13 Bamboo Based Agroforestry Systems

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1. Introduction

Bamboo is one of the fastest growing plants which have ability to survive in a wide variety of climatic and edaphic conditions. It generally forms the under-storey in the natural forests. There are 124 indigenous and exotics species, under 23 genera, found naturally and/or under cultivation (Naithani, 1993). The bamboos occur as either an under storey or in pure form in all other parts, except the Kashmir Valley. The bamboos are widely distributed in India. It is found to grow practically all over the country, particularly in the tropical, sub-tropical and temperate regions where the annual rainfall ranges between 1,200 to 4,000 mm and the temperature varies between 16° and 38°C. The most suitable conditions for occurrence of bamboo are found in between 770-1,080 m amsl. It can be also grown on marginal and degraded lands, elevated grounds, along field bunds and river banks. Two-thirds of the growing stock of bamboos in the country is available in the North-Eastern states. They abundantly occur in Andhra Pradesh, Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, Tripura, Orissa, West Bengal and Madhya Pradesh states. A few species are also found scattered in other parts of the country both in the hills and the plains. The main genera in India are: *Arundinaria, Bambusa, Cephalostachyum, Chimonobambusa, Dendrocalamus, Dinochloa, Gigantochloa, lndocalamus, Melocanna, Naohouseaua, Ochlandia, Oxytenanthera, Plaioblastus, Phyllostachys, Pseudostachyum, Schizostachyum, Semiarundinaria, Sinobambusa, Teinostachyum,* and *Thamnocalamus.* The exotic genera *Guadua, Pseudosasa* and *Thyrsostachys* are also in cultivation. Clump forming bamboos constitute over 67 per cent of the total growing stock in the country, out of which *Dendrocalamus strictus* has major share of 45 per cent followed by *Bambusa bambos* (13%), *D. hamiltonii* (7%), *B. tulda* (5%), *B. pallida* (4%) and rest other species (6%). *Melocanna baccifera*, a non-clump forming bamboo, accounts for 20 per cent of the growing stock and is found in the

North-Eastern states. India has the largest forest area of bamboos (13.96 M ha) in the world. Also, the country is rich in diversity of bamboos.

Bamboos have thousands of economic applications, hence people call them 'green gold', 'poor man's timber', 'bamboo, friend of the people' and 'cradle to coffin timber'. Bamboos play a major role in the livelihood of rural people and rural industry. This green gold is sufficiently cheap and plentiful to meet the vast needs of human populace from the 'child's cradle to the dead man's bier'. It is an excellent alternative to wood and has the potential of being effective in carbon sequestration, thus, helping in countering the emission of greenhouse gases, global warming and climate change. Bamboos are now being used for wall panelling, floor tiles, briquettes for fuel, raw material for housing construction, rebar for reinforced concrete beams, etc. The major user of bamboo in India is paper industry which consumes sizeable proportion of their total annual production. Bamboo leaves are normally utilized as fodder during scarcity. Bamboos are peerless erosion control agent, their net like root system create an effective mechanism for watershed protection, stitching the soil together along fragile riverbanks, deforested areas, and in places prone to earthquakes and mud slides. The various uses of bamboos have been depicted in Fig. 1.1.

Bamboos had been subjected to depletion by poor management practices. As a result, reproduction cannot keep pace with exploitation and there is an urgent need to secure regeneration; cultivate, protect and manage bamboos for sustainable production. There is a huge gap between the present and potential yield due to non-

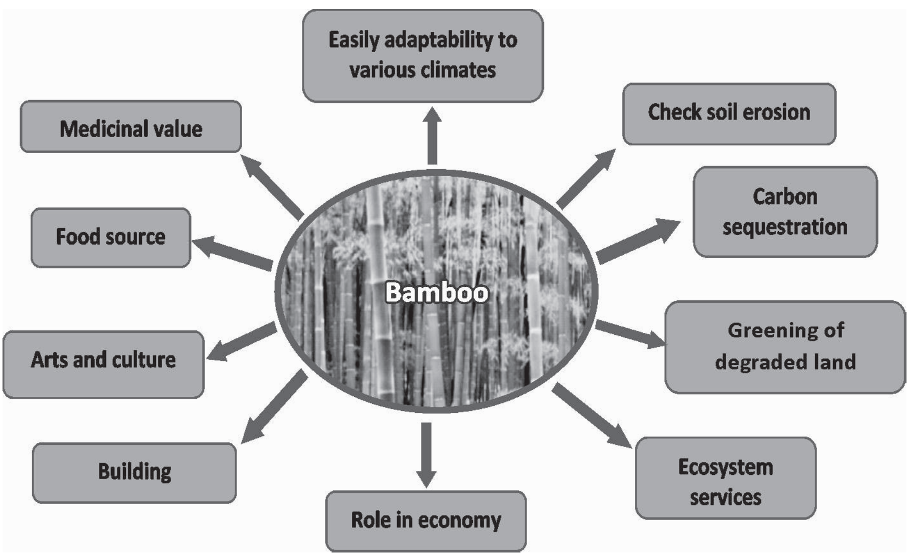

Fig. 1.1. Various uses of bamboos.

availability of sufficient quantity of quality planting material for plantation, hence, there is an urgent need to raise large scale plantations of bamboos.

2. Agroforestry

Agroforestry is the integration of woody plant with other agricultural enterprises such as crop or livestock production to derive both economic and ecological benefits. Agroforestry systems are the practice of mixed farming systems developed over centuries. Most of them are the long term land management practices having a life cycle of more than one year. They are the complex form of land management practices both in the form of ecologically and economically than other land management unit. A number of such systems are prevalent in India, of these the major one are as depicted in Fig. 2.1.

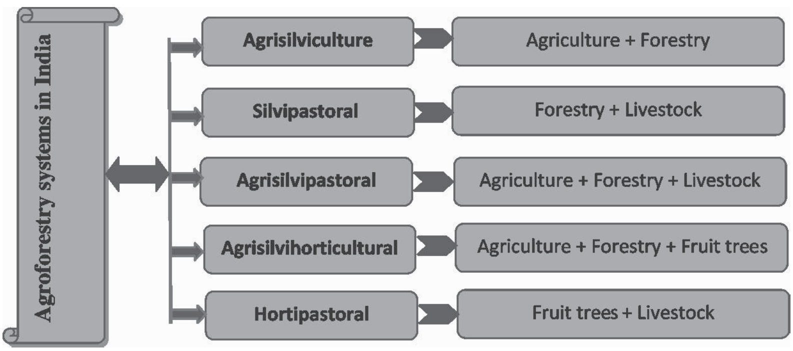

Fig. 2.1. Major agroforestry systems in India.

For lands that are unsuitable for crops, agroforestry provides a way to remove the unsuitable land from crop production over an extended period as the trees mature. It also provides social benefits by functioning as a protective system that ensures resource conservation, though, some of these are not directly measurable (Nath *et al.,* 2009).

3. Bamboos Based Agroforestry Systems

Bamboos based agroforestry can play an important role in enhancing productivity, sustainability and resource conservation. Many of the useful bamboo species can occupy the same ecological niche as trees and are well suited for agroforestry. Bamboos have many advantages over trees such as, relatively short time span from planting to harvest versatility of use which outmatches most tree species the ability to provide building materials and edible products for many years or even decades. Its growth rate is three times that of eucalypts and mature in just three years hence, there are large scale efforts to promote bamboos under agroforestry system.

Bamboos require four to five years to yield first harvest, if grown from offsets, which is much earlier than any other woody species. If raised from seedlings, first harvest is obtained after seven years. This initial period can be sustainably utilized for raising intercrops and enhancing sustainability and income of the growers. Under agroforestry system, bamboos are also benefited due to sharing of resources like irrigation, fertilizers, weeding, etc. with intercrops, as a result the quantity and quality of bamboos are expected to be much higher as compared with monoculture and unmanaged plantations. The bamboos based agroforestry practices which indicate that the safest choice of agroforestry species have come from the native vegetation, having a history of adoption to local precipitation regimes. Balaji (1991) reported that the scope of bamboo in agroforestry is very wide because of the uncertain weather conditions and increasing cost of labour. Bamboos, if properly managed, can be grown in agrisilviculture, silvipastoral, agrisilvipastoral and agrisilvihorticultural system.

Agroforestry plantations can be raised for socio-economic and ecological considerations. They can be suitably grown for intercropping for enhancing productivity and conservation of natural resources using monoculture plantations, wind breaks, riparian filter, permaculture, etc. Bamboos of different heights and growth characters may be used for integrating them with agriculture crops. The species to be selected for agroforestry models should have light crowns such as *Dendrocalamus, Phyllostachys* and *Thyrsostachys* species (Banik, 2000). It has been emphasized that basic principles for model establishment should have clear management objective, suitable management strategy, positive relationship between the model and environment, and maintain appropriate control of the compatibility and competition relationship among the species and full use of resource (Fu Maoyi and Banik, 1996).

3.1. Bamboo Based Agroforestry for Productivity Enhancement

On the basis of experiences from South China, more or less similar to the environment and bamboo types growing in South Asian countries, Fu Maoyi and Banik (1996) described bamboo based agroforestry models. Some of the models being practiced in India and worldwide have been categorized and discussed as under:

3.1.1. Bamboos in homegardens

In homesteads, they are either found mixed with a large number of other tree species or pure in patches (Krishankutty, 1988). Bamboos in the village homesteads mostly occupy the backyard and periphery of the holdings and are one of the most important crop to the farmers. Most of the species in homegardens are usually clump forming, congested in nature with large, tall branchy culms. Bamboos easily grow as inter- and under- crop with many trees.

In moist humid zones of north-east India, West Bengal and Odisha, genus *Bambusa* is most commonly cultivated. *B. balcooa, B. bambos, B. nutans, B. tulda* and *B. vulgaris* are common bamboos species in the homestead in this part. Crops like siris, aonla, bakain, banana, beetelnut, coconut, neem and semul are grown in combination with bamboos. It has been estimated that 15-30 per cent of total plant crown present in homestead in Assam, Tripura and West Bengal contains bamboos (Banik, 2000). Gangopadhyay (2003) surveyed the home gardens in 13 sample villages in five districts of M.P. in India and reported that about 15.13 per cent of families were having *D. strictus* on their fields. In less moist to semi-drier parts of Bihar, Uttar Pradesh, Madhya Pradesh and Maharashtra, *B. bambos* and *D. strictus* are commonly cultivated along with *B. balcooa, B. tulda* and *B. nutans.* In cooler parts of north-east region like Tripura, Meghalaya, Tamenglong (Manipur), some areas of Assam, Arunanchal and north Bengal, *D. hamiltonii* is grown naturally in the moist sites. In Himachal Pradesh and Uttarakhand, *D. hamiltonii* and *B. nutans* are grown by farmers in mid hills. Species like bhimal (*Grewia optiva),* khirak (*Celtis australis*)*,* shetoot (*Morus alba*)*,* kachnar (*Bauhinia variegata)* are also found growing with these bamboo species.In tarai region of Uttarakahnad, Bengali migrants are cultivating *B. balcooa, B. nutans, B. tulda* and *D. hamiltonii* with bael, citrus, kathal, moringa, neem and semul in their homesteads. At higher altitudes of Himachal Pradesh and Uttarakhand, temperate species like *Drepanostachyum falcatum* (ghad ringal), *Himalayacalmus falconeri* (deo ringal), *Thamanocalamus spathiflorus* (thaam ringal), *Thamnocalamus jaunsarensis* (jamura ringal) are usually found. In drier parts like Punjab, western Maharastra, drought tolerant species like *B. bambos* and *D. strictus* are cultivated. In Karnatka, Goa, Andhra Pradesh and western Kerala, *Pseudoxytenanthera stocksii* is cultivated which is not found in other parts of India.

3.1.2. Block plantation / agrisilviculture system

In this model, bamboos are planted at a spacing varying from 4 m x 4 m (for small sized bamboos) to 9 m × 9 m (for large sized species). The interspace is utilized for raising annual crops. It has been well documented that bamboos and tree species gradually become more competitive with age and, thus, progressively the crop yield is reduced (Behari, 2001; Shanmughavel and Francis, 2001; Ahlawat, 2014). Intercropping, with crops employed in bamboos + trees model, should have a bamboo plant to have 1 m^2 in area to ensure adequate moisture and nutrition supply. Intercropping with bamboos, however, can be done for a maximum of four years after bamboo planting, after which there is huge competition for the resources. Bamboo species can be chosen depending on climatic conditions and soil type of the area. In planting bamboos, full soil preparation may be employed on plain land. On sloping land, strip preparation leaving alternate unprepared strips to prevent water and soil erosion is recommended. It is necessary to place adequate fertilizer in the pits before planting. Under agrisilviculture system, soya bean, niger, mustard, wheat, urd and arhar and some of the important intercrops of the initial stages. Raising of shade tolerant crops such as pineapple, ginger, turmeric, shade tolerant variety of sweet potato, cinnamon, etc. within a stand of adult bamboo clumps is technically feasible and economically viable (Banik, 1997). By adopting wider spacing of bamboos and judicious manipulation of bamboos canopy, the period of intercropping could be extended further. Intercrops can also be taken by keeping large spacing between lines and less spacing between plants or within lines of bamboos. In Jabalpur, Madhya Pradesh seedlings of *B. bambos, B. nutans* and *D. strictus,* were successfully intercropped with either maize or soya bean. In Thailand, the bamboo species are also intercropped with maize and peanut. In Sikkim, farmers grow *D. hamiltonii* and *D. sikkimensis* in agriculture fields all along the irrigation channels and stream banks to meet the fodder needs of their livestock. *B. vulgaris* and *B. nutans* have been grown on homesteads throughout Bangladesh (Banik, 2000; Banik *et al.,* 2008). *B. arundinacea* is planted by farmers in depressed and water logged sites in Andhra Pradesh. Seshadri (1985) concluded that cultivation of soya bean (*Glycine max*) along with *D. strictus* was technically feasible and economically viable. The period of intercropping can be extended by adopting wider spacing of the bamboo culms and judicious manipulation of the bamboo canopy.

3.1.3. Bamboo + conifer + broadleaf timber trees

This model can be established by either converting semi-naturally mixed stands or planting new ones. The ratio of bamboos to trees is important, and in semi-naturally mixed stands this may be 7:3 or 8:2 for bamboos and broadleaf trees. The planting time for bamboos and trees should be determined based on the growth rate of the tree species involved. The tree species best adapted to bamboo crops are *Albizzia* sp., *Gmelina arborea, Tectona grandis, Lagerstroemia parviflora, Anogeissus latifolia, Phyllanthus emblica, Zizyphus xylocarpa, Bombax ceiba, Stereospermum suaveolans, Melia azedarach, Aegle marmelos, Lannea grandis, Spondius pinnata, Erythrina indica,* eucalypts, poplars, *Dalbergia sissoo,* etc., owing to their peculiar deciduous light crowns. *Areca catechu* with its narrow crown is also found to grow satisfactorily together with bamboo clumps. All species with deep umbrageous crowns like *Adina cordifolia, Ficus* spp., *Mangifera indica, Artocarpus heterophyllus, Litchi chinensis*, etc. should be avoided (Banik, 2000; Banik *et al.*, 2008).

3.1.4. Bamboos + tea model

In this model, bamboos are often planted at spacing of 6 m x 4 m and tea plants at 2 m x 0.5 m. Intercropping of seasonal agriculture crops such as soya bean and vegetables can be done for one to three years after planting. However, care should be taken to leave enough space for unhindered growth of bamboos and tea plants.

3.1.5. Bamboo as windbreak

Bamboos can be planted as windbreaks on the boundaries of agriculture field and orchards for protecting them from high speed wind. The practice is very common among the farmers in different part of the country. Mango orchards in tarai areas of Nepal are intercropped with agriculture crops, and the boundaries of orchards are planted with one or two rows of *D. sissoo* and *D. strictus*. In Cooch Behar, Dinajpur, Haldibari, Mayanaguri and Jalpaiguri areas in India, the clumps of *B. balcooa, B. bambos* and *B. nutans* have been cultivated in close spacing in one to two rows along the north western sides of rice fields as windbreaks against the dry and cold wind blowing from Nepal and Bihar (Banik *et al.*, 2008).

3.1.6. Bamboo + Medicinal Plants

The model is suitable for hilly areas in the sub-tropical monsoon climatic zone that has a mild climate and adequate rainfall. The medicinal plants are chosen to suit the topography of the site. Shade loving plants of family Araceae and Zingiberaceae can be selected for intercropping as per the choice of demand and market (Banik, 2000). Species like *Aloe vera, Catharanthus roseus, Cassia angustifolia, Curcuma domestica, Plantago ovata, Withania somnifera,* etc. can tolerate shade and are suitable to grow as intercrop due to wide adaptability.

3.1.7. Bamboo + crops + fish ponds

This model is usually made on the plain and wetlands where fish ponds are built. One to three rows of shoot-producing sympodial bamboos may be planted on the banks of pond, and crops such as soya bean and rye intercropped between bamboo clumps to form a complete food chain. Crops can be harvested as food of fish feed. Bottom mud from the ponds may be dug out in winter and used as fertilizer for bamboo clumps. The clumps of major cultivating bamboo species (*B. balcooa, B. mabbosa, B. nutans, B. vulgaris* and *D. strictus,* etc.) of south Asian countries may be replanted at 20-25 years of age for improving the productivity.

3.1.8. Bamboo + edible fungi

There are a large number of edible fungi (*Dictyophora tomentosa, Planrotus ostreatus* and *Auricularia auricula-judoe*) regarded as natural food rich in vegetable proteins grown in south China. Inoculation of *Dictyophora* sp. is done in September for varieties that grow in normal temperature and in May-June for those that require a higher temperature. Harvest is after four to eight months, depending on the fungus variety. *P. ostreatus* is inoculated in March and harvested two months later. *A. auricula-judoe* needs to be cultured in bags filled with the growth medium and hung on the bamboo (Fu Maoyi and Banik, 1996).

3.1.9. Bamboo + poultry/dairy farm

Bamboos can be used to ameliorate problems associated with the containment of animal wastes, nitrate concentration and slurry storages during dairy, beef and poultry operations. Bamboos can tolerate enormous N sources and turn it into marketable biomass. Bamboos-chicken agroforestry system is a new and common pattern in the hilly regions of Southern China and has high potential for extension throughout China. Soil nutrients and earthworm dynamics under this system have been evaluated and found that soil nutrients were improved but soil organism indicators were more sensitive than chemical ones. Earthworm quantity and mass between bamboos-chicken system and only bamboo forest were significant. While exploring a number of forage crops that hold the potential of supplying forage during lean period for dairy cattle and goats, bamboos have become a prime candidate as a perennial forage species making dormant seasons harvest possible. Having high protein content (12-19%), bamboos are comparable to alfalfa in nutritional value yet, they do not require intensive cutting, drying and storage processes of an annual crop.

3.1.10. Bamboo Based Agroforestry Models in India

3.1.10.1. North Zone

In a study conducted at G.B. Pant University of Agriculture and Technology, Pantnagar, cowpea was intercropped for first two years with eight different bamboo species planted at 5 m x 5 m spacing (GBPUAT, 2010). Results revealed that during initial two years, maximum height of 12.5 m was attained by *B. balcooa* followed by *D. hamiltonii.* Grain yield was highest in open plots. Yield of cowpea was lowest under *D. hamiltonii* in both the years. Under different bamboo species, maximum yield of cowpea was recorded under *D. asper* which was closely followed by *B. tulda*. Reduction in yield of cowpea under *D. hamiltonii* can be attributed to fast growth of this species as compared to others. In third year, the conditions were not favourable for growing of cowpea due to heavy shade (Table 3.1.10.1.1.; Fig. 3.1.10.1.1.).

In another study conducted at Pantnagar, *D. asper* grown at 5 m x 5 m spacing was intercropped with soybean (Fig. 3.1.10.1.2.). The results revealed that soya bean was successfully taken as intercrop for first three years. The yield of soya bean was highest (22.7 q ha^{-1}) in first year. In second year, the yield was 17.3 q $ha^{-1}$and in third year it

Table 3.1.10.1.1. Growth performance of bamboos and cowpea in agrisilviculture system

Species	Culm ht (m)		No. of culms		Diameter (cm)		Grain (q ha^{-1})		Straw (q ha^{-1})	
	I yr	II yr	I yr	II yr	I yr	II yr	I yr	II yr	I yr	II yr
Bambusa balcooa	6.43	12.5	8.8	6.1	4.56	6.05	9	8.2	14	12.6
B. bambos	2.65	9.5	9.7	6.0	2.67	4.46	8.5	6.5	13.5	10.3
B. nutans	4.43	9.5	10.0	12.3	2.99	3.82	8.2	6.2	12.5	9.3
B. tulda	1.58	3.2	20.3	34.3	1.15	1.11	9.1	7.1	14	10.8
B. vulgaris	2.5	6.5	3.3	5.1	2.05	4.46	10.2	9.2	16	14.2
Dendrocalamus asper	1.37	3.5	21.7	42.1	0.78	1.27	10.8	8.8	16.5	13.4
D. hamiltonii	5.96	11	6.3	11.1	5.02	7.01	7.1	5.1	11	7.9
D. strictus	3.07	8	9.2	18.3	3.18	4.78	8.5	6.5	13.1	10.3
Control	-	-	-	-	-	-	12.8	12.0	20.0	18.1

reduced to 14.3 q ha^{-1}. The succesful intercropping in this species is attributed to slow growth of *D. asper* (GBPUAT, 2010).

In north India, cost-benefit analysis of *D. strictus* plantation at Gual Pahari, Haryana revealed that this system yielded better economic returns (Rawat *et al.*, 2002). Studies on production of vermicompost was done at Garhmukteswar, Uttar Pradesh in *D. asper* stand planted at 5 m x 5 m spacing. After sixth year, the net production was 370 t yr^{-1} and 45.9 t yr^{-1} for vermicompost and bamboo culm with a net revenue of Rs. 251,600 and Rs. 83,667, respectively from 1.6 ha of land. After deduction of total plantation establishment and maintenance cost (Rs. 192,000), the net profit became Rs. 143,267 after sixth year. The consolidated profit for seventh year onwards was expected to be Rs. 335,267; i.e., Rs. 83,817 per acre (NMBA, 2006).

In study conducted under mid hill temperate conditions of Himachal Pradesh, two species, viz., *D. hamiltonii* and *P. pubescens* were evaluated for their growth performance under agroforestry with different medicinal plants during initial stages. Results revealed that *D. hamiltonii* exerted superiority in respect of most of traits, viz., height (m), diameter (cm), average crown spread, culm dry weight and development of the clump biomass than *P. pubescens*. However, the number of tiller formation per clump was about four times higher in *P. pubescens* than *D. hamiltonii*. The accumulation of the biomass (2.68 t ha^{-1}) was also higher in *D. hamiltonii* than *P. pubescens* (Table 3.1.10.1.2.; Fig. 3.1.10.1.3. and 3.1.10.1.4.).

Yield of tulsi, soya bean, *Aloe vera,* wheat and pea as intercrop was reduced under different bamboo species. Rhizome yield of turmeric and ginger, however, were enhanced when grown in association with the *D. hamiltonii* and *P. pubescens* (Table 3.1.10.1.3).

In sub-montane and low hill subtropical conditions of Himachal Pradesh at Dhaulakuan (Sirmour) and Kangra average yield of tulsi was found to be higher when it

Table 3.1.10.1.2. Survival, growth, development and returns from bamboo species under mid-hill temperate conditions of Himachal Pradesh

Parameter	*D. hamiltonii*	*P. pubescens*
Survival (%)	100	100
Average height (cm)	1.85	1.60
Average diameter (cm)	2.50	1.20
Average no. of tillers per clump	5.6	20.70
Average crown spread (m^2)	4.0	3.25
Average culm dry weight (kg)	2.16	0.85
Average clump weight (kg/clump)	12.09	10.55
Average dry biomass (t ha^{-1})	2.68	2.34
Average leaf biomass (t ha^{-1})	0.335	0.351
Average return (leafy fodder + vegetable shoot)	1,578	3,497

was grown in association with bamboo species than under monocropping after four years of establishment of bamboos. Maximum herbage yield (210 q ha^{-1} at Jachh and 137 q ha^{-1}at Kangra) of tulsi crop was recorded; when it was grown in association with *D. asper* followed by *D. hamiltonii* and *B. vulgaris*. In mid hills sub-humid condition at Solan in Himachal Pradesh, the herbage yield of tulsi was affected when grown in association with *D. asper, B. balcooa, D. strictus* and *D. hamiltonii*, and in comparison to monoculture.

At Dhaulakuan, maximum rhizome yield of turmeric and ginger was 138.2 q ha^{-1} and 320 q ha^{-1}, respectively when grown in association with *D. asper*, closely followed by *D. hamiltonii, B. vulgaris* and open plot, respectively. At Kangra, ginger, however, performed better when intercropped with *D. hamiltonii* followed by *D. strictus, D. asper* and open plot, respectively. In mid-hills sub-humid condition at Nauni, rhizome yield of turmeric and ginger were better under *D. asper.* soya bean displayed better yield performance when grown in association with bamboo species, viz., *D. asper, D. hamiltonii* at all the three locations. At Kangra, maximum soya bean yield (11.37 q ha^{-1}) was recorded in association with *D. asper* followed by *D. strictus, D. hamiltonii* and open plot. Yield of wheat, pea and *Aloe vera* declined drastically when grown as intercrop at all the three locations.

Table 3.1.10.1.3. Yield of intercrops under different bamboo species in mid hill temperate region

Bamboo species	Intercrop yield (q ha^{-1})						
	Tulsi	**Turmeric**	**Ginger**	**Soybean**	***Aloe vera***	**Wheat**	**Pea**
	Herbage	**Rhizome**	**Rhizome**	**Grain**	**Fresh**	**Grain**	**Grain**
D. hamiltonii	56.48	291.6	43.00	23.84	822	13.25	14.50
Phyllostachys pubescens	68.24	301.6	38.00	21.93	644	12.75	15.50
Open plot	80.00	280.0	35.00	24.00	850	14.00	16.34

Fig. 3.1.10.1.1. ***B. balcooa intercropped with*** **cowpea (2nd year).**

Fig. 3.1.10.1.2. ***D. asper*** **intercropped with** ***s*****oya bean (2nd year).**

Fig. 3.1.10.1.3. Bamboo+tulsi.

Fig. 3.1.10.1.4. Bamboo+ turmeric.

3.1.10.2. South zone

In an investigation on systematic plantation of bamboos intercropped with mango, cashew nut, jack fruit, kokum and rubber in the Konkan region of Karnataka, bamboos were reported to be the most profitable among the crops studied and cashew nut and mango ranked next to bamboos (Wagh and Rajput, 1991). In Kerala, Jayashankar *et al.* (1997) reported B:C ratio >1 (indicating profitability) in *B. bambos, Thyrostachys oliveri* and *D. strictus* when grown in intercropping in Kerala. The high B/C ratio of bamboos was due to negligible inputs and high farm price. Among the three species, *T. oliveri* showed better returns. In similar conditions, Krishnankutty (2004) also reported *B. bambos* as profitable crop in mixed homegarden.

In Tamil Nadu, Shamunghavel and Francis (1999) recorded higher annual net return (Rs. 13,300) when pigeon pea was intercropped with *B. bambos* in 1:1 rows at 3 m × 3 m spacing (250 plants ha^{-1}) in comparison to 1:2 rows spaced at 2 m × 2 m (500 plants ha^{-1}). In similar conditions, Shanmughavel and Francis (2001) studied intercropping performance of four crops, viz., pigeon pea, soya bean, ginger and turmeric with *B. bambos* and observed intecroping of pigeon pea and soya bean to be more productive than ginger and turmeric. The LER was 1.2 in the bamboos/pigeonpea and bamboos/soya bean models, but 1.1 in the bamboos/turmeric and bamboos/ginger models. The average annual recruitment of bamboo culms was found greatest in pure stands as compared to intercropped stands.

The feasibility of bamboo (*D. brandisii*) in abandoned paddy fields in Coorg, Karnataka revealed that bamboo at 6 m x 6 m spacing when intercropped with ginger had the highest NPV (net present value) and LEV (land expectation value) which was attributed to low input costs associated with bamboo farming and higher market value of the produce over a longer period (Viswanath *et al.*, 2007).

In Dharwad, Karnataka, intercropping studies of *D. strictus* was done with cotton at 10 m x10 m and 12 m x10 m spacing. After first year, yield of cotton crop was reduced significantly under bamboos. It ranged from 8.5 (10 m x10 m spacing) to 11.15 q ha^{-1} (12 m x10 m spacing) as compared to 15.8 q ha^{-1} in sole cropping. Results further revealed that growth parameters of bamboos, viz., height, diameter and number of new culms were however, significantly reduced under intercropping (NRCAF, 2014).

3.1.10.3. East Zone

Singh *et al.* (1992) studied the effect of *B. nutans* on the yield of some agriculture crops at mid hills of eastern Himalaya and reported that crops like ginger, turmeric, large cardamom, orchards grass and dinanath grass (*Pennisetum pedicellatum*) can be effectively grown up to a distance of 11-15 m from the bamboo rows. Rice, finger millet, soya bean, nandi setaria and fine stylo were suitable crops beyond this distance.

In degraded jhum land of Mizoram, Jha *et al*. (2004) reported that intercropping of soya bean with *Melocanna baccifera* and *D. longispathus* is feasible and gave better results than pure bamboo stands. Jha and Lalnunmawia (2003) reported that intercropping ginger under three fertilized edible clump forming bamboos was beneficial for both the components under degraded soil condition of NE India. In North-East India, Singh (2002) suggested cultivation of bamboo along water springs as an agroforestry intervention for enhancing farmers' income.

Bamboos based agroforestry system for red and laterite zone of West Bengal involving two bamboo species (*B. balcooa* and *B. tulda*) was studied by Banerjee *et al.* (2009). Results revealed that agricultural crops like paddy (upland), groundnut, cowpea, okra, bottle gourd, pigeon pea, turmeric, elephant foot yam and colocasia were found to be successfully grown as intercrop at wide spacing of 12 m x 10 m and 10 m x 10 m. Growth attributes of bamboo plants, irrespective of species and spacing, were significantly higher when grown with intercrops than sole plantation. No significant difference was observed when planted at closer and wider spacing. Further, they reported that the yield of all intercrops was higher in wider spacing (12 m × 10 m) as compared to closer spacing (10 m × 10 m) which is attributed to the fact that wider distance between two bamboo plants results into better utilization of sunlight, space, moisture and nutrients by the intercrops with minimum competition among them and between agricultural crops.

In Jharkhand, Sinha (2010) conducted intercropping study of five-year-old *D. asper* plantation spaced at 5 m x 5 m with potato, tomato and pea during the *rabi* season and with ginger during the kharif season. The monoculture of bamboos and vegetables was also carried out to compare the yield data. Results revealed that in general, the yield of all crops, with the exception of pea, decreased when cultivated in a bamboo plantation as compared to the data from the monoculture plantation. The reduction in yield was attributed to increased competition for growth resources like sunlight, moisture and nutrients in bamboo plot. Growth of bamboos intercropped with vegetables was better than the monoculture of bamboos and on the average, an additional three culms per clump emerged from intercropping of bamboos and vegetables. It was concluded that growing of vegetables with *D. asper* would increase productivity of the plantation or farm and provide additional income to farmers. The study also stressed on exploring the allelopathic effect of *D. asper* with the other crops which results in reduced yield.

In rainfed upland conditions of Odisha, studies on bamboo (*D. strictus*) based agroforestry systems were carried at two different spacings, viz., 10 m x 10 m and 12 m x 10 m. Bamboo + blackgram was found best agroforestry system followed by bamboo + greengram, bamboo + sesame and bamboo + cowpea under 10 m x 10 m spacing. The number of new culms ha^{-1} in agroforestry ranged from 872 - 894 at 10 m x 10 m while 746 - 776 at 12 m x 10 m spacing. In pure bamboo plantation, it was 700 and 588 ha^{-1} at 10 m x 10 m and 12 m x 10 m spacing, respectively. The root intensity of bamboos with different crops was higher over the bamboo grown as pure. The root intensity of bamboos was found to be 330 m^{-2} at 1m distance while, it was 20 m^{-2} at 4m distance from the clump. It decreased with increase of distance from clump and increase of soil depth. Maximum rooting intensity was observed at 10-15 cm depth of soil. It was also concluded that intercrops should not be raised within 0.5m radius of the bamboo clumps because it not only results in a negligible or no yield of intercrop, but also may affect the root system of the clump (NRCAF, 2014).

In Sonitpur (Assam), different intercrops, viz., mustard, sesame, ginger, soya bean, French bean, papaya, banana, pigeon pea, tea, citronella, vetiver and lemon grass were evaluated under different bamboo species, viz., *B. balcooa, B. nutans, B. tulda* and *D. hamiltonii*. Yield performance of the intercops revealed that there was significant decrease in three years average yield of all intercrops over control. The reduction was comparatively less in ginger, turmeric, tea and lemon grass. The first year results indicated that all crops including field and horticulture crops can be successfully grown without any significant difference from the control. C:B ratio was highest in papaya (7.69) followed by banana (6.56). It was also reported that ginger+bamboos system can provide annual income of Rs. 448,060 upto 4th year as compared to Rs. 101,800 from sole bamboo crop (Sharma, 2012). Intercropping studies were undertaken in Kahikuchi (Assam), with *B. balcooa* and *B. tulda* were undertaken for intercropping studies. *B. tulda* was grown at 10 m x 10 m while *B. balcooa* was grown at 12 m x10 m spacing. Three intercrops, viz., banana, pinapple and turmeric were grown as intercrops. Results revealed that pineapple as intercrop with *B. tulda* registered fruit yield of 63 q ha^{-1} while with *B. balcooa,* fruit yield was only 10.7 q ha^{-1} because of less flowering. Fruit yield was maximum (60.2 q ha^{-1}) in pineapple at 4.0 m away from the base of *B. tulda*. Similar results were observed in *B. balcooa.* Banana as intercrop in *B. tulda* and recorded fruit yield of 16.0 q ha^{-1} while in *B. balcooa,* fruit yield was 15.4 q ha^{-1}. Turmeric as intercrop yielded 77.0 q ha^{-1} and 222.8 q ha^{-1} with *B. balcooa* and *B. tulda*, respectively. There was no significant difference among the treatment in respect of soil nutrient builds up after three years of experimentation both in *B. balcooa* and *B. tulda*. However, the lowest amount of organic carbon and available N were recorded in the soil under sole bamboos (NRCAF, 2014).

3.1.10.4. Central and West Zone

Tiwari (2001) conducted a study to determine the financial feasibility of bamboos based agroforestry system in Kheda district of Gujarat (India) using seven management models. Results indicated that the profitability of bamboo was very high and that the crop was financially feasible even at very high discount rate. In a study conducted at JNKVV, Jabalpur (Madhya Pradesh), *B. arundinacea* and *D. strictus* were intercropped with green gram, soya bean, paddy and sesame. Different intercrops showed no significant effect on morphological growth of bamboos upto 30 month age. Results further revealed that yield of intercrops were more in open condition as compared to when grown with bamboos. The reduction was marginal (3.68-7.73 %) during first year, moderate (14.9-19.5%) in second year and severe (17.5-47.8%) in the third year which was mainly attributed to shade. The area occupied by bamboo plants in first to third year increased from 5 to 60 per cent, respectively (JNKVV, 2014). In another study in similar condition, *B. arundinacea* and *D. strictus* were grown with grasses, viz., *Pennisetum purpureum, Panicum maximum, Cenchrus ciliaris* and *Dicanthum annulatum* for three years. During the first year in the first cutting *P. maximum* recorded significantly higher yield. In the second year, *P. purpureum* recorded significantly higher green fodder (450.8 t ha^{-1}) followed by *P. maximum* (271.1 ha^{-1}) and *C. ciliaris* (150.6 t ha^{-1}). The lowest yield was recorded in *D. annulatum* (110.3 t ha^{-1}). In the third year, *P. purpureum* recorded significantly higher yield in first cutting (32. 49 t ha^{-1}) and second cutting (7.30 t ha^{-1}) closely followed by *P. maximum* and *C. ciliaris*. *D. annulatum* recorded significantly lower yield in both, first cutting (5.9 t ha^{-1}) and second cutting (2.36 t ha^{-1}) (JNKVV, 2014).

In Dapoli, Maharastra, *Pseudoxytenanthera stocksii* was planted in two spacings (10 m x 10 m and 12 m x 10 m) with two different agricultural systems. In first system, finger millet was cultivated in kharif followed by cowpea in rabi. In second system, only sweet potato was intercropped with bamboos in kharif. After two years, bamboo showed luxuriant growth when intercropped with agricultural crops. After two years, more number of new culms emerged from the bamboo intercropped with finger millet/cow pea (7), followed by sweet potato (5) and without intercrop (3). Growth parameters, viz., culm basal diameter, culm height, internode length, however, did not vary among the various bamboos-agricultural crop combinations. Yield of finger millet ranged from 7.4 - 10.0 q ha^{-1} when intercropped with bamboo whereas in sole cropping the yield was 14.2 q ha^{-1}. The yield of sweet potato under bamboo ranged from 5.8- 6.5q ha^{-1} where as in sole cropping the yield was 6.7 q ha^{-1} (NRCAF, 2014).

At Jabalpur in Madhya Pradesh, intercropping of black gram and wheat was found to have a favourable effect on the growth of *D. strictus* (6 m x 4 m spacing) and *B. nutans* (6 m x 5 m spacing). Yield of wheat ranged from 14.9-17.3 q ha^{-1} under bamboo in 4^{th} year as compared to 22.5 q ha^{-1} in control plots. Further, it was observed that pruning treatment yielded more number of harvestable bamboo culms and enhanced yield of wheat (TFRI, 2014).

Intercropping studies were conducted in Raipur (Chhattisgarh) with *B. bambos* and *D. strictus (*Naugraiya, 2014). In kharif, rice and soya bean while, in rabi wheat, mustard and linseed crops were grown at 8 m x 3 m spacing in 2009-10 and at 8 m x 6 m in 2010-11 and 2011-12 . Spice crop of turmeric was also taken on the bund between the bamboo clumps. The results obtained are given in Table 3.1.10.4.1. which indicates the feasibility of growing agriculture crops below bamboos during initial years.

Under similar condition, the production of pasture crop under bamboo based silvipasture system (at 10 m x 5 m spacing) was recorded maximum with *B. nutans* (134.6q ha^{-1}) followed by *B. vulgaris* (126.1 q ha^{-1}) and minimum under *B. bambos* (93.7q ha^{-1}) during third year (Naugraiya, 2014).

Ahlawat (2014) studied the economic viability of bamboo (*D. strictus*) based agroforestry system during 2007-2010 in semi-arid region of central India. The growth

Table 3.1.10.4.1. Grain yield in different crops under bamboo based agroforestry

Crops	2009-10 (8 m x 3 m)		2010-11 (8 m x 6 m)		2011-12 (8 m x 6 m)	
	Open	Under Bamboo	Open	Under Bamboo	Open	Under Bamboo
Wheat	21.47	10.59	15.95	10.17	18.83	6.74
Mustard	9.93	2.42	3.66	2.37	3.46	1.79
Linseed	7.9	2.14	2.18	2.03	2.91	2.87
Rice	-	-	40.52	29.76	31.58	25.01
Soya bean	-	-	58.05	42.97	69.06	51.9
Turmeric			127.29	135.53	137.39	133.82

Source: Naugraiya, 2014.

and quality of *D. strictus*, planted at 10 m × 10 m and 12 m × 10 m spacing, did not vary significantly either grown as sole or with intercrops. However, total culms were higher in sole bamboo and growth of bamboo was better in 10 m × 10 m spacing. Reduction in grain yield of sesame was 9.2, 20.2, 19.8 per cent and in chickpea was 4.5, 6.9, 8.2 per cent over that of sole crop after one, two and three years of plantation, respectively. Maximum reduction in intercrop yield was recorded nearby (0.5 m distance) of bamboo clumps, while there was no reduction in crop yield at ≥3 m distance from bamboo clump. The economics of the bamboo based system indicated that during initial three years, benefit-cost ratio (B:C ratio) of chickpea intercrop varied from 2.05-2.86 as compared to B:C ratio (2.13-3.60) of sole crop. The B:C ratios of sesame intercrop varied from 1.14-1.95 as compared to B:C ratio 1.43-2.43 of sole crop. Soil pH, organic carbon and available phosphorus increased, while EC decreased in sole bamboo and intercropped area. Maximum improvement in soil quality was under sole bamboo.

Rahangdale *et al.* (2014) conducted intercropping study in three years old plantation of *B. arundinacea* and *D. strictus* planted at a spacing of 5 m x 5 m during rainy season. Four different intercrops, viz., green gram (TM-99-37), soya bean (JS-335), paddy (JR-201) and sesame (TKG 21) were sown under bamboo and in open plots. Result revealed nonsignificant differences among the bamboo species. Growth and yield attributing characters of different intercrops were found highest in the open condition as compared to bamboo based agrisilviculture system. Among the different intercrops, soya bean showed highest yield reduction (67.9 and 49.2%) in the magnitude for grain and straw followed by green gram (61.1 and 47.2%), sesame (50.6 and 39.7%) and paddy (36.5 and 19.8%). The economic analysis of the system further revealed that the economic feasibility of bamboo based agrisilviculture system (Rs. 21,029 ha^{-1}) as it gave higher monetary return as compared to sole crop (Rs. 9,801 ha^{-1}). Growing of green gram with bamboo species gave significantly higher net monetary return (Rs. 27,736 ha^{-1}) but at par with sesame (Rs. 23,365 ha^{-1}) and was found significantly superior to paddy (Rs. 19,693 ha^{-1}) and soya bean (Rs. 13,322 ha^{-1}) under bamboo based agrisilviculture system.

3.2. Bamboo Based Agroforestry for Resource Conservation

3.2.1. Controlling erosion

Bamboos can reduce erosivity of rainfall/runoff and erodibility of soil through dissipation of rainfall energy by canopy, surface litter, obstructing overland flow and root binding. Bamboo protects riverbanks by arresting strong currents during flood periods by their extensive fibrous root system. Bamboos have an interlocking rhizome system and extensive fine fibrous root system which ramifies horizontally and vertically binding the soil particles together (Sujatha *et al.*, 2008).

On account of extensive shallow root system and accumulation of leaf mulch, bamboo stands are effective for the control of soil erosion, stream bank protection, reinforcement of embankments and drainage channels, etc. Bamboo grows well on steep hillsides, road embankments, gullies and on the banks of ponds and streams. Sharp curves in rivers can be protected with a revetment of bamboos culm cuttings and further reinforced with clumps of bamboos planted behind the revetment (White and Childers, 1945). A study estimated that a single bamboo plant can bind up to 6 m^3 of soil (HD, 1997) while in Jiulongjang and Dayingjang Rivers in China it was found that each clump could protect 12 m of river embankment besides yielding shoots and bamboo timber (Fu Maoyi and Banik, 1996). The root of *B. tulda*, were found to extend horizontally to a distance of 5.2 m (White and Childers, 1945). For monopodial species, the total length of living rhizome per hectare of *P. heterocycla*, *P. viridis* and *P. nigra* ranged from 50 to 170, 90 to 250 and 200 to 320 km, respectively (Xiao, 2002; Zhou, 2005).

Bamboo's efficacy as a soil binder was successfully used in Puerto Rico. *B. vulgaris* planted at certain strategic points along the course of river was effective in checking the erosion problem forever. In China, bamboos were found effective in protecting riverbanks after soil-rock engineering efforts, while planting of other trees failed to protect the river banks (Banik, 2010). Bamboos were also found effective in controlling landslide in Puerto Rico.

In India, bamboos have been tested for protecting severely eroded gullies of ravine class VI and VII lands with promising production potential (Dhruva Narayana, 1993). Some species of *Bambusa, Dendrocalamus,* and *Melocanna baccifera* are usually planted on the lands susceptible to floods and along riverbanks for embankment protection near the villages in Eastern India. During 2003 to 2004, a demonstration plantation had been raised from the seeds of *M. baccifera* on hill slopes for controlling erosion (Banik, 2010). For checking soil erosion, bamboos should be grown at close spacing (Banik, 2000). Biological live check dams can stabilize the eroded lands. On slopes, bamboo rhizomes tend to develop uphill side thus, stabilizing them.

3.2.2. Rainwater retention and soil moisture conservation

Bamboos, due to evergreen nature, dense foliage and large culms, can intercept more rainfall as compared to any tree species, thereby, checking the velocity of the rain drops and soil erosion. The high stem flow and funnelling ratio of bamboo plants in comparison to deciduous and coniferous plants make them better rainfall absorbent and hydrologically best suited plantation. Rao *et al*. (2012) reported that in *D. strictus*, throughfall varied from 43 to 72 per cent, stem flow varied from 7 to 22 per cent and interception losses varied from 12 to 50 per cent of the rainfall.

Bamboos take care of both excess water due to high intensity rainfall and lack of water due to extended drought periods through addition of soil organic matter by litter decomposition which helps in absorbing higher amount of water without causing surface run off and improving water absorption capacity during extended drought. The litterfall amount varies with the composition of the mixed forest, the stand density and human activity. Litter in bamboos in India varies from 4.2-11.2 t ha^{-1} yr^{-1} (Tripathi and Singh, 1994; Shanmughavel and Francis, 1996). The litter of bamboo stand has the capacity to absorb the moisture 2.7-2.9 times of its dry weight (Zhou *et al.*, 2005). A study in China proved that temperate bamboos and leaf litter can intercept 25 per cent rainfall and the leaf litter up to 0.7 mm of rainfall, which is much higher than other conifer and broadleaf tree species (Banik, 2010). Shading by bamboo canopy reduces evapo-transpiration and helps in conserving soil moisture. Bamboo stands also filter gravel and coarse sediment (Gupta, 1979) and the water infiltration is enhanced because of their dense rooting system (Sujatha *et al.*, 2008). Further, larger quantity of culm stumps, dead rhizomes and roots remain in bamboo forests after felling, leaving lots of non-capillary pore which can retain large amount of moisture.

3.2.3. Maintenance of soil health

The ability of bamboos to grow in a wide variety of soils, from marginal to semi-arid, makes them perfect for soil rehabilitation (Nath *et al.*, 2009). Due to high biomass accumulation and abundant litterfall, bamboos help in maintaining and improving the soil physical, chemical and biological properties. Bamboos have high silica, rich litter production of leaves and twigs which slowly decomposes returning substantial amounts of N, K, Mg, Ca and P (Shanmughavel *et al.*, 2000). The high fine root content helps in recovering most of the nutrients leached deeper in the soil profile (Christanty *et al.*, 1996). Improvements are also reflected through lower bulk density, lower surface resistance to penetration, increased porosity, higher rain water infiltration and greater aggregate stability. Canopy shade also alters soil conditions to promote microbial activity and the rate of soil mineralization (Arunachalam and Arunachalam, 2002). The changes/improvements in soils are, however, species-specific and dependent on size and age of the clump and site conditions. Singh and Singh (1999) reported that *D. strictus* plantation has an efficient restoration potential and positive rehabilitation effect on mine spoil land in a dry tropical region in India. It is also seen that bamboo based agroforestry models improve ecological parameters of a highly degraded basaltic tract of Jabalpur. In addition, bamboo based agroforestry system also increases the biodiversity under its habitat (Behari *et al.*, 2000).

Singh *et al.* (1992) studied the impact of 25-30 years old *B. nutans* clump raised in agrisilviculture system on chemical properties of soil. He found that available phosphorus (P) increased whereas exchangeable K and Ca, Mg decreased with increased distance from the bamboos row; soil pH and soil organic matter did not vary with distance. Patil *et al*. (2004) analyzed the effect of bamboo based agroforestry on soil profile and surface soil properties and reported that organic carbon content of these soils ranged from 0.43 to 0.72 per cent. Soil profile investigation showed that all of nutrients increased in bamboo based agroforestry site. The organic carbon content of these soils increased from 0.37 to 0.58 per cent and 0.63 per cent to 0.99 per cent, respectively.

3.2.4. Bamboos for microclimatic amelioration

Bamboos bring microclimate changes under their canopies by providing shade which prevents the soil to become too dry and help in maintaining microclimate. Shade helps in reducing soil and air temperature, solar radiation and wind speed which directly influence the soil water evaporation and humidity. Study conducted by Arunachalam and Arunachalam (2002) revealed that air and soil temperature were significantly reduced and relative humidity was significantly higher under bamboos (Table 3.2.4.1.) as compared to grasslands.

Nauguriya (2014) studied different microclimatic parameters under bamboos. At 8 m x 3 m spacing, the reduction in intensity of PAR under bamboo was minimum 7.47 per cent during end of September, but at the starting of rainy season (July to August) the reduction ranged from 20.3 to 34.4 per cent, While during winter, reduction ranged 25.8 to 48.9 per cent (October to February). At 8 m x 6 m spacing, the reduction in intensity of PAR under bamboo was minimum 11.7 per cent during end of 15th July, but at the starting of rainy season (June to September) the reduction ranged from 27.8 to 33.4 per cent. While during winter, reduction ranged from 50.4 to 60.4 per cent (October to February). Air temperature in open area up to 2 m height from the ground was recorded in range of 24.9 to 43.03°C and it was recorded 18.2 to 40.9°C under bamboo plantation (8 m x 3 m spacing). Variations in the relative humidity between open field and bamboo plantation ranged from 3.34 to 9.5 per cent (September to March). The highest variation was seen during the day hour's observations in summer (21.29%).

Table 3.2.4.1. Microclimatic variability under different species

Species	Air temperature (°C)	Relative humidity (%)	Light intensity (lx)	Soil temperature (°C)
B. arundinacea	26	54	690.0	19
B. nutans	25	57	1,680.0	22
D. hamiltonii	25	55	2,620.0	20
Grassland	28	47	2,800.0	24
LSD at 0.05 level	1.2	3.7	841.4	1.9

***Source**:* Arunachalam and Arunachalam (2002).

4. Constraints Related to Bamboo Based Agroforestry

Bamboo, being perennial grass, has higher root length densities than the dicots, thereby, making them more competitive when grown in association with field crops in agroforestry. Further, due to fast growth, bamboos close their canopy relatively in less time as compared to other tree species and competes heavily with the intercrops for light. Thus, before going for intercropping in bamboos, resource competition needs to be given top priority. Resource competition in bamboos-based agroforestry system can be checked by giving due consideration to the plant population and geometry of planting. Root management practices like trenching can also be helpful in reducing the below ground competition. In no case, bamboos should be grown at close spacing, if intercropping need to be done. For agroforestry, bamboos should be planted 8-9 m away. Trenching (30-40 cm wide and 50-60 cm deep) should be done in case of boundary plantation, so that, new culm should not pass to the nearby fields. Bamboo root competitiveness is usually a function of its rooting intensity with crown radius. Larger clumps have wider foraging zones usually extending to about 8 to 9 m. Therefore, canopy reduction treatments such as pruning and culm thinning are appropriate to surmount inter-specific competition. Pruning up to a height of 1.5 m above the ground is recommended in plantations of 4 yr and above. Removal of dry and dead culms from the centre of the clump to reduce congestion is also recommended. For successful integration of bamboos in the cropping system, there is an urgent need for screening the species of bamboo which are high yielding. The soil-plant-water interaction in the bamboos based agroforestry also needs to be studied for reducing competition. The SWOT analysis of bamboo based agroforestry is given in Fig. 4.1.

POSITIVE	NEGATIVE
Strength • High diversity • Ease to grow • Large area under bamboo • High demand of bamboo products • Low production cost • Strong indigenous knowledge associated with growing bamboo	**Weakness** • Limited choice of species • Limited supply of raw material • Non-conventional in agroforestry • Limited/poor market linkages • High resource completion with intercrops • Lack of genuine planting material
Opportunities • Diverse agroclimatic condition • Diverse range of products and markets • Demand in local as well as international market • Sustainable land use systems • Large chunk of degraded area/community Forests • Support from Ministry of Agriculture	**Threats** • Diversification into high value cash crops • Unsustainable harvesting • Lack of artisan interests • Change in lifestyle and availability of substitutes • Existing policies

Fig. 4.1. SWOT analysis of bamboo based agroforestry.

5. Conclusion

Bamboo based agroforestry systems have wide scope to be integrated on farm lands, homesteads, degraded lands, riparian filter, etc. They can help in augmenting the income of farmers besides conserving the resources efficiently. The systems, however, are not popular due to huge above ground competition with the intercrops. The competition, therefore, needs to be reduced by making suitable choice of species, adopting wider spacing or using canopy management practices. Interactions in bamboo based agroforestry also need to be studied to scale up bamboo cultivation in the country.

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