CHAPTER -2

REVIEW

OF

LITERATURE
2.1 General

Several research works have been carried out on the suitability of intercropping of leguminous trees and agriculture crops, use of woody legumes in agroforestry system in general, hedgerow or alley cropping, and shifting cultivation and its associated problems. In this chapter, an attempt has been made to review relevant literatures available in India and abroad.

2.1.1 Shifting cultivation and land degradation

Shifting cultivation had been a livelihood activity of different communities once in a while or sometime in the past, and is still in practice in tropical hilly areas of Southeast Asia, the Pacific, Latin America, the Caribbean, and Africa (Cairns and Garrity, 1999; Craswell et al., 1997; Eastmond and Faust, 2006; Kato et al., 1999; Lawrence and Schlesinger, 2001; Ramakrishnan, 1992a; Stromgaard, 1992; Thomaz, 2009). In India, it is essentially prevalent in north eastern states and to some extent, in hills of Andhra Pradesh, Bihar, Madhya Pradesh, Orissa and Karnataka (Tejwani, 1994). Agriculture in these areas mostly consists of small farms with intensive production, where varieties of crops are grown in mixtures. The average size of
jhum plot varies from 1.0 to 2.0 ha and the average family consists of two adults and three to four children (Borthakur, 1992).

In India, slash and burn agriculture is regarded as one of the major factors contributing to deforestation, especially in the hilly north-eastern region and eastern ghats. Studies on vegetation dynamics associated with slash and burn agricultural practices have been intensively carried out in the north-eastern part of India (Prasad et al., 2001). Due to increasing human population, the biotic pressure on the native forest is inevitable. The uncontrolled lopping and felling of trees for fuel wood, leaf fodder, burning of ground vegetation for forage are some of the factors responsible for exploitation of forests (Bargali et al., 1998). Rajora (1998) suggested that the indiscriminate cleaning of slopes should be prohibited and no land with more than 20 percent slope should be cleared for the cultivation.

Due to shifting cultivation and large scale deforestation, there had been a continuous degradation of the land leading to ecological imbalance including soil and water loss, which leads to problems in agricultural production (Ramakrishnan, 1992b). The annual loss of soil and crop yield due to the shifting cultivation in north eastern region of India was estimated to be 15.5 million tonnes and 52.23 thousand tonnes respectively (Chauhan, 1990). Singh and Singh (1980) also observed soil erosion at 147 tonnes/ha in the second year jhum and only 30 tonnes/ha in abandoned jhum with 50-60 percent slopes. This
shows that soil losses are much higher under the shallow-rooted vegetable cultivation than in deep rooted forest cover. The studies in ICAR on shifting cultivation on steep slopes (44-53 %) have indicated the soil loss to the tune of 40.9 tonnes per ha and the corresponding nutrient losses per ha area are: 702.9 kg of organic carbon, 145.5 kg of P$_2$O$_5$, and 7.1 kg K$_2$O (Munna Ram and Singh, 1993). The continuous short cycle of shifting cultivation in some areas left the hill barren without soil and badly degraded field are often abandoned to infestation of grass invasion.

2.1.2 Alternative farming systems

Since the early 1970s’ research have been forced to develop low input alternatives often referred to as agroforestry, to address the problem (Sanchez, 1976; Kang and Spain, 1986) associated with shifting cultivation. It is often envisaged that these alternative systems will include selected woody perennials which could diversify the production base, enhance productivity and allow a sustainable cropping systems, thereby minimizing the over exploitation of land, water and forest resources (Chauhan et al., 1993).

However agroforestry as a new applied science is of recent origin as stated by Jha (1995). The principle underlying the aim of the present investigation therefore is reclamation of degraded land due to shifting cultivation and natural causes through agroforestry system involving systematic
management of leguminous tree species or shrubs in the sloppy land in Mizoram.

Lundgrean and Raintree (1983) stated that agroforestry is a collective name of land-use systems and technologies where woody perennials (trees, shrubs, palms, bamboo etc) are deliberately used on the same land management unit as agriculture crops and/or animals, either on the same form of spatial arrangement or temporal sequence. Torres (1983) also defined agroforestry as the deliberate combination of trees with crop plantation or pastures, or both, in an effort to optimize the use of accessible resources to satisfy the objectives of the producer in a sustainable way.

According to Nair (1989) agroforestry refers to practices, which deliberately or intentionally mix or retain trees on the crop/animal production fields. It combines elements of agriculture, whether crops or animals with elements of forestry in production system in its land piece, either simultaneously or sequentially. Rao (1989) mentioned that the term agroforestry encompasses any and all techniques that attempt to establish or maintain both forest/tree and agricultural production on the same piece of land.

Patel and Singh (2000) reported that tree planting improve the physical, chemical and biological characteristics of the soil by several mechanisms such as an increase in organic matter of the soil through addition of leaf litter and
other parts, more efficient nutrient cycling within the system, biological nitrogen fixation or solubilization of relatively unavailable nutrients.

Advantages of agroforestry system in rain-fed agriculture are numerous (Singh and Korwar, 1986). Surface run-off in shifting cultivation areas is quite significant and introduction of the tree component in agriculture have numerous service functions, which make agroforestry a profitable enterprise (Gill, 2008). A strip of trees planted along contours serves the same purposes as terraces. In most tribal area in India, soil losses and surface run-off are now much higher on account of loss of forest cover. Thus, a strip of trees along contours and agroforestry practices would reduce both surface run-off and soil erosion. Growing of trees on degraded/wasteland, which is unproductive, is the prime step towards obtaining required biomass, which can meet the demands of both industry and individuals (Rao et al., 2000).

Different kinds of agroforestry systems were reported for Sikkim by Singh (1998) and Balaraman (1998). The productivity of the different agroforestry systems and their components in terms of yield and profitability especially that of agri-horticulture was low compared to the national averages. Observation on the agroforestry systems in Sikkim with special reference to large cardamom revealed that nine major agroforestry systems are in practice in the sub-tropical and mid-hill temperate zones. Only three agroforestry systems were observed in the temperate zone (Avasthe et al., 2007). Silvipastoral
system is highly suitable for those areas where livestock rearing is used to supplement income by small and marginal farmers (Singh, 1986; Puri, 1989; Vishwanathan et al., 1999). It provides firewood or fodder while grasses reduce surface soil erosion due to their high soil binding capacity and also produce much needed fodder.

Alley cropping is planting perennial trees or shrubs yielding forage in rows at some distances in association with agricultural crops. It is an agroforestry practice, which emerged as an alternative to shifting cultivation in humid tropics. It is a system in which food crops are grown in alleys formed by hedge rows of trees and shrubs. The primary purpose of alley cropping is to maintain or increase crop yields by improvement of soil fertility (through legume tree component and mulching) and microclimate (Singh, 1995). Trees in alleys form reliable fodder source in lean season, conserve the soil and moisture; and improve the soil productivity to provide sustained yield (Sekar et al., 1993).

Studies on six different viable agroforestry models in Haryana and Uttaranchal revealed that Net Present Value (NPV) for different models on six years rotation varies from Rs. 26,626 to Rs. 72,705 ha\(^{-1}\) yr\(^{-1}\) whereas benefit-cost ratio and Internal Rate of Return (IRR) vary from 2.35 to 3.73 and 94 per cent to 389 per cent respectively, and Kumar et al. (2004) reported that agroforestry has not only uplifted socioeconomic status of the farmers but also contributed towards overall development of the region.
2.2 Role of Nitrogen-fixing trees in agroforestry

A number of workers have studied the roles of Nitrogen-fixing trees in farming system which are reviewed and discussed below:

2.2.1 Restoration of soil fertility

Jha and Tiwari (1993) have suggested to introduce intensive hedgerows or alley cropping or wide alley cropping system for solving problems attributed to jhum land like soil erosion, increase run-off, loss in nutrient status. The hedgerows must be established across the slope on the contour line. *Leucaena leucocephala* or any nitrogen fixing trees (NFTs) suitable for agroforestry system are planted at close spacing. Two rows may be considered the best. Hedge forming trees species are generally felled above 10-15 cm from the ground.

Young (1989) mentioned that trees are capable to control erosion. This is achieved in two ways with trees acting as barriers or as cover. The barrier function in the conventional approach to erosion control by checking run-off of water and the canopy reduces the raindrop impact. On sloping land, leguminous tree species when planted along the contour, minimizes soil erosion. Tree foliage can be used as mulch and fertilizer for food crops (Reynolds *et al.*, 1988). Multipurpose tree species like *Leucaena leucocephala*, *Calliandra calothyrsus*, *Sesbania aegyptica* are generally preferred because they impart flexibility to the system (Singh and Singh, 1988). They provide 50 percent of
income for 20-30 per cent of the rural and tribal people in India (Theagarajan, 1994). There are many compatible species, depending upon region of the country, value, and markets.

Studies was conducted in Bangladesh on problem with soil fertility related to organic matter depletion, farmers reported that organic matter increases yield, reduces the production cost, improves crop growth and the economy, increases water-holding capacity and improves the soil structure. Some farmers are using fast-growing trees such as Flemingia macrophylla, Ipilipil (Leucaena leucophala), Glyricidia sepium, BogaMedula (Tephrosia candida), DholKolmi(Ipomoea fistulosa) (Zahid Hossain, 2001).

Nutrient added to the soil through litter fall create zone of enrichment under tree and shrub crowns (Zinike and Crocker, 1962). Study was conducted on 12 multipurpose tree species to evaluate amount of litter fall and nutrients returned and their effect on fertility status of soil. The 12 species studied were effective in bringing about improvement in the soil properties. Higher available N, P₂O₅ and K₂O as well as higher organic carbon percentage were noted under canopy of Albizia procera followed by Leucaena leucocephala (Das et al., 2007).

Nandeshwar et al. (2006) reported that Dalbergia sissoo and Gmelina arborea were among the faster growing species and appear to be promising tree
species for rehabilitation of degraded land. *Leucaena leucocephala* alley cropping trial in central Malawi have shown that plots receiving leaves of *Leucaena leucocephala* had higher organic C, total N, pH, exchangeable Ca, Mg, K, and S, and lower C/N ratios in the 0-15 cm soil layer than plots where leaves had been removed (Jones *et al.*, 1996).

Evaluation trial was conducted at Makdoompur in the district of Unnao in U.P to develop suitable silvipasture model for large scale planting of fodder tree-grass combination. Three species were *Leucaena leucocephala*, *Albizia lebbek* and *Cassia siamea* along with forage grasses like *Brachiaria mutica*, *Panicum maximum* and *Chloris gayana*. The results revealed considerable improvement of the entire system with huge amount of fodder biomass production (Mishra *et al.*, 2006).

A long-term alley cropping trial was undertaken in south western Nigeria. Two nitrogen fixing hedgerow species *Gliricidia sepium* and *Leucaena leucocephala* and two non-legume hedgerow species *Alchornea cordifolia* and *Dactyladeni abarteri* were used. Alley cropping with the four woody species greatly enhanced the total plot biomass yield/ha, higher soil organic carbon, phosphorus and potassium levels. NFTs showed higher nutrient yields than Non-NFTs (Kang *et al.*, 1999).
Ikpe *et al.* (2003) observed the effects of age (1 or 2 years) of *Tephrosia candida* fallow on nutrient accumulation, on weed biomass. Total biomass and litter were three times higher in plots fallowed for 2 years with *Tephrosia candida* than in those under natural fallow for the same period. Weed biomass was 205% lower in *T. candida* plots fallowed for 2 years than in the natural fallow.

### 2.2.2 Effect of leguminous plants on Nitrogen availability

It was reported that leguminous crops like soybeans have been described as suitable to provide nitrogen to other crops in the range of 30 and 40-80 kg/ha, respectively (Singh *et al.*, 1985; Singh *et al.*, 1986; Chandel *et al.*, 1989). Beneficial effects for succeeding crops of legumes may be of no direct advantage for intercropped species but play an important role within crop sequences. Compared to monocrops of non-legumes, mixed systems with legumes have significant positive effects on succeeding crops: in a sugarcane-based intercropping system, pulses increased organic carbon, total nitrogen and available phosphorus content but had no effect on cane yields (Yadav *et al.*, 1987). Soybeans and blackgram in mixture with maize increased yields of succeeding wheat significantly (Singh and Singh, 1984) and soybean used as green manure in mixture with maize favoured corn yields (Pandey and Pendleton, 1986).
Nitrogen fixing trees are regarded to fix atmospheric nitrogen and increase nitrogen availability in the soil. Besides fixation of atmospheric nitrogen, the possibility of direct nitrogen-transport from a legume to a non-legume crop is of special interest. Field trials conducted have shown that *Tephrosia candida* and *Cajanus cajan* increased surface soil organic carbon and total nitrogen levels over the natural bush. However, only *Tephrosia candida* plots produced improved maize grain and stover yield (Gichuru, 1991).

Nitrogen fixed by trees is transferred through fine root decay, nodule decay, excretion of nitrogen from nodules in the below ground parts or litter fall and pruning applied as mulch above the ground. Mostly nitrogen fixing trees are advocated for agroforestry since they can adopt to low nitrogen soils than the other species. About 5 per cent of the nodule weight is nitrogen. Substantial amount of nitrogen is expected to add to soil through the nodule and root decay. A proper association of annual crop benefits from such processes depend upon the proximity with the scattered trees (Pathak, 2008).

Nitrogen content increased significantly in sorghum grown intercropped with nodulated *Leucaena* over sole sorghum. In mixed culture, sorghum gains an average of 0.03 mg N day$^{-1}$ plant$^{-1}$ (Avery and Rhodes, 1990).

The integration of trees into farmland has been suggested to combat soil nutrient depletion in tropical cropping systems (Sanchez, 1995). Trees are able
to mobilise nutrients from the subsoil and then return these nutrients to the top soil making them available for an annual crop (Buresh and Tian, 1998). Trees may reduce nutrient leaching and form a ‘safety-net’ under the root zone of the annual crop (Van Noordwijk et al., 1996).

Soil analysis after seven years of experimentation revealed that tree species (up to 6 m distance) lowered soil pH by 0.3 units, improved organic carbon content by 0-15 per cent and decreased bulk density by 0.1 Mgm$^{-3}$ (Tomar et al., 1994).

Lehmann et al. (1999) stated that combining annual and perennial crops provided a higher internal nutrient cycling than the monocultures. Result of the experiment indicated that nutrient leaching losses from the topsoil (0–30 cm) were lower in the sorghum monoculture than in the tree based systems. In the subsoil (120 cm), however, leaching was effectively reduced. In the alley cropping of Sorghum bicolor and Acacia saligna leaching losses of nitrogen under the sorghum were 53% lower than in the sorghum monoculture. This could be attributed to higher root abundance and a higher ratio of nutrient uptake-to-leaching in the agroforestry system than in the monocultures indicating a higher nutrient efficiency.

Banful et al. (2000) compared Leucaena leucocephala and Flemingia macrophylia (Willd.) Merr. grown as hedgerows. The results indicated the
superiority of *Flemingia macrophylla* over *Leucaena leucocephala* in higher biomass yield, higher retention of soil moisture and lower soil temperatures than mulching with prunings of *L. leucocephala* and significantly greater growth performance of crop in *F. macrophylla* mulched plots. It was also reported that *Flemingia macrophylla* has qualities that suppress nematode populations.

### 2.2.3 Influence of Nitrogen fixing trees on crop yield

An approach to integrating calliandra (*Calliandra calothyrsus*) and *Leucaena leucocephala*, into maize (*Zea mays* L.) production system was investigated in the sub-humid highlands of central Kenya. When alley-cropped with *Leucaena* sps, maize produced significantly higher yields compared to maize monoculture. The study showed that, alley cropping with *Leucaena* sps was advantageous (Mugendi *et al.*, 1999). Growing of maize as agricultural crop in agroforestry system is very common in the world agriculture.

Mafongoya *et al.* (2003) evaluated eleven *Tephrosia vogelii* and three *Tephrosia candida* provenances in Zambia. *T. candida* provenances produced two times greater amount of above ground biomass, higher yields of maize (*Zea mays* L.), lower weed growth than the *T. vogelii* provenances. Legume residues have been credited with supplying mineral nitrogen (N) to the associated cereal crop and improving soil fertility in the long term. Xu *et al.* (1993) reported a significant increase in maize production over three subsequent years after addition of *Leucaena* residues.
Khybri et al. (1992) reported that pure cropping of paddy and wheat was found much less economical than intercropping with *Leuceana*.

### 2.3 Contour hedgerow system/Alley cropping system

Tiwari and Jha (1993) have suggested different alley cropping models for the rehabilitation of jhum land. 'Intensive hedgerow (alley) cropping on the jhum land’ is one of the models suggested and horizontal distance between the hedges depends upon the slope percentage.

Contour hedgerows of multipurpose tree species in the sloping lands are regarded to reduce soil erosion and also add significant amounts of plant nutrients to the soil via periodic prunings. Hedge rows of MPTS are periodically pruned to prevent shading and utilized for mulching/green manuring both for high as well as low rainfall zones in sloppy and plain areas (Chinnamani, 1989). These prunings which consist of leaves and immature stems are added to the soil between rows of crops. Gradual decomposition and nutrient release from added prunings could enhance the organic matter and nutrient status of the soil (Young 1989) and influence the yield of the associated agricultural crop (Wilson *et al.*, 1986; Mafongoya *et al.*, 1997). Budelman (1989) also recommended that under circumstances of limited soil nutrient resources, crop and/or animal production systems involving leguminous species should be based on recycling rather than permitting the export of nutrients.
Growing tree species as contour hedgerows is an agroforestry practice recommended to achieve soil conservation in the sloping tea lands in central highlands of Sri Lanka (De Costa, 1997). It is an adaptation of Sloping Agricultural Land Technology (SALT) which was originally developed in the Philippines (Tacio, 1993). Fujisaka et al. (1995) also described a process of farmers adapting contour hedgerows to their specific needs in the Philippines that included developing labour-saving methods and incorporating hedgerow species that offer direct cash returns.

Reducing fertilizer inputs can be achieved by adopting integrated soil fertility management systems, which incorporate biological nutrient sources in the production system. Such systems involve among others; inclusion of nitrogen-fixing leguminous herbaceous cover crops or woody species in rotational fallow or live mulch systems (Balasubramanian and Blaise, 1993) or in agroforestry systems such as alley cropping (Kang et al., 1990). In peninsular India, alley cropping proved beneficial in terms of soil and water conservation with less runoff and soil loss with 3 m alleys than with 5.4 m alleys (Rao et al., 1991).

Incorporation of woody species in alley cropping has the additional benefits for: continuous supply of organic material from the hedgerow prunings throughout the cropping season, needed for the maintenance of long-term soil
productivity with intensive land use; higher rate of nutrient cycling (Kang, 1997); soil conservation (Kang and Ghuman, 1991; Sajapongse and Syers, 1995); and increasing efficiency of fertilizer use by combining fertilizer application with plant residues and/or prunings. Although the management of the hedgerows increases labour requirement, however, the benefit-cost ratio of the system for maize production was higher due to savings in weeding cost and nitrogen contribution with the use of nitrogen-fixing leguminous hedgerow species (Ngambeki, 1985). Tree species used in hedgerows differ in their ability to enhance soil fertility through addition of prunings (Mafongoya et al., 1998). This is because of the inter-species variation in biomass of prunings produced per year (Young 1989), their nutrient contents (Palm 1995) and the rates of decomposition and nutrient release (Mugendi and Nair, 1997). The rates of decomposition and nutrient release from added prunings are determined by the climatic factors such as rainfall and temperature regimes (Meentemeyer, 1995; Mugendi and Nair, 1997) and by litter quality as determined by its lignin, polyphenol and nitrogen contents (Palm and Sanchez, 1991; Palm, 1995). Biomass decomposition and nutrient release play an important part in selection of tree species for contour hedgerows because of the need to regulate the pattern of nutrient release and synchronize it with the nutrient demand of the associated agricultural crop (Swift, 1987; Young, 1989). Chinnamani (1989) recommended that hedgerows should be planted in the direction of East and West to minimize the effect of shade.
A field trial to characterize the biomass decomposition pattern and quantify the amount of nutrients added through prunings of six tree species growing as contour hedgerows was conducted in a tea plantation in Sri Lanka. Annual biomass of prunings differed significantly between tree species. It is concluded that among the tree species tested, *Calliandra* and *Flemingia* are the most suitable species for contour hedgerows in tea plantations of this agro-climatic region because of their higher soil nutrient enrichment capacity and slower decomposition rates which would minimize leaching losses (De Costa *et al.*, 2001).

2.4 Research on permanent land use system in North East India

In the last 25 years, various research institutions working in the North-east region have significantly developed and perfected a number of agroforestry practices, such as silvipastoral systems, sericulture, tree fodder production systems, aquaforestry and microwatershed approach to develop various land use systems, self-regenerative forestry, tea and rubber plantation at low hills, improvement of shifting cultivated (jhum) land through contour hedge intercropping and other agroforestry interventions.

The noteworthy feature of North-East India is that the hills are mostly inhabited by tribal populations which are also rich in forest wealth, biodiversity, traditional knowledge systems, art and culture and the hill people have a very high affinity to the forests and land. In most hills the forest-people bonds have
been reinforced by way of religious beliefs, and taboos often based on principles of conservation management (Tiwari et al., 1998).

In the north eastern parts of the country in general and Mizoram in particular, the practice of shifting cultivation is an age old practice and with the present population pressures, this form of agriculture is proving to be a strong deterrent to conservation efforts and a threat to the existing forest cover (Nadagouder et al., 2000)

Alder tree (Alnus nepalensis) is a common early succession and nitrogen fixing tree species, which is innovated by the Nagas for its soil fertility management and yield high biomass in this farming system since time immemorial. A case study conducted by Changkija et al. (2000) on agroforestry farming based on alder tree in Nagaland indicated that the system comprising of alder tree (density 200-400/ha) with plantation of various crops has intensify swidden into a two years cropping and two years fallow cycle (relatively 1:1) of cropping of fallow periods. Other than manure deposited by the livestock and the decomposition of the crop residue no external input of fertilizer is applied to the system, yet crop yields are as high now as at any time within memory.

Jha (1995) also recommended a new cropping system for Mizoram known as Zoram Technology or Zo Tech (TGhCFS). In Zo Tech trial, NFT viz. Leucaena leucocephala, Cajanus cajan and Non-NFT species Manihot
esculenta were planted at closed spacing to establish hedges. The result shows that soil erosion and nutrient loss were less in T GhCFS in comparison with jhum land which indicated potential of T GhCFS in reclamation of degraded jhum land. Department of Agriculture in Mizoram has also developed its own contour trench farming for jhum areas (Anon., 1995).

Jha (1995) further opined that the biophysical causes and socio-economic problem of farmers in North-East India can be tackled by adopting alley cropping system in large scale. Agricultural crops, tree species varies in different agroclimatic zone, in each agroclimatic zones, suitable model must be tried with local species as well as exotics. He suggested that government should allot land permanently to the jhumias, individually or community basis as has been provided in the New Land Use Policy of the government of Mizoram.

Singh (2000) recommended contour hedgerow technology (bioterracing) as the technology is more economical than construction of bench terrace across the slope by cut and fill method. Further, Singh (2000) concluded that agroforestry technologies will play a major role in the synthesis of sustainable farming systems for economic prosperity of tribals living in north eastern hills, the degree of success will continue to vary due its location specificity, appropriate choices and a number of local factors.
REFERENCES


