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# Analysis of the impact of the use of and of climate on the vulnerability and availability of *Macaranga beillei* in Côte d'Ivoire

**KOFFI KOUAO JEAN[1,♥], YAO N'GUETTIA FRANCIS[1], TUO FATOU[1], KONE MOUSSA[1], ADAMA BAKAYOKO[1,2], JAN BOGAERT[3]**

[1]Nangui Abrogoua University. UFR-SN, 02 BP 801 Abidjan 02, Côte d'Ivoire. Tel./fax.: +225-747589663, ♥email: kouaojean@yahoo.fr
[2]Swiss Center for Scientific Research in Côte d'Ivoire. 01 BP 1303 Abidjan, Côte d'Ivoire
[3]Gembloux Agro-Bio Tech, Biodiversity and Landscape Unit, University of Liege. Passage of the Deportees, 2, B-5030 Gembloux, Belgique

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**Abstract.** *Jean KK, Francis YN, Fatou T, Moussa K, Bakayoko A, Bogaert J. 2022. Analysis of the impact of the use of and of climate on the vulnerability and availability of* Macaranga beillei *in Côte d'Ivoire. Biodiversitas 23: 5396-5405. Macaranga beillei* Prain is a vulnerable species of the Euphorbiaceae family, used in traditional medicine, and whose habitat is threatened by anthropogenic activities. This study is a contribution to the knowledge of the causes of the threat of this species in Côte d'Ivoire. The database used includes data from the SIG IVOIRE database (Gautier et al. 1999), the flora of Côte d'Ivoire (Aké Assi 2001), the GBIF website (Global Biodiversity Information Facility, wwwgbif.org) and the Paris Museum website (http://www.mnhn.fr/fr/collection). The QGIS software (Quantum GIS) version Lyon 2.12.3. and the MaxEnt (Maximum Entropy) model was used to produce potential distribution maps for the periods 1950-2000 and 2000-2050. A questionnaire was developed for the ethnobotanical survey. It emerges from this analysis that the Banco National Park is the most sampled locality with 38 samples out of 72, i.e. a rate of 52.77%. The value of the species vulnerability risk index (VI) is 2.46. In 2050, the range of the species will decrease by 6,696.127 km². The assessed extent of occurrence (EOO) and area of occupancy (AOO) values are 5,848.921 km² and 72.000 km² respectively. These results confirm that *M. beillei* is a vulnerable species.

**Keywords:** Côte d'Ivoire, ethnobotanical survey, Euphorbiaceae, *Macaranga beillei*, vulnerable species

## INTRODUCTION

Despite the International Community's longstanding interest in tropical rainforests, the latter remain endangered. Every year, more than 13 million hectares of forest disappear at an alarming rate. Thus, the West African ecosystems, which are the most varied on the planet and with a high rate of endemism (Koffi et al. 2015), are unfortunately subject to all kinds of pressure that cause their gradual degradation. Anthropogenic actions are the main causes of this degradation.

In Côte d'Ivoire, the dense rainforest, which covered approximately 15.000.000 hectares in the 1900s, has been subjected to heavy agricultural pressures and logging (Kouamé 1998) since 1980. This situation has inevitably led to a significant decline in the forest area, which is now estimated at 2.6 million hectares (Koné et al. 2014). Thus, the most observed consequences are the loss of biodiversity, the degradation of the quality of human life, the increase in the poverty rate and in land conflicts.

According to the World Health Organization, more than 80% of African populations use traditional medicine and pharmacopeia to deal with health problems using plants. However, these species, mostly ligneous, are directly used in several fields such as energy, industry, food and many others. Similarly, thanks to the appearance of certain woody species considered biophysical indicators, farmers were able to follow the evolution of the fertility of their fallow lands and determine the time to cultivate them again. This highlights the need to increase knowledge about the distribution of biotic communities in order to provide a basis for the development of future conservation strategies and sustainable use of biodiversity. However, local woody species are needed in several areas and this leads to their overexploitation. In addition, there are the harmful effects of climatic hazards which cause, on the one hand, the fragility of ecosystems and, on the other hand, the disappearance of many species (Daniabla et al. 2012; Ouattara et al. 2016; Malan et al. 2020). This is the case of *Macaranga beillei* Prain, a species of the Euphorbiaceae family. It is a shrub that can reach 5 meters in height. Indeed, the bibliography relating to this species reveals that *M. beillei* has been declared vulnerable according to the International Union for Conservation of Nature (IUCN 2020). Also, it should be noted that it is an endemic species to the Côte d'Ivoire-Ghana forest block. (William and Carel 2006). In addition, it is used in traditional medicine to treat cough (Piba 2016). Its habitat is littoral forests. However, Lachenaud (2004), points out that the vulnerability of this species is strongly due to anthropic activities which have greatly reduced its habitat.

However, in spite of this information, no study has been carried out specifically on this species in order to identify the causes of its vulnerability. The current issues related to the utility or the attribution of a capacity to ecosystem services to meet the needs of communities raise several

questions, among which this one catches our attention: Does the importance? Of a plant species explain its vulnerability? To answer this question, an ethnobotanical investigation is imperative, hence the initiation of this study entitled "Analysis of the impact of the use and of climate on the vulnerability and availability of *M. beillei"*. Thus, this preliminary study comes as a contribution to the knowledge of the real causes of the vulnerability of plant species in Côte d'Ivoire in general and in particular of *M. beillei*. Specifically, it will be a question of making an analysis of the potential distribution and an ethnobotanical survey with herbalists in view of a deduction of the main causes of the vulnerability of this species.

## MATERIALS AND METHODS

### Study area

The sampling was done throughout Côte d'Ivoire. Indeed, located in West Africa between the coordinates 4°30 to 10°30 North latitude and 2°30 to 8°30 West longitude, Côte d'Ivoire covers 322,462 km. It is bounded respectively to the north by Burkina Faso and Mali, to the west by Guinea, to the east by Ghana and to the south by the Atlantic Ocean (Djè 2014). Two major types of plant landscapes make up the Ivorian territory: a forest landscape and a savannah landscape (Brou 2005). The lower Côte d'Ivoire is occupied by the forest massifs of the South and the South-West to which the mountainous massif of Man is attached. It is covered with a dense evergreen rainforest (ombrophilous sector). Above the lower forested Côte d'Ivoire, there is an area covered with dense semideciduous forest (mesophilic sector). The pre-forest Côte d'Ivoire occupies, on the one hand, the "V Baoulé" and on the other hand a central band located above the mesophilic forest. Blocks and islets of dense mesophilic humid forest and dense dry forest are included in a more or less wooded savannah belonging to the Guinean and sub-Sudanese savannahs (Figure 1).

### Materials

The samples of *M. beillei* come from different databases: SIG IVOIRE (Gautier et al. 1999), flora of Côte d'Ivoire (Aké Assi 2001), GBIF site (Global Biodiversty Information Facility, www.gbif.org), Museum of Paris htt://www.mnhn.fr/fr/collection. QGIS software (Quantum GIS) Lyon version 2.12.3 was used to produce the spatial distribution maps. The MaxEnt (Maximum Entropy) model was used to produce potential species distribution maps (Phillips et al. 2006). GeoCat (Geospatial Conservation Assessment Tool: http://geocat.kew.org/) which is an open-source tool was used for the assessment of the Red List status of the species.

### Data collection

The methodology used for collecting data from *M. beillei* consists in establishing a compiled database. Indeed, this new database is made up of different samples collected from various sources. It includes both the total number of samples, the different localities sampled and the geographical coordinates of these localities.

### Environmental impacts on the current availability of *Macaranga beillei*

*Potential distribution of* Macaranga beillei

The potential distribution map of *M. beillei* will be produced to highlight the influence of environmental parameters. Thus, a matrix with the occurrences of the species and the geographical coordinates has been produced. This database, after being transformed from the Excel file into csv format (separator, semicolon), was submitted to the MaxEnt model Species Distribution Modeling, version 3.3, for the realization of the potential distribution map. Environmental variables were obtained from Worldclim (http://www.worldclim.org/). They cover the period from 1950 to 2000 for the current potential distribution and from 2000 to 2050 for the future potential distribution. The variables are mean precipitation, minimum and maximum temperature and 19 bioclimatic variables (BIOCLIM: http://www.worldclim.org/bioclim.htm) that can influence species distribution (Table 1).

To evaluate the predictive capacity of a model generated by MaxEnt, the AUC (Area Under Curve) is used, which is the area under the ROC (Receiver Operating Characteristic) curve. Its interpretation is summarized in Table 2 (Araújo et al. 2005). However, the purpose of the potential distribution in this work is to achieve the modeling of the ecological niche of *M. beillei*, determine the climatic factors that influence its dispersal.

*Current distribution of* Macaranga beillei

From the distribution map, the current availability and existence of previously sampled species were verified. This method has been used by many researchers, such as Kouadja et al. (2022), Kambiré (2018) and Grévin et al. (2021). Indeed, inventories relating to *M. beillei* were carried out from 1905 to 2002 mainly by Aké Assi and his collaborators.

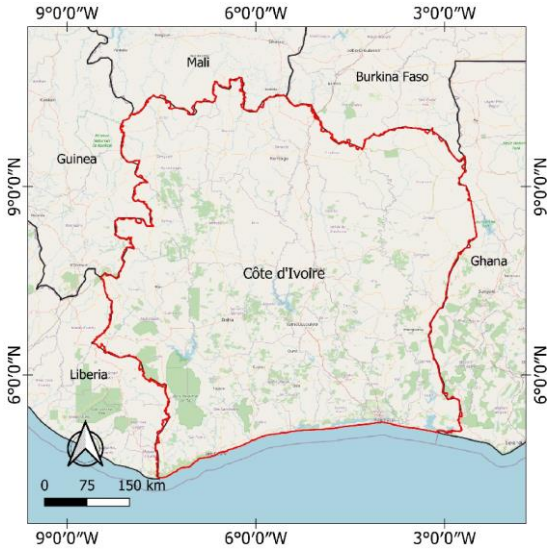


**Figure 1.** Location of Côte d'Ivoire

**Table 1.** BIOCLIM environmental variables are used to generate the potential distribution maps (http://www.worldclim.org/bioclim.htm)

| | **Bioclimatic variables** |
|---|---|
| Bio 1 | Annual Mean Temperature |
| Bio 2 | Mean Diurnal Range (Mean of monthly (max temp-min temp)) |
| Bio 3 | Isothermality (BIO2/BIO7) (×100) |
| Bio 4 | Temperature Seasonality (standard deviation ×100) |
| Bio 5 | Max Temperature of Warmest Month |
| Bio 6 | Min Temperature of Coldest Month |
| Bio 7 | Temperature Annual Range (BIO5-BIO6) |
| Bio 8 | Mean Temperature of Wettest Quarter |
| Bio 9 | Mean Temperature of Driest Quarter |
| Bio 10 | Mean Temperature of Warmest Quarter |
| Bio 11 | Mean Temperature of Coldest Quarter |
| Bio 12 | Annual Precipitation |
| Bio 13 | Precipitation of Wettest Month |
| Bio 14 | Precipitation of Driest Month |
| Bio 15 | Precipitation Seasonality (Coefficient of Variation) |
| Bio 16 | Precipitation of Wettest Quarter |
| Bio 17 | Precipitation of Driest Quarter |
| Bio 18 | Precipitation of Warmest Quarter |
| Bio 19 | Precipitation of Warmest Quarter |

**Table 2.** Validity of the MaxENT test according to the AUC values obtained (Araújo et al. 2005)

| **Interpretations** | **Values** |
|---|---|
| Excellent | 1.00 > AUC > 0.90 |
| Good | 0.80 < AUC < 0.90 |
| Acceptable | 0.70 < AUC < 0.80 |
| Bad | 0.60 < AUC < 0.70 |
| Invalid | 0.50 < AUC < 0.60 |

Thus, in order to know the current availability of this species given its special status, it is important to check the areas already explored to see the existence of the species. Also, a recent work by Lachenaud (2004) has shown that the spatial distribution area of *M. beillei* has been essentially reduced by anthropogenic activities and currently, Banco National Park is the last refuge of the species. This is how we chose the Banco National Park to carry out this verification of the current availability of *M. beillei*. In that respect, a hiking inventory with a spatial distribution map was conducted. The geographical coordinates of the samples were projected as a point on the map of Banco National Park which served as a means of orientation. Then, the same geographical coordinates of the samples were introduced into a GPS in order to locate these points. This is to verify the presence or absence of the species. All this work was done with the help of a guide from the Ivorian Office of Parks and Reserves (OIPR).

**Assessment of the status of the species**

With the "Start a new project" command of the GeoCat tool, data of *M. beillei* occurrences were imported and projected onto the world map for spatial visibility. Points that do not conform to the spatial distribution have been removed to avoid errors in the spatial assessment of the extent of occurrence (EOO) and area of occupancy (AOO). The evaluation of the area of occurrence (EOO) and the area of occupancy (AOO) was made from the command "Active EOO/AOO". The vulnerability of *M. beillei* was determined by reference to part B of the summary of the five criteria (A-E) used to assess whether a taxon belongs to one of the categories of the "threatened" group (Critically endangered, Endangered or Vulnerable) of the IUCN Red List (Table 3).

**Impact of uses on the availability of *Macaranga beillei***

*Ethnobotanical survey*

Ethnobotany, a contraction of ethnology and botany, is the study of the relationship between humans and plants. The bibliography relating to *M. beillei* reveals that it is a vulnerable species (IUCN 2020), endemic to the Côte d'Ivoire-Ghana forest block. (William and Carel 2006) and used in traditional medicine to treat coughs (Piba 2016). Unfortunately, for some authors like Lachenaud (2004), *M. beillei* is found in a very restricted area in the Abidjan-Dabou region. However, its habitat is highly threatened by human activities. Today, its survival practically depends on that of the Banco National Park.

Since this species has been mentioned among the medicinal species and even named locally by certain ethnic groups in Côte d'Ivoire (Abbey: *tofé*; Ebriés: *aboué*; Agnis: *ecba*; Gouros: *fonofa*) an ethnobotanical survey will more or less identify the causes of its vulnerability in addition to those already known. Thus, the objective of this survey is to know the availability of this species and the causes of its current status from the information given by herbalists on the method of organ removal, the uses and the place of removal of the species.

*Survey preparation*

Based on the work of Lachenaud (2004), which stipulates that *M. beillei* covers a very restricted area in the Abidjan-Dabou region, and also refers to the localities sampled by Aké Assi and his collaborators (Table S1), the ethnobotanical survey was limited to the District of Abidjan. Before choosing the survey site, a prospecting study was conducted. The objective of this survey is to identify the different markets for medicinal plants in the District of Abidjan. This is why the large markets of the different communes of the District of Abidjan were visited. The selection criteria are essentially based on the number of exhibitions, i.e. the number of stands (more than 50), the diversity and the number of plants sold. This prospecting phase lasted 1 month (September 1 to 30, 2020).

**Table 3.** Part B of the summary of the five criteria (A-E) used for the assessment of the status of a species

| **Geographic distribution, whether B1 (extent of occurrence) (EOO) and/or B2 (area of occupancy)** | | | |
|---|---|---|---|
| **Statut** | **Critically endangered** | **Endangered** | **Vulnerable** |
| B1. extent of occurrence (EOO) | < 100 km² | < 5 000 km² | < 20 000 km² |
| B2. area of occupancy (AOO) | < 10 km² | < 5 00 km² | < 2000 km² |

**Table S1.** Samples of *Macaranga beillei* collected by Aké Assi and his collaborators (1905-2002)

| No. | Species | Harvest locations | Harvest date |
|---|---|---|---|
| 1 | *M. beillei* | Abou-abou | 1969 |
| 2 | *M. beillei* | Abou-abou | 1969 |
| 3 | *M. beillei* | Accradio | - |
| 4 | *M. beillei* | Aghien, village | 1976 |
| 5 | *M. beillei* | Aghien, village | 1968 |
| 6 | *M. beillei* | Banco | 1975 |
| 7 | *M. beillei* | Banco | 1969 |
| 8 | *M. beillei* | Banco | 1969 |
| 9 | *M. beillei* | Banco | 1958 |
| 10 | *M. beillei* | Banco | 1972 |
| 11 | *M. beillei* | Banco | 1976 |
| 12 | *M. beillei* | Banco | 1973 |
| 13 | *M. beillei* | Banco | 1976 |
| 14 | *M. beillei* | Banco | 1968 |
| 15 | *M. beillei* | Banco | 1972 |
| 16 | *M. beillei* | Banco | 1955 |
| 17 | *M. beillei* | Banco | 1973 |
| 18 | *M. beillei* | Banco | 1970 |
| 19 | *M. beillei* | Banco | 1973 |
| 20 | *M. beillei* | Banco | 1967 |
| 21 | *M. beillei* | Banco | 1968 |
| 22 | *M. beillei* | Banco | 1969 |
| 23 | *M. beillei* | Banco | 1970 |
| 24 | *M. beillei* | Banco | 1969 |
| 25 | *M. beillei* | Banco | 1975 |
| 26 | *M. beillei* | Banco | 1959 |
| 27 | *M. beillei* | Banco | 1969 |
| 28 | *M. beillei* | Banco | 1969 |
| 29 | *M. beillei* | Banco | 1976 |
| 30 | *M. beillei* | Banco | 1972 |
| 31 | *M. beillei* | Banco | 1957 |
| 32 | *M. beillei* | Banco | 1976 |
| 33 | *M. beillei* | Banco | - |
| 34 | *M. beillei* | Banco | 1963 |
| 35 | *M. beillei* | Banco, arboretum | 1969 |
| 36 | *M. beillei* | Banco, centre-nord, rivière | 1972 |
| 37 | *M. beillei* | Banco, forêt | 1968 |
| 38 | *M. beillei* | Banco, nord-est | 1959 |
| 39 | *M. beillei* | Banco, nord-ouest | 1976 |
| 40 | *M. beillei* | Banco, arboretum | 1955 |
| 41 | *M. beillei* | Banco, nord-ouest | 1967 |
| 42 | *M. beillei* | Bingerville | 1955 |
| 43 | *M. beillei* | Bingerville | 1958 |
| 44 | *M. beillei* | Dabou | 1976 |
| 45 | *M. beillei* | Dabou. | 1975 |
| 46 | *M. beillei* | Dabou. | 1969 |
| 47 | *M. beillei* | Dodo | 1969 |
| 48 | *M. beillei* | Forêt d'Abou-abou | 1969 |
| 49 | *M. beillei* | Forêt d'Abou-abou | 1969 |
| 50 | *M. beillei* | Forêt d'anguededou | 1969 |
| 51 | *M. beillei* | Forêt d'anguededou | 1969 |
| 52 | *M. beillei* | Forêt d'anguededou | 1975 |
| 53 | *M. beillei* | Forêt d'anguededou | 1953 |
| 54 | *M. beillei* | Forêt d'anguededou | 1959 |
| 55 | *M. beillei* | Forêt d'Audouin. | 1975 |
| 56 | *M. beillei* | Forêt de Cosrou | 1987 |
| 57 | *M. beillei* | IRHO.,10 Km de Port-Bouët | 1973 |
| 58 | *M. beillei* | Adiopodoumé | 1970 |
| 59 | *M. beillei* | Adiopodoumé. | 1972 |
| 60 | *M. beillei* | Adiopodoumé. | 1972 |
| 61 | *M. beillei* | Adiopodoumé. | 1990 |
| 62 | *M. beillei* | Adiopodoumé. | 1946 |
| 63 | *M. beillei* | Adiopodoumé. | 1907 |
| 64 | *M. beillei* | Adiopodoumé. | 1947 |
| 65 | *M. beillei* | Adiopodoumé. | 1906 |
| 66 | *M. beillei* | Adiopodoumé. | 1987 |
| 67 | *M. beillei* | Adiopodoumé. | - |
| 68 | *M. beillei* | Adiopodoumé. | - |
| 69 | *M. beillei* | Adiopodoumé. | 1907 |
| 70 | *M. beillei* | Adiopodoumé. | 1975 |
| 71 | *M. beillei* | Sassandra. | 1905 |
| 72 | *M. beillei* | Sassandra. | 2002 |

At the end of this survey, the commune of Abobo was chosen as the site for the survey (Figure 2). There have been identified 2 major markets for the sale of medicinal plants. The first market located on the edge of the railway line in the neighborhood of Siaka Koné with a number of exhibitions of around 200, contains several departments according to ethnic groups. There are Djimini, Baoulé, Agni, Malinké, Abbey etc. and even from the community of the sub-region (Malians). The plants sold come from various localities in Côte d'Ivoire. The second market is at the heart of the largest market of Abobo with about a hundred number of exhibitions. The ethnobotanical study is carried out using a pre-established questionnaire containing specific questions on the informant and on the plant material (Table S2) submitted to the respondents during the interview. The questions are asked under the presentation of a sample of the species (Figure 3).

The study of the use of plants by a community, in general, is often approached according to two axes (Malan 2016): (i) the inventory of spontaneous or subspontaneous plant species used, in a traditional way, by the community as well as associated practices; (ii) the level of knowledge and use of these plant species in the daily life of the community. The inventory of the plants used is based on several methods of investigation, among which we can cite innocuous or occasional conversations which allow both to estimate knowledge and to solicit responses, the method of free lists or open lists which is a method particularly well suited to ethnobotanical studies which use spontaneous quotations, semi-structured or semi-structured interviews, the door-to-door method, the so-called "Show-and-tell" method which consists in showing samples of dried herbarium or fresh plants or plant photographs to respondents and the direct interview method which only takes into account the questions of a questionnaire. This work lasted two weeks, during which 100 interviews (50 herbalists per market) were carried out with herbalists of different ages, ethnicities and nationalities. These herbalists were visited step by step and questioned. The time devoted to each interview was approximately a quarter of an hour. During each interview, we collected all the information on the informant and as much information as possible concerning the method of collection, use, place of collection and availability of the species. Thus, the profile of each informant includes their age, level of education and family status. The data collected for the species (*M. beillei*), includes the common local name, the use, the mode of collection, the part used and the availability of the species.

**Data analysis**

For processing the survey data, we used the method used by Bériname et al. (2018), Badjaré et al. (2018) and Yaovi et al. (2021). Thus, we calculated the citation frequency (F). It corresponds to the ratio between the number of respondents (n) who mentioned the species and the total number of respondents (N): $F = n/N \times 100$.

**Table S2.** Results of the ethnobotanical survey on *Macaranga beillei*

| Market | Number of people who knew the species | Vernacular name | Ethnic group | Field of use | Harvest locations | Organ used | Cause of rarity |
|---|---|---|---|---|---|---|---|
| Big market of Abobo | 6 | Wangnaga brou | Malinké | Medicinal | Forest | Stem | Agriculture |
| | 10 | Trô wangnaga | Djimini | Medicinal | | and | Agriculture |
| | 5 | Êgba | Agni | Medicinal | | leaves | Agriculture |
| | 15 | Fônôfê | Gouro | Medicinal | | | Agriculture |
| | 14 | Tchôfê | Abbey | Medicinal | | | Agriculture |
| | 6 | Êbouê | Ebrié | Medicinal | | | Agriculture |
| | 5 | Tôrôh | Adjoukrou | Medicinal | fields | | Herbicide |
| Total | 61 people who know the local name of the species | | | | | | |
| Abobo, Siaka Koné market | 11 | Fônôfê | Gouro | Medicinal | Forest | Stem | Agriculture |
| | 9 | Kôgnonranbrou masramousso | Dioula | Medicinal | | and leaves | Agriculture |
| | 10 | Wangnaga brou | Malinké | Medicinal | | | Agriculture |
| | 15 | Tchôfê | Abbey | energetic | | | Agriculture |
| | 9 | Égbê | Agni | Medicinal | | | Agriculture |
| | 12 | Tôrôh | Adjoukrou | Medicinal | | | Agriculture |
| Total | 66 people who know the local name of the species | | | | | | |

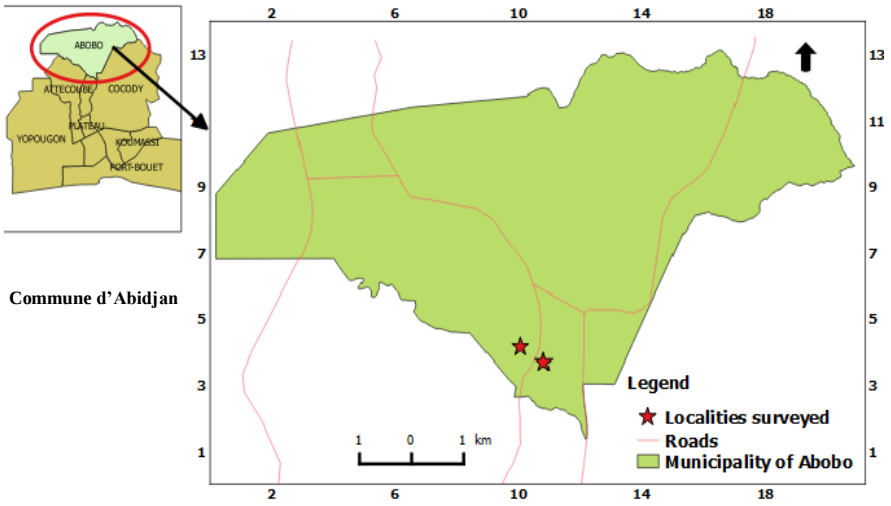


**Figure 2.** Ethnobotanical survey site: Commune of Abobo, Côte d'Ivoire (market of Siaka Koné and large market)

**Figure 3.** Interview session with an herbalist at the largest market of Abobo, Côte d'Ivoire

Similarly, the number of uses of the species was determined. It corresponds to the sum of the number of citations of use per organ of the species. This is the number of citations for a specific organ of the plant by all respondents: NUsp =∑NUorgan. Finally, the calculation of the species vulnerability risk index (VI). Thus, the risk of vulnerability, the evaluation of which is essentially based on the demands of the species and its organs and not directly on the rarity or abundance of the species, was calculated on the basis of four parameters: citation frequency of the species; number of use categories in which the species is found; collection method and organ used.

These parameters represent major indicators of the pressures and threats exerted on woody species. A scale of 1 to 3 was assigned to these parameters (Table 4). A value of 1 indicates a low risk of vulnerability for the species for the parameters indicated, a value of 2 represents a medium risk of vulnerability and a value of 3 characterizes a species

at high risk of vulnerability. When several parts of a plant are solicited in use, only the part with the highest value from the vulnerability scale is taken into account in the calculation of the indices (Birregah 2016). Based on the information contained in Table 4, the vulnerability index is calculated using the formula: IV = [(P1+ P2 + P3+ P4) /4].

Thus, if IV < 2, the plant is weakly vulnerable; if 2 ≤ IV< 2.5, the plant is moderately vulnerable; if IV≥ 2.5, the plant is very vulnerable; if 2 ≤ IV< 2.5, the plant is moderately vulnerable; if IV≥ 2.5, the plant is very vulnerable.

## RESULTS AND DISCUSSION

### Results

*Floristic analysis*

The floristic analysis made it possible to find the whole of the Ivorian territory with 72 samples of *M. beillei* harvested. It also emerges from this analysis that the Banco National Park is the most sampled locality with 38 out of 72 samples, i.e. a rate of 52.77% (Appendix 2).

### Potential distribution of *Macaranga beillei*

*Current potential distribution (1950-2000)*

The potential distribution map (Figure 4) shows the sampled points and the probability of the presence of *M. beillei* Prain. Indeed, the analysis of this map reveals that *M. beillei* Prain has a probability of presence only in the south of the country. Also, it reveals that the current potential range (from 1950 to 2000) is 19,306.676 km². The favorable area for the distribution of *M. beillei* Prain is the coast. The variables bio_2 and bio_7 (Figure 5) are the environmental variables that determine the distribution of *M. beillei* with contributions of around 18%. The model gives an AUC test value of 0.998, which means that the estimate of the distribution is excellent.

*Future potential distribution (2000-2050)*

The analysis of the future potential distribution map reveals that *M. beillei* Prain has a probability of presence that will be reduced in the future (Figure 6). Indeed, from 19,306.676 km² from 1950 to 2000, the potential distribution area decreases to 12,610.549 km² between 2000 and 2050, i.e. a loss of 6696.127 km². The loss of the distribution area of this species will gradually start from the southwest to the southeast of the Ivorian coast.

During the period from 2000 to 2050, the environmental variables that would most influence the potential distribution of *M. beillei* are bio_2 and bio_14 (Figure 7), with respective contributions of 22.7% and 10.8%. The model gives an AUC test value of 0.999, which means that the estimation of the distribution is excellent.

**Table 4.** Major parameters are taken into account for calculating the vulnerability index (Badjaré et al. 2018; Yaovi et al. 2021)

| Parameter retained | Low (scale = 1) | Average (scale = 2) | Strong (scale = 3) |
|---|---|---|---|
| citation frequency: P1 | P1 < 5 % | 5 % ≤ P2 < 15 % | P3 ≥ 15 % |
| number of use: P2 | P2 < 2 | 2 ≤ P2 ≤ 4 | P2 ≥ 5 |
| organ used: P3 | Leaf, latex | Fruit | wood, seed, bark, root, flower |

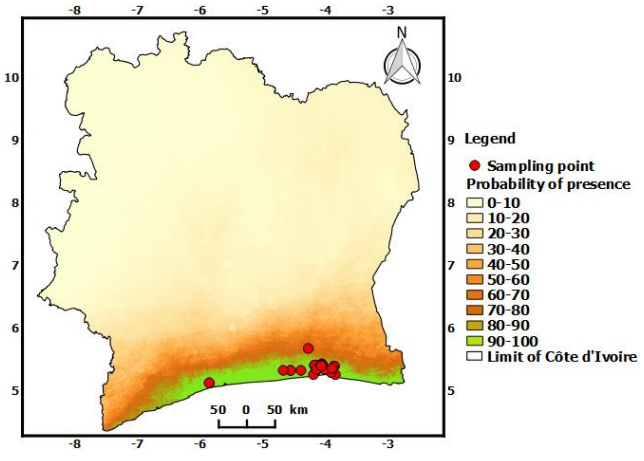


**Figure 4.** Current potential distribution map (1950-2000) of *Macaranga beillei*

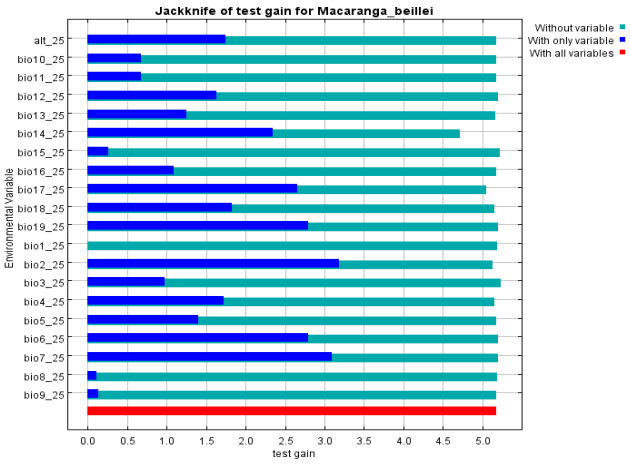


**Figure 5.** Contribution of environmental variables on the distribution *of Macaranga beillei* for the period 1950-2000

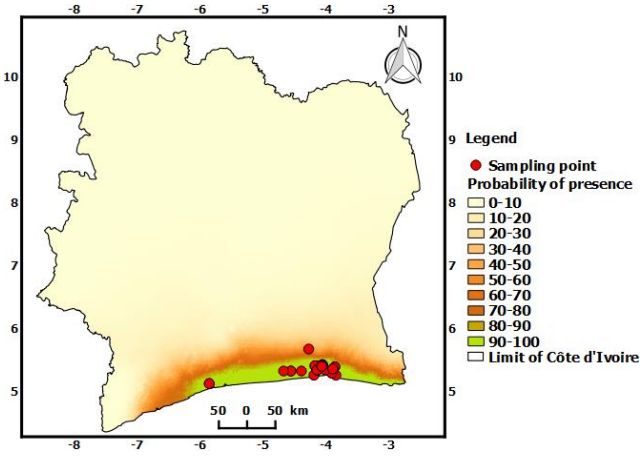


**Figure 6.** Future potential distribution map (2000-2050) of *Macaranga beillei*

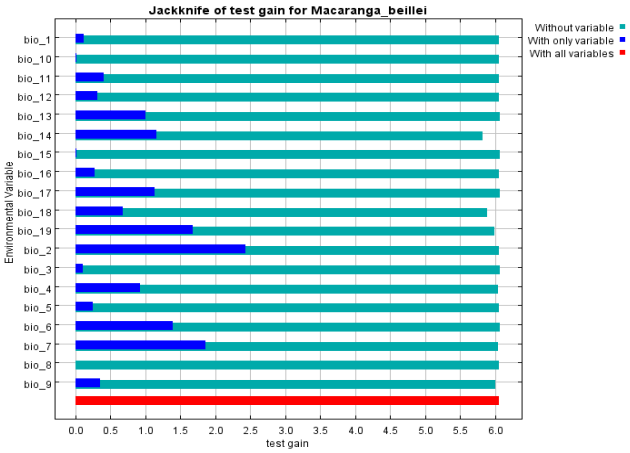


**Figure 7.** Contribution of environmental variables on the distribution of *Macaranga beillei* for the period 2000-2050

### Assessment of the status of *Macaranga beillei*

The assessment of the extent of occurrence (EOO) reveals that it extends over an area of 5,848.921 km² and that of the area of occupancy (AOO) reveals that it extends over an area of 72.000 km² (Figure 10). These values show that the species M. beillei is vulnerable.

### Current distribution of *Macaranga beillei*

Analysis of the spatial distribution of *M. beillei* Prain reveals its imminent disappearance. While the Banco National Park was the preferred refuge area of *M. beillei*, however, of the 38 samples collected by Aké Assi and his collaborators from 1905 to 2002, only 4 samples were found (Figure 8). In this figure, the geographical coordinates of the samples collected previously are very close, which means that the points are superimposed. In places where the species had previously been collected by Aké Assi and his collaborators, runoffs from Abobo flooded the area, probably causing the disappearance of the species in these places (Figure 9).

### Analysis of ethnobotanical survey data

The survey took place at the Siaka Koné market in Abobo and at the largest market in Abobo. About a hundred people were questioned at these two markets: at the Siaka Koné market, 80 herbalists (78 women and 2 men). Of the 80 people, only 61 people (Table 4) knew the plant (*M. beillei*). The other 19 people did not know it. The most frequent vernacular names are fônôfouê (Gouro) and tchôfê (Abbey). At this market, the species is not well known in Adjoukrou and Agni. However, the pronunciation of the name of this species in certain ethnic groups is different from what was said in the bibliographical research.

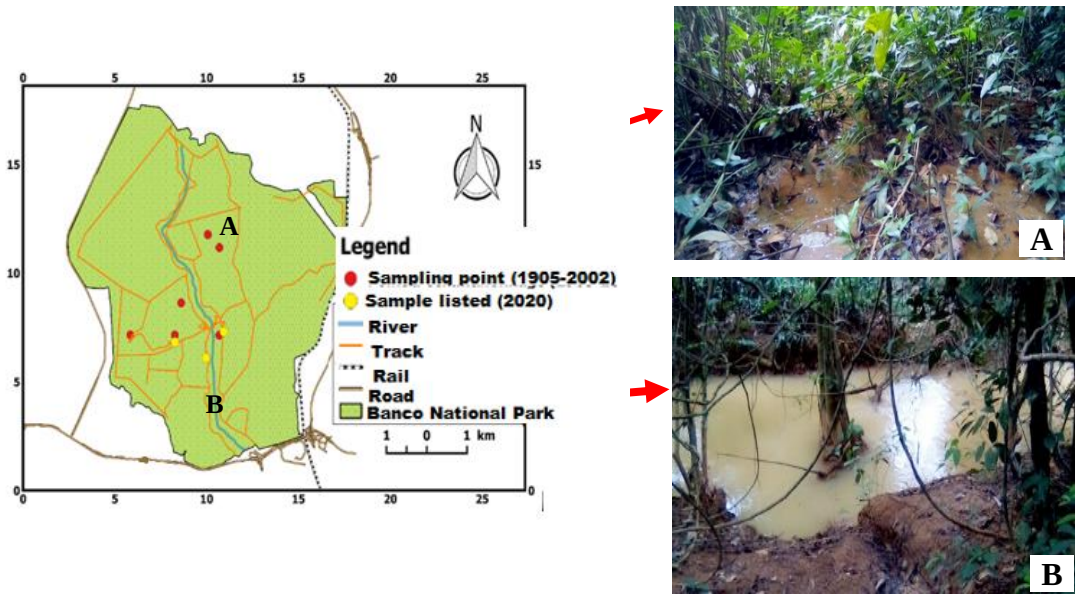


**Figure 9.** Distribution map *of Macaranga beillei* in Banco National Park, Côte d'Ivoire and modification of the environments encountered in Côte d'Ivoire. A: Habitat of *Macaranga beillei* flooded by runoffs from Abobo; B: Banco River troubled by runoffs

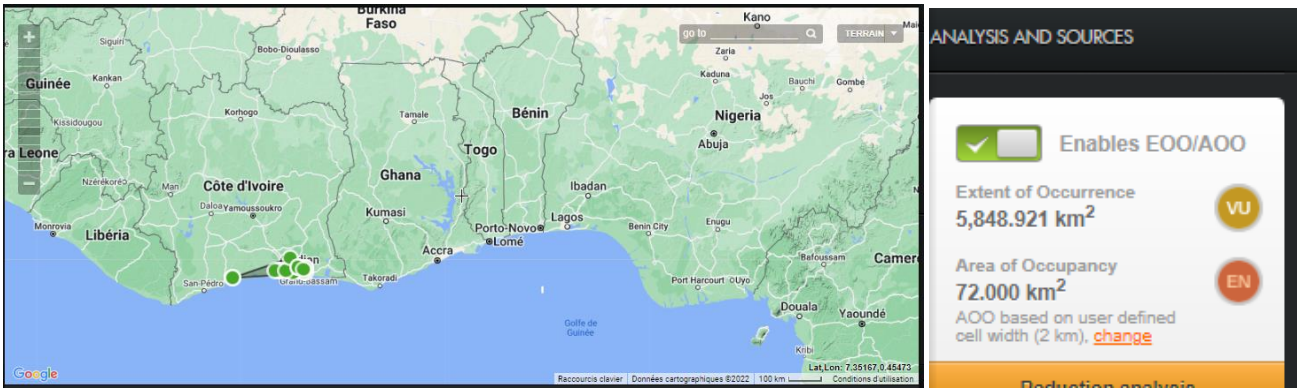


**Figure 10.** Status of *Macaranga beillei*

**Table 5.** Vernacular names of *Macaranga beillei*

| Number of people who knew the species | | Vernacular name | Ethnic group | Field of use |
|---|---|---|---|---|
| Largest market of Abobo | 16 | Wangnaga brou | Malinké | Medicinal and energetic |
| and Siaka Koné market | 10 | Trô wangnaga | Djimini | |
| | 26 | Fônôfê | Gouro | |
| | 29 | Tchôfê | Abbey | |
| | 6 | Êbouê | Ebrié | |
| | 17 | Tôrôh | Adjoukrou | |
| | 9 | Kôgnonranbrou masramousso | Djoula | |
| | 14 | Égbê | Agni | |
| Total | 127 | People who know the local name of the species | | |

**Table 6.** Causes of the rarity of *Macaranga beillei*

| Market | Harvest location | Cause of scarcity | Occurrence frequency |
|---|---|---|---|
| Big market of Abobo and Siaka Koné market | Forest and cocoa fields | Agriculture | 120 |
| | | Herbicide | 4 |
| | | Urbanization | 12 |

Regarding the largest market of Abobo, out of 70 people surveyed, only 66 people were able to recognize the species. The name in Abbey and Gouro are the most frequent (respectively 29 et 26 people) and the names in Ebrié and Djoula are the least frequent (Table 5). In these ethnic groups, *M. beillei* is used in medicinal and energetic fields (firewood). As causes of scarcity cited by respondents, agriculture is mentioned 120 times, while urbanization (construction of houses) and the use of herbicides were rarely cited (Table 6).

**Citation frequency (F)**

The citation frequency (F) value for this survey is 84.66%. This value reflects a good knowledge of *M. beillei* by the local population.

**Number of use**

There are 3 uses of the species (NUsp**)**. This value shows considerable solicitation of the *M. beillei* species by the local population. Indeed, the leaves are used in the medical field. The stem is used in two (2) fields: the medicinal field and the energy field (firewood).

**Vulnerability risk index linked to uses and demand**

The calculation of the species vulnerability risk index (VI) is 2.46. The vulnerability index IV is between 2 and 2.5. *M. beillei* is therefore moderately vulnerable.

**Discussion**

The floristic analysis carried out on *M. beillei* reveals that it is an endemic forest species to Côte d'Ivoire. *M. beillei* is mostly harvested in Banco National Park located in the heart of Abidjan, the economic capital of Côte d'Ivoire. This finding highlights the involvement of protected areas in the conservation of biological diversity and ecosystems. Thus, protected areas have an important implication in the conservation of biological diversity. Indeed, protected areas are mostly refuge areas for certain species, such as *M. beillei*. Because of the controlled access of the population and the prohibited or controlled removals, the species that shelter these ecosystems manage to multiply easily outside of the vagaries of the weather. This remark was also made by Yao et al. (2020).

Similarly, in Côte d'Ivoire, the regions best known floristically are those located along the coasts, the areas

surrounding centers of activity, research institutions, universities, classified forests, parks and reserves such as the Banco National Park (Koffi et al. 2015). Outside of these regions, large spaces very diversified in natural vegetation are not explored or are only very partially explored. These findings are consistent with those of Koffi et al. (2015) who state that in Africa, there are well-known regions, moderately known regions and poorly known regions.

Maps of the potential distribution of *M. beillei*, current and future, make it possible to identify priority areas within the framework of development plans for the benefit of different climatic zones. It constitutes a basis for the actions of conservation of this species threatened with extinction in particular because of the anthropic influence within the limits of their areas of distribution. The loss of distribution area observed in the next 50 years is due to fluctuations in climatic variables and, more precisely, the average daily variation in temperatures. Also, the loss of habitat of *M. beillei* observed (from the southwest to the southeast) is due to the fact that Côte d'Ivoire and in particular the Coastal region has already entered the vicious circle of climate change. Indeed, the analysis of 1971-2000 is normal compared to that of 1961-1990, which shows an average reduction in rainfall heights of 6% over the entire extent of the Ivorian territory, with remarkable drops of 13% in the southwest and 11% in the southeast. The rainfall has been particularly low since the 1980s compared to the 1951-1980 average (Djè 2014).

Also, it should be noted that these seasonal fluctuations are the consequences of global changes which will gradually increase and influence the dispersion of plants on the Earth's surface. This observation is similar to that made by Auzel et al. (2012). It appears from their work that global warming could generate temperatures to which the local vegetation is not adapted and which would not be synchronized with the photoperiods. The apprehended phenological changes make it possible to anticipate an imbalance in the life cycle of several species and probably local extinctions for species with less adaptive flexibility.

The models produced make it possible to highlight the different levels of influence between the environmental variables and the dispersion of these species. The MaxEnt model was applied because of the abundance of species in the environment, considering that their dispersion is still subject to these environmental variables. These environmental variables are respective determining factors in the dispersal of this species. Therefore, it can be deduced that the existence of a species in a given region is conditioned by several factors, in particular climatic factors. With regard to *M. beillei*, there is great sensitivity to the average daily variation in temperature and precipitation in the driest quarter. These factors are respective determinants in the dispersal of this species. Similarly, for this species, harvests are restricted to the Guinean domain, more precisely in the coastal strip. It can be concluded that it is a forest species.

The results of the perception and use of *M. beillei* showed that it is a species known and used locally by the population. First, the high value (84.66%) of the frequency of citation for this survey perfectly reflects the knowledge of *M. beillei* by the population. Indeed, during the survey, at the two markets (Siaka Koné and the largest market of Abobo), it was cited by the majority of herbalists as a medicinal plant for the treatment of cough and in the energy field as firewood. There is no need to say that the high value of the citation frequency can easily be justified by the fact that the population is interested in it for its care on the one hand and for firewood on the other. This observation is similar to that made by Kouakou et al. (2020). Indeed, these authors noted during their study relating to the traditional uses and availability of plants exploited in handicrafts among the Koulango and Lobi populations of the eastern periphery of the Comoé National Park (Côte d'Ivoire) that the species *Pterocarpus erinaceus*, *Raphia sudanica*, *Vitellaria paradoxa*, have been strongly cited by the population because they are the most used by these populations.

Regarding the number of uses of *M. beillei*, the value (3) obtained shows considerable solicitation of the species *M. beillei* by the local population, thus confirming the previous result. Indeed, the leaves are used in the medicinal field and the stem is used in two (2) fields: the medicinal field and the energy field (firewood). The value (2.46) of the species vulnerability risk index (IV), calculated for *M. beillei* confirms its vulnerability. Geospatial analysis of *M. beillei* showed an estimated extent of occurrence value of 5,848.921 km². Which means it is a vulnerable species. According to the criteria (A-E) for evaluating the membership of a taxon in one of the categories of the "threatened" group of the IUCN red list (critically endangered, endangered or vulnerable), a species whose surface area of occurrence is less than 20000 km², is categorized as Vulnerable on the Red List (IUCN, 2019). This vulnerability is mainly due to urbanization and agricultural activities in addition to climatic hazards. These results corroborate those of Lachenaud (2004). Indeed, for Lachenaud, *M. beillei* covers a very restricted area in the region of Abidjan-Dabou, which however could be locally abundant, but because of its habitat, which is very threatened by anthropic activities, today its survival depends practically on that of Banco National Park. Also, these results are similar to those of Vroh Bi et al. (2014). These authors, during their research on the availability of spontaneous plant species for traditional use in the locality of Agbaou, note that the scarcity of certain species is most often linked to their ecology and/or the mode of collection.

The ethnobotanical survey relating to the uses of *M. beillei*, showed that it is a species known and used locally in the medicinal and energetic fields. The vulnerability index calculated for this species confirms its vulnerability. This vulnerability is mainly due to anthropogenic actions. It emerges from this work that vulnerability corresponds to the degree of exposure to the risk of reduction or disappearance of certain plant species caused by inappropriate harvesting methods in an environment subject to increasing anthropogenic pressure and climatic variations.

In conclusion, it appears that *M. beillei* is a forest species, vulnerable, endemic to the Ivorian coastal zone

and generally harvested in Banco National Park. Also, its vulnerability is mainly due to human activities than to the fluctuation of environmental variables. Similarly, it should be remembered that, if some conservation strategies are undertaken for the maintenance and upkeep of certain species of great importance, very few significant actions are taken to effectively fight against the degradation of plant resources. Although people are aware of the importance of local species in their daily lives, they do not have the culture to conserve them through plantations. This will require a change in behavior. This involves raising awareness of the need to produce these local species, at least those that the populations consider a priority and which are adapted to their environment. It is in this sense that preferred species should be promoted by development agents. Species that are less important because they are little used have less chance of winning the consent of the populations. Despite their lesser importance, these so-called less valuable species must also be protected for the purposes of the conservation of biological diversity. This is all the more true since a species less important nowadays could be sought after later as a replacement for others, which are becoming rare in a field of use. It is therefore appropriate for the State of Côte d'Ivoire to work to safeguard biological diversity.

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