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Climatic variability and spatial distribution of herbaceous fodders in the Sudanian zone of Benin (West Africa).

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Abstract
This study focused on future spatial distributions of *Andropogon gayanus*, *Loxodera ledermanii* and *Alysicarpus ovalifolius* regarding bioclimatic variables in the Sudanian zone of Benin, particularly in the W Biosphere Reserve (WBR). These species were selected according to their importance for animals feed and the intensification of exploitation pressure induced change in their natural spatial distribution. Twenty (20) bioclimatic variables were tested and variables with high auto-correlation values were eliminated. Then, we retained seven climatic variables for the model. A MaxEnt (Maximum Entropy) method was used to identify all climatic factors which determined the spatial distribution of the three species. Spatial distribution showed for *Andropogon gayanus*, a regression of high area distribution in detriment of low and moderate areas. The same trend was observed for *Loxodera ledermannii* spatial distribution. For *Alysicarpus ovalifolius*, currently area with moderate and low distribution were the most represented but map showed in 2050 that area with high distribution increased. We can deduce that without bioclimatic variables, others factors such as: biotic interactions, dispersion constraints, anthropic pressure, human activities and another historic factor determined spatial distribution of species. Modeling techniques that require only presence data are therefore extremely valuable.
Keywords: Bioclimatic variables, Distribution, Fodders, MaxEnt, Model.

I. INTRODUCTION

Natural ecosystems provide multiple services of high importance for people's economic, social and cultural needs in the developing countries. These resources ensure important functions from an ecological perspective and provide services that are essential to maintain the life support system [1]. In the last two decades, natural ecosystems responded to environmental changes by the modification of original structure of plants populations and communities [2; 3]. Environmental change due to human activities could completely modify the species composition of the original plant communities [4]. Besides, climate variability is also viewed as a conservation problem. For many species, climate has indirect effects through the sensitivity of habitat or food supply. Indeed, the temperature and precipitations levels also have direct effect on species and ecosystems functions were affected. Relations between species and environmental variables were not fixed and included change in species distribution in order to accommodate environment variables modification [5; 6; 7].

In Sub Saharan Africa, 25-42% of species could be extinct in response to the lost of their favorable habitat (80-85%) in 2085 [8]. Nowadays, predictive niche-based models were mostly used to answer environmental, ecological and spatial distribution questions. A predictive niche-based model represents an approximation of a species' ecological niche or geographical distribution in the examined environmental dimensions [9]. It uses environmental attributes, including current climate to predict habitat that species can occupy. Then, spatial prediction of species distributions from survey data has recently been recognized as a significant component of conservation planning. But a lack of data is even more apparent in developing countries with high biodiversity [10]. One way of overcoming this data shortfall is to build models of a species' suitable habitat and distribution, which can then be used to plan data collection or prioritize interventions. Indeed, models predicting the spatial distribution of species have been especially promoted to tackle conservation issues: managing species distribution, assessing ecological impacts of various factors, or endangered species management [11; 12].

In northern Benin, livestock breeding is considered as principal activity and cattle populations were estimated to 768339 livestock units. These regions are also characterized by transhumance (from Niger, Nigeria and Burkina Faso) which causes overexploitation and following low productivity of forage plants in rangelands [13]. In this context and in climate variability conditions, pressure on rangeland species increased. It becomes necessary to identify current distribution of main fodders species in order to predict in the future spatial distribution of these species.

Habitat models are often performed at the regions or continents scales, where environmental factors such as temperature, precipitations, soils and land-cover types were relevant. This study was carried out within a smaller geographical extent and focused on relations between spatial distributions and bioclimatic variables of *Andropogon gayanus*, *Loxodera ledermanii* and *Alysicarpus ovalifolius* in the Sudanian zone of Benin. These species were selected according to their importance for animals' feed [14] and the intensification of exploitation pressure induced change in natural spatial distribution of these species. This research completes those of [15] in the central part of Benin and aims at predicting the new geographical distribution of these main fodders species by 2050.

II. MATERIALS AND METHODS

Our research was carried out in the Transboundary Biosphere Reserve involving Benin, Niger and Burkina Faso. The W Biosphere Reserve (WBR) in Benin is located in the province of Alibori, located between the parallels 11°26' and 12°26' North latitude and between the meridian 2°17' and 3°05' of longitude East. The WBR is composed of the Park (563,280 ha) which represents the core area, the hunting zones of Djona (115,200 ha) and the hunting zone of Mekrou (52,000 ha). The Fig no.1 showed the study area.

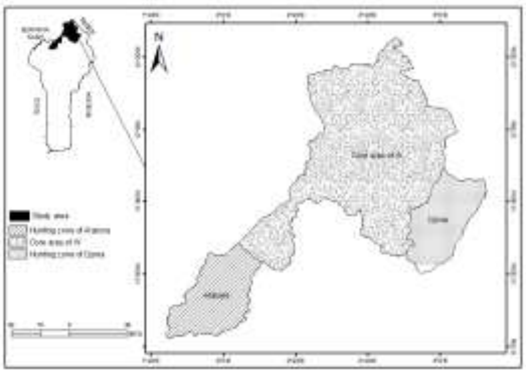


FIGURE 1: Location of the study area, the W Biosphere Reserve in Benin.

According to [16], the WBR belongs to the regional centre of Sudanian endemism and is characterized by a single rainy season and a single dry season. Various soils were distinguished: minerals, little mature, tropical ferruginous and minerals soils with gley [17]. Vegetation is a mosaic of savannas (trees, shrubs, grass and woodlands) dominated in woody layer by *Acacia ataxacantha*, *Acacia macrostachya*, *Combretum glutinosum*, *Burkea africana*, *Detarium microcarpum*, *Piliostigma thonningii*, etc. In the herbaceous layer, we have species such as: *Hypparhenia involucrata*, *Andropogon schirensis*, *Andropogon pseudapricus*, *Pennisetum polystachion*, *Diheteropogon amplectens* [18]. Nowadays, degraded savannas were also observed [19].

II.I. DATA COLLECTION

Species occurrence data

A preliminary field work was undertaken to identify in the WBR the occurrence area of *Loxodera ledermannii*, *Andropogon gayanus* and *Alysicarpus ovalifolius*. Geographic coordinates of each species were collected using the Global Position System (GPS). A distance of 500 meters was respected between two coordinates. Then, for *Loxodera ledermannii* 150 coordinates were taken, 150 for *Andropogon gayanus* and 100 for *Alysicarpus ovalifolius*. These coordinates were completed with occurrence points relative to each species on GBIF (http://www.gbif.org). The new occurrence data base obtained was used for the spatial distribution model of each species.

Bioclimatic and environmental data

Twenty (20) bioclimatic and environmental variables were tested and variables with high auto-correlation values were eliminated. Using Jacknife of AUC we retained seven climatic variables for the model. These variables were bio11: mean temperature of coldest quarter; bio14: precipitation of driest period; bio15: precipitation seasonality (coefficient of variation); bio18: precipitation of warmest quarter; bio2: mean diurnal range (max temperature-min temperature) monthly average; bio5: maximum temperature of warmest period and bio6: minimum temperature of coldest period. The seven variables were used for the spatial distribution model of the three species.

II.II. DATA ANALYSIS

A Maxent (Maximum entropy) method [9] was used to identify all climatic factors which determined the spatial distribution of *Andropogon g*ayanus, *Loxodera l*edermannii and *Alysicarpus ovalifolius*. Maxent's predictive performance was chose because it is consistently competitive with the highest performing methods [20]. Since becoming available in 2004, it has been utilized extensively for modeling species distributions and presented many advantages. One of these advantages is the requisition of presence only data, together with environmental information for the whole study area. Another advantage is that, it can utilize both continuous and categorical data and incorporate interactions between different variables [9; 21].

In this study, for the prediction of spatial distribution of *Andropogon gayanus*, *Loxodera l*edermannii and *Alysicarpus o*valifolius we used two climatic scenarios: optimist RCP 2.6 scenario and pessimist RCP 8.0 scenario. The occurrence data of all species and climate variables in Maxent model permitted to validate the models which were used. Then spatial distribution maps were realized per species. The first map presented the current spatial distribution of the specie and the second one predicted in 2050 the distribution of the same specie using the bioclimatic variables predefined.

On each map, we considered three categories of distribution: area with high distribution of the considered species (occurrence of specie between 50 and 100%), area with moderate distribution (occurrence of specie between 25 and 50%) and area with low distribution (occurrence of specie between inferior to 25%). Proportions of each category area were determined and dynamics values were calculated per class for the period 2015-2050.

III. RESULTS

III.I. Bioclimatic data

Fig. no.2 showed the Jacknife of AUC for *Andropogon g*ayanus, *Loxodera l*edermannii and *Alysicarpus o*valifolius. On this figure, we observed all seven variables which were retained for the model. We noticed that the bio14 variable (precipitation of driest period) was the less represented for all three species when the bio2 variable (mean diurnal range) was the most represented.

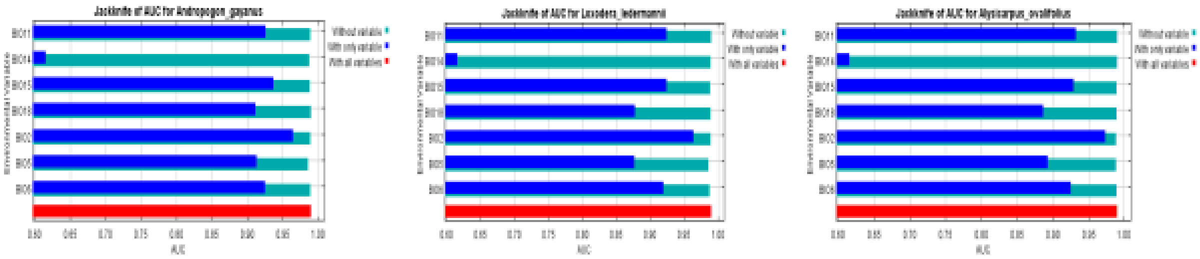
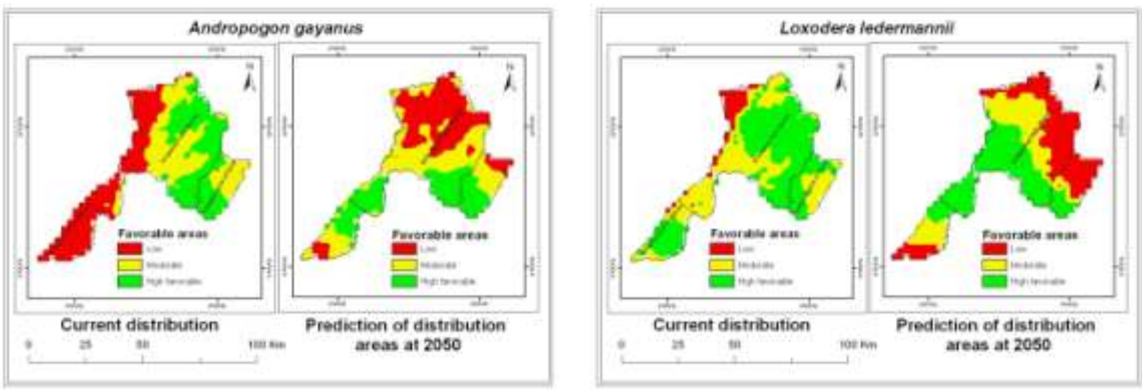


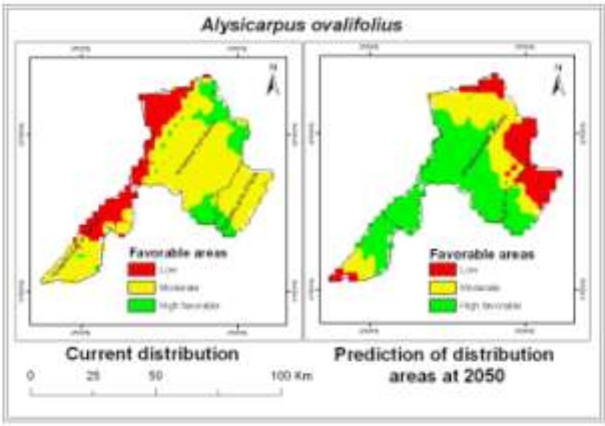
FIGURE 2: Jacknife of AUC of *Andropogon gayanus*, *Loxodera ledermannii* and *Alysicarpus ovalifolius*

III.II. Current and future spatial distribution of species in the W National Park of Benin

The current spatial distribution of species varied in function of species. We used three classes of distribution areas for classification: areas for a favorable distribution, area for a moderate distribution and area with low distribution. Fig. no3 showed current and future distribution of *Andropogon g*ayanus, Loxodera ledermannii and Alysicarpus ovalifolius species in the Park and Table 1 the dynamics' values of each class of distribution area.



(a) **(b)**



(c)

FIGURE 3: Prediction of spatial distribution of *Andropogon gayanus* (a) *Loxodera ledermannii (b) and Alysicarpus ovalifolius (c)* with scenarios 2.6 and 8.5 of climatic model at 2050 in the WBR.

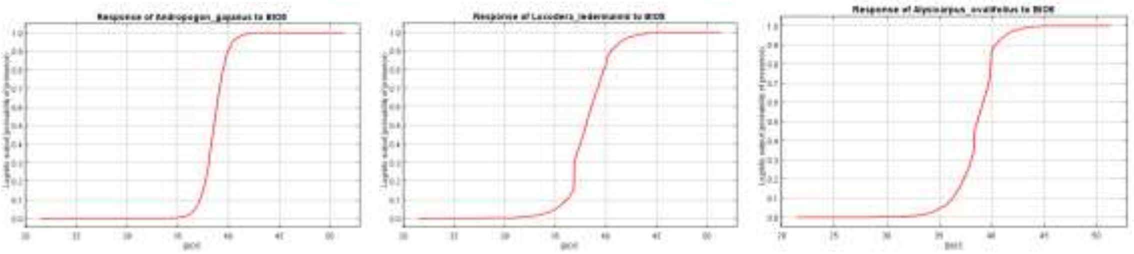
TABLE 1: Proportions and dynamic values' of *Andropogon gayanus*, *Loxodera l*edermannii and *Alysicarpus ovalifolius* (2015-2050).

Areas categories'	Current proportions (%)	Future (2050) proportions (%)	Dynamics' values (%)
Andropogon gayanus			
Low	34,2931937	35,078534	0,78534031
Moderate	33,7696335	38,4816754	4,71204188
High	31,9371728	26,4397906	-5,4973822
Total	100	100	
Loxodera ledermannii			
Low	8,63874346	37,6963351	29,0575916
Moderate	38,2198953	23,2984293	-14,921466
High	53,1413613	39,0052356	-14,1361257
Total	100	100	
Alysicarpus ovalifolius			
Low	24,8691099	18,8481675	-6,02094241
Moderate	55,2356021	28,5340314	-26,7015707
High	19,895288	52,617801	32,7225131
Total	100	100	

Model maps showed current and future spatial distribution of *Andropogon gayanus* (Fig. no.3a). In 2050, the high distribution area of *Andropogon gayanus* will regress of 5.5% while area with low and moderate distribution increased in the interval of 0.78% and 4.71% respectively. We also remarked on the current distribution map that, areas with low distribution for *Andropogon gayanus* were located in Mekrou hunting zone and in the periphery of the core area. But in 2050, we noticed that areas with low distribution of *Andropogon gayanus*, will moved from the Mekrohunting zone for the core area zone and the hunting zone of Djona. Considering *Loxodera ledermannii*, we noticed the drastically increasing of area with low distribution and proportion of this category passed from 8.63% to 37.69% of total area (Fig. no.3b). In the same time, moderate and high distribution areas were reduced. In 2050, moderate distribution area which was located in the core area and in the hunting zone of Djona will be reduced and we noticed an increasing of low distribution area of *Loxodera ledermannii* in the core area. Current and future distribution of *Alysicarpus ovalifolius* maps (Fig. no.3c) showed that areas with low and moderate distribution were reduced when area with high favorable distribution increased. Dynamics values were respectively of -6.02 %; -26.70 % and 32.72 % (Table 1) for the three categories of repartition areas.

III.III. Impact of bioclimatic variables on spatial distribution of species

The Fig. no.4 showed relation between bioclimatic variables and spatial distribution of species. Bioclimatic variables influenced the spatial distribution of *Andropogon g*ayanus, *Loxodera* *l*edermannii and *Alysicarpus ovalifolius* in the WBR. The correlation between bioclimatic variables and species areas distribution can be explained using the response of species to the action of each bioclimatic variable which contributed to the determination of future distribution. All three species responded favorably to bio5 (max temperature of warmest period) variable. We can deduce that the maximum temperature of warmest period influenced the spatial distribution of all species. We noticed that *Andropogon gayanus* responded to the all seven variables which were retained but favorable response with 100% probability value was observed with maximum temperature of warmest period (bio5). Spatial distribution of *Andropogon gayanus* was also influenced by Minimum temperature of coldest period (bio6) and precipitations of warmest quarter (bio18). The same situation is observed with *Alysicarpus ovalifolius* distribution. When we considered *Loxodera lerdermannii*, only bio5 variable determined its spatial distribution.



(a) (b) (c)

FIGURE 4: Response of Andropogon *gayanus* **(a)** *Loxodera ledermannii **(b)** and Alysicarpus ovalifolius **(c)*** with scenarios 2.6 and 8.5 of climatic model at 2050 in the WBR.

IV. DISCUSSION

IV.I. Current and spatial distribution of *Andropogon gayanus*, *Loxodera ledermannii* and *Alysicarpus ovalifolius* in 2050

Our results showed spatial distribution of Andropogon gayanus, *Loxodera ledermannii* and *Alysicarpus ovalifolius* in 2050. Spatial distribution was different for the three species. The environmental variables we used to fit the models are known to have a major direct ecophysiological impact on plant species [22; 23; 24].

For *Andropogon gayanus*, the model showed a regression of high area distribution in detriment of low and moderate areas distribution. The same trend was observed for *Loxodera ledermannii* with which we observed the increasing of area with low distribution contrarily to those of high and moderate distribution. This can be explained on the one hand by over exploitation of this fodder species and on the other hand by climatic variability induced change in distribution areas. In the hunting zone, the high proportion of low areas distribution could be due to anthropic pressure. This corroborated well with [25; 4] who showed that disturbance results were the temporal and spatial change in vegetation patterns. For [26] species distribution was affected by climate and land-use. Then, species will have the same climate niche in the future or will modify their niche in order to accommodate the climate variables.

For *Alysicarpus ovalifolius*, currently area with moderate and low distribution were the most represented but map showed in 2050 that area with high distribution increased. This permit to remark that climatic and environmental variables don't affected negatively the distribution of all three species. We can also deduce that another factors could determined the distribution of species. And this is consistent with [27; 28], who find that distribution of species, were not only affected by bioclimatic factors. Biotic interactions, dispersion constraints, anthropic pressure, human activities and another historic factor determined future distribution of species. Then distribution of species depends with biotic and abiotic factors [29; 15].

IV.2. Advantages and drawbacks of model

Modeling techniques that require only presence data are therefore extremely valuable [30]. Using this model, a new geographical distribution is realized for the species. Climatic variables such as temperature and precipitations are appropriate at global, meso and micro scales to study spatial distribution of species. The choice of the variables used for modeling also affects the degree to which the model generalizes to regions outside the study area or to different environmental conditions [9]. So it's important to eliminate variables with high auto-correlation values because a high auto-correlation between two variables induces errors in prediction [10].

In spite of the importance of this model, prediction model based on presence data has some drawbacks. Generally, it is not mature as statistical methods (linear models, additives models) and there are fewer guidelines for its use in general [9]. The amount of regularization requires further studies [31] and it was an exponential model for probabilities which is not inherently bounded above and can give very large predicted values for environmental conditions outside the range present in the study area [9]. Despite of these drawbacks, model based on presence and bioclimatic data played a vital rule in evaluation of spatial distribution of species [22; 15].

V. CONCLUSION

In our study, model for spatial distribution of *Andropogon gayanus*, *Loxodera ledermannii* and *Alysicarpus ovalifolius* in the W National park of Benin in the future (2050) was proposed. The predictive methods were most used in ecology, biogeography and species conservation studies. These models can also contribute to the conservation of species and to the definition of management strategies planning. It can also used for evaluation of environmental condition of a site and species adequacy.

VI. ACKNOWLEDGEMENTS

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