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Sympodial Bamboo Cultivation under Native Shade Trees: an Agroforestry Perspective

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ABSTRACT

Conventional bamboo cultivation practices advocates planting bamboo in cleared open areas. However, farmers in the south Konkan region of Western Ghats are traditionally cultivating bamboo in association with native trees. Various positive effects of native trees on the growth and development of individual culm, and a clump in general are reported as perceived by farmers. In addition to bamboo, farmers are getting multiple benefits derived from the preserved tree components. By considering bamboo as a main crop, I briefly reviewed various actual and possible interactions based on central biophysical hypothesis of agroforestry. Productivity of bamboo-tree agroforestry system as a whole is a function of multiple interfaces e.g. competition, mutualism, commensalism, association etc. and the mechanisms could be - various above and below-ground interactions, nutrient pumping, hydraulic lift, litter-fall and decomposition, nutrient cycling, microbial interactions, mycorrhizae association etc. and probably many others. Economic and ecosystem importance and the aspects of functional ecology in general are discussed. Importance of native trees and diversification of income sources to adopt various market and climate driven forces than monoculture farming are highlighted.

INTRODUCTION

Dendrocalamus stocksii (Munro) Kumar, Remesh and Unnikrishnan, (2004) is small to medium sized sympodial bamboo species with strong, loosely spaced, almost solid culms. Culms are thornless with minimal branching. Culms can attain height up to 15m with internodal length of 20 to 38cm and diameter 30 to 50mm (Rane, 2015). *D. stocksii* is an important commercial bamboo species in Peninsular India. It is one amongst 18 economically important bamboo species, recommended for cultivation in peninsular India by National Bamboo Mission (Viswanath et al., 2012). One remarkable feature of *D. stocksii* germplasm is its exclusive cultivation on private land outside the forest (Rane, 2015). Farmers in the south Konkan region of Maharashtra state are traditionally cultivating this species.

As per the Manual for establishment and Management of Bamboo Plantations, BTSG-KFRI, National Bamboo Mission, Govt. of India (2015) '*…planting bamboo under other trees may lead to failures in plantation establishment'*, and '*it is ideal if the area to be planted is first levelled with the help of earth movers if needed, so that it is clear of obstructions or depressions or tree stumps that could interfere with proper establishment*'. The document also states that '*It is preferred that no large trees are present except those that come outside the planting area.*'

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The above 'conventional farming' approach is highly contradictory with traditional system of bamboo cultivation in Sindhudurg district of Maharashtra. The system comprises of retaining tree species in the bamboo farm and cultivating bamboo in the partial shade of these trees (Figure 1).

Productivity benefits of bamboo-tree association

Patil (2017) has described various beneficial aspects of bamboo -tree association under traditional farming system in Sindhudurg. He recorded 28 different tree species preserved in *D. stocksii* plantation. Clumps under partial shade were reported producing taller and thicker culms than those in the open. Relative enhancement in internodal length and diameter with greater uniformity (less tapering) was observed, perhaps, as a result of competition for getting sunlight. If there is heavy shade, instead of cutting a whole tree, branches are thinned. Farmers believed that sunlight requirement for growth of bamboo is around 50% (Patil, 2017).

Tree branches provide physical support to culms especially during stormy winds or heavy rains. On the contrary, those in open spaces, were observed to develop pendulous drooping tops or sometimes even toppled. Culms under shade possess minimal branching in the lower middle portion, thus easy to harvest with minimum post-harvest residue. Farmers were neither providing synthetic-chemical fertilizers nor water to the clumps. Tree- and bamboo- leaf litter used as a mulch, generally collected at the base of bamboo clumps (Patil, 2017).

Selling of bamboo poles in this region is on 'per-pole' basis rather on tonnage or weight basis. The trade practice is that two

Figure 1. Traditional method of bamboo cultivation under partial shade of native trees. Photographs were taken from different localities in Sindhudurg district, Maharashtra.

poles with less diameter and short height are purchased by the merchants at the price of one pole. Thus higher morphometric qualities of individual pole give relatively higher economic returns (60 to 90% more prise for taller and thicker culms). It is also observed that, though the clumps under partial shade produce relatively lesser number of culms per year (i.e. 8 to 12) than the clumps in the full sunshine (14 to 18) of same age, gives approximately equal or sometimes slightly greater income per unit area. Here the reduction in number of culms produced per year is nullified by the higher price fetched by the smaller number of high quality culms. Moreover, various direct benefits like fruits, fodder, medicine, fuelwood, timber etc. are obtained from the associated trees over longer period of time. Thus, considering the total economic productivity of the system, cultivation of bamboo in association with native trees appears to be a viable business.

Scenario of the district's bamboo economy

It is confirmed from the authorities that, Sindhudurg district annually produce approx. 5000 truckloads of bamboo (i.e. approx. 60 lakh poles) goes out of the district. This entire produce is exclusively come from the privet lands and not from the forest or revenue lands. Considering an average price of ₹50 per pole (dia. 40mm with usable length 18 ft), it is estimated that bamboo farmers in Sindhudurg are annually getting income of ₹30 crores. The total bamboo economy of the district is estimated to be around ₹55 to ₹60 crores. Traditional bamboo farms, cultivating *D. sticksii,* share significantly greater quantity of the harvest.

Potential benefits from agroforestry perspective

Productivity and morphometry of bamboo clump or an individual culm is a function of various above- and below-ground interactions between bamboo and trees. Considering bamboo as a main crop, it is thus necessary to explore various tree-crop interactions from agroforestry perspective. The assessment could be based on central biophysical hypothesis for agroforestry which states that 'benefits of growing trees with crops (here bamboo) will occur only when the trees are able to acquire resources that the crops would not otherwise acquire' (Cannell, Noordwijk & Ong, 1996).

Root distribution and interactions

Kaushal et al. (2019) studied root distribution patterns and soil properties in six sympodial bamboo species. They recorded 80% of the total root distribution within 0 to 30 cm of soil layer. Most of the fine roots (47%) were observed in top 0–10 cm soil. Kittur et al. (2017) confirmed the intensive foraging zone of bamboo within 50 cm radius around the clump irrespective of spacing. Divakara et al. (2001) explained root competition and spatial distribution of roots in boundary planted *B. bambos* associated with *Tectona grandis* and *Vateria indica*. They observed profuse growth of bamboo root system at soil surface as an outcome of tree-bamboo association. This highlights effective acquiring of scarce resources than associated trees. Nearness of clumps minimized tree root activity in the upper soil layers with the increased root activity in the deeper mineral horizons.

Deep rooted trees are relatively less dependent on topsoil resources than the shallow rooted plants. Such spatial segregation of below ground niches lowers the root competition (Schroth, 1999). Atkinson and Wilson (1980) found that trees planted at different densities develop different root systems. They recorded higher proportion of root volume at depth in high density plantations.

Nutrient pumping

Spatial segregation and downward displacement of tree roots is an outcome of competition of the associated crop root system. Such trees take nutrients from deeper soil horizons and deposit them on the soil surface in the form of litter (on ground i.e. leaves, branches, bark, fruits, flowers etc. and subsurface i.e. decomposing roots in the upper soil horizon). This phenomenon is called 'nutrient pumping'. Nutrient pumping is essential to maintain and enhance the overall productivity of the system (Christanty, Kimmins & Mailly, 1997). It signifies the importance of trees in agroforestry where nutrients from deeper soil layers are made available to the associated shallow rooted crop through various rhizospheric processes, which the crop would not get otherwise (Schroth, 1999). Thus, bamboo cultivated in tree shade must be getting the benefit of nutrient pumping by trees.

Litter and nutrient dynamics

Leaf litter is the most important component of input-output system of biomass and cycling of nutrients. It acts as a key factor for restoring the fertility of soil (Das & Chaturvedi, 2006). Bamboo in general produces huge amount of leaf litter per annum. The annual leaf litter production in mature B. bambos plantations can reach upto 20 Ton/ha (Shanmughavel, Peddappaiah & Muthukumar, 2000). Shanmughavel, Peddappaiah and Muthukumar, (2000) also found that of the total above ground litter fall, 58% is leaf litter while remaining 42% is twig litter. Christanty, Mailly and Kimmins, (1996) found 4.7 Ton/ha/yr of above ground litter production by bamboo in the Javanese bamboo based talun-kebun agroforestry system while the total forest floor biomass was calculated around 13.5 Ton/ha/yr.

In general, leaf tissue accounts for more than 70% of litter fall (Krishna & Mohan, 2017). Krishna and Mohan (2017) found that 67 to 87% of the annual nutrient requirement of forest plants is satiated through the nutrients released during the decomposition of litter. Mailly, Christanty and Kimmins, (1997) described the importance of bamboo in recycling of nutrients in Telun-Kebun agroforestry system. Rao and Ramakrishnan (1989) similarly state that bamboo plays important role in stabilizing the cycling of nutrients in slash and burn agriculture system. Kumar, Rajesh and Sudheesh, (2005) confirmed this in case of *B. bambos* where significant amount of the absorbed nutrients gets recycled.

Bamboo biomass has higher concentration of K than dicot trees (Toky & Ramakrishnan, 1982) e.g. the order of major nutrient elements accumulation in the biomass of *B. bambos* was reported K > N > P (Kumar, Rajesh & Sudheesh, 2005). Since K is more readily lost through leaching and runoff, the rapid accumulation of K in the biomass is essential (Chandrashekara, 1996). Interestingly, bamboo has an ability of rapid uptake and accumulation of K which could sometimes be up to 51% of the total nutrient accumulation (Christanty, Mailly & Kimmins, 1996; Shanmughavel & Francis, 1997). Seasonal roots during rainy season, run through or just below the decomposing leaf litter on the forest floor where direct uptake of leachable elements like K, Mg, and Ca takes place (Cuevas & Medina, 1988).

Bamboo holds more N, P, and K in its living biomass than the shrubs and trees but lower concentration of Ca and Mg. Broad leaved trees, on the contrary hold much less K in the living biomass than Ca and Mg (Toky & Ramakrishnan, 1982). Thus released K from shrubs and trees is readily available to the associated bamboo. Nutrient enriched leaves of trees more rapidly decompose than the leaves with low nutrient content (Krishna & Mohan, 2017). Besides, there are litter traits e.g. leaf toughness, nitrogen, structural and non-structural carbohydrates, polyphenol concentrations, C/N ratio, lignin/nitrogen ratio etc. along with climatic factors and soil microbiota that greatly influence the rate of leaf litter decomposition (Krishna & Mohan, 2017). Root litter, in addition, enhances the level of humus below the soil surface (Schroth, 1995).

Hydraulic lift

Trees lift water from deeper soil layers and release it partly into the upper drier soil horizons. Emerman and Dawson (1996) observed this phenomenon in Sugar maple *Acer saccharum* where hydraulically lifted water was used by associated shallow rooted crops. Here understorey plant roots were growing very close to the associated tree roots. Hydraulic lift enhances N mineralization, sub-soil microbial activity and the rate of organic matter decomposition. Thus, plants growing in close association with trees can sometimes overcome surface moisture as a limiting factor. Volume of hydraulically lifted water is sometimes so high that this component must be included in the water-balance modelling studies (Emerman & Dawson, 1996).

Subordinate plants and microbial community structures

Xu, Jiang and Xu (2008) studied the effect of intensive management of *P. pubescens* stands in comparison with conventionally managed stands of same species. They found relatively more diverse microbial community structure in conventionally managed bamboo stands. Reduction in soil microbial communities can be positively correlated to the relative decline in the soil organic matter. Intensively managed bamboo plantations show less input of litter, regular clearing of under storey plants, application of fertilizers, deep tillage of soil etc. This enhances the mineralization rates of soil organic matter which negatively influence the diversity and structure of soil microbial communities (Xu, Jiang & Xu, 2008).

'Subordinate insurance hypothesis' states that subordinate plant species always have greater influence on functioning of the ecosystem than their relative abundance (Mariotte et al., 2013; Mariotte 2014). Removal of subordinate trees and shrub species adversely affect the diversity and complexities of microbial food-webs in subtropical bamboo forest ecosystems as demonstrated by Yuanhu Shao et al. (2016). Removal of associated arboreal flora in *P. pubescens* stands negatively influenced soil microbial community structures, resulting in large increase in root death with corresponding increase of fungal biomass. They recommended to maintain suitable proportion of associated tree and shrub species in bamboo plantation and also to incorporate native subordinate plants to enhance diversity and economy. Unfortunately, the present cultivation practices, recommending removal of associated arboreal species, are based on short-term economic gain. Such conventional plantation establishment theories overlook important ecosystem services and various direct and indirect values derived in the long term. Policy makers also on a same line, focused to maximize early economic gains only and not willing to perceive long-term sustainability of the ecosystem (Yuanhu Shao et al., 2016).

Mycorrhizal networks

'Wood-wide web' is relatively recently discovered unique feature of the forest ecosystem where mycorrhizal networks facilitate below-ground resource transfer amongst plants. New emerging tree seedlings get direct access to these resources as soon as they get connected into this common mycelium. Beiler et al., (2010) studied mycorrhiza networks viz. *Rhizopogon vesiculosus* and *Rhizopogon vinicolor* in the multi-aged old-growth Douglas-fir forest. They confirmed the movement of carbon and water resources through common mycelium between two and more trees. They recorded the maximum distance between two trees in the mycelium network was 43.2m, remarkably traversed through only two fungal links.

Baier et al., (2006) described the vertical distribution of ectomycorrhizal niche in a soil profile. It was observed that some genera colonize in the organic soil layer while some prefer mineral horizons. This greater depth preference enhances the accessibility to water and nutrients in the deeper horizons. Beiler et al., (2010) highlighted the importance of older trees (which they called 'hub trees') in the mycorrhizal networks. Because large trees sustain a greater number of fungal genets than small trees, the removal of older trees greatly reduces the capacity of resource transfer and can also hamper the natural regeneration potential of the forests.

Below-ground mycelial networks are so valuable for the forest ecosystems that multiple plants of different species are able to get water and nutrient resources once they get access to these mycorrhizal networks, provided that roots should equally be receptive towards particular mycorrhizal association (Beiler et al., 2010). Above findings stimulate an interest in the mycorrhizal community associations and mycelial connectivity in bamboo-tree ecosystem.

Significance of native trees

Mixed tree species always serve multidimensional ecosystem services e.g. food, cover and mate opportunities for micro and macro life forms, soil and water conservation, maintaining water table through percolation, slope stabilization, carbon sequestration and biomass, nitrogen fixation and nutrient cycling, regulating the positive effects of microclimate, resilience to winds, drought tolerance, pest regulation, minimizing the hazardous effects of various pollutants etc. (Nair, Mohan Kumar & Nair, 2009; Brockerhoff et al. 2017; Grossiord, 2019). In addition to the ecosystem services, native trees in bamboo plantation give various direct and indirect benefits to the people e.g. fruits, flowers, spices, medicine, timber, fuel wood, aesthetic and recreational values, cultural heritage, religious importance, conservation and in-situ preservation value of germplasm especially rare, endemic and threatened trees species etc. (Dhanya et al., 2014).

CONCLUSION

The traditional method of bamboo cultivation under shade trees practiced in south Konkan region is an exceptional example of agroforestry system where farmers are getting multiple, direct and indirect benefits sustainably over longer period of time. Getting optimum outputs with low or sometimes no external inputs is the key feature of this system. Nevertheless, it affords several unknown potential benefits apart from the enhanced production and income. This paper has attempted to highlight some of these based on observation and review.

Diversification of income sources in agroforestry systems possess greater resilience to adopt various market and climate driven forces than monoculture farming (Reed et al., 2017). Thus, it is important to incorporate various direct and indirect benefits/services while calculating the net productivity of the farm. Accordingly, a detailed examination of various above- and below-ground interactions between sympodial bamboo and native trees and the total productivity of the system is proposed as a next step.

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