# Planning of guadua bamboo forest: Considering both conservation and productivity

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## Abstract
More than 1000 species of bamboo have been identified around the world. Most of them growing under natural conditions (forest) and others because of their commercial value are cultivated. For managing and planning bamboo forest or bamboo plantations a proper knowledge on the specific features (growth, productivity and quality) of bamboo should be considered. Therefore, making adequate decisions depend on precise information gathered during inventories which should include information not only on variables associated with dynamics and productivity but also on ecological aspects such as biodiversity or carbon sequestration. Thus, a proper silvicultural management of bamboo forest or bamboo plantations ought be focused on obtaining a better growth, high yield and quality of the products according to the aim, whether commercial or conservation, but always supported on precise and accurate information. The species *Guadua angustifolia* (guadua) is a woody bamboo that represents an important natural resource in Colombia and particularly in the coffee region. The guadua has been traditionally used by farmers to build products such as houses, furniture, handicrafts, agglomerates, veneers and flooring. These bamboo forests are almost the only existing forest cover left in this region between 900 and 2000 meters above sea level. Currently, small fragments of forest dominated by guadua most of them not larger than 5 ha are the remnants of natural forest in that area. In this context, information from a case of study carried out within guadua stands was modelled in order to assess the possibility having constantly harvesting but simultaneously guarantying their conservation and ecological benefits.

Keywords: Modelling, dynamics, biomass, harvesting

## Introduction
About 1200 of bamboo species distributed around the world have been identified (Lobovikov, et al 2005). Some of them are successfully employed for obtaining raw material for different application such as furniture, housing, handicraft (Londoño 1998) and also mainly in Asia, bamboo species edible are an important source of incomes for rural communities (ie. Bhatt et al, 2003).

The bamboo species *Guadua angustifolia* Kunth (guadua) is a woody bamboo naturally distributed at north of South America and part of Central America (Londoño 1998). This species has been widely utilized for structural application due to high strength and dendrometric attributes (ie. culm diameter and culm length), in fact houses and bridges and roofs for rural housing are worldwide recognized. Therefore this bamboo species can be used for structural applications (Correal et al., 2009; Takeuchi et al., 2009).

The coffee region of Colombia is located between 900 and 2000 meters above sea level on the Andean mountain ranges. During several decades farmers transformed the original forest cover to coffee plantations. However, approximately 10 years ago coffee price dropped in the global market and plantations began to be eliminated and areas transformed mainly to pastures. Conventional livestock systems implemented on these areas have generated problems associated to soil degradation and biodiversity loss and consequently the productivity of these new farming systems has considerably declined (Murgueitio & Calle 1998).

The land use dynamics has generated a landscape highly fragmented. Therefore, most of the forest patches are not larger than 5 ha (Camargo and Cardona 2005). These patches are remnants of forest where guadua is the dominant species. In spite of being fragmented, these forests are an important refuge of biodiversity and might be used as stepping stones to develop strategies of ecosystems restoration. Some studies have registered more than 400 woody species (Calle  and Mendez 2009; Ospina 2002),  83 bird species (Fajardo et al. 2006) and 18 of mammals (bats) which fulfil important ecological functions as seed dispersion (Perez-Torres et al.  2007). In addition, these forests are important for carbon sequestration, where values over 100 t $ha^{-1}$ of $CO_2$ equivalent were accounted within the aboveground biomass (Arango and Camargo 2010).

Guadua bamboo forests differ on properties and characteristics (Camargo 2006; Garcia 2004). Therefore, management should be carried out according to the particularities of each stand. For a proper management Camargo (2006) and Camargo et al. (2008) established a critic level where guadua stands might be deteriorated due to the excessive harvesting. Therefore, guadua forest planning should be defined considering this limit and to procure implementing adequate practices in order to avoid any damage or deterioration.

In this paper we used information from guadua stands located in the coffee region of Colombia. We model different sceneries of harvesting and to estimate the possibilities of obtaining culms for different application as well as residuals as a source of biomass for bioenergy. Additionally, it was considered the stock of carbon remaining within the aboveground biomass of living culms.

# Methodology

Information on guadua culms was collected in Yarima farm, which is located in the coffee region of Colombia, in the municipality of Pereira. About 26 ha of natural guadua bamboo forest were assessed in terms dendtrometric and stands variables. Bamboo forests were located under the following ecological conditions: an elevation of 1150 meters above sea level, 2500 mm/ year on average of precipitation, temperature of 24°C on average and soils inceptisols slightly acids.

Values obtained on harvesting and dynamics are taken from the study previously carried by Camargo and Arango (2012), while those related with residues and biomass were obtained from Camargo et al. (2012).

A stratified sampling design (Akca 2000) was used for collecting information from 40 plots. Because of the aim of this study, the variables considered include those such as culm maturity, the total number of culms per plot and the diameter measured on the internode at breast height (Camargo 2006).

Considering the guadua stands assessed, two scenarios were defined according to the harvesting regime. In scenario 1, an annual harvesting of 25% of mature culms was simulated, whereas, in scenario 2 an annual harvesting of 12%. Both scenarios were defined for a period of 20 years considering changes on harvested culms, total living culms and dry culms. Simulations were performed by using the software Silvcamark 1.1 (Morales 2005).

Simultaneously, information on residues of biomass was collected from those areas in the farm where harvesting was being carried out. The residues as well as the dry culms harvested were accounted. The values of biomass were estimated from factors previously calculated by Arango and Camargo (2010).

# Results and discussion

A total density of 5211 culms per ha was estimated from the inventory. This value is below the average registered by other studies along the coffee region of Colombia (ie. Kleinn and Morales 2006, Camargo 2006). However it might be associated with the annual harvesting applied in this farm. In spite of the lower value, the number of culms per ha is over the limit established by Camargo (2006) and Camargo et al. (2008) of 2500 culms per ha therefore, there is any threat of deterioration.

From the sceneries simulated, it is feasible to obtain a proper number of commercial culms. Hence, it represents possibilities of incomes for selling these culms. From the scenario 1, about 317 culms per ha on average might be obtained, while from scenario 2, around 220 culms per ha. These values are important in the context of the coffee region of Colombia and correspond to the possibilities of market. However, the scenario 1 shows at the end of the period simulated, values of living culms very close to the critic limit established (2500 culms per ha). Therefore, in order to avoid deterioration of the bamboo stands, the harvest intensity should be slightly reduced. The behavior of stands under the two sceneries may be observed in figure 1 and 2.

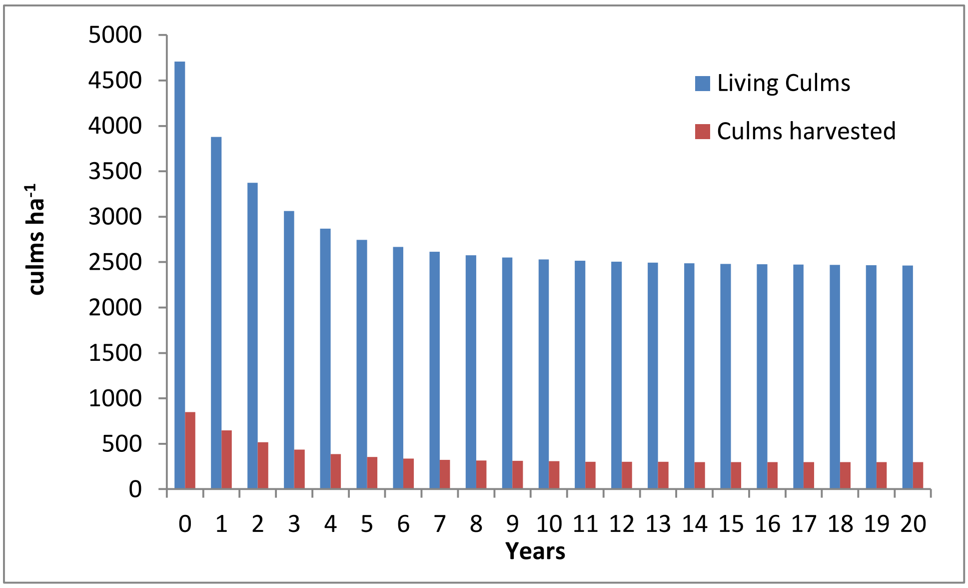


**Figure 1.** Living culms and harvested culms for a period of 20 years. Harvest intensity of 25% of commercial culms every year. Scenario 1. (Source: Camargo and Arango 2012)

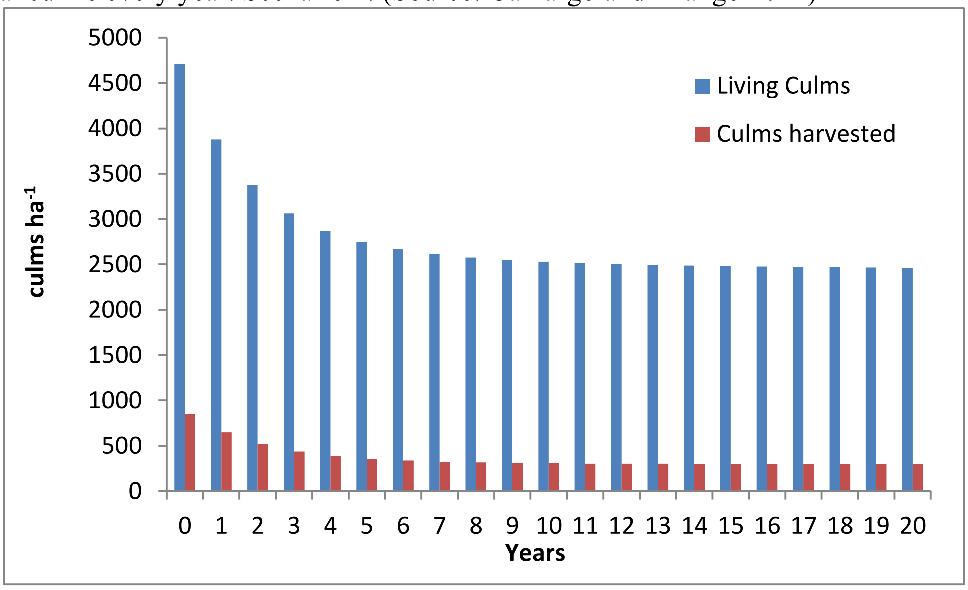


**Figure 2.** Living culms and harvested culms for a period of 20 years. Harvest intensity of 12% of commercial culms every year. Scenario 2.(Source: Camargo and Arango 2012)

If the values of living culms are kept at level suggested, the existing biodiversity registered within these forest might be benefited. In fact, it has been described by some authors (ie. Ospina 2002 or

Perez –Torrez et al. 2007). In addition, other function such as carbon sequestration calculated for both sceneries provided also evidences of the ecological worth associated with these bamboo forest. A value of 102,5 t $ha^{-1}$ of $CO_2$ equivalent for the scenario 1 and 116 t $ha^{-1}$ of $CO_2$ equivalent for the scenario 2, were estimated on average for the above ground biomass of living culms. These values represent an important stock of $CO_2$ stored and show the relevance of these forests as sink of GHG. The $CO_2$ values accounted are comparable with those with other forest ecosystems (ie. Gutierrez et al. 2006) or other bamboo species (ie. Xiaojun et al. 2011).

In addition, whether the $CO_2$ included in the culms harvested is considered, 14 t $ha^{-1}$ of $CO_2$ equivalent for the scenario 1 and 8 t $ha^{-1}$ of $CO_2$ equivalent for the scenario 2 might be added to the total value estimated for living culms. If culms harvested are used for products with high durability, these products might be also important sinks of GHG. Only 4 t $ha^{-1}$ of $CO_2$ equivalent for the scenario 1 and 6 t $ha^{-1}$ of $CO_2$ for the equivalent for the scenario 2 corresponding to the dry culms can be accounted as emission associated with harvesting of these forests. Values for the period of 20 years are shown in figure 3 an4.

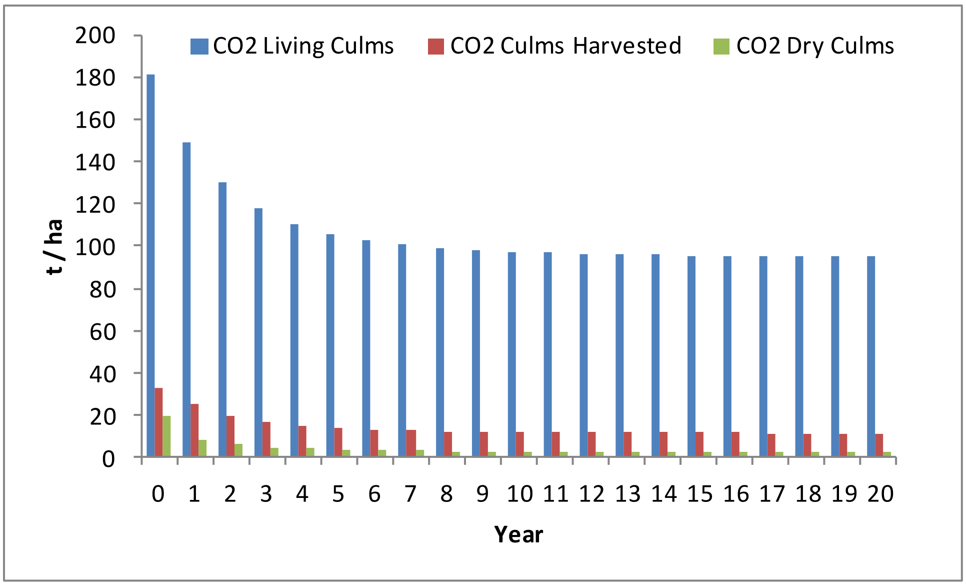


**Figure 3.** $CO_2$ stored in living culms, culms harvested and dry culms t $ha^{-1}$ of $CO_2$ equivalent for the scenario 1 for a period of 20 years. Harvest intensity of 25% of commercial culms every year.

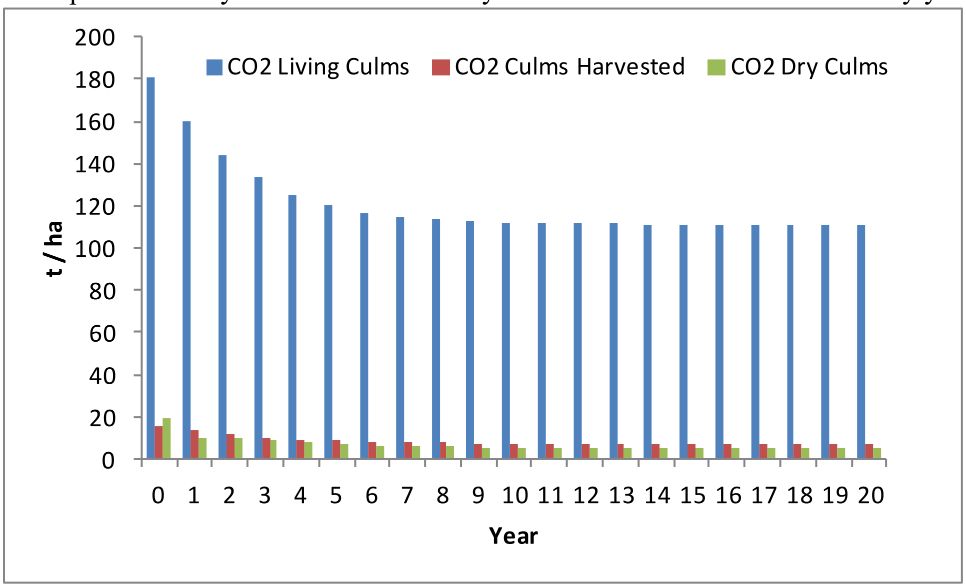


**Figure 4.** $CO_2$ stored in living culms, culms harvested and dry culms t $ha^{-1}$ of $CO_2$ equivalent for the

scenario 2 for a period of 20 years. Harvest intensity of 12% of commercial culms every year.

The proportion of biomass residues estimated from a culm harvested is about 37%. Thus, the average of culm biomass for a period of 20 years is of 1,4 t $ha^{-1}$ for the scenario 1 and 0,8 t $ha^{-1}$ for the scenario 2. Besides, if dry culms are included 1,1 t $ha^{-1}$ $year^{-1}$ and 1,8 t $ha^{-1}$ $year^{-1}$ for the scenario 1 and 2 respectively might be added. This value might increase with biomass of branches and leaves, however it is recommended do not removed from the forests this kind of residuals instead they can be used for nutrient recycling. The offer of biomass residues for the period simulated can be observed in figures 5 and 6. The possibility of using this biomass for bioenergy has been also remarked by other authors for other bamboo species (Zehui et al. 2012; Xiao et al. 2007) as well as the low costs compared with others sources (Barathi 2011).

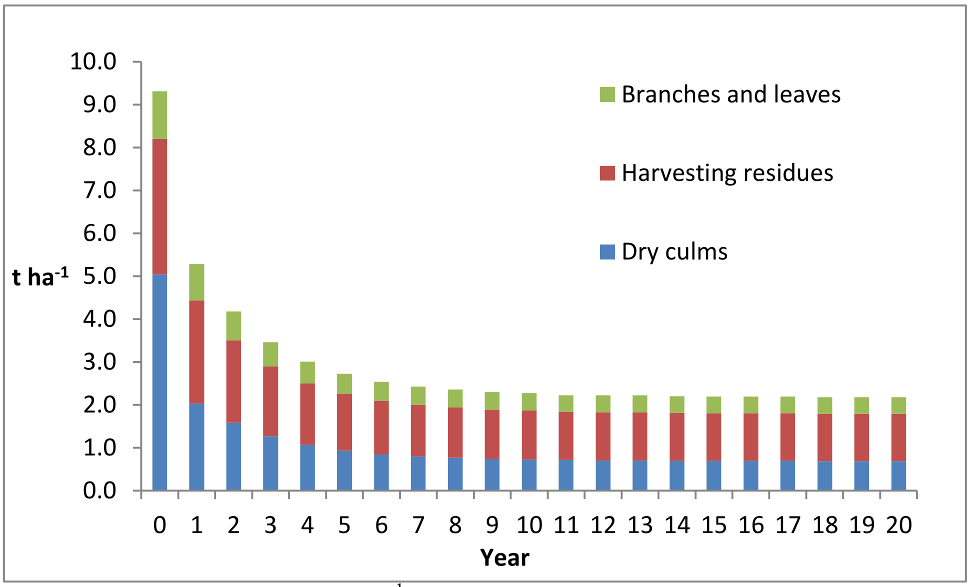


**Figure 5.** Annual offer of biomass (t $ha^{-1}$) from natural guadua stands for a period of 20 years. Harvest intensity of 25% of commercial culms every year. Scenario 1. Source: Camargo et al. 2012

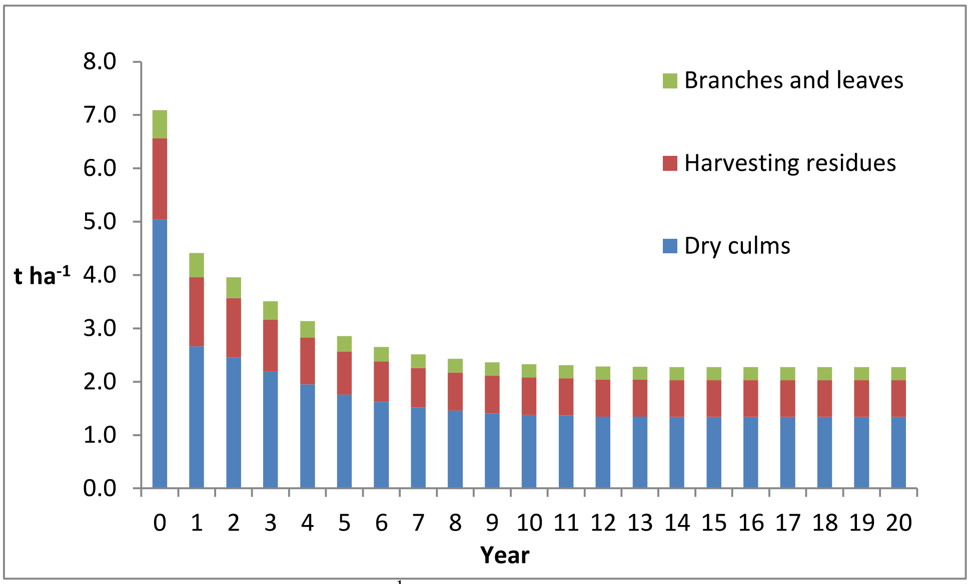


**Figure 6.** Annual offer of biomass (t $ha^{-1}$) from natural guadua stands for a period of 20 years. Harvest intensity of 12% of commercial culms every year. Scenario 2. Source: Camargo et al. 2012

# Conclusion

The guadua bamboo forests located in the coffee region of Colombia may provide important benefits to farmers. These benefits are associated with the possibilities of selling the culms and additionally, it was evidenced the potential for using harvesting residues with commercial aims. Simulating the two harvesting sceneries was important for planning the management of these bamboo forests for a period of 20 years. These results may contribute to make proper decisions on management which can guarantee both, productivity and conservation. Thus, the ecological functions of these forests are kept even under a periodical harvesting provided that the limits established are respected.

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