

# Modeling Ecological Niches And Sustainable Management Of Piper Guineense In Côte d'Ivoire For Conservation And Domestication

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## Abstract:

**Background:** Ecosystem degradation due to anthropogenic pressure is a major threat to biodiversity in Côte d'Ivoire. *Piper guineense*, a medicinal and aromatic plant, is particularly affected by overexploitation in the areas around the Taï and Azagny national parks. This study aims to model the ecological niches conducive to the domestication of *P. guineense*, to analyze current harvest levels and commercial dynamics.

**Materials and Method:** Data on the presence and exploitation of *Piper guineense* in Côte d'Ivoire were collected from a literature review. The Maximum Entropy model was used to establish the ecological niche of the species and identify the most influential environmental variables. An ethnobotanical survey was conducted in the localities surrounding the Taï and Azagny national parks. Data on local dynamics around the exploitation of *Piper guineense* were collected.

**Results:** *Piper guineense* is mainly present in the dense rainforests of southern Côte d'Ivoire, with a marked dependence on minimum and maximum rainfall. Ecological modeling indicates probable areas of presence in the studied parks, with an AUC of 0.822, demonstrating the robustness of the model. Furthermore, ethnobotanical surveys reveal that 55.79% of harvesters around Taï Park and 47.5% around Azagny Park are non-natives, suggesting a strong economic dependence of these populations on this resource. Reported harvests are more abundant around Taï Park (1968 kg) than Azagny (1274 kg).

**Conclusion:** Domestication of *P. guineense* is proposed as a viable alternative to meet the growing demand, while reducing pressure on natural ecosystems. Conservation efforts will need to include awareness-raising initiatives, harvest quotas, and the introduction of agroforestry practices for sustainable management of this resource.

**Key Word:** *Piper guineense*; Ecological model; Effective niche; Overexploitation; Agroforestry conservation

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## I. Introduction

The degradation of natural ecosystems due to anthropization represents a growing threat to biodiversity in West Africa [1]. In Côte d'Ivoire, one of the species affected by this pressure is *Piper guineense*, a plant with medicinal and aromatic properties widely exploited by local populations [2]. Traditionally harvested in natural habitats, this species faces increased overexploitation, particularly in the riparian areas of Azagny National Park and Taï National Park, which represent the largest production areas in the country [3]. This excessive exploitation contributes to the fragmentation of ecosystems and threatens the sustainability of *P. guineense* populations. In addition, anthropogenic pressure is exacerbated by the lack of adequate regulation of harvest levels in natural habitats, which increases the vulnerability of the ecosystems where this plant is exploited [4]. To address these challenges, it is crucial not only to identify natural habitats suitable for the domestication of *Piper guineense*, but also to assess current harvest levels in natural habitats. Such an assessment would make it possible to quantify the impact of harvesting practices on the sustainability of natural populations and to better guide conservation efforts. In addition, an analysis of the marketing channels of *Piper guineense* is necessary in order to understand the value chain, market dynamics, and the actors involved in the exploitation and sale of this species. This knowledge is essential to identify intervention points likely to improve the sustainable management of the resource [5].

The domestication of *Piper guineense* appears to be a viable solution to reduce pressures on natural habitats while ensuring sustainable production [4]. However, the success of such an initiative requires the

identification of ecologically suitable habitats for this species outside protected areas. In parallel, knowledge of harvest levels and marketing channels will provide a global view of the sustainability of current practices. It is therefore crucial to analyze the environmental conditions favorable to the growth and reproduction of *P. guineense* in order to guide domestication efforts [6].

To do this, the Maxent ecological prediction model will be used in this study to determine the potential ecological niches of *Piper guineense* in Côte d'Ivoire. This model, based on the distribution of the species and environmental variables, will predict the areas most suitable for domestication, while taking into account the effects of anthropization and harvesting practices [7]. This approach will provide essential information for the conservation of biodiversity and the sustainable management of natural resources, by reducing dependence on natural ecosystems while ensuring sustainable production of this plant of socio-economic importance. This study aims to identify the areas and levels of exploitation of *Piper guineense* and then to formulate sustainable management solutions.

## II. Material And Methods

**Study site:** The Taï National Park, located in the southwest of the country, is home to one of the last large primary tropical forests in West Africa, covering 5,360 km<sup>2</sup>. The vegetation is dense and humid, with a canopy rich in endemic tree species, favoring the presence of emblematic fauna, including chimpanzees, forest elephants, the Jentink's duiker (*Cephalophus jentinki*), the pygmy hippopotamus [1]. This park, listed as a UNESCO World Heritage Site, is essential for the conservation of regional biodiversity, but it is under increasing pressure due to agricultural exploitation by local populations [3].

The Azagny National Park, for its part, is located in the south of Côte d'Ivoire and covers 19,400 hectares. This park is distinguished by a mosaic of ecosystems, composed of swamp forests, savannahs, lagoons and mangroves. The wetland vegetation provides a unique habitat for species such as the African manatee (*Trichechus senegalensis*) and many bird species. The mangroves in the region play a crucial role in stabilizing the coasts and protecting lagoon ecosystems [5]. However, like Taï Park, Azagny is experiencing increasing anthropogenic pressure due to fishing, deforestation for agriculture and overexploitation of non-timber forest resources, particularly *Piper guineense* [2].

**Data collection:** To assess the presence and exploitation of *Piper guineense* in Côte d'Ivoire, a collection of bibliographic data was necessary in order to identify the information available on this species, in relation to its use, its natural habitats, and the economic activities that depend on it. Online data as well as the herbarium of the Swiss Center for Scientific Research and the national herbarium of Côte d'Ivoire at the National Center of Floristry were also consulted. The collection also includes scientific publications, technical reports, and theses dealing with the phytogeography of Côte d'Ivoire and traditional practices of exploitation of *Piper guineense*. An ethnobotanical survey was organized in the localities surrounding the two parks. This ethnobotanical survey made it possible to collect data on the local dynamics around the exploitation of *Piper guineense*, with an emphasis on the collection sites, the quantities harvested, the sales channels and the populations involved in this chain of activities. Market visits as well as open or semi-structured interviews were conducted. Focus groups were organized in two agricultural cooperatives. The localities concerned by the survey around the Taï National Park are Zagné, Para, Grabo, Taï, Djouroutou, Pékanhouébli, Gouléako 1, Gouléako 2, Sayo, Soubéré, Diéréoua, Péhé, Pillibly. The surveys carried out around the Azagny National Park concerned the localities of Grand-Lahou, Braffedon, Ahouanou, Azagny, Ebounou, Toukouzou, Ebrah, Lolobo, N'zida, Ahougnanfoutou, Gbédégbé, Attoutou.

**Study Duration:** From January 2023 to April 2024

**Data analysis:** Local dynamics consisted of identifying regional differences in *Piper guineense* exploitation practices between the localities around the Taï National Park and the Azagny National Park. This will include comparisons of collection methods, seasonality, and harvest intensity. The cooperatives made it possible to analyze the information from the focus groups to understand their role in organizing collections, managing harvested quantities, and their access to markets. Quantitative analyses were carried out for the quantities of *Piper guineense* reported and comparison tests were performed. Product flows through the different sales channels (local, regional, national) were quantified.

The *Piper guineense* presence data were modeled by maximum entropy to determine the probabilities of the species' presence throughout the territory. Georeferenced points from localities around the Taï and Azagny National Parks, as well as classified and community forests where the plant is collected, bibliographic sources and the GBIF (Global Biodiversity Information Facility) database were used [8]. These data were consolidated into a CSV file containing the geographic coordinates of the points of occurrence. Environmental variables [9] that influence the distribution of *Piper guineense* were collected from climate data [10],

topographic data such as Digital Terrain Model and vegetation cover variations. All these variables were standardized in the same spatial resolution of 30 meters and converted to ASCII format compatible with Maxent.

### III. Result

The surveys in the Taï National Park area allowed 337 people to be interviewed in 13 localities. Only people linked to the exploitation activities of *Piper guineense* were interviewed. The indigenous Guéré and Oubi constitute 14.24% of the people surveyed. The Baoulé and Malinké and Sénoufo non-natives represent 29.97% of the people surveyed, the non-natives from Liberia, Guinea, Mali and Burkina Faso represent 55.79% of the people interviewed.

Around the Azagny National Park, 442 individuals were interviewed in all 12 locations visited. The indigenous people, represented by the Ahizi and the Avikam, constitute 11% of the populations surveyed. The non-natives represent 41.5% of those interviewed. They are composed of Baoulé, Abbey, Gouro, Malinké and Sénoufo. As for the non-natives, they constitute 47.5% of those interviewed. This class is essentially made up of Mossi living in the same camps as the non-natives.

The reported collection sites for *Piper guineense* fruits in the surrounding area of Taï National Park are residual forests, cocoa plantations and the interior of Taï National Park. The surveyed populations stated that they carry out the majority of their harvests in the park which still shelters the natural ecosystems of the plant. In the localities bordering Azagny National Park, the populations stated that *Piper guineense* is almost absent in the riparian areas. Most of the harvests are carried out inside Azagny National Park.

In the Taï National Park area, the cumulative harvests reported by the interviewees are 1968 kg for the year 2023. The minimum value is recorded in the city of Taï with 19 kg harvested, then the maximum value is recorded in the city of Soubré with 409 kg. The average value per locality around the Taï National Park is  $151.38 \pm 124.91$  kg. As for the peripheral area of the Azagny National Park, the harvests reported by the local populations accumulate to 1274 kg in 2023. The minimum value of 19 kg was reported in Ahouanou, then the maximum harvest of 385 kg in Grand-Lahou. The average harvest for localities in the Azagny National Park area is  $106.17 \pm 119.78$  kg in 2023. Harvests around Taï National Park are significantly more abundant than those recorded around Azagny National Park (Mann-Whitney U test,  $U = 95$ ;  $\rho = 0.369$ ).

Part of the harvest is intended for consumption by local populations. *Piper guineense* is preferably used in food, medicine and marketed on local markets by all the populations interviewed. This part is estimated at 8% of the total production on all the different sites. The majority of the *Piper guineense* harvests are sold to wholesalers. The points of sale in the Azagny National Park area are the Grand-Lahou and Irobo markets. In the Taï National Park area, the wholesalers' points of sale are the Soubré, Guiglo and Duekoué markets. The *Piper guineense* grains purchased in these markets are resold in Abidjan and in the countries bordering Côte d'Ivoire.

Modeling of the ecological niche of *Piper guineense* shows that it is a common species in the dense rainforests of the southern forest of Côte d'Ivoire (Figure 1). The observed values show that the probabilities of presence vary between 43% and 56% and then between 57% and 89% depending on the different habitats of the Taï and Azagny national parks.

The realized Maxent model has a stable predictive performance, with a mean area under the curve (AUC) of  $0.822 \pm 0.041$ , indicating a good discrimination of the model between the presence and absence zones of the modeled species. The contributions of the environmental variables to the Maxent model are summarized in Table 1. These estimates show the increase in the regularized gain at each iteration of the model and the importance of the permutations, where the model performance is re-evaluated after randomly permuting the values of each variable. The variable with the highest contribution to the model is "Minimum Precipitation" (36.4%), followed by "Maximum Temperature" (20.1%). In terms of importance per permutation, "Minimum Precipitation" remains the most influential, confirming its crucial role in predicting the distribution of the species.

The Jackknife test of the environmental variables reveals that Mean Temperature has the highest gain when used alone, suggesting that it contains significant information when isolated. However, excluding Minimum Precipitation results in the greatest decrease in gain, meaning that this variable provides unique information not present in the other variables. This indicates that "Minimum Precipitation" and "Mean Temperature" play a central role in the Maxent model prediction for this species.

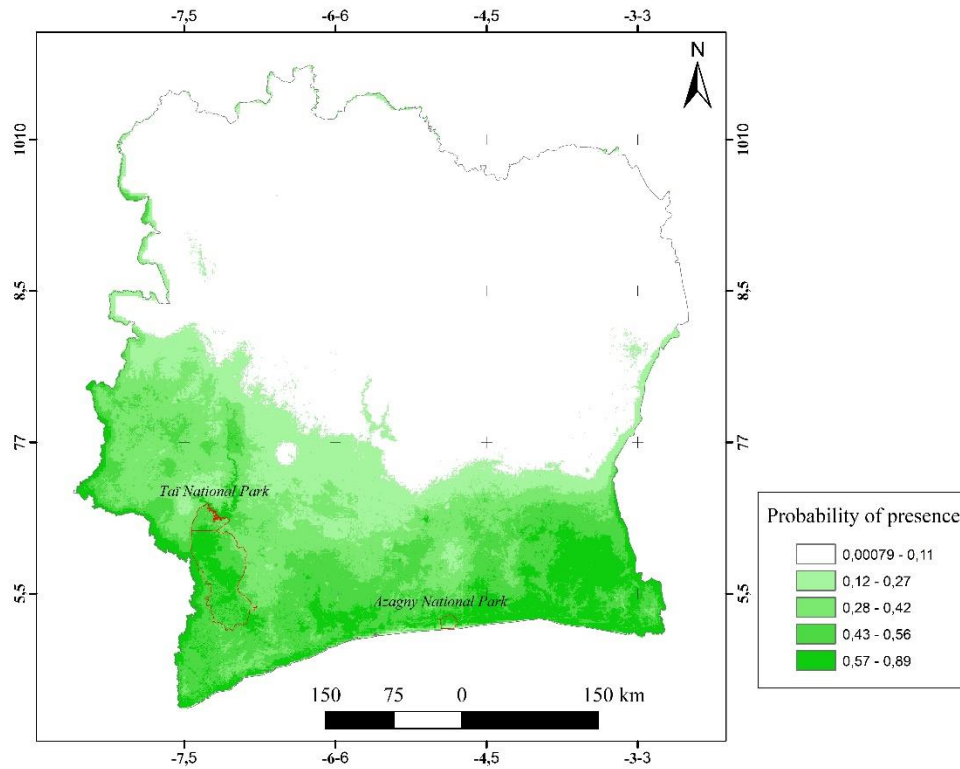


Figure 1. Ecological niche of *Piper guineense* in Côte d'Ivoire

Table 1. Contributions of variables in the formation of the distribution model

Variables	Contribution (%)	Importance per permutation (%)
Minimum precipitation	36.4	32
Maximum temperature	20.1	19.2
Maximum precipitation	14.6	9.8
Average temperature	9.2	14
Altitude	6.5	12
Precipitation standard deviation	3.4	3.9
Humidity	2.8	3.3
Standard deviation Temperatures	2.4	1.4
Average precipitation	1.9	2.5
NDVI	1.6	1.9
Minimum temperature	1.1	0.1

#### IV. Discussion

The use of *Piper guineense* by local populations for food, traditional medicine and trade demonstrates the socio-economic importance of this resource. However, increasing pressure on forests, particularly through logging within national parks, could pose challenges to the sustainability of this exploitation. Further efforts are needed to regulate harvesting practices and promote economic alternatives to reduce pressure on the parks' natural resources [11].

Analysis of the populations surveyed in the two regions highlights the ethnic diversity of the collectors, with a notable proportion of allochthons and allogenes, particularly in the area of the Taï National Park, where they represent 55.79% of the people interviewed. This strong presence could reflect the economic dependence of non-indigenous populations on forest resources for their subsistence, as has been observed in other studies on the dynamics of allogeneic populations in conservation areas in West Africa [12].

Modeling the ecological niche of *Piper guineense* with the Maxent model shows that this species is mainly associated with dense rainforests in southern Côte d'Ivoire, with high probabilities of presence in the Taï and Azagny parks. The model has an average AUC of  $0.822 \pm 0.041$ , indicating a good ability to discriminate areas favorable to the presence of the species. These results are consistent with those obtained by [7], which highlight the effectiveness of Maxent for species with a restricted niche.

Minimum Precipitation is the most important variable in predicting the distribution of *Piper guineense*, contributing 36.4% to the model. This variable is closely followed by Maximum Temperature (20.1%) and Maximum Precipitation (14.6%). The predominant role of precipitation-related variables in this model is consistent with the biological characteristics of *Piper guineense*, a species highly dependent on water regimes in its environment [13].

Domestication of *Piper guineense* could offer a sustainable solution to meet commercial and local demand while minimizing environmental impacts. Indeed, domestication of non-timber forest plants (NTFPs), as has been observed in other regions of Africa, not only ensures continued production, but also improves the quality and quantity of harvests [14].

One of the main constraints to the domestication of *Piper guineense* is the poor knowledge of cultivation techniques adapted to this species. Currently, the majority of harvests come from wild populations located in national parks, which exposes the species to risks of overexploitation. However, domestication experiences of NTFPs in West Africa, such as *Dacryodes edulis* and *Irvingia gabonensis*, have shown that introducing these species into agroforestry systems promotes both food security and income generation for local communities [15]. Domestication of *Piper guineense* could follow a similar approach, integrating this plant into existing agroforestry systems, such as cocoa plantations, where it could benefit from the shade provided by cocoa trees, while reducing pressures on forest resources.

Domestication efforts will need to be accompanied by robust conservation policies to ensure the protection of remaining wild populations in national parks. Initiatives such as raising awareness among local communities, implementing harvest quotas in classified forests, and introducing innovative agroforestry practices could help reconcile conservation and socio-economic development [16].

## V. Conclusion

This study provided a detailed overview of the exploitation and distribution of *Piper guineense* in the peripheral areas of the Taï and Azagny national parks in Côte d'Ivoire. The results show significant pressure on the natural resources of these protected areas, where *Piper guineense* harvests are largely concentrated, despite existing regulations. The collection mainly carried out in residual forests and inside national parks is evidence of unsustainable exploitation of wild populations of the species. Modeling of the ecological niche of *Piper guineense* confirms that minimum rainfall and maximum temperature are determining environmental factors in its spatial distribution.

However, the domestication of *Piper guineense* appears to be a promising solution to reduce the pressure on protected ecosystems, while maintaining a sustainable supply for local and international markets. This strategy could not only contribute to the preservation of natural habitats, but also improve the living conditions of local communities by offering an economic alternative to unsustainable logging.

Future efforts will need to focus on developing appropriate domestication techniques and integrating this species into agroforestry systems, while strengthening conservation policies. Integrated management, combining domestication and regulation of wild harvests, seems essential to reconcile the conservation of natural resources and the socio-economic development of local populations

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