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ORIGINAL ARTICLE

Bamboo: potential resource for eco-restoration of degraded lands

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ABSTRACT

Bamboo forests are important forest type in subtropical and tropical region in the world. Due to its biological characteristic and growth habits, bamboos are not only an ideal economic investment that can be utilized in many different manners but also has enormous potential for eco-restoration of degraded lands. Bamboos are one of those communities which rapidly colonized disturbed lands due to their adaptability and nutrient conservation ability. Bamboo protects steep slopes, soils, water ways, prevents soil erosion, sequester carbon and brings many other ecosystem benefits. The impact of bamboo growth on the soil may be different at their species level and it is expected that there is a large increase in the microbial biomass, particularly, in the rhizosphere zone as they do not provide only a larger root surface area but enhances the soil fertility. The important role of microbial biomass in enhancement of soil fertility has been evaluated in various terrestrial ecosystems and found to play crucial role in nitrogen and phosphorous dynamics. Hence, data pertaining to the microbial biomass influenced by bamboo growth need to be used as a potential index for soil nutrient recovery during the restoration of degraded ecosystems. The role of bamboo in eco-restoration of degraded land has received huge attention of ecologists, foresters and soil scientists. However, further extensive research is required for better insights in this aspect.

Key words: Degraded land; Bamboo; Eco-restoration; Nutrient dynamics.

1. INTRODUCTION

Bamboos are one of the most versatile and widely utilized flowering perennials of Poaceae family. These are the biggest members of the grass family, having hollow inter nodal regions with scattered vascular bundles throughout the stem in a cylindrical arrangement. There are nearly 1500 species under 87 genera of bamboos worldwide [1]. Bamboos are one of the most important species particularly in Asia, where it is frequently considered as the “timber of the poor” [2]. It has been used for many applications, from a food source to construction materials. Further, it is a potential source of essential oils and medicines [3]. Bamboo, one of the fastest-growing plants on earth due to its unique rhizome dependent system [4], with reported growth rates of 250 cm in 24 hours. However, the growth rate is dependent on local soil and climatic conditions, as well as on the species. Bamboo can be used in many ways according to the different problems, no matter what they are socially, environmentally or economically. Bambusetum of Rain Forest Research Institute (Jorhat, India) is presented on Fig. 1, and Bamboo Plantation in degraded Jhoom lands of Shercip, on Fig. 2.

Figure 1. Bambusetum of Rain Forest Research Institute, Jorhat, Assam, India.

Figure 2. Bamboo Plantation in degraded Jhoom lands of Shercip, Mizoram.

Bamboo forests have ecological and environmental functions in term of soil erosion control, land rehabilitation, water conservation and carbon sequestration [5]. The rapid increase in the rate of deforestation makes bamboo an ideal investment or choice for plantation. Biological characteristics and growth habits of bamboo make it more important in solving the problem of degraded lands, like for erosion control [6] and carbon sequestration. Bamboos in the future may be able to increase the bio-capacity by simultaneously increasing the area of fertile global hectares that is able to supply resources [7]. Land degradation has raised one of the serious debates, as it is become an important issue in the modern era due to decrease in the agriculture and forest area.

Land degradation is defined as the long-term loss of ecosystem function and productivity caused by disturbances from which the land cannot recover unaided [8]. It is the net result of derivative processes regulated by natural and anthropogenic factors. The degree of soil degradation depends on soil's susceptibility to degradative processes, land use, duration of degradative land use and the management processes. Hence, due to the decrease in the productive area, encroachment of humans in forest and agricultural lands to ensure food security in future, ecological restoration of degraded lands has paramount importance.

Ecological restoration is defined as the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed or it is the return of a damaged ecological system to a stable, healthy, and sustainable state. The basic concept behind restoring any degraded land includes: having exact knowledge and monitoring about the actual condition of the problem, including the causes and their impact and this also includes measures to conserve nutrients in degraded lands. There are so many approaches for the eco-restoration of degraded lands like mechanical and biological approach, proper land use planning, restoration of mined areas, soil amendments for enhancing productivity, improvement of shifting agriculture, afforestation and agroforestry.

Mechanical approaches are used in highly degraded areas, where other approaches are either works slow or not possible, but these are much expensive and require maintenance. Biological approaches are economically sound for restoration of degraded lands due to better soil protection capacity and most effective when amalgamated with mechanical approaches. Proper land use planning, aimed for optimization of production from degraded land as well as from conservation point of view. Ecological rehabilitation of mined areas requires capital and can be attempted by using plant species of economic value to local population. Another way to restore degraded land is soil amendments, as they improve physical, chemical and biological properties of the soil. Improvement of shifting cultivation areas is another way of eco-restoration and it can be archived by introduction of plantation crop in Jhum fields [9]. Afforestation and agroforestry, is most important approach from hydrological and erosion control point of view, but the most important thing is that all the necessities of farmers, fuel, food and timber are supplemented from the single patch of land. As, biological approach is an effective and most economical, so there is a dire need to introduce fast growing bamboo species in restoration of degraded lands. In this article an attempt has been made to discuss the importance of bamboos in eco-restoration of degraded lands.

2. BAMBOO IN ECO-RESTORATION

Bamboos are known to grow in "poor soils" and therefore used for rehabilitation of degraded lands [10]. It can be grown under diverse environmental conditions such as in full sunlight to the areas of high winds. This enables it to be used as a starting point in restoring degraded land. Adaptive capability, nutrient and water conservation of bamboos, enables it as fore-runner plants in the eco-restoration of degraded land. Because of the fast growing nature and the dense foliage of bamboos, it is able to maintain the thick layer of litter. This litter layer maintains microclimate in the understory and soil moisture, the most important factors for the restoration of degraded lands. Bamboo shoots and culms grow from the dense root rhizome system. There are mainly two types of rhizomes: monopodial and sympodial. Monopodial rhizomes grow horizontally, at a surprising rate, thus their nickname of 'runners' or 'running bamboo'. The rhizome buds develop either upward, generating a culm, or horizontally, with a new tract of the rhizome net. Bamboos grown on the hill slopes of degraded jhum land, will be able to control the runoff and soil erosion because of the presence of intensive root system. There are very few reports describing the rapid colonization of bamboos in the degraded lands. Different species of bamboos affect soil properties in different ways; among them some have been reported to increase the microbial biomass in rhizosphere zone by providing the large root surface, which helps in increasing the soil fertility [11]. Venkatesh et al. also concluded from his study that out of 11 studied species, *D. gigantells*, *D. hookerii* and *B. nutans*, has been found to be the better species for improving and maintaining the fertility status of acid soils in the NEH region [12]. Role of microbial biomass in soil productivity is already well known as it plays a major part in dynamics of major nutrient like nitrogen and phosphorus [7]. It also acts as a 'sink' and 'source' of the available plant nutrients. Mixed bamboo stands exhibit elevated amounts of advantageous soil nutrients and superior soil qualities as compared to monoculture stands, including soil porosity, aeration and bulk density [13]. Introduction of bamboo enriches soil fertility and microbial activities and also soil enzyme activity [5]. Besides this, physiochemical properties of soil were significantly better in the bamboo forests [14].

Dry matter and nutrient return to soil through litterfall and root mortality are the major components of nutrient cycling in non-bamboo and bamboo forests around the world [15-17]. The organic matter returns to soil undergo different stages of decomposition depending upon the nature of substrate and the climatic conditions [18, 19] to generate the soil nutrients which support plant growth and thus C sequestration. There were two stages of litter decomposition in most litter fractions, a quicker stage during the first year and a slower stage during the second year. Previous studies attributed the initial mass loss of litter to the leaching of soluble C initially present, and to a high microbial activity, based on the most easily degradable compounds [20, 21]. During later stages, the decomposition rate was mainly negatively influenced by slowly degradable compounds, such as lignin, phenols, and tannins [21].

Table 1. Comparison of carbon stock in bamboo and tree forest ecosystems (t C/ha) [12].

Parts / Forest	Arbor & Shrub	Litter	In soil	Total	Ref.
Moso bamboo in Lin'an (medium-intensity management)	34.2	0.66	71.48	106.34	[35 and 36]
Chinese Fir at 15th year	53.60	3.43	93.16	203.79	[27]
Moso bamboo in Yong'an (medium-intensity management)	61.3	3.01	197.36	261.67	[18]
Deciduous board leaved forest	47.75	5.85	208.90	262.50	[34]

Table 1 shows that well managed bamboo forests are likely to be a lower static carbon store as compared with other forest types (varying from 122 t C/ha to 263 t C/ha). The quantity of carbon sequester by any forest type can be extremely influenced by diverse factors like climatic and soil. However, it can be realized that bamboo will sequester prominent amount of carbon, if managed sustainably.

Non-legume (*Dendrocalamus strictus*) can also play a considerable role to restore mine spoil habitats, in the same manner that has been specially reported for leguminous species [28]. Hence, data pertaining to the microbial biomass influenced by bamboo growth need to be used as a potential index for soil nutrient recovery during the restoration of degraded ecosystems. Degradation of soil due to erosion is a major threat in any ecosystem, as it reduces the sustainability and productivity. Bamboo is also well known for controlling soil erosion, as it grows and establishes itself very well on sloppy terrains, hill slopes, embankments and gullies etc. This feature is attributed due to the extensive fibrous and inter connected root system [29]. The leafy mulch and the dense foliage of bamboo, protects soil against the beating and scorching actions of the raindrops. Also the year wise production of new culms from the rhizomes provides the opportunity of harvesting bamboo without affecting biomass and soil. Generally, roots and rhizomes of bamboo form a woven net in the rhizosphere which helps in holding the soil. In several studies, it has been reported that most of roots and rhizomes of bamboo are present in top layer of soil i.e. 0-30 cm, which made it most effective in controlling soil erosion. Planting bamboo on the sides of riverbanks and streams, helps in protecting riverbanks from the erosive action of rivers as these helps in binding the soil tightly and secondly they grows well due to ample supply of moisture. Bamboo is quite effective in conserving soil erosion in ravines [30]. Introducing bamboos in the coastal sand has been proved as an effective measure to increase tree species in coastal forest shelterbelts [31]. Bamboos were found to be suitable for increasing the overall soil fertility and preventing soil erosion [32]. A model demonstrating intercropping of Bamboo groves with folder grass was found to be most effective in controlling soil erosion. Tiwari et al. also conducted various studies and found the conservation effect of bamboo plantation on improved soil health over a period of time [33].

3. CONCLUSION

Eco-restoration of degraded lands requires basic ideas about the geographic and climatic conditions of the degraded sites. Further, technical information/review on the related studies is a prerequisite to design suitable experiments in near future. Development of implementation and monitoring program to evaluate the success of the restoration projects in order to achieve desired information is also essential. Besides identification and scheduling, tasks, use of standard methods, estimation of cost benefit ratio of the projects should also be taken in to consideration for successful implementation of such kind of studies. The role of bamboo in eco-restoration of degraded land has received huge attention of ecologists, foresters and soil scientists. It has been summarized that bamboo plantation have had an impact in changing behavior towards soil erosion control, biodiversity conservation and increasing capacities in restoration of degraded lands. There is a need to integrate local people in restoration programs by increasing awareness on bamboo importance in the same. However, further extensive research is required for better insights in this aspect.

AUTHORS' CONTRIBUTION

Study Design: GM, Data Collection: GM and KG, Analysis and Data Interpretation: SP and RK, Manuscript Preparation: GM and KG, Literature Search: GM and RK, Writing, Review and Revision: GM and NS. All authors are involved in drafting the manuscript, read and approved the final version of manuscript.

TRANSPARENCY DECLARATION

The authors declare no conflicts of interest.

REFERENCES

1. Ohrnberger D. 1999. The bamboos of the world: annotated nomenclature and literature of the species and the higher and lower taxa. Amsterdam: Elsevier.
2. Rao AN, Dhanarajan G, Sastry CB. 1985. Recent research on bamboos. Proceedings of the International Workshop Recent Research on Bamboos. Hangzhou, China. IDRC, Ottawa.
3. Ganapalhy PM, Jansscn JA, Saslry CB. Bamboo, people and the environment. Engineering and utilization. Proceedings of the Vth International Bamboo Workshop and the IVth International Bamboo Congress. 3 June 1995. Ubud, Indonesia.
4. Lessard G, Chouinard A. 1980. Bamboo research in Asia. Proceedings of a workshop held in Singarpore. IDRC, Ottawa, Canada.
5. Zhihua T, Lihua C, Xinxiao Y, Yushan Z. Effect of bamboo plantation on rhizosphere soil enzyme and microbial activities in coastal ecosystem. J Food Agric Environ. 2013; 11(3&4): 2333-2338.
6. Austin R, Levy D, Ueda K. 1970. Bamboo. New York: John Weatherhill Inc.
7. Van der Lugt P. 2008. Design interventions for stimulating bamboo commercialization–dutch design meets bamboo as a replicable model. PhD Thesis.
8. Bai ZG, Dent DL, Olsson L, Schaepman ME. 2008. Global assessment of land degradation and improvement 1: identification by remote sensing. Report 2008/01, FAO/ISRIC – Rome/Wageningen.
9. Rao KS, Ramakrishnan PS. Role of bamboos in nutrient conservation during secondary succession following slash and burn agriculture (jhum) in north-east India. J Appl Ecol. 1988; 26: 625-633.
10. Desh R. Experience in waste land development: a case study. In: Renewable energy and environment. Proceedings of the International Solar Energy Convention. Udaipur, India, 1 -3 December 1989 (Mathur AN, Rathore NS, Eds.), pp. 139-143. Himanshu Publications, Udaipur, India.

11. Arunachalam A, Arunachalam K. Evaluation of bamboos in eco-restoration of 'jhum' fallows in Arunachal Pradesh: ground vegetation, soil and microbial biomass. Forest Ecol Manag. 2002; 159: 231-239. http://dx.doi.org/10.1016/S0378-1127(01)00435-2

12. Venkatesh MS, Bhatt BP, Kumar K, Majumdar B, Singh K. Soil properties influenced by some important edible bamboo species in the North Eastern Himalayan region, India. J Bamboo Rattan. 2005; 4(3): 221-230.

13. Zheng YS, Hong W. 1998. Management of *Phyllostachys pubescens* stand Xiamen. Xiamen University Publishing House.

14. Zhang CS, Xie GD, Fan SH, Zhen L. Variation in vegetation structure and soil properties and the relation between understory plants and environmental variables under different *Phyllostachys pubescens* forests in Southeastern China. Environ Manag. 2010; 45: 779-792. http://dx.doi.org/10.1007/BF02857909

15. Bray JR, Gorham E. Litter production in forests of the world. Adv Ecol Res. 1964; 2: 101-157.

16. Vogt KA, Grier CC, Vogt DJ. Production, turnover, and nutrient dynamics of above- and belowground detritus of world forests. Adv Ecol Res.1986; 15: 303-377.

17. Tripathi SK, Sumida A, Shibata H, Ono K, Uemura S, Kodama Y, Hara T. Leaf litterfall and decomposition of different above and belowground parts of birch (*Betula ermanii*) trees and dwarf bamboo (*Sasa kurilensis*) shrubs in a young secondary forest in Northern Japan. Biol Fert Soils. 2006; 43: 237-246. http://dx.doi.org/10.1007/s00374-006-0100-y

18. Parton W, Silver WL, Burke IC, Grassen L, Harmon ME, Currie WS, et al. Global-scale similarities in nitrogen release patterns during long-term decomposition. Sci. 2007; 315: 361-364.

19. Prescott CE. Litter decomposition: what controls it and how can we alter it to sequester more carbon in forest soils? Biogeochem. 2010; 101: 133-149. http://dx.doi.org/10.1007/s10533-010-9439-0

20. Palm CA, Rowland AP. 1997. A minimum dataset for characterization of plant quality for decomposition. In: Cadish G, Giller KE (eds.). Driven by Nature: Plant Litter Quality and Decomposition. CAB International, London. pp. 379-392.

21. Berg B, Matzner E. Effect of N deposition on decomposition of plant litter and soil organic matter in forest systems. Environ Res. 1997; 5: 1-25.

22. Yiping L, Yanxia L, Buckingham K, Henley G, Guomo Z. 2010. Bamboo and climate change mitigation: a comparative analysis of carbon sequestration. Technical Report. INBAR.

23. Zhou GM. 2006. Research on bamboo forest ecosystem carbon storage, distribution and fixation. Zhejiang University. Ph. D. Dissertation.

24. Zhou GM, Jiang PK. Density, storage and spatial distribution of carbon in *Phyllostachy pubescens* forest. Scientia Silvae Sinicae. 2004; 6: 20-24.

25. Xiao FM, Fan SH, Wang SL. Carbon storage and spatial distribution in *Phyllostachys pubescens* and *Cunninghamia Ianceolata* plantation ecosystem. Acta Ecol Sinica. 2007; 7: 2794-2801.

26. Qi LH, Liu GL, Fan SH. Effects of different tending measures on carbon density, storage, and allocation pattern of *Phyllostachy edulis* forests in western Fujian province. Chinese. J Ecol. 2009; 28(8): 1482-1488.

27. Zhou YR, Yu ZL, Zhao SD. Carbon storage and budget of major Chinese forest types. Acta Phytoecol Sinica. 2000; 24(5): 518-522.

28. Anand S, Zeng DH, Chen FS. Effect of young woody plantations on carbon and nutrient accretion rates in a redeveloping soil on coalmine spoil in a dry tropical environment, India. Land Degrad Develop. 2005; 17: 13-21. http://dx.doi.org/10.1016/S0378-1127(01)00435-2

29. Zhou B, Fu M, Xie J, Yang X, Li Z. Ecological functions of bamboo forest: research and application. J Forestry Res. 2005; 16 (2) 143-147. http://dx.doi.org/10.1007/BF02857909

30. Kurothe RS, Batta RK. Sharma JP. Soil erosion map of Gujarat. Ind J Soil Cons. 1997; 25(1): 9-13.

31. Zhang M, Zheng YS, Chen LG. A preliminary report on introduction experiment of bamboo into coastal sandy area. J Southwest Forestry College. 2007; 27: 48-50.

32. Singh PV, Bhardwaj P, Kumar A. Effect of mango, bamboo and haldu plants on physico-chemical properties of soil in tarai region. Progressive Hortic. 2012; 44(1): 130-136.

33. Tiwari SP, Patel AP, Singh HB. 1998. Soil health as affected by conservation measures in ravine lands of Gujarat. In: Soil and water conservation, challenges and opportunities. Eds: Bhushan LS, Abrol IP, Rama Mohan Rao MS. Indian Association of Soil & Water Conservationists, Dehradun.