of life. In India, it is estimated that there are about 7.5 million bamboo artisans dependent on bamboo for their livelihood. It is sufficiently cheap and plentiful to meet the vast needs of human populace from the "child's cradle to the dead man's bier" hence it is known as "poor man's timber". Bamboo is labelled as `green gold' at world market.

About 40 m ha of the earth is covered with bamboo, mostly in Asia. In India, bamboo is being considered a major export item by the centre for the global market, valued at about Rs 5,00,000 million. The annual turnover of the bamboo sector in the country is estimated to be around Rs 25,000 million. The total bamboo bearing area of the country is estimated to be 13.96 m ha. Arunachal Pradesh has maximum bamboo bearing area (1.6 m ha) followed by Madhya Pradesh (1.3 m ha), Maharashtra (1.1 m. ha) and Odisha (1.05 m. ha). Though India has the largest area under bamboo and the yield per ha is estimated at around 0.4 tonnes, which is very low compared to other countries such as Japan, China and Malaysia.

Bamboos has versatile uses as building material, paper pulp resource, scaffolding, food, agriculture implements, fishing rods, weaving material, substitute for rattan, plywood and particle board manufacture. Pickled or stewed bamboo shoots are regarded as delicacies in many parts of the country. The cultivation of bamboo as a wood substitute helps to offset depletion of the rain forest. The most recent advancement in bamboo is the utilisation of bamboo fibre for making bamboo yarn into various fabrics and several spinning mills using 100 per cent bamboo yarn.

Its rapid growth ensures an effective reconstruction of damaged ecosystems and generates 30 per cent more oxygen than other trees. It helps reduce carbon dioxide gases blamed for global warming. One hectare of bamboo sequesters 62 tonnes of carbon dioxide $year^{-1}$ while one ha of young forest with other trees only sequesters 15 tonnes of carbon dioxide $year^{-1}$, which makes it an efficient replenisher of fresh air. Bamboos are good soil binders owing to their peculiar clump formation and fibrous root system and hence also play an important role in soil and water conservation.

Distribution

All the continents except Europe have native bamboos. There are over 75 genera and 1600 species of bamboo documented worldwide. In India, 125 indigenous and 11 exotic species of bamboo belonging to 23 genera have been reported. The genus *Bambusa* has the largest number of species, most of which are native to Africa, China, India and Japan. India is the second richest country of the world after China in terms of Bamboo genetic resources. Bamboos are found in almost all parts of the country expect Kashmir region. *Bambusa spp.* and *Dendrocalamus spp.* are found under tropical conditions, where as *Arundinaria spp.* commonly occur in the temperate region.

Biophysical limits

Bamboo species grow at high altitudes up to 3,500 meters. The majority of bamboos thrive at temperature ranges of 8.8°C to 36°C. Rainfall is an important factor and 750 mm $year^{-1}$ seems to mark the minimum annual precipitation required. Relative humidity is correspondingly high and ranges from 80 percent upward.

Usually bamboo prefers well drained soils but it is also found on swampy or wet stream beds. Most bamboos are found on sandy loam to loamy clay soils, derived from river alluvium or frequently from the underlying

rock. Individual species have well defined habitats and for this reason may be taken as indicators of different forest types. Saline soils are not suited for bamboo cultivation.

Reproductive biology

The flowering nature of bamboos are classified into three types *viz*., annual or continuous flowering (species flowering every year and do not die), gregarious or periodic flowering (the whole clump flowers in an extensive area and dies after seed setting) and sporadic or irregular flowering (occurs in isolated clumps).

In case of sporadic flowering, only the culms that flower die though the entire clump will die after gregarious flowering has taken place. The flowering in most species is either gregarious or sporadic at fixed intervals. However, most of economically important bamboo species bear seeds only 2 to 3 times in a century (Table 14.1).

Table-14.1: Flowering and seeding cycle of common bamboo species

Species	Flowering/Seeding cycle (in years)
Bambusa bambos	32 – 45
Bambusa tulda	35 – 60
Dendrocalamus hamiltonii	30
Dendrocalamus strictus	30 – 45

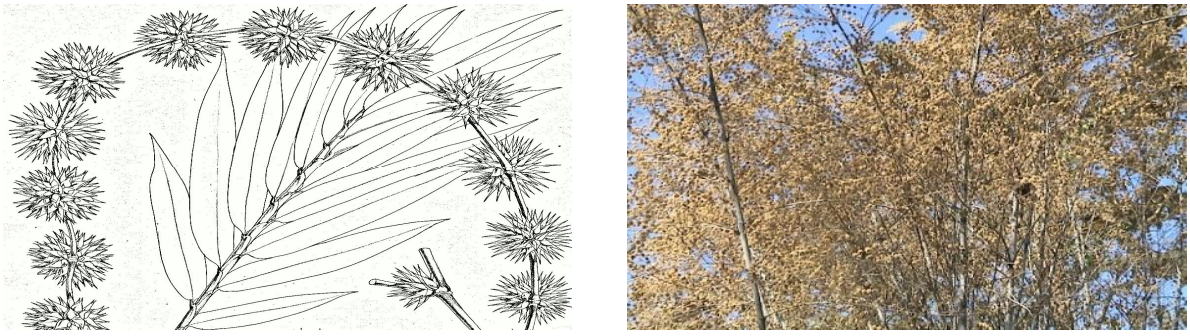


Fig-14.1: Gregarious flowering of *Dendrocalamus strictus*

Fig-14.2: Gregarious flowering of *Bambusa bambos*

Bambusa bambos (caryopsis) *Dendrocalamus strictus* (Glans) *Melocanna baccifera* (Bacca)

Fig-14.3: Bamboo fruit types

Morphologically bamboo fruits are classified in to caryopsis (a fruit having the pericarp fused to the seed coat of the single seed), glans (hard, smooth, crustaceous pericarp separated from seed coat and no venal suture) and bacca (an indehiscent fruit derived from a single ovary having one or many seeds within a fleshy wall or pericarp).

Germplasm Management

Number of seeds kg^{-1} varies depends on species (*D. strictus*: 10,000 – 25,000; *B. bamboo*: 75,000; *Melocanna baccifera:* 20 - 25). Viability of seeds varies from 2 – 3 months. The seeds of caryopsis and glans type can be stored with the control of moisture content and temperature. It can be stored by reducing its moisture content to 8 - 10 per cent with suitable desiccant (anhydrous silica gel or calcium chloride @ 100g kg^{-1}) retained viability up to 3 years with 50 – 60 per cent of germination. Bacca type seeds that germinate before becoming detached from the parent plant (Vivipary).

Propagation by seeds

Seed treatment

Seeds when sown soon after collection show more than 90 per cent germination hence pre-sowing treatment is not needed.

Sowing

Broadcast the seeds in raised beds

Germination

Bamboo seeds germinate within 5 to 10 days of sowing and seedlings attain solitary leaf stage within 7 days. The seedlings are transplant to polybags after 30 – 45 days of growth in nursery beds.

Propagation by vegetative parts

Bamboo is also propagated by the following mentioned vegetative methods:

i) By rhizome offsets

A bamboo offset is the lower part of a single culm usually with 3-5 nodes (i.e. about 1 to 1.5m) with the rhizome basal and roots attached. One season old culms are cut through with a slanting cut about 90-120 cm from the ground and the rhizomes are dug out along with the intact roots and are cut off to a length which is sufficient to include a well developed bud. These offsets are planted out sufficiently deep to cover the first 2-3 nodes. The top of the culms are cut and sealed with earth or cow dung to prevent rotting.

The survival rate of bamboo rhizome propagation is 100 per cent however, it is not a suitable propagation method to develop large scale plantations for the following reasons:

- Offsets are bulky and heavy to carry (they can weigh up to 30–35 kilograms).
- Extraction, packing and transportation of these bulky rhizome offsets is time-consuming, labor intensive, and therefore expensive.
- Availability of propagules in large number is limited.
- Offset availability can be limited to 2-3 per clump. If more are excavated the regeneration of the parent clump can be lost.
- Damage to rhizome buds during extraction and transportation often leads to failure of propagation.

ii) By rhizome buds

Sections of fresh living rhizomes of the preceding year measure about 15-30 cm long, containing at least one bud. These are planted in small pits of 30x30x30 cm size. This method is commonly employed by the villagers for propagation monopodial bamboos.

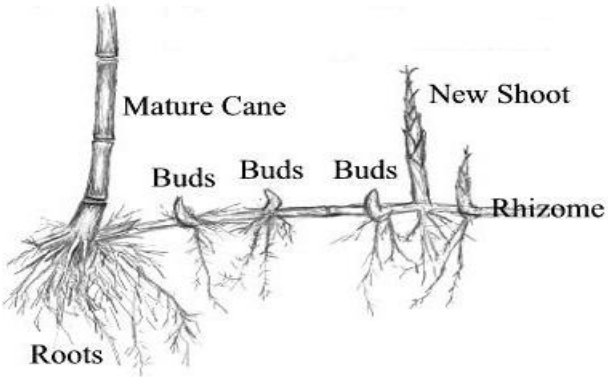


Fig-14.4: Rhizome buds

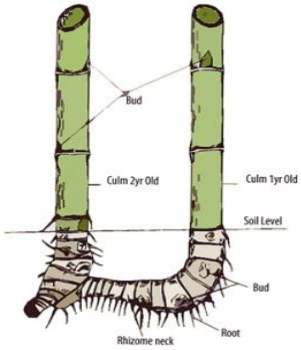
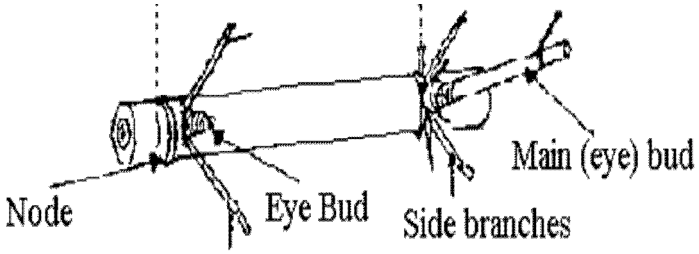


Fig-14.5: Rhizome offsets

iii) By culm cuttings

Stem cuttings or culm segments without rhizomes but with buds when planted horizontally or vertically give a high rate of propagation. It is important to plant the cuttings as soon as possible after collection if it is not possible keep cuttings in a shaded place.



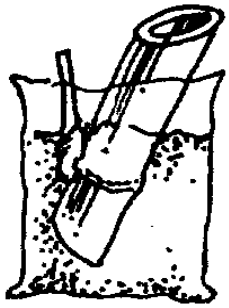


Fig-14.6: Standard culm cuttings

iv) By macro-proliferation

In macro-proliferation technique, each propagule possesses the shoot, root and rhizome parts at the time of tiller separation itself, which ensures rapid establishment and excellent survival rate.

Maintenance of seedlings

Seedlings are kept in the nursery for 3-12 months before planting in the next rainy season. To prevent inter locking between seedlings, they are transplanted to other beds after six months. Pruning of the three months old seedling stem tip induce bud activation.

Planting

The planting is done after pre-monsoon showers or just before the beginning of rainy season. In general, 2-4 seedlings or offsets or saplings pit^{-1} with the espacement of 3 x 3 m to 7 x 7 m are planted. The earth above the ground is well rammed around the offsets to prevent waterlogging.

Tree management

Clumps take 6-15 years to produce culms of full size, depending on species, soil, humidity and position of the culm in the clump.

Weeding

Required up to 2 years

Manuring

Manuring is beneficial to young plants and followed depending upon the soil fertility status.

Pruning and Thinning

Removal of congested culms at periodical intervals needed. Four to six years after planting an average of 2 culms per year removed in a cycle of 2 to 4 years. Young bamboos need protection from animals and indiscriminate fodder collection. If damaged early in life, only stunted, bushy clumps will be produced.

Harvesting

The bamboo plantations are managed on a fouryear cutting cycle employing selective felling system. Extraction of the culms starts from 4-12 years after planting depending upon the prevailing climatic conditions. The following felling rules are generally prescribed:

- Immature culms less than 2 years old should not be cut and removed.
- Young twisted culms are cut so that new culms grow.
- All the new culms and 25 per cent of the old culms should be retained.
- Cutting should begin from the side opposite to where new sprouts are emerging
- No clump should be clear felled except after flowering and when seeding has been completed.
- Culms should be cut as long as possible leaving two internodes above ground, in any case not higher than 30 cm above ground level.
- Rhizomes are not dug out and exposed.
- No felling to be done during growing season.
- In a clump containing 12 culms or more, at least 6 mature culms over one year old should be retained.
- No culm should be cut from periphery of the clump even if they are mature or malformed. The tendency to harvest only peripheral culms leads to congestion in the centre and extraction problems later on.

Yield

The annual yield of bamboo depends on the environment as well as the species. Considering a 30 year of lifecycle one clump may produce 300 culms on the whole. Well managed monoculture bamboo plantations yield up to 60 t ha^{-1} $year^{-1}$.

It is generally 3-4 tonnes ha^{-1} at as understory in forest and 5-12 tonnes ha^{-1} from plantations. In the drier parts of India, well managed and technology based *D. strictus* plantations yielded 10 t ha^{-1}. In every 3 - 4 years, bamboo yields 2500 – 3000 and 4500 – 5000 culms ha^{-1} in dry and wet regions, respectively.

Ceiba pentandra (L.) Gaertn. (Malvaceae)

Common names: White silk cotton, Kapok (English), Ilavam maram (Tamil) Safed simal (Hindi)

Ceiba pentandra is a tall, deciduous tree bearing short, sharp prickles all along the trunk and branches. Ceiba trees possess buttresses at the base of the trunk, which are widely spreading outgrowths that provide additional support and prevent the trees from falling. The generic name comes from a local South American word. The specific name, 'pentandra', is Latin for "five-stemmed"; from the Greek word "penta" (five) and "andron" (male).

The capsules of this species contain long silky hairs surrounding the seeds that allow the fruit to float in water. The floss are light and water resistant and were historically harvested to stuff pillows, mattresses and cushions. Its water repellent and buoyant character, making it ideal for preparation of life jackets, lifeboats and other naval safety apparatus. It is an excellent material for insulating iceboxes, refrigerators, cold-storage plants, offices, theatres and aircrafts. It is a good sound absorber and is widely used for acoustic insulation; it is indispensable in hospitals, since mattresses can be drying sterilized without losing original quality. The flowers are important honey source for migratory beekeepers.

The seed contains 20-25 per cent non drying oil, used as a lubricant and in soap manufacturing. The pressed cake is used as cattle feed containing about 26 per cent protein. The wood is very light and is used for preparation of plywood, packaging, lumber core stock, light construction, pulp and paper products, match splint, canoes and rafts, *etc*. Because of its wide range of uses, it has been cultivated in the boundaries of farmlands and social forestry plantations.

Origin and distribution

This species is native to tropical America and introduced into Africa. It is now naturalized in semi-deciduous

tropical forests and the most widespread species throughout the world. This species has been planted throughout the India, mostly on the roadsides, field bunds, in the back yards, gardens, *etc*.

Biophysical limits

Ceiba pentandra thrives at elevations below 500 m, but it grows up to altitudes as high as 4000 m. Mean annual temperature is 18-38^{o} C. The average annual rainfall is 750–3000 mm. The dry period should not have more than 4 months, and in this period a well distributed rainfall of 150–300 mm is required. For best results the tree should be planted on deep, permeable soils without waterlogging.

Reproductive biology

Flowers open at night, emitting a powerful odour and secreting nectar at the base of the large, bisexual flowers. The pollen is sticky and the shape of the flowers suggests cross pollination, although self pollination may occurred when stamens and stigmas of adjacent flowers of the same tree come into contact. The fruits ripen 80–100 days after flowering, the dehiscent types releasing kapok with loosely embedded seeds that are wind-dispersed.

Germplasm management

Fruit is collected by hooked knives, dried in the sun and separated from the floss by shaking the dehiscent fruits in a bag. The seeds are easily separated from the fruit floss, in which they are loosely held, by shaking dehiscent fruits in a bag. Ddepending on provenance the number of seeds kg^{-1} varies between 5,000 and 7,500. Seeds are stored up to one year in glass or plastic containers at 4°C and 60 per cent relative humidity. Long term seed storage has not proven successful, because the seed oil goes rancid.

Propagation and management

Ceiba pentandra is usually propagated by seed, although it can also be grown from cuttings. Fresh seeds have germination rates of 40–60 per cent, when pretreated by scoring lightly and soaking in water for 24 hours. Germination is good in sandy soil with temperatures of 20–30°C. Seeds start to germinate within 3–5 days after sowing. The young seedlings of 12–15 cm tall can be exposed to full sunlight. Seedlings are grown in a nursery and be transplanted into the field when they are 4–10 months old.

Tree Management

Six to seven month old seedlings are planted in the field with a pit size of 60 cm^3 and espacement of 5 x 5m to 8 x 8m during onset of monsoon. The species is generally raised at a wider spacing of 7.5 x 7.5 m in a taungya system with agricultural crops for the 1st 5 years, after which, as the canopy closes, further cultivation of crops is impossible.

Silvicultural characters

Ceiba pentandra is light demanding and growth is spindly and poor and mortality is high for seedlings and saplings in shaded locations, including small canopy gaps that close relatively quickly. It requires abundant rainfall (water) during the vegetative period and a drier period for flowering and fruiting. The tree attains a clean bole of about 12 m and about a total height of 25 m. The tree is easily damaged by strong winds and it does not survive fire.

Tending operations

General tending may be done in the 3rd and 5th years, consisting of removing dead and diseased trees. Thinning is not necessary where spacing is high, closure spacing it may be necessary for the best growth and development of *C. pentandra*.

Life cycle

The trees began to bear fruits at the age of 6th year and remain productive for more than 30 years.

Harvesting

To obtain kapok fibre, the fruits are harvested when fully ripe and, in dehiscent types, before they open. Ripeness is indicated by the fruit colour changing from green to brown and the surface possibly becoming wrinkled. The fruits are normally harvested by knocking them off the tree before.

Yield

Under optimum conditions a full grown plantation yields 1,250 – 1,750 fruits year^{-1}, giving 12–18 kg of floss

and about 25 - 30 kg of seed. A satisfactory average annual floss yield is about 450 kg ha^{-1}, whereas about 700 kg ha^{-1} is considered very good.

A tree 70 cm in diameter above the buttresses yields on average 4 m^3 of timber and trees 100 and 150 cm in diameter above the buttresses 9.3 m^3 and 23 m^3, respectively.

Casuarina equisetifolia L. (**Casuarinaceae)**

Common names: Horse tail oak, Beefwood, Beach she-oak (English), Savukku (Tamil), Junglisaru (Hindi)

Casuarina trees are an evergreen, dioecious or monoecious, non-leguminous nitrogen fixing angiosperms, resembling conifers with a finely branched crown. There are four genera that are colloquially referred to as Casuarinas *viz.*, *Casuarina*, *Allocasuarina*, *Ceuthostoma* and *Gymnostoma*. *C. equisetifolia* is the most widely planted and utilized commercially. *Casuarina* is from the Malay word 'kasuari', from the supposed resemblance of the twigs to the plumage of the cassowary bird. The specific name is derived from the Latin 'equinus', pertaining to horses, and 'folium', a leaf, in reference to the fine, drooping twigs, which are reminiscent of coarse horse hair.

C. equisetifolia wood is used extensively for making house parts, posts, fish hooks, and various other tools and artifacts. However, its extreme hardness makes it difficult to be sawn or worked with tools and it is therefore unsuitable timber for carving. It is ideal for posts and rough house construction due to it is very strong and little processing requirements. It is also useful for fencing, piling and roofing shingles. The highly regarded wood ignites readily even when green and high quality charcoal retains heat for long periods hence; it has been considered as 'the best firewood in the world'.

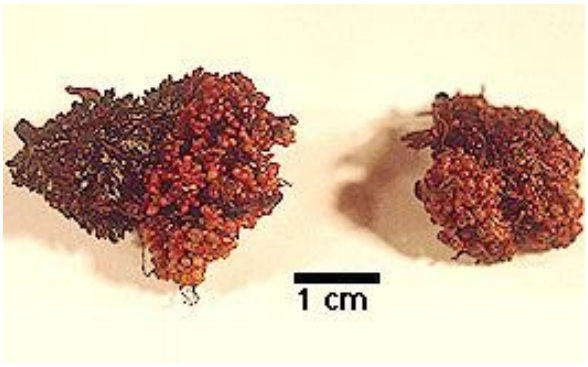


Fig-14.8: Casuarina root nodule

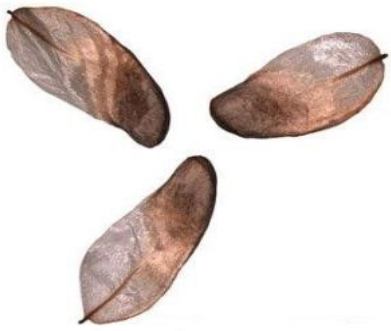


Fig-14.9: Casuarina seed

The wood is used to produce paper pulp and as a raw material for rayon fibres. The bark contains 6-18 per cent of catechol type tannins, which produces pale reddish brown colour. It is grown well in coastal sandy soils, hence, widely used to control erosion along coastlines, estuaries, riverbanks and waterways. Casuarina forms good shelter belt plantation and also helps in stabilising sand dunes. The needles are made into compost and are used as manure. The tree forms woody, spherical nodules up to 10 cm (4 inches) in diameter, in which are found a filamentous bacterium, *Frankia sp.*, which fixes nitrogen.

Origin and distribution

C. equisetifolia is native from Australia eastward into Melanesia and westward to coastal Southeast Asia, but it was also an ancient introduction over a much larger range.

It thrives best in close proximity to the sea on loose sand, growing sometimes within a few yards of high-tide level and even with its roots in the sea and rarely extending inland to lower hills. In India, it is the most popular cash crop by farmers in the coastal and inland areas of Tamilnadu, Andhra Pradesh, Odisha, West Bengal, Maharashtra, Gujarat and Karnataka.

Biophysical limits

C. equisetifolia is a low land tree and that can be planted from sea level up to 1,500 m. Although it prefers a seasonal climate (in its natural habitat there is often a 6–8 month dry season), it can tolerate dry climates (particularly if it has access to ground water supplies) with as little as 200–300 mm, and wet climates with as much as 5,000 mm of annual precipitation.

The monthly mean maximum temperature in its native area is 10 - 35^{o} C, but it is adapted to a wide range of temperatures. On the coasts of the Indian Peninsula, where it thrives well, the absolute maximum shade temperature varies from 35.56 to 41.11^{o}C and the absolute minimum ranging from 7.22 to 17.22^{o}C.

Soils are invariably well-drained and rather coarse textured principally sands and sand loams. It can also grow in infertile lateritic soils, mine tailings, sand dunes, calcareous soils, coastal lava rocks and other places where other tree species cannot. It is also able to tolerate a wide range of soil pH, up to 9.5 in some cases, but is intolerant of prolonged waterlogging and may fail on poor sands where the subsoil moisture conditions are unsatisfactory.

Reproductive biology

Trees are mostly monoecious and wind pollinated. Flowering and fruiting occur throughout the year, although not at a constant rate. Peak flowering in the Northern Hemisphere is usually from April to June and the opening of the fruits occurs mostly from September to December. Fruit is a woody cone-like head and mature about 18-20 weeks after anthesis. The fully ripe cones are greyish green or reddish brown colour and open shortly, releasing small samara.

Germplasm management

A good cone may contain 75 – 110 seeds. Number of seeds kg^{-1} ranges from 6,00,000 – 7,50,000. Storage behaviour is orthodox. The seeds start losing their viability starting within 2 weeks from being released. Viability can be maintained for several years in hermetic storage at 3^{o} C with 5-9 per cent moisture content.

Propagation

Seeds collection

Seeds are collected from the maturing (brown) cones, before they fully ripen and release the seeds. The cones are either picked by hand or shaken onto canvas sheets and later processed. Larger cones and seeds are often selected, as they are believed to produce individuals that have the highest vigor, although this has not been substantiated.

Seeds processing

Cones collected from the tree can be dried in racks in the sun or kilns to open the cones, and the seeds are then extracted.

Sowing and management

Fresh seed can be sown without pretreatment on raised or sunken beds at the rate of 10g m^{2}. Germination potential ranges from 24 – 70 per cent. Germination takes up to 2 weeks and is epigeal. Plantations can be established using containerized seedlings, bare root seedlings or rooted cuttings.

Appropriate watering, correct spacing of plants and adequate light should check damping-off diseases in the nursery. Seedlings are pricked out when 6-10 cm tall and transferred to beds or containers. Plants are typically suitable for field establishment when 25-30 cm tall.

Vegetative Propagation

Cuttings are made from small branch lets of 2 mm diameter and 10-15 cm length, and rooting is enhanced through the use of hormones Indolebutyric acid (IBA) or Indoleacetic acid (IAA).

Planting and tree management

Seedlings are usually planted out when 3–4 months old with 30–50 cm (12–20 in) in height. Seedlings both containerised as well as naked are used for out planting. Typically seedlings planted in 45 cm^{3} pits with 1 x 1 m to 2 x 2 m spacing. Some sources recommend as much as 4 x 4 m spacing, but the closer spacing will allow earlier returns.

Silvicultural characters

Casuarina is a fast growing, drought hardy, care free species for sites and climates as varied as coastal regions, hot humid tropics and even semi-arid regions. It is light demander requiring bright sunshine for best growth and development. The species does not coppice and is not frost hardy but can withstand low temperature. Monopodial with upward curving branches when young but with an open, irregular crown when mature; buttresses variable, thin and plank like. The tree tends to be more branchy and crooked on exposed

shores and tall and straight with a single trunk in protected environments.

Beach she-oak is very tolerant of wind and is oftentimes planted as a windbreak. Unlike most other trees, it has the ability to grow upright on windswept coasts. It is very tolerant of salt spray, and it is often one of the trees growing closest to the coastline. This is at least partly due to the protected location of the stomata (aeration pores) within furrows on the leafless stems. Excessive salinity may, however, decrease growth.

Irrigation management
They are susceptible to drought until their roots reach the groundwater table, which may take up to 2-3 years after planting so irrigation needed.

Pruning
C. equisetifolia is a poor self-pruner. Pruning is necessary up to 2 m to make plantations accessible for maintenance.

Thinning
Timely thinning is essential as *Casuarina* species trees demand light. For timber production, an intermediate thinning will be required for stems to develop.

Fire protection
C. equisetifolia is not fire resistant and protection is necessary.

Growth rate
The trees planted from seed can reach 2.5 - 3 m in height in a year. After 4 years, they averaged 7–8 m in height and 13–17 cm in diameter. Nine years old trees attained a mean height of 20 m and a diameter of 15 cm. Mean annual increments in the range of 4-5 m^3 ha^{-1} $year^{-1}$ however, on favourable sites, it can yield an annual increment of 15 m^3 ha^{-1} of wood in 10 years.

Rotation period
C. equisetifolia has a life span of 40-50 years and displays fast early growth. The rotation period ranges from 4-5 years for fuelwood and 10-15 years for poles and pulp.

Yields
Dry weight $tree^{-1}$ ranges from 15 to 25 kg at 3 years of age, depending on site quality. In India, plantations using 1 x 1 m or 2 x 2 m spacing on 6-15 year rotations yield 50-200 t ha^{-1}.

Eucalyptus spp. (Myrtaceae)

Eucalyptus is widely grown in 110 tropical and subtropical countries. About 40 percent of all trees in plantations in the tropics are Eucalyptus. When planted in the right situation, some Eucalyptus outperform indigenous and many other exotics in height and girth increment, producing wood rapidly in a short rotation. *Eucalyptus spp.* was first introduced to India in the Nandi hills of Karnataka by Tippu Sultan between 1782 and 1790. As many as 16 species were planted in his palace garden at Nandi hills near Bangalore, as ornamentals. Later in 1843 its plantation was extended to the Nilgiri hills of southern India.

About 170 species of Eucalyptus have been tried in India up to 2200 m altitude with an annual rainfall range of 400-4000 mm. The species which have received acceptance in India are *Corymbia citriodora, E. camaldulensis, E. Globules, E. grandis* and *E. Tereticornis*. Among the species so far evaluated in India, the Nandi provenance of *Eucalyptus tereticornis* has been the widely cultivated species in the plantation. The 1960's heralded the introduction of the hybrid *E. tereticornis* x *E. globulus* popularly known as *Eucalyptus* hybrid on a massive scale throughout India from the farthest North to the Southernmost. The success of Eucalyptus as an exotic often results from a base of genetic diversity, beneficial changes in environment such as soil cultivation, absence of pathogens, fertiliser applications *etc.*

The wood of Eucalyptus spp. is used for poles, posts, construction, low-grade veneer, plywood, flooring, furniture, tools, boxes, crates, pallets, railway sleepers, fibreboard and particleboard. It is also suitable for marine construction, ship and boat building, vehicle bodies, toys and novelties, turnery, interior trim and mine props. It is very important as fuelwood and for charcoal making, and it is an important source of pulp for the production of printing, writing, specialty and tissue papers.

Eucalyptus oil is used for medicinal purposes, especially against cough and as an expectorant, but it also has febrifuge, tonic, astringent, antiseptic, haemostatic and vermifugal properties. The dense root system makes the tree suitable for erosion control. It is also used for windbreaks and young plants make a useful living fence because they are unpalatable to livestock. It has been used in land reclamation, including the drying up of swamps. However, *Eucalyptus* is recorded to have allelopathic effects on undergrowth and crops near the tree, probably due to the release of phenolic compounds from fallen leaves. The major species of Eucalyptus cultivated in India are as follows.

i) *Corymbia citriodora* (Hook.) K.D.Hill & L.A.S.Johnson ***(Syn: Eucalyptus citriodora)***
Common name: Lemon scented gum

Corymbia citriodora is a stately evergreen tree native to Queensland, Australia. *C. Citriodora* is commonly planted throughout the tropics, in the Mediterranean area and in the Malesian area, mainly in Malaysia. *C. Citriodora* was introduced in mid 1930 in Karnataka and Kerala and was widely planted in Nilgiri hills between 1937 and 1955.

Biophysical limits
It grows an altitude of 0-1600 m, the mean annual temperature of 17-24^{o} C with a mean annual rainfall of 650-1600 mm. It is commonly found on poor, gravelly soils of lateritic origin, and prefers well drained but somewhat gravelly subsoil's.

Reproductive biology
C. citriodora is cross pollinated and the pollinating agents are usually blow flies, ants and, in particular, bees. There are 1,40,000 - 2,20,000 seeds kg^{-1}.

ii) *Eucalyptus camaldulensis* Dehnh
Common name: River red gum

E. camaldulensis was taken from its native Australia in 1803 and planted in the garden of the Count Camaldoni, for whom it is named. It is one of the most widely distributed Eucalyptus species and is probably the world's most widely planted tree in arid and semi arid lands.

Biophysical limits
River red gum occurs typically along watercourses and on floodplains, usually in open forest and woodland, up to 700 m altitude.

Annual rainfall in natural stands varies from 250–2500 mm, but planted trees can survive in areas with as little as 150 mm annually. Survival in arid regions depends on the presence of a high water table or seasonal flooding.

Planted trees grow under a wide range of climatic conditions, from temperate to hot and from humid to arid. The length of the dry season may vary from 0–8 months. Mean annual temperatures range from 13–28°C. Mean minimum temperature of the coldest month ranges from 3–22°C, mean maximum temperature of the hottest month from 21–40°C. In general, river red gum tolerates, but does not tolerate temperatures below –10°C.

River red gum occurs on a variety of soils, commonly on sandy and salty alluvial soils. It is found along the borders of salt lakes and adapted cultivars are grown on saline waterlogged soils in degraded irrigation schemes. It is not adapted to calcareous soils and provenances may differ considerably in frost, fire and salt tolerance.

Reproductive biology
Time of flowering in natural stands depends on the geography of a given location. There are 7,00, 000-8,00, 000 seeds kg^{-1}.

iii) *Eucalyptus globules* Labill.
Common name: Blue gum

Eucalyptus globulus is naturally distributed in Tasmania and south-eastern Australia, but is now widely planted and naturalized in subtropical regions around the world. Evergreen, large to very large tree up to 70

m tall, bole straight, cylindrical, up to 200 cm in diameter; bark surface usually smooth, white to cream, yellow or grey; crown narrow, but rounded in trees growing in the open. The leaves of *E. globulus* are the principal source of eucalyptus oil in the world. The leaves yield 0.75–1.0 per cent essential oil on dry weight basis.

Biophysical limits
E. globulus grows in the tropics at 2000–2800 m altitude, and in mild temperate climates at 0–1000 m altitude. The mean annual temperature is 9–19°C, the mean maximum temperature of the warmest month 19–30°C, and the mean minimum temperature of the coldest month 1–12°C. The average annual rainfall is 500–2400 mm, with a dry season of maximal 7 months.

Reproductive biology
The cream-colored flowers are borne singly in the leaf axils. The fruits are woody and range from 1.5 to 2.5 cm in diameter. Numerous small seeds are shed through valves (numbering between 3 and 6 per fruit) which open on the top of the fruit. There are approximately 70,000-100,000 seeds kg^{-1}.

iv) *Eucalyptus grandis* W.Hill
Common name: Rose gum

Eucalyptus grandis is native to the East coast of Australia. Evergreen, medium-sized to very large tree up to 60 m tall and it forms straight, clean holes up to two-thirds of the total height.

Biophysical limits
Eucalyptus grandis grows best in humid, subtropical conditions at low altitudes, in natural conditions often on slopes and in valleys, open forest and rainforest edges. It is grown from sea level up to 2500 m altitude, in areas with a mean annual temperature of 14–26°C, an average annual rainfall of 700–4000 mm, with a dry season of maximum 7 months.

E. grandis grows best on deep, well drained, fertile loam or clay-loam soils, but it also does well on sandy soils of sufficient depth. It is suitable for slightly saline sites. It is moderately tolerant to frost and wind, but does not withstand severe frost. It is highly susceptible to damage by fire.

Reproductive biology
Fruits remain closed on the tree for at least 1 year after maturity, so it is possible to gather two seed crops at a time by harvesting in alternate years. Fruits contain 3–25 healthy seeds, on average 8, and a much greater mass of infertile ovules called ‘chaff’. Fertile seeds are tiny, only about 1 mm in diameter. There are approximately 2,60,000-3,00,000 seeds kg^{-1}.

v) *Eucalyptus tereticornis* Sm.
Common name: Mysore gum

Eucalyptus tereticornis has an extensive natural distribution in a long strip about 100 km wide, from southern Papua New Guinea and the Northern tip of Queensland to Southern Victoria along the east coast of Australia. It was one of the first eucalypts exported from Australia and is now cultivated throughout the tropics, on a large scale in India and Brazil.

Biophysical limits
Its altitudinal range is from near sea-level up to 2350 m. It is successfully planted in areas with a mean annual temperature of 14–27°C, a mean maximum temperature of the warmest month of 22–42°C, a mean minimum temperature of the coldest month of 0–19°C and a mean annual rainfall of 400—3500 mm, with a dry season of up to 8 months.

It is not found on heavy clay and acid soils or on dry, shallow soil, preferring deep, well-drained, fairly light textured alluvial soil. *E. tereticornis* can stand seasonal flooding, although in natural forest it is rare under such conditions. It tolerates slightly saline conditions. In many countries it is considered to be more resistant to fire than other *Eucalyptus* species.

Reproductive biology
In plantations *E. tereticornis* starts flowering when 2–6 years old. Small clusters of white flowers appear

every year, but heavy blooming occurs only once every 3–4 years. There are approximately 3, 00, 000-6, 00, 000 seeds kg^{-1}.

Silviculture characters

Germplasm management

The capsules are collected when they just turn dark brown. Seed storage behaviour *Eucalyptus spp*. is orthodox. The germination rate can be maintained at an acceptable level for 1–2 years by hermetic storage (storing the seed in unsealed containers) at room temperature. Seed can be stored for several years if air dried and stored in the dark in sealed containers at a temperature of 1–4°C.

Nursery management

Seed treatment

No pre-sowing treatment is required.

Propagation

The most common and effective way to raise seedlings is to sow seed in raised beds under light shade conditions.

Seed rate

A sowing rate of 10–15 g m^{-2} is recommended, but the sowing density should be decreased 5 g m^{-2} in areas with a high risk of damping off. Seed germinates in 4–14 days.

Pricking out

The young seedlings are pricked out and transplanted into containers when 4–8 leaves above the cotyledons have developed. Shading is needed for the first week after transplanting, thereafter plants should be fully exposed. An additional 3–6 months in the nursery is required to obtain seedlings of plantable size.

Vegetative propagation

Eucalyptus is suited to mass vegetative propagation. Vegetative propagation using branch cuttings of 2–3 year old saplings and suckers has been successful. Cuttings from juvenile shoots (i.e. below the 10^{th} node) root readily in majority of genotypes. Elite trees are selected in young plantations (5 years old) and felled or girdled to promote coppicing. Coppice shoots of about 1 m long are collected and divided into pencil sized cuttings with 2 leaf pairs. Half of the leaf blade is then trimmed and the cuttings are dipped into a hormone preparation and planted in polypots under mist and shade. Rooted cuttings are hardened in nurseries and used for out planting.

Planting

In most tropical and subtropical countries out planting in the field occurs when the plants are 3–6 months old and 15–35 cm tall. Both containerized and naked seedlings preferred for planting. Wildlings may also be used for planting. Planting should be as early as possible after the start of the rainy season, to benefit fully from the rains and from the residual heat in the soil after a hot dry season. Eucalyptus withstands a dry spell of up to 2–3 weeks between planting and the onset of consistent rains. If there are losses due to adverse conditions, it is imperative to plant replacements as soon as possible so as to maintain a uniform stand.

De-brushing by tractor is often carried out in monoculture plantations. This is followed by ploughing and disking. The impractical situation due to slope, rocky soil or lack of equipment, seedlings can be planted in holes in soil worked to at least one m in diameter around the hole. In all cases, it is preferable to leave some months between soil preparation and planting. On slopes in particularly wet or dry climates it is recommendable to prepare raised rows either to drain excess moisture or to capture scarce moisture, and in both cases plants go on the top of the mounds.

Espacement

Initial plant spacing ranges from 1 m × 1 m to 3 m × 3 m, depending on the purpose of the trees. For mechanization, a distance between rows of 3 m is necessary, and 3 m × 3 m is the minimum spacing necessary for mechanical weeding in two directions.

Tending operations

Once seedlings are planted, they require nurturing to ensure that competition from weeds for water, soil nutrients and sunlight is kept at a minimum.

Weeding
Keep the plantations free of weeds for the first two years of growth, or until they are about 1.5m height. For plants of 1.5m and above spot weeding around the seedlings (one meter diameter) and slashing in between the seedlings should be done during the first year. It becomes less important after closure of the canopy.

Fertilization
Fertilization of the young plants can be effected from a few weeks to 3 months after planting by dressing a balanced fertilizer (according to soil conditions @ 50 - 100 g of NPK (3:2:1) fertilizer per tree) at a distance of 10–30 cm from the plant.

Fire protection
Eucalyptus has a number of mechanisms for resisting fire. The shaggy bark is highly flammable and allows fire to spread quickly to the canopy, but the thick inner bark of mature trees prevents damage to the inner part of the tree in most cases. Post fire regeneration is quick. Damaged bark is shed and buds re-sprout rapidly. In the case of top kill, many new sprouts appear from the so called lignotuber, a woody subterranean storage stem that resists fire and other damage to the aboveground stem.

Pruning
Most *Eucalyptus* spp. are self pruning ability and therefore pruning may not be necessary. However, when necessary prune to half height.

Thinning
The thinning regimes are dependent on the objectives of plantation.

Regeneration by Coppicing
Eucalyptus spp. have the ability to coppice heavily after cutting. Harvesting of short rotations is accomplished by cutting the entire tree at 10–12 cm above the ground with a chainsaw or manual saw, making the cut on a slope to allow water to run off of the stump. About 6 months after cutting, the coppice shoots are thinned to 1–3 shoots stool^{-1}, depending on a preference of shoots. It is also possible to thin at 2–3 years and thus have an appreciable auxiliary harvest of small poles in addition to the main harvest years later. At least 3 coppice stems should be left during the first coppice reduction and then reducing to 2 stems one year later depending on the management objective

The stump losses vigour after a number of coppices depending on the management objective and should therefore be replaced with a new crop. Up to three coppice harvests are usually taken, with the stand quality deteriorating after the third coppice harvest. However, a site in the Nilgiri mountains (Tamil Nadu) is said to have produced satisfactorily for over 100 years on 10 year coppice rotations. Replanting of an old plantation requires the complete removal of lignotubers and root mass.

Harvesting
Harvesting is usually done on short rotations of 5–15 years for densely planted plantations destined for production of posts, pulp, fuelwood, *etc*. Rotations of up to and beyond 30 years with a final density of 70–120 trees ha^{-1} are given for processing as sawn timber. Harvesting should be done during the rainy season. The stumps should not be less than 10 cm height. Harvesting should be done using saws and not axes because they damage the tree stump and affect its ability to coppice. The stump should not be left covered with slash as this will obstruct coppice shoots.

Timber Yield
In *E. camaldulensis* very high productivity is possible under favorable conditions: a mean annual increment of 70 m³ ha^{-1} of 4 year old trees planted at 3 m × 2 m on a fertile site with high water availability has been recorded in Israel. In the drier tropics, yields of 2–10 m³ ha^{-1} year^{-1} on a 10–20-year rotation are common, whereas in moister regions up to 30 m³ ha^{-1} year^{-1} may be achieved on 7–20-year rotations. Coppice rotations give higher yields than the initial seedling rotation (25–30 m³ ha^{-1} year^{-1} versus 17–20 m³ ha^{-1} year^{-1}) and the length of the rotation may be adjusted accordingly.

Under favorable conditions, a yield of 175 m³ ha^{-1} in a 9 year rotation has been recorded in *E. globulus*. In rotations of 8–15 years, annual volume increments are 10–35 m³ ha^{-1}.

The productivity of *E. tereticornis* yield pulp wood plantation is 50-75 t in plains, 100 – 125 t in middle altitudes and 100 – 140 t in higher altitudes at 7 years rotation.

In *E. grandis*, a mean annual increment of 14–25 m^3 ha^{-1} is recorded for good sites. The mean annual increments of 7–30 m^3 ha^{-1} in rainfed locations, whereas irrigated stands yield 40 m^3 ha^{-1}.

Jatropha curcas L. (Euphorbiaceae)

Common names: Physic nut (English), Kattamanakku (Tamil), Danti (Hindi)

The word 'Jatropha' is derived from two Greek words 'Jatros' meaning a 'Doctor' and 'Trophe' meaning nutrition. The genus Jatropha has about 170 species and distributed throughout the world. Among them, 12 species are recorded in India. *J. curcas* is promising one and is a perennial, monoecious shrub or small tree up to 6 m high.

The seeds yield 31-37 per cent of valuable oil. *Jatropha* oil is an environmentally safe, cost effective renewable source of non conventional energy and a promising substitute for diesel and other fuels. About 37 per cent tannin found in bark which yields a dark blue dye, latex also contains 10 per cent tannin and used as marking ink.

The latex of Jatropha contains the alkaloids such as jatrophine, jatropham, jatrophone and curcasin, which are believed to have anticancerous properties. Leaves are also used to treat jaundice, fevers, rheumatic pains, guinea worm sores and poor development of the fetus in pregnant women. The leaves produce a sap that has haemostatic properties and used to dress wounds and external application for piles.

Press cake cannot be used in animal feed because of its toxic properties, but it is valuable as organic manure due to higher nutrient contents (3.2 to 4.4 % N; 1.8 – 2.0 % P and 1.5 – 1.7 % K). Tender branches and leaves are used as green leaf manure. *J. curcas* is not browsed by animals and it can be growing without protection and can be used as a hedge to protect fields.

Origin and distribution

The source of *J. curcas* remains controversial, but it is highly probable that the centre of origin is Mexico and Central America. It is now naturalized and distributed in wild or semi cultivated stands in Latin America, Africa, India and South East Asia. In India, Portuguese Navigators introduced it in the 16th century.

Biophysical limits

It is hardy to establish at higher altitude (> 500 m) and in humid zones. Mean annual optimum temperature requirement is 20-38^{o} C, mean annual rainfall is 300-1000 mm or more. It can tolerate extremes of temperature but not the frost. Grows on well drained soils with good aeration and is well adapted to marginal soils with low nutrient content. It grows almost everywhere even on gravely, sandy, acidic and alkaline soils having pH ranging from 5.5 to 8.5. On heavy soils, root formation is reduced. In erosion prone areas, it is used as a soil conserving plant but does not survive well due to poor management and imperfect agronomic practices.

Reproductive biology

Flowering and fruiting depends on site, moisture and climatic conditions. Flowering is less and delayed when grown in shady conditions. In sunny condition flowering is more and early (July – September). Shrubs begin to produce flowers at 4-5 months and reach full productivity at about 3 years. The inflorescence is complex. The first branching is racemose and subsequent branches are cymose. The female flowers are 4-5 times more numerous than the male ones.

Pollination is by insects and the rare hermaphroditic flowers can be self-pollinating. After pollination the trilocular ellipsoid fruit is formed. The exocarp remains fleshy until the seeds are mature. In humid equatorial regions, flowering occurs throughout the year. Fruit development needs 90 days from flowering until seeds mature.

Germplasm management

Seeds are oily and do not store for long period. Seeds older than 15 months show viability below 50 per cent. High levels of viability and low levels of germination shortly after harvest indicate innate (primary) dormancy.

Propagation and management

Propagation by seedlings

Seed should be collected when capsules split open. Use of fresh seeds improves germination. Intervals of presoaking and drying, or partial removal of the testa are more successful than presoaking alone. In raised beds shallow furrows of 2 cm depth should be made by using a stick. Seeds should be placed in furrows at an interval of 2 cm. After placing the seeds, the furrow should be covered with a thin layer of soil. With good moisture conditions, germination takes 10 days. At 4^{th} leaf stage seedlings are transferred in to poly bags.

Vegetative propagation

Cuttings are obtained from mother plants and raised in poly pots. Large cuttings (poles) even up to 2 m can be planted directly in the field for hedgerow plantations.

Planting and crop Management

The species is easily planted by direct seeding, seedlings, transplanting of spontaneous wild plants and direct planting of cuttings. Satisfactory espacements are 2 x 2 m for rainfed and 2.5 x 2.5 m or 3 x 3 m for irrigated conditions. Live fences can be established quickly by planting cuttings directly in the field with the plant to plant spacing of 0.5 m.

Silvicultural characters

As a succulent *J. curcas* sheds its leaves during the dry season. It is very tolerant and thrives under a wide range of climatic and edaphic conditions and is best adapted to arid and semi arid regions. It is not sensitive to day length. *J. curcas* is a highly adaptable species, but its strength as a crop comes from its ability to grow on poor, dry sites. It is very drought tolerant and also withstand slight frost.

Weed management

Seedlings are susceptible to competition from weeds during their early development. Therefore weed control, either mechanical or with herbicides, is required during the establishment phase.

Manuring and nutrition

At the time of planting compost @ 2 kg pit^{-1} should be applied. Afterwards depending on soil type manuring @ 3-5 kg $plant^{-1}$ along with and NPK should be applied near the crown following ring method before monsoon. Application of GA @ 100 ppm spray induces early flowering and capsule development.

Canopy management (Pruning and trimming)

The first stage of pruning is done to develop more number of branches at the height of 30 cm. Pinching the terminal growing twig at six months age induce laterals. To give a bushy shape the plant should be trimmed during spring (February-March) up to 5 years including one pruning when the plants attains 1.5 m height. Likewise the secondary and tertiary branches are pruned at the end of first year to induce a minimum of 25 branches. During the next year each side branch should be pruned up to $2/3^{rd}$ top portion and retaining $1/3^{rd}$ of the branch on the plant. Periodical pruning are carried out depending upon the vegetative growth of plants.

Once in ten years, the plant may be cut leaving one foot height from ground level for rejuvenation. The growth is quick and the plant will start yielding in about a year period. This will be useful to induce new growth and yield stabilization there on. The pruning should be done when the tree sheds leaves and enters in the period of dormancy.

Fig-14.10: Pruning of Jatropha

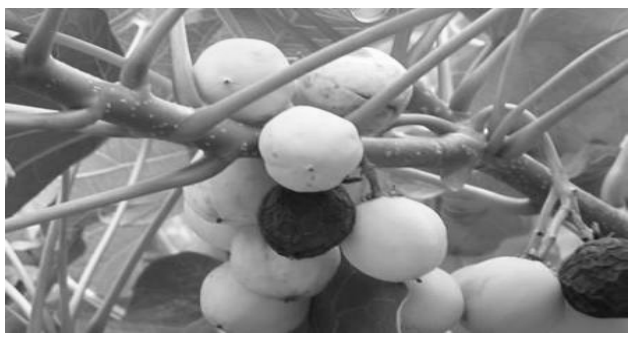


Fig-14.11: Jatropha fruits

Life cycle
J. curcas has a productive life of 40-50 years without necessitating replanting.

Harvesting
Pods are collected when they are turned yellowish and after drying seeds are separated mechanically or manually. Seeds are dried for 4-5 days to reduce moisture level 10 per cent before packing.

Yield
Under good rainfall conditions, plants bear fruit after the 1st rainy season, while directly seeded plants bear for the 1st time after the 2nd rainy season. With vegetative propagation, the 1st seed yield is higher. At least 2-3 t of seeds ha^{-1} can be achieved in semi-arid areas.

***Leucaena leucocephala* (Lam.) de Wit (**Fabaceae – Mimosoideae)

Common names: subabul (English), savundal (Tamil), koo babul (Hindi)

The specific name 'leucocephala' comes from 'leu', meaning white and 'cephala', meaning head, referring to the flowers. *L. leucocephala* is one the highest quality and most palatable fodder trees of the tropics, often being described as the 'alfalfa of the tropics'. The leaf quality compares favourably with alfalfa or lucerne in feed value except for its higher tannin content and mimosine toxicity to non-ruminants. Livestock feed should not contain more than 20 per cent of *L. leucocephala*, as the mimosine can cause hair loss and stomach problems. Forage, packed in pellets and cubes, is internationally marketed as animal feed. *L. leucocephala* is in bloom almost throughout the year, providing constant forage to honey bees. It is an excellent firewood species with a specific gravity of 0.45-0.55 and a high calorific value of 4600 cal/kg. The tree makes excellent charcoal with a heating value of 29 mJ/kg and good recovery values (25-30%).

Its pulping properties are also suitable for both paper and rayon production. Also used for particleboard production. The wood is known to be of medium density and to dry without splitting or checking. Sawn timber, mine props, furniture and parquet flooring are among increasingly popular uses. Use of short rotation *L. leucocephala* for poles is limited by their lack of durability and susceptibility to attack by termites and woodborers. Red, brown and black dyes are extracted from the pods, leaves and bark. An aggressive taproot system helps break up compacted subsoil layers, improving the penetration of moisture into the soil and decreasing surface runoff. It generally acts as a shelterbelt, providing shade and wind protection for a variety of crops, especially during early growth. *L. leucocephala* thrives on steep slopes and in marginal areas with extended dry seasons, making it a prime candidate for restoring forest cover, watersheds and grasslands. It has high nitrogen fixing potential (100-300 kg N/ha a year), related to its abundant root nodulation.

L. leucocephala was one of the 1st species to be used for the production of green leaf manure in alley cropping systems. Leaves of *L. leucocephala*, even with moderate yields, contain more than enough nitrogen to sustain crops. The finely divided leaves decompose quickly, providing a rapid, short term influx of nutrients. The tree has the potential to renew soil fertility and could be particularly important in slash and burn cultivation, as it greatly reduces the fallow period between crops. Used as a live fence, firebreak and live support for vines such as pepper, coffee and cocoa, vanilla, yam and passion fruit. Leucaena is one of the most widely used species in alley cropping, where it is planted in hedges along contours at intervals of 3-10 m with crops in between.

Ecology and distribution
L. leucocephala is originated from Southern Mexico and Central America, but currently it is extremely widespread as a cultivated tree in tropical regions including India. *L. leucocephala* is essentially a tropical species requiring warm temperatures for optimum growth and with poor cold tolerance and significantly reduced growth during cool winter months in subtropical areas. For optimal growth it is therefore limited to areas 15-25° north or south of the equator. It is now naturalized in many areas such as open habitats, semi-natural, degraded habitats, and agricultural land.

Biophysical limits
It grows an altitude: 0-2100 m however, the rate of growth decreases with an increase in elevation. Mean annual temperature requirement is 25-30° C, mean annual rainfall is 650-3000 mm. It grows well in subhumid or humid climates with moderate dry seasons of up to 6-7 months. Performs optimally on

calcareous soils but can be found on saline soils and on alkaline soils up to pH 8 and is not tolerant of acid soils or waterlogged conditions. *L. leucocephala* is known to be intolerant of soils with low pH, low phosphorus, low calcium, high salinity, high aluminium saturation and waterlogging and has often failed under such conditions. *L. leucocephala* sheds its leaves even with light frosts, and heavy frost kills all above-ground growth, although trees often sprout the following summer. *L. leucocephala* tolerates fast fires and can regrow after being burned to the crown by slower fires.

Reproductive biology
The flowers are self fertile and most seed results from self pollination. Flowering and fruiting occur throughout the year as long as moisture permits. Fruiting is associated with suppression of vegetative growth and fruits ripen in 10-15 weeks.

Germplasm management
There are 25 to 30 thousand seeds/kg. Seed storage behaviour is orthodox. Viability can be maintained for several years in hermetic storage at room temperature with 5-8 per cent moisture content.

Propagation and management
Propagation methods
Seedlings and direct sowing are recommended methods of propagation where soil-moisture conditions permit and economic weed control can be maintained. Soak the seeds in hot water and allow to cool for 24 hrs before sowing in mother bed. Before sowing the seeds are treated with microbial consortium for healthy vigorous seedlings. A germination rate of 50-80 per cent in 8 days can be achieved. The germinated seedlings then transplanted into polypots at four leaf stage.

Planting
For direct sowing seeds are sown in drills or in patches with the seed rate of 15-20 kg/ha. A spacing of 3 x 3 m to 5 x 5 m is followed for timber production and closer spacing for foliage production soil conservation. For alley cropping system line sowings are recommended with 5-7 kg of seeds per ha.

The containerized seedlings are planted in 45 cm^3 pits or auger holes with the decided spacing's. Red earth, sand, compost and microbial consortium mixture is recommended for filling the pits. Application of 15 – 30 kg P_2O_5 /ha at the time of planting encourages the initial growth.

Tree Management
Regular weeding up to two years and irrigation during dry periods are helpful the successful growth. *L. leucocephala* is a vigorous coppicer and responds well to pollarding and pruning. *L. leucocephala* based system is one of the dominant agroforestry system managed under coppice system. Coppiced stems sprout 5-15 branches, depending on the diameter of the cut surface and 1-4 stems dominate after a year of regrowth and produce poles with in 6 years.

Yield
Average dry matter yield ranges from 3 to 30 t /ha/year depending on soil, temperature and moisture conditions. For optimal yields, harvest interval can vary from 6-8 weeks in very productive sites to 12 weeks in less productive ones. Wood yields from *L. leucocephala* over short (3-5 year) rotations compare favourably with other species, ranging from 10-60 cubic m/ha a year.

Melia azedarach L. (Meliaceae)

Common names: Persian lilac (English), Malai Vembu (Tamil), Bakain (Hindi)

Trade Name: Malabar Neem

Melia azedarach being one of the broad leaved deciduous tree growing 15 m in height. Because of the divided leaves, the generic name is derived from the Greek 'melia' (the ash); the specific name comes from the Persian 'azzadirackt' (noble tree). Its wood is used for packing cases, cigar boxes, ceiling planks, building purposes, agricultural implements, pencils, match boxes, splints musical instruments, tea boxes, plyboard and fuel wood. Its high calorific value (5100 calories) makes it a viable source of feedstock for biomass power plants.

Origin and distribution
This tree is native to India but is now grown in all the warmer parts of the world. It commonly occurs in the tropical moist deciduous forests of the Sikkim, Himalayas, North Bengal and upper Assam, Deccan and the Western Ghats.

Biophysical limits
It grows an altitude of 0-1800 m, mean annual temperature of 23-27^{o} C, in its natural habitat the absolute maximum temperature varies from 37.5–47.5^{o} C and the absolute minimum from 0–15^{o} C. Annual rainfall ranges from 350-2000 mm. Deep, fertile, sandy loam soils support the best growth. It grows on variety of soils, however, deep fertile sandy loam soils shows optimum growth, while shallow gravelly soils shows stunt growth. This tree species requires high light intensity. Seedlings can tolerate frost, however, severe frost can result in plant death.

Reproductive biology
It flowers from July to October, although some forms flower throughout the summer and even throughout the year.

Germplasm Management
Fruit collection
Seeds are collected from ripened fruits during January and February. It is best to adopt ground collection of fallen drupes than obtain them by climbing and shaking of the branches. Care should be taken to collect only the ripe yellow or brown drupes. Drupes drop is limited and ripe fruit clings to the branches for several months even after the leaves have fallen.

Seed processing and handling
After collection, the drupes can be transported to the place of processing in gunny bags or bamboo baskets. Ripe yellow drupes can be depulped easily if the fruits undergo fermentation and heating as the pulp is difficult to remove. Fermentation can be hastened by soaking the fruits in slightly acidified water (pH 5.5 - 5.6) or in lime water (diluted calcium hydroxide solution). Once fermented, the drupes are macerated in bamboo baskets and thoroughly washed under running water. Sand can be used as an abrasive to remove the pulp. If the pulp is not thoroughly removed, the drupes are susceptible to disease infestation. There is 250-350 seeds kg^{-1}.

Storage and viability
Seed storage behaviour is orthodox. The drupes thus extracted have to be sun dried (12 per cent moisture content) for ten days in shade. The dried seeds are stored in gunny bags or sealed containers for 4 months to one year without losing viability at room temperature.

Propagation and nursery management
Melia azedarach can be propagated by seed, cuttings and by tissue culture. Propagation is by direct sowing of seeds or by planting out seedlings or stumps. Planting of seedlings or stumps is recommended over direct sowing.

Seed treatments
Melia azedarach seeds may be raised in nursery beds. Reports state very poor germination in Melia (< 25 %). Various pretreatments like: hot water soaking (60-70 degree C), roasting drupes at 60^{o} C for 5-10 minutes, treatment with concentrated sulphuric acid, soaking of drupes in cow dung slurry for two to fifteen days, etc., have been suggested to improve the germination rate. The best treatment involves soaking seeds in a cow dung solution for one day prior to raising in the nursery beds.

Seed sowing
The drupes should be graded in water to remove floating drupes prior to sowing. Cleaned drupes are sown in the open raised nursery beds, in drilled lines, 5 cm apart. About 6-7 kgs of dried drupes containing about 1500 numbers are required for one standard nursery bed (10 x 1m). With regular irrigation, the seeds then take one to two months to germinate. It takes six months for the *Melia azedarach* seedlings to complete the nursery stage.

Planting and tree management

Spacing

Six to nine month-old seedlings are planted in 45 cm^3 pits or auger holes with the spacing of 3 x 3 or 3 x 4 meters.

Irrigation and fertilizer requirements

During the dry season, *Melia azedarach* grows well if irrigated every 10-15 days. The growth of *Melia azedarach* seedlings and trees can be further enhanced with the application of a 25-50 gram mixture of nitrogen, phosphorus, and potassium per tree. This mixture is applied two times a year. Fertilizers can be applied as needed, depending on the growth and development of the tree.

Tree Management

Under optimal conditions *M. azedarach* grows fast. It is generally deciduous, but some forms in the humid tropics are evergreen. Pruning is done yearly to achieve straight cylindrical boles. Does not coppice well from large stumps, but excellent coppice is obtained from trees up to a girth of 0.9 m.

Yield

Timber yields of 10 year old stands of *M. azedarach* are estimated to be about 85 t/ha. likewise, 12-15 years after planting, woodlots yield about 100 m^3 posts and small sized wood and 175 m^3 logs.

***Pongamia pinnata* (L.) Pierre** (Fabaceae – Papilionoideae)

Common names: Pongam (English), Pungam (Tamil), Karanj (Hindi)

Trade name: Karanga, Pongam

P. pinnata originated from India and occurs naturally or is naturalized from south-east Asia to north-eastern Australia. It is planted in the humid tropical lowlands around the world. This species has been placed alone in its genus Pongamia, derived from the Malabar local name pongam; the specific name 'indica' obviously means of India.

Leaf is high in protein but posses several toxic factors, particularly karanjin, pongamol and tannin. *P. pinnata* flowers are considered a good source of pollen for honeybees and they yield adequate nectar. With a calorific value of 4600 kcal/kg, pongam is commonly used as a fuelwood. The bark fibre is made into string, twine or rope. Although it is a moderately strong timber that is relatively easy to saw, turn and finish, the wood is not considered a quality timber because it is not durable, tends to split and warp during seasoning and is susceptible to insect attack. The wood is used for cabinet making, cartwheels, posts, agricultural implements, tool handles etc.

Roots yield a natural pigment called pinnatin. The wood ash is employed in dyeing. It is one of the few nitrogen-fixing trees to produce seeds containing oil. Oil is the most important product of the pongam tree and vast amounts of seeds are collected for commercial processing of industrial uses. It has been found that the seed contains 27-40 per cent of oil. It is used as a lubricant, varnish, water-paint binder, in soap making and bio fuel.

In nurseries and fields the presence of nodules on uninoculated pongam seedlings is common. Therefore, this species may not be specific in its Rhizobium strain requirement. It nodulates and fixes atmospheric nitrogen with Rhizobium of the cowpea group. The tree is a host for the useful lac insect. Incorporation of leaves and the press cake into soils improves fertility. The presscake, when applied to the soil is valued as a pesticide, particularly against nematodes. In rural areas, dried leaves are stored with grain to repel insects. Decomposed flowers are valued in the tropics as rich nutrition for special plants, especially when grown in greenhouses. Because it tolerates moderate levels of salinity, pongam is an ideal candidate for recovering a variety of wastelands such as saline soil reclamation. It is also used as a host for the semiparasitic sandalwood, *Santalum album* L. It is a preferred species for control of soil erosion and binding sand dunes because of its extensive network of lateral roots.

Ecology

P. pinnata is common along waterways or seashores, with its roots in fresh or saltwater. It is very tolerant of saline conditions and alkalinity, and occurs naturally in lowland forest on limestone and rocky coral outcrops

on the coast, along the edges of mangrove forest and along tidal streams and rivers. It is a shade bearer and can grow under the shade of other trees; it is, however, not a shade demander and grows well even with full overhead light. It is also drought resistant and well adapted to adverse climatic conditions and soil moisture conditions. In its natural habitat, the species tolerates a wide temperature range. Mature trees withstand light frost, water logging and tolerate temperatures of up to 50^{o} C. In addition to rain, trees require a dry season of 2-6 months.

Biophysical limits
It grows an altitude of 0-1200 m, Mean annual temperature requirement of 1-16 to 27-38^{o} C. Mean annual rainfall is 500-2500 mm. *P. pinnata* grow on most soil types but the best growth is found on deep well drained sandy loams with assured moisture. It will also perform on sandy soils and heavy swelling clay soils. It does not do well on dry sands, although it tolerates saline conditions, alkalinity and waterlogged soils.

Reproductive biology
In Tamilnadu, flowering occurs from March to May and fruits available at June-July. However it varies depending on agroclimatic condition of the particular location. Ripe pods are collected from July-August. Pod production starts 5-7 years after sowing.

Germplasm Management
There are 500-700 seeds/kg. Seed storage behaviour is orthodox and seeds remain viable for about a year when stored in air-tight containers.

Propagation and management
Natural reproduction is profuse by seed and common by root suckers. Direct sowing is common and most successful. Remove the fruit shell before sowing. Seeds require no pre-treatment and germinate within 7 days to one month of sowing. Germination is hypogeal and the radicle develops quickly before the plumule emerges. In the raised bed nursery, it can be planted at a close spacing (7.5 x 15 cm), as young plants tolerate shade well. Seedlings attain a height of 25-30 cm in their first growing season.

Tree planting
In block plantings, the recommended spacing ranges from 2 x 2 m to 5 x 5 m. The spacing adopted in avenue planting is about 8 m between plants. Transplanting to the field should occur at the beginning of the next rainy season when seedlings are about 60 cm in height. Seedlings have large root systems and soil should be retained around the roots during transplanting. Plantations are easily established by direct seeding or by planting nursery raised containerized seedlings or stump cuttings of 1-2 cm root collar diameter. Propagation by branch cuttings and root suckers is also possible.

Tree Management
Seedling survival and growth benefit from annual weed control for the first 3 years after transplanting. Growth of young trees is fairly slow; a growth of 1.3 m in height and 0.4 cm in diameter in 13 months was generally recorded. Trees coppice well and can also be pollarded. Pruning is necessary to obtain a trunk of appropriate height. The lateral spread of roots also pruned periodically.

Yield
Growers with trees that yield 20 kg of seed per year can expect to 7 tonnes seed per hectare per year on the basis that 350 trees are planted per hectare.

***Simarouba glauca* DC. (**Simarobaceae)

Common name: Paradise tree (English), Sorgha maram (Tamil), Aceituno (Hindi)

Simarouba glauca commonly known as ‘Lakshmi Tharu’ or ‘King Oil Seed Tree’ is a versatile multipurpose evergreen tree having a height of 7-15 m with tap root system. The seeds contain 55-60 per cent oil that can be easily refined, bleached, deodorised and fractionated. It is suitable for edible and non-edible purposes. From 1950 onwards, in El Salvador and other Central American countries the oil is marketed for edible purposes under the trade name “Manteca Vegetal Nieve” (Manteca - butter; Vegetal - vegetable; Nieve - snow). The oil contains 9.2 per cent palmitic acid, 30.2 per cent stearic acid, 56.4 per cent oleic acid and 2.0 per cent arachidic acid.

The fruit pulp contains about 11 per cent sugars and used as cocoa butter substitute. The pulp (about 8-10 t ha^{-1} $year^{-1}$) can be used in the preparation of squash, beverage and jam, which are very well accepted because of their attractive natural colour, flavour and good taste. The plant is also known for its medicinal properties. The leaf and bark of *S. glauca* contain glaucarubin, a chemical useful in curing amoebiasis, diarrhea and resistance against malaria.

The filtered crude oil can be used to blend with diesel @ 5-20 per cent. The surplus oil produced can be subjected to transesterification to manufacture biodiesel, a 100 per cent substitute for diesel. The sugar rich fruit pulp used in the manufacture of ethanol (800–1000 litres ha^{-1} $year^{-1}$). The oil cake, fruit pulp, leaf litter and unwanted wood are used to generate biogas. The shell and waste wood can be used in thermal power generation. The lignocellulose contained in the huge amount of biomass produced (about 15 t ha^{-1} $year^{-1}$) can be used as feedstock for manufacturing second generation biofuels. It is also used in making soaps, lubricants, paints, cosmetics, *etc*.

The press cake (1,000-2,000 kg ha^{-1} $year^{-1}$) is rich in nitrogen (7.7 - 8.1%), phosphorus (1.07%) and potash (1.24%). There are also traces of calcium, magnesium and sodium. It is valuable organic manure. Leaf litter @ 20-40 kg $tree^{-1}$ $year^{-1}$ (10 -15 t ha^{-1} $year^{-1}$) makes good manure, improving the fertility status of the soil. Wood is insect resistant and used in manufacture of light furniture, toys, paper pulp, matches etc. The trees checking of soil erosion and helps in degraded land reclamation.

Origin and distribution

Simarouba is an exotic species mainly found in coastal hammocks throughout South Florida. It was introduced to India from El-Salvador, Brazil during 1961. Plantations of *Simarouba* have been successfully established at Amravati and Akola Centres of NBPGR in Maharashta. The forest department of Odisha state planted this species over the community lands in the coastal districts. Plants are being evaluated for different traits and agronomical evaluation at different parts of country. In Tamil Nadu it was introduced by forest department for commercial cultivation during 2000.

Biophysical limits

Smarouba can grow at elevations from sea level to 1,000 m. It is suited for temperature range of 10 to 40 °C. *Smarouba* requires 700-1000 mm rainfall for normal growth, even though it can manage well in areas with even 300 mm rainfall using proper moisture conservation measures. The crop can withstand 6-8 months of dry spell in a year. It grows well in full sun or partial shade on almost any well-drained soil with the pH of 5 to 8.5. Soils of shallow depth with canker underneath and water logging are relatively unfavourable for its growth.

Reproductive biology

The plants are polygamodioecious with about 5 per cent of the population producing exclusively staminnate (male) flowers and 40-50 per cent producing mainly male flowers and a few bisexual flowers (andromonoecious) while the remaining 40-50 per cent produces only the pistillate (female) flowers. Season and duration of reproductive phenoperiods vary according to location and climate. Flowering begins in December and continuing up to February.

Fruit is ellipsoid drupe, 2 - 2.5 cm long, with thin hard cuticle and juicy fruit pulp. Individual fruits have a development and ripening period of 1-2 months. The droplets (blackish purple in pink genotypes and brownish yellow in green genotypes) are ready for harvest by March and April.

Germplasm Management

The trees start bearing when they are 4-6 years old (grafts begin to do so in 3-4 years) and reach stability in production after another 4-5 years. Number of seeds kg^{-1} varies from 1000 – 1350.

Seed type is orthodox and the high oil content of the seed causes it to lose viability after a couple of months when it is stored at ambient conditions. The seed is stored in paper or cloth bags at room temperature, 9-12 months storage can be expected without loss in viability. Germination of fresh seed is 70-80 per cent. Further, every month's delay reduces the germination by about 20 per cent. The seed coated with pulp in a thin skinny epicarp needs to be separated, sun dried and stored till crushed for oil extraction. 1–2 years by storing the seed in unsealed containers at room temperature. Stored for 20 years by either freezing at –8°C or refrigerating at 10°C.

Nursery management
To get good germination (about 60%) freshly harvested and dried nutlets (in April/May) have to be sown immediately (within a fortnight after harvesting). Pre-treatment is generally not necessary, since it does not have any dormancy. However, soaking in water for 24 hours enhance the germination of seeds. The seeds are sown by spreading them over the bed at the rate of 0.5 kg m^{-2}, but the sowing density should be decreased in areas with a high risk of damping off. The seeds start germinating in 12 – 15 days and complete germination in 30 days. The seedlings transplant from the mother bed into containers at 5–7 leaf stage. The pricked out seedlings should be provided shade for a week and watered twice a day.

Vegetative propagation
The species is dioecious and has a male to female ratio of 3:2. This will be a problem for commercial growers because the number of female will be less in seed based progenies. Softwood cleft grafting and epicotyl grafting gives 80 per cent success, which helps in growing male and female trees in the desired ratio (1:6).

Planting and tree management
The grafts of high yielding selections of 7-8 months age or seedlings of 4 months old are used for field transplanting at the onset of monsoon. Stumps or seedlings are planted out during the rainy season when root collar diameter reaches 7-10 mm.

Planting pattern
Simarouba is cultivated profitably in alley cropping, boundary planting, bund planting, as plantations or as avenue trees.

a) Alley cropping with regular crops in inter space
Planting with the espacement of 2 m (East – West) x 10 m (North – South) (500 plants ha^{-1}).

b) Block planting for timber purpose in marginal or degraded land
Spacing: 2 m (East-West) x 4 m (North-South); 1250 plants ha^{-1} or 2 m x 2 m; 2500 plants ha^{-1}

c) Boundary planting and Bund planting
Spacing: Plant to plant 2.0 m

d) Avenue planting
Spacing: 5.0 m between the plants.

Silviculture Characters
Simarouba glauca is a light demander and capable of withstanding the drought condition. It is however, very frost tender especially in the seedling and sapling stages. It is a medium coppicer and fire tender. It can with stands pollarding. It needs no special care and requires minimum protection as it is generally not browsed by animals.

Intercultural operations
Every year ploughing and ring or crescent basin formation are taken up prior to the onset of the monsoon to harvest rain water.

Weeding
Timely weeding in the first two years helps the better establishment of saplings. Once the canopy spreads, shade loving crops or fodder crops may be grown as intercrops to get additional income and to prevent weed growth.

Manuring
Ten kg compost along with 100 g of NPK (3:2:1) fertilizer and microbial consortium mixture per tree at planting to assist establishment and early growth.

Pruning
Lateral bud pruning is done till the saplings grow to about three metres height so that the trees grow tall and straight; it also facilitates easy movement in the field. Pruning of unwanted and criss-cross branches is done to get better yield.

Thinning
Alternate rows thinned for small timber production

Rotation period
The species has a rotation age of up to 50-60 years

Harvesting
The productive branches with ripe fruitlets are shaken or beaten mildly with a stick and the fallen fruitlets are gathered. Then they are de-pulped, sun dried and can be stored for some time before transporting for processing. After decortication, the oil is extracted from the kernels by expellers in the oil mills through conventional methods. The extracted oil is refined (no hydrogenation required), packed and marketed.

Yield
A 10 years old tree yield about 20 – 25 kg of seeds and has potential to produce 2 - 2.5 t of oil ha^{-1} $year^{-1}$.

For quality timber purpose first harvesting is done by about tenth year. The coppice is allowed to grow and subsequent harvesting is done once in 7-8 years.

***Tamarindus indica* L. (**Fabaceae – Caesalpinioideae)

Common names: Tamarind (English), Puliyamaram (Tamil)

The genus *Tamarindus* is a monospecific taxon having only a single species. The name Tamarind comes from a Persian word "Tamar-e-hind," meaning date of India (dark brown pulp made from the fruit resembles dried dates).

According to World Health Organization report, tamarind fruit is an ideal source of all essential amino acids except tryptophan (82%). The fruit pulp, mixed with a little salt, is a favourite ingredient of the curries and chutneys popular throughout India. Acidity is caused by the tartaric acid, which on ripening does not disappear, but is matched more or less by increasing sugar levels. Hence, tamarind is said to be simultaneously the most acid and the sweetest fruit. The ripe fruit of the sweet type is usually eaten fresh, whereas the fruits of sour types are made into juice, jam, syrup and candy. Fruit is marketed worldwide in sauces, syrups and processed foods. The flowers, leaves and seeds can be eaten and are prepared in a variety of dishes. The seeds have accessible protein source especially in countries where protein malnutrition is a common problem. Flour from the seed may be made into cake and bread.

The foliage has a high forage value, though rarely lopped for this purpose because it affects fruit yields. In the southern states of India cooked seeds of Tamarind tree are fed to draught animals regularly. Flowers are reportedly a good source for honey production. Provides good firewood with calorific value of 4850 kcal/kg, it also produces an excellent charcoal. Wood is used for general carpentry, wheels, hubs, wooden utensils, agricultural tools, mortars, boat planks, toys, panels and furniture. In North America, tamarind wood has been traded under the name of 'madeira mahogany'. An amber coloured seed oil is suitable for making paints and varnishes. Both leaves and bark are rich in tannin. The bark tannins used in ink or for fixing dyes. Leaves yield a red dye, which is used to give a yellow tint to clothe previously dyed with indigo. It can also be used as a windbreak especially against storms. However *T. indica* is not very compatible with other plants because of its dense shade, broad spreading crown and allelopathic effects. It is thus more commonly used for firebreaks, as no grass will grow under the trees. In Tamilnadu mostly this tree is planted as avenue tree.

Ecology and distribution
The origin of *T. indica* is unknown. It is generally believed to be indigenous to the drier savannahs of tropical Africa, but certainly became naturalized long ago in tropical Asia. The species was known and cultivated in Egypt as early as 400 B.C. Early Arab and Persian merchants came across the tree while trading in India. In the Indian Brahmasamhita scriptures, the tree is mentioned between 1200 and 200 B.C. and in Buddhist sources from about the year A.D.650. *T. indica* is now cultivated in all tropical countries and it is economically important all over Southeast Asia. Tamarind trees in Urigam village (Dharmapuri, Tamil Nadu) possessing long pod is a traditional high yielding variety popular throughout the world.

T. indica grows well over a wide range of soil and climatic conditions, occurring in low altitude woodland, savannah and bush, often associated with termite mounds. It prefers semi arid areas and wooded grassland,

and can also be found growing along stream and riverbanks. It does not penetrate into the rainforest. Its extensive root system contributes to its resistance to drought and wind. It also tolerates fog and saline air in coastal districts, and even monsoon climates, where it has proved its value for plantations. Young trees are killed by the slightest frost, but older trees seem more cold resistant than mango, avocado or lime. A long, well marked dry season is necessary for fruiting.

Biophysical limits
It performs an altitude ranges from 0-1500 m, mean annual temperature requirement is up to 47^{o} C, mean annual rainfall is 350-1500 mm. It grows in most soils but prefers well drained deep alluvial soil.

Reproductive biology
Flowering generally occurs in synchrony with new leaf growth, which in most areas is during spring and summer. The hermaphroditic bisexual flowers are probably insect pollinated; honeybees collect nectar and pollen from the flowers and they contribute to pollination. *T. indica* usually starts bearing fruit at 7-10 years of age, with pod yields stabilizing at approximately 15 years.

Germplasm management
Seed storage behaviour is orthodox; no loss in viability during 1 years of hermetic storage at 4^{o} C; and viability can be maintained for several years in hermetic storage at 10^{o} C with 7-15 per cent moisture content. There is approximately 1300 seeds/kg.

Popular varieties
PKM 1, Urigam, Hasanur, Tumkur Prathisthan and Yogeshwari

Propagation and management
Tamarind is propagated by seeds and by grafting, budding and stem and air layering. Outstanding mother trees are propagated asexually. Shield and patch budding and cleft grafting are fast and reliable methods, currently used in large scale propagation.

Seed pretreatment involves soaking seeds in cold water for 12 hours. Seeds are sown in lines at 20 cm spacing in the mother beds. Germination starts in about one week and is completed in month. Germination is epigeous, and has a rate of about 60-90 per cent in 40-50 days.

Tree planting and management
Seedlings/ saplings should attain at least 60 cm before being transplanted to their final location at the beginning of the rainy season. Pits of 45 cm^3 or auger holes should be dug at a spacing of 4 x 4m to 6 x 6 m. Apply 200:150:250 g of NPK per tree per year along with 25 kg of FYM and 2 kg of Neem cake.

Growth is generally slow and the juvenile phase lasts up to 4-5 years, or longer. Intercrops like legumes, vegetables, annual drumstick, sesamum and sorghum may be raised in the alley spaces up to four years.

Young trees are pruned to allow 3-5 well spaced branches to develop into the main scaffold structure of the tree. After this, only maintenance pruning is required to remove dead or damaged wood. Trees generally require minimal care. Removal of the rootstock sprouts is necessary for grafted trees. This is possible because grafted trees come to bear within 3-4 years. The trees also respond to coppicing and pollarding. When establishing a pure plantation, final spacing should be at least 12 x 12 m.

Yield
Seedling plants start yielding in 8–10 years after planting. The tree may remain productive until it reaches old age, yielding up to 150 kg/tree with the pulp yield is about 35 per cent. PKM 1 is an early maturing variety which yields about 270 to 300 kg pods/tree with a pulp content of 40 per cent.

Tectona grandis L.f. **(Verbenaceae)**

Common names: Teak (English), Thekku (Tamil)

Teak is a universal timber species par-excellence and commonly considered as “The Queen of Timber” Domestication through plantations for one and a half centuries has made teak the most widely planted and researched tropical hardwood species. Natural cover of the teak in the world is about 29.04 million ha. Teak ranks among the top three tropical hardwood species (Eucalyptus spp. – 18 %, Acacia spp. 7 % and Teak – 4

%) in terms of plantation area (4.35 million ha) established worldwide. Teak trees can usually grow to a very impressive size, and they can grow uninterrupted in some cases for over 1000 years. The oldest and largest teak tree is located in Thailand, where it managed to live for 1500 years and reach the size of 47 meters high. The largest teak in Myanmar has a trunk width of impressive 8.4 meters (27.5 feet), and it reaches up to 34 meters (110 feet) in height. The strength, durability and workability of teak were recognized many centuries ago, leading to its relatively widespread distribution and cultivation throughout the tropics.

Wood is very durable and resistant to fungi. It is one of the best timbers for furniture and cabinet-making, wagon and railway carriages. Used for poles, beams, trusses, columns, roofs, doors, window frames, flooring, planking, panelling, and staircases, and other constructional work. Due to its better shape retention ability, teak is popular in marine constructions and is a class by itself for boat and ship building, particularly for decking. On account of its resistance to chemicals, teak articles are used in chemical laboratories and suitable for casks and vats for shipping corrosive liquids. Teak is employed for sound – boards of musical instruments, keys etc. and for different grades of plywood. Dyes are produced from the root bark and young leaves and employed for use in paper products and cloth manufacture and for dying cloth especially wool and cotton. In Ayurvedic system, the wood is considered as a laxative, sedative for the uterus, good for piles, dysentery and leucoderma. Roots were used for urinary tract problems. Bark has been used to treat diabetes. Bark astringent, used in bronchitis.

Distribution

Its natural distribution is in Southeast Asia, mainly India, Indonesia, Laos, Myanmar, Thailand. In India regular teak plantations were started as early as in the year 1842. The second largest production site of teak lumber is located in Nilambur, in Kerala, India. Mr. Chatu Menon is considered to be the father of Indian teak plantations. From that year until 1862, more than one million teak plants were raised for plantation development.

Biophysical limits

It can grow at elevations from sea level to 4,000 m but the best growth reached below 1,200 m. The minimum monthly temperature is above 13^{o} C and the maximum monthly temperature is below 40^{o} C. Teak is very strong light demanding species (75 to 100 %) throughout its life cycle. Optimal rainfall for teak ranges between 1,250 and 3,750 mm per year. For the production of good quality timber the species requires a dry season of at least four months with less than 60 mm precipitation. Teak can grow best on deep, well drained and fertile soils, especially on volcanic substrata such as igneous and metamorphic soils or on alluvial soils of various origins. The optimal soil pH is between 6.5 and 7.5.

Under favourable conditions in early life, a teak plantation may exhibit growth rates of between 10 and 20 $m^3\ ha^{-1}\ year^{-1}$. However, growth falls to the general reported level of 4 to 8 $m^3\ ha^{-1}\ year^{-1}$ as the plantation ages. In India found heartwood content of more than 50 year old trees was 77 per cent, whereas for eight year old trees it was only 30 per cent. Hence, rotations longer than eight years are necessary for producing high value logs and that faster growth rates may not be detrimental to the value of the timber.

Wood quality

The most important form characteristic determining the value of teak logs is the length of the clear bole, which is determined by the timing of flowering. Flowering is representing the transition from production of vegetative structures only to the production of reproductive structures and occurs in response to certain environmental signals. Flowering by the terminal shoot is then immediately followed by the initiation of the whorl of branches. Selection for late flowering has been suggested as a means of maximizing the duration of the vegetative period.

The general perception prevailing among teak users are that fast growing teak produces only light, weak and spongy wood. Recent studies revealed that young trees (13 to 21 years of age) are not necessarily inferior in wood density and strength to older trees aged 55 and 65 years, and hence that the rotation age of fast grown teak wood can be reduced without affecting the timber strength. Various products such as glue-edged boards, furniture, doors and small teakwood artefacts have been made from thinning materials, showing that even sapwood can be used to produce high-quality objects.

Reproductive biology
Flowering type is Hermaphroditic. Flowering takes place every year at the beginning of the rainy season, starting about one month after the first rain. The fruit is hard irregularly rounded drupe. Fruits mature four months after fertilization.

Germplasm management
Teak plants are established either by seeds or vegetative tissues (stumps, branch cuttings *etc*.). Plants raised from seeds collected at random tend to show fairly wide variability in growth, while vegetative propagation using cuttings and tissue culture ensures production of uniform planting materials of desired qualities. At present, planting material of the desired quality and of known genetic source is not available in sufficient quantity. However, seeds are very important to maintain a broad genetic base. To obtain fairly uniform planting materials from seeds, seedling or clonal seed orchards of good quality trees have to be raised for seed collection.

Seed collection
Age of mother tree is 15-45 years old. Fruits are available about 3-4 months during drier months. The number of seeds per kg is 1,100 – 1,300 and **s**eed size varies from 5to 20 cm and bigger seeds more than 14 mm, recorded better germination energy.

Seed storage
Orthodox (Seed that can be dried and stored at subzero temperatures without damage) Viability can be maintained for at least 7 years in airtight, air-dry storage at room temperature; there is no loss in viability after 7 years in airtight, air-dry storage at 0-4 deg. C with 12 per cent moisture content.

Propagation
By seeds
Teak seeds are surrounded by a hard stony endocarp and a soft fleshy mesocarp, so they require special treatment before sowing such as

- Alternate soaking and drying (24 hrs) 14 days or
- Half burning of the fruits with light running fire or
- Soaking in cow dung slurry for 24 hrs and dried alternatively in shade for 24 hours the process being repeated for 14 days or
- The fresh teak seeds were subjected to alternate chilling and heating (0^o / 50^o C for two weeks) facilitates the quick emergence of radicals.

Sowing and Germination
Line sowing is done in the raised beds. Germination usually starts after 10 days but may take 2 to 3 months.

Tissue cultured plants
Tissue cultures also perfected. It is possible to produce 500 plants from a single bud of a mature tree.

Nursery Tending
Tending begins immediately after sowing and continues until seedlings are ready to be lifted for planting. During early stages watering is essential. Seedlings prefer slight shading during the seedling stage. To minimize the variation in height, the over dominant seedlings are top pruned to open the space for the development of suppressed seedlings.

Planting and tree management
Best planting season is monsoon, it preferably after the first shower. Plough lands thoroughly and level it off. Mark the areas for pit digging by alignment and staking. Dig pits of 45 x 45 x 45 cm sizes. Refill the soil after seasoning and mixing with Farm Yard Manure and insecticides. On poor gravely sites, replace the pit soil by good soil.

In general seedlings made in to stumps (root shoot cuttings) are preferred for planting in the main field. To prepare stumps, the stem part of seedling is cut off at about 3-5 cm (leaving 1 -2 pairs of buds) above the root collar. The tap roots also cut off if longer than 15 cm and lateral roots trimmed off close to the tap root.

Espacement
As the tree is deciduous, raising pure plantations is discouraged; rather, it is recommended to mixed indigenous species. Teak can be planted at 2 x 2m, 2.5 x 2.5m or 3 x 3m espacement. It can also be raised along with agricultural crops at a spacing of 4 x 4m or 5 x 5m.

Weeding
One working in the 1st year and two workings in 2nd and 3rd year may be adequate for better growth of plants. Weeding may be carried out @ 2 operations in first and second year and one operation in the third year.

Irrigation
Irrigation during stress period boosts the growth of the plants. However, it has been observed that teak trees grown under irrigated condition grew faster but the sapwood content of trees increased, the wood became weak and wind damage became quite serious. A phenomenon of water blisters may also develop in teak trees grown under irrigated conditions. Such trees may appear quite healthy from outside but the inner heartwood may develop rot due to storage of excess water that increases the spread of fungi which may further damage the tree.

Fire protection
Fire protection is important; each year planting area should be protected by a fire line 10 m wide by clearing of all vegetation.

Pruning and Thinning
Thinning and pruning operations have a strong effect on the yield and quality of timber. To produce long boles free from knots, the usual strategy is to keep stands closed using high-density plantings, which remain untwined for the first three or four years of the plantation. Inferior trees are readily suppressed if stand density is too high. Overall, it is desirable to thin the stand to the number that is optimal for reduction of undue competition and for the best growth of the remaining trees. Accordingly, plantations must be thinned regularly and heavily, particularly in the first half of the rotation.

The spacing of trees and the number, timing and intensity of thinning strongly affect the pattern of growth and the yield of the plantation. Thinning is practised late, growth rates decline or cease, whereas if the stand is thinned too early or too heavily, the trees have a greater tendency to produce side branches and epicormic shoots. This also reduces the potential yield of the plantation since growth is diverted from the main stem, which should be free from defects such as those caused by side branches and epicormic shoots.

The timing of the first thinning is often determined by the height of the trees and is commonly carried out when the trees reach 9.0 to 9.5 m. The second thinning are carried out when the trees reach 17 to 18 m. The mean basal area is often allowed to reach 20 to 22 m^2 per hectare after the second thinning. A third thinning is then carried out to reduce the mean basal area to 13 to 15 m^2 per hectare. A final stocking of about 300 trees per hectare would be the ideal.

Rotation period
Teak trees are often allowed to grow for 60 years or more. Based on a weighed assessment of economic and silvicultural considerations, a rotation of 25 years to 40 years may at present be considered as the optimum cycle to achieve a viable balance between financial returns and the production of market quality timber.

Harvest
It takes roughly 20-30 years to produce reasonably good quality timber. On an average a tree on first quality site at 20 years of age under natural conditions of growth will yield around 0.283 m^3 of timber. Under best management with 250 trees ha^{-1}, a tree may produce maximum of 0.60 m^3 of timber.

Chapter - 15

GLOSSARY

Afforestation: The establishment of a forest or plantation in an area where the preceding vegetation or land use was not forest.

Agroforestry: An integrated land use management system in which trees or shrubs are grown in association with agricultural crops, pastures or livestock. This integration of trees and shrubs in the land-use system can be either a spatial arrangement, e.g. trees growing in a field at the same time as the crop, or in a time sequence, e.g. trees/shrubs grown on a fallow for restoration of soil fertility.

Allelopathy: A biological phenomenon by which an organism produces one or more biochemicals that influence the germination, growth, survival, and reproduction of other organisms.

Allelospoly: A term used to describe the increasing competition from trees in agroforestry systems for light, water and nutrients which results in it only being possible to carry out intercropping during the early growth period of the tree.

Alley cropping: The practice of planting annual crops between widely spaced rows of woody plants or trees.

Amensalism: Any relationship between organisms of different species in which one organism is inhibited or destroyed while the other organism remains unaffected.

Angiosperms: Flowering plants produce seeds enclosed in an ovary.

Annual Yield and Periodic Yield: The volume or number of stems that can be removed in a specific area in one year, or during a specified period, respectively.

Aspect: The compass direction towards which a slope faces, for example south-west.

Basal area: The cross-sectional area of a tree at breast height (1.3m) expressed in square metres (m^2). It's a tool used to calculate sustainable timber yield.

Biodiversity: The genetic variety of life forms and their ecosystems. Comprises genetic diversity (within species), species diversity (between species) and ecosystem diversity.

Biomass: the total weight of living matter in a population, expressed in terms of dry weight per unit area.

Bole: The tree trunk from the ground to the crown break. The bole doesn't include major branches supporting the tree crown, and may/not be straight.

Breast height: This is the standard height (1.3m above the ground) at which a tree diameter is measured.

Browsing: Animals feed on leaves, twigs, or other high-growing vegetation.

Buttress Roots: Triangular flanges joining the roots and lower trunk of trees.

Canopy: The uppermost level of foliage formed by the branches and leaves of a tree.

Carbon sequestration: The removal and storage of carbon from the atmosphere into natural or manmade reservoirs, including forests and wood products.

Catchment: The water collecting area from which water flows out into a river/ reservoir or water pool.

Climax forest: A forest community that represents the final stage (climax community) of natural forest succession for its environment.

Climatic climax: A plant community that is in equilibrium with a zonal climate. E.g. Southern Tropical wet evergreen forest.

Clinometer: an instrument used to determine ground slope or tree height

Codominant: Trees with crowns forming the general level of the main canopy in even-aged stands or, in uneven-aged stands, the main canopy of the tree's immediate neighbors, receiving full light from above and comparatively little from the sides.

Community (ecological): An ecological unit composed of a group of organisms or a population of different species occupying a particular area usually interacting with each other and their environment.

Community (social): A group of people who live near each other, share common interests, needs and sets of services.

Community forestry: Forestry practices in which the people, as communities, are directly involved in the planning, implementation and management processes of forestry.

Conifers: Evergreen trees and shrubs of the botanical group gymnosperms. These plants produce naked seeds usually in cones.

Conservation: The management of the natural environment to ensure its survival. A term covering preservation, maintenance, sustainable utilisation, restoration and enhancement of the environment.

Coppice: Regrowth that grows from dormant buds under the bark of tree stumps after the tree has been felled.

Dendrology: The scientific study of trees and woody plants, A branch of botany devoted to the study of trees and their identifying characteristics.

Crown: Upper branchy part of a tree above the bole.

Crown thinning: The removal of trees from the dominant and codominant crown classes in order to favor the best trees of those same crown classes.

DBH: Abbreviation for the diameter of a tree at breast height (1.3 metres or 4.5 feet above ground level).

Deforestation: Removal of tree crops from a piece of land without the intension of reforesting.

Dieback: The eventual death of trees from environmental stresses, such as pest attack, exposure to fungal disease, increasing soil salinity and human-induced changes.

Dominant: Trees with crowns extending above the general level of the main canopy of even-aged stands or, in uneven-aged stands, above the crowns of the tree's immediate neighbors, and receiving full light from above and partly from the sides.

Ecesis (ecology): The process by which a plant or animal becomes established in a new habitat.

Ecoregion: A contiguous geographic area having similar macroclimate, possibly with several vegetation types, and used as an ecological basis for management or planning.

Ecosystem: Any biological community and its non-living environment, including all the plants and animals in an area together with the air, land and water with which they interact.

Edaphic climax: An ecological climax resulting from soil factors and commonly persisting through cycles of climatic and physiographic change. E.g. Wet bamboo breaks.

Eddying: A current of air or water moving in a circle against the main current.

Enriched fallow: A form of agroforestry in which useful, mainly woody species are sown or planted before cultivation ceases, or at the time it does, so that during the fallow period, or when the land is next cleared for cultivation, products are available for household use or market that would not otherwise have been there (for example, fruits, bamboos, rattans, medicinals).

Exotics: Species or a plant which doesn’t belong to a area in question and had been brought from different zone of occurrence.

Farm forestry: Commercial tree production on farmland.

Felling: The process of cutting trees.

Felling cycle: The planned period, in years, within which all parts of a forest zoned for wood production and being managed under a selection silvicultural system should be selectively cut for logs.

Fertilization: The process of applying nutrients to amend the soil and improve tree growth and vigor.

Firebreak: A strip of land maintained clear of trees and combustible materials, to stop or control the spread of fire.

Forest farming: A specific form of agroforestry that involves the cultivation of high-value specialty crops under the protection of a forest canopy that has been modified to provide the shade level appropriate for a specific crop.

Free thinning: The removal of trees to control stand spacing and favor desired trees using a combination of thinning criteria without regard to crown position.

Gestation period: The time period which elapsis between planting and final harvest of the tree crop. (Syn: Rotation period).

Grazing: A method of feeding in which a herbivore feeds on plants such as grasses.

Greenhouse effect: Warming of the Earth's surface due to increases in radiated energy trapped by higher levels of atmospheric gases, including carbon dioxide, methane, chlorofluorocarbons (CFCs), nitrous oxide, ozone and water vapour, due primarily to the combustion of fossil fuels.

Gregarious flowering: Flowering of almost all the individuals over considerable area followed by death of clumps.

Gymnosperms: Non-flowering plants. Seeds not enclosed in an ovary, enclosed in a cone.

Habitat: The native environment where an animal or plant naturally lives or grows.

Hardening off: The natural process by which plants become adapted to drought, cold or heat.

Hypsometer: Any of several tools or instruments for measuring the height of trees. Examples include the altimeter, abney level, clinometer, and relascope, all of which can also be used to measure other tree or environmental characteristics.

Improved fallows: Areas left to grow up in selected trees as part of a trees-crop rotation system.

Kankar: A crust or layer of hard mineral or subsoil encrusted with calcium-carbonate occurring in arid or semiarid regions

Land capability: The ability of the land to sustain a type and intensity of use without permanent damage.

Lay farming: Rotation of arable crops with two or more years of sown pasture.

Leaf litter: Mixture of fallen and dead plant material on the forest floor, made up of leaves, bark, stems and branches.

Light demander: A species that requires abundant light for its best development and reproduction.

Log: A portion of stem/ trunk or branch which had been cut across into different lengths depending on requirement of market or form of the tree.

Logging: The process of cutting down trees for wood.

Low thinning (Thinning from Below): The removal of trees from the lower crown classes to favor those in the upper crown classes.

Lumber: The sawn product from a tree – synonym is sawn wood.

Monoculture: One type or species of plant cultivated in an area, for example plantations of a single species of tree.

Multipurpose trees: Trees that are deliberately grown and managed for more than one output. They may supply food in the form of fruit, nuts, or leaves that can be used as a vegetable; while at the same time supplying firewood, add nitrogen to the soil, or supply some other combination of multiple outputs.

Mulch: A layer of organic material covering the soil to reduce soil erosion, conserve soil moisture, and minimize soil temperature fluctuations.

Niche: The unique environment or set of ecological conditions in which a specific plant or animal species occurs, and the function the organism serves within that ecosystem.

Nurse Tree (Nurse Crop): A tree, group or crop of trees, shrubs or other planes, either naturally occurring or introduced, used to nurture, improve survival or improve the form of a more desirable tree or crop when young by protecting it from frost, insolation, or wind.

Pastureland: A land used primarily for the long term production of adapted, domesticated forage plants to be grazed by livestock or occasionally cut and cured for livestock feed.

Plantation: A forest established by man through planting seedlings or seeds of exotic or native species. They are typically characterised by straight lines and even-aged stands of trees.

Plus tree: A tree selected for production or breeding, based on superior phenotype for growth, form, wood quality and/or other desired charecters.

Pollarding: A woodland management method of encouraging lateral branches by cutting off a tree stem or minor branches two or three metres above ground level.

Polygamous: A plant bearing some flowers with stamens only, some with pistils only, and some with both, on the same or different plants.

Precommercial Thinning: A thinning that does not yield trees of commercial value, usually designed to reduce stocking in order to concentrate growth on the more desirable trees.

Pruning: This is the technique of removing dead, damaged or excess branches from trees. It is usually done from the base of the tree, and encourage trees to grow straight.

Pulpwood: Timber cut and prepared primarily for the manufacture of wood pulp and for further processing to make paper or reconstituted wood product such as fibreboard.

Range land: All areas that have predominantly grasses and shrub vegetation, including areas that are not grazed by domestic livestock.

Relascope: Hand-held instrument used to measure tree height, tree basal area, stem diameter at various heights, form class, and distance.

Reforestation: Regrowing a forest on a harvested tract of land using artificial (mechanical or hand planting) or natural (seeds or sprouts) regeneration methods.

Resiliency: The capacity of an ecosystem to maintain or regain normal development following disturbance.

Riparian Forest Buffers: Riparian forest buffers are a form of agroforestry that involves the natural or re-established streamside forests made up of tree, shrub, and grass plantings. They buffer non-point source pollution typically created by agricultural operations on land adjacent to waterways.

Round wood: It is a felled timber consists of two major subgroups namely Industrial roundwood (swanlogs, veneer logs, pulp wood and paper) and fuel wood.

Runoff: The proportion of rain falling in a catchment which flows across the surface rather than infiltrating the soil.

Salvage logging: Logging carried out to use trees that have been damaged by fire or storm.

Sapling: A general term for a tree that is no longer a seedling but not yet a pole, usually referring to trees at least 4.5 feet tall and 2 to 4 inches in diameter

Sedentary farming: A method of agriculture in which the same land is farmed every year.

Silviculture: The scientific practice of establishing, tending, harvesting, and regenerating a forest stand with desired characteristics.

Silvopasture: Silvopasture is a form of agroforestry that combines trees with forage and livestock production.

Site preparation: A forest activity to remove unwanted vegetation and woody material, and to prepare the soil for reforestation/ afforestation.

Soil erosion: Process by which soil particles are detached and transported by wind, water, and gravity to a downslope or downstream location.

Sporadic flowering: Flowering of few culms in a clump or a few clumps in a locality.

Sustainable yield: Amount of trees removed from a forest must at least equal the amount a forest is able to replace naturally.

Sawnwood: It encompasses planks, beams, boards, laths, etc. that exceed 5 mm in thickness.

Symbiosis: Close association or relationship between two or more living organisms, where at least one receives some sort of benefit from the relationship.

Taungya: A system of forest plantations in which peasants are allowed to cultivate crops for the first few years between the seedlings of a forest plantations.

Taper: The gradual decrease in the diameter of a tree stem or log from the base upwards.

Thinning: The systematic removal of selected trees to improve the vigor (health) and growth (volume) of the residual stand, and provide income to the landowner.

Urban forestry: The cultivation and management of trees and forests within cities for their present and potential contribution to the physiological, sociological and economic wellbeing of urban society.

Value-added: The increased value of a forest product as a result of processing. Producing a product of higher quality and having more monetary value.

Virgin forest: A forest in its natural state, before it has been explored or exploited by humans

Watershed: The area within a landscape which all runoff collects into a single stream or drainage system.

Wetlands: Land characterized by an abundance of moisture and is inundated by surface or ground water often enough to support a prevalence of vegetation adapted for saturated conditions.

Woodlot: A small area of planted softwood or hardwood forest managed for the production of forest products.

Chapter -16

ANNEXURE

ANNEXURE I

Trees in Forest and Agro-ecosystems

S. No	Botanical Names	Common names (English / Tamil / Hindi)
1.	*Acacia auriculiformis* Benth.	Australian wattle /Kathichavukku/
2.	*Acacia catechu* (L.f.) Willd.	Black cutch / Karungali / Khair
3.	*Acacia chundra* (Rottler) Willd.	Red cutch/ Cenkarungali/ Dant-dhavan
4.	*Acacia concurrens* Pedley	Black wattle
5.	*Acacia confusa* Merr.	Formosa acacia
6.	*Acacia ferruginea* DC.	Parambai/ Safed khair
7.	*Acacia holosericea* G.Don	Silver Wattle / Maankaadhu karuvel
8.	*Acacia lenticularis* Benth.	Kangaroo thorn
9.	*Acacia leucophloea* (Roxb.) Willd.	White-bark acacia/ Velvel/ Safed kikkar
10.	*Acacia mangium* Willd.	Mangium
11.	*Acacia mearnsii* De Wild.	Black wattle/ Seegai
12.	*Acacia melanoxylon* R.Br.	Australian blackwood
13.	*Acacia mellifera* (M.Vahl) Benth.	Black thorn
14.	*Acacia nilotica* (L.) Delile	Prickly acacia/ Karuvelum/ Babul
15.	*Acacia planifrons* Wight & Arn.	Kudaivel
16.	*Acacia senegal* (L.) Willd.	Gum arabic tree/ Kumatiyo
17.	*Adenanthera pavonina* L.	Red-bead tree/ Ani kundamani/ Badi gumchi
18.	*Aegle marmelos* (L.) Correa	Bael fruit/ Vilvam
19.	*Ailanthus excelsa* Roxb.	Tree-of-heaven/ Perumaran / Maharuk
20.	*Ailanthus triphysa* (Dennst.) Alston	White palle/ Mattipal
21.	*Alangium salviifolium* (L.f.) Wangerin	Alanji / Ankol
22.	*Albizia amara* (Roxb.) B.Boivin	Bitter Albizia/ Usilai/ Krishna Siris
23.	*Albizia ferruginea* (Guill. & Perr.) Benth.	West African Albizia
24.	*Albizia lebbeck* (L.) Benth.	Woman's tongue tree/ Vagai/ Siris
25.	*Albizia odoratissima* (L.f.) Benth.	Fragrant Albizia/ Kali siris
26.	*Albizia procera* (Roxb.) Benth.	Forest siris/ Velvagai/ Safed siris
27.	*Albizia saman* (Jacq.) Merr.	Rain tree/ Thoongumoonji/ Gulabi Siris
28.	*Alnus nepalensis* D. Don	Indian Alder/ Utis
29.	*Alstonia scholaris* (L.) R. Br.	Devil tree/ Elilaipalai/ Saptaparni
30.	*Anacardium occidentale* L.	Cashew/ Mundiri/ Kaju
31.	*Anogeissus latifolia* (Roxb. ex DC.) Wall. ex Guillem. & Perr.	Axlewood/ vel-naga-maram/ Dhawra
32.	*Artocarpus heterophyllus* Lam.	Jackfruit/ Pilla/ Kanthal
33.	*Artocarpus hirsutus* Lam.	Wild Jack/ Aiyinipila
34.	*Azadirachta indica* A.Juss.	Neem tree/ Vembu/ Balnimb
35.	*Bambusa bambos* (L.) Voss	Indian Thorny Bamboo/ Moongil / Baans
36.	*Bambusa vulgaris* Schrad.	Bamboo/ Baans
37.	*Barringtonia asiatica* (L.) Kurz	Fish Poison Tree
38.	*Barringtonia racemosa* (L.) Spreng.	Wild guava/ Isuvaradaru/ Norvisnee
39.	*Bauhinia tomentosa* L.	Bell bauhinia/ Iruvaji
40.	*Bauhinia purpurea* L.	Camel foot tree/ Mandarai
41.	*Bixa orellana* L.	Annatto tree/ Sappiravirai/ Latkan
42.	*Bombax ceiba* L.	Red silk cotton/ Mul ilavu/ Shalmali
43.	*Borassus flabellifer* L.	Palmyrah/ Panaimaram/ Taad
44.	*Boswellia serrata* Roxb. ex Colebr.	Indian Olibanum/ Kunkiliyam/ Shallaki
45.	*Butea monosperma* (Lam.) Taub.	Bastard teak/ Porasu/ Palash
46.	*Calophyllum inophyllum* L.	Alexandrian laurel/ Punnai/ Sultan Champa

47.	*Cassia fistula* L.	Golden shower/ Sarak-konnai/ Bandarlathi
48.	*Casuarina equisetifolia* L.	Whistling Pine/ Savukku/ Junglisaru
49.	*Casuarina junghuhniana* Miq.	Forest oak/ Savukku
50.	*Ceiba pentandra* (L.) Gaertn.	White silk cotton tree/ Ilavum/ Hattian
51.	*Celtis australis* L.	Nettle tree/ Batkar
52.	*Cedrus deodara* (Roxb. ex D.Don) G.Don	Himalayan Cedar/ Devadaram/ Devdar
53.	*Chloroxylon swietenia* DC.	Satinwood/ Vaaimaram/ Bhirra
54.	*Cinnamomum malabatrum* (Burm.f.) J.Presl	Country cinnamon/ Therali
55.	*Cinnamomum tamala* (Buch.-Ham.) T.Nees & Eberm.	Indian bay leaf/ Talishappattiri/ Tejpatta
56.	*Cinnamomum verum* J.Presl	Cinnamon/ Karuva/ Dalchini
57.	*Cochlospermum religiosum* (L.) Alston	Buttercup Tree/ Kattupparutti/ Galgal
58.	*Corymbia citriodora* (Hook.) K.D.Hill & L.A.S.Johnson	Lemon scented gum/ Safeda
59.	*Crateva religiosa* G.Forst.	Large garlic pear/ Mavilingam/ Bama
60.	*Cupressus cashmeriana* Royle ex Carriere	Kashmir cypress
61.	*Dalbergia latifolia* Roxb.	East Indian rosewood/ Eetti/ Shisham
62.	*Dalbergia sissoo* DC.	Bombay blackwood/ Burma eetti/ Sissoo
63.	*Delonix elata* (L.) Gamble	Creamy peacock flower/ Vadanarayanan
64.	*Delonix regia* (Hook.) Raf.	Peacock flower/ Mayirkonnai /Gulmohr
65.	*Dendrocalamus strictus* (Roxb.) Nees	Bamboo/ Kalmoongil
66.	*Dendrocalamus hamiltonii* Nees & Arn. ex Munro	Tama bamboo
67.	*Dialium guineense* Willd.	Velvet tamarind
68.	*Dichrostachys cinerea* (L.) Wight & Arn.	Bell mimosa/ Vadataram/ Khairi
69.	*Diospyros melanoxylon* Roxb.	Coromandel Ebony/ Karunthumbi/ Tendu
70.	*Erythrina variegate* L.	Red-hot-poker tree/ Kalyana murungai
71.	*Eucalyptus camaldulensis* Dehnh.	River red gum/ Karpura maram
72.	*Eucalyptus globulus* Labill.	Blue gum/ Thaila maram
73.	*Eucalyptus grandis* W.Hill	Rose gum
74.	*Eucalyptus tereticornis* Sm.	Forest red gum (Mysore gum)
75.	*Ficus benghalensis* L.	Banyan/ Alamaram/ Barh
76.	*Ficus racemosa* L.	Cluster fig/ Atti/ Goolar
77.	*Ficus religiosa* L.	Peepal/ araca-maram/
78.	*Fraxinus micrantha* Lingelsh.	Small-flowered Himalayan ash
79.	*Gliricidia sepium* (Jacq.) Walp.	Mexican lilac/ Seemai agathi
80.	*Gmelina arborea* Roxb.	White teak/ Kumil/ Gumhar
81.	*Grevillea robusta* A.Cunn. ex R.Br.	Silver oak
82.	*Grewia asiatica* L.	Phalsa/ Unnu
83.	*Grewia optiva* J.R.Drumm. ex Burret	Bihul
84.	*Guazuma ulmifolia* Lam.	West Indian elm/ Thenbachai
85.	*Haldina cordifolia* (Roxb.) Ridsdale	Haldu/ Mannakatampu/ Kadami
86.	*Hardwickia binata* Roxb.	Aachan/ Anjan
87.	*Holoptelea integrifolia* (Roxb.) Planch	Indian Elm/ Aaya maram/ Chilbil
88.	*Kigelia africana* (Lam.) Benth.	Common Sausage tree/ Marasuraikai/ Balam
89.	*Kydia calycina* Roxb.	Kydia/ Pula/ Bharanga
90.	*Lagerstroemia speciosa* (L.) Pers.	Pride of India/ Ventheku/ Jarul
91.	*Lannea coromandelica* (Houtt.) Merr.	Wodier/ Odiyamaram

92.	*Lawsonia inermis* L.	Henna tree/ Marithondi/ Mehndi
93.	*Leucaena leucocephala* (Lam.) de Wit	Subabul/ Koo babul/ Savundal
94.	*Limonia acidissima* Groff	Wood-apple/ Velanga/ Bilin
95.	*Neolamarckia cadamba* (Roxb.) Bosser	Common bur-flower/ Vellakadambai/ Kadam
96.	*Madhuca latifolia* (Roxb.) J.F.Macbr.	Indian butter tree/ Illupai/ Mahua
97.	*Mangifera indica* L.	Mango/ Ma/ Am
98.	*Manilkara zapota* (L.) P.Royen	Chappotta/ Chimaiyiluppai/ Chikoo
99.	*Melia azedarach* L.	Persian lilac/ Malai vembu/ Mallan nim
100.	*Millingtonia hortensis* L.f.	Tree Jasmine/ Maramalli/ Chameli
101.	*Mimusops elengi* L.	Spanish cherry/ Magizhamboo/ Bakul
102.	*Morus alba* L.	White mulberry
103.	*Melocanna baccifera* (Roxb.) Kurz	Muli bamboo
104.	*Parkia javanica* (Lam.) Merr.	Tree bean
105.	*Parkia biglandulosa* Wight & Arn.	Badminton ball tree/ Kalikki-maram/ Chenduphal
106.	*Parkinsonia aculeate* L.	Jerusalem thorn/ Vilayati babul
107.	*Peltophorum pterocarpum* (DC.) K.Heyne	Copper shield/ Iyalvagi/ Peela gulmohar
108.	*Phoenix sylvestris* (L.) Roxb.	Indian wild date/ Icham/ khajur
109.	*Phyllanthus emblica* L.	Indian goose berry/ Nelli/ Amla
110.	*Piliostigma malabaricum* (Roxb.) Benth.	Malabar orchid/ Puli-y-atti/ Amli
111.	*Pinus kesiya* Royle ex Gordon	Three needle pine
112.	*Pinus patula* Schiede ex Schltdl. & Cham.	Mexican weeping pine
113.	*Pinus roxburghii* Sarg.	Himalayan longleaf pine/ Seemai devadaru/ Chir
114.	*Pithecellobium dulce* (Roxb.) Benth.	Manila tamarind/ Kodukkaapuli/ Jangal jelbi
115.	*Platanus orientalis* L.	Chinar
116.	*Polyalthia longifolia* (Sonn.) Thwaites	False Ashoka/ Nettulingam/ Ashok
117.	*Pongamia pinnata* (L.) Pierre	Pongam/ Pungam/ Karanj
118.	*Populus alba* L.	White poplar
119.	*Populus ciliata* Wall. ex Royle	Himalayan poplar/ Safeda
120.	*Populus deltoides* Marshall	Cottonwood
121.	*Populus gamblei* Dode	Pipalpate
122.	*Populus nigra* L.	Lombardy poplar
123.	*Prosopis cineraria* (L.) Druce	Screw-bean/ Perumbay/ Jand
124.	*Prosopis juliflora* (Sw.) DC.	Honey mesquite/ Velikaruvel/ Vilayati babul
125.	*Pterocarpus marsupium* Roxb.	Malabar kino tree/ Vengai/ Vijayasara
126.	*Pterocarpus santalinoides* DC.	Senchanthanam
127.	*Quercus oblongata* D.Don	Woolly oak/ Banjh
128.	*Quercus glauca* Thunb.	Ring-cupped oak
129.	*Robinia pseudoacacia* L.	White Locust Tree
130.	*Santalum album* L.	Sandal wood/ Santhanam/ Safed-chandan
131.	*Sapindus mukorossi* Gaertn.	Soap-nut tree/ Poochakottai/ Aritha
132.	*Schleichera oleosa* (Lour.) Merr.	Ceylon oak/ Puvam maram/ Kusum
133.	*Senna siamea* (Lam.) H.S.Irwin & Barneby	Yellow cassia/ Manja kondrai/ Kassod
134.	*Sesbania grandiflora* (L.) Pers.	West Indian pea/ Peragathi/ Agasti
135.	*Simarouba amara* Aubl.	Paradise tree/ Sorgamaram
136.	*Spathodea campanulata* P.Beauv.	Nandi flame/ Patadi/ Rugtoora
137.	*Sterculia foetida* L.	Java olive/ Kutiraippitukku/ Jangli badam
138.	*Stereospermum chelonoides* (L.f.) DC.	Fragrant padri/ Padiri/ Padeli

139.	*Strychnos nux-vomica* L.	Quaker buttons/ Etti/ Bailewa
140.	*Strychnos potatorum* L.f.	Clearing nut/ Thenan kottai/ Nirmali
141.	*Swietenia macrophylla* King	Mahogany
142.	*Syzygium cumini* (L.) Skeels	Indian blackberry/ Naval/ Jamun
143.	*Tabebuia heterophylla* (DC.) Britton	Trumpet Tree/
144.	*Tamarindus indica* L.	Tamarind/ Puliyamaram/ Imli
145.	*Tamarix aphylla* (L.) H.Karst.	Salt cedar/ Shivappu-atru-shavukku
146.	*Tectona grandis* L.f.	Teak/ Tekkumaram/ Sagwan
147.	*Tecomella undulata* L.	Desert teak/ Rohida
148.	*Trema orientalis* (L.) Blume	Indian charcoal tree/ Yerralai/ Jivan
149.	*Terminalia alata* Wall.	Indian laurel/ Karumarudhu
150.	*Terminalia arjuna* (Roxb. ex DC.) Wight & Arn.	Arjun/ Neermarutu
151.	*Terminalia bellirica* (Gaertn.) Roxb.	Beach almond/ Thanri/ Bahera
152.	*Terminalia catappa* L.	Indian almond-wood/ Badam
153.	*Terminalia chebula* Retz.	Myrobalan/ Kadukkai/ Harra
154.	*Terminalia paniculata* Roth	Kindal Tree/ Pillamaruthu
155.	*Thespesia populnea* (L.) Sol. ex Correa	Indian tulip tree/ Poovarasam/ Paras-pipal
156.	*Toona ciliata* M.Roem.	Red cedar/ Cevvagil/ Maha nim
157.	*Ulmus wallichiana* Planch.	The Himalayan elm
158.	*Vateria indica* L.	White Damar/ Vellai kundigrigam/ Badasal
159.	*Wrightia tinctoria* R.Br.	Sweet Indrajao/ Veppalai/ Kapar
160.	*Xylia xylocarpa* (Roxb.) Taub.	Burma Ironwood/ Iirul/ Jambu
161.	*Ziziphus jujuba* Mill.	Indian jujube/ Elandai/ Ber

ANNEXURE II

Planets (Grahas) and Plants

One of the earliest uses of astrology was to help categorize the natural world. Plants are the blessings received directly from nature and they always help us either directly or indirectly. Since ancient times, each known plant species was connected with a particular planet. Such plants and there parts have been used since ancient times for religious purposes. The plants attributed to different Grahas are as follows:

S. No	Planets (Grahas)	Botanical Names	Common names (English/Tamil/ Sanskrit)
1.	Sun (Surya)	*Calotropis procera*	Shallow wart/ Vellai Erukku/ Arka
2.	Moon (Chandra)	*Butea monosperma*	Flame of the Forest/ Parasu/ Palasha
3.	Mars (Mangal)	*Acacia catechu*	Cutch Tree/ Karungali/ Khadira
4.	Mercury (Budh)	*Achyranthes aspera*	Prickly chaff flower/ Naiyuruvi/ Apamarga
5.	Jupiter (Guru)	*Ficus religiosa*	Sacered peepul/ Arasa maram / Ashwatha
6.	Venus (Sukra)	*Ficus racemosa*	Sacred Fig tree/ Atti maram/ Audumbara
7.	Saturn (Shani)	*Prosopis cineraria*	Indian gum tree/ Vanni maram/ Shami
8.	Rahu (north node)	*Cynodon dactylon*	Hariali grass/ Arugampul/ Durva
9.	Ketu (south node)	*Eragrostis cilianensis*	Kusha grass/ Dharbe

ANNEXURE III

Trees of Rashi Vanam (Zodiac Garden)

In Astrology there are 12 Zodiac signs. Like our birth stars each person is born during a particular Zodiac sign. There are 12 trees represent each one of them. How each ones luck is predicted according to the birth star similarly according to the Rashi (house) also the horoscope and luck of each person and how he is benefitted by these trees is mentioned in Astrology. All these were mentioned in Varaha Mihira's Jyotisha sashtra.

S. No.	Name	Botanical name
1.	Mesha Rashi (Aries)	*Pterocarpus santalinus*
2.	Vrishabha Rashi (Taurus)	*Alstonia scholaris*
3.	Mithuna Rashi (Gemini)	*Artocarpus heterophyllus*
4.	Karkataka Rashi (Cancer)	*Butea monosperma*
5.	Simha Rashi (Leo)	*Stereospermum chelonoides*
6.	Kanya Rashi (Virgo)	*Mangifera indica*
7.	Tula Rashi (Libra)	*Mimusops elengi*
8.	Vrishchika Rashi (Scorpio)	*Acacia catachu*
9.	Dhanu Rashi (Sagittarius)	*Ficus religiosa*
10.	Makara Rashi (Capricorn)	*Dalbergia sissoo*
11.	Kumbha Rashi (Aquarius)	*Prosopis cineraria*
12.	Meena Rashi (Pisces)	*Ficus bengalensis*

ANNEXURE IV

Trees of Nakshatra Vanam

Hinduism worships divinity not just in the forms of humans but also in the form of nature. Mountains, rivers, animals, plants, rocks, planets and even stars are considered divine. As per Vedic Jyotisha person can become free of ailments, physical, social and economic problems by planting a plant or tree as per the native's birth Nakshatra (constellation). This is perhaps one of the reasons why our ancestors considered trees as equivalent to gods and goddesses and revered them as divine elements. Worshipping the tree or plant as per the native's Nakshatra provides one with the highest merit. Nakshatravana also referred to as Nakshatravanam or Nakshatravan, is a sacred grove consisting of 27 trees that are related to 27 Nakshatras of Indian Astrology. Considering the diversity of plants involved, their medicinal value, and association with Nakshatras, many organisations are popularizing the creation of Nakshatra vanam.

S. No	Nakshatra/ Star	Vernacular Names	common Name	Botanical Name
1	Ashwini/ Aswathy/ Ashvayuja	Kanjiram/ Yett Kuchala	Strychnine	*Strychnos nux-vomica*
2	Bharani/ Apabharani	Nelli/ Perunelli/ Amla	Indian Gooseberry / Amla	*Phyllanthus emblica*
3	Krittika/ Karthika	Athi/ Ambar/ Udumbara/ Gular	Cluster Fig/ Country Fig/ Fig	*Ficus racemosa*
4	Rohini	Naval/ Jambhali/ Perunjaval	Jamun/ Black Plum	*Syzygium cuminii*
5	Mrigashirsha/ Makayiram	Karungali/ Kher	Cutch Tree	*Acacia catechu*
6	Aardra/ Thiruvathira	Karai/ Agar/ Agali chandanum/ Akil/ Sen Santhanam	Red Sandal	*Pterocarpus santalinus*

7	Punarvasu/ Punartham/ Punarpusam	Mula/ Moongil/ Velu	Bamboo	*Bamboosa arundinorea*
8	Pushya/ Pooyam/ Pusam/ Tishya	Arayal/ Arasamaram/ Pimpal/ Pipal/ Aal	Sacred Fig/ Peepal/ Ficus	*Ficus religiosa*
9	Aashlesha/ Aayilyam	Tadinangu/ Nagchampa	Cobra saffron/ Indian rose chestnut	*Mesua ferrea*
10	Magha/ Magam	Peral/ Alamaram/ Vatt/ Bargad	Banyan Tree/ Indian Fig	*Ficus benghalensis*
11	Purva Phalguni/ Pooram/ Poorva	Chamata/ Palas/ Khakda/ Modugu/ Parasu/ Polash/ Desuka Jhad/ Chalcha	Flame of the Forest/ Parrot Tree	*Butea monosperma*
12	Phalguni/ Uthram/ Uttara/ Uthiram/ Uttara Phalguni	Karuvali/ Kanniramaram/ Jamrasi	Ceylon Tea	*Cassine glauca*
13	Hasta/ Atham/ Astham	Ritha	North Indian soapnut	*Sapindus mukorossi*
14	Chitra/ Chithira/ Chithirai	Koovalam/ Vilvam/ Bel/ Bilvam/ Bilwa/	Beal Tree/ Bengal Quince/ Stone Apple/	*Aegle marmelos*
15	Swathi/ Chothy/ Suvathi	Maruthu/ Neermaruthu/ Marutham/ Arjun	Arjuna Tree	*Terminalia arjuna*
16	Vishaka/ Visakham	Dadhipala/ Vilamaram/ Kaith/ Nahar Naagkeshar/	Wood Apple/ Ceylon Ironwood/	*Limonia acidissima*
17	Anuradha/ Anizham/ Anusham	Elanji/ Magizh/ Magizham/ Maulshree/ Naagkeshar	Bullet Wood Tree	*Mimusops elengi*
18	Jyeshta/ Ketta/ Thrikketta/ Kettai	Shalmali	Red silk cotton	*Bombax ceiba*
19	Mula/ Moolam/ Vichrita	Sal/ Shala	Sal Tree	*Shorea robusta*
20	Purva Ashada/ Pooradam	Rattan/ Piramboo	Slender Rattan Cane	*Calamus pseudotenuis*
21	Uttar Ashada/ Uthradam	Plavu/ Pila/ Pala	Jack Fruit Tree	*Artocarpus heterophyllus*
22	Sravana/ Thiruvonam/ Shrona	Erukku/ Vellerukku/ Rui	Swallow Wort	*Calotropis gigantea*
23	Shravishtha/ Avittam/ Dhanishta	Paarampu/ Vanni/ Vilaytikikar/ Shashi/ Khejari	Indian Gum Tree/ Indian Mesquit/	*Prosopis cineraria*
24	Satabisha/ Shatataraka/ Chathayam/ Sathayam	Kadambu/ Kadambam/ Katampu/ Valanch	Kadam Tree	*Neolamarckia cadamba*
25	Pooruruttathi/ Purva	Ma/ Am	Mango	*Mangifera indica*

	Badrapada/ Proshtapada			
26	Uttra Badrapada/ Uthruttathi/ Uttara Proshtapada	Veppu	Neem	*Azadirachta indica*
27	Revathi	Eluppa/ Iluppai/ Moha	Butter Tree	*Madhuca longifolia*

ANNEXURE V

List of research institutes/ Organizations

International

- The International Institute of Tropical Forestry (IITF), Rio Piedras, Puerto Rico - 1939.
- The Center for International Forestry Research (CIFOR), Bogor, Indonesia - 1993
- International Centre for Integrated Mountain Development (ICIMOD), Lalitpur, Nepal - 1983
- International Union of Forest Research Organizations (IUFRO), Vienna, Austria – 1892
- International Tropical Timber Organization (ITTO), Yokohama, Japan – 1986
- World Agroforestry Centre (a brand name used by the International Centre for Research in Agroforestry, ICRAF), Nairobi, Kenya - founded in 1978 as "International Council for Research in Agroforestry".

National

- Advanced Research Centre for Bamboo and Rattan (ARCBR), Aizawl - 2004
- Arid Forest Research Institute (AFRI), Jodhpur, Rajastan- 1988
- Central Arid Zone Research Institute (CAZRI), Jodhpur – Desert Afforestation Station (1952); later expanded into Desert Afforestation and Soil Conservation Station in 1957, and finally upgraded to CAZRI in 1959
- Centre for Forestry Research and Human Resource Development, Chhindwara, MP - 1995
- Centre for Social Forestry and Eco-Rehabilitation (CSFER), Allahabad, UP – 1992
- Forest Research Centre for Livelihood Extension (FRCLE), Agartala, Tripura - 2012
- Forest Research Institute (India), Dehradun - Established as Imperial Forest Research Institute in 1906
- Himalayan Forest Research Institute (HFRI), Shimla – 1977
- Indian Council of Forestry Research and Education (ICFRE), Dehradun – 1878 as Forest School; 5th June 1906 as Imperial Forest Research Institute; 1986 as ICFRE.
- Indian Grassland and Fodder Research Institute, Jhansi (Uttar Pradesh) - 1962
- Indian Institute of Forest Management, Bhopal - 1982
- Indian Institute of Natural Resins and Gums, Namkum, Ranchi Jharkhand ((formerly Indian Lac Research Institute (ILRI)) - September 20, 1924.
- Indian Plywood Industries Research and Training Institute (IPIRTI), Bangalore - (formerly Indian Plywood Manufacturers' Research Association (IPMRA) 1962); The Institute was re- designated as Indian Plywood Industries Research Institute (IPIRI) in 1970 and renamed as IPIRTI during 1992
- Institute of Forest Biodiversity (IFB), Hyderabad, Telangana - 1997
- Institute of Forest Genetics and Tree Breeding (IFGTB), Coimbatore - 1988
- Institute of Forest Productivity, Ranchi, Jharkhand - 1993
- Institute of Wood Science and Technology (IWST), Bangalore – 1938
- National Biodiversity Authority (NBA), Chennai – 2003
- National Research Centre For Agroforestry (NRCAF), Jhansi - 1988
- Rain Forest Research Institute (RFRI), Jorhat, Assam - 1988
- Tropical Forest Research Institute (TFRI), Jabalpur, MP - 1988
- Wildlife Institute of India (WII), Dehradun - 1982

ANNEXURE VI

"Earth provides enough to satisfy every man's needs, but not every man's greed."

- Mahatma Gandhi

The United Nations has been observing designated years, decades, weeks, and days with a specific theme. The main reason behind this is to promote awareness internationally and also to take actions on very serious issues.

International Decades

Year	Activity
2014-2024	United Nations Decade of Sustainable Energy for All
2011-2020	United Nations Decade on Biodiversity
2010-2020	United Nations Decade for Deserts and the Fight against Desertification
2008-2017	Second United Nations Decade for the Eradication of Poverty
2005-2015	International Decade for Action, "Water for Life"
2005-2014	Second International Decade of the World's Indigenous People
1997-2006	United Nations Decade for the Eradication of Poverty
1994-2003	International Decade of the World's Indigenous People

International Years

Year	Activity
2015	International Year of Soils
2014	International Year of Family Farming
2013	International Year of Water Cooperation
2012	International Year of Sustainable Energy for All
2011	International Year of Forests
2010	International Year of Biodiversity
2009	International Year of Planet Earth
2009	International Year of Natural Fibres
2006	International Year of Deserts and Desertification
2003	International Year of Freshwater
2002	International Year of Mountains
2002	International Year of Ecotourism
1996	International Year for the Eradication of Poverty
1993	International Year for the World's Indigenous People

ANNEXURE VII

List of Forest/Agroforestry/Environmental conservation related Days

2nd February - World Wetlands Day

27th February - World Sustainable Energy Day

3rd March - World Wildlife Day

21st March - World Forestry Day / International Day of Forests

22nd March - World Water Day

23rd March - World Meteorological Day

22nd April - World Earth Day

8th May - National Agroforestry Day

Third Friday in May	- National Endangered Species Day
20th May	- World Bee Day
22nd May	- International Day for Biological Diversity
28th May	- World Hunger Day
5th June	- World Environment Day
17th June	- World Day to Combat Desertification and Drought
29th June	- International Day of the Tropics
28th July	- World Nature Conservation Day
29th July	- International Tiger Day (Global Tiger day)
9th August	- Day of the World's Indigenous Peoples
16th September	- World Ozone Day
18th September	- World Bamboo Day
21st September	- Biosphere Day
28th September	- Green Consumer Day
3rd October	- World Nature Day
First week of October	- World Wildlife Week
13th October	- International Day for Natural Disaster Reduction
16th October	- World Food Day
5th November	- World Tsunami Day
14th – 20th November	- National Land Resources Conservation Week
2nd December	- National Pollution Control Day
5th December	- World Soil Day
14th December	- National Energy Conservation Day

*** "Plant a Tree to celebrate these Days"***

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