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ECOLOGICAL BIOGEOGRAPHY OF LOGANIACEAE IN WEST AFRICA

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ABSTRACT
Ecological biogeography studies the factors that define the spatial distribution of species in the present time and the abiotic factors that define the ecological biogeography of plants on land have been shown to be climate affecting the vegetation. Loganiaceae species were collected from West African countries with the aid of Global Positioning System (GPS) device and other collection materials. Maximum Entropy (MAXENT) Programme for maximum entropy modeling of species' geographic distributions was used to plot the coordinates of collection using the 19 West African (climatic) environmental layers. The species distribution of Loganiaceae in West Africa is most affected by the Precipitation of coldest quarter (November – January), followed by the precipitation of the driest month (March), minimum temperature of coldest month (December) and by precipitation of warmest quarter (February - April) of the year.

KEYWORDS - Loganiaceae, Distribution, Conservation, Environmental layers, Species.

INTRODUCTION

Ecological biogeography studies the factors that define the spatial distribution of species in the present time (Monje-Nájera, 2008). Loganiaceae is a family of trees, shrubs and tendril-bearing liana with 13 genera and about 350 species distributed mainly in the tropics, subtropics and a few in temperate regions of the world (Backlund *et al.*, 2000). The family was first suggested by Robert Brown in 1814 and validly published by Von Martius in 1827 (Leeuwenberg and Leenhouts, 1980; Frasier, 2008). The family belongs to the Order Gentianales which consists of the families Apocynaceae, Gelsemiaceae, Loganiaceae, Gentianaceae and Rubiaceae. Among these, Loganiaceae was considered to occupy a central evolutionary position (Bisset, 1980; Leeuwenberg and Leenhouts, 1980; Backlund *et al*., 2000). Earlier treatments of the family have included up to 29 genera, 600 species (Leeuwenberg and Leenhouts, 1980; Mabberley, 1997) but were later reduced to 400 species in 15 genera, with some species extending into temperate Australia and North America (Struwe *et al.*, 1994; Dunlop, 1996; Backlund and Bremer, 1998). Morphological phylogenetic studies have demonstrated that this broadly defined Loganiaceae was a polyphyletic assemblage and numerous genera have been removed from it to other families, sometimes in other orders. Some of the genera circumscribed in Loganiaceae family in the Flora of West Tropical Africa have been proved to belong in another family with the advent of Molecular kits as opposed to the earlier gross-morphological classifications. Loganiaceae now consists of 13 genera: *Antonia, Bonyunia, Gardneria, Geniostoma, Labordia, Logania, Mitrasacme, Mitreola, Neuburgia, Norrisia, Spigelia, Strychnos* and *Usteria* (Backlund *et al*., 2000; Frasier, 2008). The abiotic factors that define the ecological biogeography of plants on land have been shown to be climate affecting the vegetation (Chen *et al*., 2005; Monje-Nájera, 2008) and the two important biotic factors are dispersal and predation (Chust *et al.*, 2006; Monje-Nájera, 2008). Ecological problems confronting Loganiaceae have been compounded *inter alia,* by habitat destruction, over-exploitation, desertification and climate change (Floyd *et al*., 2005; Larson 2006; Brook *et al*., 2006; Monje-Nájera, 2008). The diversity of their habitats environmentally, taxonomically and genetically are grossly challenged. They are no longer complementary; i.e. though may be rich in biodiversity but with relatively few common taxa. Furthermore, some of these habitats are currently under-represented in conservation efforts; they are threatened with genetic erosion while some are likely to be suitable as *in situ* conservation sites. In summary, these habitats are not well represented in current germplasm collections. In order to ensure effective conservation and sustainable use of Loganiaceae species, the study seeks to evaluate the climatic factors that influence the spatial distribution of the species in the family.

MATERIALS & METHODS

Loganiaceae population sampling was carried out and samples collected from several Forest Reserves and National Parks in Nigeria, Republic of Benin and Ghana with the aid of cutlass, secateurs and Global Positioning System (GPS) device. Herbaria samples with adequate location record were also collected from herbaria to complement the fresh samples from the field. Herbarium samples were prepared and deposited in University of Lagos Herbarium (LUH) and Forestry Herbarium Ibadan (FHI). The genera sampled included replicates of: 37 species of *Strychnos,* only one species of *Usteria* and one species of *Spigelia.* The distribution of Loganiaceae in West Tropical African forests was represented by plotting the coordinates obtained in the field throughout the period of collection. This was achieved by the use of Maximum Entropy (MAXENT) Programme for maximum entropy modeling of species' geographic distributions written by Phillips *et al.,* (2006). The following settings were used to run the programme: 18 presence records for training, 4 for testing, 10011 points used to determine the Maxent distribution (background points and presence points) as well as nineteen (19 - all continuous) environmental layers adopted from the world climate database designed for West Africa.

RESULTS

The logistic prediction is represented by Figure 1.0.
Warmer colours (Yellow – Orange - Red) show areas with better predicted conditions. White dots show the presence locations used for training, while violet dots show test locations.
The environmental layers used in the study from the data base for West Africa are here listed.

- Bio 1 - annual mean temperature.
- Bio 2 - means diurnal range; mean of monthly, max temp-min temp.
- Bio 3 - Isothermality $(P_2/P_7) * 100$.
- Bio 4 - temperature seasonality (standard deviation 100).
- Bio 5 - max temperature of warmest month; March.
- Bio 6 - min temperature of coldest month; December.
- Bio 7 - temp annual range (temp annual range (P_5-P_6).
- Bio 8 - mean temperature of wettest quarter; June – August.
- Bio 9 - mean temperature of driest quarter; January - March.
- Bio 10 - mean temperature of warmest quarter; February - April.
- Bio 11 - mean temperature of coldest quarter; November - January.
- Bio 12 - annual precipitation.
- Bio 13 - precipitation of wettest month; July
- Bio 14 - precipitation of driest month; March.
- Bio 15 - precipitation seasonality; coefficient of variation.
- Bio 16 - precipitation of wettest quarter; June – August.
- Bio 17 - precipitation of driest quarter; November – January.
- Bio 18 - precipitation of warmest quarter; February – April.
- Bio 19 - precipitation of coldest quarter; November - January.

A heuristic estimate of relative contributions of the environmental variables to the Maxent model shows that Bio 19 has the highest percentage contribution to the model (44.9 %) and Bio 1 has the least contribution.

DISCUSSION

The population of Loganiaceae was sampled in the study and it was gathered that both natural phenomena and anthropogenic effects are posing threats on the abundance of their species (Table 1).

TABLE 1: Summary of the field collections showing Loganiaceae population

Genera	Name of genera and species	Total species encountered	Coordinates of one collection (GPS). Latitude, Longitude
1	*Anthocleista*	9	
2	*Mostuea*	2	
3	*Nuxia*	1	
4	*Spigelia*	1	
5	*Strychnos*	37	
6	*Usteria*	1	
	Representative species		
Genera	Species	Individuals	coordinates
1	*Anthocleista djalonensis*	>1000	N 06°30′55.4″ E003°23′56.7″
	Anthocleista nobilis	<100	N 05°22.835′ E008°25.21
	Anthocleista vogelli	>2000	N 06°30′53.14″ E003°23′46.7″
2	*Mostuea brunonis*	<50	N 05°12′18 E08°21′31.9N
	M. hirsuta	<50	N 05°22′19.2″′ E008°27.25.1″
3	*Nuxia congesta*	5	N6°43′ E11°15′ N6.719° E11.27°
4	*Spigelia anthelmia*	∞	N 06°51.835′ E007°24.58′
5	*Strychnos aculeata*	<50	N 05°21.835′ E008°26.21
	S. afzeli	<50	N 06°51.835′ E007°24.580′
	S. afzeli	<50	N 7°15', E 4°10'
	S. asterantha	<50	N 07°12′07.1″ E005°01′43.9″
	S. barteri	<50	N 06°50′17.4″ E004°21′52.6″
	S. boonei	<50	N 07°11′.01″ E003°52′42.6″
6	*Usteria guineensis*	<50	N 06°52′ 45 E003°56′03.9″

Note: < = less than, > = greater than, ∞ = infinity.

Mostuea are under-storey shrubs in the high forest, as the virgin forests are being tampered with and depleted, they disappear from the wild. Majority of *Strychnos* species are woody climbers which rely on giant host trees in the high forest. Deforestation therefore has grossly depleted the population of Loganiaceae in West Africa. In the Loganiaceae species distribution modeling by MAXENT, the logistic prediction is represented by Figure 1.0. Warmer colours (Yellow – Orange - Red) show areas with better predicted conditions. White dots show the presence locations used for training, while violet dots show test locations.

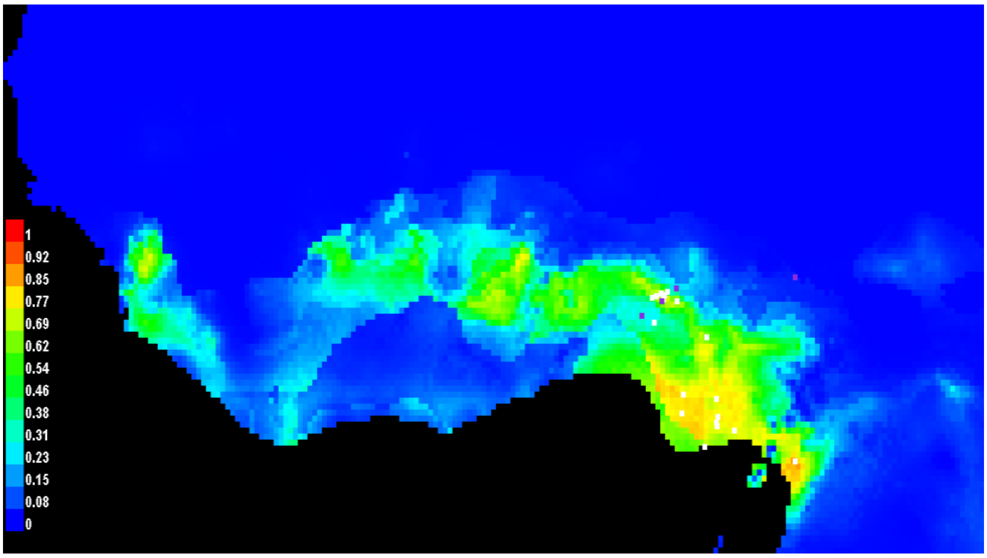
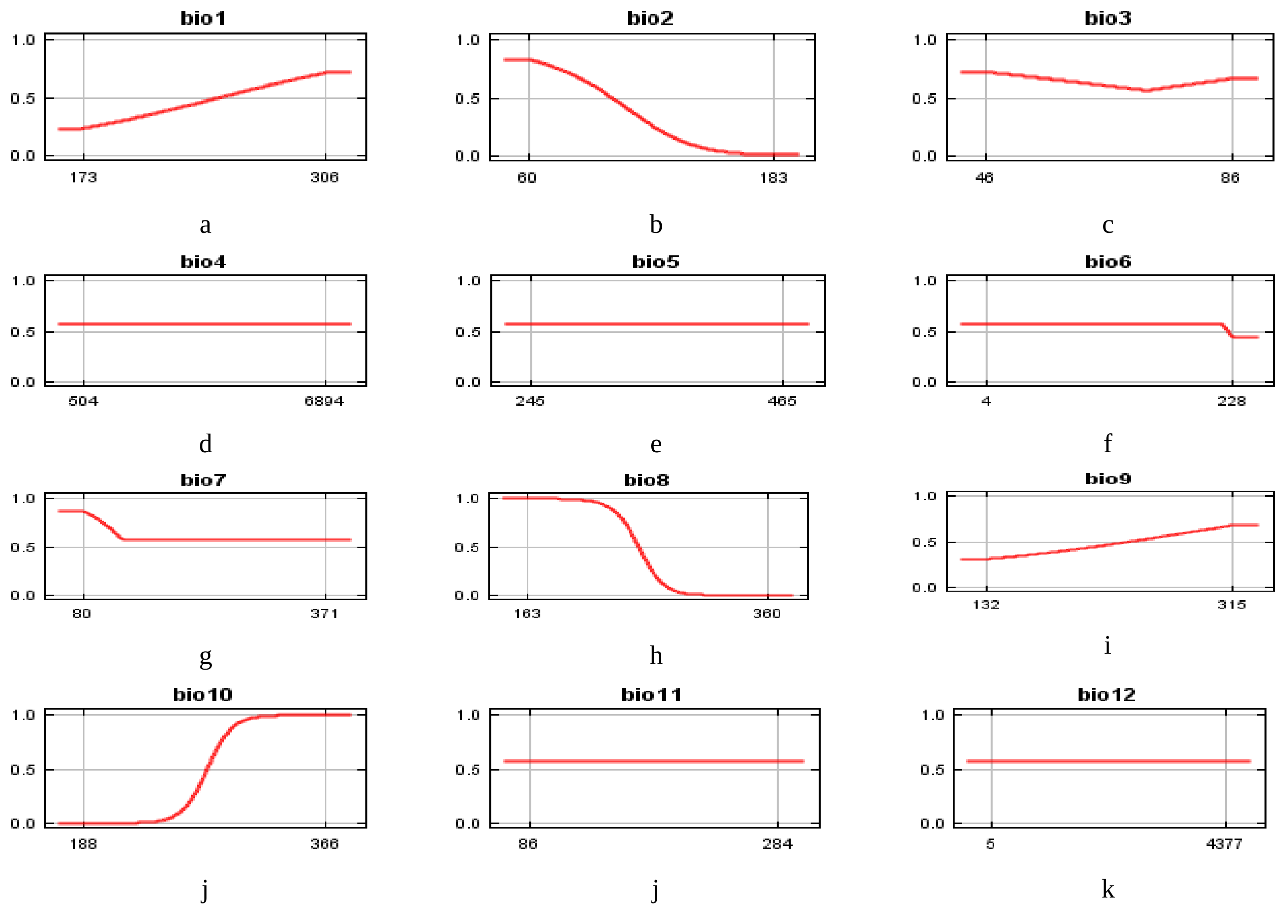


FIGURE 1.0: Species distribution for Loganiaceae in West Tropical Africa using nineteen environmental variables.

The response curves (Figure 2.0) show the marginal effect of changing exactly one variable. The curves show how each environmental variable affects the prediction; how the logistic prediction changes as each environmental variable is varied, keeping all other environmental variables at their average sample value. As each environmental variable is varied, the probability of occurrence of the samples decreases with varying Bio 2, 6, 7, 8, 13, 14, 15, 17 and 18; decreases but later increases with varying Bio 3; remains constant with varying Bio 4, 5, 11, 12 and 16; increases with varying Bio 1, 9, 10 and 19 (Figure 2.0 (a-s)).

In contrast to the marginal response curves in Figure 2.0, Figure 3.0 model was created using only the corresponding variable. The plots reflect the dependence of predicted suitability both on the selected variable and on dependencies induced by correlations between the selected variable and other variables.



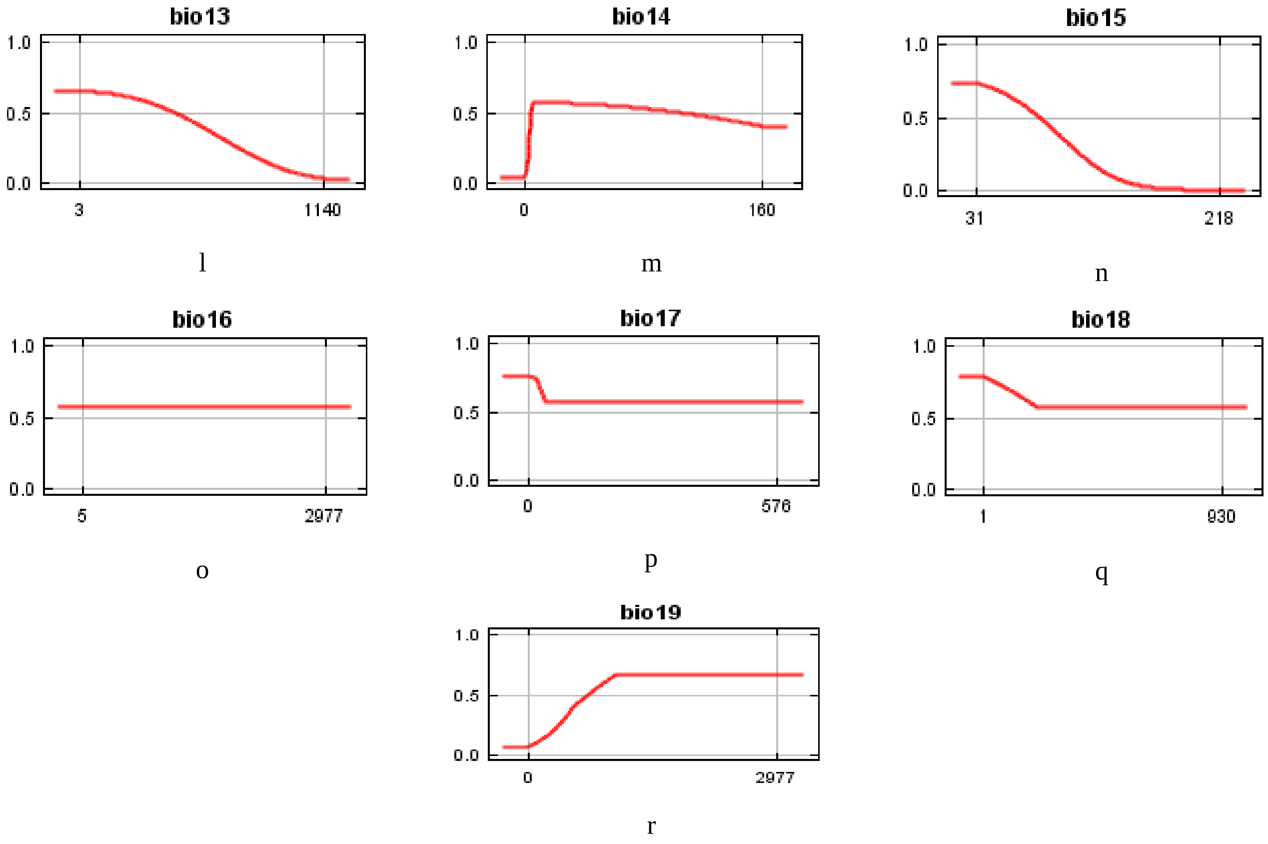
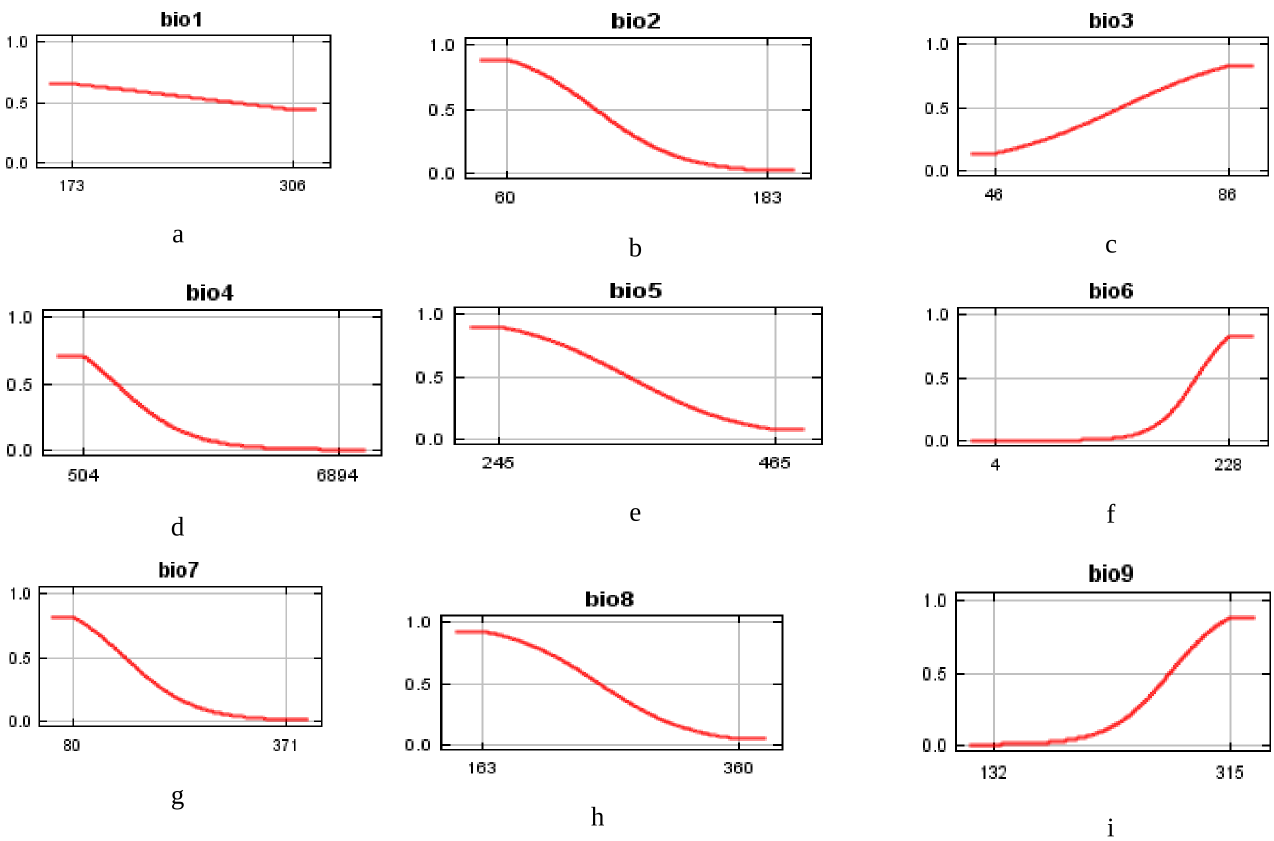


FIGURE 2.0 (a - r): The marginal effect of changing exactly one environmental variable
X axis: Environmental variable value
Y axis: Fractional value of Location



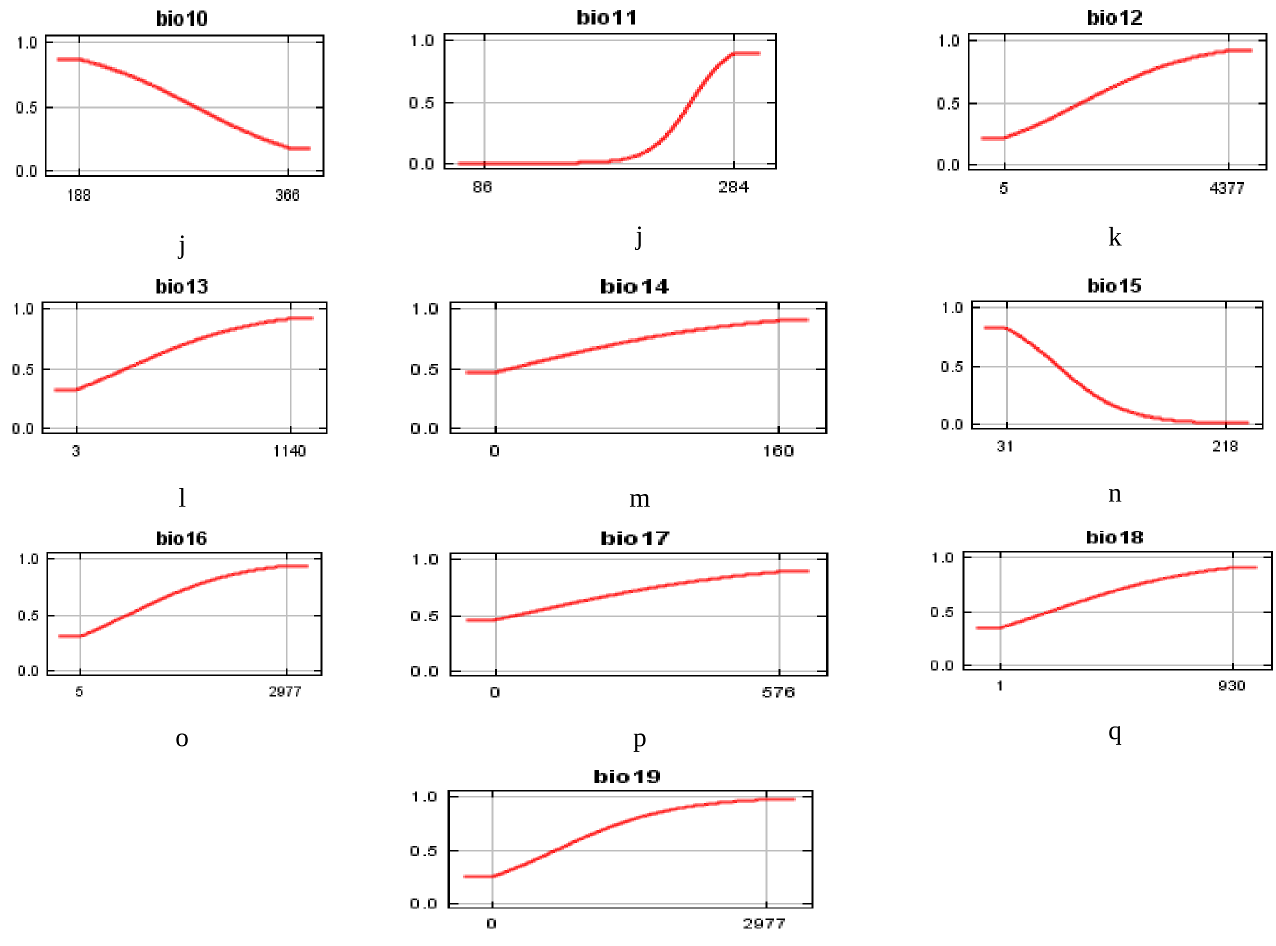


Figure 3.0 (k-s): The marginal effect of changing corresponding variables continued
X axis: Environmental variables value
Y axis: Fractional value of Location

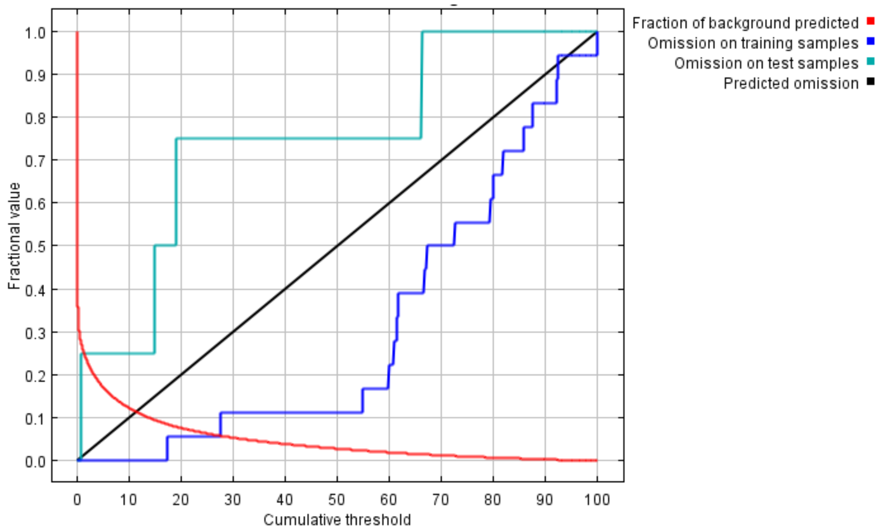


FIGURE 4.0: Omission and Predicted area for Loganiaceae.

The omission rate and predicted area as a function of the cumulative threshold is represented by Figure 4.0. The omission rate is calculated both on the training presence records and on the test records. The omission rate is close to the predicted omission, because of the cumulative threshold used. Figure 5.0 represents the receiver operating characteristic (ROC) curve. The predicted area was defined by specificity rather than true commission. This makes the maximum achievable Area under Curve (AUC) less than 1.

A heuristic estimate of relative contributions of the environmental variables to the Maxent model shows that Bio 19 has the highest percentage contribution to the model (44.9 %), Bio 1 has the least contribution (0.2 %) while Bio 5, 12 and 16 did not contribute at all (Table 2.0).

TABLE 2: Percentage variable contributions to the Maxent model

S/N	Variable	Percent contribution (%)	S/N	Variable	Percent contribution (%)
1	bio19	44.9	11	bio15	0.5
2	bio14	31.5	12	bio17	0.4
3	bio6	13.7	13	bio9	0.4
4	bio18	1.9	14	bio11	0.3
5	bio7	1.3	15	bio3	0.3
6	bio10	1.1	16	bio1	0.2
7	bio8	1.1	17	bio12	0
8	bio4	1	18	bio5	0
9	bio2	0.9	19	bio16	0
10	bio13	0.5			

In summary, the species distribution of Loganiaceae in West Africa is most affected by the Precipitation of coldest quarter (November – January), followed by the precipitation of the driest month (March), minimum temperature of coldest month (December) and by precipitation of warmest quarter (February - April).
The significances of the model to the taxonomy (collection, identification and preservation) of Loganiaceae, scientists and other plant users are:
Spigelia anthelmia: It is an annual herb that is found during the rainy seasons or in the dry but close to region of regular water supply. E.g. by droplets from roof in early rain.
Anthocleista species: Tree species found close to water; low lands, swamps. They grow stilt roots in search of water in dry zones.
Strychnos species: they are woody climbers found in thick forest; usually the understory of such forest is damp, moist with high relative humidity. When there is a river or stream in the forest, *Strychnos* form a dense network of crown (over stream) or by the river course using a suitable host.
Usteria species: they are climbers growing at the forest edges, road sides and in cultivated lands near a stream or river.

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