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What is the role of exotic medicinal plants in local medical systems? A study from the perspective of utilitarian redundancy

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ABSTRACT

Medicinal plants are an important aspect of local medical systems. The composition of a medicinal plant collection is influenced by cultural and environmental factors. Additionally, the functionality of a local medical system can be threatened by the replacement of native species with exotic ones, as well as by cultural factors such as the erosion of knowledge. The objectives of this study are: 1) examine the composition of the medicinal plant collection of two rural communities settled in the *caatinga* (savanna-like vegetation) of the state of Pernambuco (Brazil); 2) observe the role of exotic plants in the local medical systems; and 3) identify the profile of the species utilized according to the Utilitarian Redundancy Model. Similarities were observed between the medicinal floras of the communities studied, emphasizing the importance of the surrounding biome within the possibilities of species selection, although exotic species appear to contribute by increasing the diversity of species considered in the communities to be medicinal. The native species act broadly among the body systems recognized in the two communities, whereas exotic species act in specific body systems, for which there are few associated native species.

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Introduction

Local medical systems are constituted by rich collections of theoretical and practical knowledge and beliefs surrounding health, illness, social actors and medicinal resources, such as plants, animals, and even inorganic substances, which are used by human communities throughout the world (Bhasin, 2007). In Brazil, five million people require medicinal plants for basic health care (Dalevi, 2002). The importance of medicinal plants for the maintenance and survival of many traditional societies is already well documented among the scientific community (Afifi and Abul-irraimed, 2000; Agelet and Vallès,

2001); therefore, it is relevant to define which plants should be chosen by human populations for medicinal use, as well as the characteristics that justify such choices.

Local medical system cannot be considered a static social institution that has no evolution. The medicinal plant collection of a community is the product of experimentations conducted throughout the history of a community and represents an adaptation of this culture over time (Palmer, 2004). During events of adaptation of a medical system, there may be insertions and deletions of plants that compose it, with the addition of exotic plants for therapeutic indication without the operation of native ones (Albuquerque, 2006; Alencar et al., 2010).

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To understand the participation of native and exotic plants in local medical systems, authors have adapted theories and hypotheses utilized to understand ecological phenomena (Albuquerque and Oliveira, 2007; Alencar et al., 2010; Lucena et al., 2012). For instance, Albuquerque and Oliveira (2007) introduced the Utilitarian Redundancy Model based on the Hypothesis of Ecological Redundancy (Walker, 1992), to investigate the role of plants with the same function. Originally, in this hypothesis, the plants of a biological community have different roles in an ecosystem for it to maintain its balance. However, there are plants with the same ecological role, with consequent redundancy, so the ecological functions with the highest number of redundant plants tend to reduce the pressure on the balance of the ecosystem and thus preserving and ensuring the function and resilience of an ecosystem. Once there are more species participating, the ecological functions with few associated species are more susceptible to be lost in the ecosystem due to the smaller plant diversity.

Adapting the ecological hypothesis to ethnobotany, Albuquerque and Oliveira (2007) suggest that ecosystems could be represented by medical systems and ecological functions by therapeutic indication. Therefore, for a community understanding of the treatment of a disease to be preserved, there must be a greater plant diversity associated with the therapeutic indication. According to these authors, a greater number of plants cited for each therapeutic indication would represent a possibility to maintain the knowledge of therapeutic indications and the possibility of a cure for certain diseases, which contributes to the resilience of a local medical system. To the ecosystem, this represents a diminishing risk of the use pressure on certain species, considering the possibility that some species may relieve the use pressure on other, especially native species.

Exotic species inserted in traditional plant collections possess two possibilities of action. First, they could be inserted to maintain the resilience of the local medical system and preserve the functions of the therapeutic indications. Second, they could aid in maintenance, by occupying therapeutic roles that are not performed by native plants. Recently, Albuquerque (2006) introduced the Hypothesis of Diversification as another attempt to understand the role of exotic plants in local medical systems. According to the author, exotic plants are chosen with the objective to diversify the possibilities of use in therapeutic indications, occupying a role that native plants do not hold.

This study was conducted to understand the use of plants in two communities living in the same environment, and answer the following questions: 1) Are exotic plants inserted in a local medical system to act in distinct/exclusive uses? It is believed that exotic plants can act for exclusive therapeutic indications and furthermore, that there are body systems only addressed by exotic plants; 2) Will the medicinal plants utilized in the medicinal systems, differentiated in two groups according to their biogeographical origin, behave in accordance to the Utilitarian Redundancy - will they cluster in therapeutic indications at redundancy levels in groups of native and exotic plants? We expect that exotic plants contribute to their resilience for some therapeutic indications.

Materials and methods

Area of study

The study was developed between the years 2006 and 2010, in Altinho, a mesoregion of the agreste of Pernambuco (NE Brazil), located 168 km from the capital of the state, composed of 44,449 km² with a population of 22,363 inhabitants (IBGE, 2011), located at coordinates 8° 29' 32" S; 36° 03' 03" W (Fig. 1). According to the data obtained at meteorological stations located in close municipalities such as Caruaru, 60 km away from Altinho, the area has approximately 746 mm rainfall and a mean annual temperature of 23°C (Lamepe/Imepe, 2011), thus having characteristics of a semi-arid region, with more precipitation between June and July. The region is covered by a hypoxerophytic arboreal *caatinga* (savanna-like vegetation) with deciduous and semi-deciduous species. Araújo et al. (2007) stressed that the *caatinga* occupies a large area in the Brazilian northeast, presenting distinct physiognomic vegetation types; an important trait of this ecosystem is the remarkable climatic seasonality, which completely alters the landscape in some seasons of the year.

Two communities adjacent to the municipality of Altinho were studied: Carão and Letreiro. The communities are separated by a mountain range, located 16 and 9 km away from the urban center, respectively, and their only access is through unpaved roads.

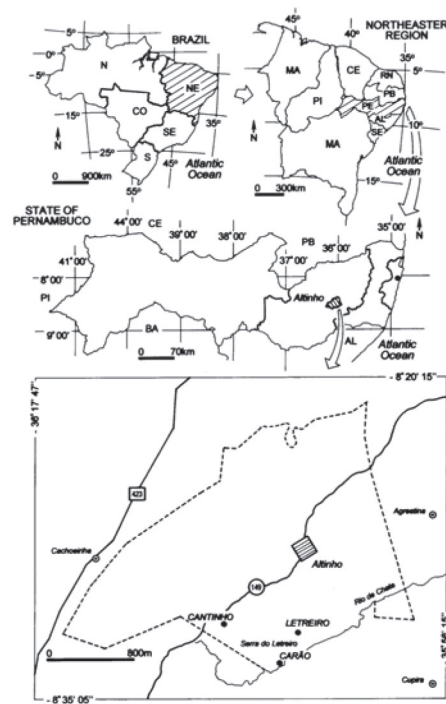


Figure 1 – Area of study: communities of Carão and Letreiro, Altinho, in Pernambuco (northeast Brazil) (Source: Alencar et al., 2010).

The communities of Carão and Letreiro practice subsistence activities, such as the cultivation in small areas of corn, common beans and cassava. However, its economy is mainly based on raising cattle for dairy production. The terrains for cultivation are found at the base of the mountain range, which limits the settlements, or even the foothills of the mountain range; the latter are only utilized by the community of Carão, due to the declivity of the terrain. The production is consumed by the communities, and the surplus is commercialized at the open street markets of the town. The communities are populated largely by Catholics and also by representatives of Protestant religions – each community maintains a small chapel, and there is a small Protestant church in Carão.

The communities possess Health Centers that receive weekly visits from a nurse and, once a month, from a doctor, with distribution of a few medications. The dwellings are still visited every month by health agents, who monitor the occurrence of diseases in the population, in addition to monitoring the treatments of illnesses such as heart disease and diabetes.

Their populations are mostly illiterate and semi-illiterate (with less than 5 years of schooling). However, there is a school for children below seven years of age in each community, while elementary and secondary school is offered at “Centro de Altinho”. In the municipality, there are no institutions of higher education.

The houses are usually made of bricks, although some construction of loam and wood (mud huts) still exists. All residences are provided with electricity, but there is no basic sewage or water supply. Water shortages occur during large part of the year (9 months, on average). Water is obtained from drilled wells on farms located far from the community, in a water tank (weir) near the community, and from the accumulated rain in rock outcroppings or masonry cisterns built to accumulate rainwater.

Historically, the communities emerged, according to stories of the older members, from settlements of a few families in the community of Letreiro in the mid-1880s. Initially, they were few families, but with numerous members, which, after marrying members of other neighboring communities or other regions, inherited lands from their patriarchs, where Carão is now located. Today, many descendent members have left the community, and many families with no direct relationship with the ancestors have settled in other communities. Families that were numerous five decades ago today comprise few members, as many migrated to large urban centers, such as Recife and São Paulo, seeking better job opportunities and an improved quality of life.

The communities studied were the target of many ethnobotanical studies on diverse aspects concerning patterns of knowledge and use of plants. Studies on the use of ethnobotanical tools for the bioprospecting of plants with greater anti-inflammatory activity (Araújo et al., 2008; Ferreira Júnior et al., 2011), antitumor activity (Melo et al., 2010), patterns of selection of medicinal plants (Alencar et al., 2010; Silva et al., 2011), and patterns of extraction of medicinal plants (Soldati and Albuquerque, 2012), among others, should be particularly stressed.

Data collection

Aiming to enlighten the community about the importance and the objectives of the research, contact was previously established with the authorities of the municipality, such as the Mayor and Secretaries of Health and Agriculture. Later, selected members of the public, as well as health agents, were interviewed as part of the sampling.

Seeking to meet the ethical aspects, prior to the interviews, the community members formally signed the Statement of Free and Informed Consent after detailed reading of the protocol. In the community of Carão, 101 people were sampled as follows: 36 men and 65 women between 19 and 83 years of age (51.15 ± 19.8 , mean \pm SD), corresponding to 90.20% of the adult population (18 years old or older). We sampled 67 people in the community of Letreiro, with ages ranging from 18 to 85 years (47.7 ± 20.4 , mean \pm SD), composed of 28 men and 37 women, representing 63.73% of the population.

Considering the complexity that characterizes the richness of plants known and utilized by a community, the authors of this study chose to use multiple data collection procedures, aiming at a triangulation of data, which could guarantee greater reliability of the collected information (Albuquerque et al., 2014).

The interviews focused on the medicinal plants existing in the community, based on the following question: Which plants do you know in the region? From the answers, other relative information concerning forms of use, collection sites, parts utilized and indication of the use of the plants mentioned were investigated. At the end of each interview, the informants participated in guided tours, in which they circulated the vicinities of their own houses recording whenever possible, notice of new plants different from the plants mentioned in the interview, according to Albuquerque et al. (2014).

At a second event, the list of the plants mentioned during the interview was read, aiming to complement the information collected; this procedure was similar to the reading back technique (Albuquerque et al., 2014). To minimize the effects of overestimation of species, fresh samples of species that could possibly present two or more denominations were collected and presented to the community members, similar to the checklist-inventory technique (Albuquerque et al., 2014).

The plant species collected during the research were identified, collected and stored at the Herbarium Professor Vasconcelos Sobrinho, of Universidade Federal Rural do Pernambuco.

Data analysis

To evaluate the floristic similarity between the two communities, the Sorensen similarity index was used. Plants mentioned during the interviews were classified according to their biogeographically distribution. Lista de espécies da Flora do Brasil (2013) and previous studies from the same research group (Araújo et al., 2008; Alencar et al., 2010) were used as database to retrieve the biogeographically distribution of species. Next, native plants were considered as those occurring spontaneously in the *caatinga* or in any ecosystem that borders it, whereas exotic plants were considered to have spontaneous

distribution in ecosystems outside South America. The Williams' G test was conducted to verify differences between the number of known and exclusive species and the proportion of native and exotic species between the two areas.

The plants mentioned during the interviews were grouped according to their therapeutic indications considering the local nosology (Albuquerque and Oliveira, 2007), without a transformation for diseases or therapeutic indications known by the "western" medical system. The therapeutic indications were grouped by body systems, according to the WHO (2006), except for those connected to cultural diseases. The proportion of indications and medicinal plants mentioned for each body system were counted, as well as the number of plants for each therapeutic indication, with their proportions evaluated according to the Williams' G test.

To evaluate the plants according to the Utilitarian Redundancy of the two communities, the Utilitarian Redundancy levels of each therapeutic indication and body system were considered. The methodology of categorization of the redundancy level is similar to that described in Albuquerque and Oliveira (2007). Thus, in the category named *extremely redundant* (ER), plants that presented therapeutic indications and/or body systems with 15% or more referenced plants were included. The category *relatively redundant* (RR) involved plants between 5 and 15% of the total, whereas the category *slightly redundant or non-redundant* (NR) was represented by the proportion of medicinal plants inferior to 5% of those mentioned in the survey.

To evaluate the native and exotic plants according to the Hypothesis of Utilitarian Redundancy, plants were grouped for each therapeutic indication, and then their proportions were measured by applying the Williams' G test (Zar, 1996). To evaluate the importance of native and exotic plants for each therapeutic indication and/or body system, the index of Relative Importance (IR) (Bennett and Prance, 2000) was calculated, and the groups were compared using the Mann-Whitney test (Ayres and Ayres, 2007).

Results

The local medical systems of two communities located in the same biome.

When evaluating the medicinal floras of both communities as a whole, the communities showed a large collection of species, corresponding to 226 citations of plants, with 115 plants common to both communities. The similarity between the known was 68%, comparing the communities according to Sorensen similarity index; 91 plants were exclusively recognized by the community of Carão (with a total of 206) and 20 plants exclusively recognized by the community of Letreiro (with a total of 135). The Williams' G test showed differences between the number of exclusive species known by two communities ($G = 18.58; p < 0.0001$).

There were also similarities in the proportion of mentions for the main species of the two communities, i.e., those with the highest numbers of mentions of use (Fig. 2), but overall, a large amount of plants (156 spp) was less than ten times reported.

According to the interviews conducted, the Medical Systems of the studied communities recognize 265 therapeutic indications: 187 were mentioned in Carão and 177 in Letreiro. Considering the contexts of the local nosology, the diseases can be grouped into 16 body systems present in the two communities. Figure 3 presents the body systems and the number of therapeutic indications recognized for each. The two communities presented a therapeutic indication similarity of 40%.

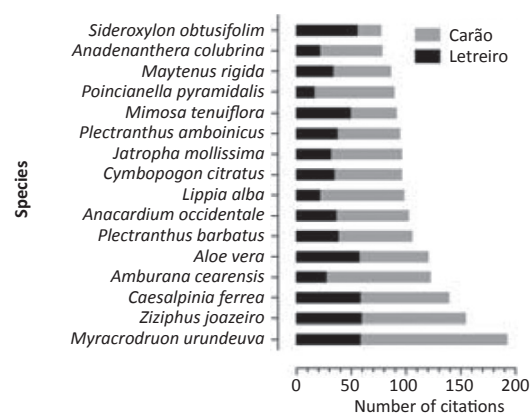


Figure 2 – Species with the highest numbers of mentions in the communities of Carão and Letreiro, municipality of Altinho, northeast Brazil.

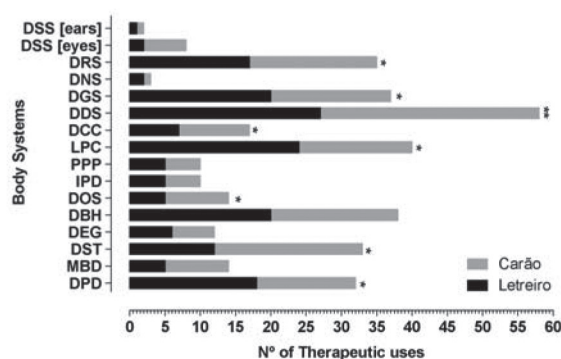


Figure 3 – Number of therapeutic indications associated with each body system (WHO) identified in the medical systems of the communities of Carão and Letreiro, northeast Brazil. (* $p < 0.05$; ** $p < 0.01$). DPD, non-defined conditions and disorders; MBD, mental and behavior disorders; DST, diseases of the skin and subcutaneous tissue; DEG, diseases of the endocrine glands, of nutrition and of metabolism; DBH, diseases of the blood and hematopoietic organs; DOS, diseases of the musculoskeletal system and connective tissue; IPD, infectious and parasitic diseases; PPP, pregnancy, parturition and puerperium; LPC, lesions, poisoning and other consequences of external causes; DCC, disorders of the circulatory system; DDS, disorders of the digestive system; DGS, disorders of the genitourinary system; DNS, disorders of the nervous system; DRS, disorders of the respiratory system; DSS (eyes), disorders of the sensory system (eyes); DSS (ears), disorders of the sensory system (ears).

Do exotic plants have distinct/exclusive uses?

Due the difficulty of identifying the botanical material, only 182 plants could be identified by geographical distribution. Evaluating only the plants common to both communities, 56 are native, without significant differences in the population of native and exotic plants common in both ($p > 0.05$). In the community of Carão, 90 species are considered exotic and 88 species are considered native; for the community of Letreiro, 58 plants, corresponding to 50% of the identified plants, were characterized as exotic. Among the exclusive plants of the community of Carão, 30 are native, whereas of the exclusive plants of Letreiro, only one is native.

In the community of Carão, the exotic plants had mean values of $IR = 0.257$, whereas native plants obtained $IR = 0.431$; thus, native plants were more versatile than the exotic ones [$Z(U) = 2.605$; $p < 0.01$]. In the plant collection of Letreiro, the data found corroborate those previously described in Carão: exotic plants with $IR = 0.277$; native plants with $IR = 0.488$, as well as native plants presenting more diverse use [$Z(U) = 3.085$; $p < 0.01$].

Exotic plants do not predominate significantly in most therapeutic indications in both communities, but among the *non-redundant* indications, 35 and 37 are treated exclusively with exotic plants, in Carão and Letreiro, respectively. The therapeutic indications with the majority of exotic plants do not belong to any specific body system; these can be found in several body systems.

Among the main therapeutic indications (those ones with a higher number of plants mentioned, corresponding a total of 50% of the floristic richness), native plants predominated in almost all cases in both communities (Table 1), with some exceptions of exotic predominance, like depression (56% in Carão and 63% in Letreiro), headache (70% in Letreiro) and colic (70% in Carão and 89% in Letreiro).

In a broader analysis, regarding the functionality of the plants according the body systems in which they act, the native plants also showed predominance, although only four body systems presented significant differences in Carão and only one in Letreiro (Fig. 4).

Are the therapeutic indications of the medical systems of the communities redundant?

Analyzing the medical system of the community of Carão, 33 indications are *extremely redundant*, 36 indications are *relatively redundant* and 118 are *non-redundant*. In the community of Letreiro, there were 28 *extremely redundant* indications, 36 *relatively redundant* indications (31 in Carão) and 113 *non-redundant* indications (Fig. 5).

Table 1

Number of botanical species and families present in the traditional medicinal plant collection of the communities of Carão and Letreiro (northeast Brazil), and common to both.

Community	Nº of species	Nº of families
Carão	206	61
Letreiro	135	52
Common in both	116	51

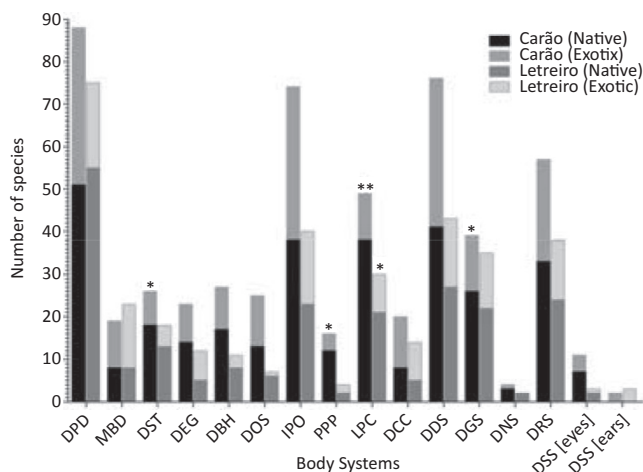


Figure 4 – Number of native and exotic species mentioned for each Body System in the communities of Carão and Letreiro, municipality of Altinho, northeast of Brazil (* $p < 0.05$; ** $p < 0.01$). DPD, non-defined conditions and disorders; MBD, mental and behavior disorders; DST, diseases of the skin and subcutaneous tissue; DEG, diseases of the endocrine glands, of nutrition and of metabolism; DBH, diseases of the blood and hematopoietic organs; DOS, diseases of the musculoskeletal system and connective tissue; IPO, infectious and parasitic diseases; PPP, pregnancy, parturition and puerperium; LPC, lesions, poisoning and other consequences of external causes; DCC, disorders of the circulatory system; DDS, disorders of the digestive system; DGS, disorders of the genitourinary system; DNS, disorders of the nervous system; DRS, disorders of the respiratory system; DSS (eyes), disorders of the sensory system (eyes); DSS (ears), disorders of the sensory system (ears).

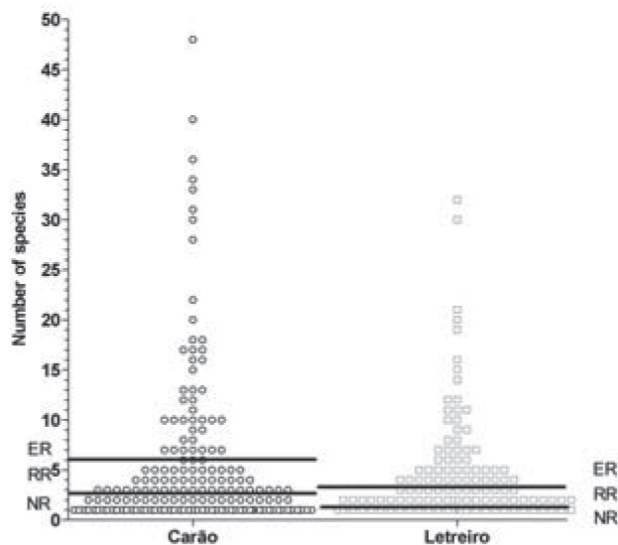


Figure 5 – Number of species referred for the Therapeutic Indications of the communities of Carão and Letreiro, in Altinho, Pernambuco, Brazil. Horizontal lines delimitate the groups of therapeutic indications: Extremely Redundant (ER), Relatively Redundant (RR) and Non-Redundant (NR).

The group of *non-redundant* therapeutic indications, in addition to possessing few mentioned plants, is also a category of fewer mentions in the community, not surpassing, in some cases, seven mentions in total. Among the *non-redundant* indications, 27 refer to native and exotic species in Carão and 14 in Letreiro, whereas 56 and 61 are referred to native plants, in each community, respectively.

Analyzing the most mentioned therapeutic indications; we observed that the community of Carão presented a higher number of plants than Letreiro for most of the therapeutic indications. For some therapeutic indications such as congestion, the community of Carão accounted for 94% of the plants mentioned in the survey. However, in some situations, Letreiro had more redundant indications than Carão, as in the case of body aches (83%) and stomachache (100%) (Table 2).

Evaluating the body systems associated to the therapeutic indications mentioned, we can observe more specialized body systems, i.e., with greater diversity of associated therapeutic indications. Some body systems are highly specialized in the community of Carão, such as Disorders of the Digestive System (31 indications) and Infectious and Parasitic Diseases (21 indications); whereas in Letreiro, the most specialized body systems are Disorders of the Digestive System (27 indications) and Lesions, poisoning and other consequences of external causes (24 indications), thus indicating a deeper knowledge of disease states and complexity in their medical systems.

Most of the Body Systems are *extremely redundant* in both communities (Fig. 6), and Disorders of the Digestive System (with a total of 94 plants), Infectious and Parasitic Diseases (with 89 plants) and Disorders of the Respiratory System (72 plants) are the body systems with the greatest amount

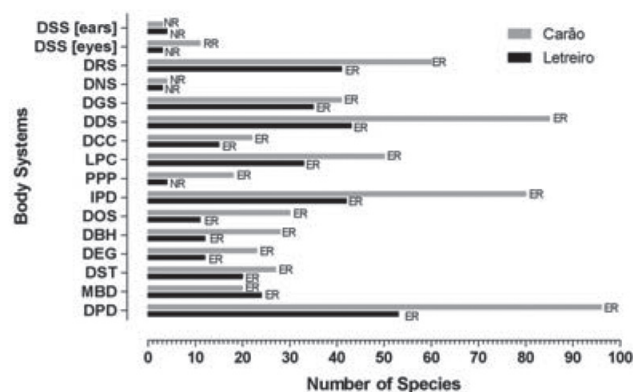


Figure 6 – Number of plants mentioned in each body system (WHO) recognized in the Traditional Medical System of the communities of Carão and Letreiro, northeast Brazil. Letters associated with the numbers indicate if the body system is Extremely Redundant (ER), Relatively Redundant (RR) or Non-Redundant (NR). DPD, non-defined conditions and disorders; MBD, mental and behavior disorders; DST, diseases of the skin and subcutaneous tissue; DEG, diseases of the endocrine glands, of nutrition and of metabolism; DBH, diseases of the blood and hematopoietic organs; DOS, diseases of the musculoskeletal system and connective tissue; IPD, infectious and parasitic diseases; PPP, pregnancy, parturition and puerperium; LPC, lesions, poisoning and other consequences of external causes; DCC, disorders of the circulatory system; DDS, disorders of the digestive system; DGS, disorders of the genitourinary system; DNS, disorders of the nervous system; DRS, disorders of the respiratory system; DSS (eyes), disorders of the sensory system (eyes); DSS (ears), disorders of the sensory system (ears).

Table 2

Main therapeutic indications with higher numbers of referred species, distinguished between native (NAT) and exotic (EXO), and the redundancy of each one.

Therapeutic Indication	Carão			Letreiro		
	NAT	EXO	RED	NAT	EXO	RED
Influenza	24	22	ER	08	11	ER
Coughing	17	13	ER	14	11	ER
Dysentery	16	15	ER	13	06	ER
Injury	28**	06	ER	14*	05	ER
Headache	20	16	ER	02	07	ER
Inflammation	22**	06	ER	13**	02	ER
Worms	10	08	ER	05	05	ER
Congestion	14	16	ER	00	02	NR
Depression	06	09	ER	05	10	ER
Catarrh	12	06	ER	07	04	ER
Cicatrizant	13*	03	ER	12**	01	ER
Inflammation of the kidneys	13*	03	ER	10**	01	ER
Diarrhea	09	04	ER	07	03	ER
Rheumatism	10	07	ER	01	01	RR
Pain in general	11	07	ER	04	01	RR
Gastritis	12*	04	ER	03	02	RR
Blood thinner	11*	02	ER	07**	00	ER
Uterine conditions	13*	04	ER	02	01	RR
Hemorrhoid	04	05	ER	03	04	ER
Fever	08	07	ER	01	03	ER
Colic	02	07	ER	01*	08	ER
Itching	07	03	ER	06	03	ER
Hitting	05*	00	RR	06	01	ER
Pain in the body	01	00	NR	07	02	ER
Stomachache	00	00	NR	07	04	ER

Letters indicate if the Body System is Extremely Redundant (ER), Relatively Redundant (RR) or Non-Redundant (NR) in the communities of Carão and Letreiro, Northeast Brazil (* $p < 0.05$; ** $p < 0.01$).

of medicinal plants associated, in addition to Non-defined Conditions and Disorders.

Discussion

The local medical systems of two communities located in the same biome.

Considering the general values of the plants mentioned in the two communities, it is expected that among all the communities inserted in the same biome, a similar floristic diversity in their medicinal plant collections is shared; however, a large number of species was found – even higher than that observed in surveys previously conducted in other rural communities of the *caatinga*. In this study, 206 plants were mentioned in Carão and 135 in Letreiro. Among several surveys conducted on medicinal plants in the *caatinga*, Almeida et al. (2010) evaluated tree communities and found approximately 81, 70 and 63 species in each tree community. Other studies recorded the presence of 187 species (Almeida et al., 2006), 119 species (Cartaxo et al., 2010), 106 species (Albuquerque and Oliveira, 2007), 107 and 86 species (Albuquerque et al., 2008) and 31 species (Barbosa, 2011). However, one must consider that in all these studies, there were fewer people interviewed than in the communities of this study, what can explain this difference and draw attention to the importance of sample size in ethnobotanical studies.

Although the two medical systems are composed of a large number of referred species, there are still many species seldom mentioned. This set of plants can indicate the existence of species with exclusive uses for certain therapeutic indications, species that are not well known in the community or species facing processes of removal from or insertion into the local medical system. In the first case, some authors suggest that there are certain chemical compounds that are unique to some plants, particularly exotic species, species that are usually used to treat specific diseases (Alencar et al., 2010; Almeida et al., 2010). The second case occurs when new plants are being tested but knowledge of those plants has not yet been validated and extended in the community. In the third case, the community may be losing knowledge of some plants due to replacement by other resources or because of the rarity of the disease they treat (Ferreira Júnior et al., 2011).

The similarity found between the communities can be related to two factors shared by them: the environment and the culture. The communities studied share the same ecosystem and were only divided by a mountain range, which is the main medicinal resource for both communities. It has been shown that people who share the same environment share the same medicinal plants, even when they come from different ethnic groups (Coe and Anderson, 1999). The two communities also share culture, as the community of Carão is formed by inhabitants of Letreiro who migrated to the other side of the mountain range after marrying and inheriting lands from the patriarchs of the communities, possibly bringing with them knowledge about medicinal plants.

However, the community of Carão held a greater knowledge of the medicinal flora than Letreiro. Letreiro has fewer informants than Carão, which may influence the outcome.

But this result may also be related to the fact that, in Letreiro, during the last 30 years, the incursions to the native vegetation by the population have progressively decreased due to the difficulty of access to the main current native resource, the mountain range, and because vegetation areas of the hillside have been transformed into pasture fields for the maintenance of cattle rearing. According to Case et al. (2005), when evaluating populations of Manus Island, the distance of human populations from areas with native vegetation decreases knowledge of traditional botany.

In another point of view about this phenomenon, Vandebroek et al. (2004) holds that it is not the proximity of the native vegetation that interferes with the knowledge of medicinal plants; however, social factors such as the proximity to urban centers have a negative influence on knowledge. According to these authors, a greater proximity to urban centers brings human populations a greater exposure to western medicine, which strongly competes with plant resource use causing a decrease in its use. In this study, the community of Letreiro has greater access to the urban center of the municipality, with inhabitants who work or even reside temporarily in the urban areas, utilizing the residence of the community only on the weekends.

Considering only the group of plants exclusive to each community, it is clear that most are exotic, which confirms the importance of the environment for information sharing. Exotic species may have been introduced later in the two communities. Albuquerque et al. (2008) compared two different ethnic groups in the same environment and found that the similarity between the groups was even higher for the native plant species. The native species found in both communities are identified as the most important local species in many communities of the *caatinga* (Almeida et al., 2005; Albuquerque, 2006). Albuquerque (2006) confirmed that the traditional populations that inhabit the *caatinga* hold a preference for native species, especially arboreal ones, as a medicinal resource, rather than exotic and herbaceous plants.

Do exotic plants act in distinct/exclusive uses?

In this study, native species showed a distinctive participation. It is known that the *caatinga* species are renowned for their diversity of uses and are characterized as extremely versatile, which, in part, can explain the high number of mentions in the literature (Albuquerque, 2010). One of the possible reasons for this selection would be the therapeutic safety (Albuquerque, 2010), as plants of the *caatinga* are present in the dry periods and their medicinal resources are always available (husks, roots, among other perennial resources). In addition, observing the sample of plants from the communities studied, it is clear that native plants are more versatile (act upon more therapeutic indications and body systems) and predominant in more indications than exotic plants.

No body system with predominance of exotic plants was found, except for the body system Non-Defined Conditions and Pains, with 63% of exotic plants referred in Carão. Although there is a predominance of native species in the medical systems, exotic plants at both communities dominated some therapeutic indications and some are referred exclusively to

exotic plants. In these cases, they can act an important role in the medical systems, for these plants may be widening the spectrum of possibilities of treatment of the therapeutic indications on which native plants seem not to act or on which native species used to act and may now be unavailable (Albuquerque, 2006).

Considering the importance of observing the participation of plants in local medical systems according to their geographical distribution, one can find studies that focus on relationships between the biogeographically origins and the medicinal applications of plants in local medical systems. They are found throughout the world, and some arguments are used to explain such patterns. The most frequently documented arguments are: 1) acculturations (Amorozo, 2002), affirming that the presence of exotic plants in local medical systems denotes alteration in the culture and knowledge of the community in favor of a stronger or more dominant one – for example, the western culture over Indian tribes and their costumes and traditions; erosion of the knowledge (Srithi et al., 2009), alleging that the abandon of native resources due to disuse causes deletions in the collection of plants, depleting it, and thus creating a strong presence of exotic species; 2) diversification (Albuquerque, 2006), claiming that the presence of exotic plants is intended to act in gaps not filled by native plants and even utilitarian redundancy (Albuquerque and Oliveira, 2007), which this study attempts to address.

Are the therapeutic indications of the medical system of the communities redundant?

The two communities possess a large number of *non-redundant* therapeutic indications, which can threaten the stability of the local medical system, as some of the therapeutic indications have up to four plants mentioned for treatment. Among previous studies in the *caatinga*, the one conducted by Albuquerque and Oliveira (2007) from the perspective of utilitarian redundancy, generated results similar to those of the present study, demonstrating a possible pattern of low redundancy of species.

Characteristics that further support the fragility of maintenance of the medical systems have been pointed in another study (Ferreira Júnior et al., 2011) such as the fact that many of the *non-redundant* therapeutic indications are also indications seldom mentioned by the community, often with only two or three mentions. Thus, the medical system of the community may be vulnerable to processes of loss of therapeutic functions due to the reduced number of species acting for certain therapeutic indications. These events, which induce fragility, can be associated from a social viewpoint with the loss of a community member who masters this knowledge or even the oblivion (in view of the disuse) of how to treat these therapeutic indications. According to the Utilitarian Redundancy Model, higher numbers of redundant therapeutic functions in a medical system will correlate with higher degrees of system flexibility and, consequently, of system resilience.

Whereas, from an ecological point of view also considered by the Utilitarian Redundancy Model, alterations in the environment such as the local extinction of a plant associated

with a therapeutic indication (mainly those *non-redundant* ones), or even cases of inaccessibility of collection, can also threaten the maintenance of a medical system. In these cases, exotic species (usually cultivated) play an essential role in the conservation of medical systems. The strong presence of exotic plants likely contributes to the maintenance of groups of therapeutic indications, easing the pressures on native species; among all the indications recognized, few were significantly dominated by native plants. However, it is worth stressing that characteristic such as spatial and time availability can influence these data and that these characteristics were not assessed in the therapeutic indications of these communities.

Regarding the utilitarian redundancy of the species associated to the Medical Systems of the two communities, we can observe that the body systems that receive the benefits of the plant collection of the community of Carão possess a higher number of associated species, thus ensuring the resilience and preservation of the Medical System of the community, once there are more *extremely redundant* body systems. Meanwhile, in the community of Letreiro, in some important Body Systems, the range of possibilities associated is lower, so the possible loss of species associated to them increases the risk of maintenance of the Medical System due to the exclusion of body systems serviced.

A significant number of plants utilized to treat health problems are linked to the following body systems: Disorders of the Respiratory, Digestive and Circulatory Systems. It is believed that these systems are important in the communities examined in this study, since they possess many associated plants as treatments. Especially for respiratory and digestive systems, the high redundancy found may result from the large number of bioactive compounds that can treat these body systems, as stated by Medeiros and Albuquerque (2013).

However, there are other Body Systems with a greater redundancy of plants, as Infectious and Parasitic Diseases (89 spp), Disorders of the Genitourinary System (61 spp) and Lesions, poisoning and other consequences of external causes (58 spp.). These systems can be the most important ones, and in addition to having more related species, they compose the group of therapeutic indications most related to the sanitation conditions of the community, such as the lack of basic sewage, septic tanks and water treatment, as well as the destination of feces and sanitary landfills. In addition, systems that reflect the precariousness of the medical system's emergency care, such as lesions and domestic or work accidents are also important.

With regard to the richness of plants in the body systems of the communities of Carão and Letreiro, these findings have certain similarities to other rural communities. Findings of Almeida et al. (2006) and Cartaxo et al. (2010) support the results of this study. The authors found the same body systems presented in this study, among the main ones, i.e., with greater numbers of associated plants, in a rural community in the interior of Ceará and a rural community in the interior of Pernambuco, respectively. In a region close to the states of Pernambuco, Bahia, Sergipe and Alagoas, Almeida et al. (2006) observed, in a rural community in the *caatinga*, similar ordinations of these body systems according to the number of plants mentioned; in spite of the subtle differences in their ordination, there was also a *non-redundant* system in common:

Disorders of the Sensory System. These similarities concerning the body systems with higher redundancy can be associated with the frequency of the injuries related to those body systems in semi-arid regions such as the *caatinga*. An analysis that considers the frequency of diseases could elucidate the richness of plants useful for certain Body Systems.

In addition to these findings, which are in accordance with the utilitarian redundancy, therapeutic indications with exclusivity of exotic plants were found, especially when the *non-redundant* group is included; therefore, exotic plants have their role in a local medical system, which can be explained, possibly, by the Hypothesis of Diversification (Albuquerque, 2006), for these plants may be widening the spectrum of possibilities of treatment of the therapeutic indications on which native plants seem not to act or on which native species used to act and may now be unavailable.

Authors contributions

NLA main author, involved in the study design, conducted the interviews, field and laboratory work, literature review and general data collection, systematization and analysis, wrote the first draft this paper. UPA contributed to designing and following progress of the research and fieldwork, data analyses, and wrote the final version this paper. FRS contributed to data analyses and helps to write the final version of this paper. All authors read and approved the final manuscript.

Conflicts of interest

The authors declare no conflicts of interest.

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