

Abundance, distribution pattern and potential suitable habitat of *Sterculia setigera* Del. in Togo (West Africa)

Wouyo Atakpama¹, Kpérkouma Wala¹, Gérard Nounagnon Gouwakinnou², Hodabalo Pereki¹, Aniko Polo-Akpisso¹, Amah Akodewou¹, Komlan Batawila¹, and Koffi Akpagana¹

¹Laboratory of Botany and Plant Ecology, Faculty of Sciences, University of Lomé, P.O. Box 1515, Lomé, Togo

²Laboratory of Applied Ecology, Faculty of Agronomic Sciences, University of Abomey-Calavi, P.O. Box 526 Cotonou, Bénin

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ABSTRACT: The present study aims to: (i) check its abundance and distribution *Sterculia setigera* Del. in Togo according to biophysical factors and (ii) forecast its potential suitable habitat. *S. setigera* trees (DBH \geq 10 cm) were numbered and human activities were recorded within 518 plots. Geographic Information System offers applications for evaluation of the abundance in relation to anthropogenic threats, human population density, elevation, annual mean temperature, annual mean precipitation, and types of soils. The distribution model based on Maximum Entropy was used to forecast the potential suitable habitat using the species occurrence data and environmental data. Occurrence data were gathered from fieldworks, herbarium records, and scientific published papers. Environmental data were formed by 19 bioclimatic variables and altitude data. Based on cross-correlations among variables, variables' contribution, and jackknife test of variables' importance, six bioclimatic variables were selected for model running. The two main variables that contributed towards predicting the potential suitable habitat were the annual precipitation and the temperature seasonality. The abundance of the species is more positively correlated by the soil type and the topography while it is negatively correlated to rainfall. Anthropogenic threats' importance increase from the south to the north of the country while human population density decrease. The most suitable habitat of *S. setigera* were predicted in eco-floristic zones I and III of Togo. Further studies on the nursery, the regeneration, the cultivar selection and the assessment of the future climate impact will be a great asset for its sustainable management and domestication.

KEYWORDS: *Sterculia setigera*, abundance, habitat suitability, sustainable management, Togo.

1 INTRODUCTION

It is known that human activities and ecological factors affect the distribution, the structure and the diversity of plant species [1-6]. Studies have demonstrated that the abundance, the distribution, and the fruiting potential of indigenous multipurpose trees depend on environmental conditions, and each species has its one exigency and ability facing environmental threats [7-10]. Apart from anthropogenic threats, the climate change is reported as a second significant driver for the biodiversity loss [11]. Uncertainties related to the climate change repercussions on the biodiversity [12] and the population livelihoods call for the need to consider the climate for a better setting up of sustainable management of plant resources.

Since the last decade, steadily request to forecast current and future distribution pattern puts forward biologists, ecologists, and conservationists to the application of Ecological Niche Modelling (ENM). These investigations intended to sustain the conservation of biodiversity, which is facing to unprecedented loss due to human activities and climate change. Growing interest in modelling methods for conservation purposes brings environmentalists and biologists to the use of the Geographical Information System (GIS) and Climate Envelops Models to determine the relationship between species spatial distribution and environmental variables. They are important support-tools to assess quickly the potential impact of climate

variation on the abundance and the distribution of species and ecosystems [13, 14], which can permit to face challenges of development.

Some of the most significant impacts of global climate change will be felt among developing countries' populations [15], from which West African rural communities, who depend mostly on agriculture, pastoralism, and natural resources. Sub-Saharan Africa is, due to its low economic development and the insecurity of local conditions (popular poverty, recurrent droughts, and overdependence on rain-fed agriculture), a region that needs special attention in building adaptation policies to avoid the adverse effect of climate change on ecosystems and access to natural resources such as fertile soils and water [16, 17].

Countless plant species providing non-timber products are acknowledged to improve sub-Saharan residents' livelihood. Products from these plants are used for dietary, medicine, cosmetic, human settlements [18-20]. Some of them such as edible fruits, and gum tree species are economically quoted to be an asset for local communities' income strength [21-24]. However, these species are threatened by human activities [25, 26] and climate change and variability. Their depletion will affect communities' livelihood and income. Therefore, the optimum achievement of the millennium development goal (lowering of poverty and environmental conservation) facing the future climate fluctuations such as rainfall, drought, and warming rise, there is a great need to assess the impact of environmental factors and human activities on the abundance and distribution of plant species and forecast the habitat suitability for their sustainable management.

Among valued West African plants, *S. setigera* has medical, dietary, cosmetic, and fodder properties [20, 27-31]. Its gum is notably a high economical raw material [32, 33]. This species is met from Senegal to Cameroon in west Africa, and from Eritrea to Angola in oriental Africa [34]. In Togo, the species is scattered from the northern to southern along different climatic, soil, and geomorphological ranges. However, the knowledge of this plant as gum species and its gum economic interest as reported by Johnson *et al.* [33] in Senegal is overlooked by Togolese [35]. On-going studies started in Togo since 2008 are justified by the diagnosis of the species as valued resources, which can improve local livelihoods [6, 29, 35, 36].

The present study (i) analysed the distribution and the abundance of *S. setigera* according to biotic and abiotic factors: rainfall, temperature, soil type, topography, human population density and anthropogenic threats, and (ii) forecasted *S. setigera* habitat suitability as a preliminary for planning its sustainable management, domestication, and gum yield in Togo.

2 METHODOLOGY

2.1 STUDY AREA

Togo, with a total land mass of 56,600 km² and a population of 6,191,155 inhabitants [37] is a West African country located from 6°06'-11°08'N and 0°09' W-1°49'W. It is subdivided into five (5) eco-floristic zones [38] established on the basis of geo-climatic factors (Figure 1). The relief is marked by Atakora mountain chain along the country from the northeast to southwest. On both sides of Atakora are settled alluvial plains: Oti and Mô plains at the northwest, and Mono plain at the southeast. The country is shared by three (3) hydrographic basins: Volta basin in the north modelled by Oti River and its feeder streams (Kara, Koumongou), Mono basin to the centre, and seaward basin in the south cross by Zio and Haho rivers.

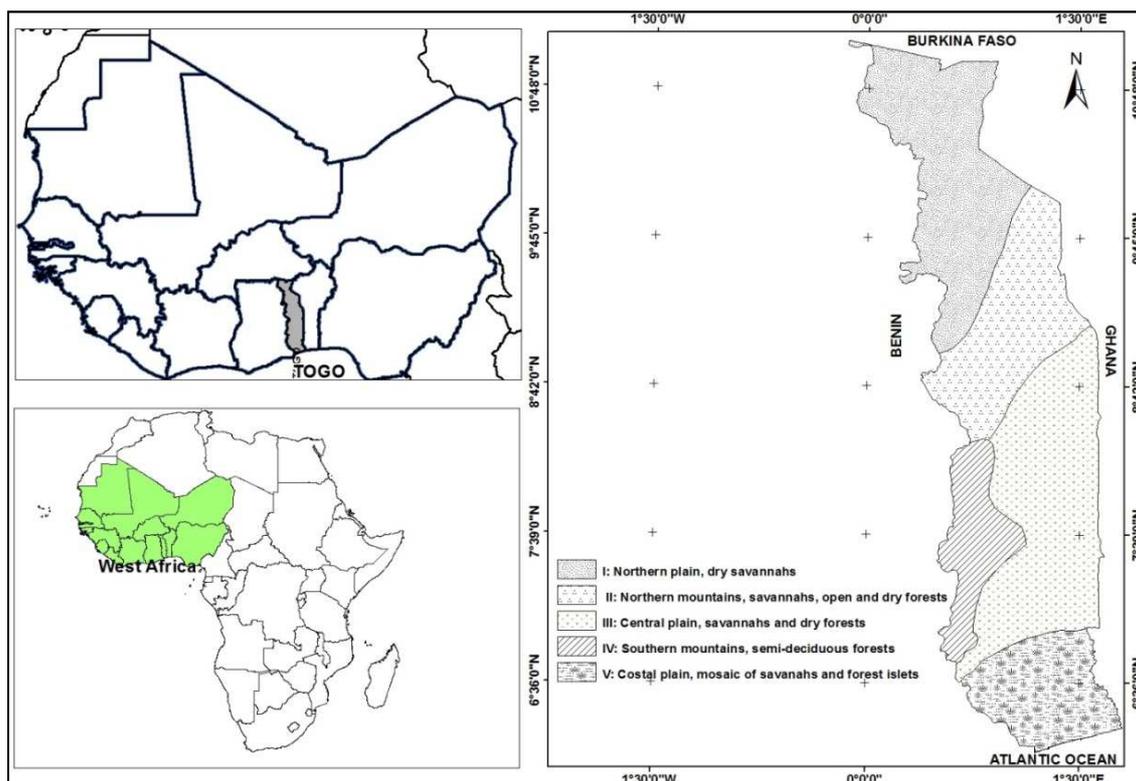


Figure 1: Location of study area

2.2 ASSESSMENT OF ABUNDANCE AND DISTRIBUTION PATTERN

2.2.1 DATA COLLECTION

Data were gathered from 10 October to 15 December 2013. Beforehand, 120 squares of 10 x 10 km were selected on a grid map of Togo. These squares were kept apart from each other at least by 10 km and covered the entire study area corresponding to the species stands early identified [6, 29]. In each square, 0 to 5 plots matching to the presence of *S. setigera* were designed. A total of 518 plots sized 30 m x 30 m in savannahs, 50 m x 50 m in parklands, 20 m x 20 m in open forests, and 50 m x 10 m in riparian forests were done. The size of plot according to each type vegetation were set with reference to previous studies realised in sub-Saharan region and Togo [3, 6, 19, 39-41]. In these plots, *S. setigera* trees with a diameter at breast height (DBH) ≥ 10 cm were numbered. Additionally, ecological variables: topography (plain, mountain side, tableland, ravine), exposition, vegetation cover, type of soil, soil texture, outcrop, and human activities (bushfire, woodcutting, plant part harvesting, grazing, field, and human settlements) occurrence were recorded. Among several parameters which can modify plant species abundance and distribution, we could distinguish: the rainfall, the humidity, the temperature, the evapotranspiration, the topography, the soil fertility, texture and moisture, and human population density and activities. Five (5) of these parameters were selected as factors, which can influence the abundance and the distribution of *S. setigera*: the annual precipitation, the annual mean temperature, the elevation, the soil type, and anthropogenic threats. The choice of these variables was based on bibliographic review [34, 42, 43]. Elevation, annual precipitation and temperature data were obtained from WorldClim Database (<http://www.worldclim.org>) derived from ≈ 1950 -2000 climate data, Version 1.4 (release 3) [44]. Soil data was obtained from Harmonized World Soil Database [45]. Human population sizes of 2010 year were obtained from data published by the Togolese General Direction of Statistic and National Accounting service [37]. Geographic coordinates and altitudes of each plot were recorded using a handheld Global Positioning System receiver (GPS GARMIN etrex 30[®]) for spatial analysis.

2.2.2 DATA PROCESSING

Geographic Information System (GIS) applications are fully used for mapping and analysis. The coordinate of each plot, coupled with densities of *S. setigera* trees per hectare ($D = \frac{n}{S} \times 10000$ with n , the number of *S. setigera* trees counted in a given plot and S , the surface of the plot in m^2) and the number of human activities per plot were projected on the eco-floristic map of Togo conformed to the coordinate system used in Togo (WGS_1984_UTM_Zone_31N). Then, the abundance and the distribution were mapped using Neutral Neighbouring interpolation technique. This technique was also used for spatial analysis of human activities level census within target sample plots during fieldworks, and human population sizes. Evaluation approach through the sum of the elevation, the annual mean temperature, and the annual mean precipitation has been achieved using the overlay analysis to determine the correlation between these three (3) factors and the abundance and the distribution of *S. setigera*. Soil data were also associated in order to mandate soils on which the species commonly grows.

The correlation between *S. setigera* distribution and densities, and environmental variables was assessed using STATA 12.0 statistical software. Each variable values were associated to each sample plot referring to geographic coordinates. The temperature, the precipitation, the soil type, and human population size variables were extracted from raster maps using Spatial Analysis Tools of ArcView GIS 10 Software while elevation, *S. setigera* densities, human activities level were generated from fieldworks data. The statistic test was used to accept or reject the correlation hypothesis of variables.

2.3 ASSESSMENT OF HABITAT SUITABILITY

2.3.1 OCCURRENCE DATA

In order to increase the accuracy of habitat suitability results [46-48], all the West Africa range of distribution of *S. setigera* was taken into account. Species records were gathered from three (3) main sources: fieldworks between 2009 to 2014 in Togo and Benin, published scientific papers, and Global Biodiversity Information Facilities portal (<http://www.gbif.org>). Gazetteers provided by the US National Imagery and Mapping Agency's (NIMA) database of foreign geographic feature names (GNS-National Geospatial-Intelligence Agency, 2005) were used to assign geographical coordinates to herbarium and published papers, which were not geo-referenced. Herbarium records were obtained for other countries apart from Togo, since the three (3) years survey allowed a numerous occurrence data from Togo. Herbarium records anterior to 1950 and those with non-assigned date of collection were removed to match with the timeframe of environmental data set. Five hundred forty-three (543) locations of *S. setigera* occurrence: 441 from fieldworks, 92 from herbarium and 10 from published papers were collected. After maintaining one record per 1 km^2 cell; as MaxEnt automatically removed duplicate, this number was reduced to 417 records.

2.3.2 ENVIRONMENTAL DATA

Current climatic data (19 variables, Table 1) and altitude data available at approximately 1 km^2 resolution were downloaded from WorldClim database (<http://www.worldclim.org>). The current data Version 1.4 (release 3) was derived from the period of 1950-2000 [44]. These data were used successfully by several authors in modelling species distribution [49, 50].

2.3.3 PREDICTION OF HABITAT SUITABILITY

The model was run with the current version of MaxEnt 3.3.3k (<http://www.cs.princeton.edu/~schapire/maxent/>, accessed 26 March 2014) using the default parameters. All duplicate records in a grid were removed to reduce the sampling bias in favour of some sites where sampling was highly intensified [51]. The choice of MaxEnt was supported by the fact that it requires presence-only data to predict the geographic distribution of a species based on the theory of maximum entropy and it can run the model using continuous and categorical predictor variables [52]. It has performed better with small sample sizes comparatively to other modelling methods and was used successfully by other scientists [49, 53-55].

Initially, 20 current environmental variables (19 bioclimatic variables and altitude variable) were used to run the model (Table 1). MaxEnt estimates the habitat suitability for the species based on the probability distribution of species occurrence that is closer to be uniform while still subjected to environmental constraints. MaxEnt generates automatically response curves (the Area Under Curve "AUC" of the Receiver Operating Characteristics Curve "ROC" of the cross-validation) for each predictor variable and a Jackknife test that estimates respectively the model performance and the relative influence of

individual predictors to the model robustness [53]. The AUC value varies from 0 to 1 (gradually from lowest to highest suitability). An AUC value of 0.5 indicates that the performance of the model is no better than random, while values closer to 1.0 indicate best model performance [56]. The AUC values <0.5 are worse than random, 0.5-0.7 signifies poor performance, and 0.7-0.9 indicates reasonable/moderate performance [57]. After scrutiny cross-correlations among variables to account for multicollinearity [58], variables were reduced to six (6). The Jackknife test and percent variable contributions were used to estimate respectively the relative influence of different predictor variables.

Table 1: Bioclimatic variables used for model running

Codes	Variables
BIO_01	Annual Mean Temperature
BIO_02	Mean Diurnal Range (Mean of monthly (max temp - min temp))
BIO_03	Isothermality (BIO2/BIO7) (* 100)
BIO_04	Temperature Seasonality (standard deviation *100)
BIO_05	Max Temperature of Warmest Month
BIO_06	Min Temperature of Coldest Month
BIO_07	Temperature Annual Range (BIO5-BIO6)
BIO_08	Mean Temperature of Wettest Quarter
BIO_09	Mean Temperature of Driest Quarter
BIO_10	Mean Temperature of Warmest Quarter
BIO_11	Mean Temperature of Coldest Quarter
BIO_12	Annual Precipitation
BIO_13	Precipitation of Wettest Month
BIO_14	Precipitation of Driest Month
BIO_15	Precipitation Seasonality (Coefficient of Variation)
BIO_16	Precipitation of Wettest Quarter
BIO_17	Precipitation of Driest Quarter
BIO_18	Precipitation of Warmest Quarter
BIO_19	Precipitation of Coldest Quarter

For model validation, 25 % of the whole records were set to test the model suitability, and 75 % were used for calibration in 10 replicates running. The average value of AUC resulting from the 10 replicate runs was used to assess the model performance. The continuous suitability index map generated by the model calibrated in 10 replicates was converted to binary habitat and non-habitat map using "10th percentile training presence threshold".

The species potential suitable habitat generated by MaxEnt were analysed and mapped using ArcGIS 10.2.2 and DivaGIS 7.5.0. ArcGIS was used to map the overall predicted suitable habitat and prepare files submitted for analysis in DivaGIS. DivaGIS was used especially to assess the habitat suitability throughout the country and to compare predicted suitability between eco-floristic zones, and the importance of protected areas in the conservation of *S. setigera*.

3 RESULTS

3.1 ABUNDANCE, DISTRIBUTION, AND BIOTIC FACTORS

The highest abundance of *S. setigera* corresponds to eco-floristic zone I and III (Figure 2A). This abundance in eco-floristic zone I is observed in the west and the northeast parts. In the eco-floristic zone IV, the species is nearest absent. The west part remains the most provide part of the zone V. Concerning the whole protected areas of Togo, the species is more represented in the complex Oti-Kéran-Mandouri and Galanguashi wildlife reserves situated in the zone I.

Regarding anthropogenic threat importance, it tends to increase from southern to northern part of the country while the human population sizes decrease globally (Figure 2B, C). Five (5) main kinds of human activities were identified: fire, agriculture, grazing, woodcutting, and plant materials harvesting (bark, leaves, fruits, and roots). The common activities are fire and agriculture (greater than 50 % of contact). The other activities are found in Sudanian zone, in particular, grazing was observed in zones I and II. Charcoal production was sometime encountered in the zone I, II, and III.

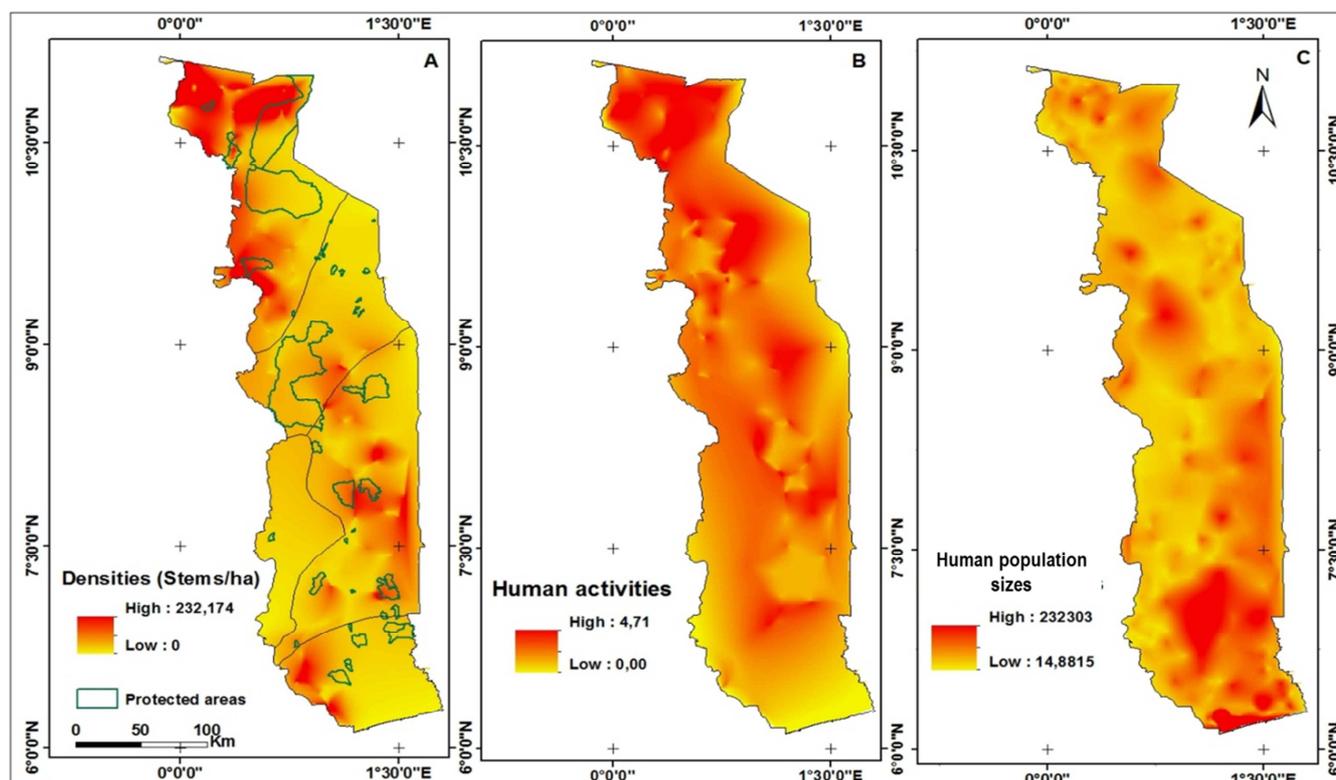


Figure 2: Comparison of areas of abundance and distribution of *S. setigera* with human activities level and population densities

3.2 IMPACT OF ABIOTIC FACTORS ON THE DISTRIBUTION AND ABUNDANCE OF *S. SETIGERA*

The analysis matching to the elevation, the mean annual temperature, and the mean annual precipitation showed that the abundance and the distribution of *S. setigera* did not fit properly when processing each parameter solely. According to the topography, *S. setigera* occurs mostly on rocky hills of eco-floristic zone I and plain of eco-floristic zone III between 80 to 250 m (Figure 3a). It was not found in areas of elevations greater than 350 m overlapping the Atakora chain and lower than 80 m corresponding to the south part of eco-floristic zone V. The high abundance of the species is associated to areas of the country where the temperature is higher (Sudanian zone) while it is nearly absent in areas with lower temperature (Atakora chain and its boundaries) (Figure 3b). When taking into account the annual precipitation, *S. setigera* trees are nearest absent within the zone with high rainfall, greater than 1250 mm (Figure 3c). Overall, the distribution and abundance are more correlated with the elevation than the temperature, and the rainfall.

The overlay of the three (3) parameters: the annual rainfall, the annual mean temperature and the elevation showed that the distribution and the abundance of the species were designed by their ensuant. The distribution of the species corresponds to elevation between 80 to 250 m with mean temperature higher than 26.5 °C and rainfall lower than 1250 mm/year (Figure 3d).

According to soil, *S. setigera* trees were found on lexisol and plinthisol (Figure 4). Within these soils, *S. setigera* is found mostly on shallow soils, quite often gravelly, outcrop and mostly on rocky hill areas.

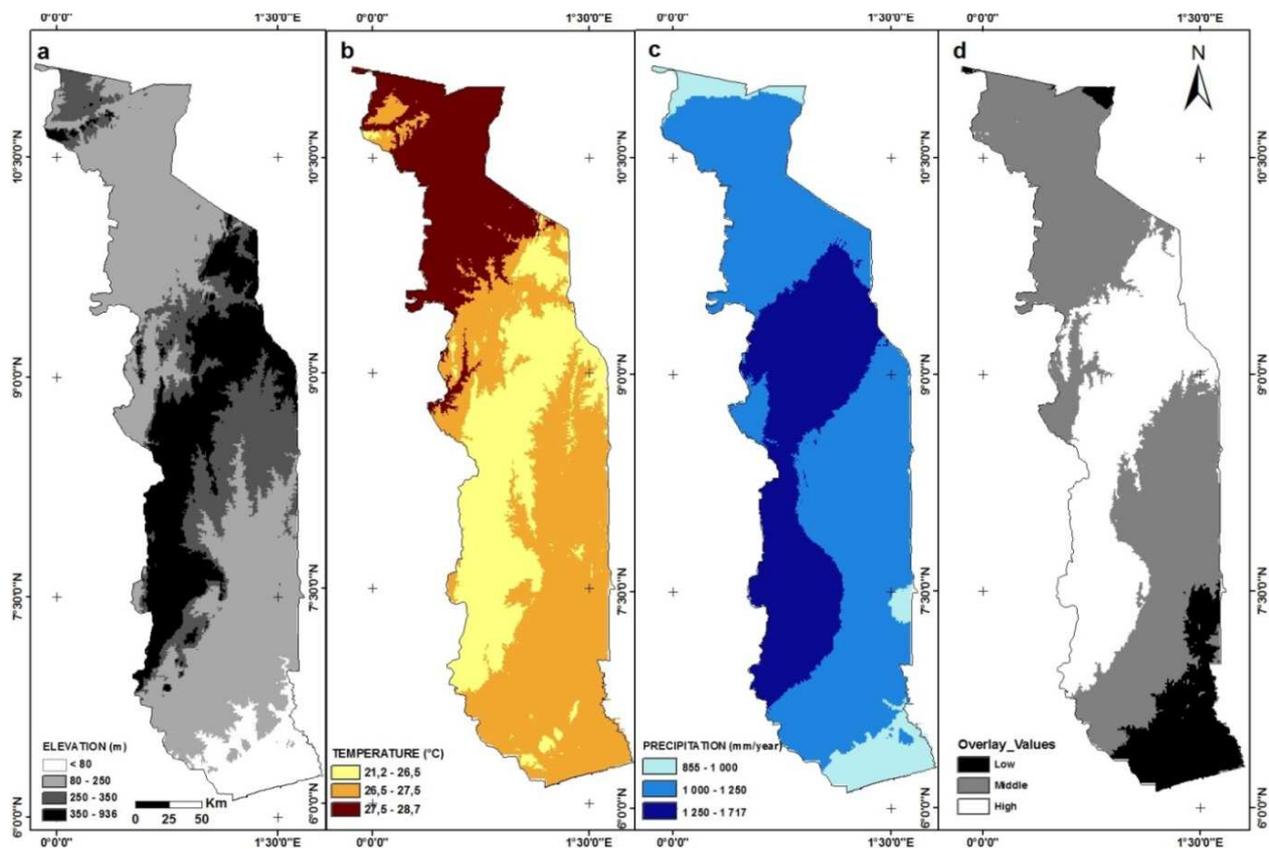


Figure 3: Classified maps of areas of distribution and abundance of *S. setigera* based on elevation, temperature and mean annual rainfall

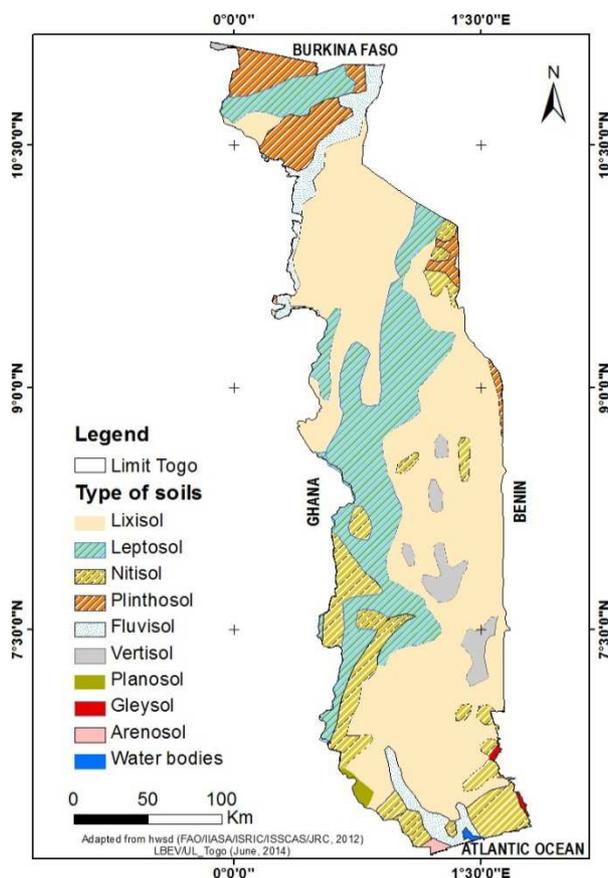


Figure 4: Soil map of Togo (FAO/IIASA/ISRIC/ISSCAS/JRC, 2012)

3.3 CORRELATION BETWEEN *S. SETIGERA* ABUNDANCE AND ENVIRONMENTAL FACTORS

Statistic tests showed a significant correlation between the overall variables and *S. setigera* distribution and abundance ($P < 0.05$). With the exception of precipitation which showed a negative correlation, there is a positive correlation between other factors and *S. setigera* density (Table 2). This result confirmed the predominance of *S. setigera* trees on hills zone with high temperature ranges particularly within the eco-floristic zone I. The negative correlation between the density of *S. setigera* and the annual mean precipitation could explain the nearest absence of the species within the zone IV. In contrast, there is no correlation between human population density and anthropogenic threats observed.

Table 2: Pairwise correlation between *S. setigera* density and environmental variables

	Soil type	Precipitation	Human population	Altitude	Temperature	Threats level
<i>S. setigera</i> density	0.17*	-0.38*	0.20*	0.18*	0.16*	0.20*
Threats level	0.12*	-0.49*	0.11	0.44*	0.30*	1.00
Temperature	0.04	-0.50*	-0.23*	-0.15*	1.00	
Altitude	0.17*	-0.20*	0.22*	1.00		
Human population	0.09	-0.16*	1.00			
Precipitation	-0.49*	1.00				

* = significant difference ($p < 0.05$)

3.4 HABITAT SUITABILITY MODEL

3.4.1 CURRENT POTENTIAL SUITABLE HABITAT

Using the value of “10th percentile training presence threshold” as a cut-off, the continuous grid with probability values 0-1 was converted to suitable/unsuitable habitat considering the occurrence below 0.25 as non-suitable habitat for *S. setigera*.

So, the probability value from 0.25-0,4 was considered as poor suitable habitat, 0.4-0.6 as moderately suitable habitat, and probability above 0.6 was considered as highly suitable habitat.

The current suitable habitat excludes a large part of eco-floristic zone IV corresponding to semi-deciduous forests, sited on the most elevated areas of the country (Atakora mountains chain), in the southern part of Togo (Figure 5). The occurrence of the species was also less predicted in the northerly part of Atakora Mountains. The overall suitable habitat represents about 93 % of the total area of the country i.e. 52,638 km². A large part of the country was considered to be moderately suitable (59 %) and highly suitable (10 %) for *S. setigera*. The high probabilities correspond mostly to eco-floristic zone I while moderate probabilities were mostly predicted in zone III (Figure 6). The model predicted also a high abundance in the southeast of eco-floristic zone V, where the species is less observed by opposition to the southwest part of this areas.

Even though, most of protected areas are predicted to be moderately and highly suitable, this habitat represent only 12 % of the total potential suitable habitat. A large part of the suitable (88 %) were located out of protected areas. The most suitable protected areas is Oti-Mandouri.

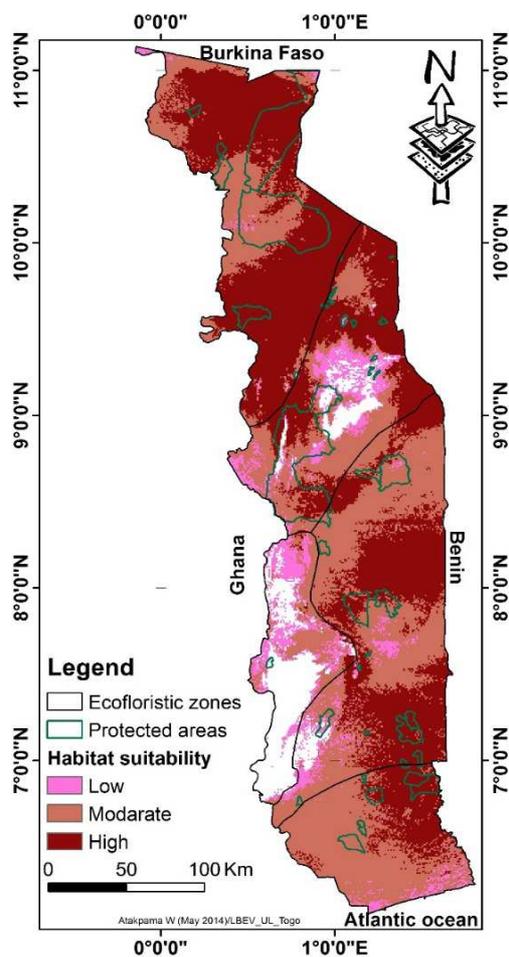


Figure 5: Potential habitat suitability model of *S. setigera* in Togo

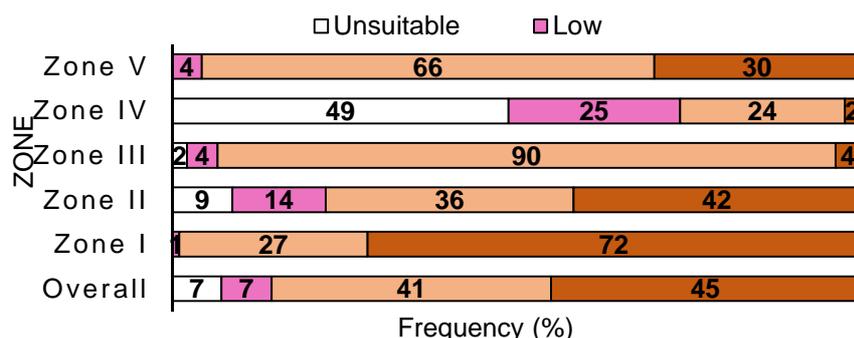


Figure 6: Habitat suitability for *S. setigera* according to each eco-floristic zones

3.4.2 MODEL PERFORMANCE AND FACTORS INFLUENCING

The model showed a good predictive ability with an average test AUC value after 10-fold cross-validation of 0.965 ± 0.006 and an average training AUC value of 0.970 ± 0.01 . The model showed the maximum training sensivity and specificity threshold of 0.128 and the equal training sensivity and specificity of 0.213.

The model performed better than random using six (6) bioclimatic variables (Table 2). These variables are the isothermality (BIO_03), the temperature seasonality (Bio_04), the mean temperature of the coldest month (BIO_06), the mean temperature of the driest quarter (BIO_09), the annual precipitation (BIO_12), and the precipitation of coldest quarter (BIO_19). Variables with the highest gain when used in isolation were BIO_12 and BIO_19, which appears to have the most useful information by itself with respective contributions of 27.0 % and 6 % (Table 1). The variable that decreases the gain the most when it is omitted is the BIO_03, which appears to have the most useful information that is not present in the other variables (Figure 7). The importance of isothermality shows that temperature is an important variable shifting the species occurrence. This should be linked to the relationship of this variable and three (3) others temperature variables, since it is the ratio between mean diurnal ranges (BIO_02), and temperature annual range (BIO_07).

Table 2: Percent contribution of the six selected variables

Variables	Percent contribution
Min Temperature of Coldest Month (TCM)	41.3 %
Annual Precipitation (AP)	27 %
Mean Temperature of Driest Quarter (TDQ)	9.2 %
Isothermality (* 100)	9.1 %
Temperature Seasonality (TS)	7.4 %
Precipitation of Coldest Quarter (PCQ)	6.00 %

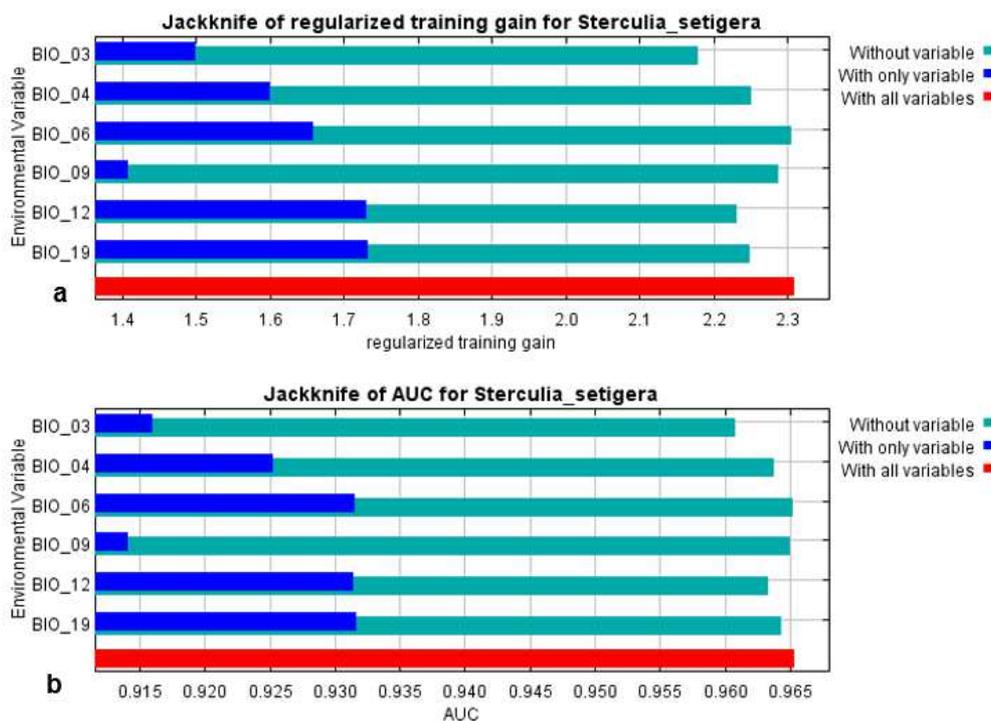


Figure 7 Relative predictive habitat suitability model power of the six chosen variables contribution for *S. setigera* based on the results of Jackknife tests in MaxEnt: (a) regularized training gain and (b) AUC (area under the ROC curve) (Values average over 10 replicate runs)

4 DISCUSSION

4.1 ABUNDANCE AND DISTRIBUTION

Plant species abundance and distribution were shaped by a combination of several factors. The present study showed that the abundance and the distribution of *S. setigera* are mostly affected by both biophysical factors (elevation and soil type) and precipitation. This finding is in accordance to the one of Atakpama *et al.* [59], who study the species stands in Sudanian zone of Togo. According to this one, the abundance of the species on hillside and tableland stands was higher than the ones found upon plains. Even though, the gradient in water and topography do not explain solely the habitat preferences of the species, they influence seedlings' emergence and mortality [60], consequently, the abundance of adult trees. Globally, the topography mostly affects indirectly the abundance and the distribution of plant species through its correlation with temperature and precipitation, and thus, through landscape diversity and configuration, soil, and water dynamics [61]. Local climate conditions: slight, wetness, type of vegetation, temperature, rainfall, evapotranspiration, soil stability, texture, and fertility could be highly changed as soon as the elevation and slope varied.

Seeds' germination and saplings' survival and growth are affected by the water availability and dynamic, the temperature range and fluctuation, and soil texture. The limitation of water losses by deciduousness of *S. setigera* adult trees and its seedlings' swollen root, which is a stock of water and nutrients help seedlings to survive drought as geophytes [8, 62]. These adaptability characteristics to the water deficit could be a reason of its availability not only from southern to northern Togo, but also its best development on rocky hills and fewer wet Sudanian domain of the country.

The lexisol and plinthosol areas where the species often grow coincides to tropical ferruginous leached and battleshop soils. The lexisol is laid on sandstone schists in eco-floristic zone I and on gneiss and granite-gneiss rocks in zone III [63]. Plinthosol is laid on sandstone schist and granite with crude texture, localized in northern part of eco-floristic zone I. The growth of *S. setigera* on tropical ferruginous soil were previously stated by Jonhson *et al.* [33] in Senegal. Its predilection of gravelly soil and rocky hills [34, 42, 43] could justify its abundance in zone I, particularly in Tone, Kpendjal, and Cinkassé prefectures, which have more rocky hills' domain and gravelly soils. Even though, threat levels are higher in Sudanian zone, the abundance of the species is due to the favourable environment: presence of rocky hills and gravelly soils unfit for agriculture.

Apart from climatic and soil factors, the abundance and the distribution of the species are also linked to human population density, living standards, and socio-cultural knowledge. Results showed that the importance of human activities is not directly linked to human population density, even though both factors affect the distribution and the abundance of the species. Human population decreases from the southern to the northern part of the country in opposition to anthropogenic threats, which tend to increase. The importance of human activities in sudanian zone should be justified by the highest poverty rate and the important proportion of famers [37, 64, 65]. Consequently, people use highly plant resources for their daily needs: alimentation, pharmacopeia, source of income and other uses. Admittedly, cultural consideration of *S. setigera* as malefic in Moba ethnic group scatted in Kpendjal, Tône, and Cinkassé prefecture could not favour the preservation of seedlings, however it is a great asset for adult individuals preservation, since the latters are not cut down during farm clearances [66, 67]. Moreover, agroforestry practices of famers of this zone and their deeply knowledge of this plant part uses by comparison to people leaving in Guinean zone [29] contribute to the conservation the species during farm clearances. The involvement of people on the distribution and abundance were previously reported for *Pentadesma butyracea*, *Tamarindus indica*, and *Vitex doniana* in Benin [7, 68, 69].

4.2 HABITAT SUITABILITY

The habitat suitability model revealed that the most suitable habitat of *S. setigera* is eco-floristic zone I and III. The species was also predicted in eco-floristic zone II and V. Therefore, the species fundamental niche is larger than its occurrence observed [6]. This result is in accordance with previous studies which showed that a species fundamental niche is always larger than its realized niche [46, 70]. Constraints of human settlements, human population density, land use, soil, and use knowledge may be the factors, which have limited the species dispersal. Apart from climatic parameters, topography, and soil characteristic, ethno-ecological knowledge and use are valuable factors, which affect plant species dispersal and survival. The soil characteristic is unsuitable for the species [42] in the predicted area of northeast of eco-floristic zone V. The human population densities, human activities and land use type [6, 37, 59] could explain the apparent absence of the species in some suitable predicted areas of eco-floristic zone II. The non-observation in areas predicted as suitable habitat may also be explained by the limitation of seed dispersal which is known to be low [8]. Therefore, human activities and climate fluctuation especially drought recurrence observed these last years [71] should reduce its regeneration capacity.

In future, the vulnerability of *S. setigera* could be increased in the face of climate change with the reduction of water availability [15, 17]. However, the capacity of the species to grow on a wide variety of soil with low nutrients [34, 42, 43], with water constraint through water and nutrient' stock within swollen roots by seedling [8] could be an asset against rude and changing climate conditions.

Even through, the prediction seem suitable, the integration of soil, evapotranspiration, and land cover variables will better improve the model. The soil through its structure, nutriments availability, and water dynamic (soil moisture content and infiltration) is an important ecological factor which affects plants species germination and growing. According to scholars, *S. setigera* could be growth on a variety of soils, but it enfolds rocky hills and gravelly soils [42, 43, 72]. The importance of edaphic variables in the quality of prediction models was showed by Coudunet *al.* [73].

The evapotranspiration is another very important ecological factor, since it is correlated to plants' transpiration. The precipitation combined to potential evapotranspiration will help to determine the water balance, a useful factor which define the soil humidity (partially explained by precipitation and temperature) and consequently plants flowering, fruiting, seeds dispersal, and germination, and plants development. Land cover and land use affect soil moisture and infiltration, and evapotranspiration [74]. Assessing the impact of such factors is important for a best strength of a niche model. Elsewhere, the distribution of plant species is not affected solely by climatic factors, the biotic factors such as human activities which could favour or hinder seed dispersal. The complex interaction among vegetation, soils, geology, climate variables, and human activities schedule plant species distribution and abundance. Despite these limits, climatic variables remain very useful and most available variables used in the assessment of species modelling, especially in a large scale.

5 CONCLUSION

S. setigera is widespread in Togo and is more abundant in respectively in eco-floristic zone I and III. Its abundance and distribution pattern were affected by biotic and abiotic factors. It enfolds tropical ferruginous soils and is met in areas less wet and elevated with relative high temperature. Human activities encountered within *S. setigera* stands increase from south to north by opposition to population sizes. So, the importance of human activities is not linked only to the presence of people but also to plant resources use knowledge and needs. The species potential habitat suitability model performed reveals habitat suitability in some areas where *S. setigera* is not observed. Apart from elevation, the two variables which affect

mostly the distribution of *S. setigera* are the annual precipitation and the isothermality. Eco-floristic zones I and III were pointed out as the most suitable habitat of *S. setigera* and could be chosen as future vulgarization areas. Conservation strategies are needed for lasting management and valorisation of the species. To improve model quality further, the combination of land use, edaphic parameters, evapotranspiration variables, and human activities data are in need. The knowledge of socio-economic importance would contribute greatly to the conservation of the species since the socio-economic value is a factor, which determine the preservation and the integration of species in agroforestry systems. Cultivars' selection, nursing, and assessment of future climate impact on the population viability will be further research priority for a sustainable management and domestication of the species in Togo. The implication of protected areas on the conservation of the species will be also investigated.

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