International Journal of Biosciences | IJB |
ISSN: 2220-6655 (Print); 2222-5234 (Online)
Website: https://www.innspub.net
Email contact: info@innspub.net
Vol. 27, Issue: 5, p. 237-246, 2025

RESEARCH PAPER

Modelling the current and future distribution of *Okoubaka aubrevillei* Pellegr. & Normand under climate change scenarios in Côte d'Ivoire

Sié Fernand Pacôme Ouattara[1], Franck Placide Junior Pagny*[2], Kouassi Bruno Kpangui[2]

[1]*Laboratory of Agricultural Production Improvement, Faculty of Agroforestry, Jean Lorougnon Guédé University, Daloa, Côte d'Ivoire*
[2]*Biodiversity and Sustainable Ecosystem Management Laboratory, Faculty of Environmental Sciences, Jean Lorougnon Guédé University, Daloa, Côte d'Ivoire*

Key words: Biodiversity conservation, Climate change impact, Ecological niche modelling, Habitat suitability, Thermal and hydric drivers, West African forests

DOI: https://dx.doi.org/10.12692/ijb/27.5.237-246 Published: November 24, 2025

ABSTRACT

Okoubaka aubrevillei Pellegr. & Normand, listed as Endangered by the IUCN, Threatened by Aké Assi (PRE-Protected Rare Endemic list), and under CITES Appendix II (2023), is facing extinction. This study models its current and future distribution in Côte d'Ivoire to identify key environmental drivers and predict suitable habitats. Occurrence data were obtained from the GBIF database, and nineteen bioclimatic variables representing both current and future periods were used to model its potential distribution in Côte d'Ivoire. Seven algorithms (Random Forest, MaxEnt, BRT, GAM, GLM, SVM, and CART) were used, with data partitioned into 70% for training and 30% for validation to ensure robust predictive accuracy. Binary suitability maps (favorable/unfavorable) were produced from probability outputs in ArcGIS to assess habitat gains and losses under future (2050) climate scenarios. The results indicate that the potential distribution of *O. aubrevillei* is mainly driven by thermal variables, while hydric factors play a secondary but complementary role. The most influential predictors are bio6 (minimum temperature of the coldest month, 55.7 %), bio8 (mean temperature of the wettest quarter, 41.8 %), and bio3 (isothermality, 31.8 %), emphasising the species' dependence on warm and moderately humid environments, with a preference for temperatures between 18-25 °C and moderate thermal variability. Hydric variables (bio11, bio14, bio15) reflect tolerance to sub-humid conditions and a minimum water requirement of 20-40 mm during the dry season. *O. aubrevillei* is a thermophilic species adapted to tropical environments with moderate humidity, whose ecological niche depends upon a balance between thermal stability and water availability. Currently restricted to southern forest zones, its distribution is projected to expand northward and into central regions by 2050, under both moderate and extreme climate scenarios. This potential expansion may be constrained by deforestation, habitat fragmentation, and anthropogenic pressure that affect the availability of suitable habitat.

***Corresponding author:** Franck Placide Junior Pagny ✉ pagnyfranckplacide@yahoo.com
* https://orcid.org/0000-0002-8385-3177
First author: Sié Fernand Pacôme Ouattara: https://orcid.org/0009-0005-1313-1258
Co-authors:
Kouassi Bruno Kpangui: https://orcid.org/0009-0004-8744-0937

INTRODUCTION

Species Distribution Models (SDMs), also known as Ecological Niche Models (ENMs), are key tools in contemporary ecological and biogeographical research. Grounded in ecological niche theory, they link species occurrences with environmental variables to predict suitable habitats and forecast potential range shifts of species under changing climatic conditions (Dimobe *et al.,* 2022, Zaheri *et al.,* 2024). SDMs have become indispensable in biodiversity conservation and ecosystem management, helping to assess the impacts of climate and land-use change, identify priority conservation areas, and support adaptive management and the planning of protected areas (Jean *et al.,* 2022, Ganglo, 2023).

Okoubaka aubrevillei Pellegr. and Normand, a monotypic genus in the family Santalaceae commonly known as the African false sandalwood, is endemic to West Africa, particularly Côte d'Ivoire. It possesses high ecological, medicinal, and cultural significance. Its bark and roots are traditionally used for therapeutic purposes, and it is revered as a sacred tree believed to possess mystical powers that inhibit the growth of surrounding plants (Alves-Ferreira *et al.,* 2025). Despite this importance, the species is severely threatened by habitat degradation, overexploitation, and climate change, exacerbated by its narrow ecological niche and low dispersal ability (Subedi *et al.,* 2024). It is currently listed as Endangered on the IUCN Red List and included under CITES Appendix II (2023), emphasising the urgent need for evidence-based conservation strategies to ensure its long-term survival (Doffou *et al.,* 2021).

The Shared Socioeconomic Pathways delineate a range of plausible future socioeconomic developments and greenhouse gas emission trajectories, serving as critical inputs for climate modelling and impact assessments (Murray *et al.,* 2021). Among these, SSP2–4.5 and SSP5–8.5 represent two distinct pathways, offering insights into divergent radiative forcing levels by the end of the 21st century (Si *et al.,* 2023). Specifically, SSP2–4.5, an evolution of the CMIP5 RCP4.5 scenario, projects a radiative forcing of 4.5 $W{\cdot}m^{-2}$ by 2100 under a middle of the road development pathway, while SSP585, building upon RCP8.5, anticipates a higher radiative forcing of 8.5 $W{\cdot}m^{-2}$ associated with a fossil-fuelled development trajectory (Zhang, 2024). These scenarios are foundational for understanding the potential range of global warming and its associated impacts, with SSP2–4.5 representing a more moderate temperature increase and SSP585 signifying a high-emission, aggressive warming trajectory (Sánchez-Arcilla *et al.,* 2024). The SSP2–4.5 scenario, characterized by intermediate mitigation efforts and a continuation of historical social, economic, and technological trends, offers a plausible representation of the current policy landscape (Richter *et al.,* 2022). Conversely, the SSP5–8.5 scenario depicts a future with minimal climate mitigation, rapid economic growth, and continued reliance on fossil fuels, leading to substantial challenges in adaptation (Goyal *et al.,* 2023). In the context of accelerating climate change, which continues to reshape habitat suitability and species distributions worldwide, assessing the current and future distribution of *O. aubrevillei* is critical for designing sustainable conservation actions (Mwangi *et al.,* 2023). Recent advances in SDMs have enhanced their ability to identify potential range expansions or contractions, locate areas at risk, and prioritise sites for ecological intervention (Sungur, 2024; Ames- Martínez *et al.,* 2025). This study therefore aims to model the present and future spatial distribution of *O. aubrevillei* in Côte d'Ivoire to identify the environmental variables most strongly influencing its habitat suitability. By mapping suitable areas under different climate scenarios, the research provides a robust empirical basis for targeted conservation planning and the sustainable management of this ecologically and culturally valuable species.

MATERIALS AND METHODS

Geographical and climatic overview of Côte d'Ivoire

Côte d'Ivoire is a country in West Africa located between latitudes 4° and 11°30′ North and longitudes 2°30′ and 8°30′ West, with a total area of 322,463 km². It is bordered by Mali and Burkina Faso to the north, Guinea and Liberia to the west, and Ghana to the east, while the south overlooks the Atlantic Ocean with a coastline of approximately 550 km (MINEDD, 2020). According to Guillaumet and Adjanohoun (1971), there are two distinct phytogeographical regions: the Guinean region in the south, with dense rainforests, and the Sudanian region in the north, characterized by woodland and savanna ecosystems. According to climatic classifications by Goethe University Frankfurt (2025), four main climatic zones have been identified: the Sudanese climate with rainfall of 1,000–1,700 mm·yr^{-1} and two seasons: dry and rainy; the attenuated transitional equatorial climate (Baoulé climate) with rainfall of 1,500-2,200 mm·yr^{-1} and four seasons: two dry and two rainy; the transitional equatorial climate (Attien climate) with rainfall of 1,300-2,400 mm·yr^{-1} and four seasons: two dry and two rainy; the mountain climate with rainfall of 1,500-2,200 mm·yr^{-1} and two seasons: dry and rainy. *O. aubrevillei* is a large forest tree native to West and Central Africa, reaching heights of up to 40 m (Veenendaal *et al.,* 1996). This species thrives in tropical rainforests and adapts to specific conditions of precipitation, humidity, and soil fertility (Nana *et a3l.,* 2023). The tree is characterized by its thick bark, broad foliage, and small, inconspicuous flowers that produce fruits that aid in seed dispersal (Mwangi *et al.,* 2023). It is important from an ecological and cultural perspective, providing medicinal benefits and being used in traditional rituals (Bagot, 2015). According to Borokini (2015), *O. aubrevillei* is found in African countries including the Republic of Guinea, Sierra Leone, Liberia, Côte d'Ivoire, Burkina Faso, Ghana, Benin, Nigeria, Cameroon, the Central African Republic, Gabon, and the Democratic Republic of Congo.

Data collection

The occurrence records of *O. aubrevillei* (Fig. 1) were obtained from the Global Biodiversity Information Facility (GBIF) and cleaned to remove duplicates records.

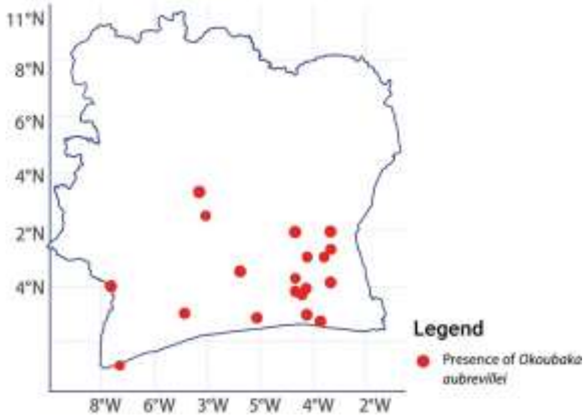

Fig. 1. Distribution of *O. aubrevillei* occurrence records projected on the study area map of Côted'Ivoire

Note: The occurrence points of O. aubrevillei were obtained from the GBIF database (accessed on 30 October 2025), and the map was generated using RStudio software.

To reduce spatial autocorrelation, occurrence data were filtered using the SDMtoolbox package at a 1 km spatial resolution, consistent with the environmental variables. Nineteen bioclimatic variables representing current (1970–2000) and future (2041–2060; mean 2050) climate conditions under the SSP2–4.5 and SSP5–8.5 scenarios were obtained from the WorldClim v2.1 database (Fick and Hijmans, 2017) at a 2.5-arc-second resolution and clipped to the extent of Côte d'Ivoire using the same tool. Species distribution modelling was conducted using seven algorithms: Random Forest (RF), Maximum Entropy (MaxEnt), Boosted Regression Trees (BRT), Generalised Additive Model (GAM), Generalised Linear Model (GLM), Support Vector Machine (SVM), and Classification and Regression Tree (CART). The resulting probability maps were converted into binary maps distinguishing suitable (1) and unsuitable (0) habitats. Finally, the binary outputs were processed in ArcGIS to generate current and future potential distribution maps of *O. aubrevillei* across Côte d'Ivoire.

Data analyses

The correlation among predictor variables can lead to variance inflation in regression coefficients, thereby complicating the identification of truly significant predictors (Ganglo, 2023). To address this issue, a two-step procedure was implemented using the USDM package (Naimi *et al.,* 2017). First, the Variance Inflation Factor (VIF) was calculated, and variables with values exceeding 8 were removed to reduce multicollinearity. Second, pairwise correlations among the remaining variables were examined, and those with coefficients greater than 0.7 were excluded, retaining only statistically independent predictors. The correlation matrix, visualised using the corrplot package, facilitated the detection of redundancies and the selection of variables that were both statistically robust and ecologically meaningful. The relative importance of the retained variables was then evaluated using the getVarImp function, and results were displayed through a variable importance plot. For model validation, 70 % of the occurrence points were used for training and 30 % for testing (Hao *et al.,* 2015).

Four performance metrics were used to assess predictive accuracy: Area Under the Curve (AUC), True Skill Statistic (TSS), correlation coefficient (COR), and deviance (Allouche *et al.,* 2006). According to Swets (1988), an AUC between 0.5 and 0.7 indicates low predictive accuracy, between 0.7 and 0.9 moderate accuracy, and above 0.9 high accuracy. Similarly, TSS values close to 1 indicate excellent model performance, whereas values near 0 or negative reflect random performance. COR and deviance values further confirmed the strong predictive ability of the models for the studied species. Response curves, generated using the rcurve function, were employed to explore the relationships between the species and environmental variables. According to Bargain and Fabri (2016), a horizontal curve indicates no preference for a variable, an increasing curve shows an affinity for higher values, a decreasing curve indicates a preference for lower values, and a unimodal curve reveals an affinity for a specific range of values. The mean TSS values, computed from ten replicates, were used to export the final modelling results. A species-specific threshold was then applied to classify habitats into two categories: suitable and unsuitable. The current and future distribution maps of *O. aubrevillei* were produced in ArcGIS by aggregating suitability layers to generate a composite map representing the potential distribution of the species under different climate scenarios. Finally, the rate of change (*Rc*) was analysed to quantify transitions between currently suitable habitats and those projected to remain or become suitable in the future (N'Guessan *et al.,* 2019). This rate was calculated using the formula (1):

$$Rc = \{(A2 - A1)/A1\} \times 100 \quad (1)$$

where: Rc represents the rate of change, $A1$ the initial area of suitable habitat under current conditions, and $A2$ the projected area under future conditions. Positive Rc values indicate an expansion of suitable habitats, whereas negative values denote a potential contraction of the species range.

RESULTS AND DISCUSSION

Criteria used to select statistics

The evaluation of spatial distribution modelling performance for *O. aubrevillei* revealed variations among algorithms (Table 1). The results were generated from the performance assessment of seven species distribution modelling algorithms (RF, MaxEnt, BRT, GAM, GLM, SVM, and CART) conducted in RStudio. Occurrence records and bioclimatic variables were split into training (70 %) and testing (30 %) datasets using cross-validation. Model performance was compared using four metrics – AUC, COR, TSS, and Deviance – and mean values from multiple runs were calculated for each algorithm.

Table 1. Mean values of model performance metrics

Methods	AUC	COR	TSS	Deviance
RF	0.88	0.54	0.67	0.18
MaxEnt	0.85	0.27	0.66	0.57
BRT	0.83	0.46	0.62	0.19
GAM	0.86	0.43	0.65	0.49
GLM	0.83	0.29	0.58	0.28
SVM	0.77	0.36	0.6	0.22
CART	0.7	0.32	0.42	0.29

Note: RF – Random Forest; MaxEnt – Maximum Entropy; BRT – Boosted Regression Trees; GAM – Generalised Additive Model; GLM – Generalised Linear Model; SVM – Support Vector Machines; CART – Classification and Regression Trees.

The Random Forest (RF) model demonstrated the highest predictive accuracy (AUC = 0.88, COR = 0.54, TSS = 0.67, deviance = 0.18). These results are consistent with recent studies showing that RF frequently outperforms other machine-learning methods in complex environmental contexts (Maravillas *et al.,* 2023; Pérez-Otáñez *et al.,* 2024). Other models, such as the Generalised Additive Model (GAM), Maximum Entropy (MaxEnt), and Boosted Regression Trees (BRT), also performed well, with AUC values ranging from 0.83 to 0.86. The choice of modelling algorithm remains crucial, particularly for temporal projections or evaluating responses under climate change scenarios (Ganglo, 2023; Moreno-Arzate and Martínez-Meyer, 2024). In contrast, SVM and CART models showed lower predictive performance (AUC=0.70–0.77), highlighting the importance of high-quality data and careful variable selection in species distribution modelling (El-Khalafy *et al.,* 2025; Zhao *et al.,* 2025).

Selection of variables

Six bioclimatic variables were selected for modelling: bio3 (isothermality), bio6 (minimum temperature of the coldest month), bio8 (mean temperature of the wettest quarter), bio11 (mean temperature of the coldest quarter), bio14 (precipitation of the driest month), and bio15 (precipitation seasonality). Bio6, bio8, bio14, and bio15 are important predictors of plant and insect habitats, affecting *O. aubrevillei* distribution in Côte d'Ivoire. These variables show how temperature and precipitation influence species survival and adaptation (He *et al.,* 2025).

Bio3 and bio8 reflect temperature variability, while bio6 represents cold tolerance. The selection of these variables aligns with niche-modelling practices, capturing how temperature and precipitation vary with elevation and landscape features (Zhang *et al.,* 2024). This understanding aids in conservation strategies, identifying essential environmental conditions needed for *O. aubrevillei* survival (Argaw *et al.,* 2024). Recent evidence indicates that temperature, precipitation, and elevation significantly determine species richness and distribution, particularly among different taxa, confirming their roles as main factors in habitat suitability assessments (Erfanian *et al.,* 2025, Silva *et al.,* 2025). Studies have underscored the importance of these variables in predicting shifts in distribution patterns under future climate scenarios for various species (Dyola *et al.,* 2022).

Relative variable importance

Bio6 contributed the most to the model (55.7 %), followed by bio8 (41.8 %) and bio3 (31.8 %), indicating that these variables explain the largest proportion of the variation in *O. aubrevillei* distribution (Fig. 2).

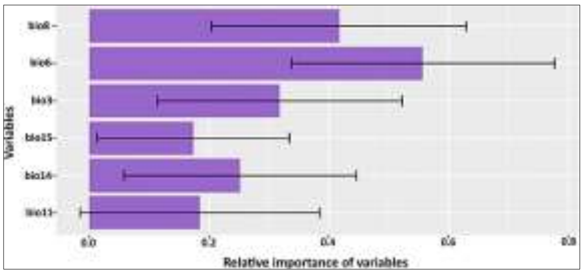

Fig. 2. Relative variable importance

Note: This figure was generated using occurrence points and the selected bioclimatic variables from this study. Data processing and analyses were performed in RStudio.

Other studies have similarly demonstrated that temperature-related predictors, such as the mean temperature of the wettest quarter and the minimum temperature of the coldest month, play a key role in shaping species' distribution limits and habitat suitability (Cadena-Iñiguez *et al.,* 2023). In contrast, precipitation variables (bio11, bio14, bio15) contributed less to the models, suggesting that they are not as limiting as temperature for the distribution of *O. aubrevillei*. Comparable findings have been reported for *Macadamia* and *Corylus* species (Li *et al.,* 2025), further highlighting the influence of thermal regimes in defining the ecological niche of *O. aubrevillei*. The relatively low impact of precipitation may indicate that the species can tolerate a wide range of moisture conditions. Similar results have been documented for other threatened taxa, such as *Zelkova carpinifolia* (Subedi *et al.*, 2024). Altogether, these findings underscore the essential role of temperature in driving the dynamics of climate-sensitive species and emphasise the urgent need for climate-focused conservation strategies (Koç *et al.*, 2024).

Response curve of the important variables of *Okoubaka aubrevillei*

The response curves (Fig. 3) indicate that the potential distribution of *O. aubrevillei* is primarily influenced by thermal variables, whereas humidity-related factors play a secondary yet complementary role. These patterns are consistent with previous ecological modelling studies showing that temperature and precipitation act as major filters for germination and persistence of both woody and understory species under varying climate change scenarios (Flores *et al.*, 2024).

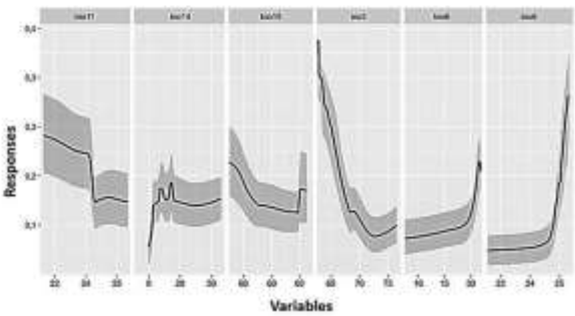

Fig. 3. Response curves of the key variables based on the ensemble models of *O. aubrevillei*

Table 2 presents the main bioclimatic variables influencing the distribution of the studied species, along with their ecological significance, response trend, and ecological interpretation.

Partial dependence plots were generated from the spatial distribution models to assess the individual effect of each bioclimatic variable on the probability of *O. aubrevillei* occurrence, while keeping all other variables constant. The six most influential variables (bio3, bio6, bio8, bio11, bio14, and bio15) were selected based on relative variable importance. Threshold values representing optimal climatic conditions were determined from the inflection points of the response curves.

The response curves (Table 2, Fig. 4) indicate that *O. aubrevillei* distribution is primarily driven by thermal variables. Minimum temperatures above 18 °C (bio6) and warm, humid conditions during the wettest quarter (bio8 > 25 °C) strongly favour the species, while moderate thermal variability (bio3 60–70 %) supports persistence. Moisture-related variables such as bio14 and bio15 have minor influence, suggesting a broad tolerance to rainfall variability. These findings are consistent with previous studies highlighting the dominant role of temperature in defining the ecological niche of climate-sensitive species.

Among the bioclimatic variables, the minimum temperature of the coldest month (bio6) and the mean temperature of the wettest quarter (bio8) exerted the strongest influence on species occurrence. A sharp increase in occurrence probability above 18 °C for bio6 and 25 C for bio8 reveals distinct thermal thresholds for optimal habitat suitability. The isothermality variable (bio3), reflecting thermal stability, indicates a preference for moderately stable temperatures rather than extreme fluctuations. Similarly, bio11 (mean temperature of the coldest quarter) suggests a broad tolerance to cooler conditions within a defined range, supporting persistence in regions experiencing seasonal thermal shifts.

This pronounced thermal sensitivity, also observed in other woody taxa such as *Leucaena diversifolia* (Schltdl.) Benth., *Cedrela odorata* L., and *Inga jinicuil* Schltdl. and Cham. ex G.Don, highlights the importance of considering optimal and ceiling temperatures for germination when predicting species distributions (Sampayo-Maldonado *et al.*, 2022, 2025; Schipper *et al.*, 2024). Comparable results for crops such as cowpea (*Vigna unguiculata* (L.) Walp.) and cotton (*Gossypium hirsutum* L.) show that germination and seedling development decline markedly outside optimal thermal ranges (Barros *et al.*, 2020).

Table 2. Response trends and ecological interpretation of key bioclimatic variables for *O. aubrevillei*

Variable group	Bioclimatic variable	Ecological meaning	Response trend and favourable range	Ecological interpretation
Temperature	bio11 (Mean temperature of the coldest quarter)	Indicates tolerance to moderately cool periods	Stable response between 22–25 °C	The species tolerates mild coolness but avoids cold extremes; thermal stability supports persistence.
	bio6 (Minimum temperature of the coldest month)	Reflects tolerance threshold to low temperatures	Sharp increase beyond 18 °C	A thermophilic species favoured by high minimum temperatures typical of humid tropical forests.
	bio8 (Mean temperature of the wettest quarter)	Represents temperature–humidity interaction	Strong increase after 25 °C	High affinity for warm and humid conditions; key driver of distribution.
	bio3 (Isothermality, %)	Ratio between diurnal and annual thermal ranges	Decrease above 70 (favourable range 60–70)	Prefers moderate thermal variability; avoids overly stable climates.
Humidity	bio14 (Precipitation of the driest month)	Reflects moisture availability during the dry season	Slight increase between 20–40 mm	Requires a minimum humidity level even in the driest periods; avoids arid environments.
	bio15 (Precipitation seasonality, %)	Measures annual rainfall variability	Nearly flat curve with minor rise at higher values (60–100 %)	Low sensitivity to rainfall seasonality; tolerates moderate precipitation contrasts.

Note: Table 2 summarises response trends and ecological interpretations of the six most influential bioclimatic variables for *O. aubrevillei*.

In addition to temperature effects, the precipitation of the driest month (bio14) is a critical determinant of the species' hydric requirements, with an observed need for 20–40 mm during dry periods indicating vulnerability to prolonged drought. Seasonal rainfall variability (bio15) can further shift habitat suitability under future climate scenarios (Bede-Fazekas and Somodi, 2024). Interactions between soil moisture deficits and elevated temperatures may trigger abrupt mortality in drought-exposed seedlings, limiting regeneration success and forest resilience (Hankin *et al.,* 2025).

Overall, the identified thermal and hydric variables highlight the dependence of *O. aubrevillei* on precise ecophysiological thresholds. Understanding these thresholds is essential for predicting future distributional dynamics and informing adaptive conservation strategies.

Spatial distribution of *Okoubaka aubrevillei* under climate scenarios

Modelling results (Fig. 4) indicate a projected expansion of the potential distribution of *O. aubrevillei* in Côte d'Ivoire under future climate scenarios. Similar patterns have been observed for other West African plant species, as climate change frequently leads to broader suitable habitat ranges (Togni and Ganglo, 2024). This projected expansion is primarily driven by an increase in thermally favourable areas. However, the actual expansion will depend on complex interactions among land-use changes, dispersal efficiency, ecological barriers, and the adaptive capacity of the species (Doffou *et al.,* 2021).

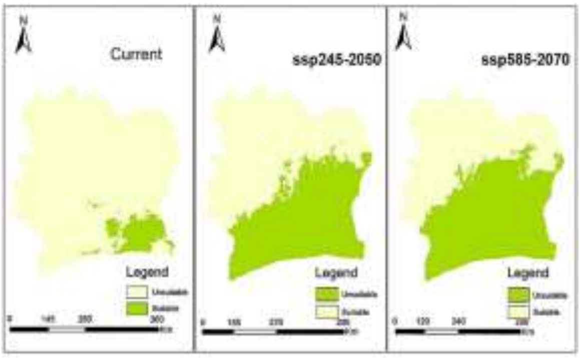

Fig. 4. Predicted distribution of *O. aubrevillei* under current (1970–2000) and future (2041–2060; mean 2050) climate scenarios in Côte d'Ivoire

Note: Occurrence points and bioclimatic variables were used to generate the maps. Data processing and analyses were conducted in RStudio.

Table 3. Comparative spatial distribution, change rate, and ecological interpretation of O. aubrevillei under current and future climate scenarios in Côte d'Ivoire.

Scenario	Suitable area, pixels	Suitable area, km²	Change rate, %	Spatial distribution
Current	1,070	22,705	-	The distribution is mainly confined to the southern forest zone, particularly along coastal and subcoastal regions such as Grand-Lahou, Sassandra, and San Pedro. These areas correspond to evergreen and semi-deciduous forests characterised by high humidity and thermal stability.
SSP2-4.5	6,755	143,379	+531.3	The potential distribution expands northward and westward, notably across regions such as Gagnoa, Daloa, and Duékoué. Suitable habitats appear within forest–savanna transition zones, where thermal and hydric conditions remain moderate.
SSP5-8.5	7,691	163,206	+618.8	The distribution becomes broader and more continuous across the southern and central parts of Côte d'Ivoire, reaching sub-humid areas such as Bouaflé, Yamoussoukro, and Zuénoula. The suitable area largely covers the forest–savanna ecotone under intensified warming and higher temperature regimes.

Note: Table 3 summarises the suitable habitat areas of *O. aubrevillei* under current (1970–2000) and future (2041–2060; mean 2050) climate scenarios (SSP2-4.5 and SSP5-8.5). Suitable areas are expressed in pixels, km², and percentage change, based on ensemble model outputs.

Table 3 presents the variation in suitable habitat areas for the species under different climate scenarios (current, SSP2-4.5, and SSP5-8.5), expressed in pixels, square kilometers, and percentage change, along with their spatial distribution across Côte d'Ivoire. Currently, *O. aubrevillei* occupies approximately 1,070 pixels (about 7 % of the national territory), with the most suitable habitats located in the southern forest zone. Future projections indicate a northward and westward shift of climatically suitable areas. Nevertheless, habitat fragmentation and declining connectivity caused by human activities may reduce these potential gains (da Silva *et al.,* 2024). Overall, the results suggest a substantial transformation of the ecological landscape. Incorporating biotic interactions and functional traits into future modelling efforts would enhance prediction accuracy (Li *et al.,* 2024). Future studies should also adopt a multidisciplinary approach to better understand ecological processes and human impacts (da Silva *et al.,* 2024). Long-term monitoring will be crucial for detecting population trends and supporting adaptive conservation strategies (Doffou *et al.,* 2021).

The suitability maps were generated using ensemble models (Random Forest, MaxEnt, BRT) that demonstrated the highest predictive performance. Suitable habitat areas were calculated from binary probability maps by multiplying the number of suitable pixels by the pixel surface area (≈ 21.23 km²). The change rate was determined by comparing current and future suitable areas. The spatial interpretation was based on visual analysis of the maps, highlighting expansion zones and projected ecological shifts.

CONCLUSION

The species distribution modelling of *Okoubaka aubrevillei* under current and future climate scenarios provides critical insights into its ecological requirements and potential responses to climate change in Côte d'Ivoire.

Temperature-related variables were identified as the primary determinants of habitat suitability, while precipitation exerted a secondary but complementary influence. Among the tested algorithms, the Random Forest model demonstrated the highest predictive accuracy, confirming its reliability for capturing complex ecological interactions.

Future projections suggest a potential northward and westward expansion of climatically suitable habitats, particularly under moderate warming (SSP2–4.5). However, the actual realisation of these gains will depend on the species' dispersal capacity, habitat connectivity, and ongoing anthropogenic pressures such as deforestation and land-use change.

The contrasting outcomes between the moderate (SSP2–4.5) and high-emission (SSP5–8.5) scenarios underscore the need for differentiated conservation responses. Under SSP2–4.5, adaptive management and sustainable use strategies should be prioritised within forest–savanna transition zones. Conversely, SSP5–8.5 highlights the urgency of climate-focused conservation actions, including habitat protection, forest restoration, and long-term ecological monitoring.

Overall, these findings provide a science-based framework for anticipating climate- induced shifts and guiding national conservation policies aimed at preserving *O. aubrevillei* and other climate-sensitive forest species in Côte d'Ivoire.

REFERENCES

Allouche O, Tsoar A, Kadmon R. 2006. Assessing the accuracy of species distribution models: prevalence, kappa and the true skill statistic (TSS). Journal of Applied Ecology **43**(6), 1223–1232. https://doi.org/10.1111/j.1365-2664.2006.01214.x

Ames-Martínez FN, Romero IC, Guerra A, Guillen JGI, Quispe-Melgar HR, Galeano E, Rodríguez-Ramírez EC. 2025. Climate change and tree cover loss affect the habitat suitability of *Cedrela angustifolia*: evaluating climate vulnerability and conservation in Andean montane forests. PeerJ **13**, e18799. https://doi.org/10.7717/peerj.18799

Argaw T, Fenta BA, Assefa E. 2024. Application of factor analytic and spatial mixed models for the analysis of multi-environment trials in common bean (*Phaseolus vulgaris* L.) in Ethiopia. PLoS ONE **19**(4), e0301534. https://doi.org/10.1371/journal.pone.0301534

Bagot JL. 2015. *Okoubaka aubrevillei*: un nouveau médicament pour les soins de support en cancérologie. La Revue d'Homéopathie **6**(2), 46–51. http://dx.doi.org/10.1016/j.revhom.2015.03.005

Bargain A, Fabri MC. 2016. Guide méthodologique de modélisation prédictive d'habitats profonds en Méditerranée. Rapport Convention Cadre Agence de l'Eau RMandC / Ifremer, Provence Azur Corse. 128p.

Barros JRA, Angelotti F, Santos JDO, Silva RME, Dantas B, Melo NFD. 2020. Optimal temperature for germination and seedling development in cowpea seeds. Revista Colombiana de Ciencias Hortícolas **14**(2), 231–239. https://doi.org/10.17584/rcch.2020v14i2.10339

Bede-Fazekas Á, Somodi I. 2024. Precipitation and temperature timings underlying bioclimatic variables rearrange under climate change globally. Global Change Biology **30**(9), e17496. https://doi.org/10.1111/gcb.17496

Borokini TI. 2015. *Okoubaka aubrevillei* (Pelleg & Norman): a synthesis of existing knowledge for research and conservation in West and Central Africa. Journal of Biology and Life Sciences **6**(1), 67–95. http://dx.doi.org/10.5296/jbls.v6i1.6399

Cadena-Iñiguez J, Barrera Guzmán LÁ, Arévalo Galarza MDLC, Cadena Zamudio DA, Watanabe KN, Arévalo Galarza GA, Aguirre Medina JF. 2023. Potential distribution modeling based on machine learning of *Sechium edule* (Jacq.) Sw. in Japan. Genetic Resources and Crop Evolution **71**(5), 2105–2115. https://doi.org/10.21203/rs.3.rs-3243661/

da Silva JP, Hermoso V, Lopes-Lima M, Miranda R, Filipe AF, Sousa R. 2024. The role of connectivity in conservation planning for species with obligatory interactions: prospects for future climate scenarios. Global Change Biology **30**(2), e17169. https://doi.org/10.1111/gcb.17169

Dimobe K, Ouédraogo K, Annighöfer P, Kollmann J, Bayala J, Hof C, Schmidt M, Goetze D, Porembski S, Thiombiano A. 2022. Climate change aggravates anthropogenic threats of the endangered savanna tree *Pterocarpus erinaceus* (Fabaceae) in Burkina Faso. Journal for Nature Conservation **70**, 126299. https://doi.org/10.1016/j.jnc.2022.126299

Doffou SC, Kouadio H, Dibi HN. 2021. Effets des variations climatiques à l'horizon 2050 sur la distribution phytogéographique de *Tieghemella heckelii* Pierre ex A. Chev. (Sapotaceae) en Côte d'Ivoire. International Journal of Biological and Chemical Sciences **15**(2), 679–694. https://doi.org/10.4314/ijbcs.v15i2.23

Dyola N, Sigdel SR, Liang E, Babst F, Camarero JJ, Aryal S, Peñuelas J. 2022. Species richness is a strong driver of forest biomass along broad bioclimatic gradients in the Himalayas. Ecosphere **13**(6), e4107.

El-Khalafy MM, El-Kenany ET, Al-Mokadem AZ, Shaltout SK, Mahmoud AR. 2025. Habitat suitability modeling to improve conservation strategy of two highly-grazed endemic plant species in Saint Catherine Protectorate, Egypt. BMC Plant Biology **25**(1), 485. https://doi.org/10.1186/s12870-025-06401-4

Erfanian MB, Barahoei H, Zeynali MM, Mirshamsi O. 2025. Employing habitat suitability modeling to assess the distribution and envenomation potential of scorpion species in Iran. Journal of Medical Entomology **62**(2), 337–346. https://doi.org/10.1093/jme/tjae151

Fick SE, Hijmans RJ. 2017. WorldClim 2: new 1-km spatial resolution climate surfaces for global land areas. International Journal of Climatology **37**(12), 4302–4315. https://doi.org/10.1002/joc.5086

Flores A, Flores-Ortíz CM, Dávila-Aranda PD, Rodríguez-Arévalo NI, Sampayo-Maldonado S, Cabrera-Santos D, Ulian T. 2024. The germination performance after dormancy breaking of *Leucaena diversifolia* (Schltdl.) Benth. seeds in a thermal gradient and its distribution under climate change scenarios. Plants **13**(20), 2926. https://doi.org/10.3390/plants13202926

Ganglo JC. 2023. Ecological niche model transferability of the white star apple (*Chrysophyllum albidum* G. Don) in the context of climate and global changes. Scientific Reports **13**(1), 2430. https://doi.org/10.1038/s41598-023-29048-3

Goethe University Frankfurt. 2025. Principaux facteurs environnementaux de la Côte d'Ivoire [Main environmental factors in Côte d'Ivoire]. Generic institutional report. Frankfurt am Main: Goethe University Frankfurt. https://www.goethe-university-frankfurt.de/50800998/Generic_50800998.pdf