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Exploring the use of bamboo for accelerated reclamation of degraded mined sites in Ghana

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Abstract: Bamboo is useful for soil erosion control, carbon sequestration and restoration of degraded land. In Ghana, the role of bamboo for land restoration has not been fully assessed. The main objectives of this study were to explore the potentials of bamboo to reclaim degraded mined land and to identify suitable bamboo species. Plots measuring 825 m^2 were demarcated on un-mined, reclaimed mined and un-reclaimed mined sites located in the moist semi-deciduous forest in Ghana. Seedlings of seven bamboo species were planted at 2m x 2 m matrix in blocks on each plot and the seedlings were assessed for survival rate, shoot production rate, height growth and qualitative phenotypic characteristics. The results indicated 97% survival of seedlings of all the species on all the plots and 70% of seedlings developed new shoots on the un-mined and reclaimed sites one month after planting while the un-reclaimed site recorded 50%. Also, the mean shoot production for reclaimed-, un-mined-, and un-reclaimed mined sites were 3.0, 2.0 and 1.0 shoots per clump respectively with corresponding mean height growth of approximately 173 cm, 113 cm and 63 cm after three months. By the tenth month, the bamboo had formed an impenetrable barricade on the reclaimed and un-mined sites. *Dendrocalamus membranaceus*, *Oxytenanthera abyssinica*, and *Bambusa vulgaris* var. *vittata* performed well on all sites in terms of foliage accumulation. Hence, they are recommended for rapid reclamation of degraded mined lands in southern Ghana.

Key words: Degraded mined land, reclamation, bamboo.

INTRODUCTION

Bamboo is a renewable resource and grows abundantly in both the tropical and sub-tropical countries (Fu and Banik, 1996). Bamboo culms possesses rapid growth capabilities hence they are able to reach maturity within three to five years (Zhou, 1995). They generally form an understorey or mixture with other tree species in the tropical natural forests. Selective harvesting can take place every year in an established bamboo forest.

The growth dynamics and the rooting system make bamboo a perfect species for preventing soil erosion and land degradation. Gaur (1987) has reported that due to its fast growth, easy propagation, soil binding properties and short rotation, bamboo is an ideal plant for use in afforestation, soil conservation and social forestry programmes. One of the best features of bamboo is its ability to sequester more carbon dioxide than just about any other plant within the first two years after establishment (INBAR,

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2010). The report stated that two year old bamboo forest can sequester 17 times as much carbon dioxide as a typical Chinese Fir plantation of the same age. Zehui (2001) has reported that the rapid growth of bamboo enables it to absorb large amounts of carbon dioxide from the air and convert it into biomass. Typically, bamboo can absorb 12 tons per hectare and releases 35% more oxygen than other plants of the same size and area. As indicated in Zehui's (2001) report, due to bamboo's high nitrogen consumption, it helps mitigate water pollution, as it takes up and transforms nutrient wastes when planted alongside manufacturing zones, intensive livestock farming areas, and sewage treatment facilities. It can also be used to desalinate sea water.

Currently, land degradation has assumed international dimensions due to detrimental impacts it exerts on agriculture and forest lands. Several productive lands are lost to land degradation annually hence causing unprecedented conversion of forest lands to agricultural field for food production. According to Bai *et al.* (2008) land degradation is defined as the long-term loss of ecosystem function and productivity caused by disturbances from which the land cannot recover unaided. It is the cumulative result of derivative processes regulated by natural and anthropogenic factors. As a result of reduction in the productive land area, rapid conversion of forest into agricultural lands to ensure food security forest encroachment for settlement and infrastructure development, restoration of degraded lands has become extremely important (Mishra *et al.,* 2014).

Bamboo is one of the species reputed for its extraordinary performance on poor or deficient soils hence it is a suitable candidate species for reclamation of degraded lands. It can be grown under diverse climato-environmental conditions such as arid, swamps, windy and sloppy lands. This enables it to be used as a pioneer plant in restoring degraded land. The inherent adaptability, as well as the nutrient and water conservation capabilities of bamboo make it a fore-runner plant in the eco-restoration of degraded land. Due to its fast growth and rapid accumulation of dense foliage, bamboo is capable of maintaining a thick layer of litter. This exceptional accumulation of litter layer assists in maintaining a suitable microclimate necessary for restoration of degraded land (Mishra *et al.,* 2014). Different species of bamboos affect soil properties in different ways; some species have been reported to increase microbial biomass in the rhizosphere zone by providing a large root surface, which helps in increasing the soil fertility (Arunachalam and Arunachalam, 2002)

According to Sharma (1980), there are about 75 genera and 1,250 species worldwide and mostly confined to South- East Asia. Fifteen genera and 43 species of bamboo are native to Africa. *Bambusa vulgaris* is one of the important sympodial bamboos widely distributed in Southwest China and elsewhere in the tropics (INBAR, 2006). Irvine (1961) identified three different types of bamboo in West Africa, including Ghana, namely *Bambusa vulgaris* (Green type and Yellow & Green striped bamboo), *Dendrocalamus strictus*, and *Oxytenanthera abyssinica*. However, *B. vulgaris* is a sympodial and the most common native bamboo species in Ghana occurring in the reserves, community lands and farmlands in the forest zones of the country and account for about 95% of Ghana's bamboo resources (Oteng-Amoako *et al.*, 2005). *Oxytenanthera abyssinica* is a sympodial and occurs mainly in the savanna zone of Ghana but its growth performance and utilization are limited due to the frequent wildfires and grazing by cattle and other ruminants in the northern part of the country.

Several other bamboo species have been introduced into the country to help diversify bamboo resources as well as providing suitable species for particular applications. Some of the introduced species are *Dendrocalamus latiflorus, Bambusa bambos, Dendrocalamus brandisii, Guadua chacoensis, Bambusa oldhamii, Bambusa ventricosa, Dendrocalamus membranaceus, Bambusa hetrostachya, Dendrocalamus barbatus* and *Bambusa edulis*.

About 70% of the local communities in Ghana use bamboo in one form or the other and majority of them are annual users of bamboo products (Tekpetey, 2011). The potential of bamboo is not adequately utilized in Ghana considering their uses elsewhere in Asia. Research and development effort on bamboo in Ghana has been focused on the utilization and the basic inventory of the natural stands (Oteng-Amoako *et al.*, 2005; Tekpetey, 2011; Essien *et al.*, 2011). Although bamboo is known as a fast growing species, growth rate and the stand dynamics differ with site, type of species and the local weather conditions. However, information on growth dynamics of bamboo which forms the basis of large scale bamboo plantation development is lacking in Ghana.

Surface mining, usually referred to as "galamsay," is one of the activities causing deforestation and land degradation in Ghana and 3,000 ha are degraded annually. This wide spread illegal mining activity in the forest zone of Ghana and its associated water pollution, land degradation and forest depletion place the forest resources under serious risk of species extinction. Both the legal and illegal mining operations cause noise and air pollution as a result of the release of dust into the environment, consequently possesses health hazards in the fringe communities. Bamboo is known to be used to reduce the noise impact, reclaim degraded land and used as barricade in several sensitive areas (Mishra *et al*., 2014). The candidate species must be fast growing both in density and height, perform well on poor soils, produce copious foliage and others. However, these functions of bamboo vary with species, local climato-edaphic conditions, and management practices adopted. Therefore the objectives of this study were to explore the potentials of bamboo for reclamation of degraded mined sites and also to select the appropriate bamboo species suitable for reclamation. This information will help bridge the gap and set the platform for large scale restoration programmes on mined sites using bamboo in the country.

MATERIALS AND METHODOLOGY

Selected sites

Three mining fringe communities were selected based on existing land conditions and proximity to the communities to the mining activities in the Ashanti Region in the Semi

Deciduous forest zones. All the selected communities had experienced various levels of alluvial mining activities in the past decade and the soils are at different levels of recovery from the past mining operations. The different soils were identified based on the nature of the land. These were un-mined sites (UMS), reclaimed mined sites (RMS) and un-reclaimed mined sites (URMS) and the description of these land forms are:

I. Un-mined site (UMS) – the site is an undisturbed fertile land covered with thick black top soils used for productive farming activities. The site contains all the necessary macro and micro plants nutrients in sufficient quantities to support vigorous plants growth. The soil has good structure which promotes aeration, root penetration, water percolation with no signs of erosion. It is predominantly covered by perennial crops such as cocoa, oil palm, and food crops such as plantain, pepper, cassava and cocoyam. (Figure 1)

II. Reclaimed mined site (RMS) – this site was mined but was backfilled with alluvial gravels and boulders covered with laterite soil mix (Figure 2). It is rich in iron and phosphorus but lacks several macro and micro nutrients such as potassium, magnesium, zinc, copper and molybdenum. The soil has good aeration but prone to compaction and erosion. The boulders may impede root penetration and may affect growth and productivity. However, since the soil is friable it allows aeration and good drainage.

III. Un-reclaimed mined sites (URMS) – this site was mined and as a remnant from the mining activities it had been naturally leveled up by rain water hence only the sub-soil remains. At the time of the present study the site was seriously eroded and compacted, and was covered with annual weeds which wither due to intense sun scorch (Figure 3).

Site Preparation and Planting

The un-mined site was used as a control in this study since it presents the ideal land productivity index in the selected communities. A plot measuring approximately 825 m^2 was demarcated in each of the identified sites. The food crops and the vegetation on all the selected sites were cleared to prevent competition. The un-reclaimed mined site (Figure 3) was harrowed to enhance root penetration and thus ensuring seedling survival. On both the reclaimed and the un-reclaimed mined sites, top soils rich in plant nutrients were used to fill the planting pits (holes) to help supply the needed nutrients during the early stages of seedling establishment to prevent seedling mortality. The bamboo seedlings used for this study were procured from the Forestry Research Institute of Ghana, the seedlings were produced from seeds under shed and seven bamboo species were planted on each site (Table 1). These species were selected based upon their availability in the nursery and their potential utilization by the selected communities. A completely Randomized Block Design was used in planting the seedlings and the same arrangement was replicated on all sites. A 4 m buffer was left between blocks to prevent overshadowing between species. The sites were pegged and planted using 2 m x 2 m spacing matrix and the pits covered with top soil on only the mined sites. The planted seedlings were watered regularly to prevent water stress and mortality. The sites were assessed for seedling survival, shoot production, height growth of dominant shoots and foliage production. Assessments were carried out on the first, third and tenth months after seedling planting on each site. However, the first assessment was performed mainly to determine seedling survival and shoot production. All seedlings without leaves were considered dead during the survival assessment and only new shoots were counted.

Table1: List of Bamboo species planted at the trial plots

Species planted on each site		
Un-mined	Reclaimed	Un-reclaimed
Dendrocalamus strictus	*Dendrocalamus strictus*	*Dendrocalamus strictus*
Oxytenanthera abyssinica	*Oxytenanthera abyssinica*	*Oxytenanthera abyssinica*
Bambusa vulgaris var. *vittata*	*Bambusa vulgaris* var. *vittata*	*Bambusa vulgaris* var. *vittata*
Bambusa oldhamii	*Bambusa oldhamii*	*Bambusa oldhamii*
Bambusa ventricosa	*Bambusa ventricosa*	*Bambusa ventricosa*
Dendrocalamus membranaceus	*Dendrocalamus membranaceus*	*Dendrocalamus membranaceus*
Guadua chacoensis	*Guadua chacoensis*	*Guadua chacoensis*

Figure 1: Un-mined sites -undisturbed natural farm land selected within a cocoa / plantain farm.

Figure 2: Reclaimed mined sites, with fair soil cover, i.e. backfilled alluvial mined site of gravels and boulders covered with laterite soil mix

Figures 3: Un-reclaimed mined sites with poor soil cover, i.e., un-reclaimed alluvium terrace ground, a remnant from the activities of "galamsey" operators which had been leveled up. Only the sub-soil remains

RESULTS AND DISCUSSIONS

Growth Assessment

The first site assessment was performed a month after planting to assess the condition of the seedlings. The results indicated 97% survival rates across sites but with varying seedling vigour. This high survival rate may be due to the application of top soils which are relatively rich in nutrients as well as the regular watering. This is because bamboo, like any other crops requires water and nutrients to establish especially during the initial stages of plant development. However, this high survival rate even on the poor un-reclaimed mined site may confirm bamboo's inherent ability to grow on nutrient deficient soils where most tree species cannot survive. The seedlings on the un-mined and reclaimed sites looked healthier than those on the un-reclaimed mined site. Also, about 70% of all the bamboo seedlings planted on un-mined and reclaimed mined sites produced new shoots while the un-reclaimed site recorded 50% of the seedlings producing shoot. Poor soil structure (compact soil) may be the major contributing factor to this relatively low shoot production.

Second Assessment

The second assessment was conducted three months after planting and the major parameters assessed were shoot production and height growth of two dominant shoots per clump. The results are presented in Table 2. The un-mined and reclaimed mined sites recorded the highest shoot production per seedling on an average, with 2.0 and 3.0 shoots per clump respectively, and corresponding mean height growth of approximately 113 cm and 173 cm, respectively (Table 2). The un-reclaimed mined site recorded the least shoot production per clump with a mean shoot production of one (1) shoot per clump and mean height growth of approximately 63 cm (Table 2). Figures 4 – 6 depict comparative growth performance of one of the bamboo species – *Bambusa vulgaris* var. *vittata* on all the selected sites.

Table 2: Growth performance of bamboo seedlings at trial sites three months after planting

Site	Average number of shoots per clump	Mean height (cm) of two dominant shoots per seedling
Reclaimed mined site	3.0	173.3
Un-mined site	2.0	112.8
Un-reclaimed mined site	1.0	62.7

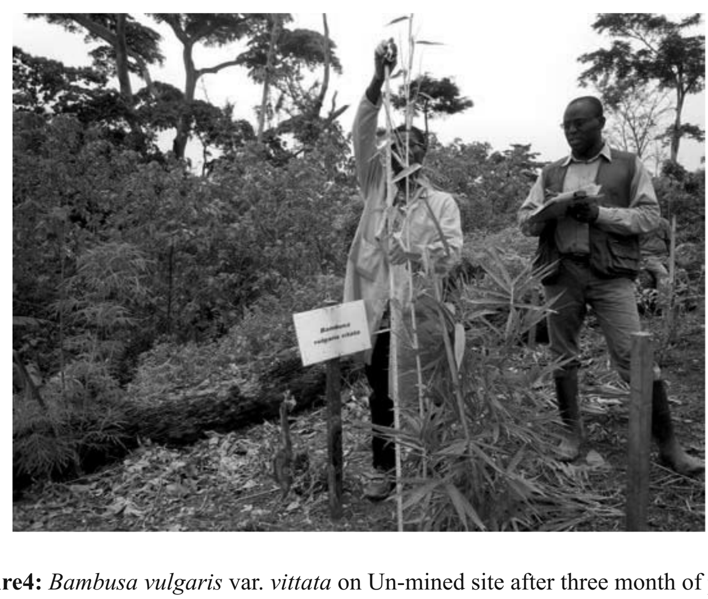

Figure4: *Bambusa vulgaris* var. *vittata* on Un-mined site after three month of planting

Figure5: *Bambusa vulgaris* var. *vittata* on Reclaimed mined site after three month of planting

Figure6: *Bambusa vulgaris* var. *vittata* on Un-reclaimed mined site after three month of planting

Third Assessment

The third assessment was conducted ten months after planting. The parameters considered in this assessment were survival of shoot, qualitative phenotypic appearance of the bamboo clump as well as biomass accumulation potential based on foliage (leaves, shoots, offshoots), culm size and height. The clumps had fairly closed up making assessment of individual culms in each clump impossible hence qualitative phenotypic characteristics were used to assess the foliage accumulation potentials of each species. The results are presented in Figures 7 – 9. Generally, the shoot production and survival rates for the all the sites were good. However there was higher shoot production and survival rate for the reclaimed site, followed by un-mined site and least on the un-reclaimed mined site. The shoot production and survival rate of each individual species on the reclaimed site was at least 30% (ranging from 30 to 60%) higher than of the un-reclaimed site. Recht *et al*. (1992) stated that roots of clumping bamboos penetrate about one meter deep into the soil for satisfactory shoot production. Therefore the higher shoot production on the reclaimed site may be due the loose and friable soil structure which provided unrestricted movement of the underground rhizomes of the bamboo. The un-mined site on the other, the shoot production and survival was at least 20% (ranging from 20 - 40%) higher that the un-reclaimed site. The foliage accumulation assessment of the bamboo species on each site is presented in Table 3. It must be stated that assessment of the species ten months after planting was short; but for rapid restoration programs such as river bank stabilization, restoration of bare mined sites, stabilization of erosion-prone sites and reserved forest boundaries restoration, ten months may be enough. For such rapid programmes, *Dendrocalamus membranaceus*, *Oxytenanthera abyssinica*, and *Bambusa vulgaris* var. *vittata* performed exceptionally well on all the sites. Therefore these species can be selected for rapid reclamation programmes. Some species such as *Bambusa oldhamii* has good lateral shoot production but has low foliage accumulation hence it may not be able to protect the soil from erosion in the first ten months. *Guadua chacoensis* on the other hand, has excellent foliage accumulation but slow shoot production for the first ten months of establishment. *D. strictus* and *B. ventricosa* are not suitable candidates for reclamation of the selected sites (Table 3) due to their slow pace of foliage accumulation. This characteristic feature is not ideal for reclaiming bare mined sites as a pioneer plant. However, they can be integrated into the fast growing ones to enhance biodiversity.

Table 3: Performance rating of bamboo species for reclamation of degraded mined sites

Bamboo species	Un-mined site	Reclaimed mined site	Un-reclaimed mined site
Dendrocalamus strictus	N.R	N.R	N.R
Oxytenanthera abyssinica	V.W	V.W	V.W
Bambusa vulgaris var. *vittata*	V.W	V.W	V.R
Guadua chacoensis	W	W	N.R
Bambusa oldhamii	W	W	N.R
Bambusa ventricosa	N.R	N.R	N.R
Dendrocalamus membranaceus	E	E	E

(E = excellent; VW = very well; W = well; NR = Not Recommended)

Figure7: *D. membranaceus* Un-mined site after ten month of planting

Figure8: *D. membranaceus* Reclaimed mined site after ten month of planting

Figure9: *O. abyssinica* Un-reclaimed mined site after ten month of planting

CONCLUSION AND RECOMMENDATIONS

The seedling survival was 95% on all the sites and on an average 70% of the seedlings planted on reclaimed and un-mined sites and 50% on the un-reclaimed mined site produced shoots one month after planting. Again, the mean shoot production per clump on reclaimed, un-mined and un-reclaimed site was 3.0, 2.0 and 1.0 respectively while the height growth of dominant shoot was 173cm, 113 cm and 63 cm for reclaimed, un-mined and un-reclaimed sites respectively. These results indicate the suitability of bamboo species for rapid reclamation of degraded mined sites. Based on this study, *Dendrocalamus membranaceus*, *Oxytenanthera abyssinica*, and *Bambusa vulgaris* var. *vittata* are recommended for rapid reclamation of degraded mined sites in Ghana and possibly any other tropical countries with similar climato-edaphic conditions bedeviled with surfacing mining activities. *Guadua chacoensis* and *Bambusa oldhamii* performed well on both un-mined and reclaimed mined sites hence they can be considered for reclamation of mined land if the land has been reclaimed after the mining activities.

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