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Research Article

Bayesian approach and Imprecise Dirichlet Model for the selection of (underused/overused) medicinal plants in the Guinean zone of Togo

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Abstract

Identifying priority medicinal plants at the local level is crucial for the improvement of integrative and strong conservation solutions around these resources. This study was carried out to determine underused and overused botanical families, and, analyse the correlation between botanical families, used plant parts, and categories of treated diseases in the Guinean zone of Togo. Ethnobotanical field surveys conducted via semi-structured interviews (individuals/focus groups) among traditional healers and medicinal plant sellers helped to identify the rich diversity of medicinal plants used in the Guinean zone. Bayesian statistics and the Imprecise Dirichlet Model (IDM) were used to detect botanical families' level of use (under/overused). A matrix analysis via phylogeny coupled with a cladogram was carried out to highlight the preferences of users in plant parts and botanical families in the treatment of diseases. It appears that 12.43% of the local flora in the Guinean zone of Togo is used in traditional medicine. The most treated diseases with a high plant diversity are general and unspecified categories of diseases (228 plants), followed by cardiovascular diseases (133 plants). Both Bayesian and IDM approaches show that the most overused families are Amaranthaceae, followed by Combretaceae, Euphorbiaceae, Meliaceae, Myrtaceae, and Rutaceae. The underused families are Cyperaceae, Orchidaceae, and Poaceae. The leaves and roots are the plant parts in high demand for the preparation of medicinal drugs. The presence of chemical groups such as phenols, flavonoids, tannins, saponosides, coumarins, and alkaloids would justify the choice of a botanical family or specific plant parts for the treatment of a category of diseases. It is necessary to develop conservation strategies for overused plant families to ensure sustainability for future generations.

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1. Introduction

Medicinal plant resources remain the key component of biodiversity and ecosystems used by modern and traditional medicine. Generally, the choice of medicinal plants results from several components such as the ethnocultural group [1], the local flora available [2], the impact of gender [3], and the related local knowledge developed [4]. Despite the boon offered by these plants, more than 20% are threatened with extinction in the world [5]. Locally, recent study showed that 165 medicinal plants are vulnerable [6].

These resources are inexorably threatened by the destruction of their ecosystems, the bad exploitation [7], and, the research of new active substance by pharmaceutical companies [8]. There is a need to identify medicinal plant conservation priorities at local levels in order to develop integrative and strong conservation approaches [9-11].

Several studies combined ethnobotany with pharmacology [12-15], and, the effectiveness of these plant drugs explains, the increase of traditional medicine to modern one [16]. Other studies have explored the diversity of medicinal plants [6, 15], related local knowledge, plant threats, conservation and restoration strategies [17]. The conclusions of these studies showed that knowledge about medicinal plants is transmitted both orally and across generations. This mode of transmission induces the overuse of some plants/botanical families (with a high threat), and others are little or not used. A selection is then observed in the choice of plants, showing the preference of some medicinal species in diseases' treatment [18].

Usually, descriptive statistics, based on frequencies [19, 20], consensus factor index [21], confirmation index [22], least squares residuals and linear regression analysis [23], log-transformed linear model or binomial analysis [24], or the contingency table are used to assess the level of botanical families used. These approaches have statistical inconsistencies [25, 26], because they do not take into account statistical interference and botanical family size [8, 27]. New methods based on statistical inference such as the Bayesian approach and Imprecise Dirichlet Model [27-29] have been proposed to discover the level of plants used, because they not only consider the uncertainty around medicinal flora data, but also around the total flora inventoried [8]. These new methodological approaches have provided more accurate and reliable conclusions [27, 30].

This study aims to use Bayesian and IDM to assess the level of use of medicinal plants in the Guinean zone of Togo. Specifically, it has been a question to: (i) analyse the existing links between the botanical families, the organs used and the treated diseases, and (ii) determine the overused and underused botanical families.

2. Materials and methods

2.1 Study area

The study is carried out in the Guinean zone which is limited to the south by the Atlantic Ocean, to the north by the Sudanian zone, to the east by Benin, and to the west by Ghana (Figure 1). This zone is chosen because of its richness in plant diversity and because it is under the most pressure from agricultural and urban development. The area can be divided into three ecological zones [31]. Firstly, the zone of plains (ecological zone III) located in the north-eastern part of the area, dominated by savannas crossed by dry forests of *Anogeissus leiocarpa*. These savannas have a varied flora, dominated by Combretaceae and Andropogonae. There are also scattered islands of semi-deciduous forests as well as gallery forests whose main species are: *Cynometra megalophylla, Parinari congensis*, and *Pterocarpus santalinoides*. Secondly, the mountains' zone (ecological zone IV) located in the north-western part of the area, has semi-deciduous humid forests [32]. The most common species are: *Hidelgardia barteri, Khaya grandifoliola, Milicia excelsa, Morus mesozygia, Parkia filicoidea, Musanga cecropioides, Triplochiton scleroxylon, Pterocarpus midbraedii*. These forests are interrupted by savannas with species like *Lophira lanceolata, Pterocarpus erinaceus, Hymenocardia acida, Crossopteryx febrifuga, Faurea speciosa*, and *Vitex doniana*. In addition, it contains 110 species classified as locally threatened and 16 species classified as globally vulnerable according to IUCN criteria [33]. Thirdly, the coastal plain (ecological zone V) in the south, shows a mosaic of croplands, fallows, thickets, bushes, grassy savannas with sacred and community forest. The mangroves, the flooded meadows, and savannas are also present in the extreme southeast.

2.2 Data collection

The basic data come from ethnobotanical surveys covering five years (2017-2020 and 2022). The localities to be investigated were chosen on a stratified sampling basis [34]. The ecological zones (Ern, 1979) and the repartition of ethnocultural groups [35] represent the strata selected. An explorative survey was conducted, in order to assess, firstly, the apprehension of the questionnaire for an improvement of the different headings and, secondly, to establish the size of the sample to be surveyed. The sample of respondents was determined by Dagnelie's formula

$$\mathbf{N} = \frac{\mathbf{U^2_{1-\alpha/2} \times p(1-p)}}{\mathbf{d^2}},$$

where "**N**" is the sample size to be determined; "**p**" is the proportion (relative frequency) of respondents with knowledge about PMTs; "$\mathbf{U}_{1-\alpha/2}$" is the standard value of confidence level (interval); and "**d**" is the margin of error set at 5% for this study. A total of 1041 persons were interviewed across 94 localities in the study area (Figure 1). During this survey, it was about to collect data about the medicinal plant parts uses, and diseases treated by each plant. The code of ethics of the international society of Ethnobiology was respected during the interview.

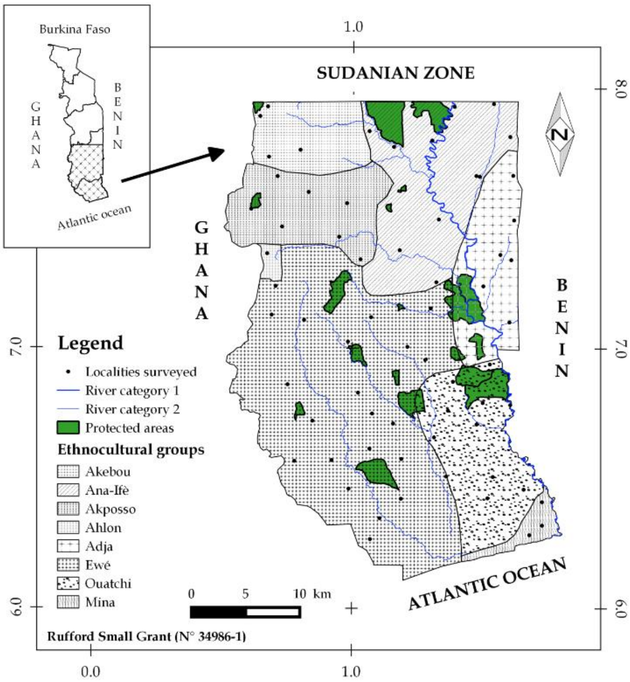


Figure 1. The location map of the surveyed villages in the Guinean zone of Togo

For good interoperability of the results on the local level use of medicinal plants, field data were supplemented by a systemic search on motor engines (Google scholar, Science direct, AJOL) and in the libraries at the University of Lomé (LBEV, DBA-UL). A total of 11 dissertations papers [6, 36-45] were retained. The keywords medicinal plant AND TOGO, plant extract AND TOGO, medicinal*, medicinal plant* had been used. Documents are stripped and withheld when a new medicinal plant citation or use is observed [2]. The Togolese plant species database has been uploaded from GBIF-Togo platform (https://www.gbif.org/dataset/b05dd467-aaf8-4c67-843c-27f049057b78) added with newly reported plant occurrences from works [33, 46-48]. The data retained for the statistical treatments were only angiosperms, and the lowest taxon used in this study was species [24]. The identification of the plants was made by both Togolese [49] and Beninese flora [50]. The nomenclature used was APG IV [51].

2.3 *Statistical analyses*

The identified various diseases and symptoms have been grouped into the 14 categories defined by the International Classification of Primary Care-2nd edition [52]. This classification has been used by several authors in research on medicinal plants [53-56]. The Bayesian and IDM calculations were carried out using the INV.BETA function of Excel© for the calculation of the interval of the most probable values [25, 27]. A heatmap graphic was produced to highlight the relationship between the botanical families, the most harvested plant parts (leaf, root, bark, stem, and fruit), and various symptoms or diseases treated. A phylogenetic diagram was produced using the "V.phylocom" package from R software, to show the possible correlation between botanical families, and diseases or symptoms [57, 58]. Phylogenetic methods are nowadays emerging tools to understand the relationship between medicinal plants [59].

3. Results and Discussion

3.1 *The most treated affections and symptoms by medicinal plants*

The identified symptoms or diseases were categorized into 14 groups as defined by ICPC-2 (Table 1). The analysis of Table 1 reveals that the most treated diseases are categories of general and unspecified diseases (UR= 229; n_i = 134 plants), followed by cardiovascular diseases (UR=133; n_i = 120 plants), and digestive system diseases (UR= 128; n_i = 107 plants).

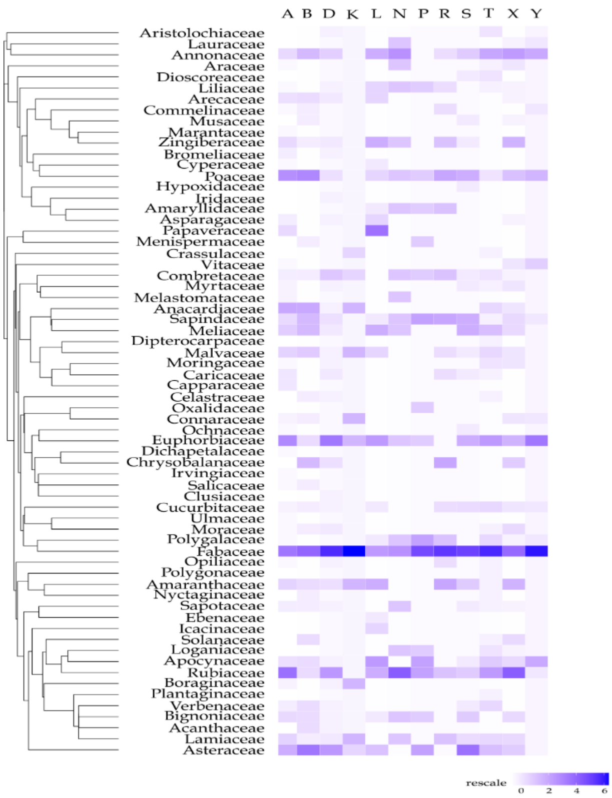
Table 1: Number of plant species used against disease categories according to CISP-2

Ailments/Symptoms (Code)	UR	UR (%)	n_i	n_i (%)
General and unspecified diseases (A)	229	20.46	134	12
Blood, syst. hematopo/ Immuneology (B)	84	7.51	61	5.45
System Digestive (D)	128	11.44	107	9.56
Eye (F)	27	2.41	22	1.97
Cardiovascular (K)	133	11.89	120	10.7
Musculoskeletal (L)	65	5.81	45	4.02
Neurological (N)	23	2.06	21	1.88
Psychological (P)	26	2.32	23	2.06
Respiratory (R)	40	3.57	32	2.86
Skin (S)	70	6.26	55	4.92
Metabol., nutrit., endocrine (T)	106	9.47	83	7.42
Pregnancy, childbirth and FP (W)	7	0.63	6	0.54
Sys. female genital and breast (X)	123	10.99	106	9.47
Sys. male genital and breast (Y)	58	5.18	53	4.74

The least treated diseases are those related to pregnancy, childbirth (UR= 7; n_i = 6 plants), followed by diseases related to the eyes (UR= 27; n_i = 22 plants). These results are similar to Agody *et al*. [60] where medicinal plants used in Maritime region of Togo are mostly used for malaria and fever. General and unspecific diseases (malaria, fever, fatigue) are treated with a high diversity of plants because, malaria is a major scourge in Togo (even in the sub-region), and constitutes 40% of consultations, and 26% of hospitalizations with lethality of 8% [61]. The low use of plants during pregnancy and, childbirth can be explained by the fear of the adverse effects of these drugs on the development of the foetus [62, 63]. Thus, several medicinal recipes are consumed sparingly, even prohibited during the pregnancy phase and patients are referred more to hospitals than to herbalists. The eye is a very sensitive organ, and the application of eye drops based on medicinal recipes remains very limited.

3.2 Correlation between botanical families and categories of diseases

A total of 370 medicinal plants divided into 64 botanical families are used for the treatment of pathologies in the Guinean zone of Togo. Fabaceae remains the most used in the treatment of diseases related to the digestive systems (25 plants), general and unspecified diseases (22 plants), and cardiovascular system (21 plants). The strong preponderance of Fabaceae for the treatment of numerous pathologies is explained by the rich diversity of this family [49]. Indeed, this family is represented by 362 plant species with distribution in all the ecological zones in the country [31]. These results support the conclusions of Moerman *et al*. [23], who stated that families containing many plant species were likely to be richer in medicinal plants than small families. The high occurrence of the Fabaceae species reflects the widespread use of these plants in treating malaria in African countries [1, 6]. This strong use of Fabaceae is also observed in northern Togo [64], in Nepal [24], Korea, and Ecuador [65]. Apart from Fabaceae, Poaceae, Euphorbiaceae, Rubiaceae and Asteraceae are really used for the treatment of several diseases. Figure 2 shows sufficiently that the choice of plants in traditional medicine is influenced by the botanical family and not by sheer coincidence.



General and unspecified disease (A); Blood, syst. Hematopo/immunology. (B); Sys. Digestive (D); Cardiovascular (K); Musculoskeletal (L); Neurological (N); Psychological (P); Respiratory (R); Skin (S); Sys. Female genital and breast (X); Sys. Male genital and breast (Y)

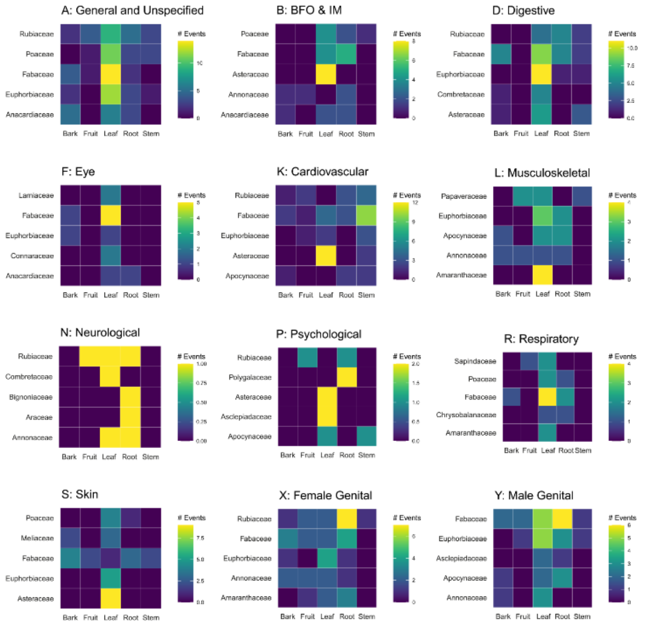
Figure 2: Phylogeny of botanical families used in traditional medicine and disease categories according to ICPC-2

Plants of the Asteraceae family are the most commonly used for the treatment of immunological (B), cardiovascular (K), and skin-related (S) diseases. For example, *Tridax procumbens* L. is commonly used to treat immunological disorders like chronic wounds. Rich in secondary metabolites [66], these laboratory-proven healing [67] and immunomodulating [68] virtues explain their increased use in traditional medicine. *Vernonia cinerea* Less is used primarily for the treatment of eczema (S). Indeed, extracted leaves from *V. cinerea* have a positive action on *Bacillus cereus* and *Enterobacter aerogenes* [69]. *Launaea taraxacifolia* L. is used to regulate blood pressure (K). It is rich in leucoanthocians and triterpenoids which, respectively, restore blood vessels, on the one hand, and have anti-vaso-depressant, cardiotonic, and antidysrhythmic potential, on the other hand [70].

Plants of the Euphorbiaceae family are widely used for the treatment of pathologies related to the digestive systems (D). Among plants, *Phyllantus amarus* Schum. & Thonn remains the most used for the treatment of viral hepatitis and digestive disorders. Indeed, the presence of phyllanthin and hypophyllanthin confers hepatoprotective properties to this plant [71, 72]. The presence of tannins and terpenoids in medicinal recipes shows positive effects on *Staphylococcus aureus, Escherichia coli, Pseudomonas aeruginosa* and, *Klebsiella spp*. These results explain the importance of *P. amarus* to treat digestive disease.

3.3 Prioritization of organs according to affections and symptoms

To characterize the therapeutic preferences, a matrix analysis between diseases, the used plant parts, and botanical families was carried out (Figure 3). The analysis showed that the leaves and roots remain the most used plant parts in traditional medicine. This result is similar to those obtained by Kantati *et al*. [15] in northern Togo, Ouattara *et al*. [73] in Ivory Coast, and Olivier *et al.* [74] in Burkina Faso. The leaves are the most used because they are more accessible [7], quick to harvest [75], and constitute a good identification factor for users [76]. In addition, the leaves, with the photosynthesis phenomenon, remain the primary production site for secondary metabolites [77, 78]. However, the intensive harvesting of roots is dangerous to the sustainability of the plant. Indeed,



(BFO & IM: Blood, Blood Forming Organs and Immune Mechanism)

Figure 3. Matrix analysis between diseases, organs used and botanical families

these harvesting methods have a significant impact on the growth and the recovery of the species in its ecosystem [79]. The presence of some secondary metabolites explains the use of these leaves in traditional medicine [80]. The roots are preferred to leaves for certain pathologies because they would contain very high concentrations of heat labile active ingredients (use often reserved for adults) [81]. This explains why the roots are more used than the leaves for the treatment of diseases related to the female/male genital systems. These results corroborate those of Assouma *et al*. [82] in Togo. The predominance of the use of target plant part in a therapeutic category essentially comes from the difference in concentration of active substance; in particular alkaloids, flavonoids, essential oils, and tannins, which often have proven therapeutic properties [83].

The leaves are more used rather than the other organs in the treatment of eye (F), and respiratory (R) affections, because the leaves contained a low concentration of active principles. These findings justify ethnobotanical ideologies that state that leaf-based drugs are often advised for children and those with weak immunity. Fabaceae plant species are highly reported for the treatment of general and

Table 2: Taxonomic group of underused and heavily used plants study area

Clade	n_j	x_i	inf (B)	sup (B)	status (B)	inf (I)	sup (I)	status (I)
Eudicotyledons	478	19	0.0257	0.0613	Under	0.0239	0.0684	Under
ANA Grade	292	15	0.0315	0.0830	Under	0.0287	0.0947	Under
Monocotyledons	171	18	0.0678	0.1603	ns	0.0625	0.1786	ns
Uncertain placement	55	11	0.1159	0.3243	ns	0.0987	0.3717	ns
Superrosids	1180	214	0.1604	0.2044	Over	0.1594	0.2067	Over
Superasterids	802	93	0.0956	0.1400	ns	0.0943	0.1437	ns
Total	**2978**	**370**	**0.1129**	**0.1366**		**0.1125**	**0.1375**	

Table 3. Underused and overused plant families in the study area

Family	n_j	x_i	Inf. (B)	sup (B)	status (B)	inf. (I)	sup (I)	status (I)
Amaranthaceae	28	11	0.2352	0.5774	Over	0.1923	0.6397	Over
Combretaceae	33	11	0.1975	0.5053	Over	0.1635	0.5654	Over
Euphorbiaceae	137	29	0.1517	0.2877	Over	0.1433	0.3071	Over
Meliaceae	16	9	0.3292	0.7702	Over	0.2445	0.8371	Over
Myrtaceae	14	6	0.2127	0.6771	Over	0.1421	0.7702	Over
Rutaceae	15	13	0.6165	0.9595	Over	0.4652	0.9862	Over
Cyperaceae	167	2	0.0037	0.0423	Under	0.0014	0.0673	Under
Orchidaceae	93	0	0.0003	0.0385	Under	0.0000	0.0886	Under
Poaceae	284	15	0.0324	0.0853	Under	0.0295	0.0973	Under
Acanthaceae	73	3	0.0149	0.1139	Under	0.0082	0.1640	ns
Anacardiaceae	24	7	0.1495	0.4939	Over	0.1111	0.5763	ns
Arecaceae	29	8	0.1473	0.4589	Over	0.1146	0.5319	ns
Cochlospermaceae	4	4	0.4782	0.9949	Over	0.1841	1.0000	Over
Bignoniaceae	12	4	0.1386	0.6143	Over	0.0779	0.7341	ns
Cactaceae	32	0	0.0008	0.1058	Under	0.0000	0.2306	ns
Caricaceae	1	1	0.1581	0.9874	Over	0.0063	1.0000	ns
Celastraceae	5	3	0.2228	0.8819	Over	0.0852	0.9681	ns
Commelinaceae	48	2	0.0128	0.1398	Under	0.0048	0.2141	ns
Lauraceae	3	2	0.1941	0.9324	Over	0.0433	0.9958	ns
Malvaceae	47	12	0.1528	0.3960	Over	0.1306	0.4461	ns
Moringaceae	1	1	0.1581	0.9874	Over	0.0063	1.0000	ns
Musaceae	4	3	0.2836	0.9473	Over	0.0990	0.9964	ns
Opiliaceae	1	1	0.1581	0.9874	Over	0.0063	1.0000	ns
Papaveraceae	1	1	0.1581	0.9874	Over	0.0063	1.0000	ns
Polygalaceae	14	5	0.1634	0.6162	Over	0.1031	0.7219	ns
Sapindaceae	19	6	0.1539	0.5428	Over	0.1073	0.6365	ns
Scrophulariaceae	46	0	0.0005	0.0755	Under	0.0000	0.1687	ns
Zingiberaceae	18	6	0.1629	0.5655	Over	0.1128	0.6598	ns

n_j : number of plant species of a family in the overall flora; x_i : number of medicinal plants in a family; inf(B), inferior limit for the Bayesian approach; sup (B), superior limit for the Bayesian approach; status (B), status for the Bayesian approach; inf (I), inferior limit for the IDM model; sup (I), superior limit for the IDM model; status (I), status for the IDM model; under: underused family; over: overused family

unspecified diseases (A), eye-related diseases (F), and respiratory problems (R). *Senna occidentalis* remains the most cited plant in the treatment of malaria (category A). The presence of chemical groups such as flavonoids, tannins, saponosides, coumarins, and alkaloids would explain the antiplasmodial activity of this plant.

The results for the underused and overused taxonomic groups are shown in Table 2. Among the 2978 existing plants in Togo, 1779 plants are found in the Guinean zone of Togo, i.e. 59.74% of the Togolese flora. Despite this rich local diversity, only 370 plants, representing 12.43% (ethnobotanicity index) of the flora are used for the treatment of diseases. Regardless of the Bayesian and IDM approach, the clade Eudicotyledons and ANA grade are underused, while Superrosids are overused (Table 2). Superrosids are widely used because they show a high proportion of used plants, with a larger 95% posterior credibility interval (0.16-0.20 for Bayes and 0.16-0.21 for IDM), which is possibly related to their small number of species. These results are similar to those obtained by de Medeiros *et al*, [8] , Weckerle *et al*, [27], Leonti *et al*, [28] , Arias *et al*, [30], Gras *et al*, [84] .

Botanical families with a 95% posterior credibility interval which is higher (overused) or lower (underused) than the interval for the whole flora (0.11-0.14) are synthesized in Table 3. It appears that Amaranthaceae, Combretaceae, Euphorbiaceae, Meliaceae, Myrtaceae, and Rutaceae are overused, while Cyperaceae, Orchidaceae, and Poaceae are underused. The overused families are generally families with few plants in the local flora, but most used in traditional medicine, while the underused families are those with many plants in the flora, but few species are used in the preparation of herbal drugs. These results corroborate those of Gras *et al*. [84] where Rutaceae remains widely used. The use of Rutaceae family is justified by it richness in volatile phenolic compounds. According to the statistical approach used (Bayes/IDM), twenty-three families have different use statuses (Table 3).

4. Conclusions

In the Guinean zone of Togo, about 12.43% of plant species of the local flora are used in traditional medicine. The most treated diseases are general and unspecified (A), followed by cardiovascular diseases (K), and those related to the digestive systems (D). The least treated diseases are those related to pregnancy (W) and those related to the eyes (F). The Fabaceae remains the most used plant species. The most used plant parts are leaves and roots. The presence of chemical groups such as flavonoids, tannins, saponosides, coumarins, and alkaloids explain the choice of plant part rather than another in the treatment of diseases. Bayesian and IDM analysis showed Eudicotyledons and ANA grade as underused, while Superrosids are overused at the clade level. At the botanical family's level, Amaranthaceae, Combretaceae, Euphorbiaceae, Meliaceae, Myrtaceae and Rutaceae are widely used, while Cyperaceae, Orchidaceae, and Poaceae are underused. These results focused on the botanical family are relevant for establishing relationship between the chemical composition, the phylogenetic aspects, and the dynamics of ethnobotanical knowledge in the Guinean zone of Togo.

Data Availability

Data will be made available on request.

Author Contributions:

Kodjovi Mawuégnigan Léonard Agbodan: data collection in the field and in the library, analyses, interpretation the data and wrote the paper. Sêmihinva Akpavi: statistical analyses, wrote the paper. Kossi Béssan Amegnaglo: data collection in the field, statistical analyses, interpreted the data and wrote of the paper. Amah Akodewou: analysed, interpreted the data and wrote the paper. Koffi Akpagana: interpreted the data and wrote the paper.

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Conflicts of interest

The authors declare no conflict of interest

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