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Biodiversity and Ecosystem Services of Bamboo Carbon Stocks Regulation in the Western Highlands of Cameroon

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ABSTRACT

In the Western Highlands of Cameroon, natural ecosystems have been significantly degraded, fostering other land-use types like bamboo stands. However, knowledge of the potential contribution of bamboo to climate change mitigation within the framework of payment for ecosystem services remains limited. This study sought to identify bamboo richness and estimate carbon stocks of dominant bamboo species in the context of payment for ecosystem services. Data collection combined information from local informants and biomass data of the main bamboo species. Bamboo biomass was collected by destructive method. The results obtained allow the identification of nine bamboo taxa in the Western Highlands of Cameroon. We found for Bambusa vulgaris and Phyllostachys aurea 13,330 ± 7718 and 38,010 ± 3361 culm ha−1, respectively. Total carbon stocks of bamboo estimated at 122.71 tC ha^{-1} for *B. vulgaris* and 125.41 tC ha^{-1} for *P. aurea* were not significantly different between bamboo species (Kruskal–Wallis test, p = .908). For bamboo areas in the Western Highlands, the monetary value of ecosystem services linked to bamboo carbon stocks is 1503 ± 624 USD ha^{-1} ranging from 1486 to 1519 USD ha^{-1} depending on the bamboo species. The monetary value of bamboo carbon stocks potential should help decision makers to consider adopting bamboo species as one of the sustainable strategies to restore degraded ecosystems.

KEYWORDS

Carbon stocks; bamboo richness; payment for ecosystem services; Western Highlands; Cameroon

Introduction

The bamboo plant is a perennial woody-stemmed grass which belongs to the Bambusoideae subfamily of the Poaceae family. It is an important Non-Timber Forest Product. It has 1718 species in the world, with 232 (14%) found beyond their native ecosystem (Canavan et al.,

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2017). A total of 115 bamboo species are reported in Africa (Tinsae & Yulong, 2021), among which 15 bamboo species are found in Cameroon (N.N. Nfornkah et al., 2020a), including *Oxytenanthera* sp. and *Yushania* sp. which are two endemic bamboo species to Africa. Bamboo is classified into amphipodia, monopodial, and sympodial (Arun et al., 2015a). It is fast growing, renewable, and easily adapts to extreme climatic and soil conditions (Terefe et al., 2019; M. Xu et al., 2018). Ecologically, bamboo ensures environmental quality through restoration, climate change mitigation, recovering soil fertility (e.g., stores Nitrogen and Phosphorus better than in other areas dominated by trees and shrub species), and biodiversity conservation (Arun et al., 2015; Borisade & Odiwe, 2018; Padgurschi et al., 2018); it also provides woody raw materials to people in diverse sectors and then an important source of income and poverty alleviation (Chimi et al., 2021; Ingram et al., 2010; Nfornkah et al., 2020b). For example, dry stems of bamboo serve as fuelwood and also charcoal, its sap is used for wine making in Tanzania and Malawi, fresh or dry leaves are used for fodder, and the seeds and young shoots are used as food (J.A. Nath et al., 2015). In Cameroon, bamboo serves for construction, fencing, furniture, fish-traps, stakes, trellises, tool handles, household utensils, and arrow shafts, as well as fuelwood (Ingram et al., 2010).

Bamboo, both native and exotic in Cameroon, covers an area of 1.215.483 ha (Nfornkah et al., 2020c). In the Western Highlands agroecological zone where the natural ecosystem is disappearing due to agricultural expansion, bamboo covers an area of 241,296 ha (which represents approximately 20% of the national bamboo area; Nfornkah et al., 2020c). Bamboo stands, especially native species or managed exotic species, appear as an alternative ecosystem which continues to provide ecosystem services to local people for their well-being. Nevertheless, bamboo forests are not sustainably managed in the Western Highlands; therefore, they are under threat of deforestation and degradation as people clear them to make way for agricultural lands and residential areas. Meanwhile, the bamboo distribution could be conserved by policymakers if more scientific data are made available to show the necessity of conserving bamboo for its ecological and socio-economic importance (Nfornkah et al., 2020b,c,d). Take, for example, the case of bamboo carbon stocks potential; it could be valorized in the domain of payment for ecosystem services and voluntary carbon stocks market, if more impetus is given to them. In fact, Yuen et al. (2017) reviewed 184 studies on bamboo biomass for 70 bamboo species, and estimated plausible ranges of 16–128 tC ha^{-1} for aboveground carbon biomass, and 8–64, 70–200, and 94–392 tC ha^{-1}, respectively, for those of belowground carbon, soil organic carbon, and total bamboo ecosystem carbon potential. These potentials of carbon stocks of bamboo ecosystems appear high compared to other natural ecosystems found, for example, in highland agroecological zones in Cameroon (Lounang et al., 2018; Temgoua et al., 2020).

Information on carbon stock and species diversity with special interest on indigenous species will help create awareness regarding the contribution of bamboo to climate change mitigation, consequently improving people's willingness to conserve bamboo resources in Cameroon, and also for conservation and environmental sustainability decisions regarding the management of bamboo forests. So, with the adherence to the international instrument such as Sustainable Development Goals (SDGs) "the 2030 Agenda for Sustainable Development" by Cameroon, this study appears as an additional piece that will provide information to the understanding and integrating bamboo into national climate change mitigation strategies and plans as indicated by goal 13 of the UN SDGs.

The study therefore sought to provide a scientific document concerning the monetary value of carbon stocks which is an indicator of the climate regulation service that could help decision makers, by showing them the capacity of the bamboo ecosystem to store carbon, allowing them the possibility to include bamboo forest in REDD+ strategies, to benefit from payment for ecosystem services. Thus, the main research question was as follows: what are the potential bamboo carbon stocks and their respective monetary values in the Western Highlands from Cameroon?

Material and methods

Study area

This study was carried out in the Western Highlands – agro-ecological zone 3 – of Cameroon, specifically in the administrative region of West Cameroon (Figure 1). The relief of the Western Highlands is mountainous with many plateaus and plains, and an altitude ranging between 1500 and 2400 m (Toukam et al., 2009). The climate is tropical with two seasons: one rainy season (April–November) and one drying season (November–April). Average precipitation oscillates from 1800 to 2400 mm year^{-1}; and temperature varies from 11° to 30°C with a mean of 21°C. (Toukam et al., 2009). According to Jiotsa et al. (2015), the soils are essentially volcanic (clay, rocks); and the vegetation is essentially Guinea savannah grassland and montane forests (Letouzey, 1985), which have undergone significant degradation in recent times due to

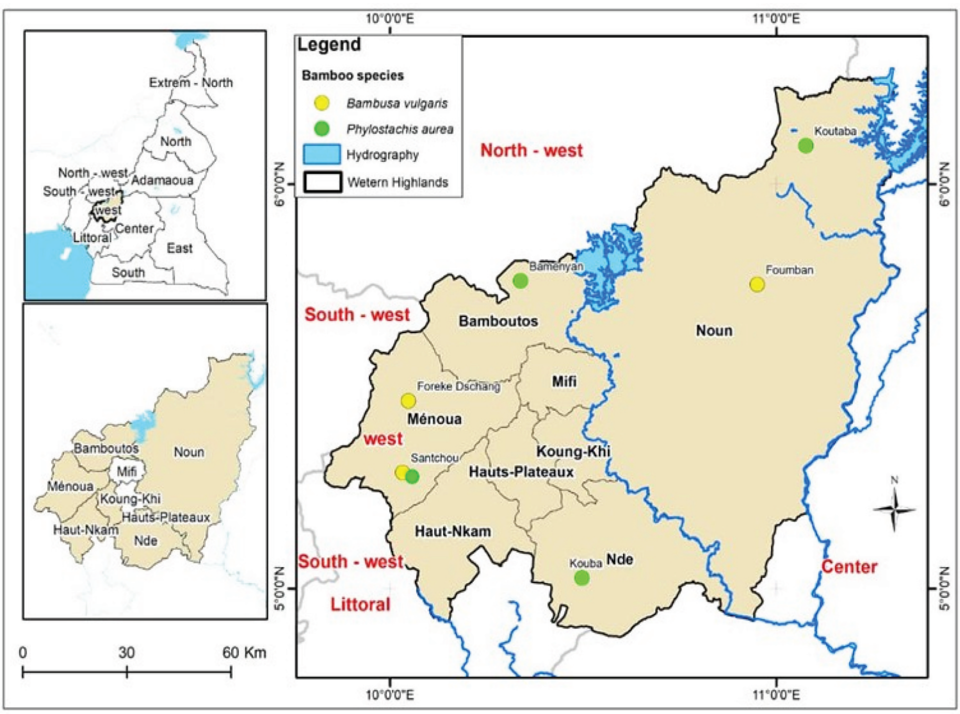

Figure 1. Map of the sampled sites in the Western Highlands of Cameroon.

anthropogenic activities like agricultural expansion which are the main occupation. Few naturally intact ecosystems are found such as sacred and gallery forests. Regarding bamboo, both native and exotic in the Western Highlands agroecological zone, Nfornkah et al. (2020c) report of 241,295.87 ha representing approximately 20% of the national area covered by bamboo.

Data collection

Preliminary data of bamboo distribution through remote-sense-based mapping in the Western Highlands (Nfornkah et al., 2020c), and local assistants indicate bamboo-dominating areas that were target localities for this bamboo inventory. Bamboo specimen vouchers were collected and pressed in a press board; their identification was done later with the help of the available Poaceae Flora. This information allows for an update of bamboo diversity in Western Highlands of the Cameroon.

Carbon stocks data collection

Two main bamboo species were identified in the Western Highlands as dominant bamboo species. It was the case of *Bambusa vulgaris* and *Phyllostachys aurea*. Ingram et al. (2010) report the dominance of *Y. alpina* on Mt. Kilum/Ijum in the North-West Region of Cameroon, which is still part of the Western Highlands agroecological zone. But, due to the sociopolitical crisis in the North-West Region, this study concentrates only in the West Region, and *Y. alpina* was not taken into account. For *B. vulgaris* and *P. aurea*, carbon stocks data were collected in the circular plot of 100 m^2 (N.N. Nfornkah et al., 2020a). For each bamboo species, a total of 10 circular plots of 100 m^2 were sampled.

In each plot established, a destructive method was used for bamboo carbon stocks biomass data collection; this consisted of felling 5% of culms with respect to age group (four age classes for this study: 1 year, ≤2 years, ≤3 years, and ˃3 years) (Davi et al., 2018). Age group was identified based on culm morphology (phenology) using guidelines of Li et al. (2016) and Kaushal et al. (2018). For each culm targeted, in addition to specimen collection, dendrometric variables such as height and the diameter at 1.50 cm (Huy & Trinh, 2019) were measured. For *B. vulgaris* (sympodial bamboo), additional data such as girth (m) and number of culms (N_{culm} $clump^{-1}$) were also collected. Then, the harvested bamboo was sorted out into components (e.g., culm, branches, and leaves), and weighed with an electronic suspension scale (capacity 300 kg) separately for total fresh biomass of the culm. Subsamples of the different bamboo components: culm (on three positions on the culm: root collar, middle, and top); branches and leaves (using electronic scale of precision 0.1 g) were collected as fresh subsamples and weighed for each bamboo sampled (Huy & Trinh, 2019; N.N. Nfornkah et al., 2020a). All these samples were taken to the Laboratory of Systematics and Ecology of the University of Yaounde 1, where they were oven dried at 104°C for culm and branches and 70°C for leaves until constant mass was obtained. Nondestructive method approach was used for bamboo belowground biomass (BGB) estimation (IPCC, 2006).

Calculation

Culm and clump density

Bamboo culm density in hectares was calculated using the following formulae:

$N_{culm} ha^{-1} = N_{culm} \times \frac{10^4}{plotarea(m^2)}$; plot area = 100 m^2

- Biomass and carbon stocks estimation (Huy & Trinh, 2019)

Total dry-weight of each bamboo component was determined using the following formula:

$$TDW = \frac{SDW}{SFW} \times TFW$$

where TDW = total component dry weight; SDW = subsample dry weight; SFW = subsample fresh weight; and TFW = total component fresh weight.

The total aboveground biomass (AGB) of each bamboo corresponds to the sum of the total dry bamboo biomass of the culm (AGB_{cl}, kg), branches (AGB_{br}, kg), and leaves (AGB_{le}, kg):

$AGB_{bamboo} = AGB_{cl} + AGB_{br} + AGB_{le}$

For the culm and/or clump AGB calculation for each plot, the extrapolation at the hectare was done using the following extrapolation factor:

$$AGB(t.ha^{-1}) = AGB \times \frac{10^4}{plot\,area(m^2)}$$

AGB corresponds to the bamboo AGB (culm or clump) in 100 m^2.

According to Yuen et al. (2017), the roots:shoots ration (RSR), which correspond to ratio AGB on BGB was used to estimate the BGB, using the following formula:

BGB = RSR × AGB.

Because this study did not directly estimate the BGB of these two bamboo species, we used available RSR for bamboo species, the genera of *Bambusa* and *Phyllostachys*. Like that, we estimated the mean RSR from 11 bamboo species belonging to *Bambusa* and *Phyllostachys* (Yuen et al., 2017). According to that, the coefficient "RSR" obtained for *Phyllostachys* was 1.33 and that of *Bambusa* was 0.32.

With the value of AGB and BGB, the total biomass corresponded to the sum of these two biomass components (AGB+BGB).

According to Huy and Trinh (2019), the carbon fraction in bamboo represents the default value proposed by IPCC (2006) for trees = 47%. Like that, bamboo carbon stocks at hectare were estimated by the following formula:

carbon stock (t C ha^{-1}) = biomasses (t ha^{-1}) × 0.47

With respect to the fact that 1 tC = 3.67 t CO_{2eq}, the following formula was used for bamboo CO_2 stocks:

Stock CO_2 (t CO_{2eq} ha^{-1}) = Carbon stock (t C ha^{-1}) × 3.67 (IPCC, 2006).

Monetary value of ecosystem services linked to carbon stocks potential of bamboo

According to Busch and Engelmann (2017) and Cannon (2018), carbon price could take the form of some combination of taxes on emissions or payments for emission reductions in tropical forest countries, with the potential to receive external funding from international carbon markets or public funds. We adopted the following conversion: 1 t CO_{2eq} = 3.3 USD (Ecosystem Marketplace, 2016), which is found in the REDD+ framework.

Data analysis

Data analysis was done using R, version 4.0.1 software. Shapiro–Wilk test shows that these data did not follow a normal distribution; thus, a nonparametric test – Kruskal–Wallis test – was used to show whether there is a significant difference between these two bamboo species with respect to the variables considered (density of culm, biomass, and carbon stocks). In the context of this study, all the statistical analyses were considered significant at 95% confidence interval.

Results

Bamboo richness in the Western Highlands of Cameroon

This study enabled us to identify nine bamboo taxa in the Western Highlands, and seven were identified until species level: *Bambusa vulgaris* Schrad. Ex J. C. Wendl., *Phyllostachys aurea* Riviére & C. Riviére, *Ochlandra travancorica* (Bedd.) Gamble, *Phyllostachys atrovaginata* C. S. Chao & H. Y. *Dendrocalamus asper, D. strictus* (Roxb.) Nees, and *Oxytenanthera abyssinica* (A. Rich.) Munro. However, two bamboo species, *Phyllostachys* sp. and *Bambusa* spp. var *longinternode*, were identified only at the general level. We can also note that we identified two subspecies of *Bambusa vulgaris*, namely, *Bambusa vulgaris* var. green and *Bambusa vulgaris* var. *vitata.*

Descriptive characteristics of two main bamboo species

The measurement of these two bamboo species parameters showed that they are different. We found in general that the measurement parameters of *B. vulgaris* were high compared to those of *P. aurea* (Table 1). However, the N_{culm} ha^{-1} was significantly higher (Kruskal–Wallis test, $p < 0.05$) for *P. aurea* compared to *B. vulgaris*. The average girth per clump, number of clump and number of culm per clump per hectare were 12.65 m, 133 culm $clump^{-1}$ znd 13330 culm ha^{-1}, respectively. The latter information was not available for *P. aurea* because it is a running bamboo species compared to *B. vulgaris* that is a clumping bamboo species (Table 1).

Table 1. Summary of measurement parameter of *B. vulgaris* and *P. aurea* in the Western highlands.

Descriptive statistic	*B. vulgaris*	*P. aurea*
Diameter (cm)	7.1 ± 1.2	3.34 ± 0.53
Height (m)	14.19 ± 1.74	9.97 ± 1.70
girth (m)	12.65 ± 7.30	-
N_{culm} ha^{-1}	13330 ± 7718	38010 ± 3361
N_{culm} $clump^{-1}$	133 ± 56	-

Table 2. Carbon stocks of the two bamboo species most abundant in the Western Highlands of Cameroon. AGB: aboveground biomass; TGB: total ground biomass (AGB+BGB).

Parameters		*Bambusa vulgaris*				*Phyllostachys aurea*			
		Min	Max	Mean	Sd	Min	Max	Mean	Sd
Bamboo components (kg)	Roots (BGB)	2.14	8.88	5.03	1.69	0.96	5.56	2.48	0.97
	Culm	5.05	20.85	10.81	4.08	0.55	2.65	1.25	0.46
	Branches	1.10	7.91	3.75	1.58	0.05	0.62	0.32	0.14
	Leaves	0	5.73	1.17	0.94	0.01	0.96	0.31	0.22
	AGB_{culm}	6.69	27.74	15.73	5.29	0.72	4.18	1.86	0.73
	TGB_{culm}	8.84	36.62	20.77	6.98	1.69	9.73	4.34	1.70
Bamboo biomass (t ha^{-1})	AGB_{culm}	89.46	363.17	197.79	93.04	57.82	170.55	114.52	41.29
	BGB_{culm}	28.62	116.22	63.29	29.77	76.90	226.83	152.32	54.91
	TGB_{culm}	118.09	479.39	261.09	122.81	134.72	397.38	266.84	96.20
Bamboo carbon stocks (tC ha^{-1})	AGB_{culm}	42.05	170.69	92.96	43.73	27.18	80.16	53.83	19.40
	BGB_{culm}	13.45	54.62	29.75	13.99	36.14	106.61	71.59	25.81
	TGB_{culm}	55.50	225.31	122.71	57.72	63.32	186.77	125.41	45.21
Bamboo $CO2_{eq}$ stocks (t CO_{2eq} ha^{-1})	AGB_{culm}	154.31	626.44	341.17	160.48	99.73	294.18	197.54	71.22
	BGB_{culm}	49.38	200.69	109.18	51.35	132.65	391.26	262.73	94.72
	TGB_{culm}	203.69	826.90	450.35	211.84	232.37	685.45	460.29	165.94

Biomass components and carbon stocks of bamboo species

Bamboo biomass with respect to bamboo components varied significantly (Kruskal–Wallis, p = .000) for both bamboo species (Table 2). Culm was the component that had a high biomass than others for *B. vulgaris* whereas, for *P. aurea*, it was roots or rhizomes that have a high quantity of biomass compared to other components. The proportions of biomass in each component of *B. vulgaris* represent 52% for culm, 24% for roots, 18% for branches, and 6% for leaves. Those of *P. aurea* represent 57%, 29%, 7%, and 7%, respectively, for roots, culm, branches, and leaves. The average culm TB (kg) was not significantly different between *B. vulgaris* and *P. aurea* (Kruskal–Wallis test, p = .908.

AGB for *B. vulgaris* and *P. aurea* was estimated at 53.83 and 92.96 tC ha^{-1}, respectively, and that of BGB was 29.75 and 71.59 tC ha^{-1}, respectively, for both bamboo species. Total bamboo carbon stock was estimated at 122.71 and 125.41 tC ha^{-1}, respectively, for *P. aurea* and *B. vulgaris* (Table 2). These values correspond to a CO_{2eq} estimated at 450.35 and 460.29 t CO_{2eq} ha^{-1}, respectively. Kruskal–Wallis test showed that whether AGB or BGB, a significant difference was found with respect to these two bamboo species (p = .000). However, for the TB and total CO_{2eq} ha^{-1}, there was no significant difference between the two bamboo species (p = .908).

Monetary value of ecosystem services of bamboo carbon stock regulation

The value of payment for ecosystem services for bamboo carbon stocks in the Western Highlands was estimated at 1503 ± 624 USD ha^{-1}. It varied with bamboo species, *B. vulgaris* has a higher value ranging between 672 and 2728 USD ha^{-1} (average of 1486 ± 699 USD ha^{-1}) whereas that of *P. aurea* varied from 766 to 2261 USD ha^{-1} (average of 1519 ± 548 USD ha^{-1}). Kruskal–Wallis test equally showed a significant difference (p = 0.02) in the monetary value for climate regulation is the service with respect to these two bamboo species. These figures highlight the place of bamboo in the REDD+ strategy and also in the payment for ecosystem services program.

Discussion

The aim of this study was to assess the carbon stocks and payment for ecosystem services of dominant bamboo species (*B. vulgaris* and *P. aurea*) in the Western Highlands of Cameroon, but also, evaluating the number of bamboo species in the Western Highlands was of prime importance. With a total of 15 bamboo species found in Cameroon (N.N. Nfornkah et al., 2020a), we confirmed a high potential of bamboo species in the Western Highlands, where nine bamboo taxa including seven bamboo species were found. Moreover, *Oxytenanthera* sp. identified is an African endemic bamboo species (Gurmessa et al., 2016). This result confirms the potential of the Western Highlands of Cameroon in bamboo diversity. It is important to mention that, between these bamboo species found, three of them were recently introduced in the Western Highlands specifically in the Botanical Garden of the University of Dschang within the framework of the "Botanical Garden's, One citizen – One tree project," which is coordinated by the Laboratory of Environmental Geomatics, Department of Forestry, University of Dschang.

As reported by N.N. Nfornkah et al. (2020a), the diversity of bamboo in the Western Highlands shows that many species are not well represented or cover small patches in the agroecological zone. It is for this reason that carbon stocks estimation was exclusively focused on bamboo species which are most abundant as reported by N.N. Nfornkah et al. (2020a). The results showed that there was no significant difference between *B. vulgaris* TC compared to *P. aurea* in the Western Highlands. This is not consistent with literature concerning bamboo carbon stocks in the world, that carbon stocks vary significantly with respect to bamboo species (Li et al., 2016; N.N. Nfornkah et al., 2020a; Nath et al., 2009, 2012; Yuen et al., 2017; Zhuang et al., 2015). Considering the AGC, there was a significant difference between the two species. This may be explained by the architecture of the species rhizomes. The carbon of the rhizome of *P. aurea* is 1.33 more than that of the AGC, while that of *B. vulgaris* is just 0.32 less than that of the AGC (Yuen et al., 2017).

The review of Yuen et al. (2017) shows bamboo carbon stocks of 70 bamboo species studied in the Asia-Pacific Region, to range from 16 to 128 Mg C ha $^{-1}$. This finding confirms the fact that bamboo species seem to have a different capacity in terms of carbon stocks despite their fast growing rate. Several reasons could explain these variations. First, ecological conditions like clump crowding, and culm position within a clump, soil fertility, and microclimate (Arun et al., 2015; Borisade & Odiwe, 2018; Maírade Campos Gorgulho, 2021; N.N. Nfornkah et al., 2020a; Yuen et al., 2017); second, differences in bamboo morphology or more specifically bamboo growth forms: sympodial, amphipodia, and/or monopodia (Arun et al., 2015; N.N. Nfornkah et al., 2020a; Yuen et al., 2017); third, the levels of ecosystem disturbances (Montti et al., 2014). The latter may also explain or confirm why both bamboo species have similar total carbon stocks, but also the difference in RSR biomasses.

N.N. Nfornkah et al. (2020a) report that *P. aurea* with an aboveground carbon stocks of 67.78 tC ha^{-1} is a bamboo species which stocks more carbon compared to *B. vulgaris*. Our findings are different to the results of these authors. The bamboo species which stored more aboveground carbon was *B. vulgaris* than *P. aurea* and secondly, carbon stock of *B. vulgaris* was 92.96 tC ha^{-1} which is different from 29.62 tC ha^{-1} found in the study of these authors. In fact, the findings of N.N. Nfornkah et al. (2020a) concerning high bamboo carbon stocks of *P. aurea* compared to *B. vulgaris* could be related to bamboo density of each bamboo species and also to the different sampling design used for bamboo culm density estimation (clumping based for *B. vulgaris* culm density evaluation according to N.N. Nfornkah et al. (2020a) and circular plot of 100 m^2 in this study). N.N. Nfornkah et al. (2020a) found 296 and 38,017 culm ha^{-1}, respectively, for *B. vulgaris* and *P. aurea* whereas we have found 13,330 and 38,010 culm ha^{-1}, respectively, for these two bamboo species. With these observations, it is not the bamboo density that could explain these differences in carbon stocks but rather the dendrometric parameters (average diameter of each bamboo species), correlated to average culm bamboo biomass of each bamboo species (N.N. Nfornkah et al., 2020a). Also, conditions like ecological, nature, and morphology could also explain differences in bamboo carbon stocks found between these two bamboo species.

Bamboo plays a remarkable role in ecosystem services (A.J. Nath et al., 2020; J.A. Nath et al., 2015; Maírade Campos Gorgulho, 2021; Marchesini Victoria et al., 2009; Montti et al., 2014; Nfornkah et al., 2020b; Paudyal et al., 2019, 2022; Terefe et al., 2019; Xayalath et al., 2019; M. Xu et al., 2018; Zhang et al., 2014). Concerning climate change mitigation, bamboo is recognized by several authors as an important carbon sink in the world and has an added advantage as one of the fastest growing plants, which can easily be integrated into national and international climate change mitigation strategies (Zhang et al., 2014; Li et al., 2016; Yuen et al., 2017; M. Xu et al., 2018; Xayalath et al., 2019; N.N. Nfornkah et al., 2020a, 2020b, 2020c, 2020d). In the Western Highlands of Cameroon, the bamboo carbon stocks appear to be high.

These results showed that the sum of total CO_{2eq} stocked by both bamboo species (about 660 t CO_{2eq} ha^{-1}) represents 10% of the total CO_2 emitted by Cameroon in 2020 (from Our World in Data). Cameroon's adherence to the REDD+, Bonn Challenge, and Afr100 Restoration initiatives, and as a member country, which has chosen to integrate in its ecosystem governance measures regarding the United Nations Framework Convention on Climate Change (UNFCCC) strategies to reduce the increasing temperature, has the opportunity to take advantage of this results to integrate bamboo in the mentioned initiatives to face climate change. This is to contribute to reducing emissions from deforestation and degradation of natural ecosystems and increasing the potential of these ecosystems to sequestrate CO_2. Policymakers could capitalize on this interest shown by Cameroon to lobby for payment for ecosystem services, especially in the bamboo sector. In this context and considering that bamboo has a fast growth rate and the total surface area covered by bamboo in the Western Highlands is large (241,295.87 ha), and representing approximately 20% of the national area covered by bamboo (Nfornkah et al., 2020c), it is necessary and important to consider this resource as a means to mitigate climate change within the framework of the REDD+ mechanism. At national level, in addition to this REDD+ strategy, bamboo ecosystem appears to be one important resource to be considered in other environmental strategies such as the Climate Change Adaptation and Mitigation Plan, payment for ecosystem services, and the Nationally Determined Contribution from the Paris Agreement.

However, a number of studies suggest a number of risks involved in planting bamboo especially exotic species, as they invade indigenous plant species, decrease biological diversity, cause food scarcity, pollute soils as farmers use fertilizers and pesticides, and grab lands (Mariyono et al., 2018; Q.-F. Xu et al., 2015; Richardson & Canavan, 2015; Roshan et al., 2018; Song et al., 2017; Q. Xu et al., 2008). Mitigating these risks, the International Bamboo and Rattan Organization (INBAR) and a team of experts/researchers have documented and made available a number of manuals, voluntary standards guidelines, and standards to guide everyone planning investment in the bamboo sector, from seedlings production, planting, sustainable management, harvesting, transformation, bioenergy, construction, trade overviews, and research and development (Durai and Trinh, 20 19; Donfack, 2020; Huy & Trinh, 2019; Kaushal et al., 2018). Exploiting these guidelines, adding the beauty on integrating bamboo in these FLR initiatives, Agriculture and Agroforestry systems will attain a good number of UN Sustainable Development Goals, especially goals 13 and 15.

Payment for carbon credits generated from these emission-reductions has also become one of the primary objectives of forestry and environmental projects worldwide. The potential of bamboo forest could represent an important source of income through the payment for ecosystem services, if regular information on emissions or reduction in greenhouse gases resulting from bamboo carbon stocks is made available. In fact, the success of these international efforts in storing atmospheric carbon in forests in Africa and elsewhere in the tropics depends on the long-term maintenance of ecosystem among which is the bamboo forest (Djomo et al., 2017).

Conclusion

This study confirmed a high bamboo richness in the Western highlands by identifying nine bamboo taxa with seven bamboo species. For the two most abundant bamboo species, carbon stocks potential were estimated at TGB = 122–125 tC ha^{-1} for the both bamboo species, thereby contributing to mitigate the effects of climate change. Policymakers should integrate bamboo within forest landscape restoration interventions policy frameworks, but also with special emphasis on indigenous bamboo species or with exotic species with special management need recommendations. The aspect or possibility for payment for ecosystem services (climate regulation) should be considered as it can serve as incentive to efforts in climate adaptation and mitigation initiatives, and can provide above 1000 USD ha^{-1} for a bamboo plantation.

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