Assessing future climate change impacts on habitat distribution of threatened plant species in the Lower Ouémé Valley Biosphere Reserve (RB-BVO) in Benin

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Abstract

Climate variability and change are currently among the greatest development challenges facing our planet. These climatic phenomena have significant impacts on plant resources, with noticeable effects such as shifts in the phenological stages of plant species and reductions in the range of their habitats. This study examines the impact of future climate variability on the distribution of suitable habitats for threatened plant species listed on the International Union for Conservation of Nature (IUCN) Red List within the RB-BVO. The methodological approach involved collecting climate data and species occurrence records. Future climate trends were analyzed using Khronostat 1.01 software and Excel spreadsheets. Additionally, simulations of the potential effects of future climate variability on suitable habitats for plant species by 2055 and 2099 under the RCP4.5 scenario were conducted using the Maxent model. The results indicate rainfall instability and significant monthly increases in temperature (a difference of 2°C between 2020 and the projected peak). These changes will likely extend heat periods within the RB-BVO region, affecting the distribution of habitats for the 16 identified threatened species. These include two endangered species (*Aphania senegalensis* and *Pterocarpus erinaceus*), nine vulnerable species (*Afzelia africana, Albizia ferruginea, Khaya senegalensis, Millettia warneckei, Nesogordonia papaverifera, Pierreodendron kerstingii, Pseudospondias microcarpa, Pterygota macrocarpa, and Ricinodendron heudelotii*), and four near-threatened species (*Chrysophyllum albidum, Eucalyptus camaldulensis, Irvingia gabonensis,* and *Milicia excelsa*). Projections for 2055 and 2099 under the RCP4.5 scenario show a reduction in suitable habitats for the conservation of these threatened species within the RB-BVO, with habitat losses estimated at 32.55% by 2055 and 44.47% by 2099. The implementation of a management and conservation plan for these threatened species in response to climate variability is therefore essential for the reserve.

Keywords: Climate variability, climate scenario, threatened species, Mono Biosphere Reserve, Benin

Introduction

Recent scientific studies highlight the acceleration of biodiversity loss, with a significant risk of mass extinction for plant species unless urgent measures are taken at both national and global levels (Heubes et al., 20212; Nair, 2023). Recent Global Assessment Report on Biodiversity and Ecosystem Services estimates that one million animal and plant species are at risk of extinction (IPBES, 2019). Africa is recognized as the most vulnerable continent to climate change due to its lower development level compared to other regions and its limited access to advanced technologies for adaptation (François and Taabni, 2012; IPCC, 2014). Consequently, many African countries, including Benin, have prioritized climate adaptation strategies in their national development plans to strengthen community resilience; however, significant challenges remain in achieving effective implementation. Benin faces severe climate change impacts, such as increased variability and recurrence of extreme weather events (e.g., devastating floods, prolonged droughts, heatwaves, and torrential rains), sea-level rise, coastal erosion, and late rainfall. It is essential to understand the effects of climate variability and change on plant resources to guide land management and conservation policies effectively (Adjahossou et al., 2016; Yaoitcha et al., 2022). Benin's forest cover was estimated at 4,625,000 hectares (42% of the national territory) in 2010 but declined to 4,311,000 hectares (39%) by 2015 due to agricultural expansion and urbanization (FAO, 2015). Climate change significantly influences plant species distribution, with factors such as annual rainfall, temperature, and potential evapotranspiration playing critical roles (Gbesso et al., 2013; Fandohan et al., 2013). This study investigates the impact of future climate variability on the distribution of suitable habitats for threatened plant species listed on the IUCN Red List within the Mono Biosphere Reserve (RB-BVO) in Benin, considering socio-economic and environmental contexts to enhance resilience and sustainable management of protected areas (Heubes et al., 2012; Gbesso et al., 2013; Akabassi et al., 2021; Yaoitcha et al., 2022).

Materiel and Methods

Study area

Located between latitudes 6° 20' 19.3" N and 7° 7' 41.7" N and longitudes 2° 4' 16.7" E and 2° 4' 22.1" E, the RB-BVO (Lower Ouémé Valley Biosphere Reserve) spans an area of 314,300 hectares (Figure 1). This community-based reserve comprises five Community Protected Areas (CPAs): the Hlanzoun swamp forest in Kossoukpa (Zogbodomey municipality), the Gnanhouizoun community forest, the sacred forests of Gbevozoun, Soligbozoun, and Lokoguédji (Bonou municipality), the Community Nature Park of the Sitatunga Valley in Zinvié (Abomey-Calavi municipality), and the Intercommunity Reserve of Greater Nokoué in the municipalities of So-Ava, Aguégué, and Sèmè-Kpodji. The zoning, as defined by UNESCO's Man and Biosphere (MAB) program, includes three areas: core zones (13,867.8 ha), buffer zones (19,917.1 ha), and transition zones (280,515.34 ha). The reserve extends across parts or all of the municipalities of Abomey-Calavi, Adjarra, Adjohoun, Aguégués, Akpro-Missérété, Avrankou, Bonou, Cotonou, Dangbo, Porto-Novo, Sèmè-Podji, Sô-Ava, Toffo, Zè, and Zogbodomey (MCVDD, 2020). The climate is subequatorial with a bimodal rainfall pattern and temperatures conducive to vegetation growth year-round. It features two rainy seasons (April to mid-July and mid-August to October) and two dry seasons (November to March and mid-July to mid-August). Annual rainfall ranges from 1,150 mm to 1,400 mm, with average temperatures between 25.7°C and 29.3°C (Kpadonou et al., 2010). The RB-BVO's hydrological network includes four major water bodies: the Ouémé River, Sô River, Lake Nokoué, and Porto-Novo Lagoon. The Mono Biosphere Reserve lies within the Afro-Tropical realm, particularly in Ecoregion 1, which consists of tropical and subtropical moist deciduous forests. It is also situated in the Dahomey Gap, a transitional zone between the Guineo-Congolian and Sudanian regional centers of endemism (Zone XI). The reserve is characterized by agroecosystems and degraded semi-deciduous dense forest patches. Plant species in these degraded forests include *Cola gigantea*, *Albizia adiantifolia*, *Newbouldia laevis*, and *Homalium letestui*. Vegetation in the agroecosystems includes species such as *Elaeis guineensis*, *Tectona grandis*, *Acacia auriculiformis*, *Commelina benghalensis*, *Pennisetum polystachion*, *Imperata cylindrica*, and *Cyperus spp* (Toffa et al., 2022; Koussouvi et al., 2024).

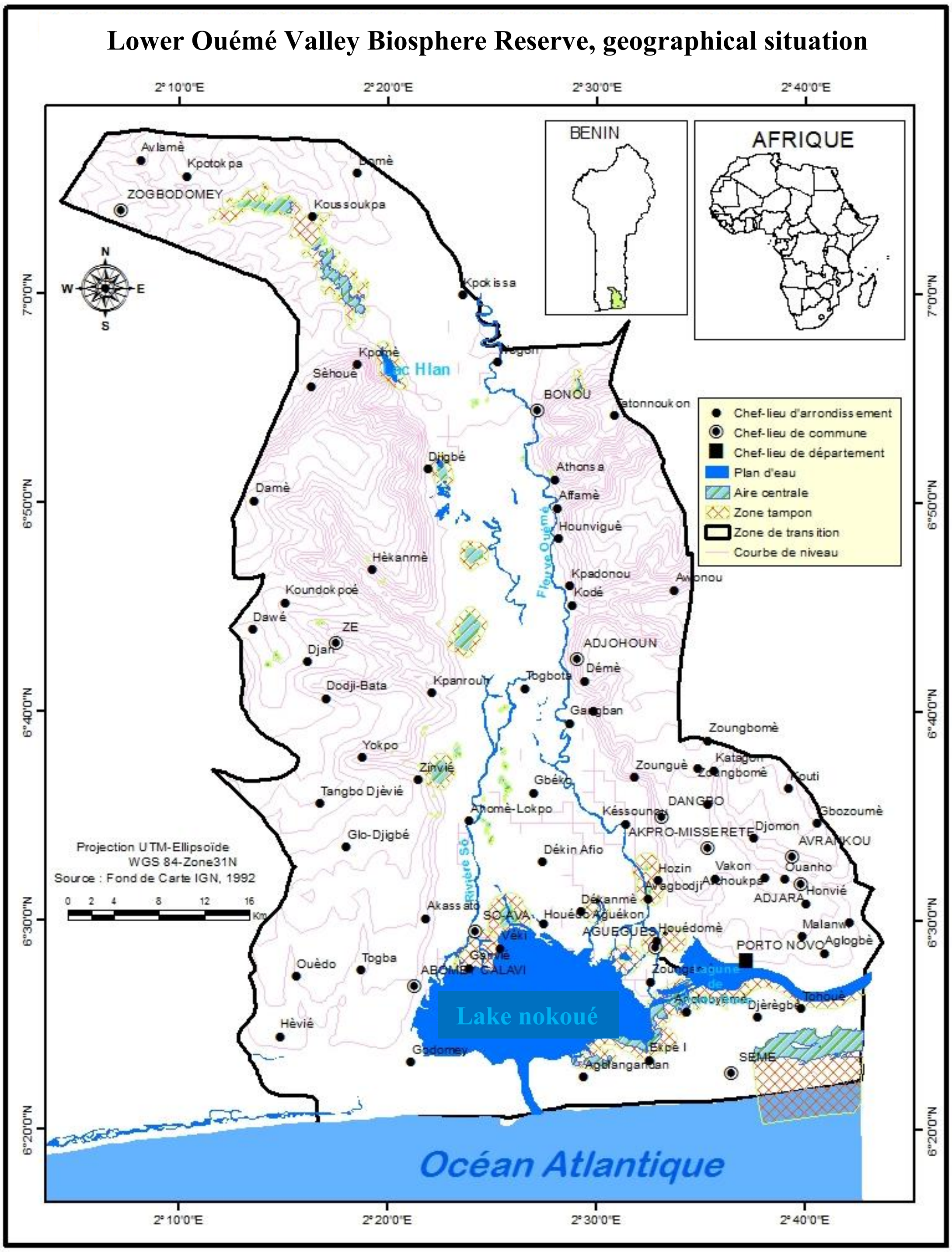

Fig. 1. Geographical location of the Community Protected Areas (CPAs) in the Mono Biosphere Reserve (RB-BVO) in Benin

Methods

Analysis of Future Climate Changes in the RB-BVO

Projections for climate parameters, including temperature and precipitation, derived from the CORDEX database for the horizon of 2099 under the RCP4.5 scenario, were used to assess potential future climate changes. The RCP4.5 scenario is well-suited for developing countries, characterized by potential population growth and high fossil fuel usage (Van Vuuren & Carter, 2014). To analyze the future climatic variability in the RB-BVO, the study focused on examining future trends in precipitation and temperature, determining rainfall indices, identifying precipitation concentration anomalies, detecting stationary breaks, assessing intra-seasonal rainfall instability, and categorizing precipitation patterns.

- **Rainfall Index**

Several approaches were employed, including calculating rainfall indices, thermal indices, Pettitt's test, and the Bayesian method of Lee and Heghinian (Benali et al., 2022; Saliba & Bărbulescu, 2025).

- **Lamb's Anomaly Index**

Lamb's anomaly index, defined as a standardized variable, was also calculated using the equation (Servat et al., 1999):

$$I_p = (X_i - \overline{X})/\sigma \quad \textbf{(1)}$$

Where they respectively represent the variable for the year, ii the interannual average variable, and the standard deviation of the rainfall and temperature series.

Detection of Non-Stationarity Breaks

To identify potential changes in future rainfall or temperature regimes, statistical tests were applied. These include break detection tests such as Pettitt's non-parametric method, the Bayesian approach of Lee and Heghinian, and Hubert's method (Lubes-Niel et al., 1998). These statistical tests were performed using the Khronostat 1.01 software, developed by the UMR Hydrosciences laboratory in Montpellier.

The Pettitt Test

The Pettitt approach is a non-parametric test derived from the Mann-Whitney test. It has been widely used for studying hydrometeorological variables in Africa (Aka et al., 1996; Ardoin-Bardin, 2004; Paturel et al., 1996; Servat et al., 1999) and in the Beninese context (Houndénou, 1999; Vissin, 2007). The null hypothesis assumes no breaks in the series of size. The test involves evaluating whether, for any point between 1 and N N, the time series (Xi) i=1 to t and t+1 to N belong to the same population. The variable under analysis is the maximum absolute value of the variable $U_{t,N}$ defined by

$$U_{t.N} = \sum_{i-1}^{i} \sum_{i-1+1}^{N} D_{ij} \quad (2)$$

The Bayesian Method of Lee and Heghinian

The Bayesian method developed by Lee and Heghinian (Bruneau and Claude, 1983; Lee and Heghinian, 1977) is a parametric approach that requires the studied variables to follow a normal distribution. It assumes a break in the mean at an unknown point in time.

$$\mathrm{Xi} = \mu + \varepsilon\mathrm{i} \text{ with} \begin{cases} i = 1,2,3, \ldots \ldots . \tau \\ \mu + \delta + \varepsilon\mathrm{i} \text{ with } \mathrm{i} = 1,2,3, \ldots . . \mathrm{N} \end{cases} \quad \mathbf{(3)}$$

The εivalues are independent and normally distributed with a mean of zero and variance σ2. The timing of the break and the magnitude of a potential change in the mean are represented by τ and δ, respectively. The potential change, including its timing and magnitude, corresponds to the mode of the posterior distributions of τ and δ. This method provides the probability that the change occurs at time τ within a series where it is assumed a priori that a change has indeed occurred at a specific point. It also estimates the probability that the magnitude of the change has the value δ. The break date is estimated as the mode of the posterior distribution, with greater precision achieved when the distribution is narrowly dispersed and unimodal. Furthermore, an analysis of interannual trends before and after the break was conducted to assess the dynamics of rainfall and temperature following the break year.

Analysis of the Impact of Future Climate Variability on the Habitat of Threatened Plant Species in the RB-BVO

- **Occurrence Data for Threatened Plant Species**

Inventories were conducted using GPS points identified within the RB-BVO. These phytosociological surveys followed a standard methodology and were complemented by occurrence data obtained from the Global Biodiversity Information Facility (GBIF, http://www.gbif.org). In total, 16,363 presence points were retrieved from this site and used for modeling the potential distribution of threatened species and predicting their dynamics by 2055 and 2099.

The global and national IUCN statuses were assigned to the documented species based on information from the IUCN Red List (www.iucnredlist.org), literature, and the Benin Red Book (Adomou et al., 2010). Botanical families for each species were recorded, adhering to the nomenclature of the Angiosperm Phylogeny Group (APG, 2003) and The Plant List (http://www.theplantlist.org).

The standardized IUCN methodology was applied to categorize species into one of seven risk categories in descending order of threat: Critically Endangered (CR), Endangered (EN), Vulnerable (VU), Near Threatened (NT), Least Concern (LC), Data Deficient (DD), and Not Evaluated (NE).

- **Selection of Environmental Variables and Climate Scenarios**

The Mono Biosphere Reserve (RB-BVO) is located in the Dahomey Gap, within the transitional Guineo-Congolian regional zone (Zone XI) as per White (1983). This zone is positioned between the Guineo-Congolian and Sudanian centers of endemism. Based on Udvardy's (1975) classification of global biogeographic provinces, the RB-BVO falls within the Afro-Tropical realm, specifically in Ecoregion 1 (Tropical and Subtropical Moist Deciduous Forests) and Ecoregion 7 (Tropical and Subtropical Grasslands, Savannas, and Shrublands). According to Adomou's (2005) phytogeographical classification for Benin, the RB-BVO spans four phytodistricts: Coastal, Ouémé Valley, Pobè, and Plateau. The ecology of woody species is influenced by various environmental factors. Climatically, mean annual temperature, average rainfall, and the length of the dry season are critical determinants of plant distribution (Nouvellet et al., 2006). Numerous bioclimatic variables are available online (e.g., http://www.york.ac.uk/environment/research/kite/resources/) for modeling species distributions or habitats. However, it is recommended to reduce the list to a few relatively uncorrelated variables (e.g., $r < 0.70$; Elith et al., 2010) that are most relevant to the studied species. In this study area, plant distribution is primarily influenced by water availability and aridity gradients (Adomou et al., 2006). Based on Pearson correlation tests, four minimally correlated variables that best represent the aridity gradient were selected: potential evapotranspiration (PET), temperature seasonality (BIO4), the aridity index of the wettest quarter (MIMQ), and the duration of the longest dry season (LLDS) (Platt et al., 2015).

Current climate data (1950–2000) were sourced from WorldClim version 1.4. Future climate projections used the regional ensemble climate model "AFRICLIM 3.0: high-resolution ensemble climate projections for Africa." Projections for 2055 and 2099 under the RCP 4.5 radiative forcing scenario, which assumes moderate greenhouse gas emission increases (IPCC, 2014), were employed. The RCP4.5 scenario offers a realistic middle path between a scenario of inaction (RCP8.5) with extreme impacts and a highly ambitious scenario (RCP2.6) that is often out of reach for developing countries. It credibly reflects Benin's current capacity to integrate climate policies into its national planning, while allowing for the simulation of significant impacts to guide future adaptation strategies. Other scenarios (RCP 2.6, RCP 6.2, and RCP 8.5) were not considered due to minimal variation in projections for the study area by 2055 and 2099 (IPCC, 2013). Climatic layers used had a resolution of 30 seconds, equivalent to a grid of approximately 1 km x 1 km.

- Modeling Techniques

Environmental variables were imported in raster format into R software (package: raster). To model suitable habitats for the species using the MaxEnt algorithm (Phillips et al., 2006), the dismo package in R (version 4.0.2) was employed. The model parameters ensured the exclusion of duplicate geographic coordinates.

To evaluate the significance of predictor variables, the permutation importance statistic was used. This statistic reflects the reduction in the predictive power of the model when the values of a given variable are randomly permuted between background and presence points. High values indicate a greater importance of the variable in the model.

Results

Temperature Variations by 2099

The analysis reveals a sharp rise in annual temperatures, peaking at 30.23°C in 2079, with a 2°C increase from 2020. A Pettitt test (99% confidence) indicates a trend shift by 2053. RCP4.5 simulations predict significant monthly temperature increases, extending heat periods in the RB-BVO and impacting plant habitat distribution (Figure 2).

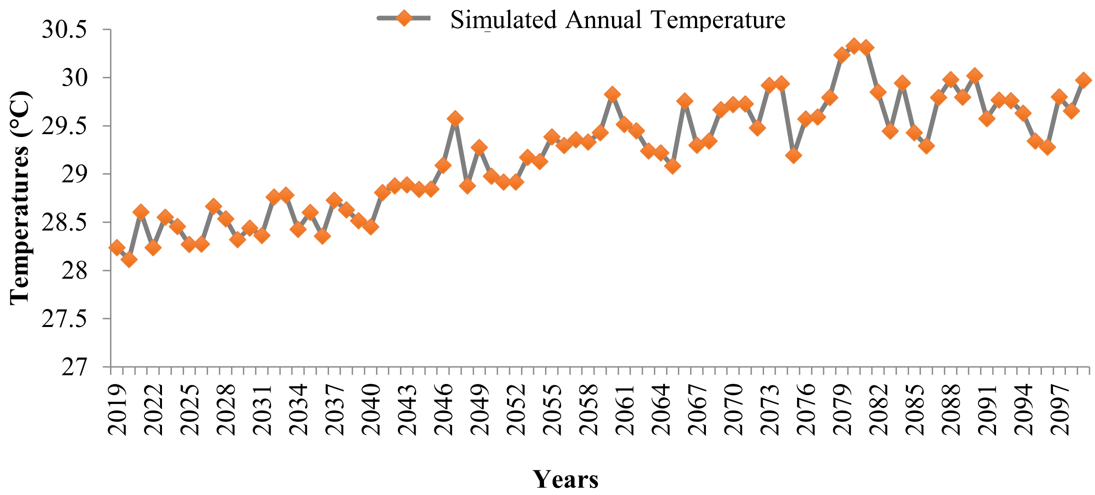

Fig. 2. Simulated annual temperature variations

Projected Precipitation Trends by 2099

Rainfall ranges from 957.84 mm (2034) to 1704.66 mm (2061), averaging 1215.47 mm with a standard deviation of 122.47 mm (10% of the mean). Future rainfall variability in the RB-BVO is projected to be half as pronounced as current levels (Figure 3).

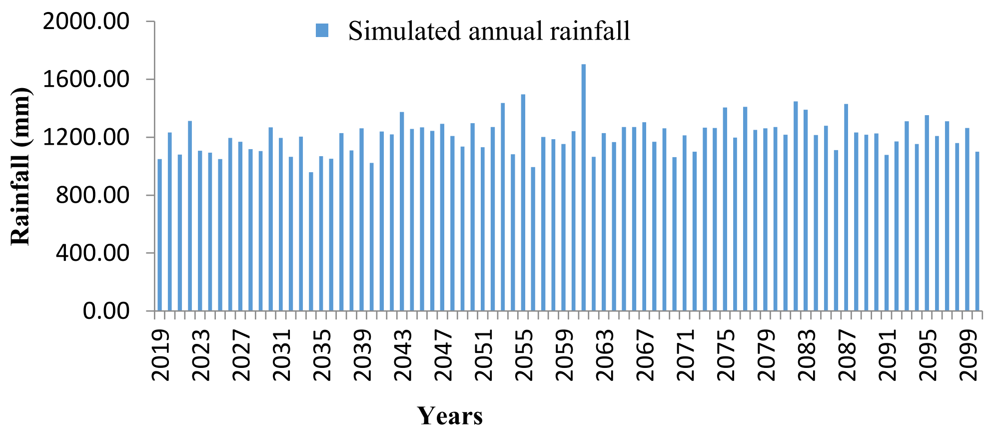

Fig. 3. Annual Variation in Simulated Rainfall

Rainfall Anomalies in Simulated Data

Figure 4 illustrates the interannual variation in rainfall by 2099. The analysis shows a distribution centered on the axis, with 70% of the data values falling between 1 and -1. These results indicate that rainfall projections for 2099 are relatively reassuring, as rainfall variability becomes less pronounced over time

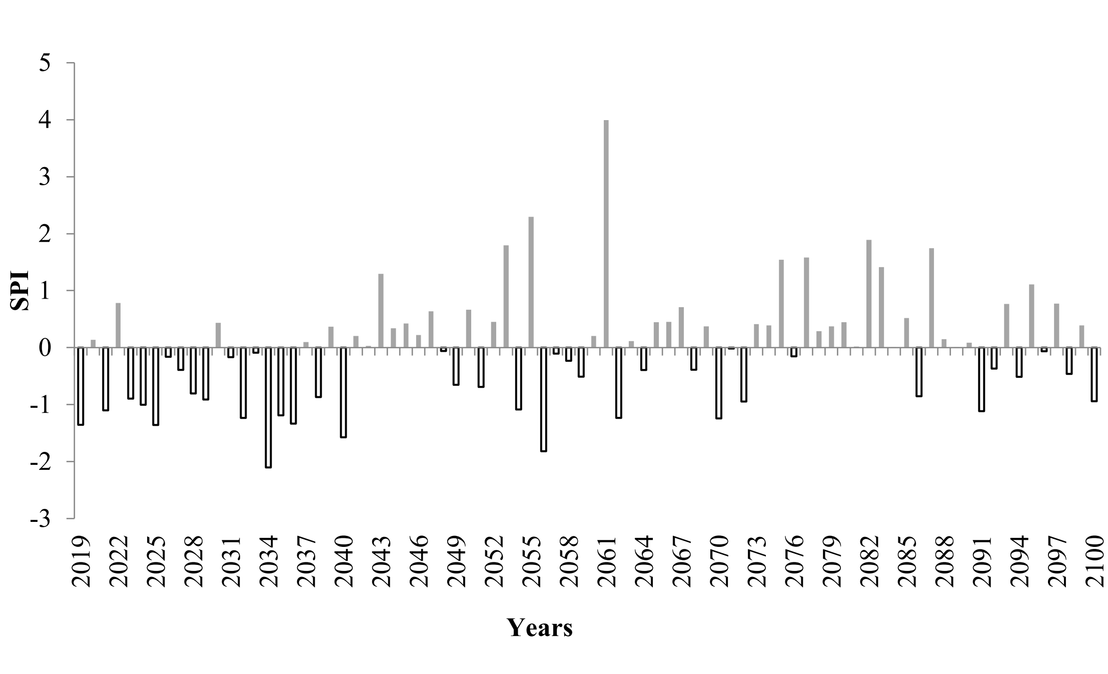

Fig. 4. Interannual Rainfall Variability by 2099

Conservation Status of Threatened Plants in the RB-BVO Listed on the IUCN Red List

Fifteen threatened plant species have been identified in the RB-BVO (Table 1). These include species classified as Endangered (EN), represented by two tree species (*Aphania senegalensis* and *Pterocarpus erinaceus*), Vulnerable (VU) species with nine trees (*Afzelia africana, Albizia ferruginea, Khaya senegalensis, Millettia warneckei, Nesogordonia papaverifera, Pierreodendron kerstingii, Pseudospondias microcarpa, Pterygota macrocarpa, and Ricinodendron heudelotii*), and four Near Threatened tree species (*Chrysophyllum albidum, Eucalyptus camaldulensis, Irvingia gabonensis, and Milicia excelsa*).

Table 1 List of Threatened Woody Plant Species in the RB-BVO

Scientific name	Family	Conservation status
Aphania senegalensis	Sapindaceae	EN
Pterocarpus erinaceus	Fabaceae	EN
Chrysophyllum albidum	Sapotaceae	NT
Eucalyptus camaldulensis	Myrtaceae	NT
Irvingia gabonensis	Simaroubaceae	NT
Milicia excelsa	Moraceae	NT
Afzelia africana	Caesalpiniaceae	VU

Scientific name	Family	Conservation status
Albizia ferruginea	Mimosaceae	VU
Khaya senegalensis	Meliaceae	VU
Millettia warneckei	Fabaceae	VU
Nesogordonia papaverifera	Sterculiaceae	VU
Pierreodendron kerstingii	Simaroubaceae	VU
Pseudospondias microcarpa	Anacardiaceae	VU
Pterygota macrocarpa	Sterculiaceae	VU
Ricinodendron heudelotii	Euphorbiaceae	VU

Impact of climate change on the distribution range of threatened plant species in the RB-BVO

Model Validation

Figure 5 shows the variation in AUC based on the conservation status of the studied species. The analysis of this figure indicates that for all species categories (Vulnerable, Endangered, and Near Threatened species), the Maxent models demonstrate good discriminatory ability for potential habitats (0.8 < AUC < 0.95).

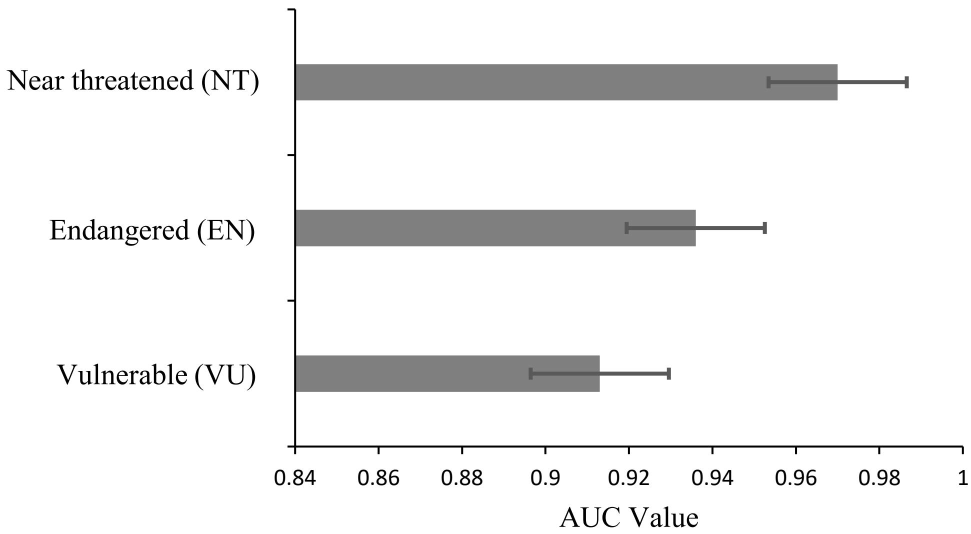

Fig. 5. Average AUC values of the different models

Contribution of Bioclimatic Variables

The analysis of the variables' contribution to the model indicates that potential evapotranspiration (PET), the duration of the longest dry season (LLDS), and the moisture index of the most humid quarter (MIMQ) are, in this order, the most significant variables, each contributing more than 10% (Table 2).

Table 2 Climatic Variables

bioclimatic Variables	Signification	Pourcentage of contribution
pet	Evapotranspiration potential	35.3
llds	Duration of the Longest Dry Season	32.8
mimq	Aridity Index of the Wettest Quarter	16.3
bio4	Temperature	14.9
SV	Gradient	0.6

Current and Future Habitat Distribution for Endangered (EN) Plant Species in the RB-BVO

Figure 6 illustrates the changes in the distribution range of endangered species and predicts their future distribution under RCP4.5 climate scenarios for 2055 and 2099. The results reveal that approximately 47% of the reserve's total area (1,568.49 km²) is currently suitable for the conservation of endangered plant species, while 1,034.53 km² (21% of the total area) is currently less favorable. Projections for 2055 and 2099 under the RCP4.5 scenario indicate a reduction in suitable habitats for endangered plant species by 42.55% in 2055 and 74.47% by 2099.

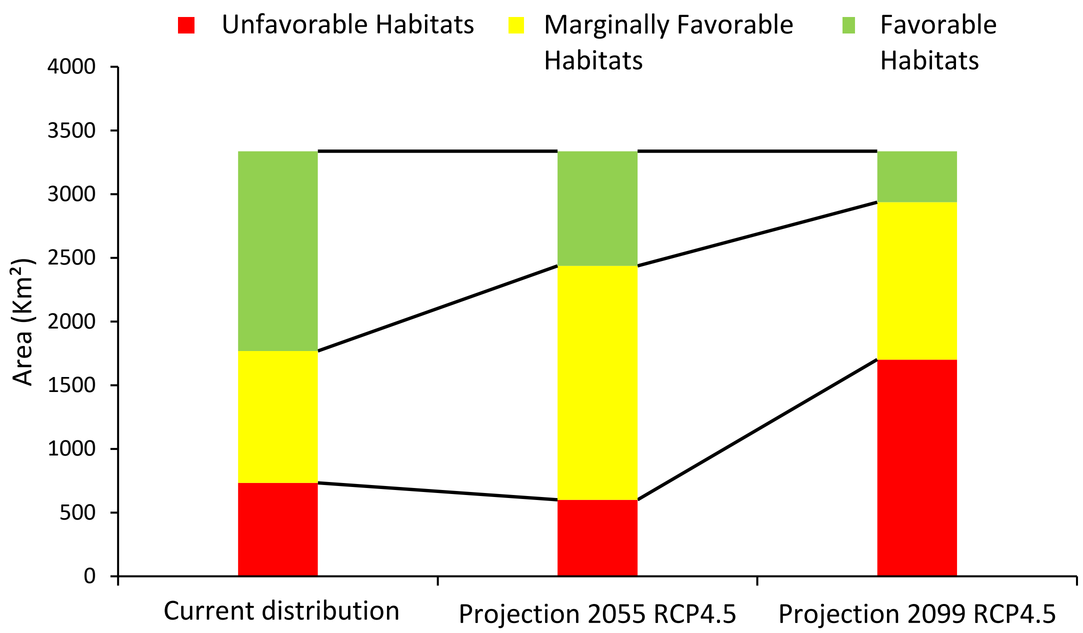

Fig. 6. Future habitat Distribution of endangered plant species in the RB-BVO

Figure 7 shows the current and future distribution of habitats for endangered (EN) plant species listed on the IUCN Red List within the RB-BVO. The analysis indicates that the wetlands around Lake Nokoué will remain favorable for species conservation by 2055 and 2099.

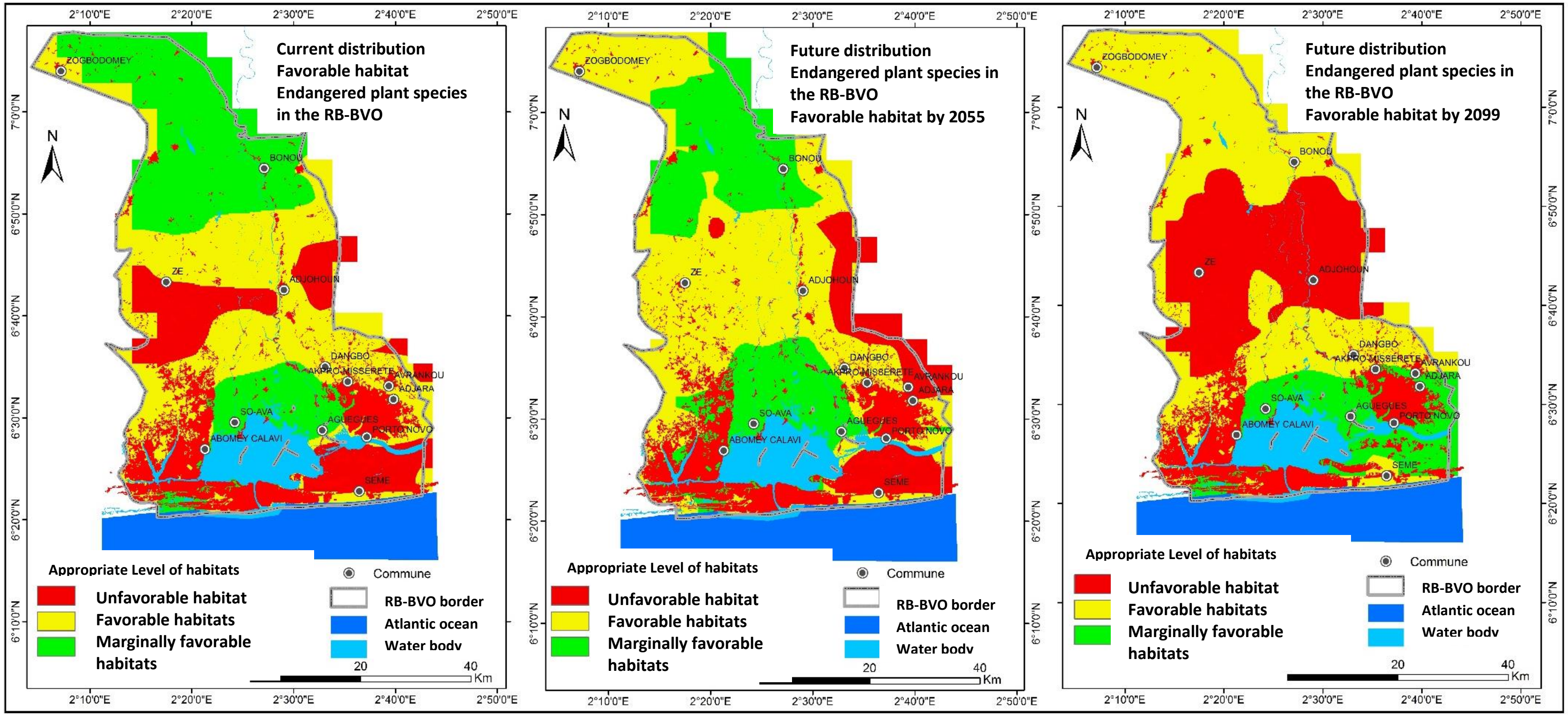

Fig. 7. Current and Future Habitats of IUCN-Listed Endangered Plants in the RB-BVO

Current and future habitats of vulnerable (VU) plants in the IUCN Red List in the RB-BVO

Modeling results show that 1,234.77 km² (37% of the RB-BVO area) is currently highly favorable for conserving vulnerable plant species (Figure 8). Projections for 2055 and 2099 under the RCP4.5 scenario indicate a reduction of 78.38% by 2055 and 67.57% by 2099 in suitable habitats (Figure 8). These results highlight the significant impact of future climate variability on plant habitats. However, the wetlands around Lake Nokoué will continue to support plant conservation (Figure 9).

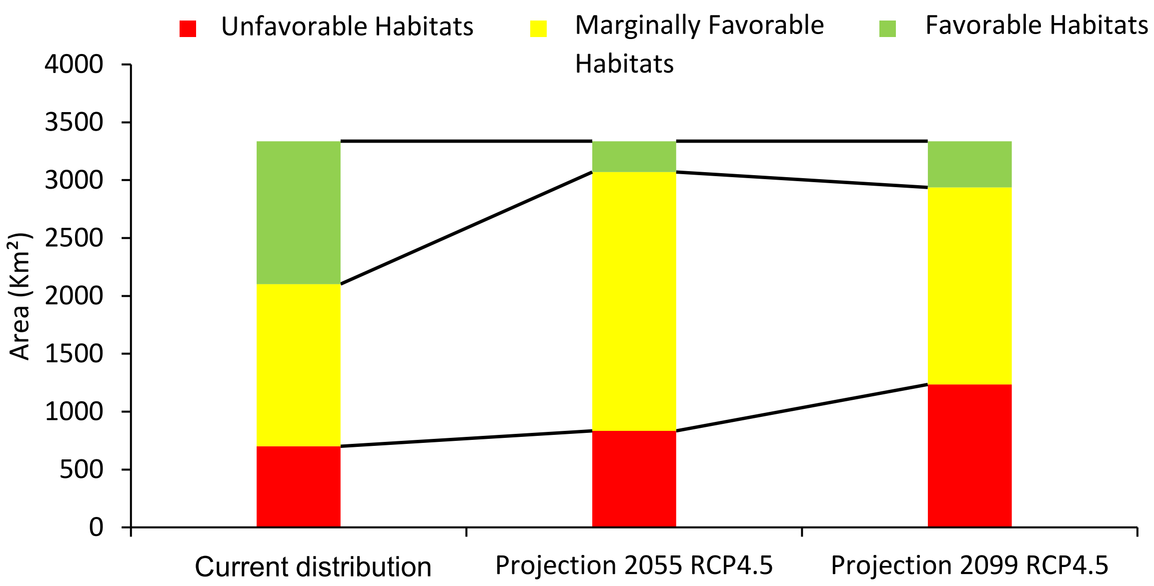

Fig. 8. Future Habitat Distribution of Vulnerable Plant Species in the RB-BVO.

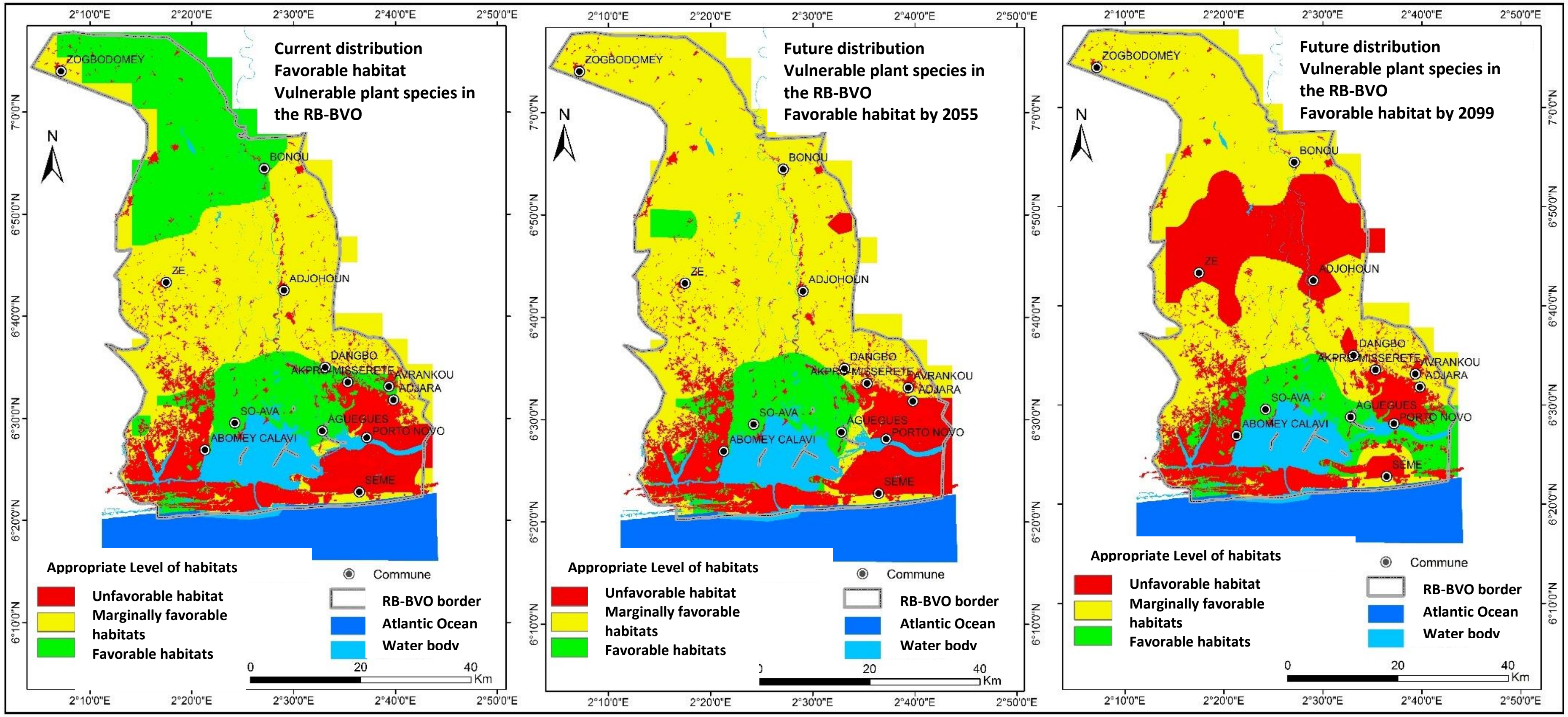

Fig. 9. Current and future habitats of Vulnerable (VU) plant species on the IUCN Red List in the RB-BVO

3.4.2.5. Current and Future Distribution of Habitats for Near-Threatened (NT) Plant Species on the IUCN Red List in the RB-BVO

Figures 10 and 11 show the distribution dynamics and projections for near-threatened plant species under the RCP4.5 climate scenarios for 2055 and 2099. Currently, about 15% of the reserve area is favorable for these species. Projections indicate a significant increase in favorable habitats by 2055 and 2099. While these projections are promising, it's important to note that most of the identified near-threatened species (*Chrysophyllum albidum, Eucalyptus camaldulensis, Irvingia gabonensis*, and *Milicia excelsa*) are already domesticated and may adapt better to disturbances than other species

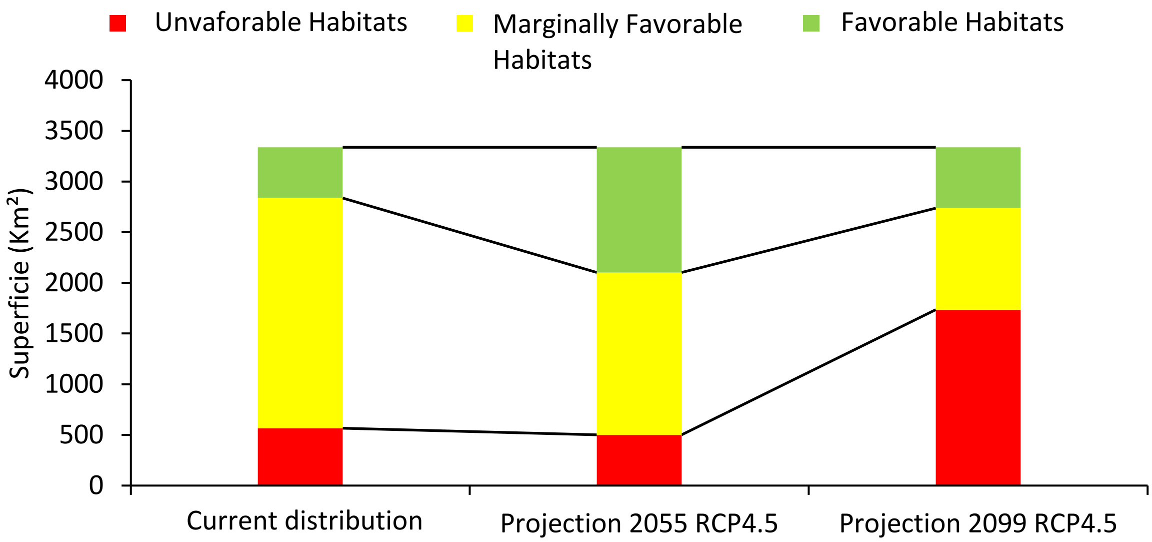

Fig. 10. Future Habitat Distribution of Near-Threatened Plant Species in the RB-BVO

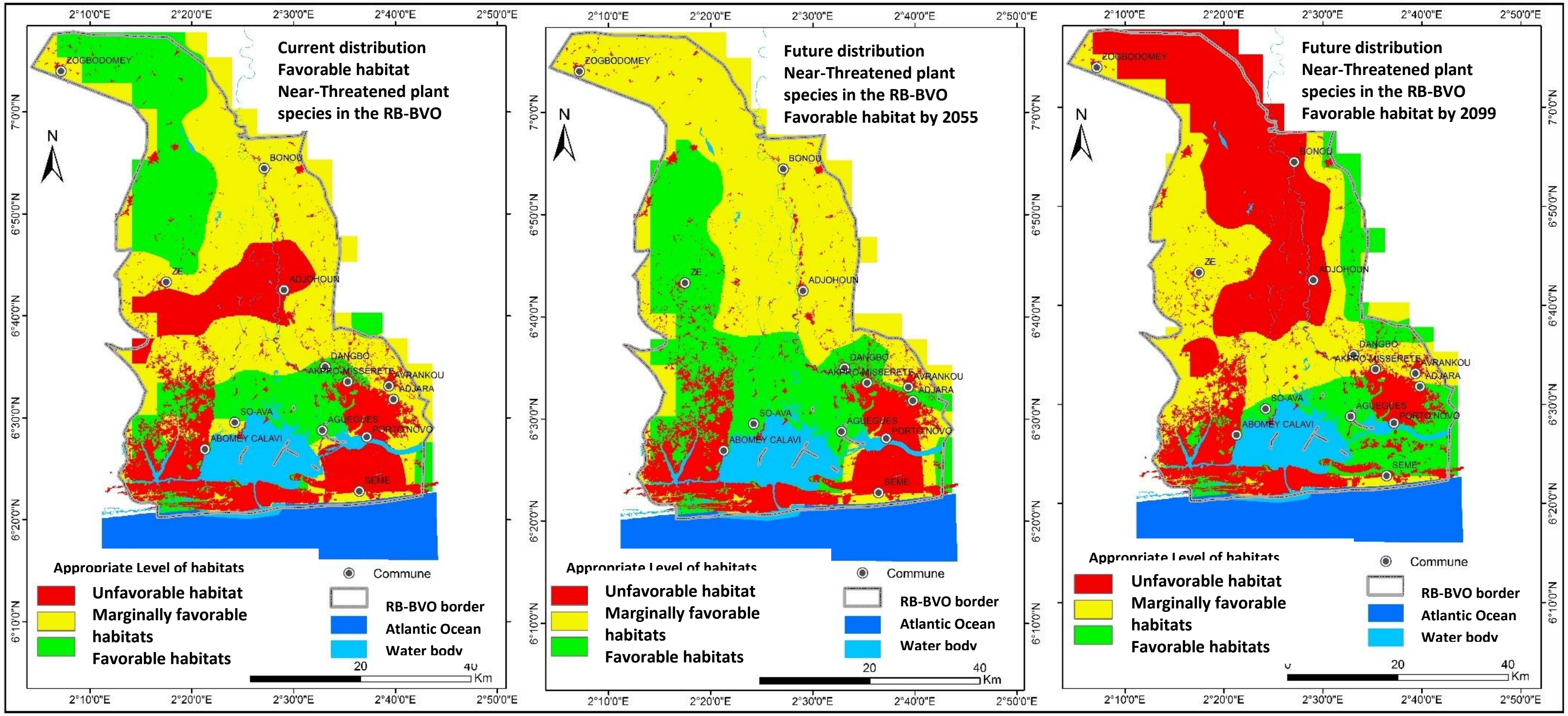

Fig. 11. Current and future habitats of Near-Threatened (NT) plant species on the IUCN Red List in the RB-BVO

Discussion

Projected Climate Trends in the RB-BVO by 2099

Analysis of climate projections for the RB-BVO (Mono–Couffo transboundary biosphere reserve) indicates a marked increase in annual temperatures, peaking at 30.23 °C in 2079—an increase of 2 °C compared to 2020. The Pettitt test, applied at a 99% confidence level, identifies a significant trend shift occurring in 2053, suggesting a lasting transition in the thermal regime. These findings are consistent with RCP4.5 scenario projections, which simulate a gradual yet steady rise in temperatures, particularly pronounced during the warmer months. Such thermal increases are not isolated. According to the IPCC (2021), intertropical regions could experience an average temperature rise of 1.5 to 2.5 °C by the end of the century under moderate scenarios, altering the phenology and geographic distribution of plant species. In particular, the longer periods of thermal stress observed in the RB-BVO simulation could affect flowering, fruiting, and even germination phases of many sensitive species (Walck et al., 2011). Regarding precipitation, projections show interannual variations ranging from 957.84 mm (2034) to 1704.66 mm (2061), with an average of 1215.47 mm and a relatively low standard deviation (122.47 mm, or about 10% of the average). These data reflect a decrease in future rainfall variability, estimated to be half as intense as current fluctuations. If confirmed, such stabilization could provide a more predictable framework for the local hydrological cycle—provided it is accompanied by a favorable seasonal distribution. However, interannual variability illustrated by 70% of anomaly values falling between -1 and +1—indicates a relatively stable distribution around the mean. This aligns with the findings of Milly et al. (2005), who suggest that while mean precipitation may change, relative variability could remain stable or even decrease in some tropical basins. Conversely, the combination of rising temperatures and reduced precipitation variability could pose ecological challenges. Several studies highlight that high temperatures coupled with stable humidity can disrupt plant water balance and increase evapotranspiration, reducing water availability for sensitive species (Allen et al., 2010; Vicente-Serrano et al., 2013). Moreover, species with low climatic plasticity—particularly endemic ones—may see their ecological niches shrink, favoring generalist or invasive species (Thuiller et al., 2005).

Impact of Climate Change on the Distribution Range of Threatened Plant Species in the RB-BVO

The Maxent models used in this study demonstrated satisfactory predictive performance for all categories of threatened species (Vulnerable, Endangered, Near Threatened), with AUC values ranging from 0.8 to 0.95. These results corroborate the findings of Yessito et al. (2022), who highlighted the effectiveness of correlative approaches—particularly Maxent—in modeling species distribution in Africa, while also warning about sampling biases and data quality. Additionally, studies conducted in West Africa have confirmed the relevance of these models in predicting the impacts of climate change on plant biodiversity (Gbesso et al., 2013; Oxfam, 2025; FFEM, 2015; GRAIN, 2009).

- **Contribution of Bioclimatic Variables**

Analysis of the bioclimatic variables revealed that potential evapotranspiration (PET), the length of the longest dry season (LLDS), and the moisture index of the wettest quarter (MIMQ) are the most influential factors, contributing 35.3%, 32.8%, and 16.3% to the model, respectively. These results highlight the importance of water-related factors in determining the distribution of plant species in the region, consistent with observations by Gbesso et al. (2013) on the influence of climate change on the geographic distribution of *Chrysophyllum albidum* in Benin. Other complementary studies have also emphasized the crucial role of these variables in modeling plant species distribution in West Africa (Mediaterre, 2020; FAO, 2004; FFEM, 2015; GRAIN, 2009).

- **Habitat Changes for Endangered Species (EN)**

Currently, about 47% of the RB-BVO area is suitable for the conservation of endangered species. However, projections for 2055 and 2099 under the RCP4.5 scenario indicate a significant reduction in suitable habitats, with a loss of 42.55% by 2055 and 74.47% by 2099. These projections align with trends observed in West Africa, where climate change exacerbates biodiversity loss, threatening human security and the livelihoods of local populations (Le Monde, 2024; Afrik21, 2024; Oxfam, 2025; FFEM, 2015; GRAIN, 2009).

- **Vulnerable Species: A Critical Situation**

For vulnerable species, the situation is particularly concerning. Currently, 37% of the RB-BVO constitutes highly suitable habitat, but this area could decrease by 78.38% by 2055 and 67.57% by 2099. These substantial losses illustrate the high sensitivity of these species to climate change, particularly due to forest fragmentation and habitat degradation—phenomena intensified by human activities and extreme climate conditions (Le Monde, 2024; Mediaterre, 2020; FAO, 2004; FFEM, 2015; GRAIN, 2009).

- **Near Threatened Species: A Contrasting Dynamic**

Unlike the other two groups, near threatened plant species appear to benefit from more favorable future conditions. Currently limited to 15% of the reserve’s area, projections for 2055 and 2099 indicate a potential expansion of suitable habitats. This dynamic may be explained by greater ecological plasticity and a degree of domestication for several of these species, such as *Chrysophyllum albidum*, *Eucalyptus camaldulensis*, *Irvingia* *gabonensis*, and *Milicia excelsa*, which provide increased tolerance to environmental disturbances (Gbesso et al., 2013; FAO, 2004; FFEM, 2015; GRAIN, 2009; Oxfam, 2025).

- **Implications for Conservation Strategy**

The projected reduction of suitable habitats for endangered and vulnerable species calls for a revision of conservation strategies in the RB-BVO. Priority actions could include:

- Protection and restoration of wetlands identified as climate refuges, particularly around Lake Nokoué, which play a crucial role in ecological resilience.
- Establishment of ecological corridors to facilitate species migration and maintain habitat connectivity.
- Integration of climate projections into protected area management plans, considering the specific impacts of climate change on local biodiversity.
- Use of ex-situ conservation methods (botanical gardens, seed banks) for the most threatened species, to preserve their genetic diversity.

Conclusion

The study on future climate vulnerability and its effects on threatened plant species in the RB-BVO revealed significant changes in climate parameters, impacting the phenology and habitats of these species. The findings confirm the intensification of climate change, particularly global warming, with a sharp rise in average temperatures projected by 2055 and 2099. This deteriorating climate strongly influences the habitats and ecology of plant species in general, and especially those at risk of extinction. Simulations of suitable habitats under the RCP4.5 scenario for 2055 and 2099 predict a notable reduction in the distribution range of threatened plant species.

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Data Availability

The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics and guidelines

Not applicable

Ethics approval and Consent to participate

This study did not involve human participants or animals and therefore did not require ethical approval. Not applicable, as this study did not involve human participants.

Ethics declaration missing.

Not applicable

Consent for publication

Not applicable.

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