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Research Article

Ecology of *Echinops giganteus* A. Rich. in Sub-Saharan Africa: Distribution, Ecoclimatic Niche, and Phytosociology

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Echinops giganteus A. Rich. is an aromatic and medicinal plant of the Asteraceae family exploited in Cameroon under the access and benefit sharing (ABS) standard. Despite its importance, little information exists on the ecology of *E. giganteus*. The aim of the present study was to contribute to a better understanding of its ecology for sustainable management in the Western Highlands of Cameroon. Occurrence data as well as stationary ecological information were collected in the field and from different databases. Bioclimatic data were extracted from the WorldClim database and processed using DIVA-GIS and Maxent software. The Braun-Blanquet quadrat method was used for the phytosociological study. Results showed that the distribution of *E. giganteus* in its wild state is restricted to sub-Saharan Africa. This distribution is likely conditioned by altitude (1000 m–2600 m), light, temperature, and rainfall. The bioclimatic variables that best explained this distribution were the mean annual temperature (Bio1: 38.8%) and the precipitation of the coldest quarter (Bio19: 24.9%), and their favorable ranges were between 2°C–32°C and 300 mm–1800 mm, respectively. *E. giganteus* is a heliophilic plant that prefers well-drained substrates and would not have a requirement for organic matter. The floristic analysis of the *E. giganteus* community identified 68 plant species in 59 genera and 28 botanical families, with the most represented family being the Asteraceae (49%). The average species richness per quadrat was 8 species, dominated by herbs. Species consistent with *E. giganteus* were *Aspilia africana* (Pers.) C. D. Adams and *Imperata cylindrica* (L.) P. Beauv. Chamaephytes and Phanerophytes were dominant among the biological types, while the phytogeographic types were dominated by Pantropical species (38.23%). The most represented diaspore types and modes of dissemination were pogonochores (35.85%) and anemochores (55.38%).

1. Introduction

The forests of the Congo Basin abound in exceptional biodiversity that constitutes a potential for the socioeconomic development of its member countries [1, 2]. However, very little is known about this biodiversity, posing a need for the regular identification and description of new species through ethnobotanical and forestry inventories [3, 4]. Some of these species are endemic and have strong socioeconomic potential that can contribute to the development of local communities [5]. Unfortunately, many of these known genetic resources and associated traditional knowledge have been exploited for decades illegally and without a sustainable management strategy to supply industries [6]. Over the years, the phenomenon has grown, and the countries of origin, as well as the rural populations, find themselves victims of the illegal appropriation of their resources. Moreover, access to these resources has become a real concern for the countries that hold genetic resources because they are diminishing at a frightening rate [7]. In Cameroon, forest ecosystems occupy about twenty-one million hectares with a floristic diversity of more than 8000 species [8]. Increasing exploitation of its resources by populations and industries has resulted in an annual loss of area in the order of 0.3 to 1% [9]. These losses pose a management and conservation problem with a risk of genetic erosion of the species [10]. Indeed, the overexploitation of certain resources has resulted in the progressive loss of biodiversity and the increased vulnerability of certain species such as *Prunus africana* (Hook.fil.) Kalkman, *Garcinia kola* Heckel, *Garcinia lucida* Vesque, *Siphonochilus aethiopicus* (Schweinf.) B. L. Burtt, and *Warburgia salutaris* (Bertol.fil.) Chiov. [11, 12].

Access to genetic resources and benefit sharing (ABS) represents the third objective of the 1992 Convention on Biological Diversity. It was made effective in 2010 by the Nagoya Protocol and standardizes the mechanism of exploitation of genetic resources. The implementation of this mechanism is an effective measure in the sustainable management of genetic resources in that it would facilitate the conservation of biodiversity as well as its sustainable use [13, 14].

In Cameroon, numerous bioprospecting activities are being carried out to identify genetic resources with high economic potential that can be valorized under the ABS principle. Several aromatic plants have therefore been identified and prioritized based on the requirements of industries, including *E. giganteus* [15–18]. Although there are intense efforts to identify potentially valuable plants, very few studies have focused on their ecology [19, 20]. A lack of ecological knowledge can hinder the conservation and sustainable use of the resource.

E. giganteus is an annual herbaceous plant with erected port habit belonging to the Asteraceae family. Because of its multiple uses, it is of great importance to human beings. In food, its roots are used as a spice. Medicinally, it is used for the treatment of fever, respiratory diseases, toothache, leucorrhoea, and earache. It is also attributed to having anti-inflammatory properties [21]. A study by Fankam et al. [22] showed that its extract had an antibacterial effect on *Mycobacterium tuberculosis*. Several other studies demonstrate its anticarcinogenic activity on several human cancer cell lines [23–25]. In agriculture, it is used as a pesticide for food preservation during storage [26]. It is prized by the cosmetics and perfumery industries for the quality of its essential oil. As such, it is exploited in the Western Cameroon Highlands according to ABS standards [18]. However, its exploitation requires the destruction of the whole plant, which increases its vulnerability. Despite this high potential, its many uses, and its vulnerability, very little information is available on its ecology.

The present study was aimed at contributing to the sustainable management of *E. giganteus* in its natural environment. The objectives were to (i) establish its current distribution map, (ii) determine the abiotic factors as well as the characteristics of its ecoclimatic niche, and (iii) make an inventory of companion species. This will facilitate a better understanding of its ecology and guide policy makers in making the right decisions for sustainable management of the resource.

2. Material and Methods

2.1. Study Area. The Western Highlands of Cameroon lie between 4°54″ and 6°36″ North latitude and 9°18″ and 11°24″ East longitude and cover an area of 3.1 million hectares. The demographic pressure in this region is high (168 inhabitants/km^2), with a contrasting topography which can be differentiated into as follows: (i) the granite-gneissic plateau in the south, which rises to between 1200 and 1400 m in altitude with poly convex reliefs; (ii) modest mountains of 2100 m in altitude in the southwest; (iii) the basaltic plateau in the north, with a calmer topography between 1400 m and 1600 m in altitude; and (iv) the Noun plain along the eastern edge of the Bamoun Plateau [27]. Soils are highly variable, ranging from andosols that are generally fertile and rich in organic matter on the High Plateaus (2000–2700 m) to ferralitic soils, deep and impoverished by intense cultivation in the valleys (1400–1500 m) [28]. The climate is of the "Cameroonian Highland" type, marked by two seasons: a dry season from mid-November to mid-March, and a rainy season from mid-March to mid-November. Average temperatures are low (19°C) and decrease as one ascends to peaks [29]. Heavy rainfall (1500–2500 mm) is witnessed in a monomodal pattern, with relative humidity ranging from 40 to 100% [30]. The vegetation is deeply marked by altitude: tree and shrub savannahs with *Annona senegalensis* Pers. and *Terminalia glaucescens* Planch. ex Benth., and grassy savannahs with *Aframomum latifolium* K. Schum. and *Imperata cylindrica*; remnants of the coastal forest; gallery forests and montane formations; and cultivated land. Agriculture is strongly practiced there, representing more than 25.2% of the farms in the whole country, with a degree of land development of about 86% of cultivable land.

2.2. Occurrence and Station Data. Occurrence data, as well as stationary ecological information, on *E. giganteus* were collected from the GBIF database, from the Cameroonian herbarium labels in Yaoundé and Limbé, and during field trips in the Western Highlands Cameroon. Google Earth Pro and Geonames tools allowed us to verify, correct, and/or assign geographic coordinates from the GBIF database based on geographic information associated with gazetteers [31]. The selected occurrence data were submitted to ArcMap 10.3.1 spatial analysis software to obtain the distribution map of *E. giganteus*.

2.3. Climate Niche Characteristics. The bands of bioclimatic variables were extracted from the WorldClim database (https://www.worldclim.org/data/worldclim21.html) at 2.5 minutes (~21 km^2) ground resolution. The 19 variables used correspond to current climate conditions and cover the period 1970–2000. They were derived from interpolations of data from more than 20,000 weather stations covering the 5 continents. These variables were as follows: (Bio1) mean annual temperature; (Bio2) mean diurnal amplitude (mean of monthly temperatures (max temp-min temp)); (Bio3) isothermality (Bio2/Bio7); (Bio4) seasonality of temperature; (Bio5) maximum temperature of the hottest month; (Bio6) minimum temperature of the coldest month; (Bio7) annual amplitude of temperature; (Bio8) mean temperature of the wettest quarter; (Bio9) mean temperature of the driest quarter; (Bio10) warmest quarter average temperature; (Bio11) coldest quarter average temperature; (Bio12) annual precipitation; (Bio13) wettest month precipitation; (Bio14) driest month precipitation; (Bio15) precipitation seasonality; (Bio16) wettest quarter precipitation; (Bio17) driest quarter precipitation; (Bio18) warmest quarter precipitation; and (Bio19) coldest quarter precipitation. The values of each bioclimatic variable were extracted at the different points of occurrence using DIVA-GIS software. The relative contribution of each bioclimatic variable to the distribution of *E. giganteus* was evaluated with the Jackknife test after running the Maxent software.

2.4. Floristic Analysis

2.4.1. Sampling Method. Data were collected at the end of the rainy season (November 2021). Phytosociological surveys were carried out in quadrats each of 25 m^2 size following the sigmatist method of Braun-Blanquet (Figure 1) [32, 33]. The installation of the quadrats was conditioned by the presence of *E. giganteus*. Its density was evaluated by the sum of the stems of *E. giganteus* observed in all the quadrats and then extrapolated to the hectare. The minimum distance between the different quadrats was at least 100 m. For each quadrat, several pieces of information were collected, notably the geographic coordinates of the quadrat, the list of species, and the global cover rate in the quadrat. For each species surveyed per quadrat, an abundance-dominance coefficient [34] was assigned: (+) species present as isolated individuals (covering less than 1%), or an average cover (MR) of 0.5%; (1) species present as sparse individuals occupying less than 5% of the area, or an MR of 3%; (2) species present as abundant individuals, covering 5–25% of the area, or an MR of 15%; (3) species with 25–50% cover, or 37.5% MR; (4) species with 50–75% cover, or 62.5% MR; (5) species with 75–100% cover, or 87.5% MR.

Fertile samples (sample with flowers and or fruits) collected and constituted in the herbarium were identified in the Herbaria of Limbé and Yaoundé.

(1) Floristic Diversity. The analysis of *E. giganteus* stand data focused on the calculation of floristic parameters and several diversity indices. These included

(i) Relative frequency (RF) is the ratio of the number of surveys where a given species is present to the total number of quadrats;

(ii) Relative abundance (RA), which expresses the importance of the species in terms of numbers as the ratio of the number of individuals of that species to the total number of species;

(iii) Alpha diversity (α) is composed of parameters such as species richness, Shannon index (H'), Simpson diversity index, and Piélou equitability (E);

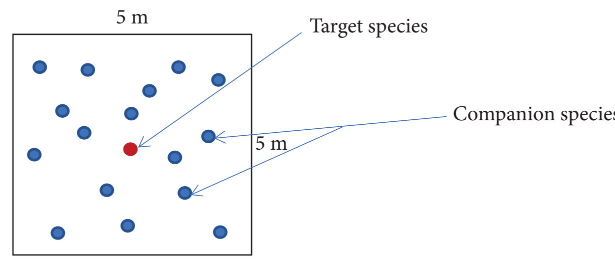

Figure 1: Flora sampling device.

(1) Species richness (S) defined as the number of species that a community contains;

(2) Shannon diversity index (H') expressing the diversity of species within plant communities [35]. It is calculated according to the following formula:

$$H' = -\sum_{i=1}^{s} (\text{Pi} \times \text{Logn Pi}), \tag{1}$$

where i takes value from 1 to s, s = number of species in that area, $Pi = ni/N$, = individuals of one particular ith species found in an area, N = total number of individuals found in that area, Logn = natural logarithm, $H' = 0$ if all individuals in the stand belong to one and the same species, H′ is also minimal if, in a stand, each species is represented by a single individual, except for one species, which is represented by all other individuals in the stand. The index is maximal (H_{max}) when all individuals are equally distributed over all species [36, 37].

(3) Piélou equitability or regularity (E) is the ratio between the effective diversity (H') and the theoretical maximum diversity (Hmax). It reflects the degree of diversity achieved by a stand in relation to the theoretical maximum and the quality of organization of a plant community. Its value is 0 when only one species is present and 1 when all species have the same abundance [38, 39].

$$E = \frac{H'}{H_{max}}. \tag{2}$$

(4) Simpson's index (D) expresses the probability that two individuals drawn at random from an infinite population belong to the same species [40]. This index will have a value of 0 to indicate the maximum diversity, and a value of 1 to indicate the minimum diversity.

$$D = 1 - \frac{\sum n(N-1)}{N(N-1)}, \tag{3}$$

where n = total number of a particular species and N = total number of all species.

(iv) Degree of presence (*P*) is the percentage of records in which the species was noted relative to the total number of records in the cluster. The scale of presence classes is represented by Roman numerals, in centesimal proportions, as follows: (V) constant species, present in 81 to 100% of the records; (IV) species present in 61 to 80% of the records; (III) species present in 41 to 60% of the records; (II) species present in 21 to 40% of the records; (I) accidental species, present in 1 to 20% of the records.

(2) Data Analysis and Processing

(i) Biological types: The classification of biological types was done following the method of Mouton [41] used by Just and Raunkiaer [42]. We distinguished (1) Phanerophytes (Ph): higher plants whose regeneration buds were located at more than 50 cm from the ground; (2) Chamaephytes (Ch): perennial woody or suffructive species, whose regeneration buds were located at 50 cm from the ground at the most; (3) Geophytes (G): buds were located below the soil surface; (4) Hydrophytes (Hy): aquatic plants whose persistent buds were located at the bottom of the water; (5) Hemicryptophytes (H): perennial plants whose buds were outcropping on the soil surface; (6) Therophytes (Th): these were the annual plants that formed their spores or seeds during a single life period.

(ii) Phytogeographic types: These were classified following the world chorology of White [43] and Saadou [44]. These are as follows: African (A) species found only in Africa; Paleotropical (Pal) species common to Africa, tropical Asia, and some islands of the Indian Ocean; Pantropical (Pan) species found in all tropical regions of the world; Cosmopolitan (Cos) species widely distributed on the surface of the Earth; Afro-Malagasy (AM) species common to Africa, Madagascar, Comoros, Mascarene Islands, and Seychelles; and Afro-Neotropical (AN) species common to Africa and tropical America.

(iii) Morphological types of species: The morphological type is generally used by several phytogeographers to explain the physiognomic and ecological organization of the vegetation of a territory or a region.

(iv) Types of leaf size of species: The size of the leaf usually indicates the degree of adaptation of the plant to the hygrometry and the sunshine of the environment. Just and Raunkiaer [42] proposed the categories of leaf size, which were completed by the notophyll class by Webb [45].

(v) Types of diaspores and modes of dispersal of species: Types of diaspores, as well as modes of dispersal, provide information on the ability of species to disperse and regenerate. They have been categorized according to the morphological criteria set by Dansereau and Lems [46] and Gorel et al. [47].

3. Results and Discussion

3.1. Current Distribution of E. giganteus. A total of 64 occurrences data were retained for the distribution map of *E. giganteus*. This distribution is restricted to sub-Saharan Africa, between latitudes 15°00′00″S and 15°00′00″N and longitudes 0°0′0″ and 45°0′00″E. It is distributed in six countries: Cameroon, the Democratic Republic of Congo, Ethiopia, Nigeria, Rwanda, and Tanzania (Figure 2). Their location corresponds to the equatorial, monsoon, and tropical savannah climatic zones. This result adds to the work of Menut et al. [48] on aromatic plants of Central Africa, who observed that the distribution of *E. giganteus* was endemic to Cameroon and Nigeria.

3.2. Ecological Characteristics. *E. giganteus* was observed in grassy savannahs, fallows, and cultivated fields, with associated herbaceous vegetation, altitudes between 1000 m and 2600 m, at the level of rounded summits, and on slopes. It was observed to grow preferentially in the open environments with strong exposure to light. Indeed, the plants of *E. giganteus* growing in the mid-shade presented a delay of growth characterized by a stunted vegetative port and very small flower heads when they had flowered. This observation could reveal the heliophilic character of the species.

As reported by Tematio et al. [28] and Tsozué et al. [49], the soils in Western Highlands of Cameroon are dominated by the typical haplohumox group. These are the soils with sandy-clay texture, poor nitrogen, low mineralized organic matter, and slightly acidic pH. It could therefore be inferred that *E. giganteus* would prefer well-drained substrates and has no requirement for organic matter. This low organic matter requirement could also be justified by the absence of humus observed on the substrate of *E. giganteus* groups.

3.3. Climatic Constraints. The characterization of the ecoclimatic space of *E. giganteus* provided information on the climatic constraints that influence its distribution. The Jackknife test from the MaxEnt niche model of *E. giganteus* showed that the individual bioclimatic variables that most explained its distribution were as follows: Bio8 (mean temperature of the wettest quarter) which were the environmental variables with the highest gain. On its own, it seemed to have the most useful information for the model. It was followed by Bio1 (average annual temperature) and Bio10 (average temperature of the warmest quarter). When omitted, the environmental variable that reduced the gain most was Bio19 (precipitation of the coldest quarter). It could therefore contain some information that the other variables did not. It is followed by the environmental variables Bio8 (average temperature of the wettest quarter) and Bio18 (precipitation of the warmest quarter) (Figure 3).

Figure 4 presents the relative contributions of environmental variables to the MaxEnt model with a value greater than 1. It shows that the environmental variables that

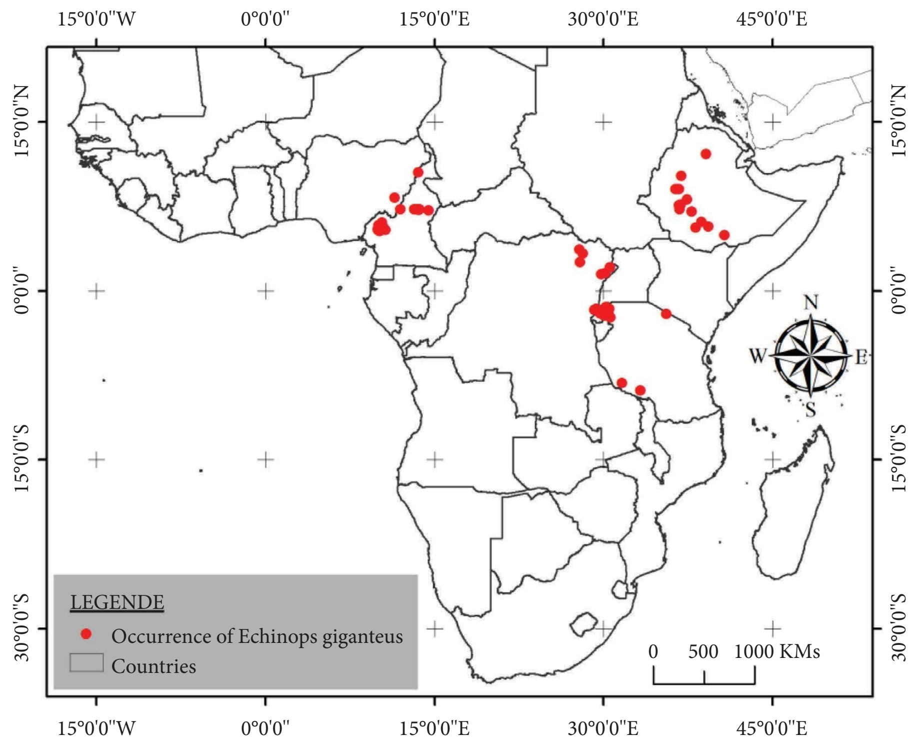

Figure 2: Distribution of *Echinops giganteus* in Africa.

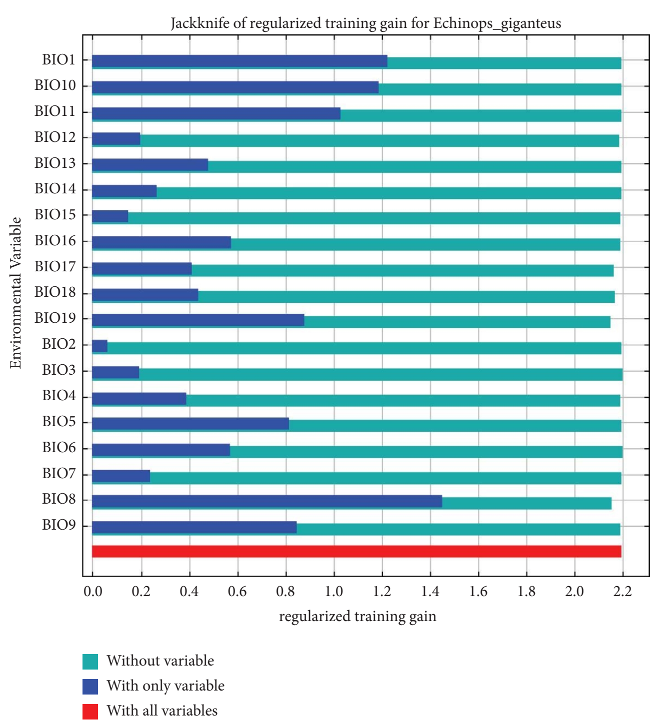

Figure 3: Statistical result of the jackknife test.

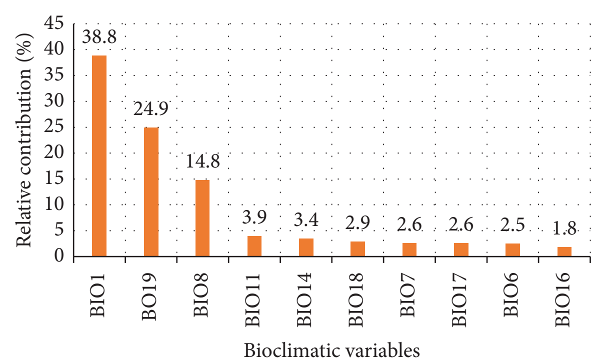

Figure 4: Contribution of each environmental variable to the niche model of *E. giganteus.*

contributed most to the model were mean annual temperature (Bio1: 38.8%), precipitation in the coldest quarter (Bio19: 24.9%), and mean temperature in the wettest quarter (Bio8: 14.8%). These variables are derivatives of temperature and precipitation, and contribute 78.5% to the distribution of *E. giganteus*. The distribution of *E. giganteus* is thus conditioned by precipitation and temperature. This suggests that relative humidity, which is closely related to both temperature and humidity, may be a significant factor conditioning the distribution of *E. giganteus* on the continent. It is widely recognized that the likelihood of a species successfully establishing a population in a new environment is an ecological process ultimately determined by environmental and nonenvironmental factors [50]. According to many researchers, the distribution of plants in tropical Africa is mainly conditioned by total rainfall, the duration of the dry season, and air and soil moisture [51, 52]. This is because water availability directly affects physiological processes related to plant germination and growth [53].

Based on the logistic function curves of the MaxEnt model (Figure 5), it was possible to determine the ranges of values favorable to the establishment of *E. giganteus* for the 3 variables that conditioned its distribution. This shows that, for logistic output values greater than or equal to 0.5, the ranges of mean annual temperature (Bio1), precipitation of the coldest quarter (Bio19), and mean temperature of the wettest quarter (Bio8) between 2°C–32°C, 300 mm–1800 mm, and 4 mm–20.5 mm, respectively, are those offering the best conditions for the distribution of *E. giganteus*.

3.4. Taxon Diversity and Diversity Indices. The total 43 surveys carried out permitted to find 68 plant species divided into 59 genera and 28 botanical families according to the APG3 classification. The Asteraceae family (49%) was the most represented with 15 genera and 29 species, followed by the Poaceae family (24%) with 10 genera and 10 species, then the Fabaceae family (7.6%) with 7 genera and 8 species (Figure 6). The average species richness per quadrat was 8 species, for an average cover of 13.41. The most represented species in the quadrats were *Aspilia africana* and *Imperata cylindrica* with presence degrees of 93% and 86%, respectively (Figure 7).

This predominance of the Asteraceae and Poaceae families provides information on the characteristics of the vegetation type of African savannas [54]. It could be explained by their capacity to spontaneously colonize the environment once the living conditions become favorable [55]. In fact, they have a very high tillering capacity, and a high regrowth capacity after grazing and bushfires [56]. They are also resistant to climatic hazards and cryptogamic diseases [57].

The density of *E. giganteus* is estimated to be 2177 feet/hectare. The mean values of Shannon's index, Simpson's index, and Piélou's Equitability were, respectively, 1.35 bits, 0.649, and 0.541. These values not only show a low specific diversity on the one hand but also a certain regularity of the species distribution around *E. giganteus* on the other hand. The Shannon–Weaver index obtained in this study is lower than that found by Ngyete Nyikob Mbogue et al. [58]. Indeed, in a similar study in the Western Highlands of Cameroon, these researchers obtained a Shannon–Weaver index of 6.92.

3.5. Ecological Spectra

3.5.1. Spectrum of Biological Types. The analysis of the global biological spectrum of the inventoried species showed the dominance of Chamaephytes and Phanerophytes in the whole of the studied flora, with respective proportions of 41.2% and 32.4%. Therophytes were in third place with 11.8%. Hemicryptophytes are less represented with 7.4%, and Geophytes come last with 4.4% (Figure 8).

The dominance of Chamaephytes and Phanerophytes reflects the adaptive strategies of plants related to competition and stress tolerance. Indeed, a predominance of Chamaephytes is characteristic of vegetation subjected to stresses of various origins. They are better adapted to drought, are more xerophilic and produce many seeds [59]. In this study, the water and bushfire were the most observed stresses in the area. Indeed, the landscape being of the mountainous type with well-drained ferralitic soils, would prevent water retention [28]. In addition, this area is subject to bushfires due to agricultural activities. The predominance of Phanerophytes reflects the adaptive strategies of plants related to competition for available resources. A study based on the analysis of ecological spectra of the flora of savannahs of the West Cameroon Highlands by Wouokoue et al. [56] reveals that the latter is dominated by Phanerophytes and Chamaephytes. Our result is similar to that of Ngyete Nyikob Mbogue et al. [58] who noted that in the Western Highlands of Cameroon Chamaephytes and Phanerophytes were the most represented biological types associated with *E. giganteus*.

3.5.2. Spectrum of Phytogeographic Types. The phytogeographic types showed a dominance of pantropical (38.2%), Afrotropical (14.7%), cosmopolitan (11.8%), and paleotropical (11.8%) species. There was a low proportion of Afro-American, Afro-Malagasy, and Cameroonian Ridge endemic species, each with 1.5% of the gross spectrum.

Phytogeographic types are good indicators of the dynamism or stability of plant communities. A predominance of widely distributed (pantropical, cosmopolitan, and paleotropical) and continentally distributed (Afrotropical) species is characteristic of heliophilic vegetation such as grassy savannas. It is also an indication of environmental disturbance [60]. This disturbance of the environment in this study could be due to the anthropogenic activities such as agriculture, grazing, and bushfires observed at the study site (Figure 9).

3.5.3. Types of Diaspores and Dispersal Modes. The types of diaspores, as well as the modes of dissemination, provide information on the capacity of groups of individuals associated with *E. giganteus* to colonize an environment and perpetuate the species.

Seven types of diaspores corresponding to four modes of dissemination were identified in the different surveys. The most dominant types of diaspores were pogonochores (35.85%) and Sclerochores (24.5%) (Figure 10), while the most dominant types of dissemination were anemochores (55.38%) and autochores (29.23%) (Figure 11).

The high proportion of anemochores (pogonochores and sclerochorees) is justified by the abundance of Poaceae and Asteraceae, which are the main dissemination strategies for savanna plants [56]. This is quite logical given the fact that the study was conducted in a savannah environment.

3.5.4. Types of Leaf Size. This study allowed for the identification of seven types of leaf size, namely leptophylls, macrophylls, megaphylls, mesophylls, microphylls, nanophylls, and notophylls (Figure 12). The dominant leaf size types were notophylls (25.8%), mesophylls (25.8%), and microphylls (21.2%). Megaphylls and leptophylls were the least represented, with 4.5% and 3% of species, respectively. No aphyllous species were observed.

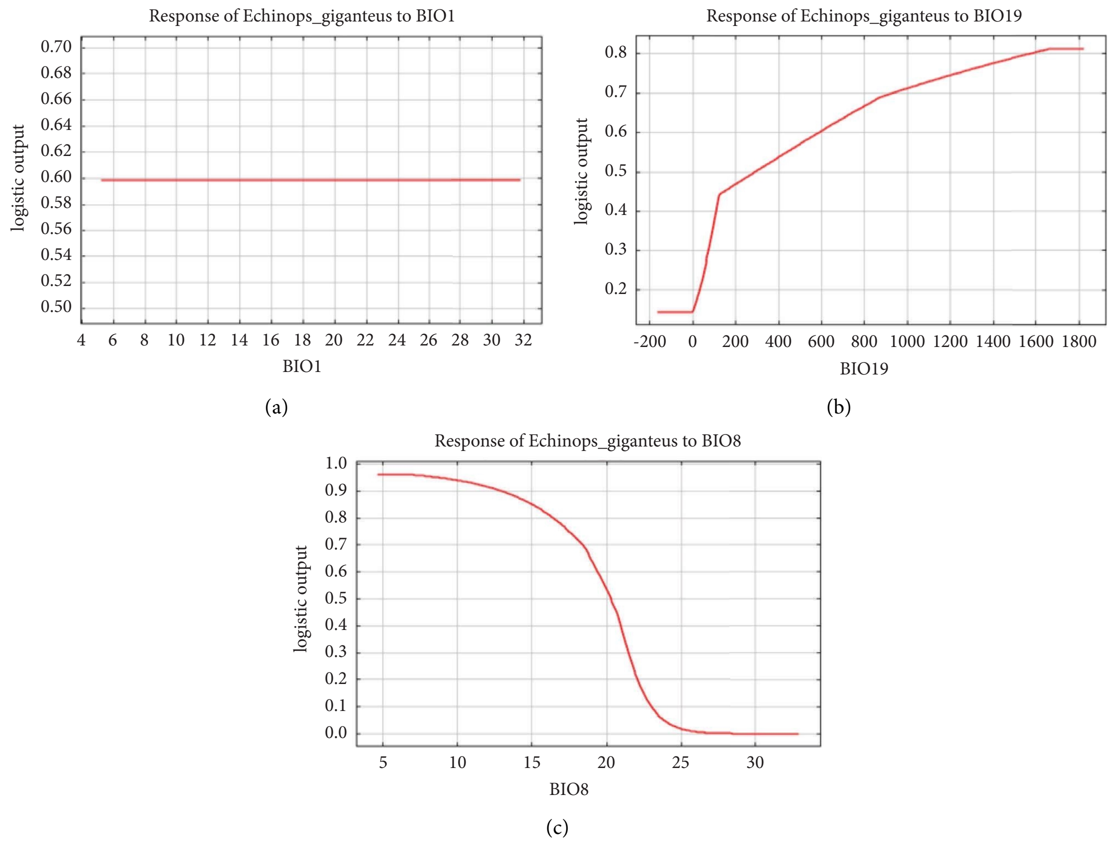

Figure 5: MaxEnt model logistic function curves of the response of key climate factors. (a) Mean annual temperature (Bio1), (b) precipitation of the coldest quarter (Bio19), and (c) mean temperature of the wettest quarter (Bio8).

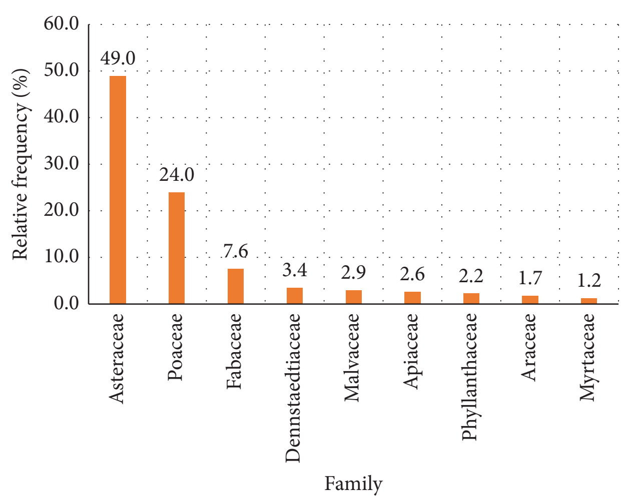

Figure 6: Diversity of families most represented in the surveys.

The size of the leaves gives information on the hygrometry and the sunshine in a general way. It represents a response to altitude, local climatic conditions, and the regional orographic gradient. The predominance of notophylls, mesophylls, and microphylls is characteristic of slope and high-altitude vegetation. This result is similar to that of [58].

3.5.5. Morphological Types. The morphological types of companion species to *E. giganteus* were represented by grasses (80.3%), shrubs (9.1%), trees (6.1%), and lianas (4.6%) (Figure 13). This high representation of herbaceous species provides information on the dynamic and regressive states of the ecosystem. The study area is a savannah ecosystem subject to regular grazing, bushfires, and agricultural

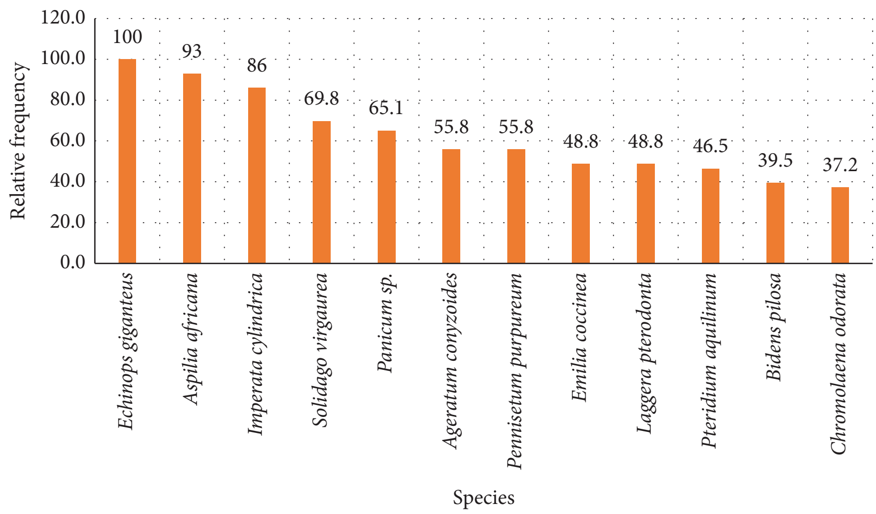

Figure 7: Relative frequency of the most represented species.

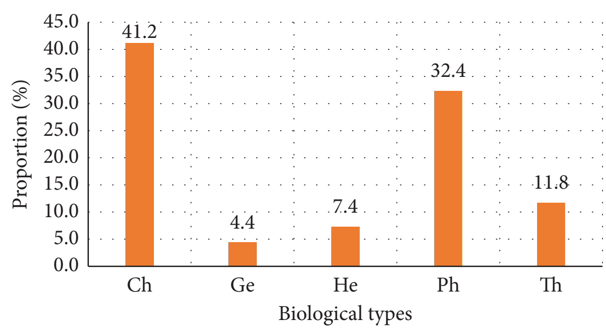

Figure 8: Proportion of biological types: (*Ch*) *Chamaephytes*, (*Ge*) *Geophytes*, (*He*) *Hemicryptophytes*, (*Ph*) *Phanerophytes*, and (*Th*) *Therophytes*.

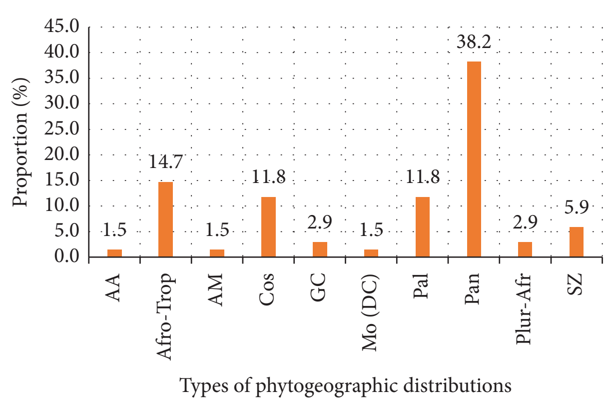

Figure 9: Proportion of phytogeographic distribution types: (AA) African, (Afro-Trop) Afro-Tropical, (AM) Afro-Malagasy, (Cos) Cosmopolitan, (GC) Guineo-Congolese, (Mo) Montane, (Pal) Paleotropical, (Pan) Pantropical, (Plur-African) Pluriregional African, and (SZ) Sudan-Zambezi.

activities. It is considered a degradation stage with floristic diversity that is sometimes important but ephemeral. It is therefore dominated by annual species with high seed production that are capable of colonizing the environment when living conditions are favorable. This would justify the predominance of Asteraceae and Poaceae.

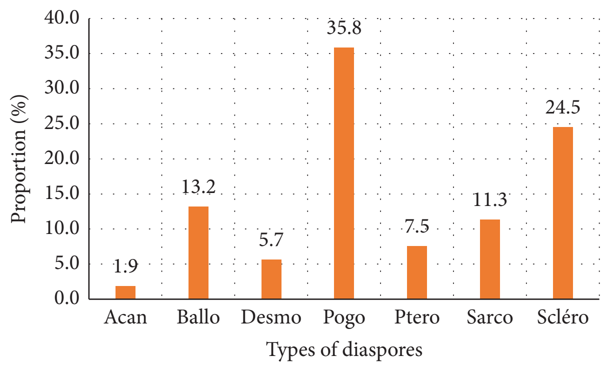

Figure 10: Proportion of diaspores types: (Acan) Acanthochores, (Ballo) Ballochores, (Desmo) Desmochores, (Pogo) Pogonochores, (Ptero) Pterochores, (Sarco) Sarcochores, and (Scléro) Sclerochores.

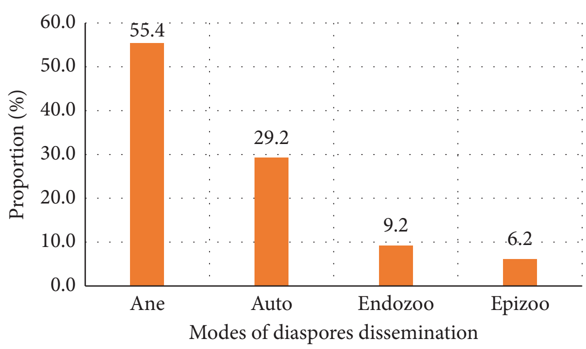

Figure 11: Proportion of different modes of diaspores dissemination: (Ane) Anemochory, (Auto) Autochory, (Endozoo) Endozoochory, and (Epizoo) Epizoochory.

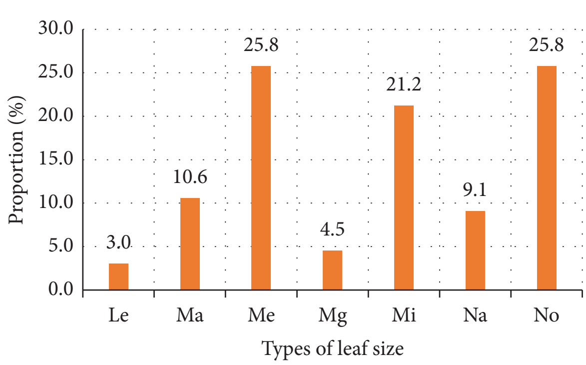

Figure 12: Proportion of the different types of leaf sizes: (Le) Leptophylls, (Ma) Macrophylls, (Me) Mesophylls, (Mg) Megaphylls, (Mi) Microphylls, (Na) Nanophylls, and (No) Notophylls.

4. Conclusion

E. giganteus is an endemic species to some countries in sub-Saharan Africa. Its ecological requirements are conditioned by substrate, altitude, sunshine, rainfall, and temperature. The predominance of biological types, diaspores types, and phytogeographic types in association with it informs about the regressive state of the vegetation. This implies a possibility that the species may be vulnerable in the Western

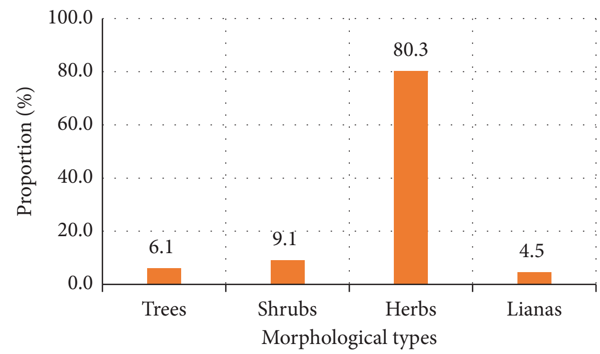

Figure 13: Proportion of morphological types.

Highlands of Cameroon in the future. Cameroonian authorities and companies exploiting the resource will need to take measures for sustainable exploitation in accordance with ABS (access to genetic resources and benefit sharing) principles. The cultivation of the resource should be favored over its exploitation in its natural state. In future work, spatiotemporal modeling of the ecoclimatic niche of *E. giganteus* will allow us to predict the potential impact of climate change on its distribution and to predict areas potentially favorable to its cultivation.

Data Availability

Occurrence data as well as stationary ecological information on *E. giganteus* were collected from the GBIF database, from the Cameroonian herbarium labels in Yaoundé and Limbé, and during field trips in the Western Highlands of Cameroon. The bands of bioclimatic variables were extracted from the WorldClim database (https://www.worldclim.org/data/worldclim21.html) at 2.5 minutes (~21 km^2) ground resolution.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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