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# Current and future distribution of *Chromolaena odorata*(L.) R. M. King & H. Roxb (Compositae) and *Hopea odorata* Roxb (Dipterocarpaceae) in the Banco national park

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***Abstract:***
***Background:*** *Invasive plant species are today among the greatest threats of protected areas integrity and their fight is a challenge which requires knowledge of the potential areas of distribution. The objective of this study is to draw the spatial distribution and to determine the potential distribution area of the invasive alien species as well as the environmental variables affecting their geographic distribution in Banco national park.*
***Materials and Methods****: The principle of "Maximum Entropy" was used to draw the habitats of Chromolaena odorata (L.) RM King & H. Roxb (proven invasive species) and Hopea odorata Roxb(potential invasive species) under current and future climatic conditions (2050 horizon of RCP 8.5 scenario). These species were chosen on the one hand based on the number of occurrences and on the other hand on their significant proportions in the park. The coordinates of presence of the species were collected and combined with environmental data (bioclimatic and topographical). The distribution surface area of potentially favorable or not zones, was calculated for each species.*
***Results****: The bioclimatic variables contributed the most to the prediction of the species model. The RCP 8.5 scenario indicates an increase of the surface area of potentially favorable zones of 3.44% and 0.27%, respectively for the Chromolaena odorata and Hopea odorata species up to 2050.*
***Conclusion:****The obtained results could constitute a guide for monitoring biological invasions in the protected areas.*
***Key words:****Modelization, Current potential distribution, Potential future distribution, Alien species, Banco national park, Côte d'Ivoire*

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## I. Introduction

Species Distribution Modeling(SDM) is an important predictive tool in conservation ecology[1, 2]. SDM consists to draw a function of environmental parameters which predicts the probability of the presence of the species. The dataset used includes data aboutspecies current presence as well as values of certain parameters, essentially environmental, of species observation sites[3,4].Several methods for modeling species distribution were developed and used[5]. Those methods differ according to the type of response took into account, the way to weight the observations and incorporate the interactions, and according to their predictive capacity[3,6]. Today, species distribution models are increasingly used to address the major problems which are understanding, describing and predicting the potential area of species, and identifying the factors determining its distribution[7]. Therefore, they represent a relevant tool for the management and conservation of the environment and biodiversity[8,9]. Among these models are those of MaxEnt "Maximal Entropy" which is one of the most effective tools because it provides very informative biogeographical information and better discrimination of suitable areas compared to unsuitable areas for species[3,5]. Therefore, the use of this algorithm is increasingly recommended to determine invasive plant species potential distribution[10,11].

Invasive plants are known as one of the direct causes of biodiversity loss worldwide[12,13].These plants proliferate, disperse and persist in an environment which is not originally their own, and this to the detriment of the pre-existing ecosystem[14]. In fact, invasive species are very competitive and can lead to a decrease in specific richness and / or a decrease in the abundance of certain species.Thus, they modify the structure, composition and quality of indigenous plant communities [15], disrupting the ecosystem running. Once introduced into a new region, the surface area is determined by many factors such as, the residence time of the species, the rate of spread of the species, the suitability of the local climate, the amount of suitable habitats available for establishment,the reproduction and the use[16]. Since climate is one of the main factors of plant distribution, changing climatic conditions can impactdistribution area change (expansion or contraction of the distribution area) in invasive plant species[17]. This can have important consequences for invaded ecosystems[18,19]. Therefore, Changes in temperature and precipitation can weaken the biotic resistance of native plant communities and favor the establishment of exotic species[19]. Their harmful effects on ecology can be extended to the local biodiversity conservation surface areas[10].

Protected areas are important zones for biodiversity conservation as well as for various ecosystem services supplying[17]. However, the integrity of these ecosystems in many parts of the world is currently threatened by invasive alien plant species[16]. The Banco National Park is not spared by this phenomenon. It contains many invasive species[20,21,22,23]which therefore constitute a serious threat forthe managers. However, the literature review has shown that managing the threat of invasive alien plants requires distribution information in both current and future climates [24,10]. The present study therefore proposes to answer the following questions: What is the current and future potential range of invasive alien species in Banco national park? (2) What are the environmental variables that contribute to their distribution in the park? To answer these questions, the study set itself the general objective of modeling the spatial distribution of two alien species: *Chromolaena odorata*(L.) R. M. King & H. Roxb, a proven invasive species in Côte d'Ivoire, et *Hopea odorata* Roxb, a potential invasive species. The choice of these species is based on their number of occurrences and their significant proportions in the park. Specifically, it involved (1) determining the current and future potential distribution of these alien species and, (2) defining the environmental variables affecting their geographic distribution. To achieve these objectives, two hypotheses have been put forward (1) the spatial distribution of *Chromolaena odorata* and *Hopea odorata*, is strongly correlated with environmental parameters, (2) by 2050, climate change will favor the expansion of these invasive species in Banco national park.

## II. Material and Methods

**Study site**

The study took place in Banco national park, located in the autonomous district of Abidjan between 5 ° 21 'and 5 ° 25' north latitude and between 4 ° 01 'and 4 ° 05' west longitude (Figure 1). In accordance with Decree No. 2018-510 from May 30, 2018, Banco National Park currently covers an area of 3438.34 ha. Data from weather station, called SODEXAM, from 2008 to 2018 show that the climate is characterized by four seasons: two dry seasons, from December to February and August to September,and two rainy seasons, from March to July and October until November. The annual temperature average is about 26 °C. The maximum rainfall average obtained is 453.43 mm in June and the minimum height is 13.66 mm in January. The soil of the park, ferrasol type[25], is characterized by sandy, ferralitic and highly unsaturated soil[26]. Banco National Park is an evergreen forest. It is a relic of psammohygrophilous primary littoral forest[27].The trees dominating the upper stratum are *Turraeanthus africanus* (Welw. Ex C. DC.) Pellegr, *Synsepalumafzelii*(Engl.) TD Penn., *Berlinia confuse* HoyIe, *Blighiawelwitschii*(Hiern) Radlk. *Coula edulis* Baill., *Dacryodesklaineana*(Pierre) HJ Lam, *Lophiraalata*Banks ex Gaertn.f., *Petersianthusmacrocarpus*(P. Beauv.) Liben and *Piptadeniastrumafricanum*(P. Beauv.) Liben[28,29].

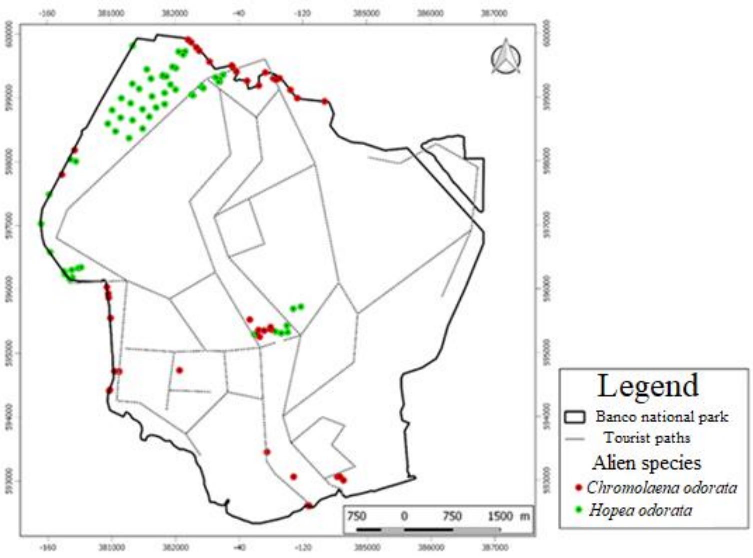



**Figure 1**: Study environment and geographic distribution of presence points used in the models.

**Data collection**

The work of [23] identified 22 invasive plant species in Banco national park. The authors identified one proven invasive species and 21 potentially invasive species. These species were identified on the basis of existing lists of invasive alien species and a field inventory. Indeed, books and papers published have been consulted and synthesized[30,31;32;33,34,35]. The Global Invasive Species Database (www.issg.org/database/welcome), CABI's invasive species collection (www. cabi.org/isc/) and the West Africa invasive plants list (http://issg.org/pdf/puplications/GISP/Resources/ wAfrica-EN.pdf) were also consulted. These data were supplemented by communications from local experts (Aké-Assi, personal communications) and observations done on the field. Subsequently, two alien species served as models for this study. These are *Chromolaena odorata* a proven invasive species, and *Hopea odorata*, a potential invasive species. They were chosen because of their frequency and abundance in Banco national park following the work of [23]. The geographic coordinates (longitude and latitude) of these two invasive species were recorded using a GPS receiver.

The environmental parameters used include climatic variables (precipitation and temperature) and topographic variables (altitude and slope). Current climate data (1950 - 2000) and future climate projections (2000- 2050) were obtained from Worldclim website (https:/www.worldclim.org) with a resolution of 30 seconds (spatial resolution of approximately 1 $km^2$in West Africa). These data include 19 bioclimatic variables (Table 1) derived from temperature and precipitation [36]. The future projection for 2050 was established according to the RCP 8.5 scenario [37]. This scenario is an improved version of scenario A.2 [38]. It was chosen because it predicts the most divergent trends for the regions of West Africa compared to other scenarios. It was used in several studies on West African ecosystems [39],[1040,41,42]. The Met Office climate model (Hadgem2-ES) was also used [37]. This model is currently the most suitable for simulating climate responses in West Africa [39,10,41,42]. The topographicparameters (altitude and slope) were extracted from a digital terrain model (DTM) of Banco National Park. Slope and altitude are frequently used as indirect variables in the species distribution[43].

**Data analysis**

**Modeling and validation of the model**

MaxEnt was used to draw suitable habitats for invasive species.In order to ensure the final model's quality, the environmental variables were subjected to correlation test to select the least correlated ones (r <0.85) taking into account the biases that the strong correlations have on the predictions [44]. For this, the ENMTools software version 1.4.4 was used [45]. To assess the model, 25% of the species observation points were used to test the model and 75% of the points were used to calibrate the model. The model performance was assessed using AUC statistics (*Area Under the Curve*,[5]). The AUC values were interpreted following the method proposed by 46 indicating that the model is excellent whenAUC> 0.90; good when 0.80 <AUC <0.90; acceptable when 0.70 <AUC<0.80; bad when 0.60 <AUC <0.70 and not valid when 0.50 <AUC <0.60.

**Table 1**: Bioclimatic variables used for Maxent test

| Codes | Bioclimatic Variables |
|---|---|
| Bio_1 | Average annual temperature |
| Bio_2 | Daytime deviation average (Maximum temperature - Minimum temperature; Monthly average) |
| Bio_3 | Isothermality (Bio_1 / Bio_7)*100 |
| Bio_4 | Temperature seasonality (coefficient of variation) |
| Bio_5 | Maximum temperature of the hottest period |
| Bio_6 | Minimum temperature of the coldest month |
| Bio_7 | Annual temperature difference (Bio_5 – Bio_6) |
| Bio_8 | Temperature average of the wettest trimester |
| Bio_9 | Average temperature of the driest trimester |
| Bio_10 | Average temperature of the hottest trimester |
| Bio_11 | Average temperature of the coldest trimester |
| Bio_12 | Annual precipitations |
| Bio_13 | Precipitation of the wettest month |
| Bio_14 | Precipitation of the driest month |
| Bio_15 | Precipitation seasonality (coefficient of variation) |
| Bio_16 | Precipitation for the coldest trimester |
| Bio_17 | Precipitation of the driest trimester |
| Bio_18 | Precipitation of the hottest trimester |
| Bio_19 | Precipitation of the coldest trimester |

The results produced by MaxEnt were imported into QGIS 2.18 to classify the different habitat levels of our model species based on presence logical probabilities thresholds generated by the models. The occurrence logistic probability of species is an indicator of the quality of habitats for the species. It varies between 0 and 1 [47]. Thus, for a probability value less than 0.5, the habitat is supposed to be "potentially unfavorable", and that

greater than 0.5, the habitat is considered as "potentially very favorable". The extent of each habitat level (surface area and percentage), under both current and future conditions, was estimated in order to assess the gain or loss in the potentially favorable area of the species to the park scale. This estimate was made using the “spatial analyst” tool in QGIS software.
The change rates (TC) from currently favorable habitats to potentially unfavorable habitats in the future and vice versa were estimated using the following formula: $\mathrm{TC} = (\mathrm{S_f} - \mathrm{S_i}) \times 100$[48], where$S_i$and $S_f$are respectively the initial surface area (current climatic condition) and final surface area (future climatic condition) of presence of the species. The positive valuesof $TC$ indicate a gain in the area of the habitat while the negative values correspond to a loss of surface.

## III. Results

**Models validation and modeling variable contributions**

AUC values for the two species vary from 0.825 and 0.896 for the current climatic conditions and from 0.843 to 0.945 in the future climatic conditions (horizon 2050) under the RCP 8.5 scenario (Table 2). This suggests a good performance of MaxEnt algorithm to predict the favorable area of the studied species.

**Table 2:** AUC values from the modeling results

| Species | AUC (current condition) | AUC (by 2050) |
|---|---|---|
| *Chromolaena odorata* | 0.825 | 0.843 |
| *Hopea odorata* | 0.896 | 0.945 |

RegardingChromolaena odorata*, the correlation analysis allowed the identification of five less correlated variables (r <0.85) and most contributing to the modeling whether under current or future conditions. These are Bio_5 (maximum temperature of the hottest period), Bio_8 (average temperature of the wettest trimester), Bio_12 (annual precipitation), Bio_19 (precipitation of the coldest trimester) and the altitude below current climatic conditions (Table 3). Bio_5 and Bio_8 are the variables whichmost contributed to the model. For future climatic conditions, the analysis of the contribution percentages of the different variables to the model prediction (Table 3) suggests that the variables Bio_1 (average annual temperature), Bio_9 (average temperature of the driest trimester), Bio_11 (temperature mean of the coldest trimester), Bio_14 (precipitation for the driest period) and Bio_16 (precipitation for the coldest trimester) more contributed to the model. From the analysis of this table, it can be stated that the variable Bio_9 more contributed to the construction of the model.

As concerning to *Hopea odorata*, six variables were chosen to run the model under current conditions (Table 3). These are Bio_3 (isothermality), Bio_14 (precipitation of the driest month), Bio_16 (precipitation of the wettest trimester), Bio_11 (average temperature of the coldest trimester), Bio_1 (average annual temperature) and Bio_4 (temperature seasonality: coefficient of variation) and Bio_7 (annual temperature difference: Bio_5 - Bio_6). Bio_3 and Bio_7 are the most determining variables of the potential distribution of *Hopea odorata*. For future climatic conditions, seven variables contributed to the modeling (Table 3).Those variables are Bio_18 (precipitation of the hottest trimester), Bio_4 (temperature seasonality: coefficient of variation), Bio_17 (precipitation of the driest trimester), Bio_16 (precipitation of the wettest trimester), Bio_8 (temperature average of the wettest trimester), Bio_19 (precipitation of the coldest trimester). Bio_18 and Bio_16 are the variables whichmost contributed to the structure of the model.

**Table 3** : Environnemental variable Contributions to the model

| Species | Periods | Bioclimatic Variables | Contribution (%) |
|---|---|---|---|
| *Chromolaena odorata* | Current | Bio_5 | **52.6** |
| | | Bio_8 | **38.9** |
| | | Bio_19 | 6.1 |
| | | Altitude | 2.2 |
| | | Bio_12 | 0,2 |
| | Future (by 2050) | Bio_9 | **88.3** |
| | | Bio_11 | 6.5 |
| | | Bio_1 | 2.5 |
| | | Bio_16 | 2.4 |
| | | Bio_14 | 0.3 |
| *Hopea odorata* | Current | Bio_3 | **48.9** |
| | | Bio_14 | **22.5** |
| | | Bio_16 | **21.8** |
| | | Bio_11 | 5.7 |
| | | Bio_1 | 0.8 |
| | | Bio_4 | 0.4 |
| | | Bio_7 | **45.2** |
| | | Bio_18 | **34.4** |

| | | |
|---|---|---|
| Future (by 2050) | Bio_4 | 3.1 |
| | Bio_17 | 4.5 |
| | Bio_16 | **10.4** |
| | Bio_8 | 2.3 |
| | Bio_19 | 0.1 |

Values in bold indicate higher contributions

**Current and future distribution of favorable habitats to the model species**

The modeling results show that overall, the habitats which are currently very favorable to *Chromolaena odorata* are mainly located in the south and center of the park. By 2050, the species would no longer be willing to practically colonize the southern part of the park. However, note that the center of Banco would remain very favorable for this species (Figure 2). At the end of the analysis of the extent of the different levels of habitats favorable to the species, it appears that approximately 263.2 ha (about 8% of the Banco National Park) are currently very favorable to *C. odorata* (Table 4). Unfavorable habitats occupy 92% of the park (Figure 4). For future projections up to 2050, the model predicts a change rate of about 3.4% in the areas which are currently favorable for it (Table 4).

The potentially favorable area to *Hopea odorata* mainly covers the western part of the park. Projections to 2050 also revealed a movement of the species towards the northern part as well as the center of the park (Figure 3). The habitat analysis gives a surface area of 181.9 ha (about 5% of the park) as a distribution area potentially favorable for the species under current conditions (Table 4). As for the area potentially unfavorable to the distribution of the species, it covers 3,256.4 ha or 93% of the Banco National Park (Figure 5). By 2050, projections revealed an increase of the change rate of about 0.27% of thepotentially favorable areas to the species (Table 4). It shifted from 181.9 ha (current climatic conditions) to 231.3 ha (future climatic conditions). From these analyzes it is suggested that climate change will increase the surface area of the current distribution of *C. odorata* and *H. odorata* in Banco National Park. This upward trend in distribution areas would be due to an increase in temperature predicted by the scenario.

**Table 4** : Surface variation of *C. odorata et H. odorata* habitats of the Banco National Park

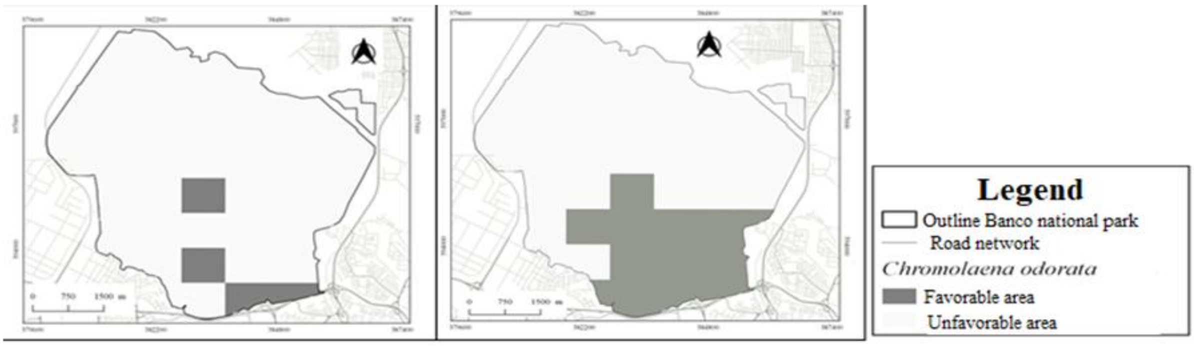
| Species | Period | Potentially favorable zone | | Change rate (%) | Potentially unfavorable zone | | Change rate (%) |
|---|---|---|---|---|---|---|---|
| | | Surface (ha) | Percentage cover | | Surface (ha) | Percentage cover | |
| *Chromolaena odorata* | Current | 263.2 | 8 | | 3175.2 | 92 | |
| | By 2050 | 1170.2 | 34 | **+3.44** | 2268.05 | 66 | **-0.28** |
| *Hopea odorata* | Current | 181.8 | 5 | **+0.27** | 3256.4 | 95 | **-0.01** |
| | By 2050 | 231.3 | 7 | | 3306.9 | 93 | |

Sign (-) indicates favorable habitat loss and (+) for a gain.

## IV. Discussion

**Environmental variables contribution analysis**

This study highlights the variables which most contribute to the development of the model and which explain the spatial distribution of invasive species. Indeed, our results have shown that it is the climatic variables which predict the distributions of the species contrary to the biophysical variables. This suppose that at the park scale, *Chromolaena odorata* and *Hopea odorata* distribution is mainly influenced by direct parameters such as temperature and precipitation. This result is in accordance with previous studies which stipulate that climatic descriptors linked to rainfall and temperature play an efficient role in delimiting the geographic area of invasive species [10,11]. This result seems to invalidate the work of [8] reporting that indirect parameters such as altitude, topography and plant cover can be effective for predicting plant species over small areas. Concerning the topographic variables, the contribution of the variable "Altitude" to the prediction of the models remains insignificant. This can be explained by the interdependence between climatic parameters and geographic factors such as altitude [49]. Indeed, temperature and altitude are factors that influence flora distribution. According to [50], these two factors are interrelated since one varies according to the other. Higher is the altitude, lower is the temperature. The present study also invalidates the observations reported by [51,52] according to which the low slopes are preferential environments for *C. odorata* while *H odorata* prefers the high slopes.




Current distribution

Future distribution (by 2050)

**Figure 2**: Current and future potential distribution of *Chromolaena odorata*(L.) R. M. King & H. Roxb


Current distribution

Futur distribution

**Figure 3:**Current and future potential distribution of *Hopea odorata*Roxb.

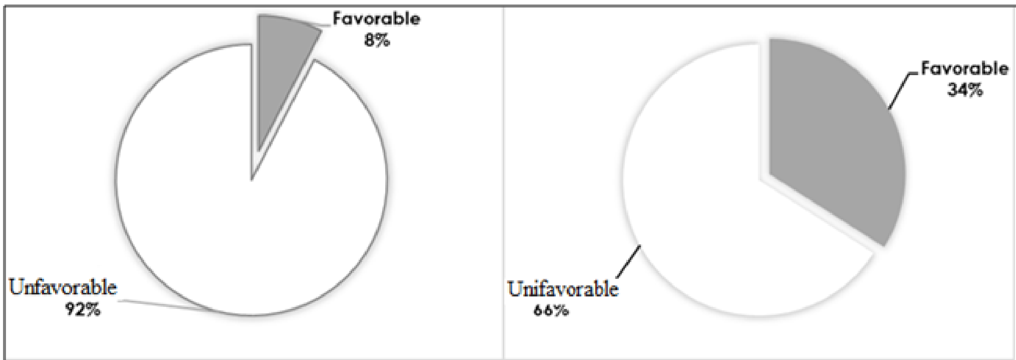



**Figure 4**: Extend of favorable habitats to the colonization of *Chromolaena odorata* of the Banco national park

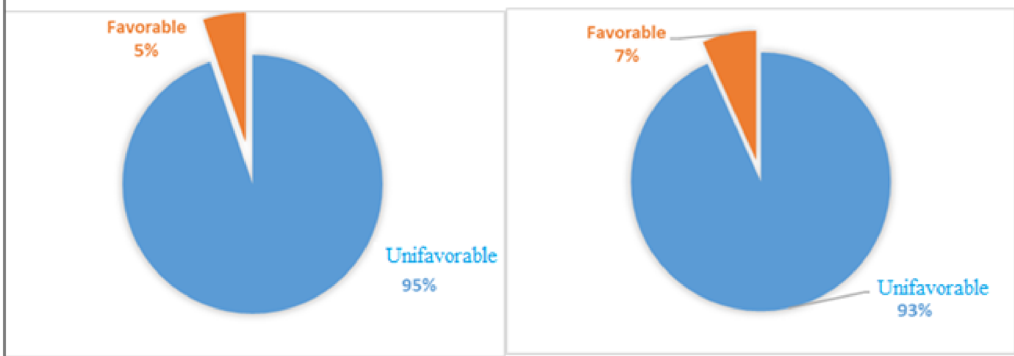



**Figure 5**: Extend of favorable habitats to the colonization of *Hopea odrata* of the Banco national park

**Invasive species potential distribution area**

The results indicate an increase of the surface area of the potentially favorable zone to *Chromolaena odorata* and *Hopea odorata* species in Banco national park. This increase would be probably explained by the projection of the raise in temperature and the fall in the level of precipitation according to the RCP 8.5 scenario. These results are in agreement with numerous studies which highlight the progression of favorable zones to the distribution of certain invasive species in conservation areas with this scenario [10,11]. As a result, the hypothesis according to which climate change could favor the expansion of invasive species seems to be confirmed. Specifically, the results show that by 2050, *Chromolaena odorata* and *Hopea odorata* will be considerably presents in the center of Banco national park. This could largely be linked to demographic pressure and anthropogenic actions. Indeed, with the construction of the forestry school, ecotourism and maintenance of the camp in the center of the park, will potentially increase the anthropic pressure. Thus, the conversion of the vegetation around these anthropic actions will also increase. This might be one of the reasons for the increase in areas favorable to invasive species [53,54,23]. Ultimately, the distribution areas modeling of invasive species as well as potential projections into the future, by 2050, show that they constitute a threat to Banco National Park.

## V. Conclusion

Invasive species distribution modeling remains a relevant way to define the geographic extent of surface areas favorable to invasive species. It allows to identify the environmental variables which affect their distribution in the case of the management of protected areas in front of biological invasions. From this study, it comes out that the bioclimatic variables contribute to the spatial distribution of *Chromolaena odorata* and *Hopea odorata* in the current conditions as well as by 2050. There will be an increase in the area of areas potentially favorable for their distribution. The potential area maps of invasive species developed in this study will improve the knowledge level and allow better management of invasive plants in order to preserve healthy ecosystems in protected areas. This study could serve as the basis for other ecological niche modeling exercises in the protected areas of Côte d'Ivoire.

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