Environment and Natural Resources Research; Vol. 6, No. 2; 2016
ISSN 1927-0488 E-ISSN 1927-0496
Published by Canadian Center of Science and Education

Modeling the Geographic Distribution of *Prosopis africana* (G. and Perr.) Taub. in Niger

Laouali Abdou[1], Abdoulaye Diouf[2], Maman Maârouhi Inoussa[3], Boubacar Moussa Mamoudou[1], Salamatou Abdourahamane Illiassou[1] & Ali Mahamane[1,3]

[1] Université de Diffa, Faculté des Sciences Agronomiques, BP 78, Diffa, Niger

[2] Université de Maradi, Faculté d'Agronomie et des Sciences de l'environnement, Département des sciences du sol et de télédétection, BP 465, Maradi, Niger

[3] Université Abdou Moumouni, Faculté des Sciences et Techniques, Département de Biologie, Laboratoire Garba Mounkaila, BP 10662, Niamey, Niger

Correspondence: Laouali Abdou, Université de Diffa, Faculté des Sciences Agronomiques, BP 78, Diffa, Niger. E-mail: abdoulaouali2000@yahoo.fr

Received: December 19, 2015 Accepted: April 14, 2016 Online Published: May 30, 2016

doi:10.5539/enrr.v6n2p136 URL: http://dx.doi.org/10.5539/enrr.v6n2p136

Abstract

Prosopis africana is a species of great socio-economic importance, threatened with extinction from its natural habitat in Niger due to overexploitation. The main objective of this study is to determine the potential geographic distribution of *P. africana* in Niger. Climatic and botanical data has been collected and used to model the distribution, on the basis of principle of maximum entropy (MAXENT) using MAXENT 3.3.3k, DIVA-GIS 7.5, and ArcGIS 10.0. programs. Rainfall and temperature are the most significant variables in the distribution of *P. africana* in Niger. Thus the southern band of the country (from the sudanian zone to the sahelio-soudanian zone), the wettest, is the area conducive to the development of *P. africana* (128,692.32 km^2 in total, 10.16% of the territory). Given the extent of this area revealed by this study, a reforestation policy implementation of *P. africana* would allow to restore its stands in Niger.

Keywords: *Prosopis africana*, Geographic distribution, Modeling, habitat, MAXENT, Niger

1. Introduction

In the third world countries, wood plants figure prominently in the socio-economic life of the people, given the many products and services (wood, food and Pharmacopeia) that they provide (Matthias, Henri, & Félix, 2000; Larwanou, Oumarou, Laura, Dan Guimbo, & Eyog-Matig, 2010; Chidumayo, Okali, Kowero, & Larwanou, 2011; Priso, Nnanga, Etame, Din, & Amougou, 2011; Laouali, Dan Guimbo, Larwanou, Inoussa, & Mahamane, 2014). They are thus subject to overexploitation and a threat of disappearance of their natural habitats, due to high population growth and climatic conditions increasingly unfavorable to their development (Ozer, Hountondji, Niang, Karimoune, Laminou, & Salmon, 2010). Indeed, the natural range of the species is influenced, among others, by climatic variables such as precipitation, temperature and wind speed (Intergovernmental Panel on Climate Change [IPCC], 2007; Chidumayo et al., 2011). However, it should be noted that according to the quality of products supplied, woody species do not have the same importance and therefore do not have the same degree of exploitation.

In West Africa, *Prosopis africana* is distinguished from other woody plants by the exploitation and use of all its organs (leaves, bark, root ...) by the rural population. For example, its wood, very resistant, is used as building materials (sheds, attics, ...) and in the manufacture of household utensils (mortar, pestle, ...) and charcoal, judged good by blacksmiths (Agboola, 2004; Akaaimo & Raji, 2006; Laouali et al., 2014). The leaves, roots and mostly the bark are usually used in traditional pharmacopoeia. The leaves and the pods pulps are also used as fodder and the seeds in food (Larwanou, 1994; Arbonnier, 2000; Agboola, 2004; Akaaimo and Raji, 2006; Larwanou, Moustapha, Rabé & Dan Guimbo, 2012; Laouali et al., 2014).

Characterized by a low capacity of natural regeneration (Ahoton, Adjakpa, M'po Ifonti & Akpo, 2009; Niang-Diop, Sambou & Lykke, 2010; Laouali, Dan Guimbo, Youchaou, Rabiou & Mahamane, 2015a) and a low fruit production (Laouali, Dan Guimbo, Chaibou & Mahamane, 2015b), *P. africana* is represented in Niger by generally isolated individuals whose spatial distribution across the territory remains unknown. But a good knowledge of the spatial distribution and the habitat of species helps to develop effective strategies for biodiversity planning and conservation (Scheldeman & Van Zonneveld, 2010), forecasting the effects of environmental change and zonation of plant diversity (Schmidt, König, & Müller, 2008). Among the methods that allow knowing the distribution of species, there is modeling.

The modeling of species distribution is an expanding field of science with rapidly evolving new methods (Guisan & Thuillier, 2005). This approach has been adopted by several authors throughout the world to determine suitable habitats for species development (Araújo, Pearson, Thuiller, & Erhard, 2005; Phillips, Anderson & Schapired, 2006; Doko, Kooiman, & Toxopeus, 2008; Kumar & Stohlgren, 2009; Fandohan, Gouwakinnou, Fonton, Sinsin, & Liu, 2013; Gbesso, Tente, Gouwakinnou, & Sinsin, 2013). This study aims to determine the suitable habitats for the development of *P. africana* in Niger through modeling of its potential distribution to better protect it and prevent its disappearance.

2. Material and methods

2.1 Study AREA

This study covered the entire territory of Niger, 1,267,000 km^2 between 11° 37' and 23° 33' north latitude and between 0° 10' and 16° 00' east longitude. Niger is bounded on the north by Algeria and Libya, to the east by Chad, to the south by Nigeria and Benin, and to the West by Burkina Faso and Mali (Figure 1).

The climate is generally warm and dry but with a variability according to a north-south aridity gradient for distinguishing a saharan zone in the north (about 2/3 of the territory) with an average annual rainfall of less than 200 mm, a sahelian zone with an average annual rainfall between 200 and 600 mm and on the south a soudanian zone whose average annual rainfall exceeds 600 mm. The passage from one zone to another is marked by a climatic transition band which implies variability in the spatial distribution of vegetation. So, from north to south, the vegetation varies from steppe to dry woodland, through savanna and Combretaceae thickets.

During the year, the mean temperature varies from 9.9 to 32.63° C in the north, from 19.44 to 32.78° C in the southeast and from 25.84 to 33.57° C in the southwest of the country.

The main types of soils in Niger are:

- raw mineral soils in the north, the least watered area of the country;
- low developed soils in the south of Tenere, in the west and center of the country;
- sub-arid soils rich in organic matter, more watered than the previous, located from west to east in the central part of the country;
- soils with sesquioxides of iron, rich in swelling clay, located in the southern part of the country;
- vertisols especially in the east in the Lake Chad basin (Saadou, 1990).

About geomorphology, Niger has a fairly wide variety of landforms: structural forms marked by the lithological and tectonic data and climatic forms related to the erosion action.

2.2 Plant Material

The genus Prosopis is represented by 45 species of trees and shrubs native to North America, Central America, South America, Africa and Asia (Akaaimo & Raji, 2006). The unique tropical african species of the genus is *Prosopis africana*, native to the Sahel region of West Africa. Its natural distribution covers from Senegal to Ethiopia in the north, Guinea to Cameroon in the south and Uganda to Egypt in the East (Weber, Larwanou, Abasse, & Kalinganire, 2008).

The tree, with a height of 12-15 m, sometimes even 20 m, is characterized by a straight and cylindrical trunk, sometimes up to 110 cm in diameter, an open crown and drooping light green foliage (Arbonnier, 2000). Its root system is of the tap type (Weber et al., 2008).

2.3 Data Collection

2.3.1 Presence Points of the Species

A series of botanical surveys in different regions of Niger has enabled to establish a database on the occurence of *P. africana* in Niger. Other databases such as that of the Garba Mounkaila laboratory of Abdou Moumouni University of Niamey, and GBIF (Global Biodiversity Information Facility) (www.gbif.org, accessed on 2/11/2014) and previous works (Weber et al., 2008; Larwanou et al., 2012) have been exploited. According to all these bases, the species occurs mainly in the sahelian and sudanian climatic zones with a higher concentration in the south-central region of the country. So, 234 presence points of the species, of which 203 in Niger and 31 distributed among eastern Burkina Faso, northern Nigeria and northern Benin were selected for this study (Figure 1). The presence points of the species have been extended beyond Niger administrative borders to improve the accuracy of the model. According to several authors (Fitzpatrick & Hargrove, 2009; Scheldeman & Van Zonneveld, 2010), it is recommended to use an area that covers to the fullest the natural distribution area of the species under the same climatic conditions.

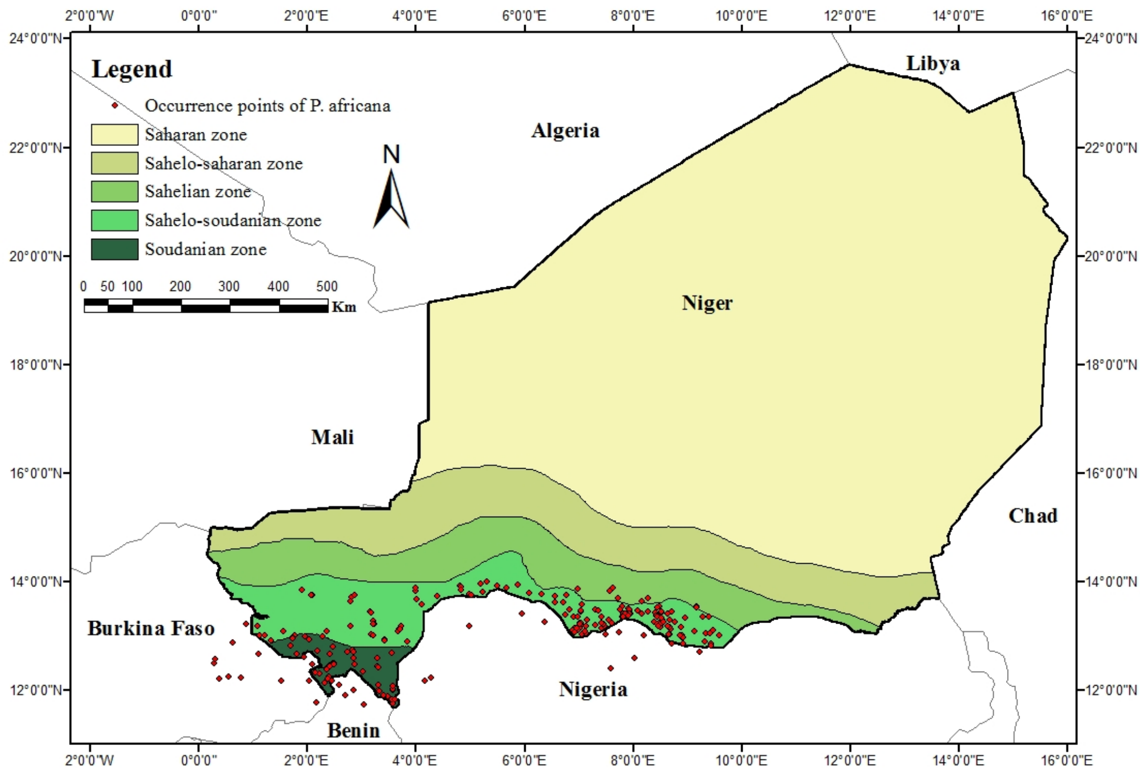

Figure 1. Presence points of *P. africana* in the study area

2.3.2 Climatic Data

As the climate is the main determinant of the ecological niche of species on a large scale (Parviainen, Luoto, Ryttari & Heikkinen, 2008), WorldClim archives have been exploited. The principle of WorldClim is to provide detailed information on the climate by interpolation of data collected around the world by more than 20,000 monitoring stations (Hijmans, Susan, Juan, Peter, & Andy, 2005).

Two types of climatic data (precipitation and temperature monthly mean, divided into 19 variables) of the 1950-2000 period were selected and used in this study. The data in raster CLM with a spatial resolution of 2.5 minutes (5 km x 5 km = 25 km^2 the pixel) have been downloaded from WorldClim archives (www.worldclim.org, accessed on 9/21/2014). Other environmental factors such as soil factors are decisive in the distribution of a species but at finer scales; do not take this into account in this study results from the tolerance of *P. africana* for most soil types (Weber et al., 2008).

2.4 Data Analysis

To generate the theoretical model of distribution of *P. africana*, data on the presence of the species and the 19 climatic variables were treated with DIVA-GIS 7.5, MAXENT 3.3.3k. and ArcGIS 10.0 softwares used in the same frame by several authors (Hijmans et al., 2005; Phillips et al., 2006; Scheldeman & Van Zonneveld, 2010; Young, Carter, & Evangelista, 2011).

The first step in the creation of the model consisted, using the DIVA-GIS program, to convert the CLM format of the imported climatic data in ASCII format to obtain environmental raster supported by the MAXENT modeling program. These rasters are made up of 19 climatic variables, some of which have been discarded after a Pearson correlation test. Indeed, among the variables that have a high correlation coefficient ($|r| > 0.7$, as proposed by Dormann et al. (2013)), only one was selected based on its ecological importance for the species, because a strong correlation between these variables would introduce a bias in the model (Warren, Glor, & Turelli, 2010; Lee, Hanneman & Hackenbrook, 2011; Dormann et al., 2013; Maël, Catherine, Beatriz, & Vincent, 2014).

From the variables used and the information layer on the occurrence of *P. africana*, the MAXENT program generated a raster on the potential distribution of the species and a file containing the various statistical results of the model. Finally, the superposition of an information layer of administrative boundaries in ArcGIS, as had been done by Scheldeman and Van Zonneveld (2010), Young et al. (2011), Hijmans, Luigi, and Prem (2012), enabled to map and to locate the potential distribution areas of *P. africana*.

To determine the individual contribution of each variable, a Jackknife test (Young et al., 2011), which consists in spread by turns the variables and generating each time a model with the remaining variables then a model with the only discarded variable, was performed (Figure 2).

Cross-validation was also used in this study. Cross-validation is a process of evaluating the efficiency of a model that consists of split the presence points in two parts to calibrate and to test the model. The calibration of a model is to adjust the parameter values (climatic variables and presence points) in order for the simulated data correspond to the actual values (Guisan & Zimmermann, 2000; Dzotsi, 2002). In this study, 75% of the species' presence points were used to calibrate the model, while 25% were used to test it. These same rates have been used by Doko et al. (2008), Young et al. (2011), Fandohan et al. (2013), Gbesso et al. (2013) to calibrate and test their models. To strengthen a model, it is important to generate it from an average of multiple repetitions of cross validation (Young et al., 2011). Cross-validation was repeated 10 times in this study. About the predictive ability of the model, it was evaluated by using the parameter AUC (Area Under the Curve). The AUC is equal to the likelihood that a randomly selected presence point is located in a raster cell with a higher probability value for species occurrence than a randomly selected absence point (Phillips et al., 2006).

A model generated by MAXENT is excellent if AUC > 0.90, good if 0.90 > AUC > 0.80, acceptable if 0.80 > AUC > 0.70, bad if 0.70 > AUC > 0.60 and invalid if 0.60 > AUC > 0.50 (Swets, 1988). The lower value of the AUC is 0.5, corresponding to a random prediction and the highest value is 1 (Phillips et al., 2006).

3. Results

3.1 Contribution of Climatic Variables and Performance of the Model

After the correlation test, only five (5) climatic variables were selected because of their low correlations ($|r| \leq 0.7$), and used for modeling. These are BIO3 (isothermality), BIO9 (average temperature of the driest quarter), BIO10 (average temperature of the warmest quarter), BIO12 (annual precipitation) and BIO18 (precipitation of the warmest quarter). Among these variables, the study reveals that BIO12 and BIO10 have the highest levels of contribution to the model (Table 1).

Table 1. The climatic variables used and their contributions to the model

Code	Variable	Contribution (%)
BIO12	Annual precipitation	82.8
BIO10	Average temperature of the warmest quarter	8.4
BIO9	Average temperature of the driest quarter	3.9
BIO3	Isothermality (Temperature Mean Diurnal Range/Temperature Annual Range) * 100	3.3
BIO18	Precipitation of the warmest quarter	1.6

The cross-validation, with an AUC of 0.953 and the Jackknife test (Figure 2) confirm the contribution to the model of BIO12 that has the highest gain when used in isolation and decreases the gain the most when it is omitted from the analysis.

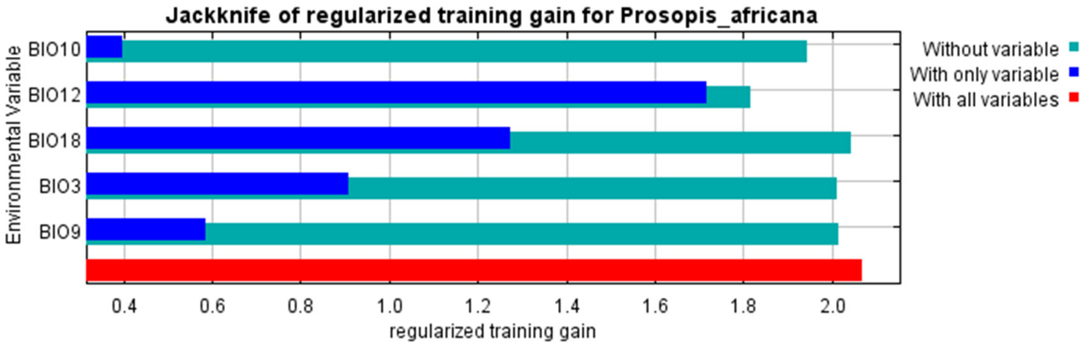

Figure 2. Jackknife test results on the 5 variables. The blue bar shows the gain obtained if a variable is used alone and the remaining variables are excluded from the analysis and the green bar shows how much the total gain is reduced if this variable is excluded from the analysis

3.2 Potential Distribution Areas of P. africana in Niger

The study reveals that favorable habitats for the development of *P. africana* in Niger, 128,692.32 km^2 in total, 10.16% of the territory, are allocated between sahelian, sahelo-soudanian and soudanian zones (Figure 3). The most favorable habitats cover an area of 41,304.32 km^2, 3.26% of the territory and are divided mostly between the sahelo-soudanian and soudanian zones, the wettest of the country. The averagely favorable habitats for the development of *P. africana*, with an area of 57,138 km^2, 4.51% of the national territory, are located mostly in the sahelo-soudanian zone. The less favorable habitats, with an area of 30,250 km^2, 2.39% of the territory, are mainly located in the sahelian zone.

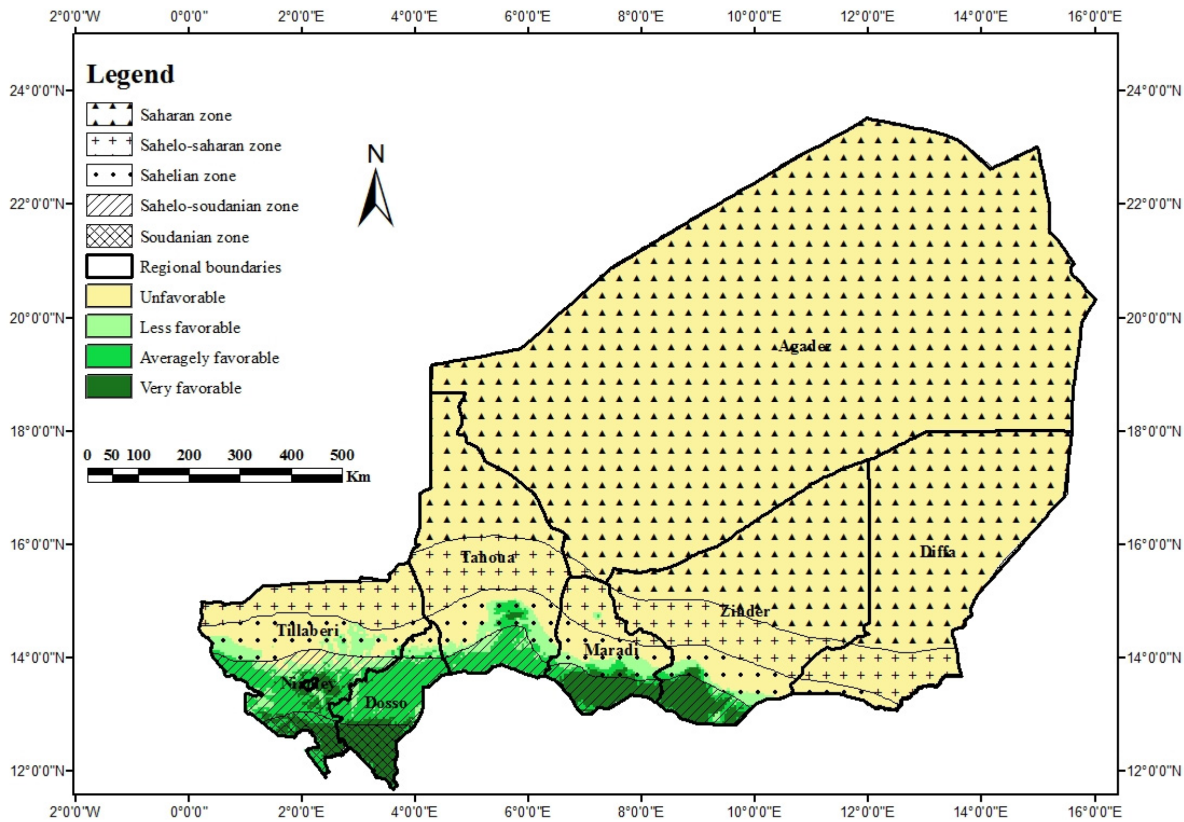

Figure 3. Potential distribution areas of *P. africana* in Niger

4. Discussion

The modeling of species distribution is very important in ecology and models can be seen as a simplified view of reality. However, the choice of data and the methodological approach affect the quality of results (Elith et al., 2006; Schmidt et al., 2008).

This study is based on a set of existing data and additional data collected in the field to fill the gaps in spatial coverage and take account of environmental variability as suggested by Hirzel and Guisan (2002) that compared the effectiveness of different sampling strategies for modeling species distribution. For these authors, systematic sampling is the best strategy for predicting the geographic distribution of species and it is the same type of sampling that was applied in this work. The low concentration of presence points of the species in neighboring countries of Niger is due to the lack of sources because field missions have not gone beyond the country's borders. Even within the country, the spatial heterogeneity of the presence points observed in the field would be partly related to the sampling effort. This could indeed vary depending on the accessibility of areas and / or the collectors' alertness, and thus constitute a limit that must be interpreted with caution, as suggested Ndayishimiye (2011). Nevertheless, the different localities surveyed cover the entire study area. The concentration of presence points of *P. africana* in the southern part, the wettest of the country, may be related to rainfall which is also one of the main factors determining the vegetation distribution in tropical zones (Saadou, 1990; Mahamane, Morou, Zaman-Allah, Saadou, Saley, Bakasso, & Jauffret, 2012). However, the spatial heterogeneity of the presence points of the species observed at the different territories in this area also suggests an influence of other factors such as human pressure, in addition to eventual sampling bias. Indeed, nearly 90% of Niger's population lives in the southern agricultural (Institut National de la Statistique [INS], 2014), the area where much of the woody vegetation is located. This demographic concentration, coupled with a shortage of farmland becoming poorer for lack of fallow could only lead to an impoverishment of the population and pressure on forest products.

The largest contribution to the model of the annual precipitation (BIO12) and the average temperature of the warmest quarter (BIO10) reflects the actual climatic conditions of the species' high concentration area that is relatively rainiest than the north part. According to Weber et al. (2008), *P. africana* prefers an annual rainfall of between 600 and 1500 mm. The effectiveness of these two direct parameters in the model, especially when the species distribution modeling covers a large spatial scale, has been noted by several authors (Guisan & Zimmermann, 2000; Fandohan et al., 2013; Gbesso et al., 2013). The type of soil is not a limiting factor in the distribution of *P. africana* because according to Weber et al. (2008), this species tolerates most soil types, although it abounds in general on land fallow or sandy clay soils. This is corroborated by the diversity of soils in the species' distribution area found in this study. Indeed, the soils are mainly sandy clay in southern Dosso region (Gavaud & Boulet, 1967), dunal to south Maradi and sandy, sandy loam, clay loam in southern Zinder (Larwanou et al., 2006; Laouali et al., 2014).

The value of AUC (0.953), closer to its maximum (1) than its minimum (0.5, corresponding to a random prediction) indicates a good model performance (Swets, 1988; Phillips et al., 2006). A high AUC value does not necessarily reflect a good performance of a model (Phillips et al., 2006; Scheldeman & Van Zonneveld, 2010) when the predicted distribution area is small compared to the total area of the study. For this study, the predicted distribution area is relatively large compared to the area of the study. In addition, the use of repetitions and cross-validation in executing MAXENT yielded a model derived from the average, most powerful.

The resulting model suggests that *P. africana* is widely distributed from the soudanian zone to the sahelo-soudanian band of the country. This potential distribution area is wider than that suggested by Bonnet, Arbonnier and Grard (2008) which is limited to a thin strip in the south of the country. It is also wider than that observed in the field through the presence points of the species. However, the probability of encountering the species is higher in the southern strip and the extreme south-west, where conditions are more favorable for its development. Indeed, a species may be absent in areas where it should be if his natural habitat has been altered by human interference (Scheldeman & Van Zonneveld, 2010). Effectively, *P. africana* is a species subject to a strong human pressure in some areas of Niger because of the domestic use of its wood and its importance in the traditional pharmacopoeia (Laouali et al., 2014), which would have contributed to the heterogeneity observed in the distribution on the field.

This study allowed estimating the distribution area of *P. africana* in Niger and revealed heterogeneity in the organization of the species in the landscape. It thus showed a theoretical distribution area wider than that observed in the field. Given the extent of the area revealed by this study and the socio-economic importance of *P. africana*, restoration operations through a reforestation policy implementation must be carried out in all habitats favorable for its development. Other endangered species in Niger must also be the subject of similar studies to identify favorable habitats for their development and proceed to their restoration.

References

Agboola, D. A. (2004). *Prosopis africana* (Mimosaceae): stem, roots, and seeds in the economy of the savanna areas of Nigeria. *Economic Botany*, *58(Supplement)*, S34-S42. Retrieved from http://www.jstor.org/stable/4256906

Ahoton, L. E., Adjakpa, J. B., M'po Ifonti M'po, & Akpo, E. L. (2009). Effet des prétraitements des semences sur la germination de *Prosopis africana* (Guill., Perrot. Et Rich.) Taub., (Césalpiniacées). *Tropicultura, 27*(4), 233-238. Retrieved from http://www.tropicultura.org/text/v27n4/233.pdf

Akaaimo, D. I., & Raji, A. O. (2006). Some physical and Engineering Proprieties of *Prosopis africana* seed. *Biosystems Engineering, 95*(2), 197-205. http://dx.doi.org/10.1016/j.biosystemseng.2006.06.005

Araújo, M. B., Pearson, R. G., Thuiller, W., & Erhard, M. (2005). Validation of species–climate impact models under climate change. *Global Change Biology, 11*, 1504-1513. http://dx.doi.org/10.1111/j.1365-2486.2005.001000.x

Arbonnier, M. (2000). *Arbres, arbustes et lianes des zones sèches d'Afrique de l'Ouest*. CIRAD - MNHN - UICN, Montpellier (France).

Bonnet, P., Arbonnier, M., & Grard, P. (2008). *Outil graphique d'identification V.1.0.* CIRAD. CD-Rom. Ed. Quæ.

Chidumayo, E., Okali, D., Kowero, G. & Larwanou, M. (2011). *Climate change and African forest and wildlife resources.* African Forest Forum, Nairobi, Kenya. Retrieved from http://www.sifi.se/wp-content/uploads/2011/11/Climate-Change-Africa.pdf

Doko, T., Kooiman, F. A., & Toxopeus, A. G. (2008). Modeling of species geographic distribution for assessing present needs for the ecological networks. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, *XXXVII* (Part B4. Beijing), 267-276. Retrieved from http://www.isprs.org/proceedings/XXXVII/congress/4_pdf/49.pdf

Dormann, C. F., Elith, J., Bacher, S., Buchmann, C., Carl, G., Carré, G., & Lautenbach, S. (2013). Collinearity: a review of methods to deal with it and a simulation study evaluating their performance. *Ecography, 36*, 27-46. http://dx.doi.org/10.1111/j.1600-0587.2012.07348.x

Doztsi, A. K. (2002). *Application du modèle CERES-Maize de DSSAT à l'analyse des stratégies de semis pour le maïs (Zea mays L.) dans les conditions de SEVE KPOTA*. Mémoire d'ingénieur agronome, IFDC Afrique/ESA -UL, Lomé, Togo.

Elith, J., Graham, C. H., Anderson, R. P., Dudık, M., Ferrier, S., Guisan, A., & Zimmermann, N. E. (2006). Novel methods improve prediction of species' distributions from occurrence data. *Ecography, 29*, 129-151. http://dx.doi.org/10.1111/j.2006.0906-7590.04596.x

Fandohan, B., Gouwakinnou, G. N., Fonton, N. H., Sinsin, B., & Liu, J. (2013). Impact des changements climatiques sur la répartition géographique des aires favorables à la culture et à la conservation des fruitiers sous-utilisés : cas du tamarinier au Bénin. *Biotechnol. Agron. Soc. Environ, 17*(3), 450-462. Retrieved from http://www.pressesagro.be/base/text/v17n3/450.pdf

Fitzpatrick, M. C., & Hargrove, W. W. (2009). The projection of species distribution models and the problem of non-analog climate. *Biodivers. Conserv., 18*, 2255-2261. http://dx.doi.org/10.1007/s10531-009-9584-8

Gavaud, M., & Boulet, R. (1967). *Carte pédologique de reconnaissance de la république du Niger*. Service cartographique de l'OROSTOM.

Gbesso, F. H. G., Tente, B. H. A., Gouwakinnou, N. G., & Sinsin, B. A. (2013). Influence des changements climatiques sur la distribution géographique de *Chrysophyllum albidum* G. Don (Sapotaceae) au Benin. *Int. J. Biol. Chem. Sci, 7*(5), 2007-2018. http://dx.doi.org/10.4314/ijbcs.v7i5.18

Guisan, A., & Thuiller, W. (2005). Predicting species distribution: offering more than simple habitat models. *Ecology Letters, 8*(9), 993-1009. http://dx.doi.org/10.1111/j.1461-0248.2005.00792

Guisan, A., & Zimmermann, N. E. (2000). Predictive habitat distribution models in ecology. *Ecol. Modell., 135*, 147-186. http://dx.doi.org/10.1016/S0304-3800(00)00354-9

Hijmans, R. J., Susan, E. C., Juan, L. P., Peter, G. J., & Andy, J. (2005). Very high resolution interpolated climate surfaces for global land areas. *Int. J. Climatol., 25*, 1965-1978. http://dx.doi.org/10.1002/joc.1276

Hijmans, R. J., Luigi, G., & Prem, M. (2012). *DIVAGIS Version 7.5 Manual*. Retrieved from http://www.diva-gis.org/docs/DIVA-GIS_manual_7.pdf

Hirzel, A., & Guisan, A. (2002). Which is the optimal sampling strategy for habitat suitability modelling? *Ecological Modelling, 157*(2-3), 331-341. http://dx.doi.org/10.1016/S0304-3800(02)00203-X

INS. (2014). *Recensement général de la population et de l'habitat, 2012. Répertoire national des localités*. Institut National de la Statistique, Niger.

IPCC. (2007). *Climate Change 2007: Synthesis Report*. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, Pachauri, R.K and Reisinger, A. (eds.)]. IPCC, Geneva, Switzerland. Retrieved from http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr_full_report.pdf

Kumar, S., & Stohlgren, T. J. (2009). Maxent modeling for predicting suitable habitat for threatened and endangered tree *Canacomyrica monticola* in New Caledonia. *Journal of Ecology and Natural Environment*, *1*(4),094-098. Retrieved from http://www.academicjournals.org/article/article1379515268_Kumar%20and%20Stohlgren.pdf

Laouali, A., Dan Guimbo, I., Chaibou, I., & Mahamane, A. (2015b). Fruit production of *Prosopis africana* (G. et Perr.) Taub., an overexploited species in the Southeastern Niger. *International Journal of Current Microbiology and Applied Sciences, 4*(5), 50-56. Retrieved from http://www.ijcmas.com/vol-4-5/Laouali%20Abdou,%20et%20al.pdf

Laouali, A., Dan Guimbo, I., Larwanou, M., Inoussa, M. M., & Mahamane A. (2014). Utilisation de *Prosopis africana* (G. et Perr.) Taub. dans le sud du département d'Aguié au Niger : les différentes formes et leur importance. *Int. J. Biol. Chem. Sci., 8*(3), 1065-1074. http://dx.doi.org/10.4314/ijbcs.v8i3.20

Laouali, A., Dan Guimbo, I., Youchaou, A., Rabiou, H., & Mahamane, A. (2015a). Etude de la germination de la graine et suivi de la croissance en pépinière de *Prosopis africana* (G. et Perr.) Taub., espèce menacée de disparition au Niger. *Annales de l'Université Abdou Moumouni de Niamey*, *Tome XVIII*-A, 1-12.

Larwanou, M. (1994). *Potentials of Prosopis africana (G. et Perr.) Taub leaf litter for soil nutrient enhancement and crop development*. M.Sc thesis. Department of Forest resources Management, University of Ibadan.

Larwanou, M., Moustapha, A. M., Rabé, M. L., & Dan Guimbo, I. (2012). Contribution de la Régénération Naturelle Assistée des ligneux dans l'approvisionnement en bois des ménages dans le département de Magaria (Niger). *Int. J. Biol. Chem. Sci., 6*(1), 24-36. http://dx.doi.org/10.4314/ijbcs.v6i1.3

Larwanou, M., Oumarou, I., Laura, S., Dan Guimbo, I. & Eyog-Matig, O. (2010). Pratiques sylvicoles et culturales dans les parcs agroforestiers suivant un gradient pluviométrique nord-sud dans la région de Maradi au Niger. *Tropicultura, 28*(2), 115-122. Retrieved from http://www.tropicultura.org/text/v28n2/115.pdf

Lee, P., Hanneman, M., & Hackenbrook, D. (2011). *Cartographie des perturbations et des perspectives de rétablissement et de protection des populations de caribou des bois dans la région de la baie James du Nord québécois : Partie 2. Cartographie des perspectives de rétablissement et de protection.* Edmonton, Alberta. Global Forest Watch Canada. 5e publication de l'Année internationale des forêts. Retrieved from http://www.globalforestwatch.ca/files/publications/20111205B_QB_Caribou_Restoration_Protection_FR_HR.pdf

Maël, D., Catherine, G., Beatriz, C., & Vincent, P. (2014). *Distribution, écologie & statut de conservation de l'Oriole de Martinique (Icterus bonana)*. DEAL Martinique. Retrieved from http://www.sosdom.lautre.net/DEAL/Carouge_Rapport_DEAL.pdf

Mahamane, A., Morou, B., Zaman-Allah, M., Saadou, M., Saley, K., Bakasso, Y., & Jauffret, S. (2012). Climate Variability in Niger: Potential Impacts on vegetation distribution and productivity. *Journal of Environmental Science and Engineering*, *B1*, 49-57. Retrieved from http://www.davidpublishing.com/davidpublishing/Upfile/2/7/2012/2012020771401153.pdf

Matthias, M., Henri, T., & Félix, H. (2000). Ligneux à usages multiples dans les systèmes agraires tropicaux : une étude de cas de Côte d'Ivoire. *Schweiz. Z. Forstwes, 151*(10), 355-364. http://dx.doi.org/10.3188/szf.2000.0355

Ndayishimiye, J. (2011). *Diversité, endémisme, géographie et conservation des Fabaceae de l'Afrique Centrale*. Thèse présentée en vue de l'obtention du Diplôme de Docteur en Sciences. Université Libre de Bruxelles.

Niang-Diop, F., Sambou, B., & Lykke, A. M. (2010). Contraintes de régénération naturelle de *Prosopis africana* : facteurs affectant la germination des graines. *Int. J. Biol. Chem. Sci., 4*(5), 1693-1705. http://dx.doi.org/10.4314/ijbcs.v4i5.65578

Ozer, P., Hountondji, Y-C., Niang, AJ., Karimoune, S., Laminou, M. O., & Salmon, M. (2010). Désertification au Sahel : historique et perspectives. *BSGLg, 54*, 69-84. Retrieved from http://popups.ulg.ac.be/0770-7576/index.php?id=942&file=1

Parviainen, M., Luoto, M., Ryttari, T., & Heikkinen, R. K. (2008). Modelling the occurrence of threatened plant species in taiga landscapes: methodological and ecological perspectives. *J. Biogeogr., 35*, 1888-1905. http://dx.doi.org/10.1111/j.1365-2699.2008.01922.x

Phillips, S. J., Anderson, R. P., & Schapired, R. E. (2006). Maximum Entropy Modeling of species geographic distributions. *Ecological Modelling, 190*, 231-259. http://dx.doi.org/10.1016/j.ecolmodel.2005.03.026

Priso, R. J., Nnanga, J. F., Etame, J., Din, N., & Amougou, A. (2011). Les produits forestiers non ligneux d'origine végétale : valeur et importance dans quelques marchés de la région du Littoral - Cameroun. *Journal of Applied Biosciences, 40*, 2715-2726. Retrieved from http://www.m.elewa.org/JABS/2011/40/6.pdf

Saadou, M. (1990). *La végétation des milieux drainés nigériens à l'Est du fleuve Niger*. Thèse de Doctorat ès - Sciences Naturelles. Université de Niamey.

Scheldeman, X., & Van Zonneveld, M. (2010). *Training Manual on Spatial Analysis of Plant Diversity and Distribution*. Bioversity International, Rome, Italy. Retrieved from http://www.bioversityinternational.org/uploads/tx_news/Training_manual_on_spatial_analysis_of_plant_diversity_and_distribution_1431_07.pdf

Schmidt, M., König, K., & Müller, J. V. (2008). Modelling species richness and life form composition in Sahelian Burkina Faso with remote sensing data. *Journal of Arid Environments, 72*(8), 1506-1517. http://dx.doi.org/10.1016/j.jaridenv.2008.02.015

Swets, J. A. (1988). Measuring the accuracy of diagnostic systems. *Science, 240*(4857), 1285-1293. http://dx.doi.org/10.1126/science.3287615

Warren, D. L., Glor, R. E., & Turelli, M. (2010). ENMtools: a toolbox for comparative studies of environmental niche models. *Ecography, 33*, 607-611. http://dx.doi.org/10.1111/j.1600-0587.2009.06142.x

Weber, J. C., Larwanou, M., Abasse, T. A., & Kalinganire, A. (2008). Growth and survival of *Prosopis africana* provenances tested in Niger and related to rainfall gradients in the West African Sahel. *Forest Ecology and Management, 256*, 585-592. http://dx.doi.org/10.1016/j.foreco.2008.05.004

Young, N., Carter, L., & Evangelista, P. (2011). *A MaxEnt Model v3.3.3e Tutorial (ArcGIS v10)*. Laboratory at Colorado State University and the National Institute of Invasive Species Science. Retrieved from http://ibis.colostate.edu/WebContent/WS/ColoradoView/TutorialsDownloads/A_Maxent_Model_v7.pdf