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Special Supplement: Bamboo

Vulnerability of ecosystems with *Guadua angustifolia* in Ecuador in light of climate changes[1]

Mario José Añazco Romero[2]

ABSTRACT

Guadua angustifolia bamboo is historically used by an important percentage of the rural and peri-urban population of Ecuador, especially in the construction of bridges, when events like El Niño and its consequential flooding occur. This study aimed to determine, in light of some climate change scenarios, the vulnerability rate of ecosystems where the *G. angustifolia* bamboo species occurs, in the coastal region of continental Ecuador. The analysis methodology, with focus on the sampled units, was based on vulnerability assessment tools for climate adaptation recommended by the Intergovernmental Panel on Climate Change. Temperature presented the highest correlation coefficient with the vulnerability rate of the ecosystems, followed by the increase in the sea level, winds and landslides. It was concluded that as the exposure and sensitivity variables increase, the adaptive capacity of ecosystems with occurence of this species decreases, and isolated plants and monoculture plantations are the most vulnerable to climate changes.

KEYWORDS: Bamboo, climate, vulnerability rate.

RESUMO

Vulnerabilidade de ecossistemas com *Guadua angustifolia* no Equador frente a cenários de mudanças climáticas

O bambu *Guadua angustifolia* é historicamente utilizado por porcentagem significativa da população rural e periurbana do Equador, em especial na construção de pontes, quando ocorrem inundações resultantes de fenômenos como o El Niño. Objetivou-se determinar, em face de alguns cenários de mudanças climáticas, o índice de vulnerabilidade de ecossistemas onde ocorre a espécie *G. angustifolia*, na região costeira do Equador continental. A metodologia de análise, com foco nas unidades amostradas, baseou-se em ferramentas de avaliação da vulnerabilidade para adaptação ao clima recomendadas pelo Painel Intergovernamental de Mudanças Climáticas. A temperatura apresentou o maior coeficiente de correlação com o índice de vulnerabilidade dos ecossistemas, seguida pela elevação do nível do mar, ventos e deslizamentos de terra. Concluiu-se que, à medida que as variáveis exposição e sensibilidade aumentam, diminui-se a capacidade de adaptação de ecossistemas com ocorrência dessa espécie, e plantas isoladas e plantações em monocultivo são os mais vulneráveis a mudanças climáticas.

PALAVRAS-CHAVE: Bambu, clima, índice de vulnerabilidade.

INTRODUCTION

Climate change has caused impacts on natural and human systems on all continents and oceans (IPCC 2014). Agricultural sectors - crops, livestock, fish, aquaculture and forest activity - possess unique characteristics that place them in the center of world forces geared towards the adaptation to these changes (FAO 2016).

Forests are essential as much for the mitigation of climate change as for adaptation (FAO 2018a, 2010). As proof, in recent decades, the services of regulation supply for forest ecosystems have claimed more and more importance, especially the duties of forests and trees in light of climate change, i.e., carbon sequestration and climate regulation (FAO et al. 2018b).

Bamboo, due to its ability to produce abundant biomass in a short time, adjusts atmospheric carbon (Yiping et al. 2010), protects the soil and waterways, and is recognized as an adequate plant to confront climate change (Shawkat et al. 2015). The primary suggestion is to use species like woody bamboos within forest and/or agroforestry systems (Arun et al. 2015).

Ecuador is a country catalogued as vulnerable to climate change (Ludeña & Wilk 2013) and the National Strategy for Climate Change of Ecuador (ENCC) contemplates developing actions to mitigate this vulnerability (MAE 2017). The action lines of the ENCC are subdivided into seven sectors, two of which are logging and agriculture (Ecuador 2012). Within these, bamboo is part of natural ecosystems

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and agroforestry settlements, interacting with agricultural and pasture species.

Historically, in Ecuador, the *Guadua angustifolia* Kunth bamboo, known as *caña guadua*, has shown a significant social contribution for rural and urban inhabitants living on the coastal area. There is a long-standing tradition to construct elevated homes from bamboo to avoid floods. *G. angustifolia* is preferred in the construction of homes due to its seism-resistant properties. About 9 % of the homes in Ecuador (331,579 housing units) use *caña guadua* as a predominant material in the walls (INEC 2015).

In Ecuador, native and introduced bamboo species may be found distributed in the four natural regions of the country (coast, mountains, Amazon and Galapagos), from the sea level to close to 4,300 m (a.s.l.), where the *Neurolepis* genus inhabits. Six genera and 44 species of native bamboo have been identified, of which 11 are endemic: *Arthrostylidum* with three species; *Aulonemia* with five species; *Chusquea* with 18 species; *Guadua* with five species; *Neurolepis* with 11 species; *Phipidocladum* with one species; and *Rhipidocladum* with one species (Londoño 2011).

The first exotic species introduced in 1923 were *Phyllostachys aurea* and *Phyllostachys bambusoides*. Currently, *Bambusa vulgaris*, *Bambusa tulda*, *Bambusa ventricosa*, *Dendrocalamus asper*, *Dendrocalamus latiflorus*, *Dendrocalamus longispiculata*, *Dendrocalamus oldhamii* (syn. *Bambusa oldhamii*), *Melocanna baccifera*, *Phyllostachys nigra* and *Phyllostachys pubescens* can also be found. The surface area with bamboo in Ecuador is 600,026 ha (Ecuador 2018), of which 34 % correspond to *G. angustifolia*, 16 % to *D. asper*, and the remaining 50 % include various species that belong to the genera *Chusquea*, *Neurolepis* and *Gynerium* (Añazco & Rojas 2015). In their natural and planted states, 60 % are natural patches predominantly with *G. angustifolia*, and the other 40 % correspond to plantations where *G. angustifolia* and *D. asper* are more frequent and, in smaller proportions, *P. aurea* and *B. vulgaris.*

G. angustifolia is endemic of America and native from Colombia, Venezuela and Ecuador (Londoño 2011). It can grow up to 30 m in height and 0.22 m in diameter. It is considered the third largest bamboo in the world, surpassed by only two Asian species: *Dendrocalamus giganteus* and *Dendrocalamus sinicus* (Corpei 2005). There are two varieties: *G. angustifolia* var. *bicolor* and *G. angustifolia* var. *nigra*. The "bicolor" variety manifests as a green culm with yellow streaks, and the "nigra" has a green culm with light black spots. Locally, they are distinguished by different names as *caña brava* (wild cane), *caña mansa* (gentle cane), *cebolla* (onion), *macana* (baton), *cotuda* (fluffy) or *castilla* (castile).

It is recognized as one of the twenty best species of bamboos in the world that, due to its ability to absorb energy and tolerate a greater flexion, has been converted into an ideal material for seism-resistant constructions. Morán (2001) mentions that there are more than 1,000 uses attributed to this species, which have been recorded from before pre-Columbian times. According to the level of transformation, three categories for the use of *caña guadua* are distinguished in Ecuador: i) primary products; ii) semi-workable products or primary transformation products; iii) greater added value (Añazco & Rojas 2015).

Currently, the important contributions of bamboo to the local and national economies are seen as very important. It is estimated that Ecuador consumes 20,903,800 stalks of bamboo annually, of which 15,531,400 correspond to *G. angustifolia*. It is calculated that 600,000 people are directly involved in the bamboo chain in the country, what represents about 4 % of the total population. These participants move about $ 90,000,000 USD annually (Añazco & Rojas 2015).

In the near future, bamboo is envisaged to have substantial contributions for the environment, particularly with climate change. In mitigation, it contributes to the fixation and storage of carbon in its biomass. In Colombia, Camargo et al. (2010) determined that, at a seven-year-old plantation, *G. angustifolia* had a fixation of 76.6 t C ha^{-1}, of which 83 % are accommodated in the air biomass. In the vulnerability framework for climate change, bamboo fulfills various roles and functions, among them protection from landslides (FAO 2009), defense of riverbanks, and it also acts on the microclimate.

The presence of bamboo at riverbanks creates a natural contention wall that detains sediments, rocks, trees and other elements that are pulled along by water currents (Umaña 2009). This is largely due to the interwoven system of rhizomes and rootlets that behave as efficient biological retaining walls. Thus, *G. angustifolia* represents a species with a protective special function to be used in hillside soils of hydrographic basins (Herrera 2010). Morán (2005) still reports its use to protect and stabilize slopes and landslides, what ensures a soil recovery and erosion control.

At the microclimate level, locally, the "thermostatic" effect of bamboo plantations is also very appreciated. This phenomenon is produced when the plant transpires, losing water in the air in the form of vapor, generating a thermic sensation within the stand of trees that is lower than outside it (Primavesi 1984).

Despite this great potential, there is an increasing need for scientific information about the role that bamboo plays in light of climate changes in general and, in particular, on the vulnerability of the ecosystems in which such plant occurs. With this purpose, this study aimed to determine the vulnerability rate of some ecosystems where *G. angustifolia* is present in the coastal region of continental Ecuador.

MATERIAL AND METHODS

This investigation is part of more general studies sponsored by the International Network for Bamboo and Rattan (INBAR), in Ecuador, carried out between 2011 and 2015. The study was completed on the Ecuador coast, defined as "the region situated between the Pacific Ocean and the foothills of the Andes mountain range" (MAE 2013). The provinces selected were Manabi, Pichincha, Guayas and El Oro (Figure 1). In each province, the main watersheds and respective sub-basins were chosen where bamboo has the highest presence, namely: Portoviejo River in Manabi, Caoni River in Pichincha, Chimbo River in Guayas, Muyuyaco River in El Oro and Siete River, located between the provinces of Guayas and El Oro.

The hydrographic sub-basins of the Chimbo and Caoni rivers are representatives of the Tropical Rainforest vegetal formation, located between 100 m and 300 m (a.s.l.), with an average annual temperature of 25 ºC and average rainfall of 2,383-2,743 mm per year. The sub-basins of the Portoviejo, Muyuyaco and Siete rivers are located between 6 m and 100 m (a.s.l.), with an average annual temperature of 21-31 ºC and average rainfall of 400-1,000 mm per year; which represent the tropical dry forest.

Based on the climate change scenarios, in the province of Manabi, an increase in the "Indian Summer" (consecutive dry days) and in the rainfall intensity are noted. If the current patterns of vulnerability are maintained, the province will end up affected, from an agricultural and forestry point of view. In the northwest of the Pichincha province, the risk maps show a trend to increased heavy rains in short periods, mainly in some agricultural areas. According to the scale adopted, the existence of a high risk can be observed in the zone near the Caoni River (CIIFEN 2007).

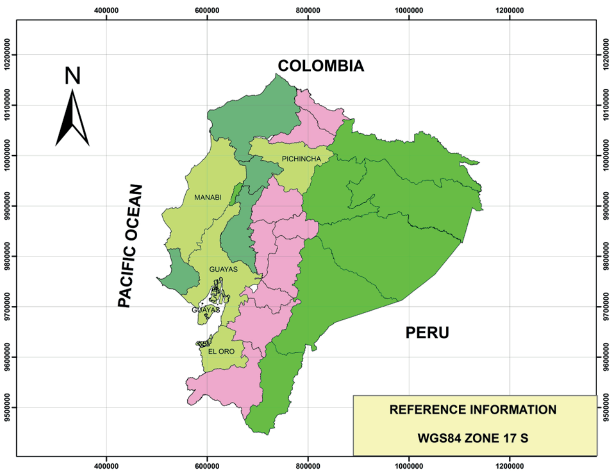


Figure 1. Map of Ecuador with its regions, provinces and study areas of bamboo.

The province of Guayas shows a high vulnerability in the zone of the Chimbo river, from where the Yaguachi and Chilintomo rivers are defined, supporting highly significant agricultural activities (CIIFEN 2012). In the province of El Oro, increases of 5-15 % in the annual rainfall and 1.0-1.2 ºC in the average annual temperature are expected in the next twenty years (CIIFEN 2016).

The criteria used to define the study units were: i) sub-basins representative of the biophysical conditions where bamboo is developed; ii) production systems with natural stands, forestry plantations, agroforestry systems and isolated plants; iii) structure of bamboo actors with small, medium and large producers or owners. The features of the units chosen to take the field information are described as it follows:

- Portoviejo River: natural stands and isolated plants on private land of small farmers (smaller than 1.0 ha to 2.0 ha);

- Caoni River: silvopastoral systems (*G. angustifolia* + *Brachiaria* spp.) and natural stand belonging to mid-sized property owners (2.0-10 ha), and bamboo plantations of large-sized property owners (greater than 10 ha);

- Chimbo River: silvopastoral systems (*G. angustifolia* + *Brachiaria* spp.) and plantations belonging to large-property owners and natural stands on land of mid-sized property owners;

- Muyuyaco River: agroforestry system (*G. angustifolia* + *Theobroma cacao*) and isolated plants on the land of small-sized property owners;

- Siete River: plantation of 100 ha of *G. angustifolia* and isolated plants on land of mid-sized property owners.

In total, 12 units were selected for the study, of which 25 % correspond to natural stands with small and mid-sized producers; 25 % to plantations of large-sized producers; 25 % to agroforestry systems with small, medium and large-sized producers; and 25 % to isolated plants with small and mid-sized producers.

The analysis of vulnerability to climate change was completed based on the definitions indicated in the conceptual framework proposed by Lim & Spanger-Siegfried (2006). Vulnerability was related to social units, and biophysical systems were described as risk-sensitive variables or climate stress. In this approach, vulnerability (V) is analyzed as a function of three main variables: V = f (E, S, CA); where: E is the exposure, S the sensitivity and CA the adaptive capacity.

For these three explanatory variables, 27 indicators were defined: 12 to characterize exposure, 6 for sensitivity and 9 for adaptive capacity. In each variable, a sub-rate was calculated, which was used as inputs to determine the general vulnerability rate of the *G. angustifolia* species.

In the exposure variable, five of the analyzed indicators were directed towards examining what is at risk due to climate change, and the other seven to assess the changes that the bamboo system will come across: population that depends on bamboo (affected population and its uses); ecology (soil, biodiversity, pests and diseases); property and surface; infrastructure for the bamboo management, use and transformation; age of the bamboo subsystems; sea level; temperature; pluvial precipitation; landslides; winds; fires; and extreme events.

For the sensitivity variable, the biophysical effects of climate change were studied, keeping in mind the socioeconomic context. The analyzed indicators were the following ones: perceptions about the "bamboo:ecosystemic services" relationship, in the case of water; bamboo industry; human settlements; energy demand; forests and their relationship with bamboo and financial services.

The adaptive capacity was the variable that allowed the analysis of how a system can adjust to climate change, climate variability and extreme episodes. The indicators subjected to analysis were the following ones: history; social context; culture; economy; technology; norms; legal and institutional support; and information.

To calculate the general vulnerability index, first, vulnerability sub-rates were obtained for each indicator. For this, an adaptation of the procedure used for calculating the indices of environmental services by the US Conservation Reserve Program was used, as well as others such as the one used in Nicaragua for the same objectives (Pagiola et al. 2007). A partial calculation scale of values was defined with the following ranges: high vulnerability (0.0-0.45); medium vulnerability (0.45-0.75); and low vulnerability (0.75-1.0). Once the sub-rates were obtained, vulnerability rates were calculated for each variable and, finally, the general vulnerability rate was calculated by the following formula: vulnerability = exposure + sensitivity - adaptive capacity.

The methodological route was composed by nine processes: i) secondary information (books, reports, articles and internet sites); ii) electronic survey; iii) workshop with Guadua experts; iv) workshop with partners of the INBAR; v) perceptions shared by farmers (sample size, n = 28); vi) field visits (n = 11): ecosystems and people involved with the bamboo value chain; vii) visits to processing centers, marketing and bamboo uses (n = 17); viii) consultations with experts (n = 16); ix) bamboo inventory. The indicators for the methodological tools used are shown in Table 1.

Pearson's correlation coefficients were determined between the vulnerability rate and the 27 analyzed indicators, as well as with the partial rates of vulnerability associated to the variables exposure, sensitivity and adaptive capacity (a total of thirty analyzes). Linear regression analyses were also adjusted to determine the correspondence between the behavior of the bamboo ecosystems and the different aspects of vulnerability. In addition, a cluster analysis of the variables was performed to determine the similarities between the studied ecosystems.

Table 1. Methodological tools, indicators and main explanatory variables used for the analysis of vulnerability of *Guadua angustifolia* in the coastal region of continental Ecuador.

Methodological tools	Indicator	Variable[1]
Guadual inventory (INBAR 2010)	01. Ecology	E
	02. Age	E
	03. Forest and its relationship with bamboo	S
Case study (Zea 2013)	04. Perceptions *vs*. scientific evidence	S
Focal group	05. Population that depends on bamboo	E
	06. Property and surface	E
	07. Human settlements	S
	08. History	AC
	09. Social	AC
	10. Cultural	AC
	11. Fires	E
Cost/benefit	12. Economy	AC
	13. Infrastructure	E
	14. Financial services	S
	15. Energy demand	S
	16. Institutional	AC
Delphi method (Pozo et al. 2007)	17. Information	AC
	18. Industry	S
	19. Legal	AC
	20. Politics	AC
	21. Technology	AC
	22. Sea level	E
	23. Temperature	E
	24. Pluvial precipitation	E
	25. Landslides	E
	26. Winds	E
	27. Extreme events	E

[1] E: exposure; S: sensibility; AC: adaptive capacity.

RESULTS AND DISCUSSION

Based on a nested structure, the results were presented in system and subsystem levels, as well as internal vulnerability rate for each indicator (Figure 2). The bamboo ecosystem represented by the *G. angustifolia* native species presents a vulnerability rate of 0.56, classified as medium. This rate contrasts what occurred in the biophysical and socioeconomic contexts where the species is developed. In the closest environment, which are the micro-basins and provinces of the Equatorial coast, these present high vulnerability rates. This also happens at a national level, being catalogued at high vulnerability (CAF 2014).

From this situation, it may be deduced that *G. angustifolia* can be used as part of the design of norms and/or strategies to confront climate changes in Ecuador. Arun et al. (2015) deliberated the role in the adaptation and mitigation of climate change of bamboo, to which they add the notable contribution to the social, economic and environmental aspects of rural life. Arce (2013) indicates that there is a greater vulnerability in the field of rural settings of Latin America and proposes different strategies for institutional and community competence.

The *G. angustifolia* bamboo system in Ecuador is made up of four subsystems: natural stands, plantations, agroforestry systems and isolated plants. Regarding the vulnerability rate, these show a difference in their behavior, where dispersed plants stand out as those that show the lowest rate and, therefore, they are the most vulnerable to climate change, while natural stands are the most resistant to this phenomenon (Figure 2). Here is also illustrated that the high vulnerability situation of dispersed plants complies with their degree of exposure, which depends on natural and anthropogenic factors, being the main ones extreme events, winds and landslides, while the secondary ones are fires.

Furthermore, at the internal level of each sub-system, its structure is a determinant factor,

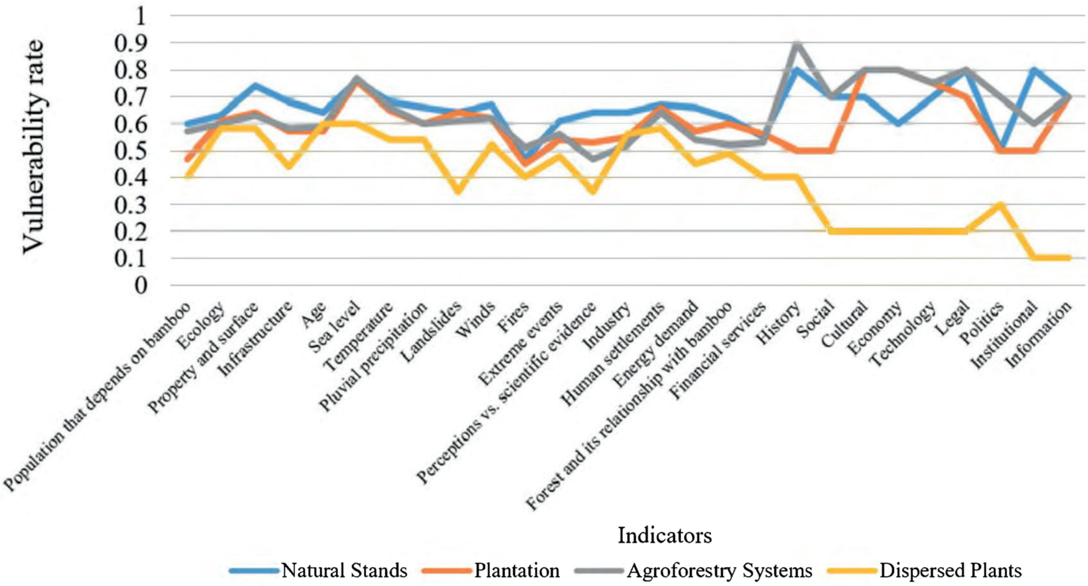


Figure 2. Vulnerability rates associated with 27 indicators for four bamboo subsystems in the coastal region of continental Ecuador.

as the complex structure that natural stands and agroforestry ecosystems possess generates a greater resistance against monocultures or isolated plants. Muñoz-Lopez et al. (2017) point out the following categorization of eco-systemic services provided for *Guadua* forests: regulation of environmental disturbances, security against disasters and regulation of the water cycle.

Statistically, dispersed plants end up being different from the rest of the subsystems. Agroforestry and plantation systems are the ones that show most similarities, above all in respect to exposure (Figure 3). The vulnerability level of these ecosystems may serve as a reference to define adaptive management technologies in light of the impacts of climate change (Felicisimo 2011).

The level of significance, in accordance to the vulnerability rate, resulted differently with each variable. Sensitivity was significant, and both the exposure and adaptive capacity resulted in highly significant (Table 2).

For the regression analysis, determination coefficients were greater than 70 % on the exposure and sensitivity variables, among the plantation subsystem, natural stands and agroforestry systems. It should be noted that the greatest adjustment to

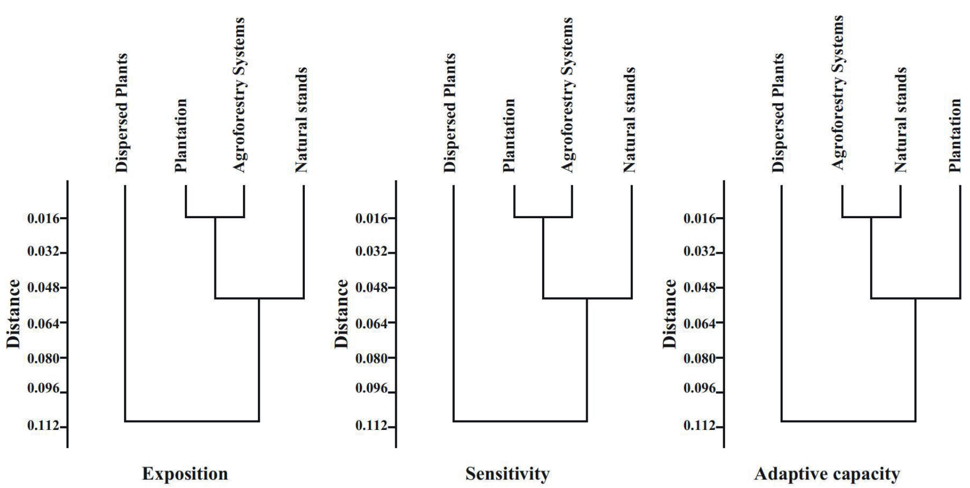
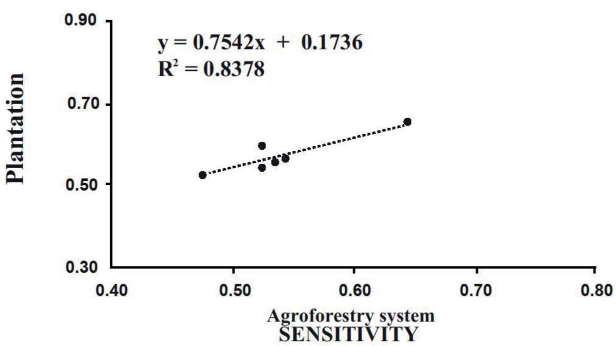


Figure 3. Cluster analysis of the vulnerability variables for bamboo ecosystems with *Guadua angustifolia* in the coastal region of Ecuador.

Table 2. Correlation coefficients between the vulnerability rate and the main explanatory variables and indicators for bamboo ecosystems with *Guadua angustifolia* in the coastal region of Ecuador.

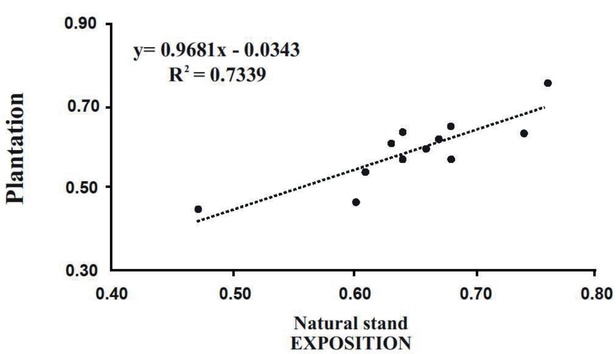
Variables	Indicators	Correlation
Exposure: what is at risk	Population depends on the reeds	0.899*
	Infrastructure	0.942*
Exposure: changes in the system	Increase in the sea level	0.976**
	Temperature	0.999**
	Precipitation	0.906*
	Winds	0.976**
	Landslides	0.974**
	Extreme events	0.931*
Sensitivity	Human settlements	0.953*
	Energy demand	0.883*
	Financial services	0.954*
Adaptive capacity	Social	0.967**
	Cultural	0.934*
	Technological	0.991**
	Legal	0.994**
	Institutional	0.974**
	Information	0.978**
What is at risk	-	0.883**
Changes in the system	-	0.999**
Exposure	-	0.975**
Sensitivity	-	0.873**
Adaptive capacity	-	0.984**

* and **: significant at 5 % or 1 % of probability, respectively.



the regression line was presented in the indicators of exposure between plantation and agroforestry system (Figure 4).

In the present study, all correlations with winds and landslides standing out were high, since such variables may, in fact, cause important changes on the bamboo system (Table 2). This coincides with the fact that, in Colombia, *G. angustifolia* is planted to prevent landslides (Yiping & Henley 2010, Turbay et



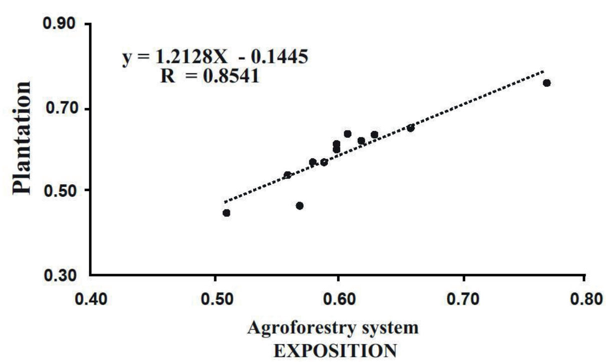


Figure 4. Diagrams of dispersion and regression lines between vulnerability variables and ecosystems with bamboo.

al. 2014), and it is also consistent with a study about the vulnerability of *G. angustifolia* used in housing to climate change that was completed in the north of Peru (Barnet el al. 2014).

The groups of indicators with the highest correlations shown in the characterization of the vulnerability were: temperature, winds, increase in the sea level and landslides for exposure; financial services for sensitivity; and legal and technological indicators for adaptive capacity (Table 2). On the other hand, those with the smallest correlations were: population for exposure; energy demand for sensitivity; and cultural indicator for adaptive capacity. The former is similar to the indicators that best correlated in the characterization of vulnerability and climate change in the agriculture of Mexico (Monterroso et al. 2012).

In the case of the agriculture of Ecuador and, in particular, the rural, family agriculture by which cacao is managed (associated with *G. angustifolia* in some manners), the scenarios show a positive impact of up to +11 % at the level of economic income for the decades 2020 and 2030 (Jiménez et al. 2012). This situation corresponds to the results of the present study, where the agroforestry systems present low vulnerability rates (Figure 2).

A total of 17 of the 27 indicators are directly related with the vulnerability rate (Table 2). Their correlation coefficients present significance at 5 % or 1 % of probability. The greatest correlation coefficient between the vulnerability rate and the indicators was with the temperature (0.99). This situation is cohesive with world and national projections, in respect to the scenarios of climate change that indicate increase in temperature, like that indicated by the third national communication of 0.6 ºC for the Ecuador coast (MAE 2017). At the national level, climate models predict a substantial warming of 5-6 ºC by the end of the century (Vanacker et al. 2018).

Studies about the impact of climate change scenarios on the biodiversity in Ecuador indicate that "the patterns of richness of species have an ascending slope, generating a loss of species for many of the studied groups, particularly angiosperms" (Cuesta et al. 2015). This slope implies mainly in changes in the temperature and rainfall patterns. This scenario will probably not affect the bamboo ecosystems with *G. angustifolia*, that has an optimal development between 17 ºC and 26 ºC, with the stretching that may occur under 11 ºC and 36 ºC. The species grows sparsely in areas where the pluvial precipitation is less than 1,200 mm per year. The best stands are present where the rainfall range is between 2,000 mm and 2,500 mm per year.

Winds and landslides are basic indicators to consider in vulnerability, due to the fact that 35 % of the Ecuadorian population live in zones threatened by landslides, floods, mudflows and debris. In addition, 30 % of the populations in the coastal and Amazon regions and 15 % of the natural surface are subject to periodic flooding (MAE 2011). Winds between June and August are of higher frequencies and associated with forest fires, since this is the period of least rainfall. Fires resulted being the indicator that registered the greatest vulnerability rate in this study.

Referring to extreme events, they have characterized the Ecuador's climate during the last years, causing significant social, environmental and economic impacts (MAE 2015). When these events occur, such as the El Niño phenomenon, bamboo ecosystems are more required, as *G. angustifolia* stalks are used for the construction of bridges, housing and agricultural infrastructure.

The pluvial precipitation presents a high significance, and its correlation level is less than for temperature (Table 2). The precipitation on the coastal region may increase by 33 % in the coming years (MAE 2017), but this would not affect the bamboo ecosystems, because the *G. angustifolia* species has a wide range of rainfall adaptation levels (between 1,200 mm and 3,000 mm per year).

Although there is no scientific evidence of the precise water requirements to maintain bamboo plantations, especially when they have commercial objectives, it is important to know that bamboo does not tolerate prolonged periods of drought. Bowyer et al. (2014) state that monopodial bamboo develops better in environments with warm and humid climates, with rainfall levels greater than 1,200 mm per year. This is important, because, according to the study "Climate Information of Hydrometeorological Threats in the Coastal Provinces of Ecuador" (MAE 2011), there are areas prone to both scarcity and excess of rainfall, one of those being the province of Manabi, where there are important zones with the presence of *G. angustifolia*.

The social, legal, institutional, technological and informational aspects showed high levels of significance (Table 2). In addition, culture, population, infrastructure, energy demand, human settlements and financial services also showed significance. The Ministry of Environment of Ecuador defines these indicators as "non-climatic factors that make people more or less vulnerable, and, therefore, acting on these factors will promote a more resilient Ecuadorian society" (MAE 2017).

Among the legal instruments, the National Strategy for Climate Change is highlighted (Ecuador 2012), which aims to reduce the social, economic and environmental vulnerability against the impacts of climate change. The studied bamboo ecosystems would form an intrinsic part of this public policy.

CONCLUSION

As exposure and sensitivity increase, the adaptive capacity decreases for each sub-system of *Guadua angustifolia*, a situation reflected in the vulnerability rate of isolated plants and monoculture plantations, that ends up being the most vulnerable to climate change.

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