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CONSERVATION

Valuation of ecosystem services of guadua bamboo (*Guadua angustifolia*) forest in the southwestern of Pereira, Colombia

Valoración de servicios ecosistémicos de bosques de guadua (*Guadua angustifolia*) al suroriente de Pereira, Colombia

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ABSTRACT

Agriculture and urban expansion have caused fragmentation of the remaining forests located along the Otún and Consotá river watershed in the municipality of Pereira, Department of Risaralda, Colombia. These forests are dominated by the guadua bamboo species *Guadua angustifolia* Kunth, which provided raw material for different purposes and additionally fulfills important ecological functions. The aim of this study was to evaluate ecosystems services associated with these forests such as carbon storage, soil water storing capacity, and the financial feasibility related to guadua culms commercialization. The carbon storage was estimated from the aboveground biomass and soil organic matter; soil water storing capacity was associated with physical soil properties. Whereas the provisioning ecosystem service was assessed through a cost-benefit analysis performed with different production scenarios. The carbon stock was found to be 672.3 t C / ha (22 % in biomass and 78 % in the soil at a depth of 45 cm). The average soil water storing capacity was 292.4 m^3 / ha. The cost-benefit analysis evidenced the financial feasibility for the scenarios when projected sales are more than 3 % than current. Bamboo forests provide ecosystem services that are yet another justification for better economic compensation and a medium to promote balance between ecosystem services and the financial situation of producers, who derive their incomes from its production.

Keywords. Benefit cost analysis, carbon dioxide capture, ecological functions, soils protection

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RESUMEN

La agricultura y la expansión urbana han causado fragmentación de bosques remanentes de las cuencas Otún y Consotá en el municipio de Pereira, Departamento de Risaralda, Colombia. Estos bosques están dominados por guadua, *Guadua angustifolia* Kunth, de la cual se obtiene materia prima para diferentes propósitos. Estos bosques, además cumplen funciones ecológicas importantes. El objetivo de este estudio fue evaluar los servicios ecosistémicos de almacenamiento de carbono, capacidad de almacenamiento de agua en el suelo y la factibilidad financiera de los bosques de guadua asociada a la venta de culmos. El dióxido de carbono fue estimado a partir de la biomasa área y la materia orgánica del suelo; la capacidad de almacenamiento de agua en el suelo se calculó a partir de la porosidad y el contenido de humedad. El servicio ecosistémico de provisión fue evaluado mediante el análisis costo-beneficio en diferentes escenarios de producción. El carbono almacenado en los bosques fue de 672,3 t C / ha de CO2 (22 % en la biomasa y 78 % en el suelo a una profundidad de 45 cm). La capacidad promedio de almacenamiento de agua en el suelo fue de 292,4 m^3 / ha. El análisis costo-beneficio evidenció una factibilidad financiera para los escenarios donde las ventas proyectadas se incrementarán 3 % respecto a las actuales. Los bosques de guadua proveen servicios ecosistémicos que son otra justificación para una mejor compensación económica y un medio para promover el equilibrio entre los servicios ecosistémicos y la situación financiera de los productores, que obtienen sus ingresos de la producción.

Palabras clave. Análisis costo beneficio, funciones ecológicas, protección del suelo, stock de carbono

INTRODUCTION

In Colombia's coffee-growing region, the forests located between 900 and 2000 m above sea level, is the last remnant of natural vegetation in this altitudinal belt. During most of the last century, agriculture, livestock production, and intensive urbanization have transformed the natural vegetation of this landscape (Koim 2009).

In recent years, studies have highlighted the ecological importance of guadua bamboo forests (*Guadua angustifolia* Kunth) and emphasized on their role for biodiversity conservation and provision of ecosystem services (Camargo *et al*. 2010b, Chará *et al*. 2010, Sanchez and Camargo 2014, Arango *et al*. 2017, Ramirez 2017). There is a need to scientifically quantify the extent of biodiversity delivered services for decision makers to formulate conservation strategies (Wunder 2006). In the lower La Vieja river basin, which is also part of Colombia's coffee-growing region, Calle and Piedrahita (2008) identified that approximately 70 % of existing plant biodiversity is confronted with poor habitat connectivity as forests are fragmented. Accordingly, this region has been demonstrated to be very biodiverse, for example floristic studies of Ospina (2002) and Ospina and Finegan (2004) registered 182 species belonging to 57 families; thereafter Ramirez (2017), found a similar value of 172 species. Likewise, in terms of fauna Sanchez and Camargo (2014), registered 115 species of birds.

Benefits of guadua bamboo forests also include soil protection and net uptake of CO_2. Guadua bamboo forests have more favorable physical soil properties than other land uses, as well as less erosion and higher nutrient retention. Compared to other tropical forests, guadua bamboo forest store high levels of atmospheric CO_2 (Camargo *et al.* 2010b, Kleinn and Morales 2006, Arango and Camargo 2010, Arango 2011), which can be explained by the exceptionally high density, of approximately 6940 culms per ha (Kleinn and Morales 2006).

Agricultural activities have generated new landscapes with altered structure and functionality; more than 75 % of the existing fragments of guadua bamboo forests are smaller than 5 ha in size, with shapes and perimeters that prove disadvantageous in terms of connectivity. This condition is in fact a threat for all the above mentioned ecological functions.

Ecosystem services are related to the capacity of ecosystems and agroecosystems to provide the conditions that all living beings need to survive Daily (1997). The Millennium Ecosystem Assessment (MEA 2005) classified ecosystem services into four types: provisioning, regulating, supporting, and cultural. The challenge is to describe and assess the conditions of ecosystems and agroecosystems through information associated with their ecosystem services.

On the other hand, the economic approach may be a proper approximation for the valuation of ecosystem services. It quantifies the benefits and the impact that changes in ecosystems have on human well-being (GIZ 2011); however, not all the benefits of conserving biological diversity pass on to those who incur in the costs of conserving it, nor do all the costs of destroying biodiversity affect those who benefit from reducing it. This implies that the values associated with biodiversity and ecosystem services, other than monetary, are rarely considered in decision-making processes related to biodiversity (Swanson 1995).

The cost- benefit method of environmental economics can be used to approximate the economic value of ecosystem services. According to Freeman III (1993), Abelson (1996), Arrow *et al.* (1996), Boardman *et al.* (1996), Davies (1997), EPA (2000), and Gil *et al.* (2005), this method allows the inclusion of the economic dimension in policy decisions, on investment, resource allocation, and reduction of the environmental impact.

This study assessed the ecological and economic value of guadua bamboo forests located in the southwestern region of the municipality of Pereira, Colombia. The ecological value is examined by ecosystem regulatory services, which are functions of climate, nutrient, water cycle regulation, and erosion control. The economic value is measured as provisioning services, which is the generation of raw material such as culms and matting.

MATERIAL AND METHODS

Study area

The Yarima farm, located southwest of the city of Pereira in the lower Consota river basin, was selected as the study site as it contains natural guadua bamboo forest, with 28 ha distributed over three stands. Stand one covered 10 ha, stand two 7 ha, and stand three 11 ha (Fig. 1).

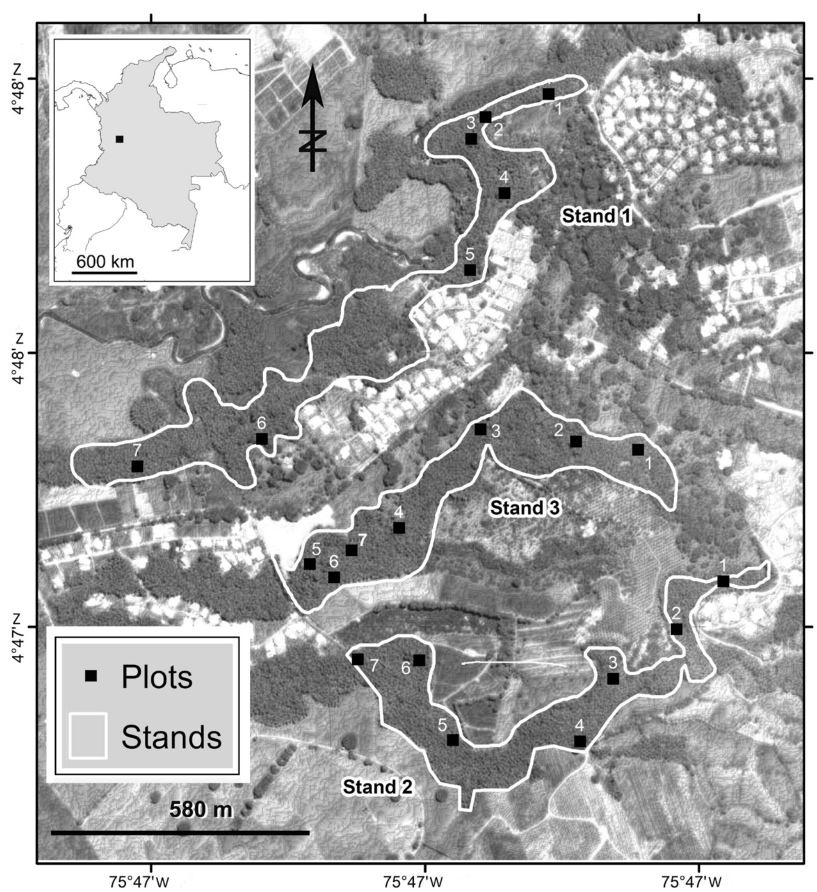

Figure 1. Study area located in lower Consota river basin in the southwestern region of the municipality of Pereira, department of Risaralda, Colombia.

Since 2007 these forests are certified under a voluntary forest certification standard in compliance with the Forest Stewardship Council (FSC) standards for bamboo management and conservation (Mejía 2010). The guadua bamboo stands are located at an altitude of 1150 m above sea level, with an average annual rainfall of 2262 mm, and an average temperature of 24 °C. Soils at this site, in the lower part of the Pereira-Armenia fluvial-volcanic fan, are characterized by hilly topography, with inceptisols influenced by pyroclastic materials mostly (volcanic ash), with a strongly acidic pH, high organic matter content, moderate fertility, and loamy clay texture according to an unpublished report from the Research Group on Management of Tropical Andean Agroecosystems of the Technological University of Pereira (Colombia) in 2014 on a description of the land units of the Yarima farm.

The valuation of ecosystem services was conducted during the second half of 2015; a total of 21 permanent plots of 100 m^2 were distributed along with the three guadua bamboo stands. Seven plots per stand were used to characterize soil properties (supplementary material 1 and 2). To characterize physical properties, soil samples were taken at four depth intervals (0–5, 5–15, 15–25, and 30–45 cm) (Supplementary material, Annex. 1) and for soil chemical properties at two depth intervals (0–25 and 25–50 cm) (Supplementary material, Annex. 2).

Information on culm diameter and total number of culms were recorded from each plot, the process of mensuration is extensively explained in Maya *et al.* (2017) and Arango *et al.* (2017). Additionally, financial information for the economic valuation was obtained directly from the Yarima farm owner and its accounting documents.

Characteristics associated with guadua bamboo forests were assessed to define the ecosystem services of regulation, support, and provisioning as defined by the MEA (2005). As follows: For the regulating services, nutrient availability, water cycle regulation, and erosion control, and sediment retention we measured the indicators of soil fertility, soil water holding capacity, and soil erodibility, respectively. Climatic regulation was related to carbon storage in soil and biomass and soil. For the supporting services, the rooting capacity was assessed through soil penetration resistance. Finally, the provisioning service was measured as the capacity to provide raw materials (culms and matting) and their market values. This information was then used to perform a cost-benefit analysis.

Furthermore, we categorized the performance of biomass carbon storage, economic performance, and soil conditions, based on critical values found in the literature. Therefore, we used the ranking methodology described by Dossman (2009) and Muñoz *et al.* (2016), where empirical continuous data are categorized between one and five levels, where five was the best condition and one represented the worst condition. By using this qualitative method, we were able to compare the importance of regulating, supporting, and provision ecosystem services for stakeholders as they were scored in the same units.

Calculations and measurements

From the 21 permanent plots, information of the total density of culms per ha and the average diameter of culms was taken from the inventory carried out by Arango *et al.* (2017), net culm volume and the average value of wood density came from the study of Maya *et al.* (2017). The values of culm biomass were then estimated considering both, net culm volume and wood density. Then according to Pan *et al.* (2004) and IPCC (c2006) the 0.5 conversion factor was used to obtain carbon stock. The total plant biomass was calculated by using an expansion factor of 1.4 based on the results of Arango and Camargo (2010) and Arango (2011).

Furthermore, soil carbon content was calculated according to the proportion of carbon obtained in samples taken up to 50 cm depth from the 21 permanents plots and the average bulk density measured at the same depth and used for determining soil mass. To qualify carbon as an ecosystem service, the critical value was assigned according to Malagón *et al.* (1995). After that, values were ranked between one and five according to Dossman (2009) and Muñoz *et al.* (2016).

Soil fertility, associated with nutrient availability, was measured considering eight chemical parameters. Acidity (pH), aluminum saturation, cation exchange capacity (CEC), base saturation, total bases, organic carbon, potassium, and phosphorus concentration. Thereafter, five categories (1-5) established by Ortega (1995) for each parameter, which ranged from very low to very high are defined.

Soil penetration resistance (associated with the rooting capacity of plants) was measured every 5 cm up to 45 cm depth with an Eijkelkamp penetrometer. Then the qualification was defined according to the critical level of 3 MPa Landsberg *et al.* (2003) and after ranked from one to five concerning to Dossman (2009) and Muñoz *et al.* (2016) and averaging the values from 5 cm down to 45 cm of depth.

Available soil water storing capacity, associated with water cycle regulation, was estimated from moisture retention curves, considering the amount of water held between field capacity and wilting point USDA (c2018). The calculation was done up to 50 cm depth. The critical level was defined according to Molfino and Califra (c2001) and then ranked according to Dossman (2009) and Muñoz *et al.* (2016).

The distribution of soil aggregates by size was used to qualify soil erodibility which represents the resistance to erosion. Therefore, the weighted average diameter of soil aggregates was calculated according to Malagón *et al.* (1995) and then ranked according to Dossman (2009) and Muñoz *et al.* (2016) between one to five.

Economic Valuation

The culms of guadua bamboo are used for commercial purposes. In this case, guadua bamboo is marketed as pieces of round culms or mats. From each culm, two pieces (poles) each of 6 m are usually obtained.

The economic valuation was based on detailed information gathered at the Yarima farm over the years 2007–2016, covering aspects such as investment costs, management plan, internal and external audits, public costs such as energy and water, taxes, and administration and operational costs including farm labor, however, for this aspect it is clarified that the workers eventually conducted out other tasks different than those related to guadua bamboo. For this reason, when financial viability was assessed, the effective worker time exclusively spent for guadua bamboo tasks was compensated reducing the number of workers paid by these labors to the equivalent number of workers that represent the effective time at 100 %. Lastly, sales revenue obtained during the study period as pieces of guadua bamboo culms preserved were also accounted.

The financial viability (FV) of the farming activity was assessed based on net present value (NPV) and benefit-cost (B/C) ratio.

- NPV is calculated by subtracting the NPV of expenditures (NPVE) from the NPV of income (NPVI) as follows:

  $$NPV = NPVI - NPVE, \text{when } \mathrm{NPV} > 0 \textit{ viable } NPV = NPVI - NPVE$$

- FV is defined as the value acquired by an investment over time, applying a discount rate as follows:

  $$FV = NPV\left(1+i\right)n$$

  where i = discount rate and n = time

- B/C ratio is defined by dividing the NPVI by the NPVE as follows:

  $$B/C = NPVI/NPVE, \text{ when B/C>1 viable}$$

Annual inflation during the period 2007–2015 was considered in both cases and applied to the monetary values of costs and incomes. A current discount rate of 8.75 % was used when applying the formula. Both the inflation rate and discount rate were obtained from the website of Banco de la República de Colombia (www.banrep.gov.co/es/inflacion-basica), which is considered the minimum acceptable rate for investment project approval.

Future scenarios (S) for six years (2017–2023) were subsequently projected at growth rates in sales of 3 %, 5 %, and 10 %, as compared to the performance of sales during the years 2014–2016. The above was also applied to a scenario in which the company had to pay for all the FSC certification costs.

In S1, S2, and S3, the Corporation for the Sustainable Management of guadua Bamboo (CORGUADUA, its Spanish acronym), a Colombian FSC-certified group, where Yarima farm is included, assumes the audits necessary for certification. S1 corresponds to the current or real scenario of the Yarima farm, S2 incorporates a 3 % growth in sales, and S3 a 10 % growth in sales during the first three years and a 5 % growth during the last three years.

In S4, S5, and S6, the Yarima farms pays for the certification costs. No growth in volume of sales was applied in S4, constant growth of 3 % was applied for all projected years in S5, and growth rates of 5 % and 10 % in sales was applied in S6, similar to S3, where a 10 % growth in sales was projected for the first three years and a 5 % growth for the last three years.

RESULTS AND DISCUSSION

Ecosystems services of guadua bamboo forests

The average carbon content stored in the total guadua bamboo biomass of the Yarima farm was 148.8 t / ha (±63.3) (Fig. 2). Values differed highly between stands mainly because of the dimensions of the culms (greater diameter and wall thickness) in culms of stand 1, and because of differences in culm density, with lowest values in stand 3. Soil carbon stock was 574 t / ha (±79.4) at 45 cm depth (Fig. 2). The soil carbon represented more than 70 % of the total carbon stored by the guadua bamboo ecosystems and showed lower variability between stands.

The values obtained of soil fertility are moderate according to the range for qualification established by Ortega (1995). The values between stands vary slightly and stand 2 showed the highest value. These values of soil fertility correspond to those registered by other studies carried out in similar conditions (Dossman 2009).

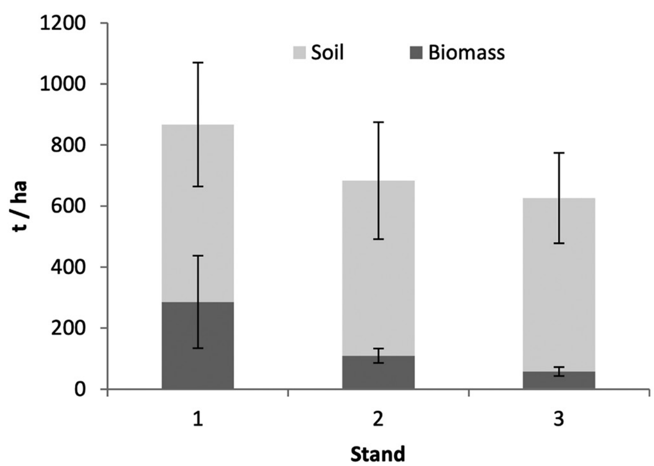

Figure 2. CO_2 stored (t / ha) in the total biomass and soil at 45 cm depth of guadua bamboo forests. Yarima farm, located in the southwestern region of the municipality of Pereira, Colombia. Vertical lines on the bars are standard deviation

Soil penetration resistance, available soil water holding capacity, and the distribution of soil aggregates by size were very similar among stands with average values of 1.27 MPa, 292.4 m^3 / ha and 5.15 mm, respectively. The values of each function or property were ranked according to the approach of Dossman (2009) and then associated to ecosystems services (Table 1).

Economic valuation

The benefit-cost analysis evidenced that, throughout the nine-year study period, the NPV for the current scenario (S1) reflected a negative value (-71,394,816 USD). Thus, this activity would be considered as nonviable. This negative value is related to the difference of the current investment value, which in this case was the investment of implementing forest certification minus the current value of recovery funds through operational flows corresponding to total income obtained from sales (NPVI) minus total expenditures (NPVE), to which the discount rate was applied. The FV showed a loss in financial terms for the 9 years.

In addition, the index of the convenience of this activity or benefit-cost ratio yields a value less than one, which might confirm that it is not profitable (Table 2). However, some of the costs associated such as those related to laborers are fully charged to guadua bamboo management when workers also support other activities within the farm.

DISCUSSION

The outcome of this study related to carbon stock shows the potential of guadua bamboo ecosystems to be a carbon

Table 1. Values of functions and soil properties ranked according to the associated ecosystem service. Values in parentheses are the standard deviation.

Soil property or function	Ecosystems services associated	Average Value Estimated	Value of the Ecosystem Services Ranked	Author of Reference for the Ranking Definition
Carbon stored in soil (t / ha at 0.5 m)	Climatic regulation	574.5 (±180.7)	4.2 (±0.05)	Malagon *et al.* 1995, Dossman 2009 and Muñoz 2016.
Soil fertility	Nutrient cycling	6 (±0.4)	2.5 (±0.15)	Ortega 1995, Dossman 2009 and Muñoz 2016.
Soil penetration resistance (MPa)	Rooting Capacity	1.26 (±0.14)	3.2 (±0.4)	Landsberg *et al.* 2003, Dossman 2009 and Muñoz 2016.
Available soil water holding capacity (m^3 / ha at 0.5 m depth)	Water regulation	292.4 (±50.7)	1.4 (±0.25)	Molfino and Califra 2001, Dossman 2009 and Muñoz 2016
Distribution of soil aggregates (mm)	Erosion resistance	5.1 (±0.13)	4.8 (±0.3)	Malagon *et al.* 1995, Dossman 2009 and Muñoz 2016

Table 2. Scenarios of economic valuation of ecosystem services provided by guadua bamboo forests in the southwestern region of the municipality of Pereira, Colombia.

Economic variable	Scenarios					
	S1	S2	S3	S4	S5	S6
NPV*	(71,394,816)	175,897,043	241,631,673	(186,103,843)	(13,611,425)	103,497,024
FV*	151,890,310	(208.025.737)	(285.767.209)	395.930.294	16.097.637	(122.401.402)
NPVI*	302.421.500	719.919.429	785.654.060	302.421.500	681.406.274	805.969.876
NPVE*	373.816.316	544.022.386	544.022.386	488.525.343	695.017.699	702.472.852
B/C	0.81	1.32	1.44	0.62	1.0	1.1

Discount rate: 8.75%. * Pesos

NPV = net present value; FV = future value; NPVI = net present value of income; NPVE = net present value of expenditures; B/C = benefit/cost.

sink. The average obtained is consistent with values registered in literature for this species e.g. Yuen *et al.* (2017) for both, soil and biomass. Also, compared to other natural ecosystems and agroecosystems, the CO_2 that is stored is also remarkably high. For example Gibbs *et al.* (2007), registered values of carbon stock in biomass for tropical equatorial forest between 193 and 200 t C / ha (approximately 706 to 732 CO_2 t / ha). On the other hand, for agroforestry systems with coffee plantations, Ehrenbergerova *et al.* (2016), found values of total carbon stock (biomass and soils) between 119 and 177 t C / ha (roughly 435 to 647 CO_2 t / ha). Guadua bamboo forests are similar to agroforestry systems, however keep the levels of biomass even after harvesting due to the growth dynamics (Arango and Camargo (2010) and Arango (2011)).

It would be important to remark that some authors are concerned about the real impact of bamboo as a carbon sink, due to its short life cycle (eg. Isagi *et al.* 1997, Düking *et al.* 2011). However, the use of guadua bamboo culms for structural application as promoted in this study is recognized to be a proper way of carbon storing for a longer time (Liese 2009). It is also, know that because of the rapid growth and dynamic bamboo species have big potential a carbon sink (Venkatesh *et al.* 2005, Nath and Das *et al.* 2007, Nath *et al.* 2008, Tariyal *et al.* 2013). The estimated values for guadua bamboo forest in Yarima farm are larger than those registered for other agroecosystems; this is the case of Magaña *et al.* (2004) in their study on full sun coffee systems where the estimated value was 10.2 t C / ha.

The moderate fertility of soils under bamboo forests is remarkable since that guadua bamboo stands are located on those steeped hills usually associated with marginal conditions. Nevertheless, soils maintain a moderate level of nutrients, showing the importance of guadua forests for supporting soil fertility. Similarly, Murgueitio (2003) found out that soils under guadua forest in the coffee region of Colombia showed nutrient content and chemical properties better or equal than those of other land uses, such as coffee or cattle farming, where usually fertilizers are applied.

One of the variables included for qualifying fertility is soil organic carbon (Ortega 1995), this variable was also higher in soils under guadua forest according to Murgueitio (2003) and is therefore associated with more carbon stored in the soils. The interaction between a high leaf litterfall with about 9 t /ha/year according to Marín *et al.* (2008) and andic soils which usually contains stable soil organic matter Matus *et al.* (2014), might explain the high potential of soils under guadua forest, facilitating their carbon sink role.

The values of the soil physical properties that were assessed are consistent with values found in previous studies (Murgueitio 2003, Camargo *et al.* 2010a) where better soil conditions were attributed to guadua forests in comparison to other land uses and coverages. Thus, the ecological functions that represent ecosystems services depend on soil properties and their interactions. Soil properties are inherent to their genesis, however, are negatively or positively influenced by land uses and the associated practices. It should be highlighted that soil use and management influence the services soils can provide (Adhikari and Hartemink 2016). One of these services that soils can provide is the maintenance of biodiversity, which on its term contribute to vital soil ecosystem functions (Adhikari and Har-

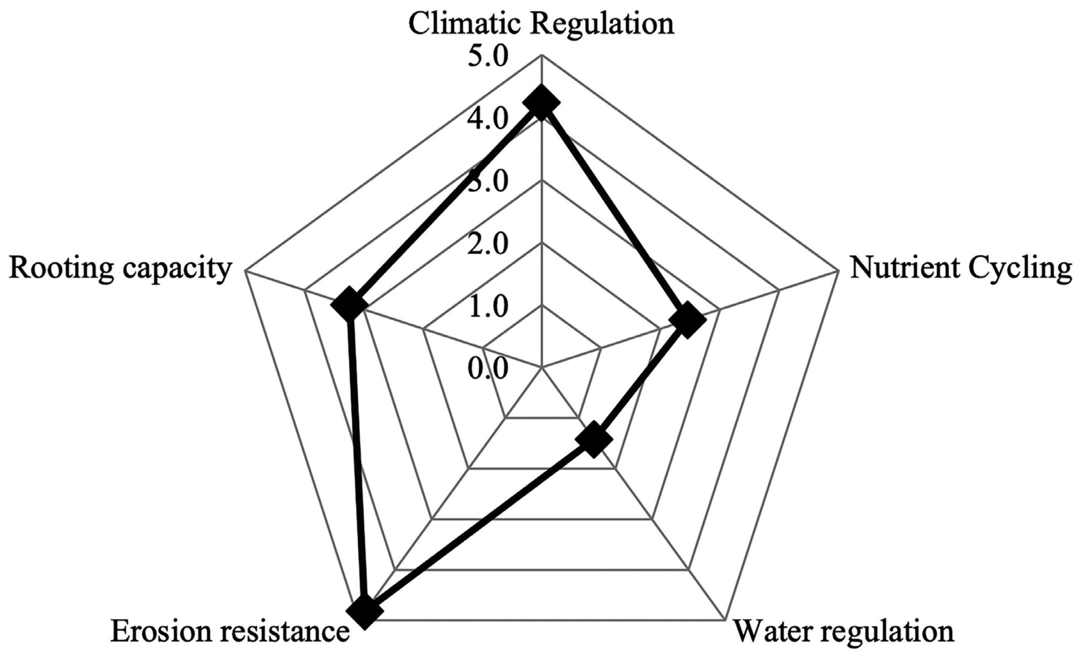

Figure 3. Qualification of soil ecosystem services in guadua bamboo forests in Yarima farm, located in the southwestern region of the municipality of Pereira, Colombia.

temink 2016) as well as to the flow of ecosystem services (Palm *et al.* 2007, Robinson *et al.* 2009, Dominati *et al.* 2010). Guadua bamboo growth improves the physical soils properties. Around the world it has been evidenced that bamboo forests are associated with improved soil protection (Stern 1995), control of erosion (Shibata *et al.* 2011) and might contribute to restore degraded land (Judziewicz *et al.* 1999).

Erosion control and climate regulation have higher contributions, and other services such as water regulation were ranked lower. This lower ranking can be explained by the location of guadua forest in soils with sandy textures, where water regulation tends to be lower. Although some soil properties might change according to the management, several of them represent the inherent conditions of soils (Dominati *et al.* 2010) and are hardly alterable. The texture is one of these properties and directly related to water regulation. Therefore, this relates to the natural condition of the soil.

Regarding to the economic valuation, the negative NPV (-71,394,816 US) for S1 indicates that the use of guadua bamboo forests is not viable. The B/C ratio was also lower than 1 (0.81). Notwithstanding, this method does not include ecological values because many do not have a monetary value and are therefore considered as intangible values. Neither does the method consider the costs avoided attributable to benefits derived from management and use of guadua bamboo forests.

Sales performance analysis for the period 2014–2016 revealed a positive scenario. Projections to seven years (S2) were made based on a 3 % growth in the volume of sales, yielding positive values (greater than one) for both NPV and B/C ratio. A 10 % growth in the volume of sales was subsequently used for 2017– 2020, followed by a 5 % growth in the volume of sales for 2021–2023 (S3), where economic benefits were greater than those estimated in S2.

Currently the cost to certification is paid directly by Yarima farm; projections that included that the Yarima farm as responsible for these certification (S4) showed a negative NPV and a B/C ratio below one. However, when sales volumes were projected to increase with 3 % (S5) and subsequently by five and 10 % (S6), the NPV yielded a positive value and the B/C ratio was higher than one.

Finally, the hypothetical exercise of considering only three workers instead of four was modeled to estimate a reduction in operational costs and the margin of losses with respect to S1. This resulted in a B/C ratio very close to one (0.98), which indicated that this scenario has a high influence on the economic success of bamboo forests.

Although the provisioning ecosystems service, which we evaluated by raw material production, was positive, when this is analyzed from an economic perspective, it shows that financial viability depends on both the market and on modifications in the internal structure (i.e. whether to include or not full time workers for activities related to guadua bamboo forest management). This scenario might be considered feasible given the demand and the organizational structure. This study demonstrated that focusing on raw material production as an indicator of provisioning services is not a comprehensive indicator of economic performance. To evaluate economic benefits, comprehensive economic metrics are needed (such as NPV and C/B) that take all costs and market characteristics into account.

CONCLUSIONS

Guadua bamboo forests are strategic to provide regulating and support ecosystem services in a similar level to other natural ecosystems. It is highly valuable if additionally, we consider that these forests are harvested and usually located on sites with marginal conditions of slope and soils. This value so far might be intangible from an economical perspective but strongly significant in terms of ecological benefits.

The current situation of guadua market does not contribute with the financial viability of these forests when are harvested, however as above assessed a small increment on sales would be enough to overcome this situation. This is an opportunity also to attract government attention of the mentioned benefits and the situation in which the owners who have permitted these forests to remain until today. Therefore, this study contributes to elucidate factors that should be considered to guarantee the permanence of these agroecosystems and their benefits, which in some cases depend on external issues but also of the improvement or optimization of processes or the structure within these rural organizations, in this case, a rural enterprise farm.

AUTOR´S CONTRIBUTION

JM reviewed literature, collected data, performed analyses, and co-wrote the manuscript; JC performed analyses and co-wrote the manuscript; CR collected data.

CONFLICT OF INTEREST

The authors declare that they have not conflict of interest.

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SUPLEMENTARY MATERIAL

The annex 1 and annex 2 are presented as supplementary material under the doi: https://dx.doi.org/10.15446/caldasia.v43n1.90594

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