International Journal of Ecology and Environmental Sciences 46 (1): 7-18, 2020
ISSN: 0377-015X (Print); 2320-5199 (Online)

Impact of Ethnobotanical Uses and Climate Change on the Population of *Boswellia dalzielii* Hutch. in the Sudanian Region of Benin (West Africa)

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ABSTRACT

Abusive exploitation, especially intensive harvesting, is the main cause of the destruction or even the disappearance of some plant species already threatened in Benin. This study aims to determine the impact of ethnobotanical uses and climate change on *Boswellia dalzielii* populations in the sudanian region of Benin.

The informants were chosen randomlyto include gender, ageclasses and sociocultural group. Asemi-structured questionnaire was administered to informants. The structural data were obtained from phytosociological surveys using the Braun-Blanquet method. Occurrence data of *Boswellia dalzielii* were collected in the study area by a GPS.

The results showed that *Boswellia dalzielii* was most frequently used for medicinal (UVs = 5,739). The cultural importance index of *Boswellia dalzielii* was higher for food (0.962**)** and medicinal (0.879) categories. The roots are the main plant part use in all categories except in construction where stems are used. The horizontal and vertical structure of *Boswellia dalzielii* populations showed that individuals of less than 5 cm diameter and less than 2 m high are highly dominant. As part of the mitigationofgreenhouse gasemissions (Representative Concentration Pathways: RCP4.5), more favorable habitats will experience a decrease of about 17% in their currently very favorable area. In the context of an increase in greenhouse gas emissions (Representative Concentration Pathways: RCP 8.5), current most favorable habitats will decrease by around 12% by 2055. *Boswellia dalzielii* ethnobotanical uses have impacts on stems density, height and basal area.

Key Words: Anthropogenic Activities; Climate Variability; Endangered Species; Habitats; West Africa.

INTRODUCTION

In developing countries where indigenous people struggle to combine survival and protection of biodiversity, natural resources are under enormous pressure. It hasbeen reported that a vast majority of thepopulation particularly those living in villages depend largely on herbal medicines (Nwinyi et al. 2004, Ouédraogo et al. 2006 a and b, Sabi Lolo Ilou et al. 2017). Land cover in sub-Saharan Africa has decreased from 31% to 28.5% between 1990 and 2015 (FAO, 2018). Benin, like other West African countries, is also experiencing serious degradation of its forest resources. According to the Spatial Observation of the Forests of Central and West Africa (OSFACO) land mapping results in Benin, deforestation and net degradation are estimated at 2.1% and 0.6% between 2005 and 2015 respectively. In the cotton basin of Northern Benin, the rate of deforestation is2.94%.Thisrateis4.25% in surroundings villages and 0.66% in protected areas. Deforestation affected 37% of the study area with 48.71% of surroundings villages and 10.22% of protected areas (Toko Imorou et al. 2019).

Abusive exploitation, especially intensive harvesting of organs, is the main cause of thedestruction or even the disappearance of some plant species already threatened in Benin, such as *Boswellia dalzielii* (Adomou etal. 2011, Houessouetal. 2013, Toko Imorou et al. 2017 and 2019, Zakari et al. 2018).

Boswellia dalzielii occupies an important place in local populations' daily life, mainly in food, pharmacopoeia, rituals and in construction. The excessive exploitation of its organs, especially the roots, bark and leaves associated with the loss of its habitat, leads to its vulnerability and rarity (Ouédraogo et al. 2005 and

2006a, Adomou et al. 2011). It is listed on the IUCN red list as an endangered species in Benin (Adomou et al. 2011).

Despite some studies on *Boswellia dalzielii* in Benin, many questions remain regarding the factors which determine its spatial distribution and the structure of its populations. As ethnobotanical uses and climate change have direct effects on the distribution and abundance of plant species, it is important to determine the impact of these two factors on the distribution and structure of *Boswellia dalzielii* populations in order to better elaborate strategies for its efficient conservation. Distribution models that represent an important predictive tool in conservation are then used to assessthe potential impact of climate change on species distribution patterns (Guisan and Zimmermann 2000, Pearson et al. 2006, Phillips et al. 2006, Elith et al. 2011). They address the major issues of understanding, describing and predicting the potential range of a species, and identifying the factors that determine its distribution (Kumar and Stohlgren 2009). This study aims to determine the impact of ethnobotanical uses and climate change on *Boswellia dalzielii* populations in the sudanian region of Benin.

STUDY AREA

The study was carried out in the sudanian region located in the north of Benin between 9°49'31" - 12°24'48" N latitude and between 0°46'09" - 3°49'28" E longitude. This region is one of the three main chorological subdivisions of Benin (Adomou etal. 2006) and includes three phytodistricts: Mekrou-Pendjari, Chaîne de l'Atacora and Borgou-Nord (Figure 1). The climate is sudanian with two seasons: a dry season (October to April) and a rainy season (May to September). The rainfall varies between 850 mm and 1200 mm. The average annual temperature varies between 25 °C and 32 °C (ASECNA 2016). The main soil types identified are: ferruginous soils, low ferrallitic soils, raw mineral soils, brown soils and hydromorphic soils (Faure 1977, Viennot1978, Faure andVolkoff 1996). The main rivers in the study area belong to the Niger and the Volta catchments. These are: Niger (120 km), Mékrou (410 km), Alibori (338 km), Sota (254 km) and Pendjari (380 km). The natural vegetation consists of dry dense forest (phytoclimax), gallery forest, woodland and savannah (savannah woodland, tree, shrub and grass savannah).

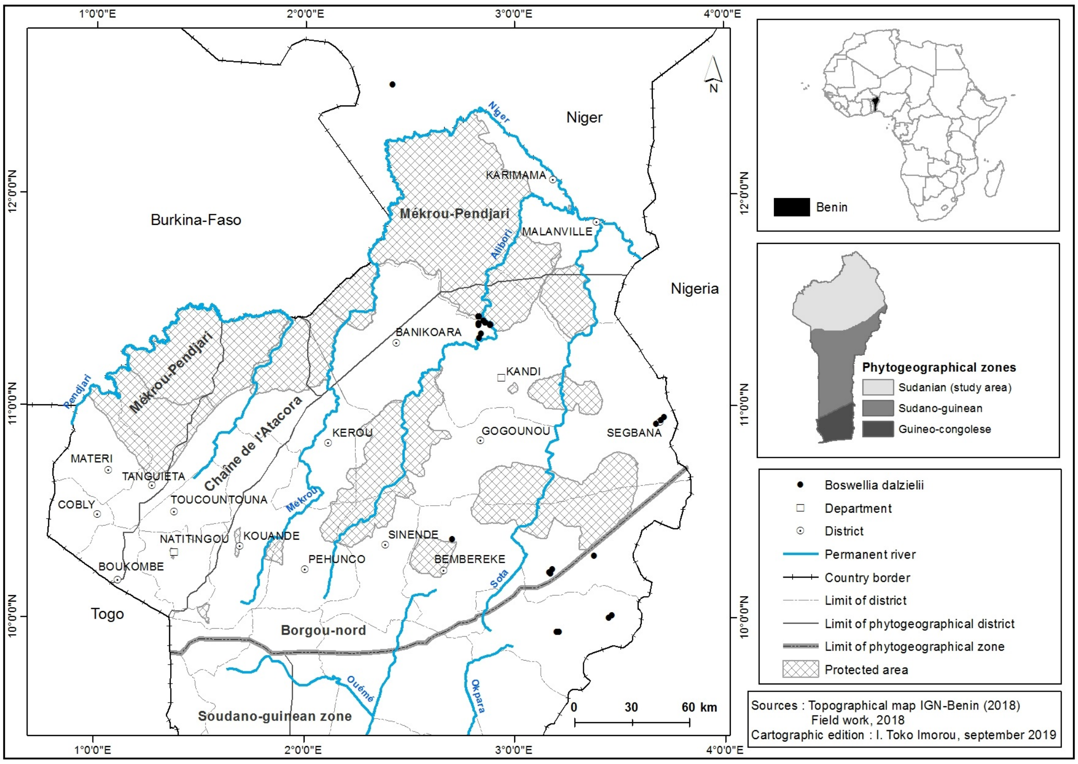

Figure 1. Location of the study area

The major sociocultural groups are: Batonu, Dendi, Gourmantche, Ditanmari, Wama, Fulani, Mokolé and Boo. They are farmers (cotton, corn, sorghum), agro-pastoralists(cotton, corn, sorghum, beef, sheep, goats) or breeders (beef, sheep, goats, guinea fowl, chicken).

Species Description

Boswellia dalzielii Hutch. (Burseraceae) is a gregarious micro-phylum species of 13 m to 15 m high. Its port is remarkable in thedry seasonby its yellowish-white bole; light yellow to grey bark exfoliating in lamellae;reddish-brown slice exuding a white and fragrant sap. Its compound leaves are arranged in terminal tufts, light green and shiny; narrowly oval laminae with saw-tooth shape. Flowering and fruiting occur in the dry season usually before the appearance of the first leaves. Its habitat is savannas with saxicolous woodlands (Arbonnier 2002, Akoegninou etal. 2006, Adomou etal. 2011). In Benin, *Boswellia dalzielii* is found in the phytodistricts of Borgou-Nord, Borgou-Sud and Zou. It is listed on the IUCN red list as an endangered species in Benin.

METHODS

Data Collection

Ethnobotanical Data

Ten (10) villages were selected randomly while ensuring the presence of the species in each of the three (3) phytodistricts. People were interviewed on presentation of *Boswellia dalzielii* specimens and its local names. After the random selection of study areas, a random sample of 50 people in each locality was used to determine the proportion p of informants who exploit *Boswellia dalzielii*. Thus, the size n of the sample was determined using the normal approximation of binomial distribution (Dagnelie 1998) :

$$n = U_{1-á/2}\, p(1-p)/d^2$$

where. n is sample size in each locality; p the proportion of informants who use *Boswellia dalzielii*; $U_{1-á/2}$ (which is 1.96) is the value of the normal distribution related to 1-á/2 probability value with á=5%; d is the error margin of the estimate which was 8% in this article.

After determining the sample size, the informants were chosen randomly to include gender (men, women), age classes (young, adult, old) and sociocultural group (batonu, fulani, gourmantche). A semi-structured questionnaire was administered to informants. 340 informants in 4 districts (Banikoara: 179 people, Ségbana: 87 people, Kalalé: 46 people and Bembèrèkè: 28 people) were interviewed.

Structural Data

The structural data were obtainedfromphytosociological surveys using the Braun-Blanquet sigmatist method (Weber et al. 2000). The main criteria in choosing plots are the presence of the species, the floristic and topographical homogeneity. A total of 60 square plots of 900 m^2 were installed only in the “Borgou-Nord” phytodistrict (42 plots in Banikoara,12 plots in Ségbana, 4 plots in Kalalé and 2 plots in Bembèrèkè). The dendrometric data collected concern the number, diameter and height of all *Boswellia dalzielii* individuals.

Occurrence Data

The geographical coordinates in decimal degree of *Boswellia dalzielii* were collected in the study area by a GPS. Added to these data are those from West Africa available on the Global Biodiversity Information Facility (GBIF.org (29 September 2019) GBIF Occurrence Download https://doi.org/10.15468/dl.l2qdz6).A total of 197 records of occurrences of *Boswellia dalzielii* were collected (70 for fieldwork and 127 from GBIF).

The environmental variables were derived from the Worldclim version 1.4 database. For future climate projections, the Africlim 3.0 regional circulation model available on https://webfiles.york.ac.uk/KITE/AfriClim was used (Platt et al. 2015). For this model, projections up to 2055 have been retained under two scenarios: Representative Concentration Pathways: RCP 4.5 and Representative Concentration Pathways: RCP 8.5. The resulting database was subjected to a correlation analysis with the ENMTools 1.3 in order to eliminate strongly correlated variables (Elith et al. 2011).

Data Analysis

Ethnobotanical data

Around 36 % of informants were women and 64 % men. Their age varied between 16 and 64 years. It was grouped into 3 demographic categories: Young (16 to 29 years), Adult (30 to 49 years) and Old ($50 years). The proportion of each category was 44.12 % for young, 33.82 % for adult and 22.06 % for old people. The socio-cultural groups of informants were batonu (43.24 %),

Table 1. Measures of importance and use of *Boswellia dalzielii* by local population

Measures	Calculation	Description	Source
Use Value (UVs)	$UVs = \sum U_{is} / n$	U : number of uses of the species reported by the informant i in the use category j. j : product, plant part or informant categories. n : number of informant for specie s or for category j. It measures the average number of uses informants know for a species.	Hounsodé et al. (2015)
Cultural Importance Index (CIs)	CIs = $\sum_{U=U_1}^{U_{nc}} \sum_{i=i_1}^{iN} UR_{Ui} / N$	U : use category, nc : number of use categories, UR_{Ui} : number of use-reports for each species in use category U by informant i and N is number of informants. This additive index takes into account not only the spread of the use (number of informants) for each species, but also its versatility, i.e., the diversity of its uses. The theoretical maximum value of the index is the total number of different use-categories (nc), reached in the unlikely case that all the informants would mention the use of the species in all the use-categories considered in the survey. In the case of species with only one use, this index would be equal to RFC (dividing the number of informants who mentioned the use of the species, also known as frequency of citation (FC), by the number of informants participating in the survey (N) Another important property of the CI index is that each addend is a measure of the relative importance of each plant use.	Tardio and Pardo-de-Santayana (2008)
Plant Part Value (PPVs)	$PPVs = \sum RU_{[pp]} / RU$	Express a value given for a specific plant part. It is equal to the ratio between the number of total uses reported for each plant part ($RU_{[pp]}$) and the total number of reported uses for the specie s. Organs (plant part) showing high values of PPV are the most often used parts of the species by informant from a given use category. The sum of all categories gave the value for each plant part.	Gomez-Beloz (2002)
Use Values calculated for men and women	$UV = \sum U_{m,w} / n_{m,w}$	Measures the average number of uses men or women knows for plant species (Medeiros et al. 2011) That measure was also calculated for ethnic group and demographic categories in present paper.	Lucena et al. (2007)

gourmantche (30.29 %) and fulani (26.18 %). Table 1 shows the measures of importance and use of *Boswellia dalzielii* by local population.

Structural Data

The density (D) of the populations expressed in stems / ha : D = N x 10000/S ; N: number of stems; S: plot area. The basal area (G) expressed in m² / ha : G= di : is the diameter at the breast height, n: the overall number of individuals' stems.

The Lorey's height (H_L in m): $H_L = g_i =$ ðD_i^2/4 ;

where gi = basal area of the tree i and hi = height of the tree i.

The horizontal and vertical structure is determined by the Minitab 14 software and is adjusted to the Weibull distribution which can take several forms depending on the value of the shape parameter c (Glèlè Kakaï and Bonou 2010).

Modeling Data

The prediction model was tested with 25% occurrence data and the remaining 75% calibrated the model in five cross-validation reps. The Jackknife test was conducted to determine the significance of the individual environmental variables used.

The AUC (Area Under the Curve) statistic (Phillips et al. 2006) was used to assess the performance of the model as well as True Skill Statistics (TSS) (Allouche et al. 2006). The model is said to perform well if AUC > 0.90; it is fair when 0.75 # AUC # 0.90 and it is bad when AUC < 0.75.

TSS is the ability of the model to accurately detect true presence (sensitivity) andtrue absence (specificity). TSS # 0 indicates a random prediction and TSS > 0.5 indicates good predictive power (Allouche et al. 2006). The raster calculator tool in ArcGIS 10.3 software has been used to categorize habitats. If the probability of occurrence (PO) < 0.5 the habitat is unfavorable. If 0.5 #PO <0.7 the habitat is moderately favorable. If PO $ 0.7 the habitat is very favorable.

RESULTS

Uses and Ethnobotanical Values of *Boswellia dalzielii*

I recorded 119 uses which were grouped into 4 categories: construction, food, medicinal and ritual. Those categories were subdivided into 10 types of uses (Table 2). *Boswellia dalzielii* was most frequently used for medicinal (UVs = 5,739). Construction category was the small uses known by informants (UV = 1,281). The cultural importance index of *Boswellia dalzielii* was higher for food (0,962**)** and medicinal (0,879) categories. The roots are the main plant part used in all categories except in construction where only stems are used (Table 3). The leaves and barks were used especially for health care and rituals.

The analysis of use values following the gender of informants showed that women were the most users of *Boswellia dalzielii*. They used frequently that species for traditional medicine and food. Figure 2 shows that men used preferably *Boswellia dalzielii* for rituals and construction.

Figure 3 shows that all demographic categories mainly exploited the species for medicinal purposes. However, young people were the most users of *Boswellia dalzielii* across all categories. There were more old people than adult ho used that species for onstruction. The analysis of use values following the informants' sociocultural groups revealed that Batonu and Fulani were the greatest users of *Boswellia dalzielii* across all uses categories (Figure 4). But, Gourmantche were the most important users of that species for medicinal and ritual purposes. They do not use it for construction.

Population Structure of *Boswellia dalzielii*

Boswellia dalzielii are a gregarious species and generally grow on gravelly soils and lateritic slabs in shrub and tree savannas. However, isolated individuals are observed.

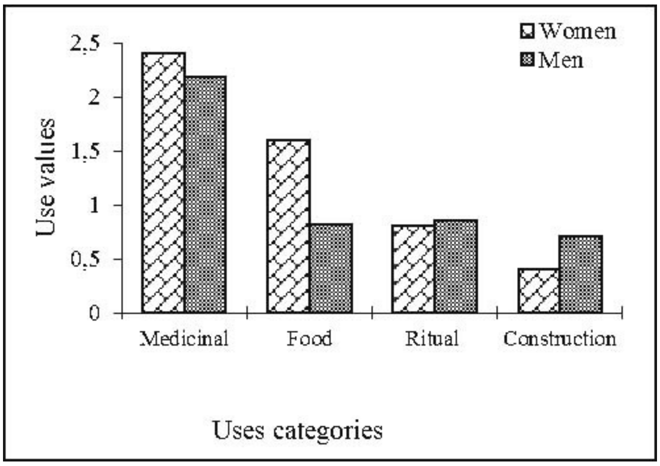

Figure 2. Importance for Gender by use categories

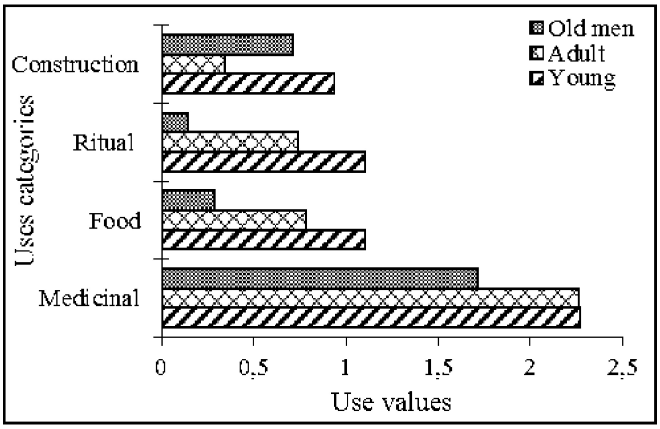

Figure 3. Importance for demographic categories by use categories

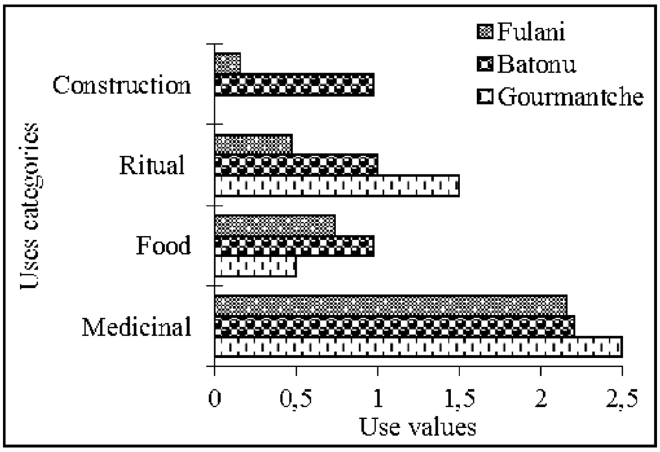

Figure 4. Importance for sociocultural groups by use categories

Table 2. Uses categories of *Boswellia dalzielii*

Categories & Types of uses		Number of citations	Use Value (UVs)	Cultural Importance Index (CIs)
Construction		**41**	**1.281**	**0.293**
	Enclosure	41	1.281	0.293
Food		**159**	**1.606**	**0.962**
	Cooked food	66	0.667	0.415
	Oily extract	12	0.121	0.038
	Powder	3	0.030	0.019
	Raw food	78	0.788	0.491
Medicinal		**924**	**5.739**	**0.879**
	Ashes	70	0.435	0.076
	Extraction	322	2.000	0.326
	Ointment	175	1.087	0.121
	Powder	238	1.478	0.242
	Tea	119	0.739	0.114
Ritual		**102**	**2.125**	**0.608**
	Ashes	52	1.083	0.294
	Bath	50	1.042	0.314
Global		**1226**	**10.751**	**2.742**

Table 3. Importance of plant part (*PPVs*) by uses categories of *Boswellia dalzielii*

Categories	Types of uses	Plant Parts						
		Root	Stem	Bark	Leaf	Fruit	Flower	Seed
Construction		**-**	**1.854**	**-**	**-**	**-**	**-**	**-**
	Enclosure	-	1.854	-	-	-	-	-
Food		**1.298**	**0.050**	**-**	**0.599**	**0.100**	**0.499**	**0.100**
	Cooked food	-	-	-	0.599	-	0.499	-
	Oily extract	-	-	-	-	0.100	-	0.100
	Powder	-	0.050	-	-	-	-	-
	Raw food	1.298	-	-	-	-	-	-
Medicinal		**1.934**	**0.461**	**1.167**	**0.430**	**0.031**	**0.031**	**-**
	Ashes	0.307	-	-	-	-	-	-
	Extraction	1.167	0.061	0.184	-	-	-	-
	Ointment	0.092	0.246	0.092	0.338	-	-	-
	Powder	0.154	-	0.860	-	0.031	-	-
	Tea	0.215	0.154	0.031	0.092	0.000	0.031	-
Ritual		**1.545**	**1.133**	**1.339**	**1.236**	**-**	**-**	**-**
	Ashes	1.545	1.133	-	-	-	-	-
	Bath	-	-	1.339	1.236	-	-	-

The horizontal structure of *Boswellia dalzielii* populations showed that individuals with a diameter of less than 5 cm are dominated the population (Figure 5). The diameter distribution followed a straight asymmetric distribution with a Weibull C shape parameter value of the order of 2.076 characteristic of mono-specific stands with predominance of young individuals or small diameters. It is noted that populations of *Boswellia dalzielii* are characterized by young individuals that do not mature due to anthropogenic pressure.

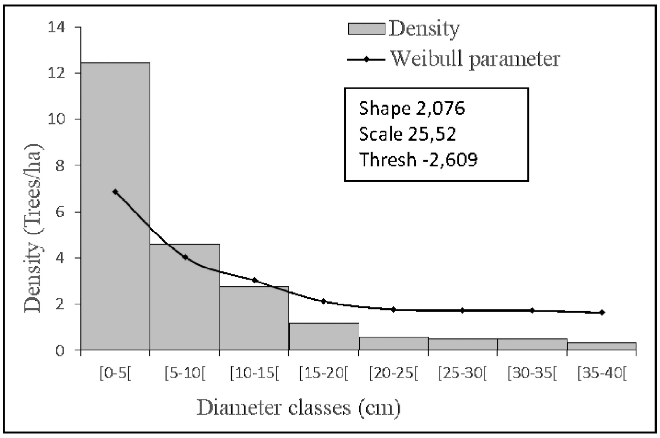

Figure 5. Diametric structure of *Boswellia dalzielii*

The vertical structure of *Boswellia dalzielii* populations shows that individuals less than 2 m high are largely dominant with a density of 12.03 stems ha^{-1}. In addition, individuals with a height between 2 m and 8 m are very poorly represented (Figure 6). On the other hand, individuals whose height is greater than or equal to 14 cm are not represented. This height structure follows a straight asymmetric distribution with a Weibull C shape parameter of 2.5734 characteristic of mono-specific stands with predominance of young or low height individuals. *Boswellia dalzielii* populations are believed to be dominated by juveniles that were expected to ensure the survival of the species. Unfortunately this dynamic is interrupted by anthropogenic activities that inhibit juveniles' growth.

Impact of Climate Change on the *Boswellia dalzielii* Distribution Areas

Contribution of Variables to the Prediction of the Ecological Niche

Table 4 presents the contribution of variables to the prediction of *Boswellia dalzielii* habitats. The variables used contributed to the prediction of habitats (Table 4). Among these variables, the number of dry months (dm), the minimum temperature of the coldest month (bio 6) and the precipitation of the driest quarter (bio 17) contributed the most to the prediction of *Boswellia dalzielii* habitats from their order of integration in the prediction model. Thus, in terms of the importance of permutation (Table 4), it appears that the permutation of the variable''dm''causes the reduction of the predictive power of the model by almost 52.6% and that of the minimum temperature of the coldest month reduced to 19%. From this, we can deduce that the permutation of these two variables reduces the prediction of the model to nearly 71.9%.Therefore, these two variables were the most important in the prediction of the species' habitats. On the other hand, other variables such as bio 17, bio 14 and bio 16 have had a weak influence on the discrimination of these habitats.

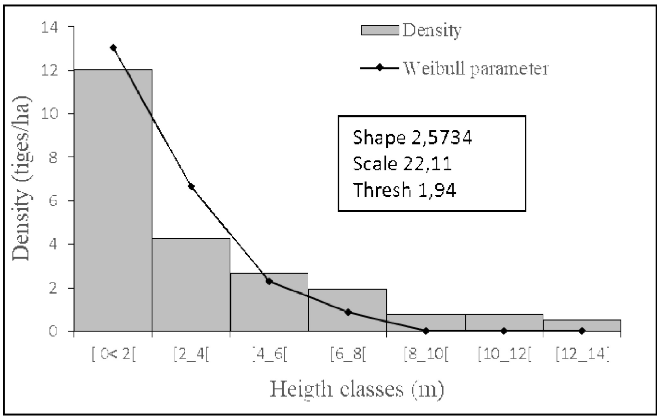

Figure 6. Height structure of *Boswellia dalzielii*

Model predictive power and Jackknife test

The average value of TSS obtained is 0.68 ± 0.032. That of the AUC is 0.88 ± 0.037. These values indicate the good performance of the model in predicting the spatio-temporal dynamics of *Boswellia dalzielii* habitats in the

Table 4. Contribution of variables to the prediction of *Boswellia dalzielii* habitats, based on modeling results

Variable	Denomination	Contribution (%)	Importance of permutation (%)
dm	Number of dry months	58.1	52.6
bio 6	Minimum temperature of the coldest month	13.4	19
bio 17	Precipitation of the driest quarter	11	11.7
bio 14	Precipitations of the driest month	9.7	7.5
bio 16	Precipitation of the wettest quarter	7.8	9.3

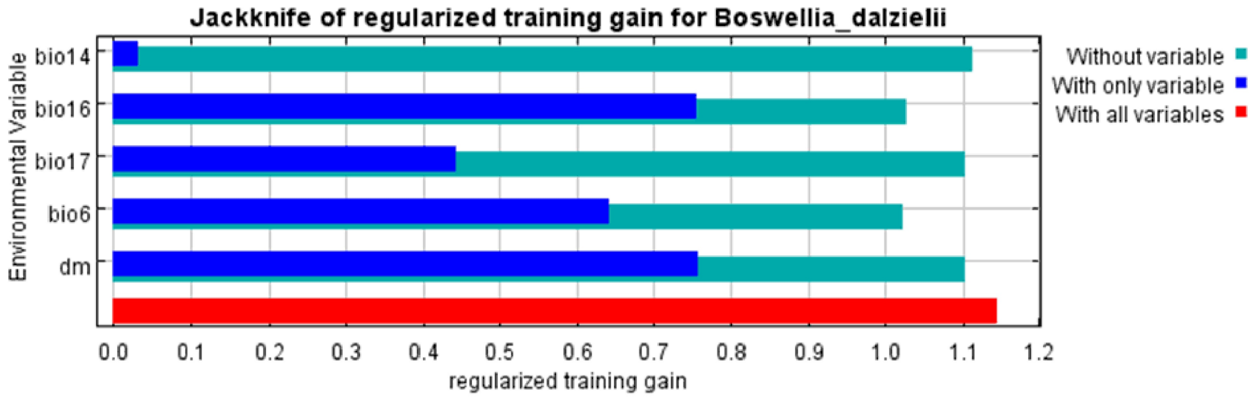

Figure 7: Jackknife test on environmental variables used

study area. Figure 7 presents the Jackknife test on the importance of the variables used. Fgure 7 shows that the variable that increases the information gain explaining the distribution of *Boswellia dalzielii* is the number of dry months (dm). It is followed by the precipitation of the wettest month (bio 16), then by the values of the minimum temperature of the coldest month (bio 6) and the precipitation of the driest quarter. The precipitation of the driest month contributed little to the gain of information.

Current and Future *B. dalzielii* Distribution Areas

The current and future *Boswellia dalzielii* distribution areas varied spatially and temporally according to the scenarios used. Table 5 shows the variation in the areas of present and future *Boswellia dalzielii* habitats. Figure 8 shows the spatial distribution of these habitats in the sudanian region of Benin.

The areas of *Boswellia dalzielii* habitats vary from one prediction scenario to another (Table 5). In the current climatic conditions, the habitats more favorable to *Boswellia dalzielii's* distribution represent an area of 29022 km². These habitats are located northwest and extend north, west, southeast, and part of the central sudanian region (Figure 8). Moderately favorable ones cover an area of 23383 km² of the study area and are located east and center to south. The unfavorable habitats cover an area of 6001 km² and are located in the extreme south, southwest and part of the center.

As part of the mitigation of greenhouse gas emissions (Representative Concentration Pathways: RCP 4.5), more favorable habitats will experience a decrease of about 17% in their currently very favorable area. On the other hand, those moderately favorable and unfavorable will experience an increase of 21.15% and 0.69% of their current surface respectively (Figure 8). In thecontext of an increase in greenhouse gas emissions (Representative Concentration Pathways: RCP 8.5), currently more favorable habitats will decrease by around 12% by 2055 (Table 5). On the other hand, those moderately favorable and unfavorable will experience an increase of the order of 15.05% and 0.32% of their current surface area respectively (Figure 8).

DISCUSSION

Pressure and Ethnobotanical Values of *B. dalzielii*

Ethnobotanical use is the main form of pressure on *Boswellia dalzielii*. The medicinal properties of *Boswellia dalzielii* mentioned by the populations are its antitoxic, antiseptic, healing, antimycotic and coridic properties among others. It is used against all forms of poisoning, snake bites, scorpion stings, epidermal diseases (shingles, mange, ringworm, scab, etc.), oral diseases (dental caries, gingivitis), gastrointestinal diseases (ulcers, colic, diarrhoea, dysentery and hemorrhoids), rheumatism, leprosy, syphilis, dyspepsia, malaria, influenza and infantile diseases (dentition). According to magico-religious uses, *Boswellia dalziellii*, also known as an incense tree, is used to praise homes to fight against evil spirits that cause sleep disturbances and nightmares. Finally, the rhizome of this species is also used forfood purposes by humans and animals including rodents.

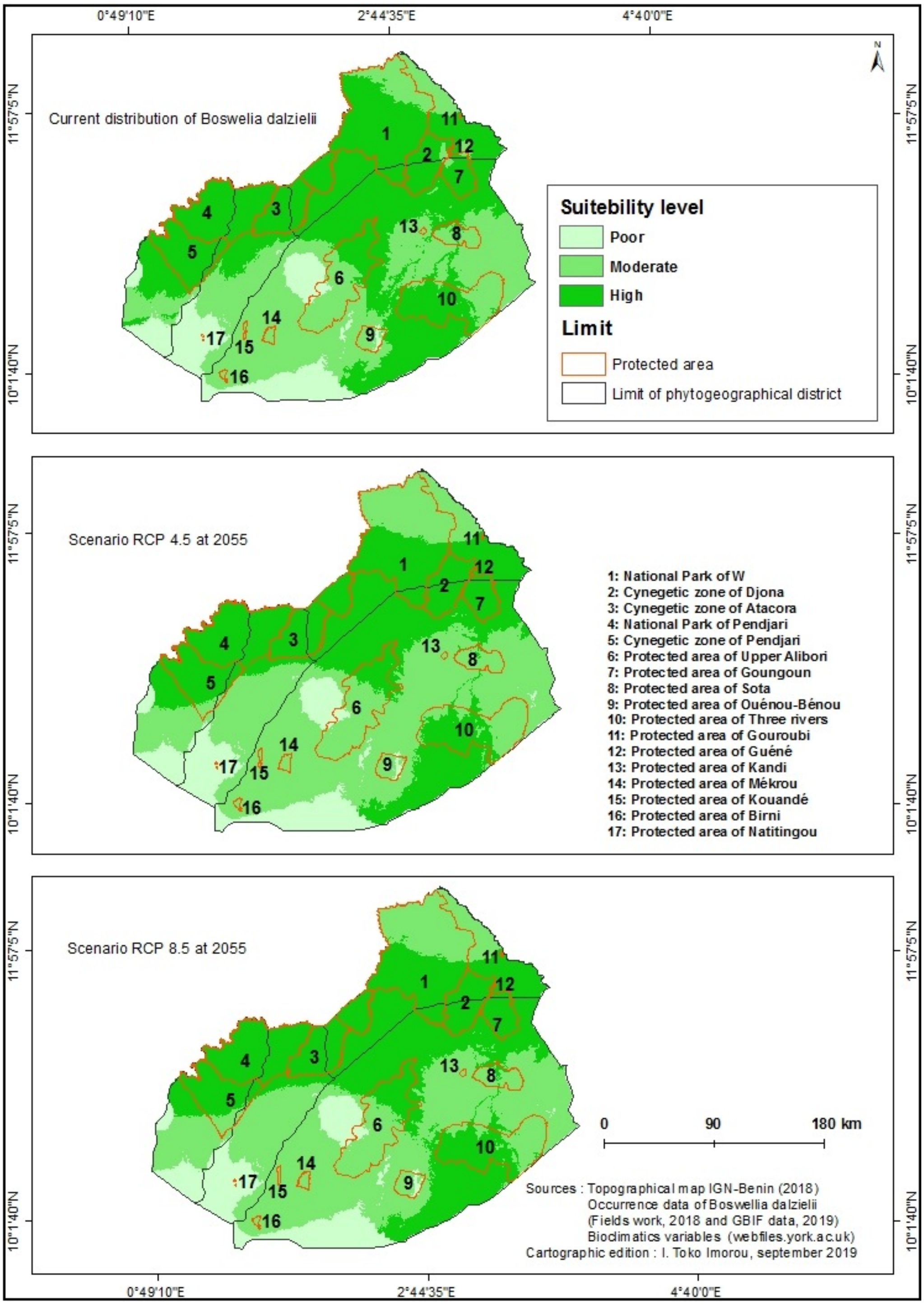

Figure 8. Spatialisation of *Boswellia dalzielii* habitats in the Sudanian region

The same results to the therapeutic properties of *Boswellia dalzielii* are found in West and Central Africa (Nwinyi et al. 2004, Ohadoma et al. 2016, Younoussa et al. 2016, Mbiantcha et al. 2017, DeCarlo et al. 2019). In Nigeria, the aqueous extract of *Boswellia dalzielii* stem bark possesses antimicrobial, anti-ulcer activities and reduced gastrointestinal motility (Nwinyi et al. 2004, Ohadoma et al. 2016). In Burkina Faso, the oleogum resin essential oilof *Boswellia dalzielii*, rich in á-pinene, are comparable in composition to other frankincense essential oils are used in medicine (DeCarlo et al. 2019). In Cameroon, the methanolic extract of *Boswellia dalzielii* stem bark and leaf possesses antinociceptive effects against inflammatory nociception as well as against neuropathic pain (Mbiantcha et al. 2017) and a significant ovicidal, larvicidal and pupicidal activities against mosquitoes (Younoussa et al. 2016).

Roots, bark and leaves are the most used organs. This form of use compromises the survival of the species because uprooting kills the species, debarking and defoliating inhibits growth in diameter and height of the species.On the other hand, the flowers, the stems and the fruits are less solicited because these organs are very rare in the study area. Indeed, the strong stress of the roots, barks and leaves of *Boswellia dalzielii* prevents these individuals from reaching the phenological stages of flowering and fruiting. The same results are found in West Africa (Ouédraogo et al. 2005, 2006a and b, Ouédraogo and Thiombiano 2012, Cakpo et al. 2017).

After ethnobotanical use, the wildfires that consume all the seedlings of the species is the second form of pressure on *Boswellia dalzielii*. These fires are the result of threshing or defensive fires to protect *Anacardium occidentale* plantations and the cotton fields. On the other hand, agriculture through clearing has a negligible impact on the species because it grows on marginal lands that are generally uncultivated.

Population Structure

The low stem density and basal area of *Boswellia dalzielii* observed in the study area are related to anthropogenic pressures, climatic and edaphic conditions. This observation is consistent with studies in West Africa that have reported that the significant low tree-density could be explained by the strong exploitation pressure, but also by a probable poor resilience of trees to bark harvest in the drier conditions. Indeed, bark harvest worsens the vulnerability of trees by exposing them to rapid drying up and pest attack (Ouédraogo et al. 2005, 2006a and b, Assogbadjo et al. 2009, Ouédraogo and Thiombiano 2012, Cakpo et al. 2017). *Boswellia dalzielii* is a threatened species in West Africa (Arbonnier 2002, Akouegninou et al. 2006, Ouédraogo et al. 2006a and b, Adomou et al. 2011).

Niche Modeling

The ecological niche modeling of *Boswellia dalzielii* from the Maxent model (Maximum Entropy) (Phillips et al. 2006) made it possible to highlight the most important bioclimatic variables, particularly the number of dry months (dm), the minimum temperature of the coldest month (bio 6), the precipitation of the driest quarter (bio 17). The two climate scenarios (RCP 4.5 and 8.5) used indicate a decrease in the area of the habitats which is currently very favorable to the distribution of the species by 2055. This decrease is more highlighted in the context of the mitigation of the emissions of greenhouse gases (RCP 4.5) only as part of their increase (RCP 8.5). In addition, the northern part of the Sudanian region, which is less watered than the south, seems more conducive to the conservation of this species in space and time. This proves that the ecological preferendum of *Boswellia dalzielii* evolves in the opposite direction to that of the climatic gradient of the study environment. These results confirm the ecological characteristics of the species. Indeed, according to Arbonnier (2002), Akouegninou et al. (2006) and Adomou et al. (2011), *Boswellia dalzielii* is a very dry Sahelo-Sudanian to Sudano-Guinean savanna species on dry, rocky or shallow soils.

Several authors have implemented the Maxent model to evaluate the effects of climate change on the ecological niche of species (Engler et al. 2004, Saliou et al. 2015, Yilmaz et al. 2016, Ganglo et al. 2017, Qin et al. 2017, Zakari et al. 2017, Agbanou et al. 2018). The advantage of Maxent is that presence data are taken into account in addition to environmental variables in the study area (Thorn et al. 2009, Saliou et al. 2015, Ganglo et al. 2017, Zakari et al. 2017). This model can make inferences from incomplete information despite the limitation of occurrence data (Phillips et al. 2006). Efficient deterministic algorithms have been developed to ensure convergence to the optimal distribution by the model (Elith et al. 2011).

CONCLUSION

This study revealed that *Boswellia dalzielii* was most frequently used formedicinalpurposes.The rootsare the main plant part used in all categories except in construction where stems are used. These ethnobotanical uses have impacts on stems density, height and basal area. In the context of greenhouse gas emissions' increase, current most favorable habitats of *Boswellia dalzielii* will decrease. Thus, this species offers a promising option for future works to elucidate the drivers of lower distribution in Benin.

ACKNOWLEDGEMENTS

This study was partially supported by the Laboratory of Cartography (LaCarto) of the University of Abomey-Calavi (Benin). I'm grateful to the informants and the students who helped in field work.

Conflict of Interest: I declare no conflict of interest.

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Received 27 October 2019
Accepted 11 February 2020