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Predictive modeling of the rate of occurrence favorable to *Cola attiensis* Aubrév. & Pellegr., in a context of climate change using a nomogram

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Abstract

Climate change poses a pressing challenge to the distribution patterns of plant species, necessitating innovative approaches to predict occurrence rates in affected ecosystems. In this study, we focus on Cola attiensis, an economically and ecologically important plant species endemic to Côte d'Ivoire. Our novel methodology employs a nomogram, traditionally used for intricate mathematical equations, to model the intricate relationships between topographic, climatic variables, and the presence of C. attiensis. By integrating field occurrence data and bioclimatic variables, we delineate the potential habitat of this species. Utilizing logistic regression-based nomogram predictions, we estimate the probability of occurrence, with the minimum temperature of the coldest month emerging as the most influential variable. Calibration curve analysis convincingly demonstrates the validity of our model by accurately predicting occurrence probabilities. The implementation of this nomogram holds significant implications for effective ecosystem management, enabling the estimation of *C. attiensis* survival probabilities in its potential habitat. The total vulnerability score of *C. attiensis* in its potential habitat was higher than 80%. These findings provide crucial insights for the formulation of conservation and management strategies aimed at protecting this endemic species in Côte d'Ivoire. However, future research endeavors should address complex biological interactions, uncertainties in climate projections, and incorporate additional variables to advance our understanding of species dynamics.

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Introduction

Climate change poses one of the most urgent and complex challenges of our time, affecting various aspects of our environment, including biodiversity. The Intergovernmental Panel on Climate Change (GIEC, 2020; IPCC, 2021) has emphasized the need for scientific efforts to understand and anticipate the impacts of climate change on ecosystems. In particular, scientists are striving to unravel how plant species will respond and adapt to these changing environmental conditions. This knowledge is essential for informing effective conservation and ecosystem management strategies (Couch and Haba, 2021; Nduche *et al.*, 2023).

The tropical region of West Africa harbors diverse and unique plant species, which face significant threats due to climate change (IUCN, 2016). Among these species, *Cola attiensis* Aubrév. & Pellegr. holds a critical ecological and economic importance (Bouquet & Debray, 1974). This plant, listed as endangered according to Walter et Gillet (1998) on the Red List A1c, B1+2c criteria of IUCN (IUCN, 2012a & 2012b; IUCN, 2015). This publication increases the number of documented narrowly endemic. *C. attiensis* is recognized for its cultural significance and various uses, particularly in the food and pharmaceutical industries (Iwu *et al.*, 1992; Akotto *et al.*, 2014). However, the potential impacts of climate change on the distribution and viability of *C. attiensis* remain poorly understood.

In this study, we embark on a pioneering investigation aimed at predicting the rate of occurrence favorable to *C. attiensis* in the context of climate change. By shedding light on the potential effects of climate change on this valuable species, we aim to contribute to its conservation and promote sustainable ecosystem management strategies.

To achieve our objectives, we employ an innovative approach centered around the utilization of a nomogram, a powerful graphical tool that enables the resolution of complex mathematical equations by visually representing the relationships between variables (Tournès, 2016; Xiang *et al.*, 2017). By leveraging this tool, we can model the intricate connections between pedoclimatic factors and the presence of *C. attiensis*, thus providing insights into its occurrence rates under different climate scenarios. Accurate and reliable climate data are pivotal for our methodology. We rely on high-resolution climate datasets from reputable sources, including national climate databases, to ensure the robustness of our analyses (Hijmans *et al.*, 2005). Additionally, we combine these climatic data with comprehensive records of *C. attiensis* occurrences obtained through rigorous field surveys, botanical collections, and public databases. This multifaceted datas*et al*lows us to obtain a precise and comprehensive understanding of the current distribution patterns of *C. attiensis*.

The construction and validation of the nomogram involve meticulous statistical analyses. We employ advanced techniques such as logistic regression to identify the climatic variables that exert the most significant influence on the species' presence (Gillet, 2011; Marmion *et al.*, 2009). These variables may encompass temperature, precipitation, humidity, and other crucial factors. By integrating these insights into the nomogram, we can visualize and interpret the intricate relationships between these variables, facilitating the prediction of the favorable occurrence rate for *C. attiensis* (Toffa *et al.*, 2022).

Our study holds immense potential for advancing our understanding of the impacts of climate change on plant species and guiding conservation efforts. By incorporating precise climate data, advanced statistical analyses, and a visually appealing nomogram (Filleron *et al.*, 2017), we aim to provide valuable insights for effective ecosystem management and the conservation of *C. attiensis* in the face of climate change challenges.

Our research endeavors to bridge the knowledge gap surrounding the potential impacts of climate change on this valuable plant species, thereby empowering decision-makers with crucial information for conservation and sustainable management of ecosystems. Through a holistic and interdisciplinary approach, combining robust climate data, advanced statistical techniques, and an innovative nomogram, we aim to contribute to the broader understanding of the intricate relationships between climate change and biodiversity conservation.

Material and methods

Study Area

The study was conducted in Côte d'Ivoire, focusing on the occurrence range of *C. attiensis*. Fig. 1 provides an illustration of the study area, which encompasses various locations, including Abidjan, Adzopé, Agboville, Akoupé, Arrah, Fresco, Divo, Sipilou, Tabou, and Yakassé-Attobrou, primarily situated in the southern half of the country. It is important to note that *C. attiensis* also exists in other African countries such as Cameroon, Equatorial Guinea, and Gabon (Kouamé *et al.*, 2018). Côte d'Ivoire exhibits significant rainfall variability, with levels ranging from 900 mm/year in the North-East to 2,200 mm/year in the South-West. Furthermore, the eastern half of the country has experienced an increase in interannual average temperature. In terms of habitat preferences, *C. attiensis* tends to thrive in forests characterized by the presence of Nesogordonia papaverifera and Khaya ivorensis. The study area encompasses both the geological areas of the coastal sedimentary basin and the crystalline basement. These specific geographic and climatic characteristics of the study area are crucial to consider in understanding the distribution and ecological requirements of *C. attiensis*.

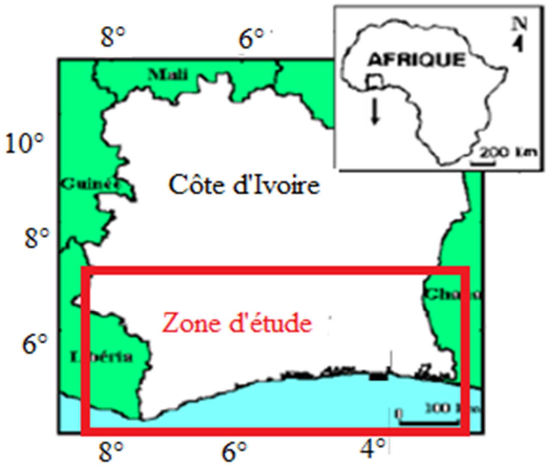

Fig. 1. Study area for the distribution of *Cola attiensis* in Côte d'Ivoire.

Collection of climate and occurrence data of C. attiensis

For this study, climate data were collected and occurrence data of *C. attiensis* were compiled to better understand the species' distribution and ecological requirements. Climate data used in this study were obtained from the WorldClim version 1.4 database (Hijmans *et al.*, 2005), which provides comprehensive and reliable climatic information. We selected a set of bioclimatic variables that are relevant to our study, considering their potential influence on the rate of occurrence favorable to *C. attiensis*. The selected bioclimatic variables include annual mean temperature (Bio1), maximum temperature of the hottest month (Bio5), minimum temperature of the coldest month (Bio6), mean temperature of the warmest quarter (Bio10), average temperature of the coldest quarter (Bio11), annual precipitation (Bio12), precipitation in the wettest month (Bio13), precipitation in the driest month (Bio14), precipitation in the wettest quarter (Bio16), and precipitation in the driest quarter (Bio17). These variables capture important aspects of the climatic conditions that may influence the presence and abundance of *C. attiensis*.

To ensure the robustness of our analysis and avoid multicollinearity issues, we carefully selected 10 bioclimatic variables out of the initial 19 available in the database. This selection was made considering the presence of autocorrelation among certain variables (Legendre, 2018), allowing for a clearer interpretation of the effects of each variable on the rate of occurrence favorable to *C. attiensis* (Johnson and Omland, 2004). By including these variables in our analysis, we aim to uncover the key climatic factors driving the distribution of this species. Occurrence data for *C. attiensis* were compiled from the Global Biodiversity Information Facility (GBIF; www.gbif.org), a widely recognized and reliable source of biodiversity data. Georeferenced points of species occurrence were selected, ensuring their reliability by eliminating those with unreliable coordinates. In total, 67 points, including 21 occurrences and 46 absences, were retained from various regions in Africa, including Côte d'Ivoire, Cameroon, Gabon, and Equatorial Guinea.

By incorporating data from multiple regions, we aim to capture the species' distributional patterns across its entire range and examine any potential variations in occurrence rates.

Construction of the nomogram

To predict the rate of occurrence favorable to *C. attiensis*, we utilized logistic regression as the modeling technique, taking into account the most influential climate variables that impact the species' presence (Pearson and Dawson, 2003; Iasonos *et al.*, 2008). The logistic regression model incorporated the 10 selected bioclimatic variables as independent variables, while the presence and absence of the species served as the dependent variable. Through multivariate logistic regression, we obtained regression coefficients, which were then used to weigh the different bioclimatic variables in the nomogram. The construction of the nomogram was based on the equation derived from the logistic regression model (Seo *et al.*, 2020). The nomogram provides a graphical representation of the relationships between climate variables and the probability of *C. attiensis* presence. By inputting specific values of the climatic variables, it becomes possible to draw a line on the nomogram, enabling the determination of the probability of species presence. This approach offers a logical and intuitive method (Meng *et al.*, 2022) for predicting the rate of occurrence favorable to *C. attiensis* under different climate change scenarios (Guisan & Zimmermann, 2017). In constructing the nomogram, we assigned points to predictor variables based on their effect size relative to the most influential variable and considered bidirectional interactions. By adjusting scores accordingly, we accounted for the varying contributions of each variable (Jalali *et al.*, 2019). By superimposing a vertical line on the corresponding probability of occurrence, we estimated the probability of *C. attiensis* survival in its potential habitat using the total scores obtained. This framework allows for the comparison of different climate change conditions and scenarios, providing valuable insights into the species' response to environmental changes.

Validation of the nomogram

To evaluate the performance and calibration of our predictive model based on logistic regression, we employed the calibration curve, a widely used method (Pearce & Ferrier, 2000a; Seoane *et al.*, 2005). The calibration curve enables a comparison between the predicted probabilities and the actual observations. In logistic regression, the calibration curve is typically generated by dividing the predicted probabilities into intervals and calculating the mean predicted probability for each interval. (Pearce & Ferrier, 2000b). These average probabilities are then compared to the observed frequencies in each interval. A well-calibrated model shows close alignment between the predicted probabilities and the observed frequencies (Austin & Steyerberg, 2012).

By utilizing the calibration curve, we quantified the nomogram's ability to accurately discriminate between the presence and absence of *C. attiensis*. This validation process allows us to assess the reliability of our nomogram in predicting the rate of occurrence favorable (Wu *et al.*, 2020) to *C. attiensis* in the context of climate change. The methodology outlined above ensures the collection of precise climate data, the construction of a nomogram based on logistic regression, and the validation of this nomogram. This comprehensive approach strengthens the robustness of our predictions and enhances our understanding of the potential implications of climate change on the occurrence of *C. attiensis*.

Statistical Analysis

The collected soil data underwent a rigorous processing procedure to ensure data quality and coherence for the predictive modeling of *C. attiensis*. This data processing was analyzed using R software version 4.3.0 (R Core Team, 2023), a widely adopted statistical programming language known for its capabilities in environmental data analysis. Significance was defined at 95% confidence level ($p < 0.05$). Initially, the raw data was imported into R, and a preliminary visual inspection was performed to identify any errors or outliers. Observations containing errors were identified and either corrected or excluded from the analysis to mitigate any potential adverse impact on the results. Subsequently, specific R packages such as 'dplyr' and 'tidyr' were utilized to clean and transform the data and restructure the data into a format suitable for the predictive modeling of *C. attiensis*. To enhance the predictive modeling process, relevant variables were selected or derived from the processed soil data. This involved feature engineering techniques, including the creation of derived variables, interaction terms, or transformations, to capture potential relationships between the soil characteristics and the occurrence of *C. attiensis* and R packages 'rms' was utilized. Overall, the data processing steps in R ensured the quality, consistency, and suitability of the soil data for accurate and reliable predictive modeling of *C. attiensis*.

Results and discussion

Results

Relationship between topo-climatic variables and the presence of C. attiensis

The results (Table 1) provide important insights into the relationships between topo-climatic variables and the presence of *C. attiensis*. The independence test yielded a χ2 value of 10.09 (p = 0.0064), indicating a significant relationship between the minimum temperature of the coldest month and the rate of occurrence favorable to *C. attiensis*.

Table 1. Results of independence tests from the Wald and Wolfowitz analysis of variance.

	χ^2	df	ρ
Minimum temperature of the coldest month	10.09	2	0.0064
Non linear	2.23	1	0.135
Slope	7.62	2	0.0222
All interactions	7.26	1	0.0071
Aspect	7.9	2	0.0193
All interactions	7.26	1	0.0071
slope * aspect	7.26	1	0.0071
Total non linear + interaction	9.94	2	0.0069
Total	11.53	6	0.0734

Higher minimum temperatures were found to favor the presence of this species. The non-linear regression test showed a χ2 value of 2.23 (p = 0.135), suggesting a potential non-linear relationship between another studied variable and the rate of occurrence of *C. attiensis*, necessitating further investigation. The independence slope test revealed a χ2 value of 7.62 (p = 0.0222), signifying a significant relationship between slope and the rate of occurrence of the studied species. Specific slope characteristics were found to influence the presence or absence of *C. attiensis*.

The independence aspect test demonstrated a χ2 value of 7.9 (p = 0.0193), indicating a significant relationship between the aspect (orientation) of the terrain and the rate of occurrence of *C. attiensis*. Certain orientations were identified as more favorable for this species. *The independence tests for slope**aspect interactions displayed significant values for all interactions, suggesting that the combined effects of these variables have a significant impact on the rate of occurrence of *C. attiensis*. The global independence test yielded a χ2 value of 11.53 and a corresponding p-value of 0.0734. Although not statistically significant, it suggests the existence of unexamined factors that may influence the rate of occurrence.

In summary, the results indicate significant relationships between the minimum temperature of the coldest month, slope, aspect, and interactions between certain variables and the rate of occurrence favorable to *C. attiensis*. However, the possibility of a non-linear relationship and the presence of other unexamined factors in the species' habitat warrant further investigation.

Table 2 presents the results of β coefficient estimations in the logistic regression model, providing valuable insights into the significance of variables and their relationship with the rate of occurrence of *C. attiensis*. The following key findings emerge from the analysis :

Minimum temperature of the coldest month (Temp_min_froid) exhibits a substantial β coefficient of 113.64, indicating its significant influence on the rate of occurrence favorable to *C. attiensis*. A higher minimum temperature during the coldest month positively affects the presence of the species. The slope variable demonstrates significance, with a β coefficient of 35.60 (P = 0.0058). This suggests that the terrain's slope has a notable impact on the rate of occurrence of the studied species.

Although the aspect of the slope has a β coefficient of 0.0165, the associated p-value (P = 0.0602) is slightly higher, indicating a lack of statistical significance. However, there may exist a trend or marginal influence of aspect on the rate of occurrence of *C. attiensis*. The interaction between slope and aspect exhibits significance, as indicated by a β coefficient of -0.1376 (P = 0.0071). This suggests that the interaction between these two variables plays a significant role in influencing the rate of occurrence.

Table 2. Probability estimation of logistic regression variance.

	β	S.E.	Wald Z	Pr(>|Z|)
Intercept	-606.0001	259.0682	-2.34	0.0193
Minimum temperature of the coldest month	113.6434	48.8931	2.32	0.0201
Slope	35.6001	12.9144	2.76	0.0058
Aspect	0.0165	0.0088	1.88	0.0602
Slope *Aspect	-0.1376	0.0511	-2.69	0.0071

Prediction of the rate of occurrence favorable to C. attiensis

Nomogram analysis

Fig. 2 presents the nomogram constructed using the logistic regression model obtained from the results in Table 2. First, points were assigned to the predictor variables based on their effect size relative : As the regression coefficient in the model increased, the points in the nomogram also increased. So, the minimum temperature of the coldest month (Temp_min_froid), which was the most influential variable, creating a relative scale of contribution for different variables. Then, the scores were adjusted accordingly by including the bidirectional interactions. The findings highlight the minimum temperature of the coldest month as the most influential variable in the model, followed by slope.

The aspect of the slope and the interaction between slope and aspect also exhibit significant influences, with aspect potentially exerting a marginal effect. These results provide crucial insights into the determining factors shaping the rate of occurrence favorable to *C. attiensis* within the context of climate change and topography.

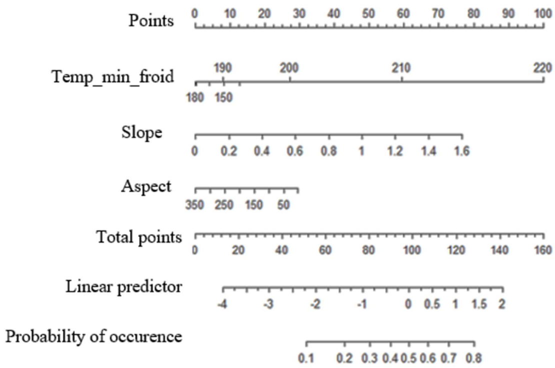

Fig. 2. *Cola attiensis* nomogram.

Nomogram caculation

Finally, by superimposing a vertical line on the corresponding occurrence probability, the estimated survival probability of *C. attiensis* in its potential habitat could be estimated based on the total scores obtained (Fig. 3). This allows for the comparison of different conditions and climate change scenarios. The Temp_min_froid had the highest effect and was assigned 100 points. The remaining variables were assigned a smaller number of points proportional to their effect size. Thus, slope would receive 31.3 points (β slope / β Temp_min_froid) x 100.

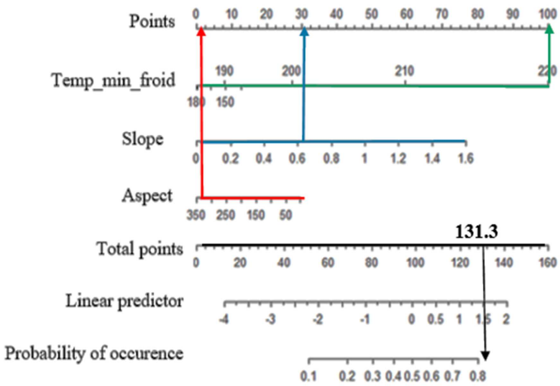

Fig. 3. Prediction of *Cola attiensis* occurrence using a nomogram.

Similarly, aspect would receive 0.015 points. The total points accumulated by the main effects are equivalent to: 100 points (Temp_min_froid) + 31.3 points (slope) + 0.015 points (aspect), 131.3 points. Referring to the total points and superimposing a vertical line on the occurrence probability, the estimated survival probability calculated is 0.81 based on the main effects model and 0.8 (80%).

When all bidirectional interactions are included, the calculation is 131.3 points + 0.05 points + 21.46 points, totaling 152.5 points. The estimated survival probability when all bidirectional interactions are included is above 0.80. Thus, the total vulnerability score of *C. attiensis* in its potential habitat was higher than 80% (Fig. 3).

Validation of the prediction model using the calibration plot

The calibration plot analysis (Fig. 4) in predicting the occurrence probabilities for the studied species, demonstrates the proximity of the prediction rate and the actual occurrence rate to the Y = X line (blue line) indicates a high level of calibration. Ideally, a calibration curve would follow a perfect diagonal line where the predicted values precisely match the actual values. While the observed calibration plot may deviate slightly from the ideal line, its close alignment with the reference line Y = X suggests good calibration of the logistic regression model. This implies that the model provides accurate estimates of occurrence probabilities for *C. attiensis*. The proximity between the actual occurrence probability and the predicted occurrence probability, as indicated by the calibration plot following a Y = X relationship, demonstrates the model's ability to capture the variations in occurrence probabilities effectively. This reliability enhances confidence in the model's results and underscores its robustness in predicting the rate of occurrence favorable to *C. attiensis* across different topographic and climate change scenarios.

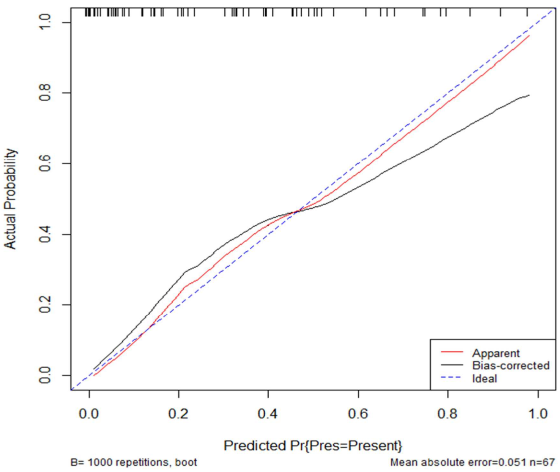

Fig. 4. Calibration plot based on the logistic regression model.

In summary, the calibration plot analysis confirms the model's accuracy and reliability in estimating occurrence probabilities for *C. attiensis*. This validation strengthens the model's utility for predicting the species' occurrence rates and contributes to our understanding of its distribution dynamics in the face of climate change.

Discussion

This study utilized a logistic regression model (Harrell, 2022) to predict the occurrence rate of *C. attiensis*. The findings emphasized the significance of minimum temperature in the coldest month, slope, and aspect of the slope as key predictive variables, consistent with previous research (Ankrah *et al.*, 2023). The results indicated that minimum temperature in the coldest month played the most critical role, influencing the occurrence of *C. attiensis*. Higher minimum temperatures were associated with improved survival and growth, while lower temperatures constrained its development, suggesting the species' temperature tolerance (Alimonti *et al.*, 2022). Furthermore, the slope of the terrain emerged as an important factor, affecting hydrological conditions, soil drainage, and sun exposure, thus influencing the species' preferred habitat (Zhang *et al.*, 2022). On the other hand, the aspect of the slope had a less pronounced impact on *C. attiensis* occurrence, implying that slope orientation might have limited relevance to the species' preferred environmental conditions (Moeslund *et al.*, 2013). The analysis of interactions revealed a significant effect of the interaction between slope and aspect of the slope on *C. attiensis* occurrence, highlighting the importance of considering the combined influence of topographic features when evaluating the species' habitat preferences. The calibration curve demonstrated good agreement between actual and predicted probabilities, enhancing the reliability of the model.

Implications of using the nomogram for ecosystem management

Using the nomogram enables estimation of the probability of *C. attiensis* occurrence under different climate change scenarios (Jalali *et al.*, 2019; Borumandnia *et al.*, 2021).

This information can guide decision-making regarding the protection and restoration of suitable habitats for *C. attiensis*, supporting effective ecosystem management and conservation efforts. However, the approach has limitations. It relies on past climatic data, and uncertainties associated with future projections need to be considered. Incorporating more sophisticated climate models and additional environmental variables could enhance prediction accuracy. It is also important to explore other factors, such as soil composition, species competition, and biotic interactions, which may influence *C. attiensis* occurrence. Moreover, the validity of the results depends on the quality and availability of species occurrence data, warranting efforts to collect precise and comprehensive field data to improve model robustness (Elith *et al.*, 2006; Wisz *et al.*, 2008; Phillips *et al.*, 2009; Yu *et al.*, 2020).

These references address aspects related to species distribution model validation, the importance of precise occurrence data, prediction error evaluation, and model robustness improvement. They provide relevant information on best practices and recommended methods for collecting and utilizing species occurrence data. In Yu *et al.* (2020), the authors emphasize the need to improve the robustness of species distribution models by considering regional and local occurrence patterns of butterflies. This study highlights the significance of collecting comprehensive field data to enhance model accuracy and reliability. Phillips *et al.* (2009) investigate sample selection bias and its impact on presence-only distribution models. They stress the need to carefully consider background and pseudo-absence data to improve model performance and mitigate bias. Wisz *et al.* (2008) conduct a meta-analysis on the effects of sample size on species distribution model performance. Their findings underscore the importance of collecting sufficient data to achieve accurate and reliable predictions. Elith *et al.* (2006) provide novel methods to enhance prediction of species distributions using occurrence data. Their work highlights the significance of appropriate modeling techniques and the incorporation of relevant environmental variables (Jiang *et al.*, 2017). These references contribute valuable insights into the validation process of species distribution models and the collection of precise occurrence data. By following the recommended methods and practices outlined in these studies, researchers can improve the reliability and robustness of their models, leading to more accurate predictions of species distributions.

Limitations of the approach and future research directions

Although, certain limitations need to be considered. Firstly, the model relies on past climatic data, and future projections may be subject to uncertainties. Further studies employing more sophisticated climate models and incorporating different environmental variables could enhance prediction accuracy. Additionally, the current approach primarily focuses on climate and topographic variables. It is important to explore other factors such as soil composition, competition with other species, and biotic interactions, which could also influence the occurrence of *C. attiensis*. Understanding the complex interactions between these variables will contribute to a more comprehensive understanding of the species' habitat requirements and improve the accuracy of predictions. Finally, the validity of the results depends on the quality and availability of species occurrence data. Additional efforts should be made to collect precise and comprehensive field data to improve the model's robustness. Integrating data from various sources, such as citizen science initiatives and remote sensing technologies, can help overcome data limitations and enhance the reliability of the model. These limitations highlight areas for further research and improvement of the current approach. By addressing these limitations and incorporating additional variables and high-quality data, future studies can enhance the predictive capabilities of the model and provide more accurate assessments of *C. attiensis* occurrence in the context of changing environments.

Conclusion

The logistic regression-based nomogram has proven to be a valuable tool in estimating the probability of *C.*

attiensis occurrence based on climatic and topographic variables. The identification of minimum temperature in the coldest month, slope, and aspect as key predictors highlights the importance of these variables in shaping the species' distribution. This knowledge has significant practical implications for ecosystem management and the conservation of *C. attiensis*. However, it is important to acknowledge that our modeling process is an ongoing endeavor, and there are avenues for further improvement. Future research should expand the scope of our models by incorporating additional influential factors, such as soil composition, interspecies competition, and biotic interactions. These factors hold promise in enhancing our understanding of *C. attiensis* distribution patterns and can contribute to more comprehensive management strategies. To ensure the accuracy and robustness of our predictions, a continued commitment to data quality is paramount. Collecting precise and accurate field data remains essential in refining our models. Embracing advanced data collection techniques and emerging technologies can further enhance the reliability of our predictions and provide a solid foundation for decision-making.

The nomogram-based approach has shed light on the intricate relationship between environmental variables and *C. attiensis* occurrence, enabling effective ecosystem management and informed conservation strategies. As we embark on this journey, it is crucial to foster innovation and collaboration. By pushing the boundaries of our knowledge and working together, we can safeguard the future of this remarkable species.

The challenges posed by climate change, environmental factors, and population growth present significant obstacles to the occurrence and survival of fragile plant species like C. attiensis. Urgent conservation actions are required to protect and restore their habitats, mitigate the impacts of climate change, and ensure the long-term persistence of these valuable plant populations. By prioritizing these conservation efforts, we can contribute to the preservation of biodiversity and maintain the ecological balance of our ecosystems.

In summary, the utilization of the logistic regression-based nomogram has provided valuable insights into *C. attiensis* occurrence, emphasizing key predictors and offering practical applications for ecosystem management and conservation. By embracing further research, refining our models, and taking decisive conservation actions, we can overcome the challenges faced by this species and secure a sustainable future for *C. attiensis* and other vulnerable plant populations.

Contributions

Akotto OF and Assamoi KCWS designed the study. All the authors contributed in the data analysis and revising of the manuscript, while Akotto OF wrote the manuscript.

Ethics declaration

The authors declare that they have no conflict of interest.

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