Medicinal Plants from the Ankaratra Mountain In Madagascar: Diversity and Uses

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Abstract

Background

The Ankaratra Mountain, the third summit of Madagascar, is covered in a large part by herbaceous vegetations. It is among regions where ethnobotanical works have not been done yet. Besides, there have not been so far any surveys of medicinal plants conducted in savannah vegetation from Madagascar. The objective of the present communication was to study the diversity of medicinal species encountered in this mountain, the most used species in traditional medicine and the most important species used to treat diseases with medicinal plants.

Methods

The voucher specimens of surveyed species in the Ankaratra Mountain were shown individually to 26 local traditional healers. Semi-structured interview was employed and dealt with the main questions such as: do you know this plan? Do you know the uses of this species in traditional medicine? Do you know the method of preparation?

Results

Of the two hundred and three species (203) of medicinal plants inventoried in the Ankaratra Mountain, 139 (73.9%) are endemic and 69 (33.9%) are new to the ethnopharmacopea. The savannah vegetation hosts the highest number of species (35.5%). They are also more cited than the forestry species. Endemic species are the most used (FC=77.8%) and the most important (FL=71.6%). The most diversified and the most used genera are dominated by the best-represented ones in endemic species. The most cited diseases are those which require particular knowledge and those frequently encountered in Madagascar.

Conclusion

This work provides the first information on the ethnobotany of plant species in the Ankaratra Mountain. These data can be considered as a valuable tool to support any actions directed to the conservation of the flora from the massif. The ecological study of the most cited endemic species and the most important in the treatment of diseases as well as their chemical and pharmacological investigations are among our perspectives of research.

Introduction

The Ankaratra Mountain is the third highest point of Madagascar that emerges in the median part of the island and reaches 2643m in Tsiafajavona [1]. Figuring among the key biodiversity areas in Madagascar [2], the east slope of the Mountain is largely composed by the New Protected Area of Ankaratra Manjakatompo, as referred to the enactment n° 2015-711 in April 21, 2015. No structure of protection exists in the west slope.

This work is related to the ethnobotanical study of the herbaceous and remaining forestry vegetations of the Ankaratra Mountain.

It is of great importance for a number of reasons. Medicinal plants sold on the market in the city of Antananarivo are well-documented [3] [4], while the Ankaratra massif belongs to the regions in which no ethnobotanical work has been carried out [5], and where healers and crowds from other regions practicing annual cults collect medicinal plants [6] [7]. In addition, the island has 3,245 medicinal species [8] the majority of which are inventoried in unprotected areas [5]. Finally, analyzes of the literature cited in the "Synthesis and analysis of data on inventories of medicinal plants in Madagascar" [8] revealed that no inventory of medicinal plants exists on the grassy vegetations of Madagascar.

The general goal of this work is to fill out the data on medicinal plants from Madagascar by means of ethnobotanical surveys conducted in areas where few data have been recorded. These data are useful for the valorization of medicinal species and their conservation. The specific objectives are to know the diversity of medicinal species in the mountain, identify the most used species in traditional medicine and the important species to treat diseases with the medicinal species encountered in the studied area.

The following hypotheses are to be verified in the course of this research:

- The most used medicinal plants mainly belong to the large families of the flora;

- The large majority of medicinal plants used by Antakarana are endemic;

- The most used plants are those which are frequently encountered in the studied area;

Methods

Studied area

The Ankaratra Mountain belongs to the southeast part of the Itasy Region and the North part of the Vakinankaratra Region (Figure 1). The west slope is composed of the Rural Commune of Manalalondo, Andranomiely, Marofangady and the East Mahatsinjo whereas the East slope consists of the Rural Commune of Tsiafajavona and Sabotsy Namantoana.

Figure 1: Location of study area

This mountain is composed of is made up of trachytic, ordanchitic, basanitic and ultra-vulcanian eruptions. The soil is of volcanic nature, more or less deep, clayey to clayey-silty, black color and not very crumbly; the elements shrink by drying and become very hard [9] [10].

Two climatic seasons occur in the massif, the hot and humid season, from November to April and the cool and dry season, from May to October. The two slopes receive a climatic dissymmetry mainly concerning the rainfall regimes [10]. Indeed, during the hot and humid season, the western part is much more interested in the NW monsoon than the eastern part. Conversely, the latter are more marked by fine

rains coming from the humid east trade wind, while the western slopes are warmed and cleared of any cloudiness by the descent of this trade wind, during the cool and dry season.

The annual rainfall ranges between 800mm and 1000mm during the rainy season. The dry season takes place from April to October where the mean monthly height of rainfall is 40mm. The temperature average is 7.1°C in August and 26.7°C in January [11].

These physical factors give rise to vegetation dominated by herbaceous vegetation which are hardly modified by the human activities since the 6th century [12], land for culture and reforestations [13]. The herbaceous vegetation is found in the rocky escarpments and the non cultivated areas. They are associated with numerous endemic species, such as those of the Asteraceae family: *Helichrysum bracteiferum*, *H.gymnocephalum*, *H. benthamii, H. bojeri*, *Rochonea cinerarioides*, *Syncephalum arbutifolium;* those of the Lamiaceae family: *Tetradenia goudotii*, *Salvia cryptoclada;* those of the Malvaceae family: *Dombeya ankaratrensis*, *Kosteletzkya velutina;* those of the Apiaceae family: *Pimpinella perrieri, P. ebracteata, P. humbertii, Billburttia capensoides*.

The forestry formations cover only few areas and are present in the foot of east slope. They consist of evergreen humid forest [14] inside of which remain ancestral tombs and waterfalls that attract many traditional pilgrims on the major dates of the Madagascan lunar calendar [6] [15], which is dominated by high trees of *Dicoryphe stipulacea.* The upper stratum is rich in epiphyte, mostly species belonging to the Orchidaceae family like *Oberonia disticha,…*The reforestations hold few areas and are generally composed of *Acacia dealbata, Eucalyptus robusta, Cinnamomum camphora* [6].

The populations, the Antankaratra, descendant of Andriampenitra [16] [17] [6] are of the Merina ethnic group. Being parts of the Itasy and Vakinankaratra regions, the studied area is among the most crowded zones in Madagascar. The density reaches up to 125.6 hab. /km^2 [11]. People in this area live on agriculture and farming. The cultivable surface is still wider by covering approximately 72% of the all surfaces. The main productions and speculations are food cultures such as potatoes, rice, manioc, maize, sweet potatoes… (Figure 2)and the cash crop: tomatoes, pineapples, vegetables… the culture of fruit trees like *Prunus persica* is also practiced by populations in the suited area.

Figure 2: Culture of potatoes (A), rice (B) and fruit trees (C)

About the farming, the populations go in for the zebu breeding, goat breeding, poultry, but the practice fish farming (Figure 3) is also very common.

Figure 3: Goat breeding (A), zebu breeding (B) and fish farming (C)

Data collection

This research agreed by the CNARP Council of Scientific Orientation in 2017, was conducted after getting the Research authorizations from the Environnement, Ecology and Forests Ministry and from the local authorities and the agreement from informants.

The fieldwork which have 02 steps, was carried out at the end of dry season in 2018 (September and October 2018) and the beginning of the rainy season in 2019 (October and November 2019). The first step is dedicated to the inventory of plant species present in the natural vegetation. To do so, the Braun Blanquet [18] fitted to the savannah is chosen. Sixteen plots of which 5 are distributed in forest with 20m x 50m dimensions, 11 in savannah with 20m x 8m dimensions are set. All species found in each plot are counted and then vouchered.

The second step deals with the collection of data about the empirical uses of plant species encountered. Local traditional healers who can give related information are sought out. The surveys will be started only when their agreement is obtained by laying out the objectives of this work. Twenty-six traditional healers composed of 24 men and 02 women, well known in the studied area, have accepted our request (Figure 4).

The voucher specimens of the species inventoried in the Ankaratra Mountain are shown individually to the informants. The cited uses are recorded following a previously established form. The main questions asked during the inquiry are: Do you know this plant? Do you know the uses of this plant in traditional medicine? Do you know the method of preparation?

Figure 4: Data collection: the team during the floristic inventory on a steep slope near Tsiafajavona from the summit of the West side (A), and the making of the reference herbaria (B) and Traditional healer in its reception room in front of a herbarium reference during the ethnobotanical survey (C)

Data analysis

The botanical identification of the collected specimens are done using the reference vouchers at the Department of Ethnobotany and Botany of CNARP, Flora Department of the Botany and Zoology Park in Tsimbazaza and the specimens available on line of Paris National Museum of Natural History. The updated scientific names and the phytogeographical distribution are obtained by consulting the database of the Madagascar Vascular Plant Catalogue and the database of African plants. A database of the medicinal flora is created under Excel table, which compiles the information used to sort the data, determine the proportions and draw the diagrams.

The most cited species are determined according to the value of their quotation frequency. It is the percent of informants citing the species (nu) with regard to the total number of informants (Ni) [19]. The more the quotation frequency is high, the more the species is well-known and is very employed in traditional medicine.

FC (%) = (nu / Ni) x 100

The fidelity level (FL) as described by Friedman et *al.*, [20]. It is the percent of informants agreeing to say that a species is used in the most part to treat a defined disease. The high level of fidelity of a species for a disease means that this species is the most preferred and is very known to treat such disease.

$FL = (N_p / N_u) X 100$

It is the ratio between the number of informants who cite a species for a given disease (Ip) and the total number of informants who cite the species for any disease (Iu).

The analyses of variances are realized to better understand the degree of significance of the species quotation frequency and the fidelity level in function of the endemism.

Results

Diversity of medicinal plants

The Ankaratra Mountain is rich in medicinal plants. The majority of species encountered are almost medicinal. Two hundred and thirty five species are surveyed in the studied area (Appendix 1). They are distributed in 173 genera and 82 families. This work has revealed that 203 of them, distributed in 172 genera and 82 families, are traditionally used for therapeutic purposes.

The Dicotyledons are the most diversified and account for 167 species which are distributed in 143 genera and 64 families. The Monocotyledons are represented by 23 species distributed in 17 genera and 8 families. The Pteridophytes which are the least diversified encompass 13 species distributed in 12 genera and 10 families (Table 1).

Table 1: Synopsis of the medicinal species in the Ankaratra Massif

	Species	Genera	Families
DICOTYLEDONS	167	143	64
MONOCOTYLEDONS	23	17	8
PTERIDOPHYTES	13	12	10
Total	**203**	**172**	**82**

These species are encountered in four types of habitats, namely herbaceous savannah which house the highest number of species (35.5%), the rainy forest of the mountain holds 31.5% of species, the degraded forest with 17.2% of species, and the shrub savannah with 13.3% of the species (Figure 5A). Consequently, the species with herbaceous habit are prevalent in Ankaratra, with a percentage of 53.2%. The trees and shrubs represent 29.1 and 10.8%, respectively. The lianas only accounted for 7.4% of the all species (Figure 5B). The greater part of the medicinal species inventoried are endemic with a percentage of 73.9%. They largely have priority over the introduced species, which have a percentage of only 7.2% (Figure 5C).

Figure 5: Percentage of species according to ecology (A), life forms (B) and endemism (C); (FD: degraded forest, FH: humid forest, SH: grassy savanna, SA: shrub savanna, H: grass, a: shrub, A: tree, L: liana, AE:

indigenous endemic, I: introduced, NE: indigenous not endemic)

At the genus level, the first four most diversified genera in terms of medicinal species are composed of savannah and endemic species. The most diversified genera have a high percentage of species. *Helichrysum* is the most diversified with 14 species, which represent 8.8% of the all species inventoried. It is followed by *Senecio* and *Salvia* with *7* (3.9%) and 4 (2.3%) species respectively, and *Pimpinella* and *Gerbera* with 3 (1.7%) species each. The species of the genera *Helichrysum, Salvia* and *Pimpinella* are all endemic, which is not the case for *Senecio* and *Gerbera*.

Regarding the most diversified families in traditional medicine, the richest families in medicinal species are the most diversified ones inventoried on the floristic standpoint. The Asteraceae accounts for more than half of the families of medicinal plants inventoried during this work (63.4% or 52 species). It is followed by the Rubiaceae which represents 17% or 14 species, while the Poaceae is found at the rate of 14.6% or 12 species, and the Lamiaceae and the Apiaceae go for 13.4% (11 species) and 12.2% (10 species), respectively.

The most cited taxa in traditional medicine

The quotation frequencies of the species, as calculated using the Singh formula, vary between 4.2% and 100%. Among the first ten most cited species, the first eight such as *Tetradenia goudotii, Clematis pimpinellifolia, Billburttia capensoides, Micromeria flagellaris, Agauria polyphylla, Helichrysum benthamii, Hubertia faujasioides, Lycopodiella cernua,* have each a quotation frequency of 100%. Those of *Pimpinella perrieri* and *Inulanthera brownii* reach 95.8% (Table 2, Figure 6). Among these species, nine belong exclusively to Madagascar and six are aromatic plants.

Table 2: Top ten most cited species

Scientific names	Frequency of citation (%)
Tetradenia goudotii Briq.	100
Clematis pimpinellifolia Hook.	100
Billburttia capensoides Sales & Hedge	100
Micromeria flagellaris Baker	100
Agauria polyphylla Baker	100
Helichrysum benthamii R. Vig. & Humbert	100
Hubertia faujasioides (Baker) C. Jeffrey	100
Lycopodiella cernua (L.) Pic. Serm.	100
Pimpinella perrieri Sales & Hedge	95.8
Inulanthera brownii (Hochr.) Källersjö	95.8

Moreover, the first twelve most cited genera have the maximal quotation frequency of 100%. Four of them belong to the most represented genera regarding the inventoried species. They are *Helichrysum, Senecio, Pimpinella, Micromeria, Salvia, Vernonia, Hubertia, Agauria, Geranium, Indigofera, Vaccinium, Buddleja*. All of the representatives specific to these genera are endemic and all the species of the four genera (*Helichrysum, Pimpinella, Micromeria, Salvia*) are aromatic.

Figure 6: most used species: *Tetradeniagoudotii* (A), *Billburttiacapensoides* (B), *Helichrysumbenthamii* (C) and *Inulanthera brownii* (D)

Concerning the quotation frequency of the families, 15 families have the maximal quotation frequency of 100%. They are Asteraceae, Apiaceae, Rubiaceae, Lamiaceae, Ericaceae, Poaceae, Ranunculaceae, Euphorbiaceae, Fabaceae, Lycopodiaceae, Hypericacee, Malavaceae, Geraniaceae, Scrophulariaceae and Asphodelaceae.

Relation between the quotation frequency and the endemism, biological forms and ecology

The variance analysis of the quotation frequency of the species in relation to the endemism, to the biological forms and to the ecology is presented in the figure 7. These results show that:

- The endemic autochthon species are more cited than non endemic autochthon and introduced ones with a highly significant difference ($p<0,0001$),
- The herbaceous species and the shrub species are more cited than the trees and the liana with a highly significant difference ($p<0,0001$),
- The species from herbaceous savannah are most cited than those from other kinds of vegetations.

Figure 7: Analysis of variance of the frequency of citation of species depending on endemism (A), life forms (B) and ecology (C); (FD: degraded forest, FH: humid forest, SH: grassy savanna, SA: shrub savanna, H: grass, a: shrub, A: tree, L: liana, AE: indigenous endemic, I: introduced, NE: indigenous not endemic)

Diseases treated with plants

Sixteen diseases categorized using the international classification of diseases are treated with plants in Ankaratra (Figure 8). The first mostly cited disease (FC=29.9%), the Symptoms, signs and abnormal clinical and laboratory results, not classified elsewhere (SYMP), is the one which requires particular knowledge, and is treated with the great number of species (165 species or 81.2%). The two following groups are among the diseases frequently encountered in Madagascar, namely some infectious and parasitical diseases and the digestive tract diseases with quotation frequencies of 13.7% and 10.7%, respectively. The plants associated to these diseases correspond to 97 species (47.7%) and 93 species (45.8%), respectively. The quotation frequency of the five diseases such as the respiratory tract diseases (18 species or 8.8%), the eyes diseases and their appendages (9 species or 4.4%), the nervous system

diseases (22 species or 10.8%), the mental and behavior disorders (2 species or 0.9%), the ear diseases and the mastoid apophysis (4 species or 1.9%) do not exceed 1%.

Figure 8: Diseases treated with plants corresponding species rate (SYMP: Symptoms, signs and abnormal results of clinical and laboratory examinations, not elsewhere classified, MIP: Certain infectious and parasitic diseases, MAD: Disease of the digestive system, INC : Unclassifiable, MAR: Disease of the respiratory system, MPT: Diseases of the skin and subcutaneous cellular tissue, LTE: Traumatic injuries, poisonings and certain other consequences of external causes, MSO: Diseases of the osteoarticular system, muscles and connective tissue, MAG: Diseases of the genitourinary system, MEN: Endocrine, nutritional and metabolic diseases, GAP: Pregnancy, childbirth and the puerperium, MAC: Diseases of the circulatory system, OEA: Diseases of the eye and its appendices, MSN: Diseases of the nervous system, TMC: Mental and behavioral disorders, ORA: Diseases of the ear and mastoid process)

Important species for every disease

The fidelity level varies from 5.2 to 100%. Only species that are cited at least by three informants are considered in their identification.

The traditional healers give a huge importance to 8 endemic species with a fidelity level value of 100%:

- *Cantharanthus lanceus, Helichrysum bojerianum* and *Helichrysum fulvescens* used to treat some infectious and parasitical diseases,
- *Oncostemum bojerianum* and *Psiadia lucida* indicated to look after the Symptoms, signs and abnormal results of clinical and laboratory analysis, not classified elsewhere,
- *Pteridium aquilinum* and *Gerbera bojeri* reputed to be efficient respectively against the skin diseases and the sub-cutaneous cellular tissue, and Traumatic injury, poisoning and certain other consequences of external causes..
- *Kniphofia ankaratrensis* and *Solanecio angulatus* well known on the treatment of Endocrine, nutritional and metabolic diseases,

One hundred and seven species are cited at least by three informants. Concerning each of diseases treated with the plants, the first five species having the highest fidelity level are to the number of 64 and presented in the table 3. This table shows that:

- The fidelity level of species used to treat some infectious and parasitical diseases, and Symptoms, signs and abnormal results of clinical and laboratory analysis not classified elsewhere, the inclassables diseases, the skin diseases and the sub-cutaneous cellular tissue and the digestive tract diseases exceed 50%. The informants have more knowledge on these diseases and most of them agreed the uses of these species.
- The fidelity level of species used for caring pregnancy, childbirth and puerperium, the eye diseases and its appendices, the ear diseases and the mastoid apophysis do not reach 50%. The informants

have few knowledge about these diseases and that the majority of them diversify the uses of these species.

Table 3: Top five species with the highest fidelity level (FL) by disease

Scientific names	Diseases	FL (%)
Cantharanthus lanceus (Bojer ex A.DC.) Pichon	Certain infectious and parasitic diseases	100
Helichrysum bojerianum DC.		100
Helichrysum fulvescens DC.		100
Helichrysum chermezonii Humbert		85.7
Helichrysum cf *fulvescens* DC.		80
Garcinia verrucosa Jum. & H. Perrier	Pregnancy, childbirth and the puerperium	40
Indigofera bojeri Baker		40
Hypericum japonicum Thunb.		33.3
Crassula ankaratrensis Desc.		25
Pyrostria italyensis (Cavaco) A.P. Davis &Govaerts		25
Stoebe pachyclada Humbert	Unclassifiable	100
Aphloia theiformis (Vahl) Benn.		88.2
Croton mongue Baill.		87.5
Dioscorea hexagona Baker		83.3
Pityrogramma calomelanos (L.) Link		83.3
Gerbera bojeri (DC.) Sch. Bip.	Traumatic injuries, poisonings and certain other consequences of external causes	100
Maesa lanceolata Forssk.		60
Plectaneia thouarsii Roem. &Schult.		50
Athrixia debilis DC.		44.4
Micromeria sphaerophylla Baker		40
Pteridium aquilinum (L.) Kuhn	Diseases of the skin and subcutaneous cellular tissue	100
Kosteletzkya velutina Garcke		87.5
Asplenium cancellatum Alston		80
Indigofera thymoides Baker		66.7
Cyperus betafensis Cherm.		50

Hypericum japonicum Thunb.	Diseases of the circulatory system	66.7
Dombeya lucida Baill.		50
Melicope madagascariensis (Baker) T.G. Hartley		50
Indigofera thymoides Baker		33.3
Pyrostria madagascariensis Lecomte		33.3
Euphorbia emirnensis Baker	Disease of the digestive system	66.7
Eragrostis cylindriflora Hochst.		66.7
Centella tussilaginifolia (Baker) Domin		57.1
Pimpinella ebracteata Baker		50
Aloe capitata Baker		50

Scientific names	Diseases	FL (%) Level
Micromeria sphaerophylla Baker	Diseases of the genitourinary system	80
Clematis mauritiana Lam.		50
Dianella ensifolia (L.) DC.		33.3
Buddleja madagascariensis Lam.		33.3
Pilogyne emirensis (Baker) W.J. de Wilde &Duyfjes		33.3
Anthospermum emirnense Baker	Disease of the respiratory system	76.9
Osmunda regalis L.		66.7
Hypericum japonicum Thunb.		66.7
Poa ankaratrensis A. Canus & H. Perrier		50
Ilex mitis (L.) Radlk.		40
Helichrysum plantago DC.	Diseases of the eye and its appendices	27.3
Dombeya lucida Baill.		25
Radamaea montana Benth.		22.2
Helichrysum stenoclinoides (Baker) Humbert		16.7
Centella tussilaginifolia (Baker) Domin		14.3
Kalanchoe campanulata	Diseases of the ear and mastoid process	12.5
Kalanchoe pumila Baker		12.5
Phellolophium madagascariense Baker		6.3
Hubertia faujasioides (Baker) C. Jeffrey		5.9
Anthocleista madagascariensis Baker	Diseases of the nervous system	75
*Panicum dregeanum*Nees		75
Elionurus tristis Hack.		33.3

Tarenna angolensis Hiern		33.3
Panicum subalbidum Kunth		33.3
Kniphofia ankaratrensis Baker	Endocrine, nutritional and metabolic diseases	100
Solanecio angulatus (Vahl) C. Jeffrey		100
Impatiens baronii Baker		40
Polygala ankaratrensis H. Perrier		40
*Eragrostis cylindriflora*Hochst.		33.3
Salvia parvifolia Baker		27.3
*Equisetum ramosissimum*Desf.	Symptoms, signs and abnormal results of clinical and laboratory examinations, not elsewhere classified	85.7
Inulanthera brownii (Hochr.) Källersjö		83.3
Billburttia capensoides Sales &Hedge		80
Hubertia faujasioides (Baker) C. Jeffrey		70.6
Senecio resectus Bojer		57.1
Drosera madagascariensis DC.	Mental and behavioral disorders	72.7
Hypericum bojerianum H. Perrier		20

Relationship of the fidelity level to endemism, biological forms and ecology

The results of the variance analysis of the fidelity level versus the endemism, biological forms and ecology are summarized in figure 9. It shows that:

- The endemic species are of great importance in the treatment of diseases. The variance analyses of the fidelity level versus the degree of endemism of medicinal plants display a significant difference (p=0.0001) (Figure 9A). The endemic species have a high fidelity level, so they are very important for use to treat the diseases in comparison with autochthon but non-endemic species and those which are introduced. Among the 54 species having a fidelity level more than 50% and employed for the treatment of the first six diseases, only five species, namely *Clematis mauritiana, Ranunculus multifidus, Equisetum ramosisimum, Osmonda regalis* and *Lycopodiella cernua* are not endemic.

- The informants give much importance to herbaceous species which have a very significant difference (p=0.0001) (Figure 9B).
- The species from herbaceous savannah are more important in their health care than that of others. Nevertheless, the difference with those from rainy forest is not significant (Figure 9C).

Figure 9: Fidelity level according to endemism, life forms and ecology (FD: degraded forest, FH: humid forest, SH: grassy savanna, SA: shrub savanna, H: grass, a: shrub, A: tree, L: liana, AE: indigenous endemic, I: introduced, NE: indigenous non-endemic)

Discussion

Diversity of medicinal plants

The vegetations of the Ankaratra Mountain are rich and diversified in medicinal species. The number of medicinal species inventoried in the studied area is almost the same as that surveyed in the Zafimaniry region [21]. However, the informants in the Zafimaniry region are eight times as many as those of Ankaratra. Moreover, the observed vegetations are various in the Zafimaniry region, like the forest, the savannah and the savoka, whereas in Ankaratra, only species from savannah and forests are subjected to survey. Considering the number of species per informant, one informant in the Zafimaniry knows on the average 2.4 species and one traditional healer in Antakaratra makes use of 8.4 species, that is to say more than three times more. Thus, in Ankaratra, where all the informants are traditional healers, the species diversity of medicinal plants is high.

The comparison of the list of the Ankaratra medicinal flora with the database related to the synthesis and analysis of the medicinal plants inventoried in Madagascar [8] reveals that 69 medicinal plants out of 203 surveyed during this work are found to be new to the Malagasy ethnopharmacopeia. Given that, the traditional healers hold an important place in the conservation of particular knowledge on the use of plants in traditional medicine. It is inherited from their ancestors and the methods of use are known and transmitted generation to generation [22]. The occurrence of these newly identified medicinal plants might have two origins. First, the variation of ecological conditions at local level leads to a local endemism of the flora which is able to elaborate specific secondary metabolites. Secondly, the local inhabitants have knowledge dedicated to the use of these species because of their long contact with ecosystem.

Diversified and cited family and genera in traditional medicines

The most diversified genera are dominated by the genera which are the most prolific in endemic species. The most diversified families are first those among the large families of the Madagascar flora such as the Asteraceae and the Lamiaceae [25].These results give support to those obtained by Moerman and Estabrook [26] who state that the number of medicinal species in a family is positively correlated to the number of species in a given family.Then, the Apiaceae joins these two families. This family is diversified in the mountains [27]. Indeed, 11 species are inventoried in the Ankaratra Mountain, that is approximately

half of the Apiaceae species encountered in Madagascar [28]. Any how, the species of this family are also among the important families in traditional medicine in Madagascar [8]. Medicinal plants families encountered in the Ankaratra massif coincide also with the diversified families of the flora of it massif and that of the flora of Madagascar.

The most cited taxa/ important species for a given disease and endemism

The informants from Ankaratra use more and give much importance to endemic species. The use frequency and fidelity level of the endemic species are significant in Ankaratra. These facts have three origins. Firstly, the endemic species predominate in the flora of Ankaratra Mountain. Indeed, the most dominant and the most frequent plants have the highest use values because they are available, remarkable or visible by the human communities [29] [30].

The higher use of endemic species by traditional healers in Madagascar corroborates the findings of Lyon and Hardesty [31] during their works in the Anosy region. Then, autochthonous knowledge on medicinal plants is concentrated among the traditional healers. The endemic medicinal species are known only by traditional healers and/or anybody who lives around the forests [32] [33], in our case, the natural ecosystems in the Ankaratra Mountain. The same statement has been proved by Kunwar et al [24] who have also indicated in their works that there is a significant difference between the number of medicinal plants pointed out by the traditional healers and the aged. The similar facts have been found in the regions close to India [34] [35] and other parts of the world [36], where the inhabitants living in the regions at higher altitudes use a most important number of autochthonous species. Given that Ankaratra is the third summit of Madagascar, our results are in line with the conclusion of Byg et al. [23], suggesting that the villages at high altitude have known and used more medicinal plants than the inhabitants from the villages at low altitude. Besides, the places far from houses, with difficult access, at high altitude and the areas without perturbation were frequently cited by the traditional healers as sanctuaries for products of good quality [24]. This is confirmed by the presence of two sacred sites in the Ankaratra massif where many traditional healers perform periodic worship services throughout the year [24]. Endemic species are then very important in traditional Malagasy medicine and the Ankaratra Mountain is considered as an important reservoir of medicinal plants and traditional knowledge.

Important species for a given disease and other uses in Madagascar

The species having the highest fidelity levels in Ankaratra are compared with those of Madagascar as ascertained by [8]. Two species among the first 88 ones having the highest fidelity levels in Ankaratra are found in the list related to those of the whole Madagascar. These are *Drosera madagascariensis* and *Hubertia faujasiodes.*

The first species has a high level of fidelity in the treatment of diseases of the respiratory system throughout Madagascar, but it is considered very effective in mental and behavioral disorders according to traditional healers at the study site. The second species is mainly used in the treatment of diseases of the genitourinary system throughout Madagascar, while it is of high importance in the treatment of

Symptoms, signs and abnormal clinical and laboratory findings, not elsewhere classified for Antankaratra. When considering species of maximum importance for a disease in the study site:

- The use of *Cantharanthus lanceus* in the treatment of infectious and parasitic diseases (FL: 100%) including abdominal colic in Ankaratra is a new recipe in the Malagasy pharmacopoeia. The same is true for *Salvia cryptoclada* which is indicated in the treatment of Traumatic Injury, poisoning and certain other consequences of external causes including insect or spider bite at a fidelity level of 100%.
- *Helichrysum bojerianum* is used as an anti parasitic and anti infectious (FL: 100%), indicated especially in abdominal colic in the inventory site. It is known in the care of children's cough (Respiratory System Disease) from other parts of Madagascar.
- *Gerbera bojeri, Kniphophia ankaratrensis* are new species in the Malagasy ethnopharmacopoeia.

From these facts, the species important for the treatment of each disease vary according to the localities. Indeed, the history, the culture of the population and the degree of isolation or connections with other cultures [37] and ecological factors [38] can affect the patterns of traditional use and choice of plants. However, the different causes leading populations to choose a given medicinal plant are complex and dynamic, and the understanding of this process is still rudimentary [39]. Thus, in many cases, the widely distributed plants (*Chenopodium ambrosioides and Psidium guajava* (in our case) have similar uses in several regions [40] and the same degree of importance.

Diseases treated with medicinal plants

For the traditional healers from Ankaratra, the most cited diseases are those which need particular knowledge (SYMP) and those frequent in Madagascar (MIP, MAR). This correlation between diseases treated with plants and the most morbid diseases is also observed in other regions of Madagascar [41] [33][22][8] and in Africa [42]. However, some diseases require more knowledge that only the specialists can gain during their experiences or acquaintances, referring to an heavenly healer [43]. So, the majority of plant species in a given region, with their properties held by traditional healers, constitute one of the effective means of treating many diseases that are rife in this region.

Conclusion

The ethnobotanical survey conducted in the Ankaratra Mountain shows the richness of herbaceous formations in medicinal plants. Two hundred and three species out of the 235 species inventoried are used in traditional medicine. These species are encountered in 4 types of vegetations, namely the rainy forest, the degraded rainy forest, the shrub savannah and the herbaceous savannah. The herbaceous savannah and the rainy forest are very important since they host 35.5 and 31.5% of the total species, respectively. These species are also important in the treatment of diseases, although the species from the savannah are the mostly cited. The use of endemic species is very significant regarding the quotation frequency and the level of fidelity. Special measures at national level are essential to mitigate the threats

to natural resources inventories and traditional knowledge linked to the cultural specificity of the site studied.

All these data constitute a useful tool to reinforce the conservation of the flora from the Ankaratra Mountain, not only the eastern slope, but also the western slope. The ecological studies of the most cited and the most important endemic species in the treatment of diseases as well as the chemical and pharmacological of these studies are in prospect.

Declarations

Ethics approval and consent to participate

Not applicable

Consent for publication

This research was approved by the scientific steering committee of the National Center for Pharmaceutical Research Application in 2017. After receiving the acceptance of the focal point of the access and benefit sharing of biodiversity, we obtained the authorization of the ministry in charge of forests and the environment under the reference N ° 038/17 / MEEF / SG / DGF / DSAP / SCB.Re, N ° 297/18 / MEEF / SG / DGF / DSAP / SCB.Re and N ° 204/19 / MEEF / SG / DGF / DSAP / SCB.Re. The use and the publication of the data during this work received the voluntary acceptance and the consent of all the stakeholders of this study, including the traditional healers, the local community and the local authorities of the Itasy region and that of Vakinankaratra.

Availability of data and materials

All the herbarium specimens cited in the manuscripts are available in the herbarium of medicinal plants of Madagascar or CNARP

Competing interests

The authors declare that they have no competing interests

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Authors' contributions

As a part of my PhD thesis AR carried out ethnomedicinal survey and botanical identification of the Ankaratra Mountain with FMR, CMR, JR, MHA and SRR. MAR and RR MZ supervised this ethnobotanical project. VER helped in editing the manuscript and the translation into English language. VR provided

technical expertise in the conception of the work and compiling data into the draft. FMR carried out the statistical analysis and CMR translate the disease. All the authors read and approved the final manuscript.

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References

1. Bégué L. Chronique phytogéographique. La végétation de Madagascar. Bois et Forêts des Trop. 1966, 106: 56-65
2. Rakotobe ZL, Rahantamalala J, Andrianarisata M, Andriambolantsoa S. A participatory approach for plant conservation in Madagascar. Scr Bot Belgica. 2013, 50: 54-58.
3. Randriamiharisoa MN, Kuhlman AR, Jeannoda V, Rabarison H, Rakotoarivelo N, Randrianarivony T, Rakotoarivony F, Randrianasolo A, Bussmann RW. Medicinal plants sold in the markets of Antananarivo, Madagascar. J Ethnobiol Ethnomed. 2015, DOI 10.1186/s13002-015-0046-y.
4. Rakotoarivelo N, Randrianarivony T, Rakotoarivony F, Randrianasolo A. "*Mangidy*": Malagasy folk beverages sold in Madagascar's marketplaces. Ethnobot Res Applic. 2019, org/10.32859/era.18.29.1-14.
5. Rakotonandrasana SR, Rakotondrafara A, Rakotoarisoa M: Résultats des analyses préliminaires sur l'état de lieux des plantes médicinales de Madagascar. Acte du Forum de la Recherche : Biodiversité et les Objectifs du Développement Durable; Antananarivo: Ministère de l'Enseignement Supérieur et de la Recherche Scientifique; 2017: 197-200.
6. Blanchy S. Héritage ancestral et conservation dans l'Ankaratra (Madagascar) : échelles politiques, régimes de savoir. Journal des africanistes 2016, 86 (1) : 30-59.
7. Correges D. Les sites de cultes ancestraux entre histoires locaux et mondialisation des ressources (Ankaratra, Madagascar). Journal des africanistes. 2016, 86(1) : 60-84.
8. Rafidison V, Ratsimandresy F, Rakotondrafara A, Rakotondrajaona R, Rasamison V, Rakotoarisoa FM, Rakotonandrasana SR. Synthèse et analyse des données sur les inventaires de plantes médicinales de Madagascar. Ethnobot Res Applic. 2019, dx.doi.org/10.32859/era.18.40.1-19.
9. Zebrowski C. Propriétés des andosols de l'Itasy et Ankaratra. Cahier de l' O.R.S.T.O.M., série Pédologie. 1971, IX(1) : 83-108.
10. Raunet M. Le milieu physique de la région volcanique Ankaratra-Vakinankaratra- Itasy (Madagascar). Antananarivo, Madagascar : Institut de Recherches Agronomiques Tropicales et des Cultures Vivrières ; 1981.

11. Office Nationale de l'Environnement (ONE). Tableau de bord environnemental : Région Itasy. Antananarivo, Madagascar ; 2007. Disponible sur https://www.pnae.mg/tbe/region-itasy.html.
12. Razafindrazaka H. Le peuplement humain de Madagascar : Anthropologie génétique de trois groupes traditionnels. Thèse de Doctorat, France: Université de Toulouse III; 70p.
13. Randrianantoandro JC, Andriantsimanarilafy RR, Rakotovololonalimanana H, Hantalalaina EF, Rakotondravony D, Ramilijaona O, Ratsimbazafy J, Razafindrakoto GF, Jenkins RKB. Population assessments of chameleons from two montane sites in Madagascar. Herpetological Cons Biol. 2009, 5(1): 23-31.
14. Moat J, Smith P. Atlas de la végétation de Madagascar. Kew, London : Royal Botanic Gardens; 2007. 124p.
15. Razafindralambo L. L'Ankaratra au croisement de concepts et d'intéréts divergeants: conservation de la Biodiversité et héritage ancestral. Journal des africanistes.2016, 86 (1) : 86-104
16. Dez J. Le Vakinankaratra, esquisse d'une histoire régionale. *Bulletin de Madagascar.* 1967, 256 : 657-702.
17. Dez J. La légende de l'Ankaratra. *Annales de l'université de Madagascar, série Lettres et Sciences humaines.* 1971, 12 : 93-126.
18. Braun-Blanquet J. Plant The study of plant communities. New York and London: Hafner publishing company; 1965.
19. Singh AG, Kumar A, Tewari DD. An ethnobotanical survey of medicinal plants used in Terai forest of western Nepal. J Ethnobiol Ethnomed. 2012, org/10.1186/1746-4269-8-19.
20. Friedman J, Yaniv Z, Dafni A, Palewitch D. A preliminary classification of the healing potential of medicinal plants, based on a rational analysis of an ethnopharmacological field survey among Bedouins in the Negev Desert, Israel. J Ethnopharmacol.1986, 16: 275-287.
21. Rakotondrafara A, Rakotondrajaona R, Ratsimbason M, Rasamison V, Rakotonandrasana Ethnobotany of medicinal plants used by the Zafimaniry clan in Madagascar. J Phytopharmacol. 2018, 7(6): 483-494.
22. Rakotonandrasana SR, Rakotondrafara A, Rakotondrajaona R, Rasamison V, Ratsimbason M. Plantes médicinales des formations végétales de la baie de Rigny- Antsiranana à Madagascar. Bois et Forêts des Trop. 2017, 331 (1) : 55-65.
23. Byg A, Salick J, Law W. Medicinal plant knowledge among lay people in five eastern Tibet villages. Human Ecol. 2010, 38: 177-191.
24. Kunwar RM, Shrestha K, Malla S, Acharya T, Sementelli AJ, Kutal D, Bussmann RW. Relation of medicinal plants, their use patterns and availability in the lower Kailash Sacred Landscape, Nepal. Ethnobot Res Applic. 2019, .doi.org/10.17348/era.18.7.1-14.
25. Gautier L, Chatelain C, Callmander MW, Phillipson PB. Richness, similarity and specificity of Madagascar flora compared with Sub-Saharan Africa. Pl Ecol Evol 2013, 145: 55 - 64.

26. Moerman DE, Estabrook GF. Native Americans' choice of species for medicinal use is dependent on plant family: Confirmation with meta-significance analysis. J Ethnopharmacol. 2003, 87: 51-59.
27. Sales F, Hedge I, Coutinho AXP, Marques A. Apiaceae subfdamily Apioideae in Madagascar. S Afr J Bot. 2004, 70(3): 446-448.
28. Van Wyk B.-E, Tilney PM, Magee AR. African Apiaceae. A synopsis of the Apiaceae / Umbelliferae of sub-Saharan Africa and Madagascar. Pretoria, South Africa: Briza Academic Books ; 2013. 317p.
29. Thomas E, Vandebroek I, vanDamme P, Goetghebeur P, Douterlungne D, Sanca S, Arrazola S. The relation between accessibility, diversity and indigenous valuation of vegetation in the Bolivian Andes. J Arid Env. 2009, 73: 854- 861.
30. Johns T, Kokwaro JO, Kimanani EK. Herbal remedies of the Luo of Siaya District, Kenya: Establishing quantitative criteria for consensus. Econ 1990, 44: 369-81.
31. Lyon LM, Hardesty LH. Quantifying medicinal plant knowledge among non-specialist Antanosy villagers in southern Madagascar. Econ Bot. 2012, 66 (1): 1-11.
32. Quanshah N. Ethnomedecine in the Maroantsetra Region of Madagascar. Econ Bot. 1988, 42 (3): 370-375.
33. Rakotonandrasana SR. 2013. Les plantes médicinales de l'aire protégée de Zahamena (Madagascar) et de ses environs : richesse floristique et endémicité. Scr Bot Belgica. 2013, 50: 356-362.
34. Garbyal SS, Aggarwal KK, Babu CR. Return of biodiversity in Darma valley, Dharchula Himalayas, Uttaranchal, North India following fortuitous changes in traditional lifestyle of the local inhabitants. Current Science. 2005, 88(5): 722–725.
35. Malik Z, Bhat J, Ballabha R, Bussmann RW, Bhatt. Ethnomedicinal plants traditionally used in health care practices by inhabitants of Western Himalaya. J Ethnopharmacol. 2015, 172: 133-144.
36. Adnan M, Holscher D. Diversity and abundance of medicinal plants among different forest-use types of the Pakistan Himalaya. Econ Bot. 2011, 66: 344-356.
37. Akerreta S, Cavero RY, López V, Calvo MI. Analyzing factors that influence the folk use and phytonomy of 18 medicinal plants in Navarra. J Ethnobiol Ethnomed. 2007, 3:16.
38. Savo V, Joy R, Caneva G, McClatchey WC. Plant selection for ethnobotanical uses on the Amalfi Coast (Southern Italy). J Ethnobiol Ethnomed. 2015, doi:10.1186/s13002-015-0038-y
39. Heinrich M, Kufer J, Leonti M, Pardo-de-Santayana M. Ethnobotany and ethnopharmacology - interdisciplinary links with the historical sciences. J Ethnopharmacol. 2006, 107:157–160.
40. Guarrera PM. Usi e Tradizionidella Flora italiana Medicina popolare ed etnobotanica. Rome, Italy: Aracne Ed; 2006.
41. Rakotoarivelo NH, Rakotoarivony F, Ramarosandratana AV, Jeannoda V, Kuhlman AR, Randrianasolo A, Bussmann RW. Medicinal plants used to treat the most frequent diseases encountered in Ambalabe rural community, Eastern Madagascar. J Ethnobiol Ethnomed. 2015, DOI 10.1186/s13002-015-0050-2.

42. Tugume P, Kakudidi EK, Buyinza M, Namaalwa M, Kamatenesi M, Mucunguzi, Kalema J. Ethnobotanical survey of medicinal plant species used by communities around Mabira Central Forest Reserve, Uganda. J Ethnobiol Ethnomed. 2016, DOI 10.1186/s13002-015-0077-4.
43. Léontien EV. Plantes médicinales de la Côte d'Ivoire : Une étude ethnobotanique des usages médical et comestible des plantes sauvages par les Ando de la Côte d'Ivoire (Afrique occidentale). Wageningen, Nederland : Mededelingen Land Bouwhoge School ; 1975.

Figures

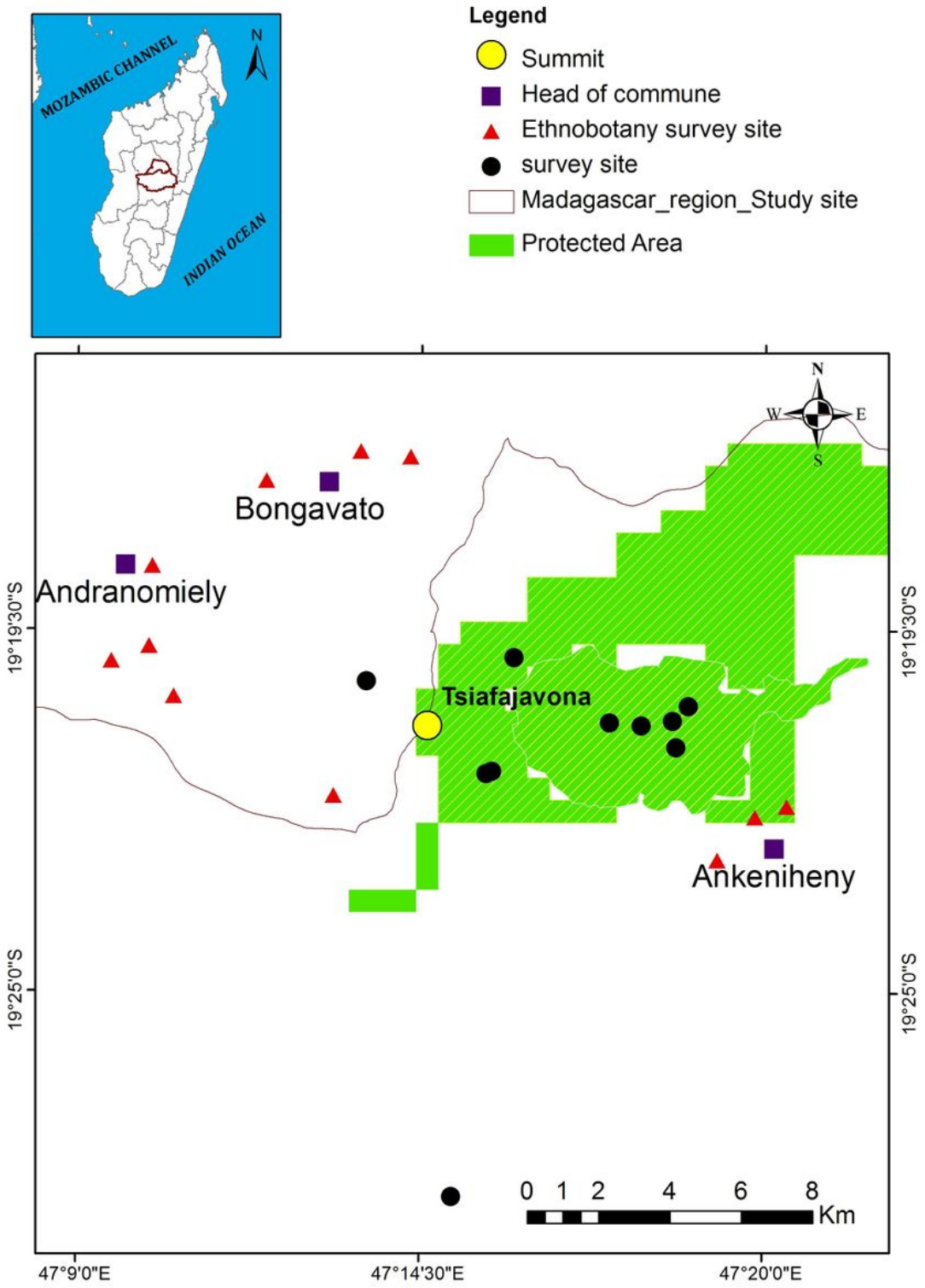

Figure 1

Location of study area

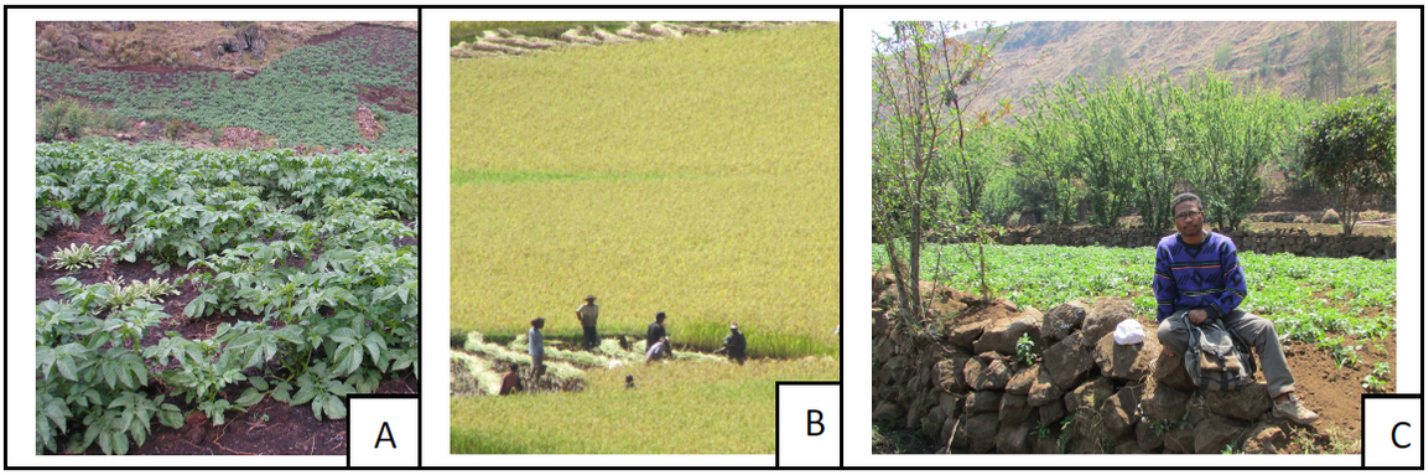

Figure 2

Culture of potatoes (A), rice (B) and fruit trees (C)

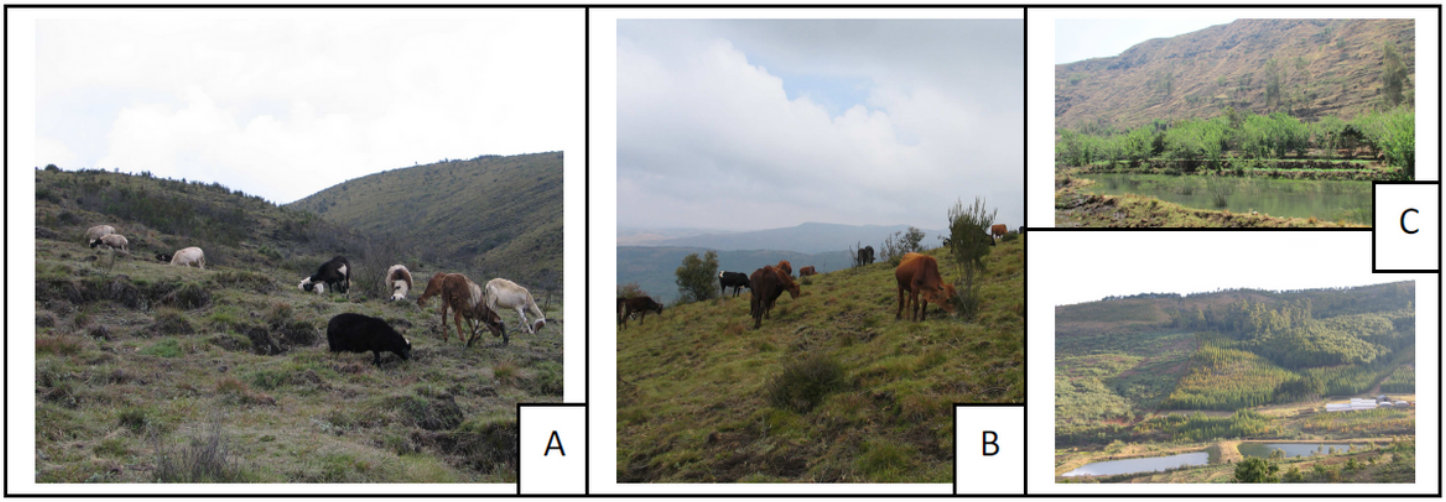

Figure 3

Goat breeding (A), zebu breeding (B) and fish farming (C)

Figure 4

Data collection: the team during the floristic inventory on a steep slope near Tsiafajavona from the summit of the West side (A), and the making of the reference herbaria (B) and Traditional healer in its reception room in front of a herbarium reference during the ethnobotanical survey (C)

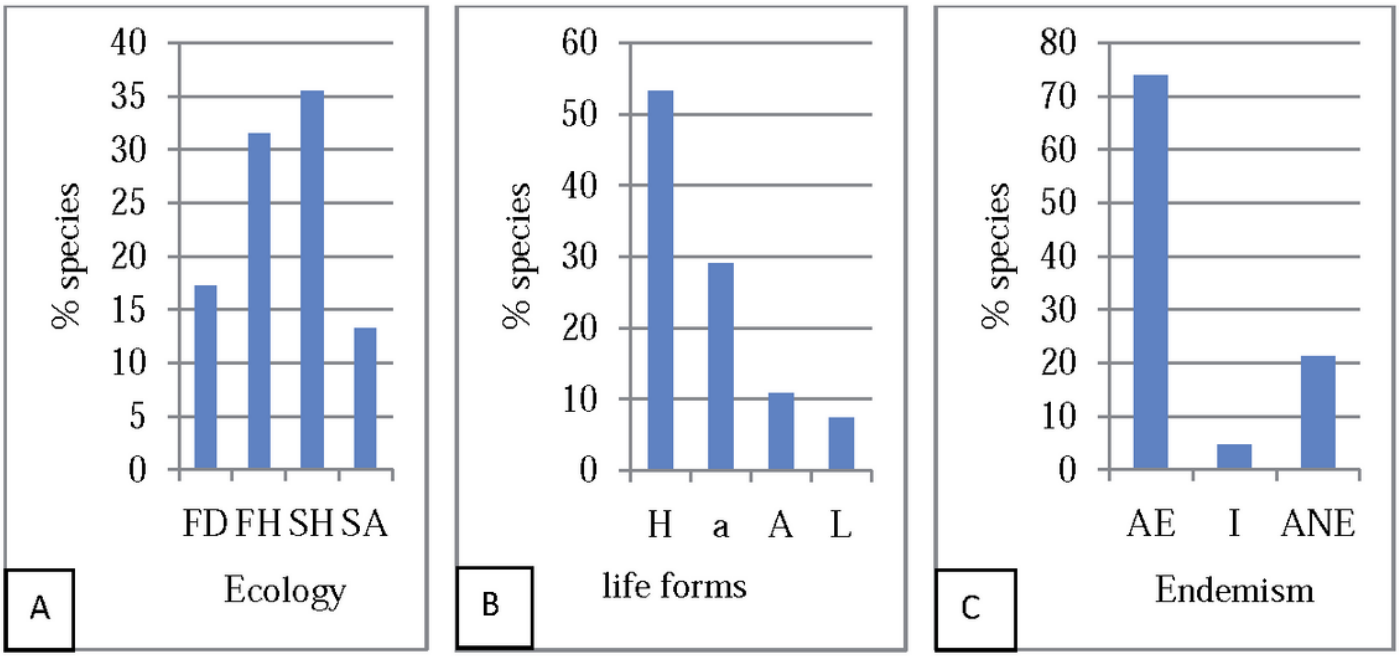

Figure 5

Percentage of species according to ecology (A), life forms (B) and endemism (C); (FD: degraded forest, FH: humid forest, SH: grassy savanna, SA: shrub savanna, H: grass, a: shrub, A: tree, L: liana, AE: indigenous endemic, I: introduced, NE: indigenous not endemic)

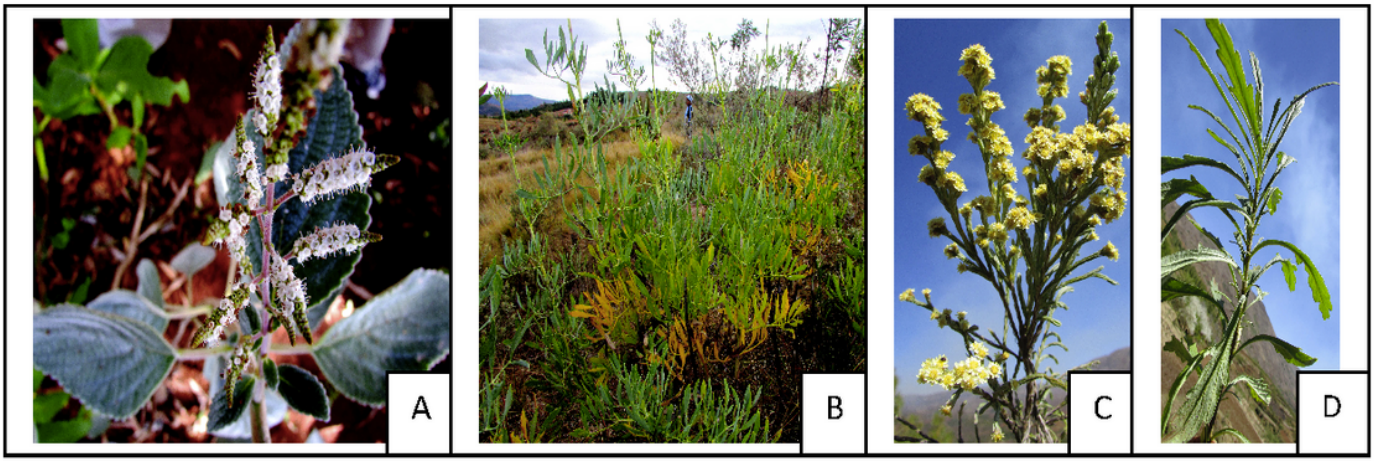

Figure 6

most used species: Tetradenia goudotii (A), Billburttia capensoides (B), Helichrysum benthamii (C) and Inulanthera brownii (D)

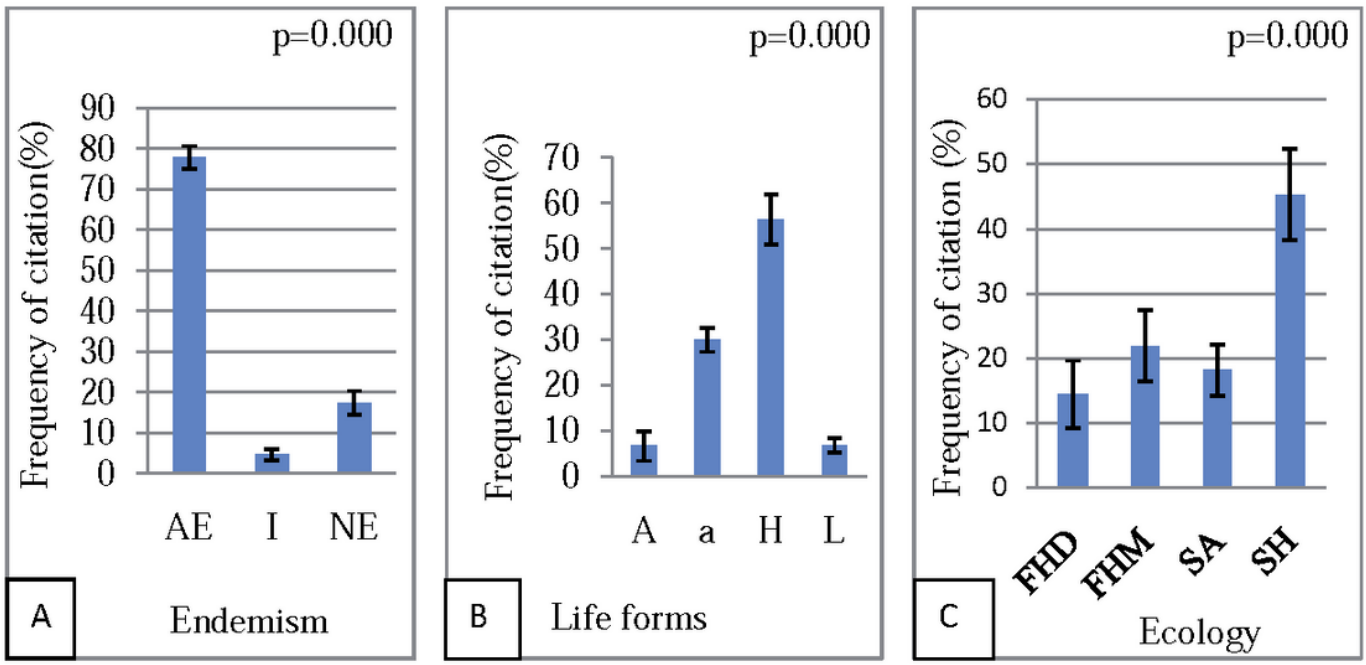

Figure 7

Analysis of variance of the frequency of citation of species depending on endemism (A), life forms (B) and ecology (C); (FD: degraded forest, FH: humid forest, SH: grassy savanna, SA: shrub savanna, H: grass, a: shrub, A: tree, L: liana, AE: indigenous endemic, I: introduced, NE: indigenous not endemic)

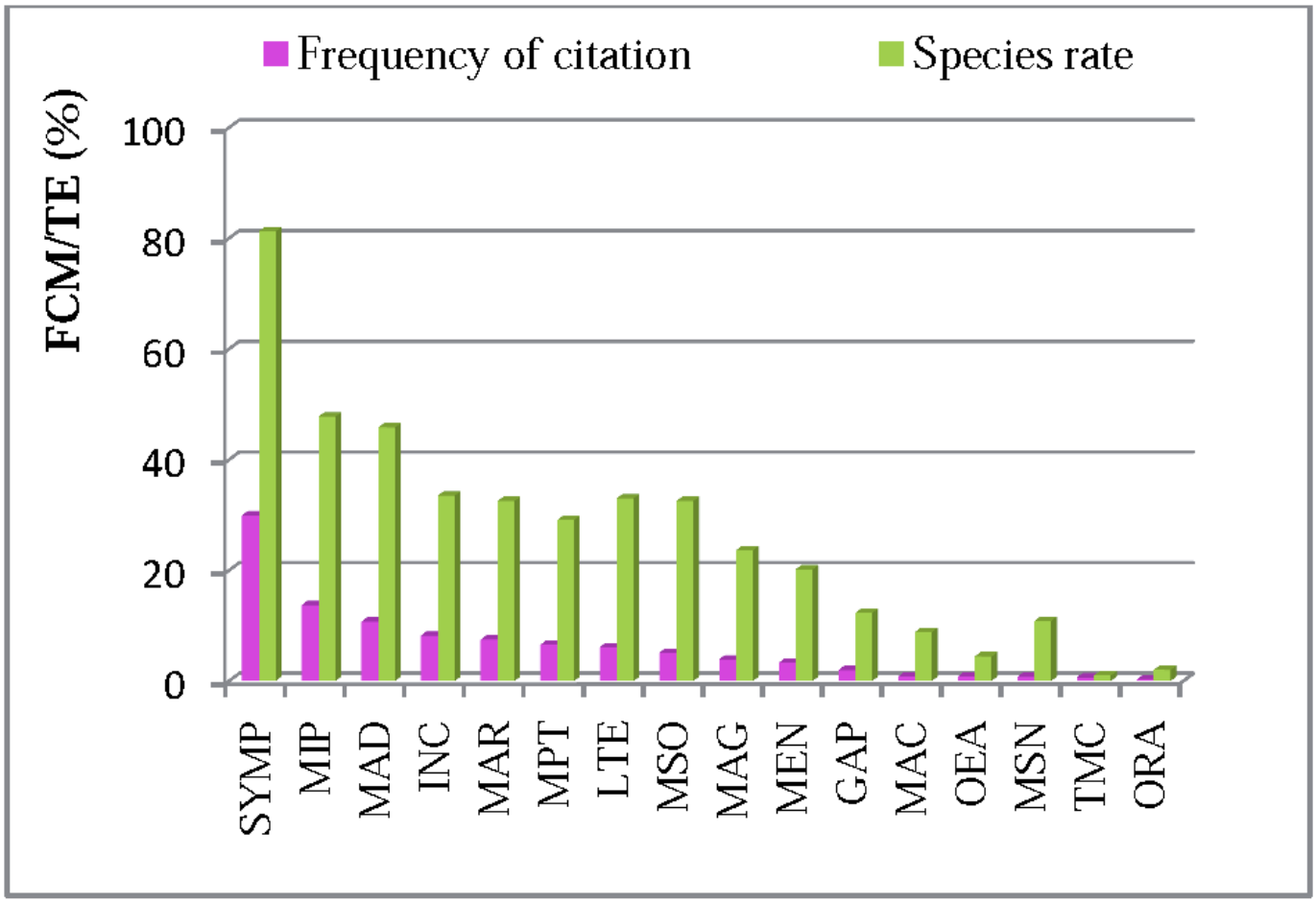

Figure 8

Diseases treated with plants corresponding species rate (SYMP: Symptoms, signs and abnormal results of clinical and laboratory examinations, not elsewhere classified, MIP: Certain infectious and parasitic diseases, MAD: Disease of the digestive system, INC : Unclassifiable, MAR: Disease of the respiratory system, MPT: Diseases of the skin and subcutaneous cellular tissue, LTE: Traumatic injuries, poisonings and certain other consequences of external causes, MSO: Diseases of the osteoarticular system, muscles and connective tissue, MAG: Diseases of the genitourinary system, MEN: Endocrine, nutritional and metabolic diseases, GAP: Pregnancy, childbirth and the puerperium, MAC: Diseases of the circulatory system, OEA: Diseases of the eye and its appendices, MSN: Diseases of the nervous system, TMC: Mental and behavioral disorders, ORA: Diseases of the ear and mastoid process)

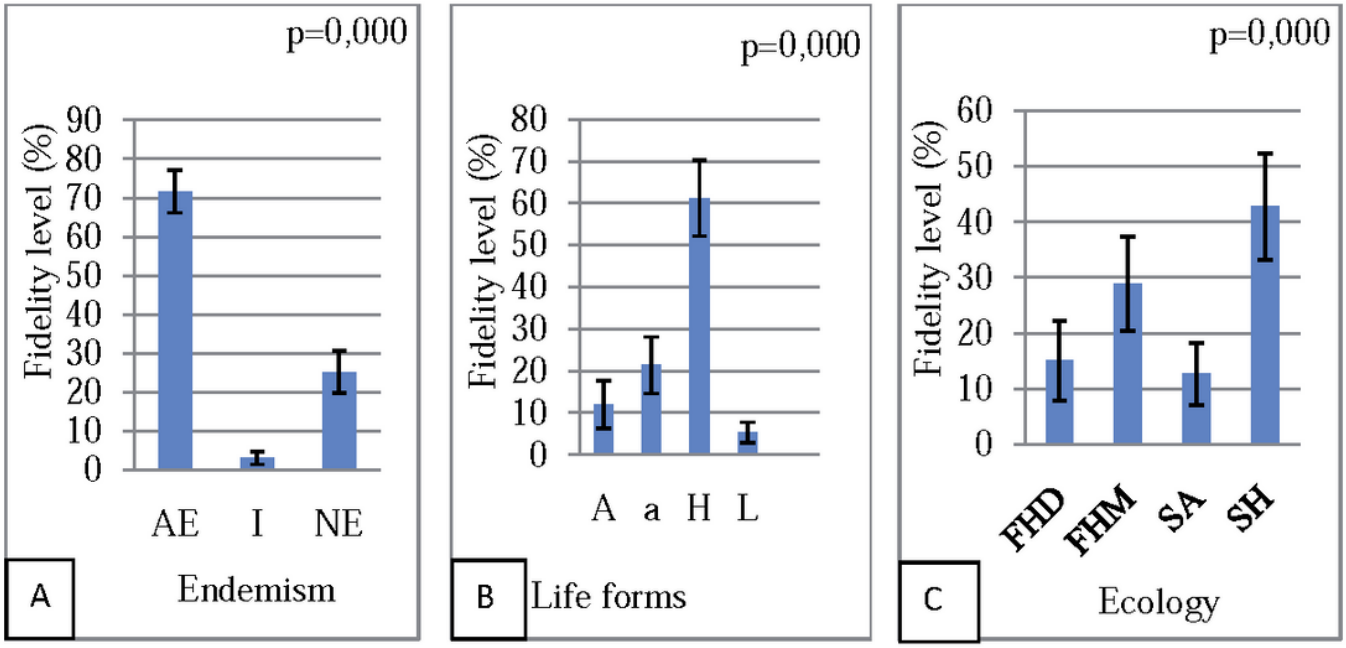

Figure 9

Fidelity level according to endemism, life forms and ecology (FD: degraded forest, FH: humid forest, SH: grassy savanna, SA: shrub savanna, H: grass, a: shrub, A: tree, L: liana, AE: indigenous endemic, I: introduced, NE: indigenous non-endemic)

Supplementary Files

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