academicJournals

Vol. 5(9), pp. 231-240, September 2013
DOI: 10.5897/JENE12.075
ISSN 2006-9847 ©2013 Academic Journals
http://www.academicjournals.org/JENE

Journal of Ecology and the Natural Environment

Full Length Research Paper

Climatic niche of *Dacryodes edulis* (G. Don) H.J. Lam (Burseraceae), a semi-domesticated fruit tree native to Central Africa

Gilbert TODOU[1, 2, 3]*, Geo COPPENS d'EECKENBRUGGE[2], Hélène I. JOLY[2], Amougou AKOA[3], Jean-Michel ONANA[4] and Gaston ACHOUNDONG[4]

[1]Université de Maroua, Ecole Normale Supérieure, BP : 55, Maroua, Cameroun.
[2]CIRAD-Bios/UMR 5175, CEFE, 1919 route de Mende 34293 Montpellier Cedex 5, France.
[3]Université de Yaoundé I, Faculté des Sciences, BP : 812, Yaoundé, Cameroun.
[4]IRAD, Herbier National du Cameroun, BP. 1601, Yaoundé, Cameroun.

Accepted 24 July, 2013

Dacryodes edulis is a fruit tree growing naturally in the rainforests of Central Africa. To provide data to scientists and forest managers for the habitat of _D. edulis_ in the wild, the study of ecological niche and environmental adaptation was carried out. The geographical coordinates of 168 collections of wild individuals and 19 climatic parameters were treated under Geographical Information System. Potential spatial richness, favourable climatic parameters and elevation of the species were described. The favourable climatic conditions for natural growth of _D. edulis_ were mainly revealed in the forests of Gabon and Equatorial Guinea. In Cameroon, these conditions were well marked in the regions of Kribi and Bipindi (South), in the forest of Yingui and Yabassi (Littoral), in the Dja Forest (East) and South-West towards the border with Nigeria. The mean of favourable annual precipitation is 2205.26 ± 505.5 mm per year. The optimal annual mean temperatures stretch from 23.5 to 25.5°C. The favourable elevations stretch from 0 to 800 m. These values are smaller than ones for domesticated individuals which represent fundamental climatic niche. Prospect in forest areas with the best favourable climatic conditions and elevation for natural growth of _D. edulis_ should be encouraged to ensure _in situ_ conservation of wild populations for maintaining genetic diversity.

Key words: *Dacryodes edulis*, ecological niche, environmental adaptation, *in situ* conservation.

INTRODUCTION

Dacryodes edulis (Burseraceae), commonly known as safou, plum tree or atanga, is an edible fruit (Figure 1) native to Central Africa. It grows naturally in evergreen forest. This species is characterized by two pseudo-stipuls, at the base of the petiole (Figure 2). This character differentiates it from other *Dacryodes* species. *D. edulis* is regarded as a multipurpose species. It produces edible fruits highly valued by local people and used in commercial transactions, even beyond the borders of Africa (Tabuna, 2000). In addition to human consumption and trade, the species is commonly grown in agroforestry systems used to shade the main species such as cocoa and coffee trees (Sonwa et al., 2002). Different parts of the plant are used in traditional medicine

*Corresponding author. E-mail: gitodou@hotmail.com.

Abbreviations: CEFE, Centre d'Ecologie Fonctionnelle et Evolutive; **IFORA**, Iles Forestières Africaines.

Figure 1. Fruits of *D.edulis.*

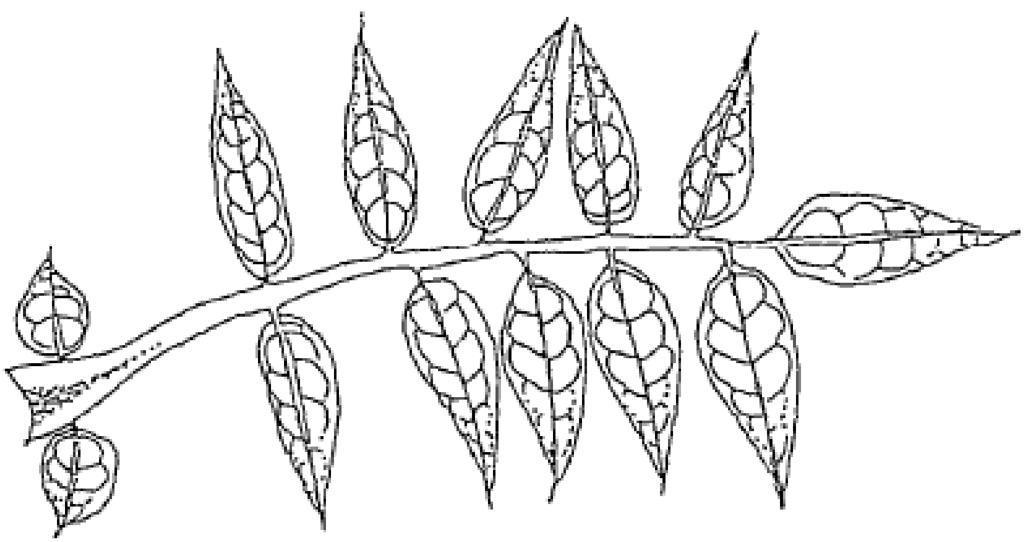

Figure 2. Leaf of *D. edulis.*

(Ajibesin, 2011).

Culture of *D. edulis* in the Gulf of Guinea is secular (Chevalier, 1916). Because of domestication, its spatial distribution is extended inside Africa in twenty countries (Orwa et al., 2009) and also in tropical Asia in the Malay Peninsula (Aumeerudy and Pingo, 1989). Despite its importance in the live of local populations, *D. edulis* is among the species whose natural distribution and ecological niche are poorly understood. However, like most forest species of Congo Basin, wild *D. edulis* undergoes reduction in the number of individuals caused by agriculture, timber exploitation and global climate change. It appears very difficult to envisage a reliable *in situ* conservation of a species (for wild individuals) in order to maintain genetic diversity when the knowledge of the natural distribution and the ecological niche are poor.

The main objective of this work was to provide data to scientists and forest managers for the wild habitat of *D. edulis*. The specific objectives are: (1) to determine the geographical distribution and the spatial potential richness of *D. edulis* in its natural habitat, (2) to characterize its climatic niche (precipitation, temperature) and (3) to determine the favourable elevations for its natural growth.

MATERIALS AND METHODS

Collection of geographical data

The geographical coordinates (latitude, longitude, and elevation) were obtained from three different sources.

1. The geographical coordinates of specimens conserved in six recognized Herbaria (Herbier National du Gabon (LBV); Herbier National du Cameroun (YA); Limbe Botanic Garden (SCA), Muséum national d'Histoire naturelle de Paris (P); Royal Botanic Gardens, Kew (K); Missouri Botanic Garden (MO) and Global Biodiversity Information Facility (GBIF) portal (www.gbif.org) were collected. Web sites including Google Earth, world-gazetteer.com and diva-gis.org were used to determine or complete geographical coordinates for samples with these data which are not indicated or are partially specified. The ecological notices indicated by collectors have been used to identify samples from wild individuals.
2. Specimens collected in natural forests mentioned in the literature (Aubreville, 1962; Onana, 2008) with their geographical coordinates were selected.
3. The geographical coordinates of specimens (leaves or cambium) collected in natural forests for DNA extraction (conserved in the laboratory of CEFE in Montpellier, France) during IFORA's prospection between 2006 and 2010 in Cameroon and in Gabon were considered. These leaf or cambium samples collected (with herbarium specimens in support) were identified using the identification key developed by Lam (1932), leaning on systematic reviews in the genera (Pierlot, 1996; Onana, 1998, Onana and Cheek, 2003).

All duplicate samples or already mentioned in one of the sources have been eliminated to retain one. In total, the geographical data (latitude, longitude and elevation) of 168 collections were compiled.

Data analysis

Geographic distribution and estimation of the spatial richness

The geographical data of collections were entered into the software DIVA-GIS 4.1 (Hijmans et al., 2005). The natural geographical distribution was established from the geographical coordinates of each sample. The potential geographical distribution was modeled using nineteen climatic parameters extracted from BIOCLIM (Busby, 1991) and DOMAIN (Carpenter et al*.,* 1993) available in DIVA-GIS.

Ecological niche and adaptability

The characteristics of ecological niche were studied based on the cover of the forest, climatic factors and elevation of collection sites. From these parameters, the map showing the ground cover in which the species could grow naturally was made following the spatial location of collection points. Graphs describing the ecological requirements from the data of the elevation and nineteen climatic parameters were made using the software STATISTICA version 6. Statistical processing was done by descriptive statistics and calculation of the correlation coefficient (r).

RESULTS AND DISCUSSION

Natural geographic distribution of *D. edulis*

The natural distribution of *D. edulis* is focused in the center of endemism Lower Guinea. It stretches along the Atlantic in five countries (Congo, Gabon, Equatorial Guinea, Cameroon and Nigeria). The species occurs mainly throughout Gabon especially towards the Atlantic Coast, Equatorial Guinea and in the forests of South and south-West Cameroon. No individual with wild characters have been reported in the highlands of western Cameroon. Despite forest degradation in south of Nigeria, few individuals have been reported in close proximity to Cameroon.

Figure 3 shows the geographical distribution according to vegetative cover. It appears that *D. edulis* grows naturally in moist evergreen forest. In fact, *D. edulis* is not a naturally gregarious species like *Dacryodes buettneri*. Individuals were always observed isolated in forests. Identification is difficult because wild individuals are the upper canopy. In cases where several individuals were observed on a small area, archaeological remains and domesticated plants (mango tree, avocado tree or palm tree) demonstrating the existence of ancient habitations were recorded in places suggesting the old plantations. This is the case in Cameroon where several individuals were observed on the road of Kumba-Mamfe, beside the viaduct (Ndian Basin in Cameroon) cited by Kengue (2002a) as a natural wild population. During our prospection in Cameroon, eleven forest populations of wild *D. edulis* were observed and characterized; some have developed on old plantations (Table 1). These populations have been observed in oceanic regions directly subject to the monsoon, with prevailing winds from Southwest and in the regions of Centre, South and East characterized by equatorial climate or transition tropical climate, according to subdivisions based on regional climate stations homogeneous (Olivry, 2006). Individuals in the rain forests of centre, south and east Cameroon are sympatric with other species of the genera such as *D. klaneana*, *D. macrophylla* in undisturbed forests.

Potential natural geographical distribution of *D. edulis*

Based on nineteen climatic parameters, suitable forests for natural growth of *D. edulis* have been identified by the potential natural geographical distribution modeling (Figure 4). In Gabon, the ecological conditions favourable to natural growth were observed in the forests of Lopé and Waka Koulamoutou and in the forest of Oyem and Minkebe in the north. In Cameroon, these conditions were noted in the south (the forests of Kribi and Bipindi), in the atlantic cost (the forest of Yingui and Yabassi), in the congo basin (the forest of Dja) and in the south-west area (forests of Mamfe and the border with Nigeria). In

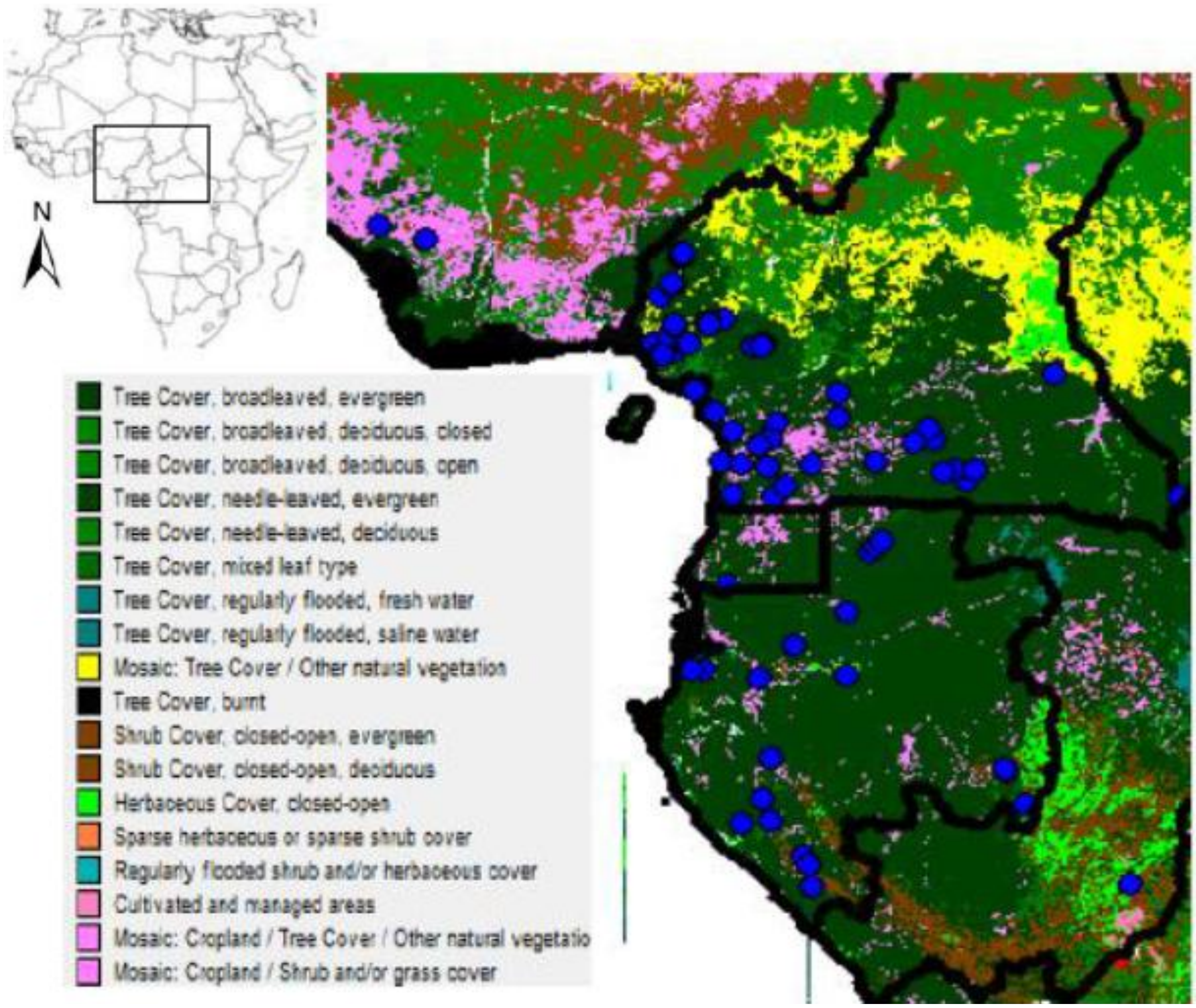

Figure 3. Distribution of wild individuals of *D. edulis* and existing vegetation. The blue points indicate actual distribution. The vegetation was extracted from DOMAIN (Carpenter et al., 1993) available at DIVA-GIS.

Nigeria, wild individuals of *D. edulis* can be found in forests of southern part along the Atlantic Ocean. In Equatorial Guinea, natural forests of continental part have climatic conditions favourable for the natural growth of this species.

The potential natural location of *D. edulis* is much reduced comparatively to actual geographical distribution because of domestication. Research surveys in the areas shown are favourable to the natural growth of the species of interest in order to estimate the abundance of population. The knowledge of potential natural geographical distribution of *D. edulis* is essential to preserve wild populations for maintaining genetic diversity. A similar approach was used to plan conservation activities of six species of *Passiflora* from the Andes (Segura et al., 2003). Likewise, six new populations of *Capsicum flexuosum* in Paraguay were identified using the same approach (Jarvis et al., 2005).

The natural distribution of *D. edulis* is linked to theorical forest refuge of Maley (1987, 1996). Indeed, the dynamic character of tropical forests and climate change during the quaternary glaciations have caused changes in the expansion of forests.

Favourable annual precipitation for the natural growth of *D. edulis*

The favourable mean annual precipitation for the natural growth of *D. edulis* is 2205.26 ± 505.5 mm per year. The confidence interval of annual precipitation is not large [1500, 3000] for the reason, that is, it is very close to the optimal annual precipitation ranging from 1600 to 2600 mm per year (Figure 5). This small extent is justified by the fact that these are the individuals that grow naturally without human intervention. They are growing in their original ecological niche. For the individuals collected in plantations, the confidence interval of precipitation is wide, ranging from 1400 to 4000 mm per year (Kengue, 2002b). The domesticated individuals can grow on the high rainfall areas on the slopes of Mount Cameroon to

Table 1. Characteristics of forest with wild individuals of *D. edulis* in Cameroon.

Administrative unit	Massif forest	Vegetation	Bioclim		GPS		Alt.
			An. Prec.	An. Temp.	Lat.	Long.	
South region	Bipindi (Ngovayang massif)	Green forest normally not degraded without visible traces of human	2280	24.2	3.11	10.43	253
	Kribi (massif of UFA 09-026, CUF)	Green forests normally not degraded without visible traces of human	2503	26.6	2.84	10.17	95
	Kribi (massif of UFA 09-028, EFFA)		2623	26.1	3.33	10.07	52
Centre region	Eséka (massif of UFA, TRC)	Green forest normally not degraded without visible traces of human	2170	25.7	3.46	10.66	331
Littoral region	Massifs of Yingui and Yabassi	Green forests normally not degraded without visible traces of human	2467	23.8	4.55	10.47	466
East region	Reserve of Dja	Green forests normally not degraded, without visible traces of human	1622	23.6	3.34	12.75	640
South-West region	Reserve forestière de Mokoko	Green forest degraded by clearing and establishment of plantations	3057	23.9	4.43	9.09	284
	Rhumpi mounts	Green forest degraded by clearing and establishment of plantations	2635	19.8	4.85	9.25	628
	NNW Mamfe (massif of UFA, TRC)	Green forest developed on old habitations (human traces visible)	2591	26.5	5.87	9.35	172
	South Mamfe (massif of UFA, TRC)	Green forest developed on old habitations (human traces visible)	2814	25.7	5.48	9.24	327
	Massif of Bakossi	Green forest normally not degraded without visible traces of human	2798	22.9	4.90	9.72	nd

Alt. = Elevation (m); An. Prec. = annual precipitation (mm); An. Temp. = mean annual temperature (°C); Lat. = Latitude; Long. = Longitude; nd = not determined.

monsoon areas that have 4 months with less than 50 mm per month of rainfall (Verheij, 2002). The consequence is that the excess rainfall promotes vegetation against fruiting which is sparse and irregular.

Favourable mean annual temperature for natural growth of *D. edulis*

The confidence interval of mean annual temperature for the natural growth of *D. edulis* is 21.8, 25.8, while the optimal mean annual temperature range from 23.5 to 25.5°C (Figure 6). These values are compatible with the ones of Isseri (1998) who found that the mean annual temperature ranged from 23 to 25°C and are favourable for the best development and fruiting of *D. edulis*. The average mean annual temperature is 24.7 ± 1.4°C. The range of mean annual temperature favourable for natural growth of wild individuals of *D. edulis* is smaller than the one of individuals observed in plantations and they can grow in temperatures ranging from 19 to 26°C. However, low temperatures (<20°C) explain the very slow growth of individuals (5 to 7 years) and, individuals with high temperatures are characterized by poor fruit set (Kengue, 2002b).

Contributions of nineteen climatic parameters to natural growth of *D. edulis*

Considering only the significant factors (contribution of climatic parameters), two factors were retained for the principal component analysis (PCA) (Table 2). Both factors account for 68% of total variance. The first representing 39% of the variance showed a positive correlation with temperature. It distinguished individuals from those warm periods and cold periods. The second factor accounts for 29% of the variance. It showed a positive correlation with the number of individuals for precipitation of dry periods and negative corre-

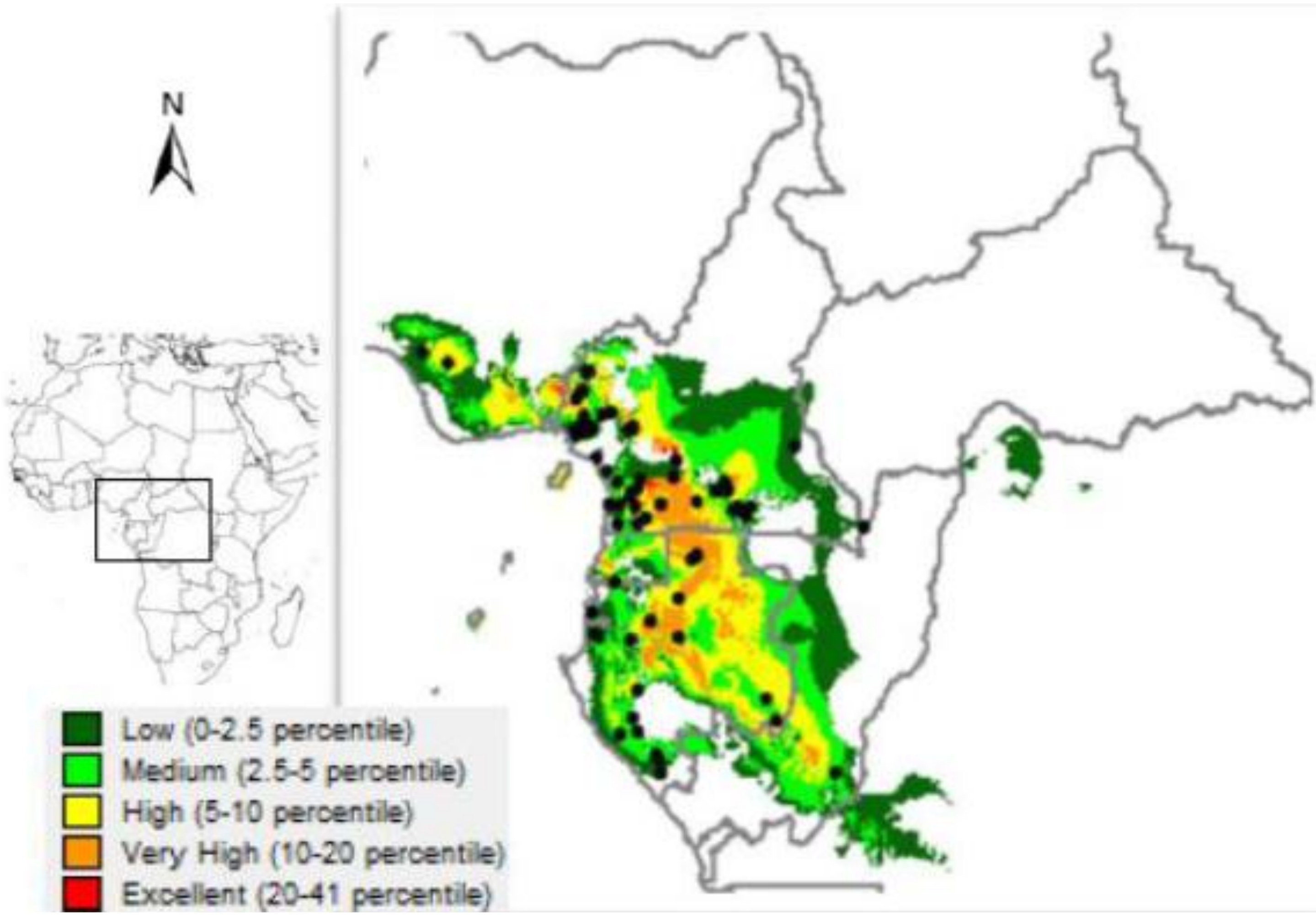

Figure 4. Potential natural geographical distribution of *D. edulis.* Potential geographic distribution estimated from simulations based on 19 climatic parameters extracted from BIOCLIM is represented in color. The red color indicates the area that connects the most favourable climatic parameters to the natural growth of *D. edulis*. The green color represents areas where the probability of finding individuals is low. The black points indicate the actual distribution.

lations with the seasonality in temperature and annual temperature variation.

Distribution of observations of wild *D. edulis* on orthogonal plans allowing for temperature and precipitation parameters showed significant correlations between these parameters ($r \geq 0.6$ or $r \leq -0.6$ and $p < 0.05$). Only one positive correlation was observed, between the precipitation seasonality and the temperature seasonality with $r = 0.73$ and $p < 0.05$. Five negative correlations were noted between the driest periods and annual temperature range and temperature seasonality. Precipitation of wettest month is negatively correlated with the mean monthly temperature range and precipitation seasonality with isothermality (Table 3). The negative relationships between precipitation and temperature suggest a substantial gradient in potential evapotranspiration that is in relation with distance of equator.

Favourable elevations for natural growth of *D. edulis*

The analysis of the relation between elevation and observation points of wild *D. edulis* showed that the natural growth of *D. edulis* is restricted to lowlands, from sea level to only 800 m of elevation (Figure 7). The mean of favourable elevation is 341 ± 200 m. No wild individual have been observed above 800 m elevation. Human planted *D. edulis* at various elevations up to 1800 m, in agro-ecosystems as the western highlands of Cameroon. According to Verheij (2002), plantations of *D. edulis* can successfully develop up to 1000 m.

According to Hutchinson (1957), there is difference between a fundamental niche (the abiotic conditions under which a population can persist in the absence of additional constraints) and a realized niche (where a population is competitive enough to occur naturally).

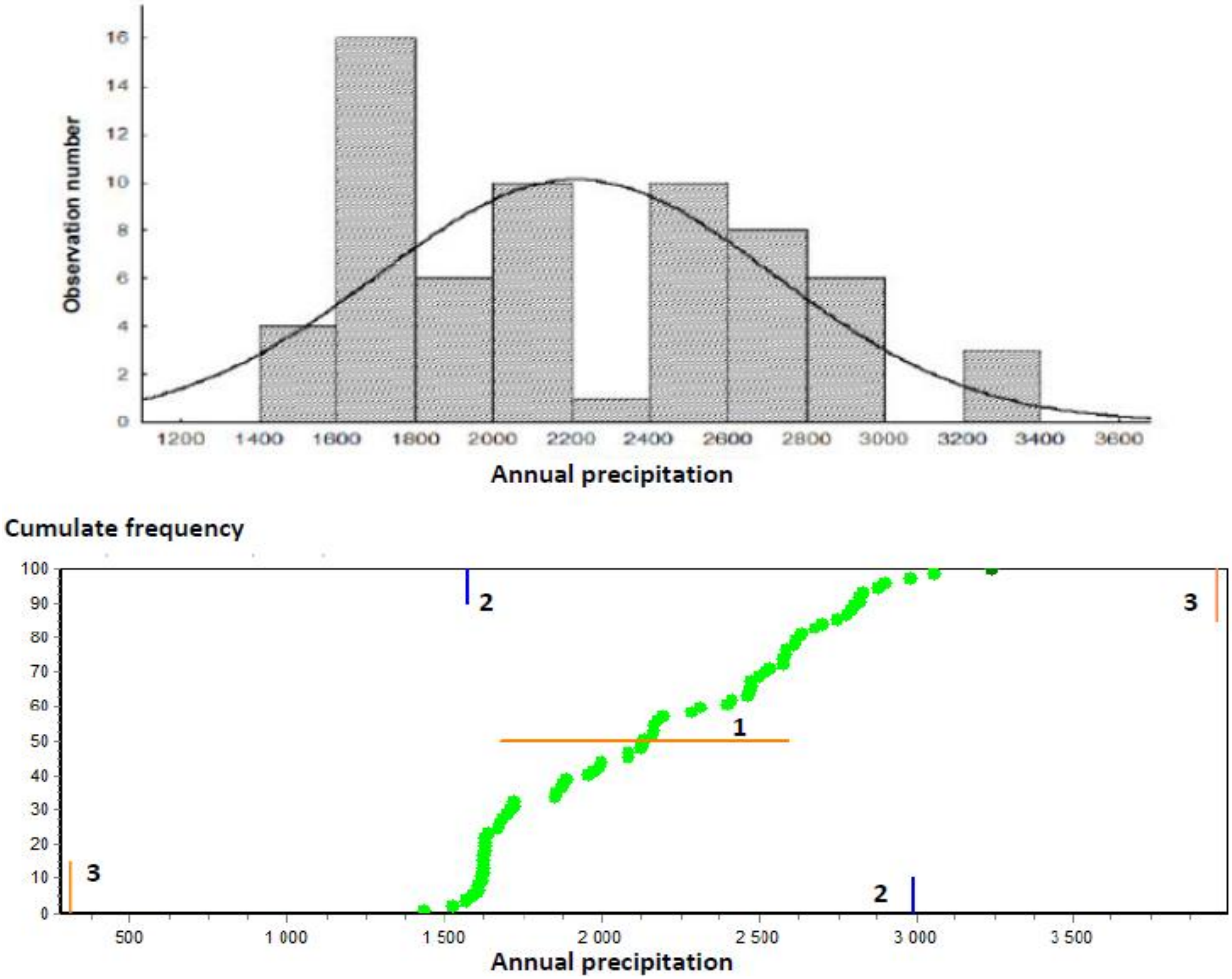

Figure 5. Annual precipitation favourable for natural growth of *D. edulis*.

Human successfully planted *D. edulis* even outside its native natural geographic range and under large interval of rainfall, under large interval of temperature and under large interval of elevation. To this successful degree that the plantations of *D. edulis* occur, the climatic range of domestic distribution represents attributes of the fundamental climatic niche.

Conclusion

Use of Geographical Information System (GIS) is an interesting approach to study the potential natural geographical distribution and ecological niche of plant species. This can help to plan *in situ* conservation activities and sustainable use. The study on *D. edulis* gave a better estimation of abundance of individuals in areas underexplored. The results will support the efforts of countries to conserve and sustainably use natural populations in central Africa. Although, *D. edulis* is not gregarious in forests, eleven teeming forests with large numbers of individuals likely to be protected and conserved have been identified in Cameroon. *D. edulis* species is of great ecological plasticity. Human intervention on the geographical distribution of *D. edulis* has modified the natural distribution. The climatic range of domestic distribution represents attributes of the fundamental climatic niche when the natural distribution represents attributes of the realized climatic niche. However, the extreme conditions greatly modify and retard growth and production of indivi-

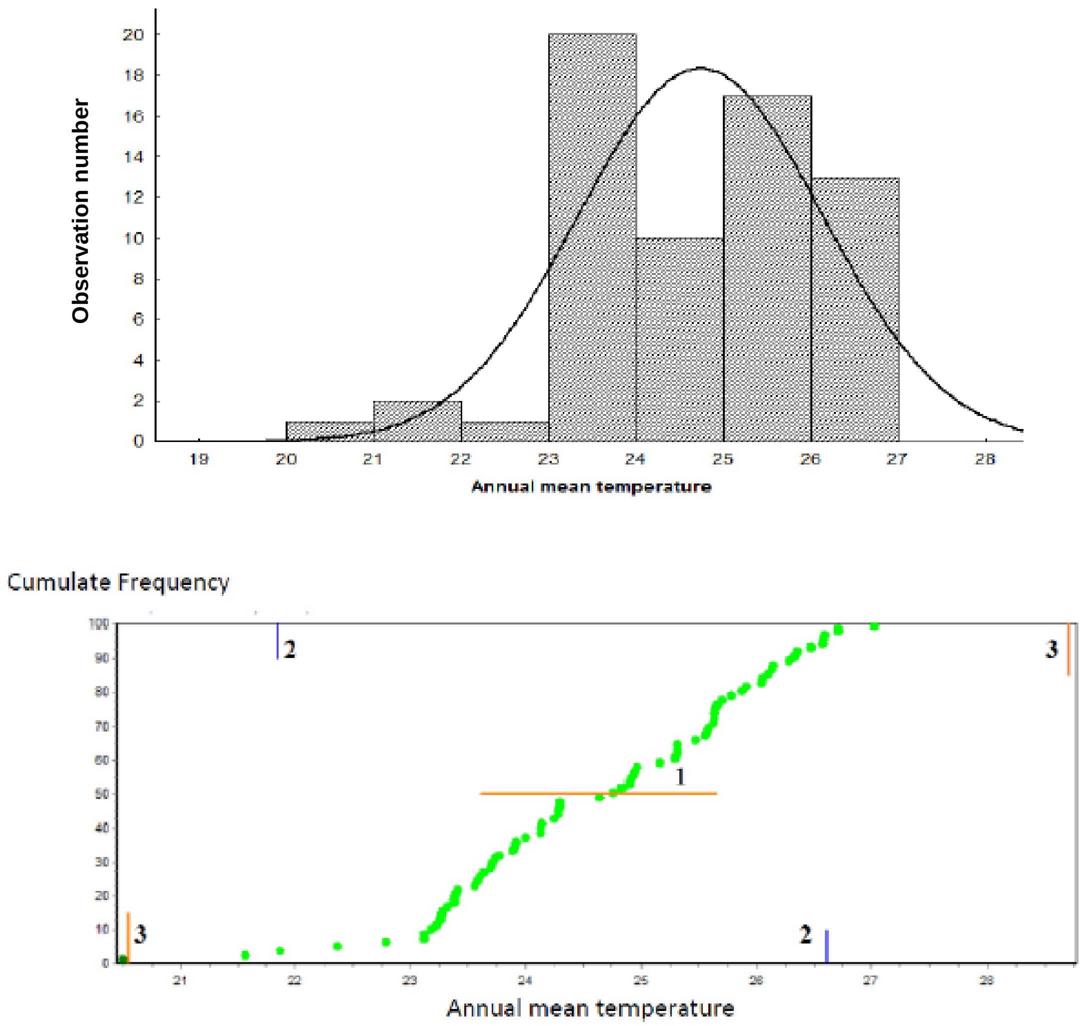

Figure 6. Favourable annual mean temperature for natural growth of *D. edulis*.

Table 2. Mean of nineteen climatic favourable parameters for natural growth of *D. edulis* and values of two significant factors of PCA.

BIOCLIM parameters	Means ± standard deviation	Factor 1	Factor 2
BIO1	24.70 ± 1.39	**0.91**	-0.28
BIO2	8.76± 1.13	-0.60	-0.41
BIO3	75.32 ± 4.55	-0.50	0.63
BIO4	92.27 ± 21.74	0.30	**-0.71**
BIO5	30.81 ± 1.44	**0.72**	-0.47
BIO6	19.17 ± 1.76	**0.91**	0.24
BIO7	11.64 ± 1.54	-0.36	**-0.72**
BIO8	24.23 ± 1.45	0.67	-0.56
BIO9	24.50 ± 1.71	**0.88**	0.26
BIO10	25.67 ± 1.48	**0.90**	-0.34
BIO11	23.44 ± 1.33	**0.88**	-0.09
BIO12	2205.26 ± 505.44	0.64	0.46
BIO13	377.15 ± 79.33	0.67	0.34
BIO14	25.72 ± 19.38	0.02	**0.85**
BIO15	65.43 ± 8.02	0.28	-0.65

Table 2. Contd.

BIO16	952.10 ± 254.61	0.65	0.38
BIO17	113.84 ± 71.19	-0.01	**0.88**
BIO18	516.03 ± 146.55	-0.11	-0.43
BIO19	585.67 ± 496.68	0.44	0.61
Experimental variance		7.46	5.51
Percentage of variance		0.39	0.29

Climatic parameters that correlated significantly (r > 0.7 or r < -0.7 and p < 0.05) are indicated in bold. BIO1 = annual mean temperature, BIO2 = mean monthly temperature range (mean of monthly (max temp - min temp)), BIO3 = isothermality (BIO2/BIO7) (* 100), BIO4 = temperature seasonality (standard deviation *100), BIO5 = Max temperature of warmest month, BIO6 = Min temperature of coldest month, BIO7 = temperature annual range (BIO5-BIO6), BIO8 = mean temperature of wettest quarter, BIO9 = mean temperature of driest quarter, BIO10 = mean temperature of warmest quarter, BIO11 = mean temperature of coldest quarter, BIO12 = annual precipitation, BIO13 = precipitation of wettest month, BIO14 = precipitation of driest month, BIO15 = precipitation seasonality (coefficient of variation), BIO16 = precipitation of wettest quarter, BIO17 = precipitation of driest quarter, BIO18 = precipitation of warmest quarter, BIO19 = precipitation of coldest quarter.

Table 3. Significant correlations between the precipitation and temperature parameters.

Parameter	Values of r Pearson	Relative equations
BIO15 / BIO4	0.73	BIO15 = 40.34 + 0.27 * BIO4
BIO13 / BIO2	- 0.64	BIO13 = 770 – 44.89 * BIO2
BIO15 / BIO3	- 0.72	BIO15 = 160.87 – 1.267 * BIO3
BIO17 / BIO4	- 0.61	BIO17 = 299.80 – 2.015 * BIO4
BIO14 / BIO7	- 0.60	BIO14 = 110.58 – 7.291 * BIO7
BIO17 / BIO7	- 0.60	BIO17 = 418.18 – 26.15 * BIO7

BIO1 = Annual mean temperature, BIO2 = mean monthly temperature range (mean of monthly (max temp - min temp), BIO3 = isothermality (BIO2/BIO7) (* 100), BIO4 = temperature seasonality (standard deviation *100), BIO5 = max temperature of warmest month, BIO6 = Min temperature of coldest month, BIO7 = temperature annual range (BIO5-BIO6), BIO8 = mean temperature of wettest quarter, BIO9 = mean temperature of driest quarter, BIO10 = mean temperature of warmest quarter, BIO11 = mean temperature of coldest quarter, BIO12 = annual precipitation, BIO13 = precipitation of wettest month, BIO14 = precipitation of driest month, BIO15 = precipitation seasonality (coefficient of variation), BIO16 = precipitation of wettest quarter, BIO17 = precipitation of driest quarter, BIO18 = precipitation of warmest quarter, BIO19 = precipitation of coldest quarter.

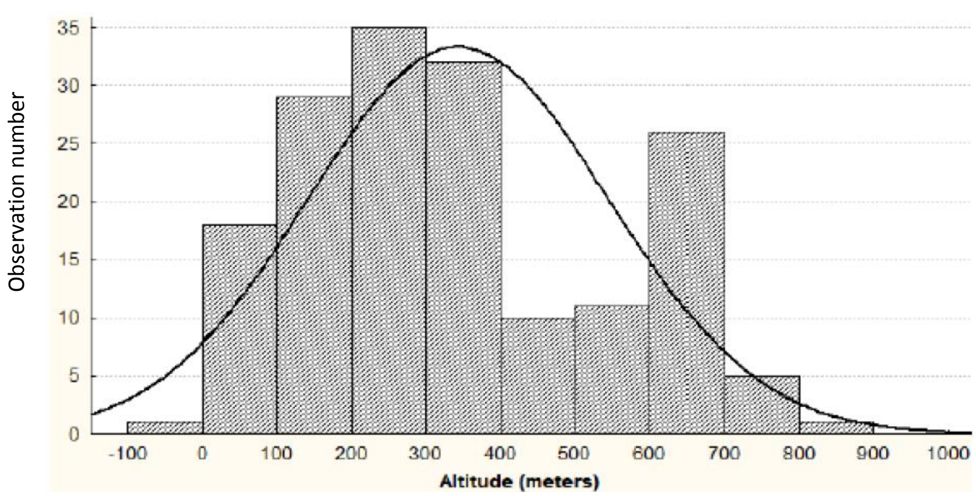

Figure 7. Favourable attitudes for natural growth of *D. edulis.*

duals.

ACKNOWLEDGEMENTS

The specimens from Gabon and Cameroon's forests have been collected for IFORA project financed by the ANR. The authors thank the staff of the National Herbarium of Cameroon for facilitating identification of specimens.

REFERENCES

Ajibesin KK (2011). *Dacryodes edulis* (G. Don) H.J. lam., A review on its Medecinal, Phytochimical and Economical Prospecties. Res. J. Med. Plant 5: 32-41.

Aubreville A (1962). *Flore* du Gabon, Irvingiaceae, Simaroubaceae, Burseraceae, Laboratoire de phanérogamie, Paris. pp.101.

Aumeerudy Y, Pingo F (1989). Phytopracties in tropical regions: a primary survey of traditional crop improvement techniques, UNESCO/MAB/Laboratoire de Botanique Tropicale. Montpellier.

Busby JR (1991). BIOCLIM - a bioclimate prediction system. In: Marguels C. R., Austin M., P., (Eds.), Nature conservation: cost effective biological surveys and data analysis. CSIRO, Melbourne, 4-68.

Carpenter G, Gillison AN, Winter J (1993). DOMAIN : a flexible modelling procedure for mapping potential distributions of plants and animals. Biodivers. Conserv. 2: 667-680.

Chevalier A (1916). Les végétations utiles de l'Afrique Tropicale Française, La forêt et les bois du Gabon. Paris.

Hijmans RJ, Guarino L, Bussink C, Mathur P, De la Cruz M, Barrentes I, Rajas E (2005). DIVA-GIS. A geographic information system for the analysis of species distribution data. Manual, version 5.2.

Hutchinson GE (1957). Concluding remarks. Cold Spring Harbor Symposia on Quantitative Biology. 22: 145–159.

Isseri FG (1998). Etude phytogéographique du safoutier (*Dacryodes edulis*) et quantification de la production du safou au Cameroun, Université de Ngaoundéré Mémoire de Maîtrise. p. 69.

Jarvis A, Williams K, Williams D, Guarino L, Caballero PJ, Mottram G (2005). Use of GIS for optimizing a collecting mission for a rare wild pepper (Capsicum flexuosum Sendtn.) in Paraguay. Genet. Resour. Crop Evol. 52: 671-681.

Kengue J (2002a). Safou (*Dacryodes edulis* (G. Don) H. J. Lam), International centre for underutilized crops, Southampton, UK.

Kengue J (2002b). Fruits for the Future 3 – Safou (*Dacryodes edulis*). International Centre for Underutilised Crops (ICUC), Southampton, United Kingdom of Great Britain and Northern Ireland. pp.148

Lam HJ (1932). Beiträge zur morphologie der Burseraceae. Insbesondere der Canarieae. Ann. Jard. Bot. Buitenzorg 42: 202.

Maley J(1987). Afrique. Fragmentation de la Forêt Dense Humide ouest-africaine et extension d'une végétation montagnarde à basse elevation au Quaternaire récent: implications paléoclimatiques et biogéographiques. Palaeoecol. Africa 18.

Maley J (1996). Le cadre paléoenvironnemental des refuges forestiers africains: quelques données et hypothèses. In: Van der Maesen L. J. G., van den Burgt X. M., Van Medenbach de Rooy J. M. (Eds.), Biodiver. Afr. Plants. pp. 519-535.

Olivry JC (2006). Fleuves et rivières du Cameroun. Collection Monographies Hydrologiques d'ORSTOM n° 9. MESRES-ORSTOM, Paris.

Onana JM (1998). Les Burséracées du Cameroun : taxonomie, biométrie foliaire et biologie. Univ. Yaoundé, Cameroun, Thèse de doctorat de 3e cycle. p. 267.

Onana JM (2008). A synoptic revision of *Dacryodes* (Burseraceae) in Africa, with a new species from Central Africa. Kew Bull. 63: 385–400.

Onana JM, Cheek M (2003). A new species of *Dacryodes* (Burseraceae) from Zambia, Kew Bull. 58: 219-224.

Orwa C, Mutua A, Kindt R, Jamnadass R, Simons A (2009). Agro-forestree Database:a tree reference and selection guide version 4.0 http://www.worldagroforestry.org/af/treedb/

Pierlot R (1996). Deux nouvelles espèces de *Dacryodes* (Burseracées) du Zaïre. Bull. Jard. Bot. Natl. Belg. 65 359-367.

Segura Sergio, Coppens d'Eeckenbrugge G, Lopez L, Grum M., Guarino L (2003). Mapping the potential distribution of five species of *Passiflora* in Andean countries. Genet. Resour. Crop Evol. 50: 555-566.

Sonwa DJ, Okafor JC, Mpungi Buyungu P, Weise SF, Tchatat M, Adesina AA, Nkongmeneck AB, Ndoye O, Endamana D (2002). *Dacryodes edulis*, a neglected nontimber forest species for the agroforestry systems of West and Central Africa. Forests Trees Livelihoods 12(1/2) 41–55.

Tabuna H (2000). Les produits forestiers non ligneux alimentaires de l'Afrique Centrale sur les marchés français et belge, Museum National d'Histoire Naturelle de Paris, PhD Thesis. pp. 226.

Verheij EWM (2002). *Dacryodes edulis* (G.Don) H.J.Lam. in Oyen, L.P.A. & Lemmens, R.H.M.J. (Editors). PROTA (Plant Resources of Tropical Africa / Ressources végétales de l'Afrique tropicale), Wageningen, Netherlands. <http://www.prota4u.org/search.asp>.