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Patterns of medicinal plant use by inhabitants of Brazilian urban and rural areas: A macroscale investigation based on available literature

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ABSTRACT

Ethnopharmacological relevance: Although the relationship between local people and plants may be idiosyncratic, some human behaviors are common to different communities and can be influenced by cultural and environmental factors. Thus, this study drew upon a systematic review and meta-analysis to evaluate if there are patterns of medicinal plant use in different Brazilian ethnobotanical studies and if these patterns are influenced by the urbanization or ecosystems where the studies were conducted.
Materials and methods: The factors evaluated concerned the origin of the species used (native vs. exotic), plant habit (woody vs. non-woody) and plant parts (permanent and non-permanent). Two kinds of analysis were performed: the integrative and the meta-analytical.
Results: The factors varied depending on the ecosystems in which the studies were conducted. In the Amazon, Cerrado and Caatinga, native and woody medicinal species dominated; conversely, this pattern was not the case for the Atlantic Forest and Pampas ecosystems. Permanent plant parts were predominant in the Cerrado, and considering only native plants, permanent parts dominated in the Amazon, Cerrado and Caatinga. Urbanization did not significantly affect these patterns. Additionally, the species relative importance (RI) did not change as a function of the ecosystem or the degree of urbanization.
Conclusions: The phenomena observed in this study can be explained in light of the chemical ecology and historical and cultural aspects of the species, and the findings have important implications for bioprospecting and conservation.

1. Introduction

One topic that has recently aroused the interest of ethnobotanical researchers has been the search for patterns of use of plant resources across communities (Albuquerque et al., 2007). Different populations may agree on the form of use of plants, selecting them based on the same criteria or using species with similar characteristics. In this sense, it is interesting to note the factors (cultural and ecological) shared by different populations that could explain certain similarities in the use of plants.

Regional analysis may constitute an important tool to access usage patterns. Some ethnobotanical studies have used existing literature to observe broad-scale behaviors in the use of plants (Albuquerque et al., 2007; Molares and Ladio, 2009; De la Torre et al., 2012). For example, Molares and Ladio (2009), in a quantitative review of the use of medicinal plants by the Mapuche (Argentina), noted the existence of a common body of knowledge that was shared by different communities and the predominance of native herbaceous species in the pharmacopoeias. In a study in the Brazilian semiarid region, Albuquerque et al. (2007) observed that although there is a predominance of herbaceous species in the pharmacopoeias compared to shrubs and trees, such dominance does not persist when analyzing the relative importance of these species. Also, by analyzing plant use in local communities of Ecuador, De la Torre et al. (2012) found a positive relation between the number of species used and ecosystem species richness.

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Macroscale analyses based on reviews can be guided by statistical principles, just like primary studies. Therefore, to provide greater analytical power to a quantitative review, we proposed the use of a systematic review and meta-analysis (Glass, 1976) to check for similarities and differences in the ways different people use plant species. Meta-analysis is a tool that is already being applied in various fields, including medicine (DerSimonian and Laird, 1986; DiMatteo et al., 2000; Stroup et al., 2010), social sciences (Patall et al., 2008) and ecology (Arnqvist and Wooster, 1995; Cooper, 2009; Endara and Coley, 2011).

Meta-analysis can only be applied in a limited way in ethnobotanical research because the current diversity of approaches in the area, linked to the relatively recent nature of this field, prevents the combined analysis of the scattered data from various local analyses (Albuquerque and Medeiros, 2012). However, the study of medicinal plants has a huge potential for this type of approach because the therapeutic use of plants has been a favorite subject among ethnobotanical researchers. Thus, this study aims to assess the patterns of use of medicinal plants by Brazilian populations documented on ethnobotanical literature. The country was chosen given its diverse cultural and environmental contexts which could therefore challenge the idea of 'unique patterns' of medicinal plant use, providing different situations where we could possibly find distinct responses.

We present below our investigation questions as well as the theoretical background that made us propose them. There are a number of ethnobotanical questions which could be answered by means of meta-analytic tools (see Albuquerque and Medeiros, 2012). However, the proposed questions were chosen for some reasons: (1) they could be answered with a simple species-indication list and (2) previous literature has proposed hypotheses to answer them, but those hypotheses has shown not to be applicable in every situation, so that analyzing under which contexts it does work (or doesn't) is necessary.

Our first group of questions is related to the investigation of general patterns for medicinal plant use in Brazilian ethnobotanical studies.

- What are the most important medicinal plants documented on Brazilian ethnobotanical literature? With this question we want to draw a profile of the most common and versatile species presented in previous ethnobotanical literature.
- What is the prevailing habit of the plants in documented Brazilian folk medicine? Regarding plant habits, Stepp and Moerman (2001) proposed the employment of the apparency hypothesis to understand why herbaceous species are proeminent in pharmacopoeias around the world. According to this hypothesis, non-apparent plants (usually herbs) tend to stand out in pharmacopoeias because, from the perspective of defense against herbivory, they invest primarily in qualitative compounds, while apparent species invest in quantitative compounds. Therefore, the qualitative compounds would have the greatest application for medicinal purposes (Stepp and Moerman, 2001).
- What is the prevalent origin (native vs. exotic) of the plants in documented Brazilian folk medicine? This question relates to the global process of plant homogenization, which is also influencing medicinal plant use (Medeiros, 2013). Ethnobotanical studies around the world are often concerned about exotic species entrance on local medical systems (Alencar et al., 2010a; Medeiros, 2013). Therefore, we want to explore if the reunion of Brazilian literature on the subject still highlights native species or if the exotic are already strongest in local pharmacopoeias.
- What is the predominant plant part in documented Brazilian folk medicine? Literature has shown that leaves are the most important plant part in several cases, which is why we intend to test it for Brazilian literature.

The second group of questions includes differences regarding ecosystems and urbanization. We added those variables because we do not believe there are unique behavioral patterns, as environment can play an important role in the way people use plant resources. Ecosystem and urbanization differences were used as comparison artifacts because they are responsible for deep changes in the environment. And those environmental changes are precisely what we need in order to check if there are 'universal patterns', 'environment-dependent patterns' or no pattern at all. The questions are exhibited below.

- Are there variations in the habits that prevail among the plants used in different ecosystems or areas (urban vs. rural)? Although the apparency hypothesis is well accepted worldwide, studies performed in semi-arid regions have found a different pattern in which arboreal species stand out (Almeida et al., 2005; Alencar et al., 2009). The seasonality hypothesis, developed in the semiarid Brazilian ecosystems, is being used to explain such a situation. This hypothesis postulates that in environments with strong seasonality, people can prioritize the use of perennial species and permanent plant parts as an adaptive strategy to guarantee safety in resource acquisition because they are available throughout year (Albuquerque, 2006, 2010; Monteiro et al., 2006a, 2006b). Thus, we want to check if this differential pattern can be found in more seasonal contexts.
- Are there variations in the origins (native vs. exotic) that predominate among the plants used in different ecosystems or areas? We believe that the role played by exotic plants may change as a response to external influences and native species ability to effectively treat diseases. While the fist statement can be tested by comparing the proportion of exotic species in different contexts of urbanization, the second has to do with ecosystem differences.
- Are the exotic species of greatest relative importance for medicinal purposes the same in different ecosystems? We believe that there are 'global medicinal plants' which are well rated and applied in different regions, because of their versatility, efficiency and historical dissemination. This idea makes us expect that, regardless the ecosystem being considered, popular exotic species will be the same.
- Are there variations in the plant parts (permanent vs. non-permanent) that predominate among the plants used in different ecosystems or areas? The seasonality hypothesis is also being used to test if seasonal environments make permanent (available all year) plant parts dominate local pharmacopoeias. Although most ethnobotanical studies developed in non-seasonal environments agree that leaves are the most common resource employed for medicinal purposes, we need to check whether if it is also true for seasonal contexts, were leaves are not available throughout the year.
- Do local communities in the same ecosystem have similar repertoires of plants in their pharmacopoeias? Although it the answer for this question is apparently obvious, it can show if environmental conditions play an essential role in medicinal plant selection or if people from different places within the same ecosystem use a really distinct repertoire of species among all those that are offered in the environment.

2. Methods

2.1. General characterization and systematic review

The present study was based on a research review, focusing on the results of primary research. The objective is the integration of the results to carefully generalize the findings. Thus, a comprehensive search was conducted of articles from the ethnobotanical literature in Brazil concerning medicinal plants or general ethnobotanical articles that included medicinal use, among other types of use. The search used the keywords "Medicinal plants + Brazil", "Plantas medicinais + Brasil", "Ethnobotany + Brazil", "Etnobotânica + Brasil", "Ethnopharmacology + Brazil" and "Etnofarmacologia + Brasil" in the major databases and publishers of scientific journals (Scopus, Scirus and Scielo). The search was performed from November 2010 to June, 2011. For each paper found, its references were analyzed with the aim of identifying additional studies that were not uncovered using the established search criteria. Even studies that were not available online could be included, since we could find them in the libraries of 'Universidade Federal de Pernambuco', 'Universidade Federal Rural de Pernambuco' and 'Universidade Federal de Brasília'. After the articles had been found, they were filtered based on the inclusion and exclusion criteria described below.

2.2. Initial selection of studies: Inclusion and exclusion criteria

This systematic review included only studies that contained a list (partial or total) of medicinal plants that were known and/or used in urban or rural areas and that provided a list of the therapeutic indications of the species as well as presenting the scientific names of these species. Because most studies do not differentiate ethnobotanical knowledge from effective use,[1] these two instances were not analyzed separately.

Reviews were excluded from the analysis because meta-analyses only use primary data. Thus, the reference lists of review articles were used to identify the primary studies on which the reviews were based. Manuscripts that displayed lists of medicinal plants without presenting a methodology for data collection based on interviews were also ignored.

For multiple case studies conducted in the same area, only one (the most complete) study was used as part of the analysis because dependent data could bias the results. Studies with at least one botanical family were included in the review, but studies with only one or few species were not included because they could not be used as part of a meta-analysis, since it would not be possible to perform internal species comparisons. Studies focusing on one or few therapeutic indications were also considered as well as studies that included only native or wild species. However, the use of studies with specific botanical families, therapeutic indications or biogeographical origins was limited when compared to complete studies, as detailed in the 'Data analysis' section.

2.3. Secondary study selection: Risk of bias

Studies acquired with the bibliographic search that met the initial inclusion criteria were classified according to the risk of bias as 'low risk', 'moderate risk' and 'high risk'. The reliability of the sample was the main criterion, with other criteria used to assess a possible increase in the degree of risk, as detailed below.

(A) Classification criteria for the three degrees of risk of bias
- Sample reliability—high risk of bias for studies with serious sample problems, moderate risk of bias for studies with small sample problems and low risk of bias for studies without sampling problems or whose problems were not evident. Common sampling problems are (1) non representativeness of samples based on the whole community or on family chiefs; (2) lack of indication about the population (universe) and (3) lack of information about the criteria adopted in cases of intentional samples. The details of the criteria for this classification can be found in Medeiros (2012).
- Identification of the plant material—high risk of bias when less than 60% of the taxa were identified to species level, moderate risk of bias when 60% to 80% of the taxa were identified and low risk of bias when more than 80% of the taxa were identified to the species level.

(B) Criteria for an increase in risk level (from low to moderate risk of bias)
- Lack of specification that the material was identified by comparing voucher specimens or consulting experts.
- Presentation of a partial list of the species used (e.g., only the 20 most cited). Investigations that presented complete lists of plants or plants cited by at least 80% of the respondents were still considered to have a low risk of bias.
- Presence of restrictions of the studied habit, distribution, therapeutic indications or taxonomic groups. For example, studies with only herbs, forest species for malaria or studies with only Cactaceae.

Studies with low and moderate risks of bias were selected for the analyses, whereas studies with a high risk of bias were completely disregarded.

2.4. Data processing

Of all of the taxa recorded in the studies, only those that were identified to the species level were considered. The scientific names of the species were updated using the databases of the Missouri Botanical Garden (www.tropicos.org) and the List of Brazilian Floral Species ("Lista de Espécies da Flora do Brasil" http://floradobrasil.jbrj.gov.br/2012). These same lists served as the basis for classifying species as native or exotic to Brazil and native or exotic species for each ecosystem. For additional information on the origin of the species and habit classification, the databases of the Missouri Botanical Garden and the New York Botanical Garden (http://sciweb. nybg. org/Science2/vii2.asp) were used. The classification system considered in this study was the APG III (The Angiosperm Phylogeny Group, 2009).

The habit classification followed the logic of lignification to differentiate woody and non-woody species. Woody species were considered as shrubs when the branching of the trunk occurred near the base and as an arboreal species when the branching occurred at a height closer to the apex. Based on this perspective, non-woody vine species were classified as herbs, while lianas were considered shrubs.

The therapeutic indications were classified for body systems according to the World Health Organization (WHO, 2010). The indicators regarding "cultural illness" (Pinto et al., 2006) were not considered, since they were not considered by all studies and they are not of real interest to this research, although we assume that some of them may hide in supernatural explanations official diseases. Each study was classified according to the ecosystem in which it was conducted and the degree of urbanization (urban, rural, or urban-rural). A general concept that considers the following ecosystems (based on the Brazilian classification scheme) was considered: (1) the "Cerrados" (Brazilian Savannah), (2) the "Caatingas (seasonally dry tropical formations)", (3) the various forms of Atlantic forest (Rainforest from the Atlantic coast) *sensu lato* (mangroves, upland forests, araucaria forest, etc.), (4) the Pampas (Grassland typical of temperate areas), (5) the Pantanal (seasonally flooded forests), (6) the Amazon (Rainforest

[1] Some plants may have a medicinal use known to the people of an area without necessarily being used by them. More information about the difference between knowledge and use can be found in Reyes-Garcia et al. (2005) and Ramos et al. (2008).

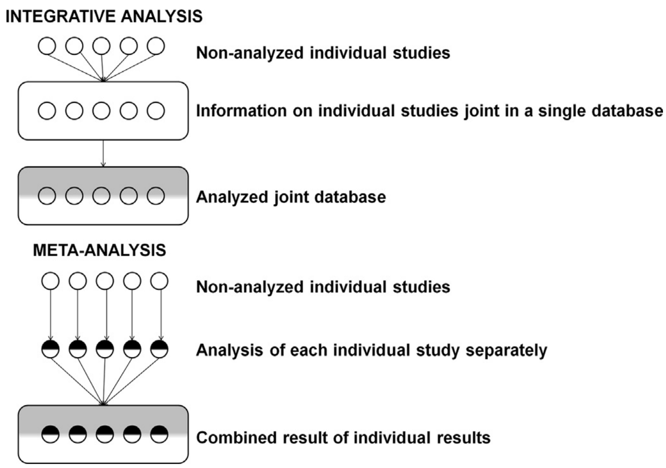

Fig. 1. Analytic steps for both integrative analysis and meta-analysis. Half filled forms represent analyzed data.

of the Northern region) and (7) the "Mata dos Cocais" (Arecaceae-dominated forests).

For studies that did not mention the ecosystem, a search was made based on the Brazilian Geographic and Statistical Institute (IBGE: http://www.ibge.gov.br/cidadesat). For the case studies that did not mention urbanization and when this information could not be accessed from secondary sources, the category 'no information' was created.

2.5. Data analysis

Two different strategies were applied to analyze the secondary data. When possible, the strategies were used together to answer similar questions in order to triangulate the data. The two approaches selected were the integrative and the meta-analytic (Fig. 1). Both approaches were performed using the statistical program R, version 2.13.2 (The R Foundation for Statistical Computing).

2.5.1. Integrative approach

The integrative approach involved the combination of the study results in a single unit of analysis. For example, to compare the proportions of native and exotic species in urban and rural areas, according to the integrative approach, all of the species native to Brazil found in studies in urban areas were combined, and the same was performed for native species in rural areas, exotic species in urban areas and exotic species in rural areas, excluding repeated entries (if species *x* appeared as exotic in two studies for rural communities, it was counted only once). Thus, the χ^2 test was applied to a contingency table (in this case, 2×2) (Zar, 1996) to examine differences in the proportion of native and exotic species between urban and rural areas.

The same procedure was used to calculate differences in the proportion of native and exotic species among ecosystems (in a 2×6 table), differences in the proportion of woody and non-woody species by urbanization level (2×2), woody and non-woody by ecosystem type (2×6), permanent vs. non-permanent parts by urbanization level (2×2) and permanent vs. non-permanent plant parts by ecosystem type (2×6). χ^2 goodness-of-fit were also used to check for differences in the total species number among the classes: native vs. exotic, woody vs. non-woody, herbs vs. shrubs vs. trees and permanent vs. non-permanent parts. In addition to the general analysis in a 2×6 contingency table for differences among ecosystems, paired post hoc analyses were also conducted, with the *p* values adjusted using the Bonferroni method. Monte Carlo simulations (10,000 replicates) were used for the χ^2 analyses of contingency tables that contained values below 5.

Analyses were developed not only in terms of the number of species but also in terms of the versatility of these species, i.e., the number of medicinal attributes that the plants possessed. For this analysis, the relative importance (RI) of the plants was calculated (Bennett and Prance, 2000) using the formula:

$$RI = \frac{NPS}{NPVS} + \frac{NBS}{NBSVS}$$

where NPS is the number of properties assigned to species *x*, NPVS is the number of properties assigned to the most versatile species, NBS is the number of body systems treated by plant *x*, and NBSVS is the number of body systems treated by the most versatile species.

In the RI estimation of the integrative approach, all of the therapeutic indications and body systems assigned to each plant in all of the studies were included, but in a non-cumulative manner (i.e., if the same disease is recorded for the species *x* in two different studies, it is only considered once). Thus, the nonparametric Kruskal–Wallis test (Zar, 1996) was used to check for differences between the RI of native vs. exotic, herbs vs. shrubs vs. trees and woody vs. non-woody species.

The RI was calculated for each ecosystem and each degree of urbanization. In these cases, the NPS, NPVS, NBS and NBSVS were considered only for the ecosystem or urbanization level in question. The Spearman correlation coefficient was used to assess the relationships between the RI of exotic species in different ecosystems, and the same approach was used to test the relationship between the RI of exotic species in urban and rural areas.

To test if plant versatility was influenced by the persistence of plant parts, permanent plant parts were considered as those potentially available throughout the year (roots and stems), whereas the non-permanent (leaves, flowers, fruits, and seeds) parts were thus classified because they might not be available throughout the year. This division is a hypothetical classification because some species do not lose their leaves at any time of year. It is often valid only for seasonal ecosystems. However, as our intent is to compare seasonal to non-seasonal environments, this virtual classification may be useful since it can show if in seasonal contexts there is a proportionally higher use of roots and stems when compared to non-seasonal environments.

Thus, we calculated a modified RI (RI^p) according to the following formula:

$$RI^p = \frac{NPSp}{NPSVp} + \frac{NBSp}{NBSVSp}$$

where NPSp is the number of properties assigned to the species *x*, considering the information attributed to permanent parts and to the non-permanent parts separately, NPSVp is the number of properties attributed to the most versatile species-permanence combination, NBSp is the number of body systems treated by plant *x*, considering only the systems assigned either to permanent parts or to non-permanent parts, and NBSVSp is the number of body systems treated by the most versatile species-permanence combination. Subsequently, a Wilcoxon test was performed between the RI^p for permanent parts and the RI^p for non-permanent parts.

Finally, to examine whether the species composition in studies was influenced by the ecosystem and degree of urbanization, an analysis of similarity (ANOSIM) was performed with a binary data matrix, containing the studies as objects, species as descriptors and 'ecosystems' and 'degrees of urbanization' as factors. Studies on specific taxa, specific habits or specific origins were not considered in this analysis. For example, studies that only considered Cactaceae, only woody species or only native species were excluded.

For an integrated analysis of general patterns, the species were classified as native or exotic to Brazil, unlike the meta-analytic and the integrated analyses that compared the proportion of native and exotic species by ecosystem. In the latter case, analyses were performed considering the native and exotic species of the ecosystem of each study. Additionally, studies in urban–rural areas or areas without information regarding urbanization were excluded from the integrated analyses using χ^2 and Kruskal–Wallis tests, along with studies in ecotone areas (e.g., an area that covers both Cerrado and Atlantic Forest). The studies with composite or unidentified categories were used only for the composition of the total RI of the species. Plant parts that were different from root, stem, leaf, flower, fruit and seed were also disregarded in the analyses, although they did contribute to the overall RI of a species.

2.5.2. Meta-analysis

For this approach, we will use 'plant origin' as an example of the meta-analytical principles applied in this study. Each study will have an effect size, according to the amount of native and exotic species they have. The higher the discrepancies between the two origins, the higher the effect size. The sample variance was also calculated for each study.

Then, these effect sizes and variances of all studies were analyzed together to determine the total effect and evaluate whether the results of the studies were influenced by the ecosystems and degree of urbanization.

The first set of analyses compared the richness of native and exotic, woody and non-woody species and the use of Permanent and non-permanent parts of species in each study. For this comparison, the effect size (yi) and variances (vi) were calculated for each of the three analyses using the R 'escalc' function with the 'metafor' package, based on the 'PLO' measure (specific for dichotomous variables).

In addition to calculating the RI for the integrative analysis, RI values were also calculated separately for the species in each study. Thus, unlike the integrative analysis, the meta-analysis values for the number of properties of the species (NPS), number of properties of the most versatile species (NPVS), number of body systems assigned to each species (NBS) and number of body systems of the most versatile species (NBSVS) considered the studies individually and not the sum of the properties and systems of all of the studies. This RI was used in the analyses of native vs. exotic and woody vs. non-woody species. The RIp values used to compare permanent vs. non-permanent parts were calculated considering the data from the studies individually.

The effect sizes and variances of the RI values for each study were also calculated using the 'escalc' function but with the measure 'SMD' (standardized mean difference), which considers the mean and standard deviations of the study RI for each category (e.g., native and exotic).

After determining the *yi* and *vi* values, meta-analyses were performed using the function 'rma' in the 'metafor' package considering a mixed-effects model, to examine if there was an influence due to urbanization and ecosystem factors, as well as a random effects model, to examine if there were general patterns that were independent of the ecosystem type or degree of urbanization. Studies conducted in ecotonal areas were not included in the mixed-effects model, nor were those conducted in urban-rural regions or where the level of urban development could not be defined. However, these studies were used for the random-effects model.

To avoid biasing the results, each analysis excluded a specific group of studies. Analyses comparing the total number or RI of native and exotic species excluded studies that only considered one origin (e.g., only native or wild species). The comparison of the total number and RI of woody vs. non-woody plants excluded studies with specific habits (e.g., woody), and studies were also excluded that only considered a particular taxonomic group (e.g., Cactaceae). Exclusively for the meta-analyses of RI, studies that included only the main therapeutic indication(s) of plants were excluded.

Table 1
Studies that took parto f the systematic review and their characteristics. Ecos—Ecosystem, Urb—Urbanization, Tax—Taxa, Hab—Habit, Ori—Origin, Ind—Indications, AF—Atlantic Forest, CA—Caatinga, PA—Pampa, AM—Amazon, CE—Cerrado, MC—Mata dos Cocais, U—Urban, R—Rural, S—Urban-rural or not informed, A—All, Cac—Cactaceae, Woo—Woody, Spo—Spontaneous, Nat—Native, Ma—Malaria and correlated illnesses.

Author	Ecos	Urb	Tax	Hab	Ori	Ind
Albertasse et al. (2010)	AF	U	A	A	A	A
Albuquerque and Andrade (2002)	CA	R	A	A	A	A
Almeida et al. (2009)	AF	U	A	A	A	A
Andrade et al. (2006)	CA	R	Cac	A	A	A
Baldauf et al. 2009	PA	S	A	A	A	A
Begossi et al. (1993)	AF	S	A	A	A	A
Brandão et al. (1992)	AM	S	A	A	A	Ma
Brandão et al. (2006)	CE and AF	U	A	A	A	A
Cartaxo et al. (2010)	CA	R	A	A	A	A
Cruz-Silva et al. (2009)	AF	U	A	A	A	A
Dorgioni et al. (2001)	AF	U	A	A	A	A
Franco and Barros (2006)	CE and MC	R	A	A	A	A
Freitas and Fernandes (2006)	AM	R	A	A	Spo	A
Garlet and Irgang (2001)	PA and AF	R	A	A	A	A
Hanazaki et al. (2006)	AF	U	A	A	A	A
Lima et al. (2007)	AF	U	A	A	A	A
Lima et al. (2009)	AF	U	A	A	A	A
Macedo et al. (2007)	CE and AF	U	A	A	A	A
Maciel and Guarim-Neto (2006)	AM	S	A	A	A	A
Merétika et al. (2010)	AF	U	A	A	A	A
Moreira and Guarim-Neto (2009)	CE	R	A	A	Nat	A
Negrelle and Fornazzari (2007)	AF	R	A	A	A	A
Oliveira et al. (2007)	CA	R	A	Woo	Spo	A
Oliveira et al. (2010)	AF	U	A	A	A	A
Pereira et al. (2009)	CE and AF	U	A	A	A	A
Pilla et al. (2006)	CE and AF	R	A	A	A	A
Ritter et al. (2002)	AF	S	A	A	A	A
Rizzo et al. (1999)	CE	U	A	A	A	A
Roque et al. (2010)	CA	R	A	A	Spo	A
Silva et al. (2011)	CA	R	A	A	A	A
Souza (2007)	CE	U	A	A	A	A
Ustulin et al. (2008)	CE	U	A	A	A	A
Vendruscolo and Mentz (2006)	PA	U	A	A	A	A
Vila Verde et al. (2003)	CE	U	A	A	Nat	A

3. Results

A total of 126 articles fulfilled the inclusion criteria of this study. However, most of these studies had a high risk of bias (92). Thus, a total of 34 studies served as the basis for this systematic review (Table 1). Of these, six were classified as having a low risk of bias and 28 had a moderate risk of bias. Due to the low number of studies with low risk, the analyses were performed considering the two degrees of risk together. A brief synthesis of the main results found in this research is available in Table 2.

3.1. What are the most important medicinal plants documented on Brazilian ethnobotanical literature?

It was possible to identify a total of 717 species used in traditional medicine by the populations considered for this study. This number is most likely much higher in reality because studies with a high risk of bias included different species from those considered here. There is also a lack of studies in some Brazilian

Table 2
Synthesis of the main results found in the research. RI=relative importance.

Question	Results from integrative analysis	Results from meta-analysis
What are the most important medicinal plants documented on Brazilian ethnobotanical literature?	– *Rosmarinus officinalis* L. (RI=1.93) – *Ruta graveolens* L. (RI=1.92) – *Aloe arborescens* Mill. (RI=1.80) – *Bidens pilosa* L. (RI=1.74) – *Plectranthus barbatus* Andr. (RI=1.69)	Not applicable
What is the prevailing habit of the plants in documented Brazilian folk medicine (woody vs. non-woody)?	**Considering number of species** -Woody habits **Considering RI** -No differences between habits	**Considering number of species** -No differences between habits **Considering RI** -No differences between habits
What is the prevalent origin (native vs. exotic) of the plants in documented Brazilian folk medicine	**Considering number of species** -Native **Considering RI** -Exotic	**Considering number of species** -No differences between habits **Considering RI** -No differences between habits
What is the predominant plant part in documented Brazilian folk medicine (permanent *x* non-permanent)?	**Considering number of species** -Non-permanent parts **Considering RIp** -Non-permanent parts	**Considering number of species** -Non-permanent parts **Considering RIp** -No difference between parts
Are there variations in the habits that prevail among the plants used in different ecosystems or areas (urban vs. rural)?	**Considering number of species** -Variation found for ecosystems but not for urbanization **Considering RI** -Not applicable	**Considering number of species** -Variation found for ecosystems but not for urbanization **Considering RI** -Variation not found
Are there variations in the origins (native vs. exotic) that predominate among the plants used in different ecosystems or areas	**Considering number of species** -Variation found for ecosystems and for urbanization **Considering RI** -Not applicable	**Considering number of species** -Variation found for ecosystems but not for urbanization **Considering RI** -Variation not found
Are the exotic species of greatest relative importance for medicinal purposes the same in different ecosystems?	-Positive result (High correlation between exotic species' RI for most ecosystems combinations)	Not applicable
Are there variations in the plant parts (permanent vs. non-permanent) that predominate among the plants used in different ecosystems or areas?	**Considering number of species** -Variation found for ecosystems and for urbanization **Considering RIp** -Not applicable	**Considering number of species** -Variation found for ecosystems but not for urbanization **Considering RIp** -Variation not found
Do local communities in the same ecosystem have similar repertoires of plants in their pharmacopoeias?	– Positive result for ecosystems – Negative result for urbanization	Not applicable

ecosystems, such as the Pantanal region and the "mata dos cocais" (the transitional area between the Amazon and Caatinga ecosystems).

The medicinal species with the greatest relative importance (RI) were *Rosmarinus officinalis* L. (1.93), *Ruta graveolens* L. (1.92), *Aloe arborescens* Mill. (1.80), *Bidens pilosa* L. (1.74) and *Plectranthus barbatus* Andr. (1.69). Table 3 displays the 100 species with the greatest RI values. The majority of versatile species were those with a wide distribution, which are cultivated or growing wild in many parts of the country. Among the species native to Brazil, *Chenopodium ambrosioides* L. had the greatest RI (1.56). *Myracrodruon urundeuva* Allemão was the most prominent native tree species (RI=1.43) in this regard.

3.2. *What is the prevailing habit of the plants in documented Brazilian folk medicine?*

Of the 717 species identified in this study, 311 were herbs, 212 were trees, and 194 were shrubs, and these differences were significant ($\chi^2=33.21$, $p<0.001$). Although these findings depict an apparent predominance of herbaceous species, if the data are analyzed by contrasting woody species (trees and shrubs) with non-woody species (herbs), the first group (406 spp.) was significantly more prominent ($\chi^2=12.59$, $p<0.001$).

The random-effects model, however, showed that the studies were very heterogeneous in terms of the number of woody and non-woody species, such that there was no definite pattern of

Table 3
Indications for the 100 species with higher relative importance values considering Brazilian ethnobotanical studies of medicinal plants.

Species	Indications	RI
Rosmarinus officinalis L.	Anemia, antimicrobial, asthma, bradycardia, sedative, cardiotonic, dandruff, nervous breakdown, menstrual cramps, diphtheria, digestive, diuretic, pain, headache, joint pain, migraine, stimulating, stress, expectorant, fever, wound, fortifying, heart fortifying, weakness, flatulence, skin hydrating, infection, urinary infection, indigestion, not defined, nervousness, memory improvement, high blood pressure, low blood pressure, irregular blood pressure, cardiac problems, circulatory problems, stomach problems, hepatic problems, problems in the nervous system, pulmonary problems, hair loss, rheumatism, weak blood, sinusitis, tachycardia, cough, tranquilizing, helminthiasis	1.93
Ruta graveolens L.	Amenorrhea, antiemetic, antiseptic, arthrosis, increase organism defenses, calming, colic, Menstrual cramps, conjunctivitis, postpartum depression, depurative, pain, headache, toothache, earache, stomachache/diarrhea, emollient, Fever, wound, furuncle, influenza, hematoma, intestinal infection, eye infection, inflammation, ear inflammation, ovary inflammation, eye inflammation, uterine inflammation, eye cleaning, uterine cleaning, indigestion, discomfort, nervousness, lice, stomach problems, intestinal problems, renal problems, uterine problems, rheumatism, tetanus, cough, thrombosis, helminthiasis	1.92
loe arborescens Mill.	AIDS, allergy, asthma, increase organism defenses, heartburn, bronchitis, cancer, prostate cancer, dandruff, hair care, depurative, dermatitis, skin diseases, pain, expectorant, wound, hair strengthening, gastritis, influenza, hemorrhoid, herpes labialis, infection, ovary infection, inflammation, ovary inflammation, hair cleaner, indigestion, injury, not defined, flap, dry skin, insect bite, circulatory problems, prostate problems, digestive problems, stomach problems, hepatic problems, column problems, pulmonary problems, hair loss, burn, rheumatism, blood bladder, ulcer, helminthiasis	1.80
Bidens pilosa L.	Inappetence, Anemia, antimicrobial, appendicitis, calculus of kidney, itching, congestion, diabetes, dysentery, pain, erysipelas, external wounds, wound, baby's belly button wound, flatulence, gonorrhoea, hemorrhoid, hepatitis, hepatoprotective, jaundice, swelling, infection, ovary infection, inflammation, throat inflammation, ovary inflammation, kidney inflammation, lesion, malaria, dry skin, insect bite, circulatory problems, digestive problems, hepatic problems, throat problems, eye problems, renal problems, urinary problems, rheumatism, cough	1.74
Plectranthus barbatus Andr.	Amoebiasis, antiemetic, heartburn, sedative, cholagogue, high cholesterol, colics, menstrual cramps, congestion, nasal congestion, digestive, siuretic, pain, headache, toothache, stomachache/diarrhea, liver pain, intestinal pain, nausea, digestion stimulating, expectorant, fever, flatulence, gastritis, giardiasis, influenza, hemorrhoid, billiary infections, hepatic infection, liver inflammation, indigestion, discomfort, mycosis, lice, high blood pressure, circulatory problems, digestive problems, stomach problems, hepatic problems, pulmonary problems, blood problems, alcoholic hangover, rheumatism, tonic, dizziness, cough, triglycerides, tuberculosis	1.69
Plantago major L.	Astringent, antiemetic, asthma, heartburn, cramping, cancer (prevention), menstrual cramps, conjunctivitis, dermatitis, diuretic, pain, earache, stomachache/diarrhea, throat pain, expectorant, fever, external wounds, wound, gastritis, influenza, hemorrhoid, infection, throat infection, uterine infection, inflammation, mouth inflammation, throat inflammation, laxative, dry skin, constipation, circulatory problems, digestive problems, throat problems, ovary problems, renal problems, respiratory problems, psoriasis, rheumatism, cough, skin ulcer	1.67
Cymbopogon citratus (DC.) Stapf	Anemia, antiemetic, stroke, calming, cardiotonic, high cholesterol, colics, congestion, Corrução (epidemic gangrenous proctitis), depression, depurative, diabetes, digestive, dispneia, pain, headache, stomachache/diarrhea, weight loss, migraine, inappetence, fever, flatulence, influenza, insomnia, indigestion, nervousness, nutraceutical, expectoration, high blood pressure, low blood pressure, irregular blood pressure, digestive problems, stomach problems, hepatic problems, renal problems, relaxant, cold, sedative, somniferant, dizziness, cough, TPM, tranquilizing	1.61
Matricaria chamomilla L.	Amenorrhea, antiemetic, antiseptic, urinary incontinence, bronchitis, sedative, colics, menstrual cramps, intestinal colics, congestion, digestive, children's diseases, pain, stomachache/diarrhea, nausea, fever, wound, influenza, infection, inflammation, mouth inflammation, urethral inflammation, mouth irritation, laxative, to clean children's intestine, eye cleaning, indigestion, nervousness, nevralgia, high blood pressure, constipation, stomach problems, intestinal problems, cold, rheumatism, sinusitis, somniferant, tranquilizing, helminthiasis	1.58
Ocimum basilicum L.	Afta, sedative, colics, menstrual cramps, dermatitis, dysentery, diuretic, pain, throat pain, hair strengthening, flatulence, influenza, inflammation, eye inflammation, insomnia, laxative, nervousness, nutraceutical, flap, cardiac problems, hepatic problems, maternal milk production, hair loss, rheumatism, hoarseness, sinusitis, cough, helminthiasis	1.57
Chenopodium ambrosioides L.	Anemia, bronchitis, sedative, gob, colics, congestion, diabetes, digestive, pain, stomachache/diarrhea, expectorant, external wounds, wound, fracture, flatulence, gastritis, influenza, hematoma, hemorrhoid, infection, inflammation, lesion, injury, mycosis, not defined, lice, pneumonia, stomach problems, intestinal problems, gallbladder problems, rheumatism, scabies, susto infantil, tonic, cough, ulcer, helminthiasis, child helminthiasis	1.56
Lippia alba (Mill.) N.E.Br.	Swollen belly, calming, colics, menstrual cramps, congestion, depurative, discomfort, digestive, headache, stomachache/diarrhea, migraine, inappetence, fever, fortifying, flatulence, influenza, infection, throat inflammation, insomnia, indigestion, menopause, not defined, nervousness, insect bite, high blood pressure, cardiac problems, stomach problems, hepatic problems, intestinal problems, throat problems, cold, rhinitis, hoarseness, sedative, dizziness, cough, helminthiasis	1.54
Achyrocline satureioides (Lam.) DC.	Afta, anguish, antiemetic, heartburn, sedative, high cholesterol, colics, congestion, digestive, diuretic, headache, toothache, stomachache/diarrhea, bladder pain, weight loss, nausea, heavy stomach, estomatite, expectorant, fever, wound, fortifying, weakness, influenza, inflammation, insomnia, irritation, laxative, nits, indigestion, discomfort, avoid belly growth, nervousness, high blood pressure, digestive problems, stomach problems, hepatic problems, renal problems, cough, triglycerides	1.53
Citrus aurantium L.	Abortive, anemia, anguish, stroke, bronchitis, sedative, colics, menstrual cramps, diabetes, headache, migraine, fever, uterine wound, wound, influenza, inflammation, throat inflammation, insomnia, labyrinthitis, nervousness, memory improvement, expectoration, high blood pressure, constipation, cardiac problems, stomach problems, throat problems, problems in the nervous system, renal problems, cold, sinusitis, cough, vitamin	1.53
Foeniculum vulgare Mill.	Antiemetic, asthma, heartburn, calming, gob, colics, children's colic, digestive, diuretic, children's diseases, headache, earache, Stomachache/diarrhea, bladder pain, fever, flatulence, influenza, inflammation, gastrointestinal inflammation, insomnia, intoxication, cleaning, not defined, high blood pressure, constipation, digestive problems, stomach problems, intestinal problems, respiratory problems, maternal milk production, cold, sedative, Children's somniferant, cough, helminthiasis	1.50
Myracrodruon urundeuva Allemão	Allergy, antiseptic, cancer, ovarian cysts, itching, headache, toothache, stomachache/diarrhea, leg pain, expectorant, wound, fracture, gastritis, influenza, bleeding, infection, urinary infection, inflammation, inflammation in the female organs, ovary inflammation, inflammation in the external organs, inflammation in the internal organs, lesion, injury, flap, hepatic problems, intestinal problems, renal problems, respiratory problems, urinary problems, uterine problems, tonic, cough, ulcer, skin ulcer	1.43

Table 3 (*continued*)

Species	Indications	RI
Plantago australis Lam.	Antiemetic, antimicrobial, heartburn, cramping, cancer (prevention), dental care, depurative, pain, stomachache/diarrhea, fever, external wounds, wound, influenza, hemorrhoid, infection, throat infection, urinary infection, inflammation, ovary inflammation, dry skin, high blood pressure, constipation, circulatory problems, digestive problems, throat problems, ovary problems, respiratory problems, uterine problems, rheumatism, cough, ulcer	1.42
Malva sylvestris L.	Amenorrhea, antimicrobial, asthma, bronchitis, itching, earache, external wounds, wound, influenza, hemorrhoid, infection, mouth infection, throat infection, laryngeal infection, ear infection, eye infection, inflammation, mouth inflammation, gastrointestinal inflammation, bladder inflammation, throat inflammation, tooth inflammation, ear inflammation, eye inflammation, uterine inflammation, laringitis, constipation, stomach problems, bladder problems, ovary problems, renal problems, hoarseness, cough, Úlcer	1.41
Allium sativum L.	Asthma, bronchitis, high cholesterol, menstrual cramps, faint, pain, headache, earache, throat pain, external wounds, influenza, infection, inflammation, indigestion, dry skin, spider bite, snake bite, pneumonia, high blood pressure, circulatory problems, digestive problems, rheumatism, hoarseness, sinusitis, dizziness, cough, tuberculosis, helminthiasis, to the voice	1.40
Maytenus ilicifolia Mart. ex Reissek	Anemia, antiseptic, heartburn, sedative, cancer, high cholesterol, depurative, dermatitis, diuretic, pain, stomachache/diarrhea, external wounds, wound, abnormal colonic fermentation, gastritis, kidney inflammation, laxative, indigestion, not defined, high blood pressure, digestive problems, stomach problems, eye problems, tonic, Úlcera	1.37
Citrus sinensis (L.) Osbeck	Heartburn, sedative, mumps, cirrhosis, colics, liver colic, congestion, depurative, headache, nausea, inappetence, fever, gout, influenza, insomnia, indigestion, nervousness, high blood pressure, constipation, cardiac problems, digestive problems, intestinal problems, rubella, measles, dizziness, cough, triglycerides	1.34
Baccharis crispa Spreng.	Heartburn, sedative, high cholesterol, colics, depurative, desintoxicante, diabetes, digestive, diuretic, pain, stomachache/diarrhea, weight loss, fever, uterine wound, hematoma, hemorrhoid, throat inflammation, urethral inflammation, laxative, high blood pressure, circulatory problems, digestive problems, stomach problems, hepatic problems, renal problems, rheumatism, triglycerides, urinary retention, inflammed vein, helminthiasis	1.33
Tanacetum vulgare L.	Amenorrhea, asthma, diabetes, pain, stomachache/diarrhea, emollient, wound, gout, infection, injury, flap, circulatory problems, stomach problems, hepatic problems, throat problems, ovary problems, blood problems, alcoholic hangover, rheumatism, blood bladder, tonic, cough	1.31
Citrus limon (L.) Osbeck	Astringent, anemia, antiseptic, heartburn, bronchitis, calculus of kidney, sedative, gob, high cholesterol, colics, headache, throat pain, weight loss, migraine, wound, influenza, high blood pressure, not defined, nutraceutical, expectoration, throat problems, stomach problems, cold, cough, vitamin	1.30
Symphytum officinale L.	Asthma, cancer, dandruff, high cholesterol, diabetes, pain, stomachache/diarrhea, urinary pain, edema, weight loss, external wounds, wound, gastritis, hemorrhoid, hepatitis, infection, inflammation, injury, skin spots, dry skin, irregular blood pressure, circulatory problems, rheumatism, triglycerides, skin ulcer	1.30
Persea americana Mill.	Arthritis, arthrosis, cystitis, high cholesterol, constipation, diabetes, diuretic, pain, joint pain, kidney pain, weight loss, hypoglycemiant, infection, urinary infection, inflammation, bladder inflammation, eye inflammation, flap, high blood pressure, stomach problems, hepatic problems, bladder problems, renal problems, urinary problems, sedative, urinary retention, allergy	1.27
Aloe vera (L.) Burm.f.	Amoebiasis, heartburn, bronchitis, cancer, dandruff, itching, hair care, dermatitis, stomachache/diarrhea, nausea, erysipelas, inappetence, wound, fortifying, hemorrhoid, hair hydrating, high blood pressure, inflammation, lesion, nervousness, stomach problems, hair loss, burn, cell regeneration, ulcer, helminthiasis	1.24
Anacardium occidentale L.	Antiseptic, stroke, cancer, ovarian cysts, diabetes, pain, toothache, earache, stomachache/diarrhea, wound, gingivitis, influenza, hemorrhoid, female hygiene, hypoglycemiant, infection, inflammation, throat inflammation, tooth inflammation, inflammation in the internal organs, uterine cleaning, flap, throat problems, uterine problems, ulcer, vitamin	1.24
Achillea millefolium L.	Antimicrobial, calculus of kidney, gob, colics, children's colic, digestive, pain, headache, muscle pain, throat pain, fever, influenza, hemorrhoid, intestinal infection, inflammation, indigestion, not defined, nervousness, pneumonia, low blood pressure, digestive problems, stomach problems, intestinal problems, bladder problems, renal problems, burn, cold, cough	1.21
Libidibia ferrea (Mart. ex Tul.) L.P. Queiroz	Asthma, sedative, cirrhosis, congestion, diabetes, pain, stomachache/diarrhea, column pain, kidney pain, expectorant, gastritis, influenza, bleeding, inflammation, labyrinthitis, lesion, not defined, pulmonary problems, renal problems, uterine problems, rheumatism, cough, helminthiasis	1.18
Mentha ×piperita L.	Aphrodisiac, anemia, antiemetic, antiseptic, sedative, cardiac collapse, colics, children's colic, digestive, children's diseases, pain, headache, fever, influenza, skin hydrating, insomnia, not defined, stomach problems, çhildren's fright, cough, helminthiasis, children's helminthiasis	1.16
Calendula officinalis L.	Allergy, antiseptic, cancer, pain, wound, influenza, hemorrhoid, infection, inflammation, dry skin, pneumonia, circulatory problems, ovary problems, respiratory problems, rheumatism, ulcer	1.11
Sambucus australis Cham. & Schltdl.	Allergy, bronchitis, catapora, depurative, diabetes, children's diseases, earache, throat pain, erysipelas, fever, wound, influenza, swollen articulations, not defined, circulatory problems, cold, rheumatism, measles, cough	1.10
Anadenanthera colubrina (Vell.) Brenan	Allergy, antiseptic, bronchodilator, bronchitis, cancer, itching, nasal congestion, pain, stomachache/diarrhea, back pain, expectorant, wound, influenza, infection, inflammation, throat inflammation, pulmonary problems, renal problems, uterine problems, cough, tuberculosis, helminthiasis	1.09
Artemisia absinthium L.	Abortive, antiemetic, colics, digestive, pain, headache, stomachache/diarrhea, nausea, influenza, inflammation, intoxication, to clean the stomach, indigestion, high blood pressure, constipation, digestive problems, stomach problems, hepatic problems, bladder problems, renal problems, alcoholic hangover, helminthiasis	1.09
Malva parviflora L.	Antimicrobial, menstrual cramps, pain, toothache, throat pain, joint pain, finger pain, expectorant, fever, external wounds, wound, furuncle, influenza, hemorrhoid, infection, inflammation, ovary inflammation, dry skin, circulatory problems, digestive problems, rheumatism, cough	1.09
Ocimum carnosum (Spreng.) Link & Otto ex Benth.	Sedative, speck in the eye, menstrual cramps, colitis, digestive, dysentery, headache, stomachache/diarrhea, fever, nail fungus, influenza, high blood pressure, throat infection, constipation, cardiac problems, digestive problems, stomach problems, renal problems, urinary problems, cold, rheumatism, cough	1.09
Mentha × villosa Huds.	Stroke, cardiotonic, high cholesterol, menstrual cramps, pain, headache, earache, migraine, expectorant, fever, influenza, high blood pressure, intestinal infection, inflammation, indigestion, eye problems, sinusitis, helminthiasis	1.08
Morus nigra L.	Antioxidant, antiseptic, stroke, sedative, high cholesterol, depurative, diabetes, diuretic, emollient, expectorant, wound, inflammation, menopause, high blood pressure, throat problems, renal problems, hormone replacement	1.08
Echinodorus grandiflorus (Cham. & Schltr.) Micheli	Blood thinner, calculus of kidney, bladder mucus, cystitis, cholagogue, depurative, diabetes, digestive, diuretic, chagas disease, pain, weight loss, urinary infection, inflammation, skin cleaning, indigestion, stomach problems, hepatic problems, bladder problems, renal problems, rheumatism	1.07

Table 3 (*continued*)

Species	Indications	RI
Sida rhombifolia L.	Heartburn, cramping, high cholesterol, depurative, children's toothache, stomachache/diarrhea, weight loss, fatigue, wound, scalp fortifying, hair strengthening, infection, nerve inflammation, high blood pressure, circulatory problems, hair loss, urinary retention	1.06
Ocimum gratissimum L.	Bronchitis, high cholesterol, menstrual cramps, digestive, diuretic, stomachache/diarrhea, stimulating, fever, flatulence, gonorrhoea, influenza, high blood pressure, insomnia, eye cleaning, paralysis, problems in the nervous system, cold, sudoriferous, cough, triglycerides	1.05
Ziziphus joazeiro Mart.	Antiseptic, oral antiseptic, heartburn, dandruff, constipation, stomachache/diarrhea, expectorant, fever, wound, hair strengthening, influenza, inflammation, insomnia, teeth cleaning, indigestion, stomach problems, rheumatism, cough, tuberculosis, helminthiasis	1.05
Momordica charantia L.	Abortive, allergy, diaper rash, itching, headache, Stomachache/diarrhea, skin eruption, fever, wound, influenza, nervousness, lice, cardiac problems, renal problems, scabies, helminthiasis infantile	1.04
Petroselinum crispum (Mill.) Fuss	Diuretic, urinary pain, fever, wound, hepatitis, jaundice, bladder infection, ear infection, uterine infection, bladder inflammation, ovary inflammation, kidney inflammation, indigestion, memory improvement, high blood pressure, circulatory problems, hepatic problems, bladder problems, ovary problems, renal problems, urinary problems, hormone replacement	1.04
Plectranthus amboinicus (Lour.) Spreng.	Blood thinner, antimicrobial, bronchitis, congestion, pain, headache, earache, migraine, expectorant, influenza, inflammation, throat inflammation, inflammation in the internal organs, uterine inflammation, laxative, indigestion, stomach problems, hepatic problems, throat problems, pulmonary problems, renal problems, cough	1.02
Citrus aurantiifolia (Christm.) Swingle	Bronchitis, sedative, high cholesterol, colics, vaginal discharge, children's teeth, diuretic, toothache, stomachache/diarrhea, fever, gastritis, influenza, insomnia, pneumonia, high blood pressure, eye problems, renal problems, cough	1.01
Croton heliotropiifolius Kunth	Blood thinner, allergy, anemia, swollen belly, itching, depurative, headache, stomachache/diarrhea, column pain, wound, influenza, inflammation, indigestion, not defined, stomach problems, foot cracks, cough	0.99
Poincianella pyramidalis (Tul.) L.P. Queiroz	Congestion, diabetes, stomachache/diarrhea, expectorant, wound, blood in feces, gastritis, influenza, bleeding, hepatitis, sexual impotence, urinary infection, inflammation, indigestion, stomach problems, rheumatism, cough	0.99
Eugenia uniflora L.	High cholesterol, colics, menstrual cramps, colitis, diabetes, dysentery, diuretic, stomachache/diarrhea, throat pain, urinary pain, fortifying, furuncle, influenza, high blood pressure, low blood pressure, irregular blood pressure, stomach problems, cold, cough	0.98
Melissa officinalis L.	Calming, cholagogue, digestive, headache, stomachache/diarrhea, migraine, influenza, infection, inflammation, insomnia, irritation, indigestion, not defined, nervousness, ringworm, high blood pressure, low blood pressure, cardiac problems, relaxant, cold, sedative, tranquilizing	0.97
Cuphea carthagenensis (Jacq.) J.Macbr.	Stroke, diabetes, children's diarrhea, digestive, stomachache/diarrhea, leg pain, gout, hemorrhoid, intestinal infection, indigestion, nervousness, high blood pressure, circulatory problems, stomach problems, hepatic problems, intestinal problems, renal problems, varicose veins	0.96
Salvia officinalis L.	Antiemetic, bronchitis, sedative, gob, nervous breakdown, congestion, depression, digestive, pain, stress, wound, influenza, infection, inflammation, nutraceutical, stomach problems, respiratory problems, oral candidiasis, cough, allergy	0.96
Stachytarpheta cayennensis (Rich.) Vahl	Cancer, poultice, high cholesterol, digestive, stomachache/diarrhea, weakness, furuncle, influenza, hepatitis, infection, inflammation, indigestion, calculus of gallbladder, stomach problems, hepatic problems, urinary problems, sinusitis, cough, tumor	0.96
Amburana cearensis (Allemão) A.C.Sm.	Bronchitis, congestion, nasal congestion, pain, expectorant, wound, dry throat, influenza, high blood pressure, infection, inflammation, indigestion, halitosis, pneumonia, respiratory problems, uterine problems, rhinitis, hoarseness, sinusitis, dizziness, cough, thrombosis	0.95
Cunila microcephala Benth.	Anemia, bronchitis, children's tranquilizing, gob, colics, children's colic, pain, stomachache/diarrhea, nausea, expectorant, fever, influenza, infection, cardiac problems, stomach problems, chest problems, pulmonary problems, cold, rhinitis, measles, cough, helminthiasis	0.95
Muehlenbeckia sagittifolia (Ortega) Meisn.	Acne, allergy, high cholesterol, depurative, desintoxicante, diabetes, wound, chilblain, furuncle, gout, hemorrhoid, insect bite, blood problems, rheumatism, scabies	0.95
Petiveria alliacea L.	Allergy, antiemetic, arthrosis, colics, dermatitis, diuretic, skin diseases, pain, headache, toothache, fever, wound, furuncle, infection, inflammation, labyrinthitis, rheumatism, sudoriferous	0.94
Piper mikanianum (Kunth) Steud.	Abortive, antimicrobial, pain, external wounds, furuncle, influenza, hemorrhoid, infection, inflammation, dry skin, circulatory problems, intestinal problems, rheumatism, cough	0.93
Xanthium strumarium L.	Abortive, pain, external wounds, influenza, hemorrhoid, infection, inflammation, dry skin, circulatory problems, pulmonary problems, renal problems, rheumatism, cough, tuberculosis	0.93
Aloysia gratissima (Gillies & Hook. ex Hook.) Tronc.	Bronchitis, high cholesterol, to reduce fatty veins, headache, dor de friagem, column pain, dor pulmonar, fever, influenza, nervousness, pneumonia, high blood pressure, digestive problems, stomach problems, cold, cough, helminthiasis	0.92
Bowdichia virgilioides Kunth	Acne, arthritis, arthrosis, diabetes, headache, spur, wound, weakness, gout, influenza, bleeding, inflammation, stomach problems, column problems, rheumatism, Sífilis, ulcer	0.92
Piper regnellii (Miq.) C.DC.	Acne, depurative, headache, wound, fertilizer, influenza, infection, inflammation, indigestion, circulatory problems, hepatic problems, ovary problems, blood problems	0.91
Cynara cardunculus L.	Antiemetic, sedative, high cholesterol, depurative, diabetes, digestive, diuretic, dst, weight loss, hypoglycemiant, high blood pressure, irregular blood pressure, digestive problems, hepatic problems, renal problems	0.90
Hymenaea courbaril L.	Blood thinner, anemia, bronchitis, depurative, expectorant, weakness, influenza, herpes labialis, leucemia, lice, prostate problems, stomach problems, throat problems, pulmonary problems, renal problems, cough	0.90
Polygonum punctatum Elliott	Allergy, itching, colics, corrução (epidemic gangrenous proctitis), dysentery, stomachache/diarrhea, body pain, *dormideira*, fever, wound, influenza, hemorrhoid, injury, circulatory problems, renal problems, helminthiasis	0.90
Handroanthus impetiginosus Mattos	Blood thinner, anemia, antimicrobial, cancer, nasal congestion, conjunctivitis, pain, wound, influenza, inflammation, cardiac problems, stomach problems	0.89
Passiflora edulis Sims	Aphrodisiac, asthma, calming, whooping cough, nervous breakdown, headache, toothache, stomachache/diarrhea, insomnia, nervousness, high blood pressure, cardiac problems, sedative, tranquilizing	0.88
Alternanthera brasiliana (L.) Kuntze	Antimicrobial, cystitis, dysentery, pain, headache, toothache, fever, wound, influenza, infection, throat infection, inflammation, throat inflammation, injury, stomach problems, throat problems, ear problems, cough	0.87
Mentha pulegium L.	Allergy, calming, children's tranquilizing, children's tea, colics, digestive, stomachache/diarrhea, fever, flatulence, influenza, infection, inflammation, insomnia, stomach problems, respiratory problems, sedative, cough, tranquilizing	0.87
Stryphnodendron adstringens (Mart.) Coville	Astringent, amoebiasis, antiseptic, vaginal discharge, stomachache/diarrhea, fever, uterine wound, wound, hemorrhoid, infection, inflammation, inflammation in the female organs, vaginal irritation, malaria, hepatic problems, tumor, ulcer	0.85
Citrus reticulata Blanco	Bronchitis, sedative, high cholesterol, headache, migraine, fever, influenza, high blood pressure, stomach problems, throat problems, ovary problems, cold, cough	0.84

Table 3 (*continued*)

Species	Indications	RI
Mikania glomerata Spreng.	Asthma, stroke, bronchitis, gob, epilepsy, influenza, expectoration, high blood pressure, digestive problems, eye problems, renal problems, rheumatism, cough	0.84
Scoparia dulcis L.	Inappetence, itching, colics, children's teeth, digestive, diuretic, toothache, stomachache/diarrhea, influenza, hemorrhoid, hepatoprotective, indisposition, inflammation, bladder inflammation, kidney inflammation, gynecological problems, renal problems, urinary problems, hoarseness, cough	0.84
Nasturtium officinale W. T. Aiton	Anemia, bronchitis, pain, emollient, expectorant, lung fortifying, influenza, nutraceutical, memory improvement, cardiac problems, hepatic problems, throat problems, thyroid problems, respiratory problems, hair loss, cough	0.83
Bauhinia forficata Link	Calculus of kidney, cystitis, high cholesterol, vaginal discharge, diabetes, diuretic, pain, influenza, hypoglycemiant, bladder infection, kidney infection, bladder inflammation, kidney inflammation, menopause, high blood pressure, bladder problems, renal problems, urinary problems, rheumatism	0.82
Opuntia ficus-indica (L.) Mill.	Swollen belly, dysentery, stomachache/diarrhea, choking, furuncle, influenza, urinary infection, uterine inflammation, vaginal inflammation, constipation, burn, rheumatism	0.82
Artemisia alba Turra	Abortive, amenorrhea, pain, headache, toothache, muscle pain, fever, influenza, indigestion, cardiac problems, circulatory problems, cold, rheumatism, sinusitis, cough	0.81
Uncaria tomentosa (Willd. ex Roem. & Schult.) DC.	Abscess, arthrosis, cancer in the female urinary tract, cirrhosis, contraceptivo, diabetes, fever, gastritis, bleeding, inflammation, menstrual irregularities, internal cleaning, osteoporosis, rheumatism, tumor	0.81
Aristolochia triangularis Cham. & Schltdl.	Amenorrhea, high cholesterol, diabetes, fatigue, influenza, infection, flap, stop smoking, insect bite, stomach problems, renal problems	0.80
Ipomoea batatas (L.) Lam.	High cholesterol, diabetes, pain, toothache, erysipelas, wound, gingivitis, high blood pressure, bladder inflammation, respiratory problems, rejuvenation	0.80
Phyllanthus tenellus Roxb.	Abortive, calculus of kidney, sedative, cystitis, vaginal discharge, diuretic, stomachache/diarrhea, urinary pain, flatulence, urinary infection, bladder inflammation, laxative, not defined, hepatic problems, bladder problems, ovary problems, renal problems, helminthiasis	0.80
Tradescantia zebrina Bosse	Calculus of kidney, speck in the eye, cystitis, conjunctivitis, hyposphagma, diabetes, kidney pain, eye inflammation, skin spots, not defined, intestinal problems, bladder problems, renal problems, vitiligo	0.79
Casearia sylvestris Sw.	Blood thinner, anemia, high cholesterol, weight loss, swollen legs, laxative, snake bite, high blood pressure, cardiac problems, circulatory problems, prostate problems, ovary problems, triglycerides	0.77
Origanum × *majoricum* Cambess.	Bronchitis, sedative, high cholesterol, colics, children's colic, diphtheria, earache, stomachache/diarrhea, bladder pain, cardiac problems, throat problems, chest problems, cough	0.77
Acanthospermum australe (Loefl.) Kuntze	Antimicrobial, bronchitis, digestive, dysentery, diuretic, toothache, stomachache/diarrhea, fever, gout, bleeding, vaginal inflammation, malaria, stomach problems, hepatic problems, bladder problems, renal problems	0.76
Curatella americana L.	Astringent, antiseptic, arthritis, bronchitis, corrução (epidemic gangrenous proctitis), diabetes, stomachache/diarrhea, wound, inflammation, high blood pressure, cold, cough	0.74
Laurus nobilis L.	Allergy, amenorrhea, heartburn, menstrual cramps, influenza, indigestion, menopause, constipation, circulatory problems, hepatic problems, rheumatism, ulcer	0.74
Coronopus didymus (L.) Sm.	Abortive, joint pain, expectorant, external wounds, internal wounds, wound, lung fortifying, fracture, influenza, inflammation, injury, flap, cold, cough, helminthiasis	0.73
Arctium lappa L.	Mumps, Wound, Furuncle, Gastritis, Infection, throat inflammation, ovary inflammation, constipation, throat problems, renal problems, rheumatism	0.72
Strychnos pseudoquina A.St.-Hil.	Blood thinner, anemia, headache, fever, weakness, flatulence, influenza, malaria, stomach problems, hair loss, helminthiasis	0.72
Aloysia citriodora Palau	Calming, menstrual cramps, digestive, fever, influenza, hemorrhoid, nervousness, high blood pressure, cardiac problems, stomach problems, renal problems, sedative, cough	0.71
Maytenus rigida Mart.	Calculus of kidney, constipation, gastritis, hematoma, infection, vaginal infection, urethral inflammation, kidney inflammation, lesion, hepatic problems, renal problems, urinary problems, rheumatism, cough	0.71
Chaptalia nutans (L.) Pol.	Pain, external wounds, hemorrhoid, infection, inflammation, liver intoxication, dry skin, circulatory problems, hepatic problems, rheumatism	0.70
Gossypium herbaceum L.	Asthma, influenza, infection, infection in the female reproductive system, uterine infection, inflammation, irregular blood pressure, circulatory problems, hepatic problems, burn	0.70
Carica papaya L.	Bronchitis, diuretic, stomachache/diarrhea, expectorant, influenza, skin cleaning, indigestion, high blood pressure, constipation, stomach problems, cough, ulcer, helminthiasis	0.69
Vernonanthura phosphorica (Vell.) H. Rob.	Abortive, bronchitis, stomachache/diarrhea, leg pain, influenza, inflammation, stomach problems, hepatic problems, pulmonary problems, rheumatism, sinusitis, cough, tuberculosis	0.69
Borreria verticillata (L.) G.Mey.	Abortive, colics, menstrual cramps, dysentery, stomachache/diarrhea, influenza, hemorrhoid, not defined, stomach problems	0.68
Schinus terebinthifolius Raddi	Dandruff, toothache, leg pain, wound, inflammation, para puérperas, gynecological problems, cough, úlcer	0.68
Cinnamomum verum J. Presl	Sedative, colics, fever, weakness, influenza, internal infection, indigestion, high blood pressure, circulatory problems, digestive problems, stomach problems, respiratory problems	0.67
Gymnanthemum amygdalinum (Delile) Sch.Bip. ex Walp.	Cholagogue, digestive, skin diseases, headache, stomachache/diarrhea, weight loss, wound, indigestion, stomach problems, hepatic problems, renal problems, blood bubble	0.67

dominance ($k=32$, $\hat{\tau}^2=0.27$, $p=0.83$). This result indicates that the prominence of woody plants is cumulative, considering that, while studies tend to share the same non-woody species, each study has a sample of very different woody species. Thus, this difference is reflected in the integrated analysis, which accumulates the species present in different studies, but is not reflected in the meta-analysis.

The integrative comparison of RI values of woody and non-woody species did not show a significant difference (woody mean=0.32, non-woody mean=0.37, $H'=0.77$, $p=0.38$), which suggests that the versatility of the species is not influenced by their habit. This result was also observed in the meta-analysis ($k=28$; $\hat{\tau}^2=0.04$; $p=0.87$).

3.3. What is the prevalent origin (native vs. exotic) of the plants in documented Brazilian folk medicine?

With regard to the origin of the species used, there was a very similar pattern to that observed in their habits. The integrative analysis revealed a significant difference ($\chi^2=108.56$, $p<0.001$) between the number of native to Brazil (498 spp.) and exotic (219 spp.) species. However, this difference is again only apparent cumulatively, and when analyzing the results so that each of these studies was a sample (meta-analytic tool), there was no trend of dominance of any of the origins ($k=29$, $\hat{\tau}^2=0.35$, $p=0.10$). This result also indicates that studies tend to share the same exotic species and have different native species, so that the former have a lower cumulative value than the latter.

Regarding the relative importance of native and exotic species, the integrative analysis showed that there were differences between the native (to Brazil) and exotic species (mean native=0.29, mean exotic=0.47, $H'=32.12$, $p<0.001$). However, the random effects model found no such difference ($k=24$, $\hat{\tau}^2=0.09$, $p=0.45$). This apparent discrepancy occurs because in the integrative analysis, the RI calculation is based on the total indications of a species, whereas in the meta-analysis, the RI is calculated only for the therapeutic indications of the studies individually. Thus, the cumulative analyses favored exotic species because these species were present in various studies and thus had a greater probability of being cited for different therapeutic indications, and thus, these exotic species were considered more versatile. In contrast, native species were not the same in different studies, which made them stand out when the quantities were summed but not in terms of versatility.

3.4. *What is the predominant plant part in documented Brazilian folk medicine?*

The most commonly used plant parts were the leaves (in 391 spp.), stem (189 spp.), roots (137 spp.), fruit (63 spp.), seeds (57 spp.) and flowers (51 spp.), and these differences were significant ($\chi^2=579.5$, $p<0.001$). Because some studies did not report the parts of each of the species used, not all of the species were associated with their used parts.

When the integrative analysis was reduced to the use of permanent parts (in 294 spp.) vs. non-permanent parts (in 449 spp.), there were also significant differences ($\chi^2=32.3$, $p<0.001$) in favor of the use of non-permanent parts. This result is driven by the use of leaves, the main component of Brazilian pharmacopoeia. The meta-analysis also showed a greater importance of non-permanent plant parts among the studies ($k=22$, $\hat{\tau}^2=0.68$, $p<0.001$).

The integrative analysis showed that the RIp of non-permanent parts was significantly greater than the RIp of permanent parts of the species ($V=103692.5$, $p<0.001$). However, the meta-analysis did not indicate such a result ($k=19$, $\hat{\tau}^2=0.00$, $p<0.10$). This difference may be because the plants that appear in several studies have a greater use of non-permanent parts, and thus, the therapeutic indications and body systems associated with them accumulate, emphasizing the non-permanent parts in cumulative analyses. However, when the RIp is calculated for each study individually, this cumulative emphasis of non-permanent parts no longer appears.

3.5. *Are there variations in the habits that prevail among the plants used in different ecosystems or areas (urban vs. rural)?*

In general, considering the integrative analysis, ecosystems present different patterns regarding the number of woody and non-woody species used in local pharmacopoeias. Caatinga and Cerrado have similar patterns, based on the predominance of woody medicinal species, while the Atlantic Forest and Pampas regions both show increased use of non-woody species (herbs). Despite a slight predominance of woody species, the Amazon differed significantly only from the Pampas ecosystem and can be considered to be intermediate between the two patterns (Table 4). The meta-analytic tool using a mixed-effects model also indicated that the ecosystems differed in the number of woody and non-woody species ($k=25$, $p<0.001$).

If only the native species of each ecosystem were considered, differences were also identified ($\chi^2=29.3$, $p<0.001$), with the Caatinga and the Cerrado having a greater predominance of woody species and thus differing significantly from the Pampas (predominance of non-woody) and Atlantic Forest ecosystems (similar use of woody and non-woody). The Amazon had an intermediate pattern, with greater amounts of woody species, but to a lesser degree when compared with the Caatinga and the Cerrado. Amazon differed significantly from the Pampas according to the χ^2($p=0.02$).

Although the ecosystems differed significantly in terms of the number of woody and non-woody species, the same pattern was not true when considering the relative importance of these species ($k=23$, $p=0.35$). Regarding urbanization, there were no significant differences in the proportion of woody and non-woody species between urban and rural areas found in the integrative analysis ($\chi^2=3.41$, $p=0.06$), although there was a weak trend of increased use of woody species in rural areas. The meta-analysis also showed no differences relative to the degree of urbanization, whether between the number of woody and non-woody species ($k=25$, $p=0.66$) or the RI values of woody vs. non-woody species ($k=23$; $p=0.74$).

3.6. *Are there variations in the origins (native vs. exotic) that predominate among the plants used in different ecosystems or areas?*

The predominant origin also varied according to the ecosystem. In general, the integrated analysis showed that the Cerrado had a greater proportion of native (to the ecosystem) species used in pharmacopoeias, thus differing significantly from all of the other ecosystems (results in Table 4). The Pampas was the ecosystem with the greatest predominance of exotic species used by local people, thus also differing from the others. The other ecosystems did not differ statistically, although the Amazon and the Caatinga had a slight predominance of native species, while the Atlantic Forest had a slight prevalence of exotic species.

From the point of view of the meta-analysis, there was also a difference in the number of native and exotic species among the ecosystems ($k=18$, $p<0.001$). However, this result was not reproduced for versatility; there was no difference in the RI of native and exotic species among the different ecosystems ($k=16$, $p=0.51$).

Urbanization influenced the proportions of native and exotic species in the integrative analysis such that rural areas had a proportionally greater number of native species (342 vs. 195 exotic) and urban areas had a greater number of exotic species (212 vs. 197 native). However, this result was not reflected in the meta-analysis in terms of number of species ($k=18$, $p=0.23$) and in terms of RI ($k=16$; $p=0.58$).

3.7. *Are the exotic species of greatest relative importance for medicinal purposes the same in different ecosystems?*

The exotic (to Brazil) species of greatest relative importance tended to be the same in the different ecosystems; there was a significant correlation of the RI of exotic species between different combinations of ecosystems (results in Table 5). The only exceptions (with no significant correlation) were the Caatinga vs. Atlantic Forest and the Caatinga vs. Pampas ecosystems, indicating a trend of the Caatinga ecosystem to behave slightly differently regarding the relative importance of exotic species, favoring alien plants that were not important in the Pampas and Atlantic Forest.

Table 4
Number of species for each ecosystem considering differences in habit, origin and used parts, as well as the *p*-values (chi-square with Bonferroni adjusted p). AM—Amazon, CA—Caatinga, CE—Cerrado, AF—Atlantic Forest, PA—Pampa.

	AM	CA	CE	AF	PA
1–Habits per ecosystem					
N non-woody	38	65	89	165	82
N woody	57	106	146	138	59
p-values	AM	CA	CE	AF	
CA	1				
CE	1	1			
AF	0.19	0.008	0.002		
PA	0.09	0.006	0.002	1	
2—Habits per ecosystem (only native species)					
N non-woody	15	24	43	67	17
N woody	37	66	123	79	8
p-values	AM	CA	CE	AF	
CA	1				
CE	1	1			
AF	0.48	0.05	0.004		
PA	0.02	0.003	0.001	0.68	
3—Origin per ecosystems					
N exotic	43	81	69	157	116
N native	52	90	166	146	25
p-values	AM	CA	CE	AF	
CA	1				
CE	0	0			
AF	1	1	0		
PA	0	0	0.005	0	
4—Parts per ecosystem					
N non-permanent	18	89	125	231	85
N permanent	27	68	101	78	14
p-values	AM	CA	CE	AF	
CA	0.71				
CE	0.86	1			
AF	0	0.001	0		
PA	0	0	0	0.31	
5—Parts per ecosystem (only native species)					
N non-permanent	14	34	75	98	9
N permanent	23	56	83	41	3
p-values	AM	CA	CE	AF	
CA	1				
CE	1	1			
AF	0.005	0	0.001		
PA	0.56	0.32	1	1	

Table 5
Results of the Spearman correlation coefficient for the relative importances of exotic species in different Brazilian ecosystems. AM—Amazon, CA—Caatinga, CE—Cerrado, AF—Atlantic Forest, PA—Pampa.

	AM	CA	CE	AF	PA
AM	**1**	0.16*	0.40****	0.24****	0.20***
CA	0.16*	**1**	0.30****	0	0.02
CE	0.40****	0.30****	**1**	0.33****	0.26****
AF	0.24****	0	0.33****	**1**	0.28****
PA	0.20***	0.02	0.26****	0.28****	**1**

** $p > 0.01$.
* $p < 0.05$.
*** $p > 0.001$.
**** $p < 0.001$.

3.8. Are there variations in the plant parts (permanent vs. non-permanent) that predominate among the plants used in different ecosystems or areas?

According to the integrative analysis, the Atlantic Forest and Pampas ecosystems showed a strong predominance of non-permanent parts, differing significantly from the others and resembling each other (results in Table 4). The other ecosystems had a similar behavior of equilibrium between permanent and non-permanent parts, with a slight emphasis on permanent parts in the Amazon and non-permanent parts in the Caatinga and Cerrado.

If the same analysis was performed but excluding species that are exotic to the ecosystems, a similar pattern was found based on the similarity between the Atlantic Forest and Pampas due to the high proportions of non-permanent parts. However, the difference lies in the fact that, considering only the native species, permanent parts are also more representative in the Caatinga and Cerrado together with the Amazon region (Table 4).

The meta-analysis considering the number of species with the use of non-permanent vs. permanent parts by ecosystem also showed the influence of this factor ($k=18$, $p>0.001$).

Regarding urbanization, the integrative analysis revealed a significant difference in the use of the permanent vs. non-permanent proportion in urban and rural areas ($\chi^2=17.45$, $p>0.001$). Both areas had a higher prevalence of use of non-permanent parts. However, in the urban areas, there was a greater discrepancy between the number of species with uses for the permanent and non-permanent parts, while in rural areas, the two values were closer (urban: 272 spp. with non-permanent parts used vs. 108 spp. with permanent parts used; rural: 292 spp. with non-permanent parts used vs. 214 spp. with permanent parts used). Analyses performed only with the native species also showed differences in the proportion ($\chi^2=12.58$, $p<0.001$). However, in this case, there was a greater number of native species with permanent parts used in rural areas (171 spp. versus 157 spp. with non-permanent parts used) and a greater number of native species with non-permanent parts in the urban area (120 spp. compared with 66 spp.).

Because the meta-analysis did not consider differences in proportion but rather considered to which side the relationship tended (to the side of permanent or non-permanent parts), the analysis of the total number of species with permanent vs. non-permanent parts used revealed no significant differences between the urban and rural areas ($k=18$, $p=0.50$). When the RIp was considered, the meta-analysis did not reveal any influence of the ecosystem ($k=17$, $p=0.72$) or urbanization ($k=17$, $p=0.46$).

3.9. *Do local communities in the same ecosystem have similar repertoires of plants in their pharmacopoeias?*

The ANOSIM revealed that the ecosystem greatly influenced the species composition of its pharmacopoeia ($R=0.40$, $p=0.012$). This result means that studies in the same ecosystem recorded the same species, while large differences in this composition were found in studies conducted in different ecosystems. The same pattern was not observed when the species composition was compared in urban and rural areas ($R=0.03$, $p=0.35$), i.e., the degree of urbanization did not influence the species composition.

4. Discussion

4.1. *Plants with elevated value of relative importance*

There was a clear concentration of widely distributed exotic plants among species with higher RI. This finding can be attributed to two basic factors:

(1) The prestige of these species, which usually came from the Old World and spread throughout Brazil, and the ancient nature of the use of these species, associated with their effectiveness, may have caused a body of knowledge on different properties of these species to be created and diffused.
(2) The widespread distribution and transmission of these species makes them present in a large number of studies. Accordingly, with a greater number of studies that record the uses of the species, the probability is greater that there are many reports of therapeutic indications and body systems, which make these species stand out in RI.

The great regional (and global) importance of these species is also reflected in the amount of pharmacological and phytochemical studies on the species. For *Rosmarinus officinalis* L., which is the species with the greatest RI, there is a large number of studies that show some of the most popular uses for the species, such as antimicrobial activity (Bozin et al., 2007; Gachkar et al., 2007; Mangena and Muyima, 1999; Oluwatuyi et al., 2004; Pintore et al., 2002), antioxidant activity (Bicchi et al., 2000; Bozin et al., 2007; Gachkar et al., 2007), anti-ulcerogenic properties (Dias et al., 2000) and diuretic properties (Haloui et al., 2000), among others.

Ruta graveolens L., the species with the second-largest RI, is also listed in a variety of studies that corroborate the popular use of the species by Brazilian populations. The studies tested, among other things, the plant's antimicrobial (Ivanova et al., 2005; Oliva et al., 2003; Meepagala et al., 2005), anti-inflammatory (Raghav et al., 2006), cytotoxic (Ivanova et al., 2005; Wu et al., 2003) and antiplatelet activities (Wu et al., 2003).

Myracrodruon urundeuva Allemão, the tree species native to Brazil with the greatest relative importance, is a widely distributed plant, occurring in the Caatinga, Cerrado and Atlantic Forest ecosystems (Silva-Luz and Pirani, 2012), and whose activities, especially its anti-inflammatory properties, are strongly supported by the phytochemical and pharmacological literature (Souza et al., 2007; Viana et al., 1997).

4.2. *Patterns related to habit*

The findings of this study do not show a general pattern of use of non-woody species but rather a change in the proportion of woody and non-woody species used depending on the ecosystem, in contrast with the general premises of the ecological apparency hypothesis (see Albuquerque and Lucena, 2005; Stepp and Moerman, 2001). Accordingly, if the compounds with the greatest medicinal uses are from herbaceous species, and considering that chemical efficiency is a factor of great importance for the selection of medicinal plants, one would expect that the findings of our study would reveal a greater number of non-woody medicinal plants, both in the overall analysis and considering each ecosystem individually. However, this pattern was not the case.

Chemical analyses from some recent studies may help explain the results of this study. Almeida et al. (2011), for example, compared the medicinal use and chemical properties of Caatinga and Atlantic Forest plant species and found, contrary to the apparency hypothesis predictions, that for Caatinga plants, there was an increased presence of some qualitative compounds in trees compared to herbs. These results have also been found in other studies for the ecosystem (Alencar et al., 2009; Almeida et al., 2005). With regard to the Atlantic Forest, Almeida et al. (2011) found no difference in the occurrence of qualitative compounds among habits. Considering the possibility that qualitative compounds possess greater medical potential, these chemical findings explain the fact that among the native species in the Caatinga, the woody habit predominates, and in the Atlantic Forest, there are no strong differences among the prevalent habits. However, it should be made clear that that the medicinal use of a species is not always related to qualitative compounds (Almeida et al., 2011).

The results observed in this study, which show the differences among the most common habit in the ecosystems, allow us to infer that the environmental particularities of each ecosystem will significantly influence the biochemical pathways of the species. Consequently, these particularities will affect how people appropriate the medicinal resources. Therefore, it is necessary that studies using this perspective of phytochemistry–ethnobotany interface are conducted in other Brazilian ecosystems to identify the chemical behavior of plants in different macroenvironmental conditions (see Albuquerque et al., 2012).

However, it is not just chemical efficiency, discussed here in terms of secondary compounds, that may influence the preferred selection of woody or non-woody species. The very availability of herbs, trees and shrubs in a given environment can interfere with this relationship. In the Pampas, for example, the higher incidence of non-woody medicinal species, as evidenced in this study, was expected because the flora of this ecosystem is dominated by these species, especially grasses (Pillar et al., 2009). Accordingly, Thomas et al. (2011), in a study in the Bolivian Amazon, analyzed the over- and underuse of herbs, shrubs and trees and considered not only the total numbers of medicinal species for each of the habits but also the proportion of medicinal plants in a given habit compared to the total flora thereof. The authors observed that when considering the total values, there was a greater number of medicinal woody species (trees, followed by shrubs), which is similar to the pattern found in the present study for the Brazilian Amazon. However, when analyzing these values in relation to the occurrence of each habit in the local vegetation, Thomas et al. (2011) observed an overuse of shrub and herbaceous species and underuse of tree species. This result shows that the trees were often used as medicinal species simply because they were dominant in the ecosystem, given that the proportional analysis did not highlight them as significant. The environment can therefore act by providing greater possibilities for the use of certain resources.

Another condition that seems to affect the greater use of woody species in areas of Cerrado and Caatinga, but cannot be used to explain the patterns found in the Amazon, concerns the markedly seasonal characteristic of these ecosystems (seasonality hypothesis). The same hypothesis is valid to explain why in these environments, especially for the native flora, permanent plant parts (stems and roots) are prioritized at the expense of non-permanent parts.

4.3. Patterns related to the origin

The larger number of native species observed in the integrative analysis and the lack of confirmation of this trend in the meta-analysis follow a logic that is presented in Fig. 2. It is evident that the strong differences in the diversity of native species among the different ecosystems are responsible for the importance of these species from a regional point of view, although this result is not reflected in the analysis of local groups (meta-analysis).

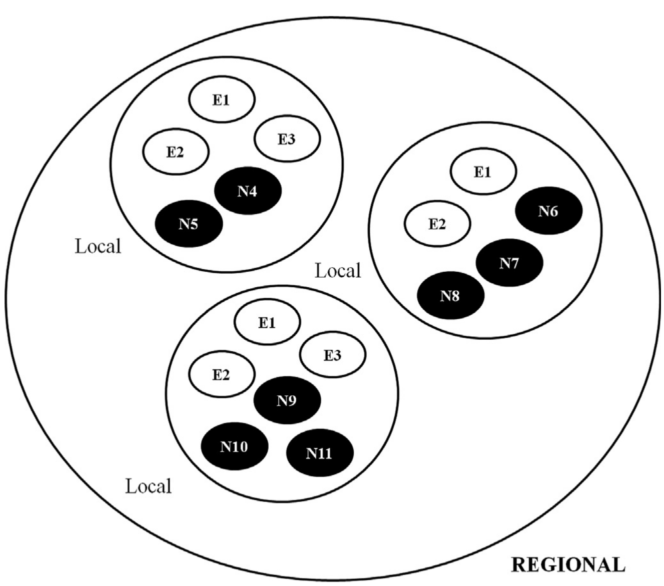

Fig. 2. Distribution model of native and exotic species in the cited studies, considering the analysis of local groups and a regional group. Letter 'E' represents the exotic species, while letter 'N' represents the native species. Each number refers to a different species. In this case, because exotic species were generally the same across studies and native species varied widely, the regional analysis (integrative) benefits the native species, whereas the analysis of local assemblies displays no difference in the number of native and exotic species.

The fact that the analyses indicate that some ecosystems have more exotic plants than others may be related to a number of factors. Through evolutionary processes and environmental influences, some ecosystems can stimulate the production of a greater amount of bioactive compounds in their native species, while other ecosystems have less diversity of these compounds (Voeks, 2004). In the latter case, exotic species could be added to the pharmacopoeia more effectively to fill gaps not filled by native species (Alencar et al., 2010a).

One explanation for this phenomenon, especially the contrast of the greater number of exotic species in the Atlantic Forest compared to the Caatinga and Cerrado, may be related to the resource-availability hypothesis (Albuquerque et al., 2012; Coley et al., 1985; Endara and Coley, 2011). According to this hypothesis, faster-growing plants invest less in defense compounds than slow-growing species. Because resource-rich environments generally have faster-growing species (Albuquerque et al., 2012; Endara and Coley, 2011), regions with limiting resources, such as the Caatinga and Cerrado, would tend to accumulate a larger amount of potentially bioactive compounds.

Thus, people set in ecosystems such as the Atlantic Forest could address this deficiency with the use of exotic species, which most likely evolved in environments that stimulate the production of bioactive compounds, such that this production would already be genetically determined. It is necessary, therefore, that future studies investigate if there are indeed gaps in the pharmacopoeias of Atlantic Forest and Pampas environments that need to be filled by exotic species.

However, another possible explanation for the increased use of exotic species in areas of Atlantic forest and Pampas lies in historical factors. From this point of view, the predominance of the use of exotic species in areas of Pampas and Atlantic Forest can be explained by the fact that these environments were the initial targets of European settlement in Brazil. Therefore, the populations of these ecosystems have lived longer with the arrival of the exotic plants to the country, which would facilitate the process of inclusion in the local pharmacopoeias. Historical studies in areas of Atlantic Forest show the use of some of the exotic plants in past centuries (Alencar et al., 2010b; Medeiros et al., 2010; Medeiros and Albuquerque, 2012), with their use influenced even by the doctors who graduated from European schools, bringing with them knowledge on the plants used in the old world (Alencar et al., 2010b).

It is also possible that the system of ownership and protection of native vegetation influences the use of native or exotic species. In areas of Atlantic Forest, for example, forest areas tend not to be owned by communities and, most often, are protected in conservation areas, which would hinder access to native species. Natural areas of Caatinga and Cerrado, in contrast, tend to be present in rural village properties or in areas of common use, thereby facilitating access to native species. The possible explanations suggested in the present study for the differences in the proportions of native and exotic species among ecosystems need to be fully investigated to determine which of them actually influences this finding.

The observation that these exotic species exhibit high versatility in various ecosystems indicates a clear pattern of differential selection, based on the inclusion and importance of a specific set of species in the pharmacopoeias. This pattern may be the result of cultural diffusion or the convergence of independent findings. Although the first option is more feasible, it is interesting to take into account, for an overview of bioprospecting, the relational efficacy hypothesis proposed by Bletter (2007), in which plants that are used for the same purposes by populations that are distant from each other are considered highly likely to be effective, because it is possible that the medicinal uses constitute independent discoveries in the different communities. For our context, although the hypothesis of knowledge diffusion is more acceptable, analyses of the use of these plants by distant Brazilian populations, especially with regard to exotic plants with a high potential for natural dispersion, may identify species that are actually chemically efficient.

4.4. Patterns related to the parts used

The greater use of non-permanent plant parts, particularly leaves, has also been demonstrated in a range of studies around the world (Afroz et al., 2011; Allabi et al., 2011; Bradacs et al., 2011; Novais et al., 2004; Rehecho et al., 2011; Tabuti et al., 2003). Exceptions may be found in some parts of Africa, where roots predominate in local pharmacopoeias (Bruschi et al., 2011; Giday et al., 2007; Maroyi, 2011; Teklehaymanot, 2009). Accordingly, the results of these studies in Africa are similar to patterns found for species native to the Caatinga, Cerrado and Amazon. In the case of the first two systems, as already mentioned, this phenomenon may be related to the hypothesis of climatic seasonality (Albuquerque, 2006; Monteiro et al., 2006a, 2006b).

However, there must be an effort to analyze the phytochemical and pharmacological aspects of the permanent and non-permanent plant parts in various ecosystems, especially in situations that appear contrary to expectations, such as the Amazon region. In this ecosystem, due to weak seasonality and because leaves are commonly used in areas with low seasonal variation, one would expect a predominance of the use of non-permanent plant parts. At the same time, the fact that Amazon tree species can reach impressive heights can contribute to the use of roots and bark.

4.5. Floristic similarity among ecosystems

As in this systematic review, other studies have already demonstrated a strong environmental influence on the repertoire of useful species, mainly because as the floristic similarity increases, so does the likelihood of use of the same species by different populations. By comparing the knowledge of two indigenous communities of different origins in Nicaragua, Coe and Anderson (1999) observed that the vast majority of species used were the same due to the complete overlap of territories and consequent similarity in the supply of environmental resources. Some studies have suggested that people tend to use referentially (but not exclusively) plants that grow close to their settlements, be them spontaneous or cultivated, and that more common species are more likely to be used (Johns et al., 1990; Parada et al., 2009). In fact, Parada et al. (2009) have shown that the minority of the plant species are acquired without being cultivated or gathered in the wild. This can be the main driver of the similarities among studies performed in the same ecosystems.

Even in cases of cultural similarities, environmental differences may play a role in limiting the resources available and thus act to generate heterogeneity in the use of resources. Ladio et al. (2007), comparing the knowledge of Mapuche peoples inhabiting forest and steppe zones, noted the key role of the environment because the similarity in the use of plants was not high among communities from different ecosystems. The same result was found by Inta et al. (2008) in a study of the Akha people in Thailand and China. However, these two studies have in common the fact that despite the floristic dissimilarity, the form of resource use (mode of use, ways of life, and botanical families) is quite similar in communities with the same ethnic background. This finding means that while the environment acts to generate floristic differences in resource use, aspects related to how they are used (i.e., human-plant interactions), which result from cultural similarity, are maintained. Therefore, both culture and environment must be considered when seeking to explain a relationship between people and plants.

4.6. Limitations and future perspectives

From a statistical viewpoint, this study has some limitations. The first issue is the small number of studies that met the inclusion criteria. Due to this problem, some ecosystems were not represented, such as the Pantanal. Additionally, the fact that very few articles were classified as having a low risk of bias did not allow for the execution of sensitivity analyses, which are intended to counteract patterns observed considering the studies with both low and moderate risk by comparison with the findings based only on studies with a low risk of bias.

Furthermore, there was a lack of homogeneity in the studies considered; some of them included only the native species, while others only included plants with a specific characteristic, etc. Although such studies were excluded from the meta-analyses due to their shortcomings (e.g., the comparison of native vs. exotic species excluded works with only native species), it is possible that the methodological and thematic bias in the studies may have, in some way, affected the results (e.g., studies of the native species in a given ecosystem may favor the emergence of woody species).

Other limitation has to do with the fact that not all studies mentioned the deposit of voucher specimens in herbariums and in those cases we do not have a proof of the specie's identity.

Still, we believe that such methodological and thematic limitations has not affected the patterns found but only interfered in specific aspects of the results. We therefore propose that, after a greater accumulation of investigations focusing on medicinal plants, a new analysis is to be performed to strengthen or disprove our findings. However, there is a the need for local ethnobotanical studies to be performed following the principals of representativeness and quality research design so that future regional analyses can find patterns using quality information.

5. Final considerations: Implications for conservation and bioprospecting and theoretical implications

Some observations can be made from the results found in the present study:

1) It was possible to detect patterns related to the number of species. However, these patterns were not reproduced when considering the versatility of these species. This result may indicate that the environment directly affects the quantity of medicinal plants with a given trait. However, once a species with a trait that is different from the prevalent traits is introduced into the system, there is no distinction from those that are given greater local importance. In other words, the selection of species for medicinal purposes is influenced by environmental factors and varies regarding the importance of native or exotic, woody and non-woody and permanent and non-permanent plant parts. However, the differential selection of these plants, as expressed by their local importance, is not strongly influenced by the ecosystem, and there are no significant local variations in the characteristics mentioned above.
2) The influence of the ecosystem on the patterns of use of medicinal plants was quite evident, as opposed to the type of

urbanization, the influence of which was restricted to the proportion of the species used with permanent and non-permanent parts. However, it is necessary to clarify that the fact that the environment influences the patterns of selection of medicinal plants does not mean that the process follows a deterministic logic.

3) Some of the differences in the results of the integrative and meta-analysis regarding the general profile of the studies relate to the statistical logic of each of these analyses. While an integrative analysis considers the data based on a logic of "regional diversity", meta-analyses consider the patterns that emerge from a set of "local diversities". The findings relating to each of these approaches should therefore be interpreted based on a regional profile or the joint analysis of local profiles, depending on the analysis in question.

Based on the results found in the present study, it is possible to suggest that, from the perspective of bioprospecting, the different Brazilian ecosystems have the potential to provide particular types of medicinal resources. Accordingly, based on the present results, it is recommended that ecosystems such as the Caatinga, the Cerrado and the Amazon are targeted for the prospecting of native and/or woody species whose permanent parts are used. In contrast, in the Pampas, the greatest medicinal potential should come from non-woody species and non-permanent plant parts, while in the Atlantic Forest, non-permanent parts have great bioprospecting potential, as do both woody and non-woody species.

With regard to elucidating aspects of the relationships between people and plants, it is evident that macro-environmental factors exert considerable influence on the patterns of selection of medicinal plants. Additionally, cultural aspects are also observed as key factors in this relationship, which may explain, for example, the fact that in different and distant communities, exotic plants receive the same prominence as the versatile plants.

Finally, it is important to emphasize the importance of using systematic reviews and meta-analyses in the search for the patterns of use of plant resources. Therefore, it is recommended that these tools be applied in different contexts of ethnobotanical research with the aim of observing behavior at larger scales.

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