INNOVARE JOURNAL OF AGRICULTURAL SCIENCE

Vol 4, Issue 2, 2016

ISSN- 2321-6832

Review Article

FODDER PRODUCTION THROUGH AGROFORESTRY: A BOON FOR PROFITABLE DAIRY FARMING

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Received: 28 September 2015, Revised and Accepted: 23 Febuary 2016

ABSTRACT

In Indian agriculture, livestock plays a pivotal role in the development and progress of mankind with crop production program as a complementary enterprise. However, livestock productivity is constrained by an acute shortage of feed and fodder. A general agreement is that there is a shortage of 40.4% dry fodder and 24.7% green fodder against the requirement of 650.7 and 761.5 million tonnes (Mt) for dry and green fodder, respectively. In India, there is a deficit of green fodder, particularly during the summer season. In India, only 4.4% of the cultivated area is under fodder crops with annual total forage production of 846 Mt. In Gujarat, the total area under forage crops is about 7.96 thousand hectares and the production of green and dry fodder in Gujarat is 57.64 and 15.25 Mt. Besides having several benefits, agroforestry is an important source of fodder. Diversification of land use systems with agroforestry is a necessary strategy for providing a variety of products for meeting requirements of the people, insurance against risks caused by weather aberrations, controlling erosion hazards, and ensuring sustainable production on a long-term basis.

Keywords: Agroforestry, Fodder, Fuel.

AGROFORESTRY

Agroforestry is a collective name for land use systems and practices in which woody perennials are deliberately integrated with crops and/or animals on the same land management unit [1].

There are different types of agroforestry practices that can be used, these includes improved fallow, *Taungya*, home gardens, alley cropping, growing multipurpose trees and shrubs on farmland, boundary planting, farm woodlots, orchards or tree gardens, plantation/crop combinations, shelterbelts, windbreaks, conservation hedges, fodder banks, live fences, trees on pastures, and apiculture with trees [2,3]. The different types of agroforestry technologies have been found to address specific human and environmental needs. One of the important benefits is the production of fodder to feed livestock. Farmers have enjoyed increased incomes from livestock production, increased crop production, and reduced labor especially for herding cattle from adoption of agroforestry practices [1]. Improved soil fertility through the production of leguminous and other agroforestry trees is another benefit. Planting shrubs in fallow for 2 years and rotating with maize has improved maize yields compared with planting continuous unfertilized maize [4]. Timber and firewood as well as environmental services such as wind breaks, carbon sequestration and biodiversity among others are more benefits that can be obtained from agroforestry practices [1].

Global scenario

Agroforestry is practiced in all continents of the world. A high percentage of tree cover is found in nearly all continents of the world, the highest being in Central America and Southeast Asia. There is now general agreement about the magnitude and scale of the integration of trees into agricultural lands and their active management by farmers and pastoralists. Dixon [5] estimated a total 585-1215 million hectares (Mha) of land in Africa, Asia and the Americas under agroforestry, while Nair *et al.* [6] estimated a land area of 1023 Mha under agroforestry worldwide. Almost half of the world's agricultural lands have at least a 10% tree cover, suggesting that agroforestry, an integrated system of trees, crops and/or livestock within a managed farm or agricultural landscape, is widespread [7]. Agroforestry is contributing substantially in economic growth of various countries. The economic importance of agroforestry can be partly understood by examining data on the export value of major tree products. FAOSTAT [8] shows that conservative estimate of international trade of this list of tree products was valued at a whopping US$ 140 billion in 2009. The actual production levels are much higher, considering that the list includes only well-known and common tree products and that many tree products in developing countries are not marketed internationally (e.g. firewood, fodder, medicinal uses) and for products such as fruit, as much as 90% of production is consumed domestically. In addition, the positive externalities (or ecosystem services) represented by trees (e.g. carbon sequestration, nutrient cycling, provision of shade, etc.) are not counted.

Agroforestry research at the international level is conducted by the International Centre for Research in Agroforestry, now named as World Agroforestry Centre, which was started in 1978 at Nairobi in Kenya. Now it is a CGIAR Consortium Research Centre with five regional offices located in Cameroon, India, Indonesia, Kenya and Peru. The Center's aim is to increase use of trees in agricultural landscapes to improve their food security, nutrition, income, health, shelter, social cohesion, energy resources, and environmental sustainability of small holders.

Indian scenario

Indian agriculture is facing diverse challenges and constraints due to growing demographic pressure, increasing food, feed, pulp, fodder and timber needs, natural resource degradation, and climate change. Diversification of land use with agroforestry as a component can address some of these challenges. Agroforestry has traditionally been a way of life and livelihood in India for centuries. The country has also been in the forefront since organized agroforestry research started worldwide. It developed robust agroforestry science, innovations, and practices that are attracting global interest.

India faces a critical imbalance in its natural resource base with about 18% human and 15% livestock population of the world being supported only on 2.4% geographical area, 1.5% forest and pasture lands and 4.2% water resources. Agriculture sector contributes about 15% national gross domestic product, employs 56% of the total workforce and supports about 58% of the total population. Thus, this sector is very

vital not only to provide income support but also to ensure livelihood security for the majority of the people [9].

Presently, in India, about 60% the cropped area is rainfed, which contribute about 44% food-grain production. Its contribution in coarse cereals and pulses is about 90%, in oilseeds 60% and in the case of cotton it is about 80%. A significant proportion of livestock population (66%) is also in the rainfed areas. However, these areas are characterized by low input use and low yield levels. The yield levels are highly prone to variety of risks. For such areas, diversification of land use systems with agroforestry is a necessary strategy for providing variety of products for meeting requirements of the people, insurance against risks caused by weather aberrations, controlling erosion hazards and ensuring sustainable production on a long-term basis. Besides, 90% of the forests in the country are performing the critical functions of protecting fragile watersheds and are not fit for commercial exploitation [10].

Agroforestry is playing the greatest role in maintaining the resource base and increasing overall productivity in the rainfed areas in general and the arid and semi-arid regions in particular. Agroforestry land use increases livelihood security and reduces vulnerability to climate and environmental change. There are ample evidence to show that the overall (biomass) productivity, soil fertility improvement, soil conservation, nutrient cycling, micro-climate improvement, and carbon sequestration potential of an agroforestry system is generally greater than that of an annual system [11]. Agroforestry has an important role in reducing vulnerability, increasing resilience of farming systems and buffering households against climate-related risks. It also provides for ecosystem services - water, soil health, and biodiversity. Therefore, agroforestry will be required to contribute substantially to meet the demands of rising population for food, fruits, fuelwood, timber, fodder, biofuel, and bio-energy as well as for its perceived ecological services (Fig. 1).

To meet the requirement of the population in 2050 an increase by 1.5 times in fodder, two times in food grains and fuelwood, and three times in timber production will be required (Table 1). Furthermore, to meet the energy requirement from biodiesel and achieve 20% blending in diesel, a three-fold increase in production of biodiesel will be required [12].

Agroforestry has the potential to provide most or all the ecosystem services. The Millennium Ecosystem Assessment [13] has categorized the ecosystem services into provisioning service (e.g. fuelwood, fodder, timber, poles, etc.), regulating service (hydrological benefits, microclimatic modifications), supporting service (nutrient cycling, agro-biodiversity conservation), and cultural service (recreation, esthetics).

Agroforestry systems on arable lands envisage growing of trees and woody perennials on terrace risers, terrace edges, field bunds, as intercrops, and as alley cropping. Agroforestry practices for non-arable degraded lands such as bouldery riverbeds, torrents, landslide, shifting cultivation areas, waterlogged soils, control of desertification, mine spoil rehabilitation, and treatment of saline and alkaline lands have been developed and demonstrated. Agroforestry land use in conjunction with soil and water conservation and animal husbandry needs to be emphasized.

Organized agroforestry research in India began in the late eighties when the Indian Council of Agricultural Research launched the All India Coordinated Research Project (AICRP) on Agroforestry in 1983. Further, National Research Centre for Agroforestry was established in 1988 at Jhansi to accelerate basic, strategic and applied research in agroforestry, now named as Central Agroforestry Research Institute (CAFRI) in December 2014. At present, there are 37 Centers under AICRP on Agroforestry representing the major agro-ecologies of the country with the project coordinating unit at CAFRI, Jhansi.

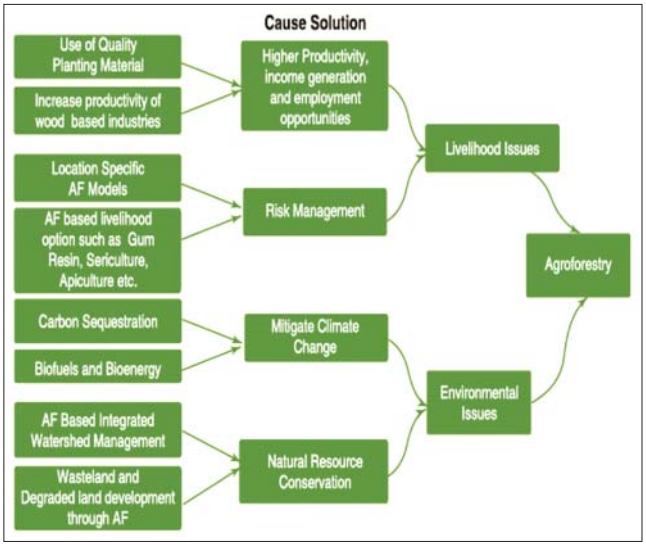

Fig. 1: Agroforestry as the solution to the challenges faced by agriculture

Table 1: Total domestic demand for various commodities [9]

Items	2010-11	Projected for 2025	Projected for 2050	Contribution from agroforestry in 2050
Food grains (Mt)	218.20	320.00	457.1	41.14*
Fruits (Mt)	71.20	106.00	305.3	47.74*
Fodder (Mt)	1061.00	1170.00	1545	154.50
Fuel wood (Mt)	308.00	479.00	629	308.00
Timber (Mt)	120.00	171.00	347	295.00
Biodiesel (Mt) required for 20% blending of diesel	12.94	22.21	37.92	30.34
Area (Mha) required for TBOS	12.32	15.86	21.67	17.34

*Food-grains/fruits production from systematic agroforestry systems *viz.* agri-silviculture/agri-horticulture only considered

In fact, agroforestry has proven as an important tool for crop diversification. National Agriculture Policy, 2000 recommends agroforestry for sustainable agriculture and advocates bringing up agroforestry in areas currently under shifting cultivation. National Forest Policy, 1988 sets a goal of increasing forest cover on one-third geographical area of the country. Major Policy initiatives including National Forest Policy 1952, 1988 and the National Agriculture Policy 2000, Task Force on Greening India 2001 and National Bamboo Mission 2002 emphasized the role of agroforestry for efficient nutrient cycling, organic matter addition for sustainable agriculture and for improving forest cover.

India launched the much-needed National Agroforestry Policy (NAFP) in 2014. The NAFP is a path-breaker in making agroforestry an instrument for transforming lives of rural farming population, protecting ecosystem and ensuring food security through sustainable means. The major highlights of the policy are: Establishment of institutional setup at national level to promote agroforestry under the mandate of Ministry of Agriculture; simplify regulations related to harvesting, felling and transportation of trees grown on farmlands; ensuring security of land tenure and creating a sound base of land records and data for developing an market information system for agroforestry; investing in research, extension and capacity building and related services; access to quality planting material; institutional credit and insurance cover to agroforestry practitioners; increased participation of industries dealing

with agroforestry produce; strengthening marketing information system for tree products.

The current area under agroforestry in India is estimated as 25.32 Mha or 8.2% of the total geographical area of the country. There is further scope of increasing the area under agroforestry in future by another 28.0 Mha. The major share of the land to be brought under agroforestry will come from fallows, cultivable fallows, pastures, groves, and rehabilitation of problem soils. Thus, a total of 53.32 Mha (Table 2), representing about 17.5% of the total reported geographical area (TRGA) of the country, could potentially be brought under agroforestry in the near future, which will make agroforestry a major land-use activity, after agriculture (140.86 Mha, 46.08% of the TRGA) and forestry (69.63 Mha, 22.78% of the TRGA) in India [12].

At present agroforestry meets almost half of the demand of fuelwood, 2/3 of the small timber, 70-80% wood for plywood, 60% raw material for paper pulp and 9-11% of the green fodder requirement of livestock, besides meeting the subsistence needs of households for food, fruit, fiber, medicine, timber, etc. However, current biomass productivity per unit area and time is less than 2 t/ha/y. Agroforestry practices have demonstrated that this could be safely enhanced to 10 t/ha/y by carefully selecting tree-crop combinations. Area under forest is degrading due to tremendous demographic pressure and infrastructure growth needs while the agricultural area is almost stable. In India, nearly 120.72 Mha land or 37% of the total geographical area is under one or the other forms of soil degradation (e.g. water erosion: 93 Mha, wind erosion: 11 Mha, salt affected soils: 6.74 Mha, and 16.53 Mha of open forest area [14]). About 56.54 Mha area has been treated under various watershed development programmes, however, a sizeable area is yet to be treated. Trees are known to grow even in areas polluted by heavy metals and other hazardous industrial chemicals. In fact, there are trees, which can absorb and tolerate such pollutants, which not only reduce crop yields but also impair quality of crop produce.

A number of agroforestry tree species, e.g. *Terminalia arjuna, Eucalyptus hybrid*, *Morus alba* and *Syzygium cumini, etc*. have been evaluated and identified for their potential for phytoremediation [15]. In India, 24.68 Mha area is affected by chemical pollution. These areas can be brought under cultivation through biological amelioration. Agroforestry can play a vital role in such endeavours. Meeting diverse needs of people and livestock from limited land resources is only possible, when agroforestry becomes common land use on the majority of arable and non-arable lands. This will not only avert degradation but also enhance total productivity and restore eco-balance simultaneously. Agroforestry answers many problems that are faced by today's agriculture in terms of stability in production, regular returns, restoration of fertility, indiscriminate deforestation, drought mitigation, and environmental pollution.

FEATURES OF AGROFORESTRY

Agroforestry practices are intentional systematic combinations of trees with crops and/or livestock that involve intensive management of the interactions between the components as an integrated agro-ecosystem. To be called agroforestry, a land-use practice must be intentional, intensive, interactive and integrated.

Table 2: Land use (Mha) scenario at present and projected for 2050

Classification	1970	2010	2050
Forest cover[#]	63.83	69.63	69.63
Net area sown	140.86	140.86	142.60
Other uncultivated land (Fallow, pastures, cultivable waste, misc. tree crops and groves)	54.46	55.18	53.44
Not available for cultivation	44.60	40.00	40.00
Reporting area	303.75	305.67	305.67
Agroforestry[$]	-	25.32	53.00

*Source: Agricultural Statistics at a Glance, 2010, Directorate of Economics and Statistics, Ministry of Agriculture, Govt. of India. [#]Forest Survey of India, State of Forest Report 2009. [$]Dhyani *et al*. (2013)

CLASSIFICATION OF AGROFORESTRY SYSTEMS

Nair *et al.* (1993) classified agroforestry on structural, functional, socioeconomic, and ecological basis.

Based on structure (composition and dimension of crop)

Agri-silviculture

In this system, tree species are grown and managed in the farmland along with agricultural crops. The aim is to increase overall yield of the land. Based on the nature of the components, this system can be grouped into various forms.

Improved fallow species in shifting cultivation

Fallows are croplands left without crops for a period ranging from one season to several years. The objective of improved fallow species in shifting cultivation is to recover depleted soil nutrients. In shifting cultivation, people cleared a forest, burnt the slash, raised a crop for few years and then shifted to clear another forest. As civilization progressed, people took to settle cultivation but many tribal communities still practice shifting cultivation. The practice is largely confined to the North-Eastern hill state and Orissa. It is called "*Jhum"* in the North-Eastern hill region and "*Podu"* in Andhra Pradesh and Orissa. The task force on shifting cultivation [16] estimated the forest area affected by shifting cultivation to be 4.35 Mha. The main function of the fallow is to maintain or restore soil fertility and reduce erosion. Some plants can be introduced primarily for their economic value.

The Taungya system

The *Taungya* (Taung=hill, Ya=cultivation) is a business word coined in Myanmar in 1850. The *Taungya* is one of the earliest forms of land use in which trees are regularly arranged and agricultural crops are harvested on a temporarily basis. In *Taungya* cultivation, the major objective is harvest of the tree. Annual crops are interplanted for 1-3 years, mainly to meet the household requirements. It has helped to settle shifting cultivators and the landless by providing employment and income in "forest villages." However, the system has important shortcomings such as insecure land tenure for the farmers. *Taungya* systems are of three types: Departmental, leased and village *Taungya*.

Multi-species tree garden

In this system of agroforestry, various kinds of tree species are grown mixed. The major function of this system is the production of food, fodder and wood products for home consumption and sale for cash.

Alley cropping

Alley cropping also known as hedgerow intercropping, in which food crops are grown in alleys formed by hedgerows of trees. The woody plants are cut regularly and leaves or twigs are used as fodder or mulch on the cropped alleys to reduce evaporation from the soil surface, suppress weeds and all nutrients and organic matter to the top soil. Trees or shrubs must be amenable to lopping management besides being multi-purpose (including nitrogen fixing) and fast growing (i) *Leucaena leucocephala,* (ii) *Sesbania sesban,* (iii) *Cassia siamea,* (iv) *Gliricidia maculata,* and (v) *Calliandra* spp.

Multipurpose trees and shrubs on farm lands

In this system, various multipurpose tree species (MPTs) are scattered haphazardly or according to some systematic pattern on bunds, terraces or plot/field boundaries. The major components of this system are multipurpose trees and common agricultural crops. The primary role of this system is the production of various tree products and the protective function is fencing, social values and plot demarcation, examples of multipurpose tees employed in agroforestry are *L. leucocephala, Acacia*

albida, C. siamea, Casuarina equisetifolia, Azadirachta indica, Acacia senegal, Cocos nucifera, etc.

Crop combination with plantation crops

Perennial trees and shrubs such as coffee, tea, coconut and coco are combined into intercropping system in numerous ways including (a) multi-storeyed agroforestry system - this system is managed by the combination between cultural practices and respects the natural processes of vegetation production and reproduction. It represents a profitable production system and constitutes an efficient buffer between villages and forests. This is common in coastal parts of Southern India, where coconut is grown with black pepper and tapioca, (b) mixture of plantation crops in alternate or other regular arrangement, (c) shade tree for plantation crops, and (d) intercropping with agricultural crops.

Agroforestry for fuelwood production

In this system, various multipurpose fuelwood/firewood species are intercropped on or around agriculture lands. The primary objective is to produce firewood. Tree species commonly used as fuelwood are *Acacia nilotica, Albizia lebbeck, C. siamea, C. equisetifolia, Dalbergia sissoo, Prosopis juliflora,* etc.

Shelter belts

In general, shelter belt is a wide belt of trees, shrubs and grasses, planted in rows at right angle to the direction of wind velocity and planted for wind protection. A shielding or screen structure especially against weather is called shelter and belt is a zone or band or broad strip of anything. Therefore, a shelter belt is a term which is broader than windbreak. A shelter belt is a broad strip of trees, shrubs, etc. to provide a screening structure for the protection of crops against any type of weather. Properly oriented and perforated shelterbelts are effective in giving protection against wind damage through reducing mechanical damage, reducing moisture stress, reducing soil erosion and altering temperature conditions.

Windbreaks

Any barrier erected to break or slow down the effect of wind is known as a windbreak. In North India, strong winds cause uprooting and lodging of crops. Windbreaks have been effective in increasing crop production in semi-arid region. A maximum protection is obtained when windbreaks are planted in the right angle to the direction of wind. In areas with 5% slope, windbreaks should be planted along the contours.

Soil conservation hedges

Trees can be planted on soil conservation works (grass strips, bunds, risers, and terraces), wherein they play two roles: To stabilise the structure and to make productive use of the land they occupy. In some of steep slopping landscape of the country, the risers or terraces are densely planted with trees. In this system, the major groups of components are: Multipurpose and/or fruit trees and common agricultural species. The tree species used for soil conservation are *Grevillea robusta, Acacia catechu, Pinus roxburghii, Acacia modesta, P. juliflora, L. leucocephala,* etc.

Silvi-pastoral system

In the silvi-pastoral system, improved pasture species are introduced with tree species. In this system, grass or grass-legume mixture is grown along with the woody perennials simultaneously on the same unit of land. This system provides fodder, fuelwood and small timber under arid conditions. *S. sesban* increases forage production of *Cenchrus ciliaris, Setaria anceps, Desmanthus, and Chrysopogon fulvus* gives higher yield when grown with *E. hybrid.* This system is again classified into three categories:

Protein bank

In this silvi-pastoral system of agroforestry, various multipurpose trees (protein rich trees) are planted on wasteland and rangelands for cut and carry fodder production to meet the feed requirements of livestock during the fodder deficit period in winter. About 25% of the total annual diet of livestock is composed of trees and shrubs. Tree species for dry areas are *A. modesta, A. nilotica, Ailanthus excelsa, A. lebbeck, L. leucocephala, Ziziphus mauritiana, Tecomella undulata,* etc*. A. nilotica* seeds contain crude protein (18.6%), whereas *L. leucocephala* seeds are the highest in protein (about 30%).

Living fence of fodder trees and hedges

Fodder trees and hedges are planted along the border as live fences. Trees like *Sesbania grandiflora, Gliricidia sepium, Erythrina abyssinica, Euphorbia* spp., *Acacia* spp., *Katkaranj,* etc. can be used.

Trees and shrubs on pasture

In this system, various trees and shrubs are scattered irregularly or arranged according to some systematic pattern, especially to supplement forage production. The trees and shrub species used for humid and sub humid region are *Derris indica, Emblica officinalis, Psidium guajava, Tamarindus indica* and for dry region: *Acacia* spp., *Prosopis* spp., and *T. indica.*

Agri-silvi-pastoral system

This system is the result of the union between silvi-pastoral and agri-silvicultural systems. Under this system, the same unit of land is managed to get agricultural and forest crops where farmers can also rear animals. This system holds promise especially in highland humid tropics. It may be tree, livestock-crop mix around homestead, wood hedgerow for browsing, green manure, soil conservation or for an integrated production of pasture, crops, animals and wood.

Homestead agroforestry

Farmers generally plant trees in and around their habitations, courtyard, threshing floor and in the field. These house gardens are aimed to satisfy the family needs of fruit, fuel, fodder and small timbers. The system of home garden is more prevalent in high rainfall areas of Kerala and Tamil Nadu. In India, every homestead has around 0.2-0.5 ha land for personal production, on which trees are grown for timber, fruit, vegetable, small plots of sugarcane in more open patches and a surrounding productive live fence of bamboo. Home gardens epitomise the qualities of agroforestry systems. They are highly productive, extremely sustainable and very practicable. Food production is the primary function of most home gardens.

Multipurpose forestry production system

Forest is managed to yield multiple products in addition to wood. They are grown to yield fruits, flower, leaves, honey, gum, lac, and medicine. This system is best suited for hill tribal.

Based on the dominance of components

Silvi-agriculture

The trees are the major component of land use and agriculture crops are integrated with them, e.g. shifting cultivation, *Taungya* cultivation.

Agri-silviculture

The agricultural component is the major one and trees are secondary, e.g. hedge cropping and alley cropping.

Silvi-pastoral system

Trees are the major component and pasture is secondary to allow the animals for grazing.

Pastoral-silviculture

Pasture is the major component and trees are secondary, sometimes allowing overgrazing of forest beyond its carrying capacity.

Agro-silvi-pastoral system

The combination of crops, trees, and pasture, e.g., home garden, wherein trees, herbs, shrubs, climbers, and grasses are grown on the same land.

Silvi-agri-pastoral

Silviculture is the dominant component, agriculture and pasture are secondary.

Based on arrangement of components

The arrangement of component gives first priority to the plants. Such plant arrangement in multispecies combinations involves the dimension of space and time.

Spatial arrangement

Spatial arrangements of plants in an agroforestry system mixture may result in dense mixed stands (as in home gardens) or in sparse mixed stands (as in most systems of trees in pasture). The species or species mixture may be laid out in zones or strips of varying width. There may be several forms of such zones, varying from micro zonal arrangements (such as alternate rows) to macro zonal ones. A common example of the zonal pattern is hedgerow intercropping (alley cropping). An extreme form of planting is the boundary planting of trees.

Temporal arrangement

Temporal arrangement of plants in agroforestry system may also take various forms.

Coincident

Different crops occupy the land together, e.g., coffee under shade trees, pasture under trees.

Concomitant

The components stay together, for some part of life, e.g. agricultural crops grown for only a few years.

Intermittent

The scope is dominated, the annual crops grown with perennial crops.

Interpolated

Space and time are dominated different components occupy the space during different times in home garden.

Based on allied components

Agroforestry-cum-sericulture

This is a very complex system of agroforestry. In this system, crops/ vegetables are grown along with tree species (silk host plants). The larval excreta are good manure for the crops/vegetables.

Agroforestry-cum-apiculture

The land is managed for concurrent production of flowers, crops, and honey. Flowering plants often favor increase of parasites and predators of crop pests and thus an anti-regulatory biocontrol system. The main purpose of this system is the production of honey.

Agroforestry-cum-pisciculture

It is a system under which silviculture of mangroves and fish is done simultaneously. In paddy field, fish can easily be reared by planting trees on field bunds or boundary. This system can be followed in high rainfall areas.

Agroforestry-cum-lac culture

In this system, crops are grown along with lac host plants. It is a very common in Chotta Nagpur plateau of Bihar.

Multipurpose wood lots

In this system, special location-specific MPTs are grown mixed or separately planted for various purposes such as wood, fodder, soil protection, soil reclamation, etc.

Functional classification of agroforestry system

Agroforestry system has two functions, i.e. production and protection.

Productive function (producing one or more products)

The various productive functions of agroforestry system are:

Food	Fodder	Fuelwood	Other wood	Other product

Protective function (protecting and maintaining production systems)

The protective functions of agroforestry are:

Windbreak	Shelterbelt	Moisture conservation
Soil conservation	Soil improvement	Shade (for crop/animal/man

Socioeconomic classification

Based on major socioeconomic criteria, agroforestry systems have been grouped into three categories:

- Commercial: For example, eommercial production of agricultural plantation crop such as rubber, oil palm, etc.
- Intermediate: Between commercial and subsistence scale of production.
- Subsistence: Satisfying basic needs and managed by owner and his family.

Ecological grouping of agroforestry systems

Based on major agro-ecological zone, agroforestry systems are grouped into the following categories:

Humid/sub humid lowlands	Semiarid/ arid lands	Highlands

Thus, it can be seen that there may be many approaches to agroforestry classification. However, a system based on the nature of the components and their major functional characteristics for specific purpose appears more logical, simple and pragmatic purpose oriented approach. Again the choice of system may depend on many factors such as social, ecological, and economical. However, selection of right agroforestry system for the right situation is necessary.

OBJECTIVES OF AGROFORESTRY

Biomass production

The maximum production of biomass per unit area in time is the primary objective of agroforestry systems.

Soil management

To manage land efficiently so that its productivity is increased and restored. Agroforestry practices enrich soil by nitrogen fixation and addition of organic matter. Agroforestry helps in meeting nutrient requirement of plants growing in association with trees and at the same time, the soil structure and infiltration rates are also improved.

Soil conservation

Compared to the permissible limit of soil loss 4.5 t/ha/y, the average soil displaced is around 16 t/ha/y. Wastelands should be treated through agroforestry.

Agro-based village industries

To provide raw materials for developing small cottage industries in rural areas (raw materials namely, wood, pulp, fiber, medicinal material

ingredients and oils, gum, wax, resin, lac, tannins, dye, green manure, soap substitutes, etc.).

Moderation of micro-climate
The micro-environment in the neighbourhood of trees is moderated by adopting an agroforestry programme. The field crops in vicinity of trees receive multidirectional effects and benefits. The impact is more prominent in arid and semi-arid zones.

Basic rural needs
To provide basic needs of small and marginal farmers for food, feed, fodder, fruit, firewood, small timber, etc.

Employment
To generate employment opportunities to rural poor.

Land improvement
Improvement of degraded lands and wastelands is done.

Increased productivity
To increase production of fruits, fodder, fuelwood, and forest products.

ADVANTAGES OF AGROFORESTRY

The following are main benefits of agroforestry:
- Agroforestry improves environment
- Agroforestry is a good source of fuelwood and energy to rural poor
- Agroforestry provides fodder and feed to animals
- Agroforestry enriches soil with organic matter and nutrients
- Agroforestry prevents soil erosion
- Agroforestry provides windbreaks and shelter belts
- Agroforestry provides raw materials to small cottage industries
- Agroforestry maximises production and higher income
- Agroforestry provides employment opportunities
- Agroforestry is a paying occupation
- Agroforestry helps in biodrainage improvement
- Agroforestry creates esthetic value
- Agroforestry system offers opportunities to augment soil water availability to crops
- Efficient use of degraded lands through agroforestry system is possible
- Salinization and waterlogging is controlled.

DISADVANTAGES OF AGROFORESTRY

Although there are several advantages of agroforestry system, there are few disadvantages which include as follows:
- Prolific seeding habit of *L. leucocephala* resulting in weedy growth depresses the yield of arable crops
- Root and shade effect of trees on cultivated crops even 20 m in the case of babul (*A. nilotica*)
- Long gestation period-trees take several years to mature
- Harbour birds, pests and diseases that are harmful to food crops
- Agroforestry system requires more labor, which may cause scarcity at times in other farm activities
- Allelopathic effect of trees on crops, e.g. *Eucalyptus* species
- The fact that agroforestry system is more complex, less well understood and more difficult to apply, compared to single crop farms.

FODDER TREES

Fodder trees are playing an important role in reducing the fodder shortage problem in India. In most parts of our country after the end of rainy season, animals suffer badly due to lack of protein rich diet since availability of fodder become scarce. The situation becomes serious during the dry season under rainfed conditions, when generally no crop can be grown and natural pasture, grasses, and weeds become unproductive. Farmers either feed their animals with the low-quality hay of the stored crop residues or they travel long distances to gather green grasses or fodders. In such circumstance, shrubs and fodder trees are able to withstand the drought, stay green, and provide a nutritious fodder for livestock [17]. Alarming shortages of forage in our country can be solved partially by planting fodder trees capable of sustained production of palatable forage high in protein and total digestible nutrients. Through the plantation of these species on degraded lands under silvi-pastoral systems and in farmer's fields under various agroforestry systems, fodder availability can be enhanced. Oaks, *Grewia optiva, Celtis australis* in Western Himalaya, and *Ficus* spp., *Alnus nepalensis* and *Bauhinia* spp., in Eastern Himalayas have been used as important fodder trees. Lopping of *Prosopis cineraria* (Khejri) in western Rajasthan, *A. lebbeck*, *Albizia procera*, *A. indica* in northern and central India for leaf fodder, use of pods of *A. nilotica* and *P. juliflora* for fodder are common practices since old days. Most of these species are important source of fodder during lean period as well. Advantages of tree fodder are that trees can be grown on steep, rocky mountain slopes, in arid, saline, or water-logged soils, and in areas with severe climatic conditions. Furthermore, trees do not need heavy inputs of fertilizer, irrigation, labor, pesticides, etc., as are generally needed to grow conventional fodder crops. Trees use and recycle nutrients that are beyond the reach of grasses and other herbaceous plants. Trees that accumulate nitrogen enhance forage quality. Their relative deep root system can exploit deep moisture resources and, using this and other strategies, trees are more tolerant to dry periods than pastures.

COMMON AGROFORESTRY-FODDER PRODUCTION MODELS

A number of fodder production systems have been designed to produce sufficient foliage for livestock feeding particularly during the dry season. These production systems include various types of agroforestry-silvi-pastoral systems, where trees, animals and pastures are deliberately combined to obtain benefits and services.

Fodder bank systems
Trees are planted as close as 1 m × 1 m and are cut regularly to induce maximum herbage production. The cut herbage is usually carried to animal feeding stalls; sometimes sheep or goats are brought to the plots and allowed to forage on the cut branches of naturally-growing fodder. The system is called fodder bank, which provides reserve fodder when it is in short supply, usually in the dry season.

Protein bank
This is a type of fodder bank which intentionally chooses trees, shrubs legumes with high protein-containing leaf biomass. Commonly used species include *L. leucocephala and G. sepium*.

Three-strata forage system
This is another type of fodder bank; it involves the planting of forages, shrubs and trees to form three canopy layers or strata in a unit of land. Pasture grasses, vines and herbs occupy the lower strata; shrubs occupy the middle strata and trees occupy the upper strata. The combination of grasses and trees can ensure year-round supply of fodder.

Live fence or boundary systems
Single or double rows of fodder trees are planted along farm boundaries. The trees have the dual purpose of providing fodder and serving as live fence posts. If intended to enclose animals, the trees are usually planted densely, as in hedges, to prevent animals from getting out. In some cases, thorny species are planted as thick hedges to prevent livestock from straying into crop plots and also to fence them off from wild animals.

Hedgerow intercropping systems
Fodder trees, mostly leguminous are planted as hedges in single, double or triple rows. The spaces in between hedgerows are planted with pasture grasses. As in fodder banks, herbage may be cut and carried to animal feeding stalls. The more common practice is to let the animals forage on the cut tree branches and pasture grasses.

Tree plantation+animal grazing systems

The understory of tree plantations is utilized as grazing area for cattle, sheep, and goats. The plantation may be of forest trees, fruit trees, coconuts, oil palms, or rubber. The livestock is allowed to graze freely on improved pasture grasses planted under trees.

Indigenous cut-and-carry systems

As the name implies, the fodder is cut and carried to animal stalls. Farmers have a long been practicing this system. Indigenous legumes such as *Ficus*, *Acacia*, *Leucaena*, *Gliricidia,* and *Albizia* are the most preferred fodder tree species.

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