GENERAL INTRODUCTION AND LITERATURE REVIEW
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The present scenario of ever increasing population and decreasing land to man ratio renewed the awareness of productive and protective value of trees and rejuvenated concept of agroforestry (Huxley, 1983). The term agroforestry is new but, the technology is old evolved over a long time scale, right from the day of human nomadic civilization.

An optimal relationship between forest and agriculture is an age old concept in the traditional societies for securing subsistence livelihood. Shifting agriculture is the first to evolve among the traditional agroforestry systems (Podoch and Jong, 1987). Increase in population and industrialization added to it in the eighteenth century resulted in decline of available forest land, reducing the shifting agricultural cycle to 2-3 years, making it no more a sustainable life support system (Ramakrishnan and Toky, 1981; Aweto, 1981; Trenbath, 1982). Taungya system in south-east Asia introduced by British Colonial government evolved as a landuse to mitigate the problems due to shifting cultivation (Gajaseni, 1992). This system was introduced to India by Brandis in 1956, (Seth, 1981). It is practiced widely in the states of Kerala, West Bengal, Uttar Pradesh and to a little extent in Tamil Nadu, Andra Pradesh, Orissa, Karnataka and North Eastern Hill (Tejwani, 1987). Along with the temporal pattern agroforestry systems simultaneously spatial pattern evolved in the traditional societies.

The spatial pattern agroforestry systems are wide spread in all ecological and geographical regions in India. Primarily the shade trees were grown together with tea and coffee, and inter cropping under coconut etc., and other tree crops since late 19th century
There has been also extensive research on inter-cropping with coconut and rubber (Tejwani, 1987). Variety of horticultural trees were also inter-cropped (mango, guava, pine apple, banana, apple, citrus, apricot, peach, plum, etc.). However Tejwani, (1987) depicts apple is not amendable to inter cropping as they can grow in high densities with high productivity. Some experiments on pastoral silviculture systems were started in 1950’s (MOA, 1982) at a time when high energy input agriculture started appearing on an experimental basis.

A large number of institutes and research foundations like International Center for Research in Agroforestry (ICRAF), 1978; have been conducting research on agroforestry systems. National Research Council (NRC) USA, (1982) called for increased research into traditional agroforestry systems as a possible model. Indian Council for Agricultural Research (ICAR) initiated All India coordinated research projects on agroforestry in 1983 at eight research institutes of Indian Council of Agricultural Research (ICAR) and twelve Agricultural Universities in different geographical locations. This project was expanded in 7th and 8th five-year plan.

The Indian Council for Agricultural Research (ICAR) for the North Eastern Hill has suggested an alternative model, for shifting cultivation. Forest land to be on top, followed by horticulture in the middle and bench terrace in the lower slopes (Singh, 1981), but this model could not get wider acceptability due to various cultural reasons and also due to high capital cost (Ramakrishnan, 1992).
Though wide variety of practices are available, only some of the systems are well described (Ramakrishnan, 1992). There are many systems and practices that are yet to be adequately described. The researches so far, apart from indicating possibilities for increased production in fodder-fuel plantations, have not really improved the components of agroforestry systems and their management (Tejwani, 1987).

In the Nineteenth century, the agroforestry system turned out to be a site specific, problem solving natural resource management practice. This recognition led to extensive research on multipurpose trees for agroforestry systems (Tejwani et al., 1960; Tejwani, 1994; Ahuja et al., 1978; Huxley, 1983; Fonzen, 1984; Simons, 1993). Among the MPT’s maximum research had been done on N-fixing trees (NAS, 1979; Brewbaker, 1985). The success of agroforestry systems will depend upon the extent to which the productive, protective and service potential of MPT’s are understood and exploited through research and realized through development and extension efforts (Nair, 1991). In the central Himalaya MPT’s have been in use among the local communities selected through their empirical knowledge.

*Acacia albida* and *Prosopis cineraria* tree species had been identified as potential agroforestry in the arid parts of the country (Puri and Monga, 1990; Mann and Saxena, 1980). *Leucaena leucocephala* was identified for the both inter crop and contour growth (Gupta et al., 1988; Kang and Fayemilihin, 1995). In the Kumaon Himalaya *Babulhinia variegata* and *Grewia optiva* are rated high for their fodder. *Ficus palmata, Prunus cerasoides* and *Pyrus pashia* are rated low for fodder and fuel but at the same time these
species are extensively found on the terrace bunds (margins of the terraced slopes). They are also attached with religious importance. It is reported that these species with their sparse crown structure benefit the crop growth (Negi, 1995). *Pyrus pashia* has a wide ecological amplitude and was observed as an element of co-occurring most forest systems of the region too (Rana *et al*., 1999). Even though scientific explorations have come out with variety of useful plants, it is very often felt that social acceptability of a species is a key to success of an agroforestry practice (Macdicken *et al*., 1991; Nautiyal and Purohit, 1988). *Sapium sabiferum* is an introduced species to this region as a plantation crop in eighteenth century (Atkinsson, 1878). The species had economically viable quantity of wax and edible oil (Seril, 1997) apart from fodder and fuel wood option. But, the species potential has not been exploited due to non availability of feasible technology (Sharma *et al*., 1996).

The productive, protective and service potential of MPT’s not only depends upon their individual level characteristics, but also on their linkages in the system (Tejwani, 1987). Linkages and productive, protective and service potential of the trees are well established and understood in the traditional agroforestry systems by the farmers through their trial and error experiences.

Many studies focus on possible combinations of perennials and annuals, for increasing productivity and profitability (Nair, 1979; Nelliat and Bhat, 1979; Bavappa, 1980; Buckingham, 1885). In the recent past the service potential of agroforestry systems has been explored in relation to the productive aspects (Nelliat and Bhat, 1979; Verghese,
et al., 1978 a & b). The complimentary and competitive attributes of agroforestry systems are not only limited to their potential yield but also to their protective aspects, which are rarely touched upon as in (Ramakrishnan, 1992).

Research activities in Himalaya were initiated much earlier than 1815 (Pokaryal, 1993). The literature of earlier period is very descriptive (Pant, 1935). Later researchers focused attention on economic benefits and its viability (Swarup, 1964; Ashis, 1979). Then arose the question of sustainability of these agroforestry systems in Kumaon on long term basis, (Shah, 1982). Sustainability questions could be answered only through integrated approach. Such integrated studies are very few for example, Ramakrishnan, 1991 in the north eastern region and Rahlan, (1991) in central Himalayan villages.

In the recent past, attempts were made to classify empirically rich agroforestry systems from the point of developing rural development programs (Come, 1982; Nair, 1985; Gholz, 1987; Atul et al., 1990; 1990; Tejwani, 1994). Come, (1983) suggested twenty four types of agroforestry systems based on the associated agricultural products, major functions of the tree component, and spatial arrangement of trees. Tejwani, (1987) building on Comes approach, distinguished forty-eight classes of agroforestry systems in India. Nair, (1985;1991) suggested eighteen types of system with three classes considering agro-ecological zones together with socio-economic aspects. Zou and Sanford, (1990), classified agroforestry systems of China by system type and system unit. Nair’s (1985;1991) Classification system has gained wider acceptability as it reveals the biological, environmental, social and economic relationships among and within the
components of agroforestry systems. Recently Qiu Fugeng; Fang Jia Xing, (1996), classified agroforestry systems into six types. They are farm-forestry, forestry-farm, forestry-animal husbandry, farm-forestry-fishery, forestry-cash crop, and regional farm forestry based on ecological and economic principles, related to optimal use of space and time by agroforestry species to maintain a dynamic balance of diverse benefits.

In an agroforestry system tree leaf litter contributes the maximum, apart from residue of crop left back (Bhardwaj and Gupta, 1983). Apart from fodder and fuel wood obtained from the tree component, mulch derived from tree litter can provide a low input alternative to fertilizer (Montagnini et al., 1993). Mulch can have several effects on soil properties, both physical and chemical (Stigter, 1984; Vander Werf, 1985). Soil temperature, soil moisture, and soil erosion can also be mediated by mulch.

Research on crop residue has been an important thematic area of research in studies on agroforestry. Crop residues constitute an essential component of livestock diet in most part of Africa (Sanford, 1989), Asia (Thole et al., 1988), Latin America (MacDowell and Hildebrand, 1980) and Caribbean (Parra and Escobar, 1985). The same is also used as fuel and construction material (Sanford, 1989; McIntire et al., 1992). McIntire et al., (1992) discusses on variety of ways of removal and feeding of crop residue to the animals, from high to low energy consumption pattern depending upon the circumstantial needs. Powell and Unger, (1988) concludes that crop residue’s utility and economic and ecological values may drastically vary. Allowing animals to graze in between the cropping activities has been
recognized as the best option by some researchers (Powell and Ikpe, 1992; ILCA, 1993; Wiliams et al., 1995). Residues left in the field play important role in nutrient cycling, erosion control, water conservation and maintenance of favorable soil physico-chemical properties. Stangle (1995) found residues more effective when recycled as livestock excreta.

Many studies are available on the impact of quality of litter on soil fertility (Gilbert and Bocock, 1960; Lousier, 1978; Staaf, 1982). Chemical quality of the resources is important for the decomposition process through which the nutrients are released into the soil (Swift et al., 1979; Haynes, 1986). Traditionally C:N ratio was used to asses the quality of organic resources and explain their decomposition potential (Pastor et al., 1987; Berendse et al., 1989; Potter et al., 1997). The role of N:total polyphenolic compound and N:lignin ratio are used (Post et al., 1992; Schimel et al., 1994; Rutibiliano et al., 1996) on soil fertility are much recent concerns. Mixture of litter of different species may have synergistic or non-synergistic effect depending upon the chemical properties of the constituent species. Even though the pine needles decompose very slowly (Upadhyay, 1988), some studies report that mixture of broad leaves with the pine needless accelerate the decomposition (Gustafson, 1943; Thomas, 1968; Staaf, 1980). Klemmedson, (1992), reports higher rate of decomposition of Oak when mixed with pine.

Higher concentration of organic nitrogen enhances the decomposition of crop residue (Recous, et al., 1995) but at the same time the incorporation of crop residue reduces the nitrogen leeching by inducing the N immobilization. There are also many
negative correlation. Apart from the natural functions of the biological components the weeds may also act as good mulch and nutrient sources if managed properly as shown by Swamy and Ramakrishnan, (1987) and Toky and Ramakrishnan, (1982).

In an agroforestry system tree and crop components share the nutrients from a common pool. The time of demand and supply of the nutrients between these two components need to properly adjusted to obtain high output from the system (Mann and Shankarnarayan, 1980, Gupta, et al., 1988, Singh et al., 1993). This synchronization has been one of the philosophy on which the research activities of Tropical Soil Biology and Fertility (TSBF, Head Quarters Nairobi) program. Synchrony reduces competition between the microbes and plants and between different components of production system for limiting nutrients and maintains tight nutrient cycle (Lodge et al., 1994). Nutrient cycling can be enhanced by synchronizing the application of organic soil amendments, such as crop residues and manures to soils so they decompose and release nutrients in a pattern that coincides with crop nutrient demands (Swift et al., 1989: Ingrim and Swift, 1989). Organic materials such as cereals, which have C:N ratios greater than 20 to 30 (Alexander, 1977) and N concentrations below 15 g per kilogram (Bartholomew, 1972) temporarily immobilize soil N and release nutrients more slowly than manures that have lower C:N ratios and higher N content (Somda et al., 1995).

In most traditional systems farmers rely principally on organic matter recycling to sustain their agricultural productivity and maintain fairly constant levels of soil organic matter (SOM). The left back biomass maintains equilibrium between soil nutrient
immobilization and mineralization processes (Barber, 1979; Larson et al., 1972; Powell and Hons, 1991).

Nutrient dynamics in managed systems is complex. Soil nutrients are considered among the least resilient components of the sustainability (Fresco and Kroonenberg, 1992). Many studies are available on output-input budgets (Spedding, 1975; Frissel et al., 1978; Stinner et al., 1984; Rosswall and paustin, 1984; Sharma, 1989). However most of them are at field scale. Budgeting the nutrients at field scale are useful but at the same it is felt that whole-farm nutrient budgets provide a better management perspective (Sanchez, 1995). Nutrient removed though grain is the major cropland deficit (Powell and Caulibaly, 1995). Loss through run off and leaching may be substantial on poorly managed slopes (Mishra and Ramakrishnan, 1983). Maximum amount of nutrients are removed through crop production but at the same time considerable quantity of nutrients are recycled back into the system through weeds and crop residue in the Himalayan region (Swamy and Ramakrishnan, 1988). Substantial quantities of nutrients are returned to the system as manure and through precipitation (Saxena and Ramakrishnan, 1986; Powell and Unger, 1988). Nutrient from the parental material are available to the crops only through deep rooted perennials (Gholz, 1987). Input-output balances are negative for many farming systems in the distorted agroecosystems in the tropics (Ramakrishnan 1991; Stoorvogel and Smaling, 1990), while in intensively fertilized cropping systems of the temperate region a large, positive balance leads to nitrate and phosphorous pollution. Agroforestry interventions may overcome the problems of nitrogen and phosphorous in
balances (Shanchez, 1995).

Economic and ecological efficiency of agroforestry systems have been worked out by many authors (Maikhuri and Ramakrishnan, 1990; Wannawong et al., 1991; Ramize et al., 1992; Willis et al., 1993). In biological relationships, the components may be competitive as well as complementary and supplementary (Filius, 1982; Hoskstra, 1985; 1987; Raintree, 1983). In shifting cultivation, tree components act complementary and supplementary to the crop sub-system. Through ecological succession, the nutrients accumulate in the plant biomass and soil and are subsequently used for crop growth (Ramakrishnan, 1993). In central and North Western Himalaya settled farming on terraced slopes is the dominant landuse (Rao and Saxena, 1994). The trees and crops coexist and the tree component is usually competitive. The degree of competition depends on the combination of crops and trees. The positive aspect of the tree component is related to its contribution in enriching the soil with organic input through litter fall into the system (Toky et al., 1989). In tree-crop coexisting system the production of crops may be lower. However by selecting or allowing socio-economically and ecologically sound tree species, the agroforestry system may bring several advantages, such as reduced pressure on surrounding forests, recycling nutrients from deeper soil horizon, permanent ground cover, soil protection (Bremer et al., 1984), and also economic benefits (Singh et al., 1997). Multi-storeyed canopies can also produce large amounts of biomass (Conway, 1985). Likewise, increased diversity in the agroecosystem spreads producer risk, provides a wide array of income and food sources and distributes labour evenly.
Incorporation of mixed cropping and selective weeding (Saxena and Ramakrishnan, 1983) with harvest throughout the year could make the system ecologically and economically more efficient (Ramakrishnan, 1993; Willis et al., 1993).

The efficiency of agroecosystems both in terms of energy and economic currencies increases with increase in diversity of crops in time and space (Ramakrishnan, 1992). Traditional, agroecosystems with high level of biodiversity were yield more than two units of food energy for each unit of energy input (Leach, 1976; Spedding and Walsingham, 1976; Pimental and Pimental, 1979). Mitchell, (1979) worked out the average energy efficiencies of different systems in the Indian plains. However studies Toky and Ramakrishnan, (1982) reported energy efficiency much higher than that in plains Mitchells, (1979). In the high altitude villages of Western Himalaya complex interaction between crops and trees affecting energy and economic efficiency during a change from traditional agriculture to horti-culture are discussed by Singh et al., (1997).

Variety of comparisons made at system level, on yield performances (Sundryal et al., 1994) energy performance (Mishra and Ramakrishnan, 1981). Toky and Ramakrishnan, (1982), found energy efficiency of monoculture to be much lower than that of mixed cropping. Studies on comparative account of energy efficiency of improved and traditional variety (Singh, 1995), different agroforestry systems at different altitudes (Semwal and Maikhuri, 1996) and different communities (Maikhuri et al., 1997) are available for some locations.

The traditional agroforestry systems in the central Himalaya has evolved through
constant interaction between cropland, forest type, private support system, animal husbandry and domestic system. Increase in the human and livestock population resulted in decrease in natural resource base. This led to a change in social values and resource use pattern (Singh and Singh, 1991). The area under agriculture is increasing (Sharma and Chaudhry, 1997). Coniferous and broad leafed forest are the two major category of forests present in this region. Coniferous forests are dominated by Pinus roxburghii and broad-leaved forests are dominated by Oaks (Quercus spp.) While Oaks are used minor for timber, fuel wood and fodder Pine is used only for minor timber and fuelwood by the local people. However the Pinus sps. are rated low in fuel wood quality by the local people (Upadhyay, 1988). It has been also reported that Pinus is gradually encroaching in natural climax zone of Quercus in this region (Singh et al., 1984).

In many developing countries realization has been made that of fuel wood extraction, if practiced beyond a limit, leads to deforestation and desertification (Mishra and Ramakrishnan, 1982; FAO, 1982; Fox, 1984;). In the Himalayan villages it has been estimated that more than 60 % of fodder energy and 70 % of fuel wood energy are extracted from the village forest and common land (Atul et al., 1994; Singh et al., 1984). The estimated fuel wood consumption in the central Himalaya (about 1.2 to 3.6 Kg per head per day) (Pandey and Singh, 1984) was much lower than the other part of the Himalaya (Gangwar and Maikhuri, 1989). However it has been seen that considerable quantity of biomass is met from agroforestry systems (Dick, 1980; Negi and Singh, 1990). Some experiments show that a well vertically stratified agroforestry system could
supply 64 % of the farmers fuelwood need from an average land holding size of one hectare (Nitis et al., 1994). Studies by Atul et al., (1994) in Himachal Himalaya show that the agroforestry systems were able to meet 2.3 million tones of fuel wood requirement of the state. Ralhan et al., (1991) found that the labour energy devoted to collect fodder, bedding material and fuel wood from the forests is greater than that of devoted to agronomic activities. These authors report that one unit of energy production through agronomic yield requires two to nine units of energy from the forest/support area. Similar conclusions are drawn in, Singh, et al., (1994) reports and Sharma, and Singh, (1994). Pandey and Singh, (1984) report the current rate of exploitation of forests for agriculture and commercial purposes cannot sustain the forests in the Central Himalaya. This increase in demand would result in further decrease in primary production Odum, (1983) suggests that when exploitation exceeds more than one third of the net primary productivity of forest over a long period, nutrient supply would soon become inadequate to support the primary productivity.

The animal husbandry provides a link between the cultivated land and the forest in respect of biomass and nutrient flows. Animal husbandry in the Himalaya enables conversion of plant biomass into high energy material like milk and meat, and farm yard manure (FYM). The FYM addition to the crop fields varies between 35-80 t/ha/yr depending on the crop grown, type of forest vegetation available around the villages and quality of the resources (Sen et al., 1997). Animal husbandry contribute about 12% of the total agricultural economy (Negi, 1990) yet, the traditional societies of central Himalaya
are stocked with poor quality animal (Singh et al., 1992). There are many studies made on the animal husbandry (Maikhuri, 1991; 1992; Farooque et al., 1994). At higher altitudes (Farooque and Saxena, 1996), animal husbandry can contribute 46-62% of the total rural economy. Ralhan et al., (1991) and Pandey and Singh, (1984) suggest efficiency in resource flow and sharing between the landscape/farming system components (Forest and support area, animal husbandry, cropland and domestic system) to be the key factors for agroforestry systems sustainability in Central Himalaya.

Inspece of more than 80% of the population of Himalaya involved in the agriculture is able to produce only 25% of the food requirement, the rest 75 % of the food energy demand is met from the market (Sharma and Singh, 1994). The traditional farming in this region is also reported to be destabilized (Sharma, 1989; Rao et al., 1999). Singh and Singh, (1991) suggests that forestry may be a solution. Sharma and Chaudhry, (1997) stresses on an integrated approach ranging from pure forestry at one extreme to the integration of tree crops, annual food crops and livestock at the other end. Singh et al., (1997) suggest that expansion of agro-horticulture with improved marketing, could reduce the degradation of forest resources in the region. The forest policy in the region provides for unlimited use, free of any cost, of the forest based resources by the local communities. Such policies may contribute towards unjudicious use of forest resources.