

# Bamboo Based Agroforestry for Marginal Lands with Special Reference to Productivity, Market Trend and Economy



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## **AGROFORESTRY, ITS COMPONENTS AND FUNCTIONS**

Agroforestry is collective name for land-use systems in which woody perennials (trees, shrubs etc.) are grown in association with herbaceous plants (crops, pastures) or livestock, in a spatial arrangement, a rotation, or both. There are usually both ecological and economic interactions between the trees and other components of the system.

Agroforestry refers to land use systems in which trees are grown in association with agricultural crops, pastures or livestock. The association may be in time, such as a rotation between trees and other components, or in space, with the components grown together on the same land.

Application of agroforestry principles can be separated into ecological, economic and social components. The primary objective is perhaps to obtain ecological benefits and resultant environmental protection.

Agroforestry provides a land owner the opportunity to develop a portfolio of short and long term investments that allow for some spreading of some financial risks through diversification. Diversification gives financial advantages but also introduces the need for additional management expertise to deal with the added complexity.

For lands 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. There are usually both ecological and economic interactions between the trees and other components of the system. It is the ecological interactions that are the most distinctive feature, taking place above ground (shading, evapo-transpiration), below ground (root interactions with respect to water and nutrients) and through transfers of biomass, as when tree litter or prunings are added to the soil.

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For convenience, all woody perennials including trees, shrubs, palms and bamboos, are covered by the word 'trees'. In exceptional cases, woody plants grown as annuals (*Sesbania* spp.) are also included.

The Main Components of Agroforestry are trees, agricultural crops, pastures, livestock and soils. Other components, viz., insects and fish occur in specialized systems. The living components together with the soil make up the 'plant-soil system' or 'plant-soil-animal system'.

Trees and forests were always considered as an integral part of the Indian culture. Planting of trees was regarded as noble acts during the ancient times. Now, due to increasing population and huge gap between demand and supply, forests were ruthlessly exploited to meet the increasing demand of fuel, fodder and timber. Hence, in the light of ever increasing demand, concept of multiple use of land with multipurpose tree species has become immensely important.

Agroforestry has both productive and service functions. The distinctive contribution to production is to obtain tree products from the farm; these include the fuelwood, fodder and fruit (three Fs'), together with construction wood and a host of other items, such as gums, resins, thatching and medicinal products. The relative importance of these products varies between systems, according to environment and socio-economic circumstances. This range of products serves to diversify the output from farms, giving a broader economic base and greater food security.

The major service function of Agroforestry is its role in soil management, including control or erosion and maintenance and improvement of soil fertility.

## **AGROFORESTRY HYPOTHESES**

The general soil-agroforestry hypothesis states that appropriate agroforestry systems have the potential to control runoff and erosion, maintain soil organic matter (OM) and physical properties, and promote nutrient cycling and efficient nutrient use. The following hypotheses can be grouped (Table 1) with reference to processes in plant-soil systems, above- and below-ground effects of trees on soils, tree-crop competition and production and also to specific role in reclamation of degraded land.

Table 1. Twelve hypotheses for soils and Agroforestry (Young, 1997)

	Hypothesis related to		Hypotheses
A.	Processes in plant-soil systems	i)	Control of runoff and soil erosion, reduction in losses of water, soil material, OM & nutrients
		ii)	Augmentation of soil-water availability in land-use systems
		iii)	Maintenance of Soil OM & biological activity at levels satisfactory for soil fertility
		iv)	Maintenance of more favourable soil physical properties through OM & plant roots
		v)	Increase in N inputs through fixation to agroforestry systems
		vi)	Retrieval of plant nutrient (Nutrient Mining) from lower soil horizons and weathering rocks.
		vii)	Leading to more closed nutrient cycling than agriculture & thus more Nutrient Use Efficiency
		viii)	Check & reduce soil toxicities
B.	Above- & below-ground effects of trees on soil	ix)	Decomposition of tree litter & prunings, contribution in maintaining soil fertility & Synchronization of nutrient uptake requirements of associated crops for released nutrients after tree residue decomposition ( <i>'Synchrony'</i> hypothesis)
		x)	Role of roots is as important as above ground biomass & uptake of nutrients by tree-root systems that would otherwise be lost by leaching ( <i>'Tree root leaching'</i> or <i>'Safety-net'</i> hypothesis)
C.	Reclamation	xi)	Employment of Agroforestry systems to reclaim eroded & degraded land
D.	Tree-crop competition & production	xii)	Increasing total biological productivity ( <i>'Resource uptake'</i> hypothesis) & Leading to sustainable land use without affecting yield ( <i>'Production'</i> hypothesis)

## SOIL FERTILITY & LAND DEGRADATION

Land productivity is the capacity of land resources as a whole to support the growth of required plants, including crops, trees and pastures on a sustained basis. Under natural ecosystems, fertility or productivity is maintained by a constant interaction between soils and plant communities, with a high degree of internal recycling. A natural equilibrium is reached, changing only slowly with plant succession or in the longer term climate change. The use of land for production, whether as agriculture, agroforestry or forestry, inevitably disturbs this equilibrium. The diverse natural vegetation communities are replaced by single crops or a smaller number of plant species, and C and nutrients are necessarily removed from the plant-soil ecosystem as harvest.

If production is to be sustained, ways must be found to maintain or restore fertility. The earliest solution was simply to clear more land, making use of the fertility built up under the natural ecosystem. This became systematized in the practice of shifting cultivation, the earliest form of agroforestry. In modern agriculture, decline in fertility is checked by a range of practices like return of crop residues, green manuring, compost and animal manure to restore OM and some nutrients, crop rotation, intercropping etc. Plantation forestry also encounters problems of soil fertility, owing to the large removal of OM and nutrients which takes place during clear felling.

The requirements of a growing world population have led to widespread pressures upon land resources and frequently to land degradation. In addition to loss of soil fertility, land degradation includes degradation of water, forest and pasture resources, loss of biodiversity and also desertification. The recognized forms of soil degradation are soil erosion, physical, chemical and biological degradation, salinization and soil pollution.

- The soil that develops under natural forest and woodland is fertile. It is well structured, has a good water-holding capacity and has a store of nutrients bound up on the OM. Farmers know they will get a good crop by planting on cleared natural forest.
- The cycles of C & nutrients under natural forest ecosystems are relatively closed, with much recycling and low inputs and outputs.
- The practice of shifting cultivation demonstrated the power of trees to restore fertility lost during cropping.
- Experience of reclamation forestry has demonstrated the power of trees to build up fertility on degraded land.
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Approaches to soil management, including problems of soil degradation and low soil fertility, have recently undergone major changes. Soil constraints were to be overcome by inputs like improved crop varieties, fertilizers, chemical control of pests and diseases and use of irrigation. Three to five fold increase in crop yield could be achieved through these inputs but with additional risks of environmental and other problems.

The problem of land shortage and soil management has thus led to a modified view on soil management based on the following approaches:

- Finding ways of making the use of marginal lands sustainable
- Reclamation and restoration of degraded land
- Improved germplasm for plant varieties adaptable to soil constraints
- Maintenance of soil OM and biological activities beneficial to soil physical conditions and balanced nutrient supplies
- Improvement of nutrient cycling and nutrient use efficiency in agro-ecosystems
- Strategic use of external inputs including fertilizers to overcome deficiencies
- Improvement of water-use efficiency

## **AGROFORESTRY AS PRACTICAL MANAGEMENT OPTION**

Agroforestry can contribute to all these aspects and has a major role to play in some of these. Agroforestry is suited to soils of low fertility and to degraded lands owing to i) the potential of many trees to grow on poor soils and ii) their soil regenerative capacity. In view of the capacity of trees to grow under difficult climatic and soil conditions, coupled with their potential for soil conservation, agroforestry is particularly well suited to adverse environment and main types of marginal lands but has a potential also on more fertile soils and in the temperate zone. Most economic studies have shown agroforestry in a favourable light. The range of technologies and systems permits agroforestry to be applied over a wide range of environmental conditions. It does not require inputs that are costly or in short supply; it is a relatively low-cost form of development. The technology employed, that of managing trees, is generally familiar to farmers although skilled extension advice is highly desirable. Agroforestry is thus a very widely applicable as a practical management option.

The tangible and intangible benefits of agro forestry as suggested in the leaflet are mentioned below:

- To meet the demand of fuel, fodder and timber for the increasing population.
- To reduce the biotic pressure on existing forests.
- To obtain maximum output in terms of yield from the same piece of land.
- To develop wasteland/ degraded lands by planting suitable tree species with agricultural crops.
- To reduce the environmental pollution by planting tree species.
- To reduce soil erosion.
- To increase the soil fertility by planting nitrogen fixing tree species.
- To create availability of raw material for wood based industries.
- To create opportunity of employment to local people and to increase the return in terms of money by increased crop production.

## **SOIL IMPROVEMENT BY TREES**

### *Processes of increase additions*

Maintenance or increase of soil OM  
Nitrogen fixation  
Nutrient uptake  
Atmospheric inputs  
Increase water infiltration  
Water retrieval

### *Processes of reducing losses from the soil*

Protection from erosion  
Nutrient retrieval and recycling  
Reduction in the rate of OM decomposition  
Reduction of water loss from evapotranspiration  
Increased water storage capacity

### *Processes affecting soil physical conditions*

Maintenance or improvement of soil physical properties  
Penetration of compact or indurated layers by roots  
Modification of extremes of soil temperature

### *Processes affecting soil chemical conditions*

Reduction of acidity  
Reduction of salinity and sodicity  
Reduction of soil toxicities caused by pollution

### *Soil biological processes and effects*

Improvement in the activity of soil fauna  
Improvement of N mineralization through the effects of shade  
Root nodulation  
Exudation of growth-promoting substances by the rhizosphere

## **Adverse Effects of Trees on Soils**

Allelopathy  
Acidification  
Removal of OM & nutrients in tree harvest

## **BENEFICIAL PROPERTIES OF WOODY PERENNIALS SUITABLE FOR SOIL FERTILITY MAINTENANCE OR IMPROVEMENT**

- i) A high rate of production of leafy biomass.
- ii) A dense network of fine roots, with a capacity for abundant mycorrhizal association.
- iii) The existence of deep roots.
- iv) A high rate of N fixation.
- v) A high and balanced nutrient content in the foliage; litter of high quality (high in N, low in lignin and polyphenols).
- vi) An appreciable nutrient content in the root system.
- vii) Either rapid litter decay, where nutrient release is desired or a moderate rate of litter decay, where maintenance of a soil cover is required.
- viii) Absence of toxic substances in the litter or root residues.
- ix) For soil reclamation, a capacity to grow on poor soils.
- x) Absence of severe competitive effects with crops, particularly for water.
- xi) Low invasiveness.
- xii) Productive function or service functions other than soil improvement.

Not all of these properties are compatible. A species needs to be acceptable and desirable in agroforestry systems from other points of view, especially production. A tree might have all the desirable properties above but if it is not planted and cared for, it would not be effective in improving soil fertility. So many trees and shrubs have been used widely for soil conservation, fertility improvement or soil reclamation but it is unlikely that there is any species that has all the properties listed. Keeping in mind the above considerations, bamboo is considered to be the suitable species for agroforestry models particularly on degraded lands in our country.

### **WHY BAMBOO ?**

Bamboo is a group of most beautiful and useful woody plants belong taxonomically to the sub-family *Bambusoideae* under the family of *Gramineae*. These are known to be the fastest growing woody plants with a growth rate ranging from 30 – 100 cm per day in growing seasons. It can grow up to a maximum height of more than 36 m with a diameter of 1 – 30 cm. The culm can reach its full height in a matter of two to three months. It also has the fastest growing canopy for the re-greening of degraded areas.

Bamboo is not only an ideal economic investment that can be utilized in many different manners but also has enormous potential for alleviating many problems. The increasing rate of tropical deforestation makes the search for alternative natural resources important. Immensely important

also are the concept of multiple use of land with multipurpose tree species and increasing the desired level (33%) of tree cover. The characteristics of bamboo make it a perfect solution for the environment and social consequences of tropical deforestation. Its biological characteristics make it a perfect tool for solving many environmental problems such as erosion control and CO<sub>2</sub> sequestration. On account of extensive rhizome-root system and accumulation of leaf mulch, bamboo serves as an efficient agent in preventing soil erosion, conserving moisture reinforcement of embankments and drainage channels etc. (ZHOU *et al*, 2005).

Bamboo generates plenty of oxygen, lowers light intensity and protects against U-V irradiations and is an atmospheric and soil purifier. The increased permeability of the soil reduces surface run-off, evaporation loss, allows better water penetration into the soil and increases drainage capacity of the soil. Sharma *et al* (1992) have also reported that bamboo conserves soil moisture and mitigates the adverse drought effects on flora and fauna. It is also seen that bamboo based agroforestry models improve ecological parameters of a highly degraded basaltic tract of Jabalpur (Behari *et al*, 2000). Additionally, quality of strength, light weight and flexibility make bamboo a viable alternative to tropical timbers which are also in short supply for furniture and building material industries.

- ✓ Bamboo is 17% Stronger in tensile strength than steel
- ✓ Bamboo is 27% stronger than Red Oak
- ✓ Bamboo is 13% harder than hard Maple
- ✓ Everything in wood can be produced from bamboo

## **HOW DOES BAMBOO GROW ?**

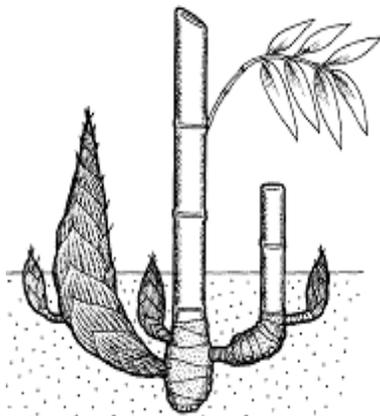
Bamboos are evergreen, monocotyledonous plants which produce primary shoots without any later secondary growth. Each shoot has a distal aerial part called the culm, a proximal, ground-level part called the culm neck, and a subterranean part called the rhizome. Culms consist of nodes and internodes — the former with meristematic tissue from where culm sheaths and branches arise. Young culms with compressed internodes and including a part of the culm neck are harvested for edible shoots and the mature culms provide timber. Rhizomes as culms consist of nodes and internodes.

Bamboos grow in fits and starts. For much of the year nothing much appears to be happening, and then in one brief season they explode with growth. In general, the first year or two after transplanting, you will not see tremendous above-ground growth, as the plant is putting most of its energy into its root system.

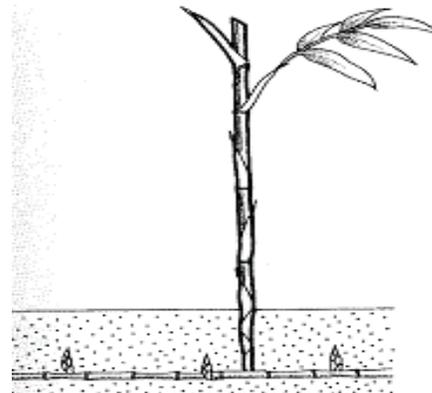
During the summer to autumn, most species manufacture and store sugars in their rhizomes. Rhizomes produce the roots, top growth, and new rhizomes. Then in spring and sometimes fall, they pump the accumulated energy into new shoots (culms), which grow to full size in about 30-60 days. The branches and leaves develop in another 30-60 days. Shoots of some species have actually been clocked growing 4 feet in one 24 hour period. As the plant's rhizome system expands, its ability increases to produce larger, taller, and more numerous culms annually. Thus, each year's "crop" of shoots is larger than the last, until the mature size for the species is reached and new culms continue to come up at the mature size.

Individual culms and rhizomes only live an average of 5-10 years, and the culms grow no taller or bigger with age. That is why the older parts of the plant are frequently the smallest. Old or dead culms can be thinned out to make more light available for new growth. The size and appearance of any particular bamboo variety may vary significantly depending upon climate and conditions. Size alone is greatly affected by location, temperature, nutrition, water, and sun exposure. Mature plants may be able to absorb as much as 3,300 mm of rainfall equivalent water per year (33 million l/ha/year) and contain on an average 288, 44, and 324 kg of N, P, and K per hectare.

According to their morphology, bamboos are broadly divided into **monopodial** (or “**running**”) bamboos with “**leptomorph**” rhizome systems, and **sympodial** (or “**clumping**”) bamboos with “**pachymorph**” rhizome systems. The internodes of leptomorph rhizomes are longer than broad, and lateral buds on nodes can produce either new shoots or other rhizomes. The internodes of pachymorph rhizomes are broader than long, and lateral buds on nodes produce only rhizomes. In sympodial bamboos, new culms develop from buds on elongated culm necks (pseudo-rhizomes) rather than from buds on rhizomes. Generally, monopodial bamboos are native to temperate climates with cool, wet winters, and sympodial bamboos to tropical climates with a pronounced dry season.



Clumping Root Structure



Running Root Structure

## HOW TO PROPAGATE BAMBOO ?

A bamboo propagule must develop all three morphological parts – the aerial part (culm) and two underground parts (the rhizome and root). Bamboos can be propagated through seed or by vegetative means. Due to the scarcity of seeds, vegetative methods are the only option.

- |                               |   |  |
|-------------------------------|---|--|
| <b>Seed origin</b>            | : | Seedlings and macroprogules (by macro propagation)   |
| <b>Vegetative propagation</b> | : | <ul style="list-style-type: none"> <li>i) Micro propagation through tissue culture</li> <li>ii) Through clump division (offset, rhizome), whole culm cuttings, double or single culm cuttings, Split culm technique, branch cuttings Layering, Marcotting, etc.</li> </ul> |

Under natural conditions, bamboo seeds germinate in rainy season after gregarious flowering. The seedlings spring up and survive in large numbers on bare ground. Some of the seedlings develop into clumps after 5-10 years

There are two potential advantages in using vegetative propagation. First, the methods reproduce the mother plant identically since they produce clones. Known high yielding plants can thus be propagated and a degree of selection introduced into the production system. This is not possible with seeds since they are genetically heterogeneous and do not necessarily reproduce the characteristics of the plants from which they are obtained. Second, refined techniques of vegetative propagation have been found to cut costs of bamboo plantations in comparison to the use of more conventional vegetative propagation methods. However, there is a danger that flowering, and death, could occur in a short period after propagation.

## **METHODS OF VEGETATIVE PROPAGATION**

True-to-type progeny with genetic qualities identical to the mother plant are obtained through vegetative propagation.

### **THE OFFSET METHOD**

An offset is the lower part of a single culm (usually with 3-5 nodes i.e. about 1-2.5 m) with the rhizome axis basal to it and its roots. The culm should be between 1 and 2 years old and from a healthy clump. In general the method applies to thick walled clump forming species. The culm is cut with a slanting cut and the rhizome to which it is attached is dug up and cut off to a suitable length to include well developed buds.

Offsets are normally obtained and transplanted just before the rainy season. Collecting of offsets is frequently done 2-3 months before planting; in this case they should be kept in a temporary nursery near the site. In most tropical to subtropical regions mid-March to mid-May is the collecting period. It is advisable to seal the slant cut of the culm with wax/cow dung or earth.

### **THE RHIZOME METHOD**

The 'rhizome' is an underground stem consisting of two parts, the rhizome proper and the rhizome neck which is the base of the rhizome proper. As a stem, the rhizome, has nodes. The neck always lack buds and usually roots. The rhizome proper has roots or root primordia and buds at all or most of the nodes (Banik 1995). Reports on the propagation of bamboos through rhizome planting are scanty and rhizome planting is mainly limited to non-clump forming (Monopodial with Leptomorph rhizomes) bamboos.

Rhizome cuttings are sections of fresh living rhizomes of the preceding year measuring about 15-30 cm long, containing at least one bud are planted in pits or polypots.

## **STEM OR CULM CUTTINGS**

For culm-or stem-cutting propagation technique, generally, culm segments of 1 or usually 2-3 nodes bearing healthy buds or branches are used. Since rooting in addition to shoot emergence is the precursor for rhizome-genesis and subsequent culming, growth promoting substances have been widely used to accelerate rooting response. Use of split-culm reduces the weight of the planting stock.

Propagation through culm cuttings is possible throughout the year with varying success with or without growth hormone if watering and temperature is maintained with a thick pad of straw mulching. However, the best result so far obtained with two node culm segments of 8 to 21 months old during March to May without rooting hormones under the tropical situations of eastern India.

Propagation through branch cuttings are also possible with poor rooting percentages and rhizome development.

## **LAYERING METHODS**

Layering is a method of bringing a culm or branch in contact with soil so that propagation occurs. There are four types of layering : i) ground, or simple layering; ii) stump layering; iii) air layering or marcotting; and iv) seedling layering. For ground layering and stump layering suitable media are 1:1 coconut husk : sand, cow dung : sand, sawdust : sand or peat moss : sawdust. For air layering coconut fibre or coir or peat moss is preferable.

## **UTILITY OF BAMBOOS**

Due of their strength, straightness, lightness combined with extraordinary hardness, range of size, abundance, short period in which they attain maturity, make them suitable for a variety of purposes and uses. There is more than 1500 documented uses of bamboo and estimated current world market is US\$ 10 billion which is expected to reach US\$20 billion by 2015. The size of domestic bamboo economy is Rs. 2043 crore while the market potential is estimated at 4463 crores.

### **A. Traditional Uses**

- i) Edible bamboo shoots
- ii) Pulp & Paper industry
- iii) Charcoal & Activated Charcoal
- iv) Building and Construction Materials
  - Bamboo house, Shade house, construction frame, door-window frames,
  - Bridges, Fencing, ladder,
  - Concrete reinforcement in highways and buildings
  - Partition walls etc.
- v) Transportation
  - Truck & Rly. Carriages, packaging,

- Transportation of fruits, vegetables, livestock etc.
- vi) Household & Farm Utilities
  - Bullock cart, fishing net, fishing rod/poles, stretcher, biers,
  - Poultry house, cold storage rack, wagon rack,
  - Vegetable stakes, trellis poles, shade laths,
  - Basketry weaving, fire works
- vii) Craft products (cottage industry)
  - Handicrafts, wood working inlays, slat chair, cushion, sofa sets,
  - Furnitures, tools, bamboo sticks, umbrella sticks, toys,
  - Screen, Venetian blinds, mats,
  - Incense (Joss) sticks, Chopsticks, toothpick, Cotton swab, ice-cream sticks,
  - Bed spread, table wares, cattle sensor,
- viii) Musical Instruments
  - Flutes, Wind Chimes, Pan pipes, Xylophones
- ix) Soil Conservation and Carbon Sequestration
  - Check dams, bamboo barrier in pond-river banks & land slips
- x) Ornamental & Landscaping
  - Specimen plants, living screen, hedges, riparian buffer zone.

## **B. New Generation Value-added Products :**

### **i) Composites and wood substitutes –**

Bamboo mat board (made from layers of woven bamboo mats that have been impregnated with resin and together in a hot press)

Bamboo mat corrugated sheets (with enhanced toughness, resilience & ductility)

Flattened bamboo boards (using planed flattened bamboo after cross cutting, splitting, flattening and planing the strips. Flats are glued, put in core with either glued surface veneer or surface mat and bonded together in a hot press – used for panel, partition & shuttering ply etc.).

Bamboo Jute composites (similar to resin bonded mat board & Ply board with jute content of 35-40% - has more strength & resistant to moisture)

Bamboo strip boards – round bamboo flattened and hot pressed with glu - used for floors of truck body, Railway carriages & containers

Bamboo flooring – Laminated bamboo flooring or laminated bamboo parquet (block flooring)- Radial parquet, horizontal parquet, bamboo mosaic, vertical cut parquet.

Plywood, Particle board, Fibre board

ii) Bamboo charcoal/activated carbon, Vinegar & Triacetate,

iii) Bamboo gasification for power/thermal applications

- iv) Bamboo fibre reinforced thermoplastics
- v) Bamboo rayon & artificial fibre
- vi) Edible bamboo shoot products – Dry shoot, canned shoot, soft packages  
keeping fresh & soft shoot, ready shoot food, healthy & nutritious food
- vii) Construction and structural applications – bamboo housing in tourist spots,  
Tsunami and earthquake resistant houses, Airport, hotel lounges etc.
- viii) Bamboo Juice - Medicinal bamboo drip  
- Bamboo juice drinks, soft drinks, beer and bamboo wine
- ix) pencil, match industry

## CHOICE OF SPECIES FOR PLANTATION

Bamboos vary widely in their shape, size, wall thickness, physical properties of their wood, internode length, branching pattern, length and thickness of individual fibre (for pulping), soil binding capacity, palatability of young shoots, aesthetic aspects etc. The diversity in respect to physical and chemical characteristics is of great importance for bamboo utility. In selecting species for plantation, primary consideration should be given to the products or purpose for which these are to be grown.

In order to achieve the expected objectives i.e. fast growth, high quality and high yield, certain species should be selected that have adaptability and bring economic benefits and are suitable for particular environmental conditions, soil and topography. In order to reach the targets, it is necessary to know the requirements of species with reference to climate, topography, soil and other factors. One or a few kinds may prove better for one purpose under one set of conditions.

### Selection Criteria

#### i) Structural uses, construction, furniture frames and plywood bamboo

Erect, straight with stout culm, tall and thick, thick walled to solid internodes, comparatively shorter internodes with silicious cover, low moisture content and shrinkage value, high density of culm wood.

Species : *Bambusa arundinacea* (Kanta bans), *Bambusa balcooa* (Vulki, Short variety - Guri vulki), *B. vulgaris* (Basni), *Dendrocalamus giganteus*, *D. strictus*, *Gigantochloa* spp., *Schizostachyum* spp. etc.

#### ii) Thatching, walling, mats and handicrafts and novelty items

Erect and clambering, long internodes with shiny skins, small to medium sized culm diameter, smooth, less branched, high elasticity, good splitting ability.

Species : *Bambusa arundinacea* (Kanta bans), *B. blumeana*, *B. textiles*, *B. polymorpha*, *B.*

*Tulda* (Taral and Jawa), *B. vulgaris* (Basni), *Dendrocalamus giganteus*, *D. longispathus*, *Cephalostachyum* spp., *Gigantochloa* spp., *Melocanna bambusoides*, *Ochlandra stridula*, *Schizostachyum* spp. etc.

### iii) Pulp, paper and rayon

Vigorous growth, maximum biomass, easy to chip, less in silica, lignin and higher in cellulose, long fibres, higher length to width ratio.

Species : *Bambusa arundinacea* (Kanta bans), *B. textiles*, *B. tulda*(Taral and Jawa), *B. vulgaris* (Basni), *Dendrocalamus hamiltonii*, *D. longispathus*, *D. strictus*, *Gigantochloa* spp., *Melocanna bambusoides*, *Ochlandra travancica*, *Phyllostachys pubescens*, etc.

### iv) Edible shoots

Edible, open type of clumps for ease in shot harvesting, non-thorny, wide range of culm emergence period, higher shoot production per clump.

Species : *Bambusa balcooa*, *B. bambos*, *B. blumeana*, *B. nutans*, *B. pallida*, *B. polymorpha*, *Chimonobambusa hookeriana*, *Dendrocalamus asper*, *D. Beecheyana* *D. Brandisii*, *D. giganteus*, *D. hamiltonii*, *D. latiflorus*, *D. longispathus*, *D. membranaceus*, *D. oldhami*, *D. strictus*, *D. sikkimensis*, *Gigantochloa asper*, *G. levis*, *G. macrostachya*, *Phyllostachys bambusoides*, *P. dulcis*, *P. edulis*, *P. iridescens*, *P. Praecox*, *P. pubescens*, *Schizostachyum dullooa*, *Thyrsostachys siamensis*, etc.

### v) Flutes & other musical instruments

Species : *Bambusa tulda* (taral), *D. membranaceus*, *Pseudostachyum polymorphum* etc.

### vi) Sticks, umbrella stick etc.

Solid internode, strong but thin culm

Species : *Dendrocalamus strictus*, Baijnathi lathi, *Pseudostachyum polymorphum* etc.

vii) **Bamboo handicrafts** – most suited and highly preferred species of NE India are : *Dendrocalamus longispathus*, *Melocanna baccifera* & *Schizostachyum dullooa*.

For areas with a marked dry season, the selection of drought-tolerant bamboos like some *Bambusa* sp., *Gigantochloa levis* or *Bambusa blumeana* would be acceptable. For areas with high and regular rainfall or a very short dry season, *Schizostachyum lumampao*, *Dendrocalamus asper*, *Gigantochloa atter* and *Bambusa* sp. are more suitable

## PRODUCTIVITY & ECONOMY

India is one of the richest country in bamboo population with about 130 species belong to 25 genera of the total 1250 species under 75 genera found in the world. Bamboo occurs almost ubiquitously in the country upto 3000m above MSL except in Kashmir.

Bamboo covers 8.957 million ha of forest area equivalent to 12.6% of total forest cover of the country (Rai & Chauhan 1998). The area since increased to 9.607 million ha in 2005. In addition to that bamboo is being cultivated in 1.754 million ha area under private ownership (FAO, 2006).

The NE region of the country holds more than 67% of the growing stock . The 83% of the total growing stock comprises of three main species viz., *D. strictus* (53%), *B. bambos* (15%) and *M. baccifera* (15%).

The estimated annual harvest which is put to different uses is about 13.47 million ton (Anon., 2003a). The average productivity of Indian bamboos averaged at 1.5 t/ha/yr which is very poor in comparison to that of China (3.79 t/ha/yr) (Gupta 2008).

In most part of the country, bamboo resource base has been under managed and is commonly over exploited. However, stand type, species and region wise productivity varies. In Assam, the annual yield of *M. baccifera* and *B. tulda* is 3.1 to 5.0 t/ha/yr while for *D. strictus* and *B. bambos* in Western Ghats, the figures are 3.0 and 6.0 t/ha/yr respectively. It is seen that in case of some species, intensive cultural operations and scientific management can produce much higher yield. In Taiwan, intensive cultivation with fertilization in *D. giganteus* resulted 20-30 t/ha yield. (Singhal & Gangopadhyay, 1999, Tripathi, 2008).

Bamboos cultivated under degraded lateritic soil following appropriate silvicultural operations except fertilization at 6m x 6m spacing produces merchantable dry bamboo to the tune of 1.3 to 2.3 t/ha/yr, 4.37 to 6.68, 9.37 to 12.45 and 9.95 to 14.28 t/ha/yr after 6, 7, 8 and 9 yr of stand establishment from culm cuttings (Nath & Krishnamurty, 2008).

As regards biomass production by bamboos, there is a wide variation depending on species and region of cultivation. Even within the same region, production potential varies due to clump densities, mode of plantation and silvicultural management adopted. Total above ground biomass in both monopodial and sympodial bamboo types generally varies between 7 to 165 t/ha as recorded from 26 bamboo species world wide (Kleinhenz & Midmore 2001). Total biomass production from natural bamboo forest (*D. strictus*) of Chatra and Latehar in Jharkhand has been recorded from 1.30 to 43.63 t/ha due to varying clump density. In the aforementioned plantations under same edapho-climatic condition, the above ground biomass production by 6 yr old different species are : *B. balcooa* – 17.125 t/ha, *B. bambos*- 17.116 t/ha, *B. nutans* - 16.39 t/ha, *B. vulgaris*- 12.905 t/ha, *D. strictus*- 12.156 t/ha. On an average allocation of total above ground biomass to culms, branches and leaves

are 82, 12 and 6% in monopodial species and 77, 13 and 10% in sympodial bambos (Kleinhenz & Midmore 2001).

Homestead bamboo is a major source of income for villagers in many parts of India. In a preliminary study on economy of bamboo plantations in homestead from *Tarai* region of North West Bengal, the net revenue earned has been worked out after deducting establishment and maintenance cost. Starting from 5<sup>th</sup> yr onwards after planting the net revenue, on an average, amounts to Rs. 50,000 per ha during 1<sup>st</sup> harvest and about Rs. 1,50,000 to 2,50,000 in subsequent harvest seasons.

As per 1998 estimation, bamboo plantation total reserve volume is 150-170 million tones. Under the present management and marketing level, 20-30 million tones of bamboo culms and 3.2 – 4.0 million tones of bamboo shoots are produced yearly, with an estimated value of 5.0 billion US\$. Natural bamboo forest can provide a total of about 50 -70 million tones of culms and 0.27 – 0.30 million tones of shoots annually with value of 1.0 – 1.2 billion US\$. There is a great potential for further development in the country (Yuming & Jiru, 1998)

## Some economic aspects bamboo products

Table 2. The current and expected size of market for nbamboo products were estimated by Nation Mission on Bamboo Trade and Technology Development (Planning Commission, GOI) in 2003 (Anon.2003a & 2003b)

Sl	Product/Application	Current (2001)Market (Rs. in Crore)	Expected Market (in 2015) (Rs. in Crore)
1	Bamboo shoots	4.8	300
2	Bamboo as wood substitute	10000	30000*
3	Bamboo ply board	200	500
4	Bamboo ply board for use in Trucks & Railways	1000	3408
5	Bamboo Flooring (domestic + Export)	100 + 100 = 200	1950
6	Bamboo Pulp & paper	100	2088
7	Bamboo Furniture	380	3265
8	<b>Building &amp; Construction</b> (Scaffolding +Housing+ Road+Bamboo Grids+	-	(861+1163+274 +1000)= 3298
9	Tiny Cottage Industry ( Agarbatti, Sticks, fire crackers, ice cream sticks, ladder, pencil, match industry)	394	600

\*(in next 20 yr)

## BAMBOO SHOOT, ITS PRODUCTION AND MARKET STRENGTH

Bamboo shoots form a part of traditional cuisine, fresh, dried, shredded or pickled. A bamboo shoot is the young culm harvested at the time or shortly it appears above the soil surface. Edible shoots are rich in vitamins, amino acids, protein and cellulose and low in fat. There is, however, also a growing market for processed (fermented, roasted and boiled) and packaged shoot representing an opportunity for establishing commercial processing units. In Manipur, bamboo based food processing units produce canned bamboo (in brine, in curried vegetable and in syrups), shoot candies, shoot chutneys, sweet pickles, fermented shoots (*Soibum & Soidon*) and bamboo shoot powder for local and overseas markets.

The INBAR (International Network on Bamboo and Rattan) has selected six species which are most suited for the development of bamboo shoot industry in India. These are : *Bambusa balcooa*, *Dendrocalamus giganteus*, *D. hamiltonii*, *D. strictus* and *elocanna baccifera*. Other promising edible shoot producing species are : *D. sikkimensis*, *Chimonobambusa hookeriana*, *D. longispathus*, *B. balcooa*, *B. tulda*, *Phyllostachys bambusoides* etc. *D. asper* is the introduced species highly regarded for culinary purposes.

There are presently three large scale processing units at Dimapur (900 t/yr), Jorhat (200 t/yr), Bongaigown (300 t/yr) with clusture level processing technologies and also branding and marketing support. Shoot industry holds the promise of rapid growth. Bamboo shoots carry the potential of value added economic activity and provide employment and income generation at rural and community level through cultivation and processing. The 900 TPA processing unit in NE costs at Rs. 1.20 crore with IRR estimates to be 30%. According to the Planning Commission estimate bamboo shoot market was around 5.0 crore in 2001 and with potential of 25% growth per annum it captured a market worth 300 crores.

Like total and above ground biomass, shoot biomass may also vary substantially within individual species, even when cultivated at the same site. Although *D. latiflorus* may have a yield potential up to 41 t/ha of edible shoots per year, production from average 7.4 to 20.3 kg per clump per year i.e., 0.74 to 2.03 t/ha/yr with 100 clumps/ha is very common in China (Kleinjhenz & Midmore, 2001). For well managed reasonable stands (2225 culms/ha for larger and 9000-12000 culms/ha for small to medium sized 3-4 yr old), the ranges of production are 10-20 t/ha and 10-30 t/ha in monopodial and sympodial bamboos respectively (Kishwan & Nautiyal, 2008)

An estimate (2002-2005) has shown that 5685 t/yr of fresh bamboo shoots are sold in markets of NE region excluding Assam and Sikkim with largest value (2188 t/yr) in Manipur followed by Arunachal Pradesh (1979 t/yr). The state wise production and cost returned analysis for edible shoots in NE states are presented in Table 2. The availability of

tender shoots in this region varies from 42 to 84 days in a yr. Among the bamboo species *D. haniltonii* is consumed in largest quantities (1854 t/yr) followed by *D. giganteus* (1095 t/yr) and *M. baccifera* (845 t/yr), lowest quantity (1.7 t/yr) with *Schizostachyum dullooa*. The net income appears to be Rs. 18.85 and Rs. 22.90 million for fresh and processed bamboo shoots respectively in the region. The financial investment and physical efforts in the form of Man Days for collection, processing, transportation, sale etc, required for merchandising these products in the region accounts for Rs. 18.91 and Rs. 17.48 million respectively for fresh and processed shoots.

As stated earlier, during late nineties, China produced 3.2-4.0 and 0.27-0.30 million tons of bamboo shoots from plantation (*Phyllostachys pubesense*, *Phyllostachys bambusoides* etc.) and natural forests respectively. There is report on large scale consumption also (10,000 – 20,000 t/yr) in China, Japan and Thailand. Total export from Thailand and China were 29.5 million \$ in 1994 and 540.0 million \$ in 1998 respectively. United States imported 30,000 tons of canned shoots each year during early nineties from Taiwan, Thailand and China. It would generally take 30,000 acres of badly managed or 3000 acres superbly managed land to produce 30,000 tons (Lewis, 1996).

Bamboo comes into production in 3 to 4 yr and reaches maximum productivity in 7 to 8 yr. In USA, Oregon Bamboo Co. in Myrtle Creek, OR produced 2 to 10 t shoots per acre and the distributors pay upto \$2 per lb which retail for about \$6 per lb (Anon, 1997b).

In Kerala, six bamaboop species viz, *Bambusa bambos*, *B. tulda*, *B. brandisii*, *Dendrocalamus hamiltonii*, *D. longispathus* and *D. strictus* produce shoot during June to September. It regularly irrigated, the duration of shoot emergence can be increased. In *B. bambos* and *D. hamiltonii*, the average number of shoots and production were 23 and 30-50 kg and 53 and 20 – 40 kg respectively per clump in 4 yr.

A good clum structure for plantation devoted to shoot production is in the ratio of 4:4:2 for 1<sup>st</sup>, 2<sup>nd</sup> and 3<sup>rd</sup> yr respectively and 50-60% of the shoot can be harvested every year. At harvesting, a shoot may contain 80-90% moisture and the edible content is typically around 30%.

Tapping of available resosources, technology development, value addition may lead to develop huge market potential for bamboo shoots in NE region alone for boosting export and socio-economic upliftment.

**Table2. Sale of fresh and processed bamboo shoots in the North-East region and Cost-return analysis of edible bamboo shoots**

Sale of fresh and processed bamboo shoots in the North-East region					(Rs. million/yr)					
State	Fresh shoots		Processed shoots		Fresh shoots			Processed shoots		
	Availa- bility (Days/yr)	Sale (t/yr)	Availa- bility (Days/yr)	Sale (t/yr)	Gross sales	Finan.+ Phys. Invest.	Net income	Gross sales	Finan. + Phys. Invest.	Net income
Arunachal	84	1979	162	481	12.15	3.35	8.80	32.61	15.13	17.48
Manipur	84	2188	191	114	17.14	11.46	5.68	5.19	1.40	3.79
Meghalaya	53	442	70	39	2.26	1.11	1.15	1.18	0.59	0.59
Mizoram	81	433	-	-	1.86	1.07	0.79	-	-	-
Nagaland	76	442	76	19	2.58	0.74	1.84	0.83	0.26	0.57
Sikkim	-	-	32	27	-	-	-	0.57	0.10	0.47
Tripura	42	201	-	-	1.77	1.18	0.59	-	-	-
<b>Total</b>		<b>5685</b>		<b>680</b>	<b>37.76</b>	<b>18.91</b>	<b>18.85</b>	<b>40.38</b>	<b>17.48</b>	<b>22.90</b>

Source : Singha *et al* 2008

## **BAMBOO AND AGROFORESTRY**

The basic tenet of agroforestry is that polycultures can share in the resilience of natural ecologies; possible benefits for the farmer include wider economic opportunity, increased habitat for beneficial species, and lower management costs. By designing bamboo into mixed-use agroforestry complexes we can maximize its functionality while integrating it with other production crops.

In agroforestry systems where each plant receives individual care, bamboo shows promising results. This system is especially important and significant for developing country like India. Under this system because of use of various intercrops, products are obtained even in the early stages of plantation and the income is much higher than any other system.

While cultivated in mixed cropping home gardens in Kerala, bamboo (*Bambusa bambos*) showed holds the second position in terms of profitability (Benefit-Cost ratio) among the crop groups (Krishnankutty, 2004). The high B/C ratio of bamboo was due to negligible inputs and high farm price.

Seshadri (1985) observed that growing of soybean as an intercrop of bamboo during the first six years is technically feasible and economically viable. He also reported that the period of intercropping can be extended further in wider spacing of the bamboo culms and judicious manipulation of the bamboo canopy. Balaji (1991) reported that the scope of bamboo in agroforestry is very wide because of the uncertain weather condition and increasing cost of labour involved in agriculture these days. In an investigation on systematic bamboo plantation intercropped

with mango, cashew nut, jack fruit, kokum and rubber in the konkan region of Karnataka, bamboo is reported to be the most profitable among the crops studied and cashew nut and mango ranked next to bamboo (Wagh and Rajput, 1991).

In order to restore degraded agricultural lands in central India, Behari (2001) developed successful seven agroforestry models with three bamboos (*B. bamboos*, *B. nutans* and *D. strictus*). The inter crops are : Soybean (*Glycine max*), Niger (*Guizotia abyssinica*), Moong (*Phaseolus aureus*), Wheat (*Triticum aestivum*), Urad (*Phaseolus mungo*), Pigeon pea (*Cajanas cajan*) and Mustard (*Brassica campestris*).

Shanmughavel and Francis (2001 & 2002) recommended intercropping of Pigeon pea, Soybean and Turmeric in bamboo (*B. bambos*) plantations based on comparative growth and yield. The land equivalent value (LEV) i.e., the land area in sole system required to produce the same yield as in one ha of intercropping, for bamboo-turmeric system is 1.2. However, pigeon pea and soybean provided most benefits in terms of productivity (Shanmughavel and Francis, 2001). Intercropping ginger under three fertilized edible clump forming bamboos was beneficial for both the components under degraded soil condition of N E India (Jha and Lalnunmawia, 2004)

The feasibility of bamboo (*D. brandisii*) in abandoned paddy fields in Coorg, Karnataka have shown that bamboo at 6m x 6m spacing intercropped with ginger had the highest NPV (net present value) and LEV (Land expectation value). This may be attributed to low input costs associated with bamboo farming and higher market value of the produce over a longer period (Viswanath, Dhanya, and Rathore, 2007) .

Agroforestry system with bamboo species constitute a sustainable land use option for the Dong Cao Catchment in Northern Vietnam where bamboo (56% of which are *B . blumeana*), *Acacia mangium* and *Tephrosia candida* were chosen as test species for simulating and comparing filter effects of different agroforestry systems with intercropping, hedgegrows or fallow rotation (Nguyen, 2004). In that study bamboo accounted for a higher percentage of the income than did trees in the total household economy. It made up 7-14 % of the income compared to 1-10% from trees. Intercropping with bamboo showed reduced run-off and lower erosion in comparison to similar agroforestry systems with *Acacia mangium* and *Tephrosia candida*.

Bamboos of different heights and growth characters may be used as windbreaks and thereby protect gardens and other agricultural systems from the damaging effects of either winds or the frosts that roll off the hillside. Increased crop productivity can be achieved by careful arranging bamboo hedgerows in the landscape.

### **Vermi-compost with bamboo**

With increasing thrust in application of bamboo in agroforestry is economically rewarding when vermin-compost was produced under edible bamboo (*D. asper*) stand (Anon, 2006) (Table 3-5). The Merino Farm at Gahr Mukteswar, UP is one agency that carried out bamboo agroforestry in a scientific manner. After 6<sup>th</sup> year of operation by Merino Century Laminating Co. Ltd., the net production was 370 t/yr and 45.856 t/yr for vermin-compost and bamboo culm with a net revenue of Rs. 2,51,600 and Rs. 83,667 respectively from 4.0 acres of plantation at 5m x 5m. After deduction of total plantation establishment and maintenance cost (Rs. 1,92,000), the net profit became Rs. 1,43,267 after 6<sup>th</sup> year. The consolidated profit for 7<sup>th</sup> year onwards was expected to be Rs. 3,35,267 ie., Rs. 83,817 per acre.

**Tables 3-5. Economy of Bamboo plantation : Agro Forestry model with vermicompost at Merino Farm, Garh Mukteshwar, Dist – Ghaziabad, Uttar Pradesh.(source :NMBA)**

Yr of plantation	Oct , 2000
Species	<i>Dendrocalamus asper</i>
Spacing from plant to plant	5m x 5m
Area of plantation	4 acres
No. of clumps	776
Exp incurred till date (including interest rate 15%)	Rs. 192000

Harvesting Results		Some ratios		
Jan-06	Per culm	Per clump	Per Acre	Per Kg
12274		16	3069	-
45856 Kgs	3.74	59.09	11464	-
Rs. 99614	8.12	128	24904	2.17
Rs. 10528	0	0	0	0.23
Rs. 5419	0	0	0	0.12
Rs. 15947	1.30	21	3987	0.35
Rs. 83667	6.82	108	20917	1.82

Vermicompost	Total	Per Acre
Total production (Mt/yr)	370 M.T./Yr	92.5
Gross revenue (Rs./ Yr)	740000	185000
Expenditure (Rs./ Yr)	488400	122100
Net Revenue (Rs./ Yr)	251600	62900
<b>Net Results – Up to 6th Year</b>		
Profit – Bamboo	Rs. 83667	Rs. 20917
Profit – Vermi	Rs. 251600	Rs. 62900
Total	Rs. 335267	Rs. 83817
Less-Exp till date	Rs. 192000	Rs. 48000
Net Profit	Rs. 143267	Rs. 35817
<b>Profit – 7th year onwards</b>	Rs. 335267	Rs. 83817

### **Bamboo-Poultry/Bamboo-Dairy Farm**

Bamboo-Chicken agroforestry system is a new and common pattern in the hilly regions of Southern China and has high potential for extension throughout China (Zhao et al 2006). 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 bamboo-chicken system and only bamboo forest were significant.

Bamboo can be used to ameliorate problems associated with the containment of animal wastes, nitrate concentration and slurry storages during dairy, beef and poultry operations, in some countries. Bamboo can tolerate enormous N sources and turn it into marketable biomass. While exploring a number of forage crops that hold the potential forage supply during lean period for dairy cattles and goats, bamboo has become a prime candidate as a perennial forage species making dormant seasons harvest possible. Having high protein content (12 – 19%), bamboo is comparable to alfalfa in nutritional value yet does not require intensive cutting, drying and storage process of an annual crop (Hanson, 1998).

### Some successful Agroforestry Systems with Bamboo

Sl	Region/state/	Agricultural Components	Forestry Components	Source
	<b>AGRICULTURAL CROPS :</b>			
1	Tamil Nadu	Soybean( <i>Glycine max</i> )	<i>D. strictus</i>	Seshadhri, 1985
2	Konkan, Karnataka	Mango, Cashewnut, Jackfruit, Kokum & Rubber	<i>B. bambos</i>	Wagh and Rajput, 1991
3	Central Region	Wheat, rice, maize, jowar, bajra, pulses, oil seeds etc.	Bamboos of different spp.	Dwivedi, 1994
4				
5	Southern Region	Rice, tobacco, Chillies, Sugarcane	<i>Dendrocalamus hamiltonii</i>	Dwivedi, 1994
6	N E Region	Paddy	<i>D. hamiltonii</i>	Dwivedi, 1994
7	Jabalpur, M.P. (Degraded Soil)	Soybean ( <i>Glycine max</i> ), Niger ( <i>Guizotia abyssinica</i> ), Moong ( <i>Phaseolus aureus</i> ), Wheat ( <i>Triticum aestivum</i> ), Urad ( <i>Phaseolus mungo</i> ), Pigion pea ( <i>Cajanas cajan</i> ) and Mustard ( <i>Brassica campestris</i> ).	<i>B. bamboos</i> , <i>B. nutans</i> and <i>D. strictus</i>	Behari, 2001
8	Kallipatty, Tamil Nadu	Pigeon pea, Soybean & Turmeric	<i>B. bamboos</i>	Shanmughavel & Francis, 2001 & 2002
9	N E India (Degraded Soil)	ginger	Edible	Jha & Lalnunmawia, 2004
10	Coorg, Karnataka	Ginger	<i>D. brandisii</i>	Viswanath, Dhanya, and Rathore, 2007
	<b>VERMICOMPOST :</b>			
1	Ghaziabad, UP	Vermicompost Earthworm	<i>D. asper</i>	Anon, 2006
	<b>LIVE-STOCK :</b>			
1	Southern China	Chicken	Bamboo sp.	Zhao <i>et al</i> 2006

## COMPETITIVE INTERACTIONS IN BAMBOO-BASED AGROFORESTRY

Being perennial grasses, bamboos have higher root length densities than the dicots. Thus in mixed species system, bamboos may out-compete the field crops or other tree crops grown in association. However, inter-specific competition in bamboo-based agroforestry system can be overcome by planting crop 8-9m away from the bamboo clumps. Trenching (30-40 cm wide and 50-60 cm deep at 5-6m away from the clumps) to spatially isolate bamboo roots from the rest of the crops is recommended, if crops are to be planted at shorter distances. 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.

The success under bamboo system may be ascribed to the nutrient pumping or mining action of the bamboo, slow decomposition of its silica-rich litter and the extremely high biomass of bamboo fine roots. Bamboo recovers much of the nutrients leached deeper into the soil profile and deposits them at or near the soil surface as above ground litter and dead fine roots. The bio-geo-chemical role of bamboo is behind the sustainability of this agroforestry system (Christanty *et al* 1997). The success of bamboo based agroforestry system in restoring degraded lands lies in the fact that this system is associated with silvicultural and agricultural operation in continuity and under this system the disturbed sites can be rejuvenated in successional stages.

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To,  
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Forest Plantation Research and Evaluation  
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Sub – Article related to AGROFORESTRY with reference to Jharkhand, Reg..

Sir,

With reference to your advertisement (P.R. 2075 (Forest) 08-09) published in the news paper *Prabhat Khabar* dated 21<sup>st</sup> February, 2009, we came to know about the invitation of Research – Paper/ Article related to AGROFORESTRY by the Department of Forest and Environment, Ranchi, Government of Jharkhand.

In this regard, we are sending an article entitled “Bamboo Based Agroforestry for Marginal Lands with Special Reference to Productivity, Market Trend and Economy”, to be published on the website and to be presented in the symposium on 21<sup>st</sup> March, 2009. Hope the article will fulfill the purpose.

Thanking you in anticipation.

Yours Faithfully,

**Dr. S.Nath**

Scientist – E  
Head  
Soil and Land Reclamation Division  
Institute of Forest Productivity,  
ICFRE, Lalgutwa, Ranchi, Jharkhand

**Forwarded :**

**Rameswar Das, IFS**  
Conservator of Forests  
& Group Coordinator Research  
Institute of Forest Productivity,  
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