Introduction to Medicinal and Aromatic Plants in Brazil

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Abstract MAPs have a long history in traditional medicine, and are still looked upon by certain Brazilian ethnic groups (e.g. Tupis and Guaranis), as "divine sources of healing". In relation to extreme diversity and long, as well as rich traditions, the public knowledge on this special group of economic plants, is still relatively scarce, although much has been done to explore and utilize MAPs. Two of the world's diversity hotspots (including the hottest of hotspots) can be found in the territory of Brazil (Mata Atlantica and Cerrado). These territories have been intensively studied to reveal the levels of habitat loss, rate of species extinction and to save their exceptional levels of plant endemism. In the past, there had been no reliable census of the plant species of Brazil flora. The first nationwide assessment of the naturalized flora of Brazil has revealed that as a result of human presence and actions, non-native species are widespread in all Brazilian biomes and regions. So called Mega-Developments taking place in certain domains of Brazil (e.g. the Amazon) already have major implications on the Global Climate Change. Traditional medicines, including herbal medicines, will continue to be used in Brazil to some capacity, similarly to several countries of the developing world, where 70–95% of the population rely on these traditional medicines for primary care. Brazil is one of the few countries in the world that provides public support for the payment for herbal medicines approved only on the basis of long-standing and widespread prior use. Brazil has a list of 12 herbal medicines funded by the government. The Ministry of Health of Brazil has presented a National Policy on Integrative and Complementary

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Practices (PNPIC), in 2008, in order to coordinate a Unified Health System (SUS) in Brazil and to establish policies to ensure integrality of health care. This policy is expected to contribute to the farther exploration, safeguarding and sustainable/modern utilization of medicinal plant resources in Brazil.

Keywords Medicinal and aromatic plants · Flora of Brazil · Biomes · Biodiversity hot-spots · Endemic species · Conservation · Folk medicine · Integrative medicine

1 Introduction

The Federative Republic of Brazil is the largest country on the South American continent and this regards both its population size and geographic dimensions. Brazil is not only a large country but due to its most diverse topographic conditions and habitats it has also a diverse flora and fauna.

It is not frequently mentioned but according to literature resources, Brazil was given its name after the plant pau-brasil (*Caesalpinia echinata* L.), a member of the Fabaceae – Caesalpininioidae family which was used in the past as a source of a valuable dye-stuff known as "brasiline" (Goncalves De Lima et al. 1961 as cited by Mitra et al. 2007). Different parts of pau-brasil are commonly used in Brazil, as adstringent, healing agents, oral analgesics and tonics, with the bark of the trunk also being used to treat diarrhea and dysentery and to strengthen the gums (da Silva Gomes et al. 2014).

According to a still existing ancient tradition plants are looked upon as divine sources of healing, especially among the different ethnic groups like the Tupis in the north and the Guaranis in the south that inhabit the Amazon rain forests (Mitra et al. 2007). There were even times, when Bertoni, a nineteenth century botanist held strong convictions that the wild Guaranis had a better knowledge of plants compared to that of the Europeans of the sixteenth century (Marini-Bettòlo 1988 1977).

Public knowledge on the extreme and unique plant diversity, as well as rich traditions of their use by the native and later settler populations in Brazil is relatively scarce in relation to their values. The present chapter is to serve as a modest introduction to this wonderful world of natural wealth, with a special focus on medicinal plants. Due to the page limitations, this introduction cannot be complete, but can only aim at offering an insight into the recent information on the honorable amount of existing and ever enlarging knowledge.

2 Biodiversity Hotspots in Brazil

In a simplest way the expression biodiversity "hotspot" denotes a biogeographic region that is threatened by destruction. The concept takes its origin from the British ecologist Norman Myers, who in 1988, published a paper in which he identified 10 tropical forest so called "hotspots" (Myers 1988) with the aim to throw light on the

mass extinction that is overtaking Earth's species.. These regions were characterized both by exceptional levels of plant endemism and serious levels of habitat loss.

In the years to come, the number of hotspots was expanded to 18 (Myers 1990). Conservation International, adopting Myers' hotspots as its institutional blueprint, in 1996, made the decision to undertake a reassessment of the hotspots concept. Three years later an extensive global review was undertaken, which introduced quantitative thresholds for the designation of biodiversity hotspots and resulted in the designation of 25 hotspots. Since then – with the recognition of the North American Coastal Plain, in 2016, the number of Earth's hotspots has arisen to 36.

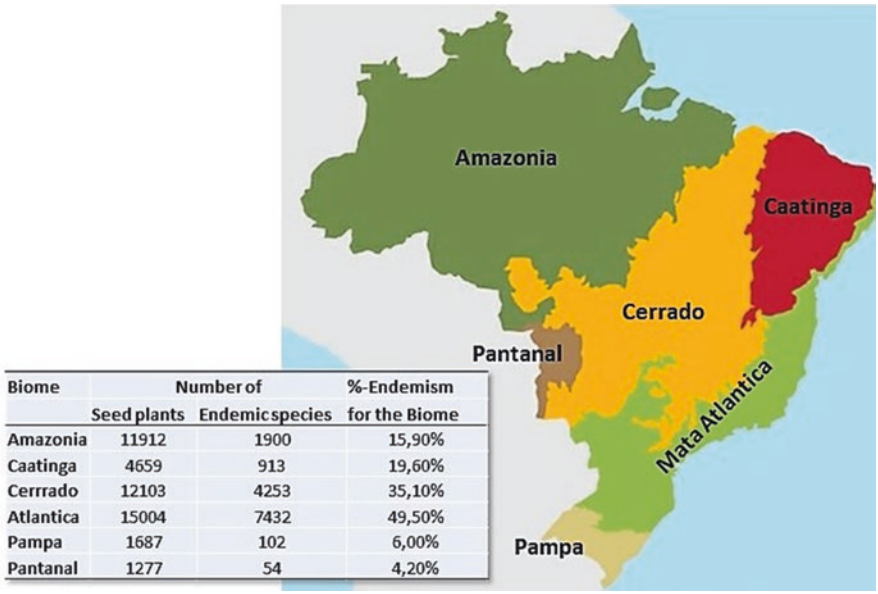
Brazil is the home to the world's richest flora (40,989 species; 18,932 endemic) and includes two of the hottest hotspots (Mittermeier et al. 1997, 2004): Mata Atlântica (19,355 species) and Cerrado (12,669 species) (Forzza et al. 2012a, b). According to Begossi et al. (2000) hotspots in Brazil include a variety of ecosystems with mangroves, with savannah or cerrado or with forests.

Published estimates of described diversity were frequently divergent because the country lacked an authoritative inventory of plant, algal, and fungal species. In 2012, Rafaela C. Forzza et al. (2012a, b) published the results of their analyses with a focus on species endemism and the degree of threat. As a major and perhaps unexpectedly new conclusion they stated that **Brazil has fewer described species of plants**, algae, and fungi but higher levels of endemism than were previously reported. These analyses were assisted by the contributions of more than 100 scientists in the countries concerned and around 800 references in the professional literature. An area to qualify as a hotspot had to contain at least 0.5% or 1500 of the world's 300,000 plant species as endemics. It has been also concluded that 15 of the world's 25 hotspots contain at least 2500 endemic plant species, and 10 of them at least 5000.

3 Diversity of Plants in Brazil

Estimates of described diversity of Brazil are frequently widely divergent because of the lack of an authoritative inventory of plant, algal, and fungal species (Forzza et al. 2012a, b). According to Vieira (1999) with nearly 55,000 native species distributed over six major biomes, Brazil can be regarded as the country with the greatest biodiversity on our planet. The six major biomes as illustrated in (Fig. 1) are the following: Amazon (30,000); Cerrado (10,000); Caatinga (4000); Atlantic rainforest (10,000), Pantanal (10,000) and the subtropical forest (3000).

The Brazilian Amazon Forest (tropical rainforest) is a rather fragile ecosystem that covers nearly 40% of all national territory, with about 20% legally preserved. Its productivity and stability depend on the recycling of nutrients, and its efficiency is directly related to the biological diversity and the structural complexity of the forest Anon (1995) cited in (Vieira 1999). Giacometti (1990) estimated that there are about 800 plant species of economic or social value in the Amazon. Of these,



Biome	Number of		%-Endemism
	Seed plants	Endemic species	for the Biome
Amazonia	11912	1900	15,90%
Caatinga	4659	913	19,60%
Cerrrado	12103	4253	35,10%
Atlantica	15004	7432	49,50%
Pampa	1687	102	6,00%
Pantanal	1277	54	4,20%

Fig. 1 Major biomes of Brazil. (After: R. C. Forzza et al. 2012a, b)

190 are fruit-bearing plants, 20 are oil plants, and there are hundreds of medicinal plants (van den Berg et al. 1988).

In a comprehensive 9-year market study on the impact of forest degradation on medicinal plant use and health care in Eastern Amazonia, Shanley and Luz (2003) stated that over the last three decades, forest degradation in the Brazilian Amazon has diminished the availability of some widely used medicinal plant species. One-third of the 300 species logged in eastern Amazonia are also valued for food, medicines, and gums and resins. Forests represent an important habitat for medicinal plants used in eastern Amazonia: 9 of the 12 top-selling medicinal plants are native species, and 8 are forest based. Five of the top-selling species have begun to be harvested for timber, decreasing their availability for medicinal purposes. Remarkably, several of these medicinal plants have no botanical substitutes, and frequently there are not pharmaceuticals that could substitute them in treating the diseases they are used. This verifies the following statement by Shanley and Luz (2003): “When rural communities sell timber, they often lose valuable fruit, medicinal, and game-attracting species”.

In 2000, Laurance (2000) described mega-development trends in the Amazon and its implications for Global Climate Change. The study described four global-change phenomena that are having major impacts on Amazonian forests: (1) accelerating deforestation and logging that have increased from 1.1 million ha $year^{-1}$ in the early 1990s, to nearly 1.5 million ha $year^{-1}$ from 1992 to 1994, and to more than 1.9 million ha $year^{-1}$ from 1995 to 1998. (2) patterns of forest loss and fragmentation are rapidly changing: The construction of major new highways is providing direct conduits into the heart of the Amazon and may largely bisect the forests of the

Amazon Basin. (3) climatic variability is interacting with human land uses, creating additional impacts on forest ecosystems. As an example, in 1997/1998 the El Niño drought led to a major increase in forest burning, with vast wildfires out of control (mainly in the northern Amazonian state of Roraima). (4) rapidly diminishing, intact Amazonian forests, which in turn, are a globally significant carbon sink. As a result of long term carbon-flux, as well as atmospheric CO_2 and isotope investigations it was established that not only is the destruction of these forests a major source of greenhouse gases, but it is reducing their intrinsic capacity to help buffer the rapid anthropogenic rise in CO_2 (Laurance 2000).

The "Cerrado" is the second largest ecological dominion of Brazil, where a continuous herbaceous stratum is joined to an arboreal stratum, with variable density of woody species. The cerrados cover a surface area of approximately 25% of Brazilian territory and around 220 species from cerrado are reported as used in the traditional medicine (Vieira 1999).

The "Caatinga" extends over areas of the states of the Brazilian Northeast and is characterized by a xerophitic vegetation that is typical of semi-arid climates. The soils that are fertile, due to the nature of their original materials and the low level of rainfall, experience minor runoff Anon (1995) cited by Vieira (1999). This northeastern region of Brazil comprises about one third of the country's territory. It is a semi-arid region with a flora rich in aromatic, toxic and medicinal plants. Various important medicinal plants (e.g. *Lippia* spp. and *Vanillosmopsis arborea*) have their centers of genetic diversity in this region, and the use of local folk medicines is common. Several important aromatic species are reported for this region (Craveiro et al. 2007).

The Atlantic Forest extends over nearly the entire Brazilian coastline. It is one of the most endangered ecosystems of the world, with less than 10% of the original vegetation remaining. The climate, here, is predominantly hot and tropical with a precipitation ranging between 1000 and 1750 mm. The landscape is composed of hills and coastal plains, accompanied by a mountain range (Vieira 1999). Several important medicinal species are found in this region, such as *Mikania glomerata, Bauhinia forficata, Psychotria ipecacuanha*, and *Ocotea odorifera*.

The Meridional Forests and Grasslands include the mesophytic tropical forests, the subtropical forests, and the meridional grasslands of the states of southern Brazil. The climate of this area is tropical and subtropical, humid, with some zones of temperate climate. Due to its naturally fertile soils and mild climate, this area had seen a rapid colonization mainly by European and, more recently, by Japanese immigrants, during the nineteenth century (Vieira 1999). As a consequence, several medicinal plants have been introduced, or naturalized, e.g.: chamomile (*Matricaria recutita*), calendula (*Calendula officinalis*), lemon balm (*Melissa officinalis*), rosemary (*Rosmarinus officinalis*), basil (*Ocimum basilicum*).

The Pantanal is a geologically lowered area filled with sediments which have settled in the basin of the Paraguay River. Pantanal flora is formed by species from both Cerrado and Amazon vegetation. More than 200 species useful for human and animal consumption as well as for industrial use have been recorded in this region (Vieira 1999).

4 The Flora of Brazil: Native vs. New Naturalized Species

The Brazilian flora, like many other floras in the world, are composed of both native and naturalized (introduced) species.

The need for a census of the Brazilian flora with sufficient scientific credibility to guide conservation planning has existed for a long time. According to Forzza et al. (2012a, b) the last complete inventory of Brazilian plants was the detailed and comprehensive Flora brasiliensis, published between 1833 and 1906, in which 19,958 species of plant, algae, and fungi were recorded for Brazil. Although, in the century to follow, virtually thousands of new species and their distributions were recorded, it was not followed by the sensus or comprehensive survey of the Brazilian flora for a long-long time. Existing knowledge was based mostly on estimates. According to this the number of described species of plants and fungi range between 60,700 and 70,210 (Lewinsohn and Prado 2005), while the most recent figures indicate 56,108 vascular species, with 12,400 (22%) species being endemic (Giam et al. 2010).

The largest plant families in Brazil, in terms of the number of species, are: Fabaceae (3200 spp. with 2144 endemics), Asteraceae (1900 spp.), Euphorbiaceae (1100), Myrtaceae (1038) and Rubiaceae (1000).

5 Naturalized Species in the Brazilian Flora

A recent study by Zenni (2015) has revealed that regarding the number of naturalized species, it was the Atlantic Forest had the largest number. In relation to the biome's total richness, it was the Pampa that had the highest proportion of naturalized species. The extent of naturalization expressed by the number of naturalized species seems to have been affected both by human population size and the proportion of remaining natural vegetation. Forty-six species were naturalized in five out of the six biomes and there were no records of species having naturalized in all six biomes. Remarkably, the Family Poaceae had the highest numbers of naturalized species in all biomes: nearly half of the recorded species belonged to this family, followed by the Asteraceae and Fabaceae. In fact, these species of these three Families were considered as top three families, in terms of the number of naturalized species in five out of the six biomes of Brazil.

In this context, it should be mentioned that the need to understand the patterns and drivers of species naturalizations and invasions has been expressed by many. Comprehensive reviews by Simberloff et al. (2013) and Zenni (2015) discuss the impacts of biological invasions that can be regarded as a pervasive component of global change. These studies have generated a remarkable understanding of the

mechanisms and consequences of the spread of introduced populations and are useful in preventing and reducing the negative impacts caused by biological invasions.

Recognizing that human-mediated species introductions are important elements of the Anthropocene and that non-native species can form invasive populations that affect biodiversity, ecosystem services, or farming Zenni (2015) analyzed data on 32,634 identified vascular species in the Brazilian List of seed plants of which 525 were naturalized, non-native species. From this study the following important conclusions are worth highlighting: (1) the Atlantic Forest had the largest number of naturalized species, whereas the Pampa had the highest proportion of naturalized species in relation to the biome's total richness; (2) the number of naturalized species was affected both by human population size and proportion of remaining natural vegetation; (3) the plant Family Poaceae had the highest numbers of naturalized species in all biomes, and, together with Asteraceae and Fabaceae, forms the top three families in number of naturalized species in five of the biomes studied; (4) there were no records of species that have naturalized in all six biomes; (5) half of the 46 naturalized species, in five out of six biomes, belong to the Family Poaceae.

6 REFLORA Programme

The study of the Brazilian Flora, which is generally recognized as the richest in the world (Forzza et al. 2012a, b) has a long history. During the eighteenth and nineteenth centuries, European naturalists, who travelled to or resided in Brazil, and also a few Brazilian botanists, collected plant specimens and sent them to herbaria in Europe. Their main aim was to study and/or identify the plants found on that distant continent and explore their potential uses. Many of these plant collections served as the basis for the description of species or genera that were new to science (and these plants have become nomenclatural types), or simply formed part of the large collection of samples that were used to describe the over 22 thousand species of the Flora brasiliensis (Martius et al. 1840–1906).

Recognizing their scientific value, in 2010/2011, the Brazilian Government established the REFLORA (Brazilian Plants: Historic Rescue and Virtual Herbarium for Knowledge and Conservation of the Brazilian Flora) Program with the objective to rescue and make available images and information concerning Brazilian plants deposited mainly in overseas herbaria through an on-line facility, the REFLORA Virtual Herbarium.

To-date, the Rio de Janeiro Botanical Garden (JBRJ) hosts the physical structure of the Reflora Virtual Herbarium. It is responsible for receiving the repatriated images and transcribing the data associated with the samples. Thus, images and data derived from the repatriation process, together with images and data from the herbarium of the Jardin Botânico do Rio de Janeiro are made available to the scientific community and the general public (Anon n.d.).

Importantly, in addition to European and American herbaria, Brazilian herbaria have also begun the publication of their images and data in the REFLORA Virtual Herbarium, in 2014. The so called "Brazilian List", was concluded, in 2015 with the publication of five papers and their respective databases to open the way for a brand new system, the Brazilian Flora 2020 project, in 2016. The Brazilian Flora 2020 project is part of the Reflora program with some 700 scientists working in a network to prepare the monographs. The work platforms provided by the REFLORA Virtual Herbarium and the Brazilian Flora 2020 are meant to serve as fundamental tools that enable Brazil to meet the target No. 1 of the Global Strategy for Plant Conservation for 2020, i.e. the preparation of the Flora of Brazil online (Table 1).

The on-line plant identification tool of Reflora (Reflora Herbarium) and the English version of Flora do Brasil 2020 (Brazilian Flora 2020) are accessible at the following respective links: http://floradobrasil.jbrj.gov.br/reflora/herbarioVirtual/ConsultaPublicoHVUC/ConsultaPublicoHVUC.do, http://reflora.jbrj.gov.br/reflora/listaBrasil/PrincipalUC/PrincipalUC.do?lingua=en#CondicaoTaxonCP.

Table 1 Vegetation types and Phytogeographic domains, as recorded by Flora do Brazil 2020

Vegetation type	Phytogeographic domain
Antrhopic area	Amazon rainforest
Caatinga (stricto sensu)	Caatinga
Amazonian Campinarana	Central Brazilian savanna
High altitude grassland	Atlantic rainforest
Flooded field (Várzea)	Pampa
Grassland	Pantanal
Highland rocky field	Amazon rainforest
Carrasco vegetation	Caatinga
Cerrado (lato sensu)	Central Brazilian savanna
Riverine forest and/or gallery forest	Atlantic rainforest
Inundated forest (Igapo)	Pampa
Terra firme forest	Pantanal
Inundated forest (Várzea)	Amazon rainforest
Seasonal evergreen forest	Amazon rainforest
Seasonally semideciduous forest	Caatinga
Ombrophyllous forest (tropical rain forest)	Amazon rainforest
Mixed ombrophyllous forest	Central Brazilian savanna
Mangrove	Atlantic rainforest
Palm grove	Central Brazilian savanna
Coastal forest (Restinga)	Atlantic rainforest
Amazonian savanna	Amazon rainforest
Aquatic vegetation	Amazon rainforest
Rock outcrop vegetation	Central Brasilian savanna

7 Germplasm Conservation of MAPs in Brazil

The scientific literature seemingly does not abound in documents on the germplasm conservation of medicinal plants in Brazil. The 21 documents that our SCOPUS search has yielded for the period 1989–2017. seems to indicate that the first mention of this topic was in 2002, when Vieira (2002) illustrated some of the vast potentials of Brazilian flora and called attention to the enormous task to elaborate a program for genetic resource conservation of these species: a task that requires multi-institutional and multi-disciplinary collaboration. He also stated that plant collections will have an important role in the future, providing genetic material for chemical characterization, breeding of new crops, improving our understanding of secondary metabolism, and in preserving an important part of our cultural and national heritage pathways. The second publication by de Oliviera and Martins (2002) presented a methodology, on the example of ipecac (*Psychotria ipecacuanha*), by which the threat of genetic erosion to a wild plant species growing in a given geographic region can be assessed in a quantitative manner.

Remarkably, however, the conservation of medicinal plants in Brazil – independently of their germplasms – has been an increasingly frequent topic with 157 scientific publications (Fig. 2a), with two maxima (19 and 17 publications), in 2011. and 2017., respectively. As regards the sources of publications (Fig. 2b), the majority of papers were published in Brazilian scientific journals (in Revista Brasileira de Plantas Medicinals (23) and Acta Botanica Brasilica (9)).

An analysis of the frequency documents by subject areas reveals that the conservation of medicinal plants has been dealt with from various scientific approaches, quasi in the form of multi-institutional and multi-disciplinary collaboration, as foreseen by Vieira in 2002. The sciences involved and their share in the total number of 157 documents is as follows: Agricultural and Biological Sciences (42.4%), Medicine (27.8%), Pharmacology, Toxicology and Pharmaceutics (26.6%), Biochemistry, Genetics and Molecular Biology (24.1%), Environmental Science (15.8%), Social Sciences (11.4%), Multidisciplinary (2.5%), Veterinary (2.5%), Arts and Humanities (1.9%), Chemistry (1.9%), Other (7.6%).

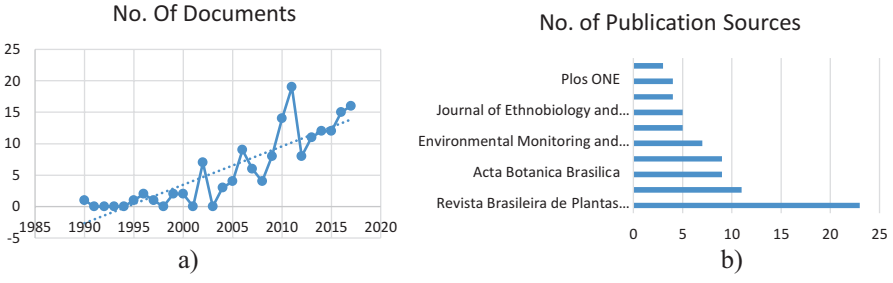


Fig. 2 Annual distribution (**a**) and Journal source (**b**) of documents on the conservation of medicinal plants, in Brazil (SCOPUS 1990–2017) n = 157

8 Effect of Chiang Mai Declaration

Since the early 1990s, roughly soon after the publication of the so called Chiang Mai Declaration, in 1988 (Akerele and Heywood 1991), serious efforts have been made to collect and preserve the genetic variability of medicinal plants also in Brazil. The National Center for Genetic Resources and Biotechnology (Cenargen), in collaboration with other research centers of the Brazilian Agricultural Research Corporation (Embrapa), and several universities, launched a program to establish germplasm banks for medicinal and aromatic species. An incomplete list of these, with a special focus on the endemic species of the Caatinga, is contained by Table 2.

In a historical perspective and also in order to properly appreciate the significance of above activities, we should reiterate that the need for the sustainable use of natural resources, including MAPs, was first duly recognized by the Chiang Mai Declaration (1988), when the international scientific community expressed alarm over the consequences in the loss of plant diversity (Máthé 2015). The Declaration highlighted the urgent need for international cooperation and coordination to establish programs for the conservation of medicinal plants with the ultimate aim to ensure that adequate quantities are available for future generations.

Remarkably, the subsequent decades were marked with an upsurge in activities, especially in the form of several declarations and sets of recommendations calling for the Conservation and Sustainable use of natural biodiversity, including medicinal plants.

As most of the crude drugs are sourced by wild-crafting (collection), the expectations vs. the "sustainable collection" of MAPs has gained on importance all over the world. This presumption seems to have been verified by the (slightly) increasing trend in the number of documents retrieved by the SCOPUS search (Fig. 3) that has yielded a total of 151 documents. Remarkably, this trend has become more expressed only as of the 2000s, i.e. following a lag-period of ca. 10 years. Focusing on Brazil, the SCOPUS search on sustainable collection of medicinal plants for the period 1995–2017. has yielded only a total of 14 documents (Fig. 3) from these 11 published in Brazil (11) and 1-1 in France, UK, US, respectively.

54.3% of the documents dealt with subjects belonging to agricultural and biological sciences, 30.5% sciences that can be ranked to Pharmacology, Toxicology and Pharmaceutics, whereas hardly less than one third of the documents (27.8%) with issues related to Medicine (Table 3). These data indicate that sustainable collection of medicinal plants is a multidisciplinary activity demanding the input of a broad range of disciplines.

In this regards we should refer to the relatively large number of surveys published either in the Brazilian journals of local significance or in the Portugese language that are less covered by SCOPUS. Thus, the upward trend seems to be even more apparent. also in the activities in Brazil (Assis et al. 2015).

Table 2 List of medicinal and aromatic species with high priority for germplasm collection and conservation in Brazil with a special focus on Caatinga

Species	Common name	Habit	Active substance/ pharmacological action	Region	Conservation form
Achyrocline satureioides L.	Macela	Herb	Hypotensive, spasmolytic	Cerrado	Field collection
Ageratum conyzoides L.	Mentrasto	Herb	Anti-inflammatory	Ruderal	Field collection
Amburana cearensis(Allemaõ) A.C. Sm	Cumaru	Tree	Sinusitis	Caatinga	In situ, field
Anadenanthera columbrina (Vell) Brenan	Sngico	Tree	Grippe	Atlantic Forest, Caatinga	Field collection
Aniba roseodora Ducke	Pau rosa	Tree	Linalool	Amazon forest	In situ
Apodanthera congestiflora Cogn	Cabeça-de-negro	climbing	Blood purifying,	Amazônia, Caatinga, Cerrado, Mata Atlântica, Pampa, Pantanal	Field
Astronium urundeuva (Fr. All.) Engl.	Aroeira	Tree	Anti-inflammatory, anti-ulceric	Cerrado	In situ, cold chamber
Baccharis trimera DC.	Carqueja	Herb	Hepatic disturbs	Ruderal	Field collection
Bauhinia forficata L.	Pata de Vaca	Tree	Diabetes	Atlantic forest	Cold chamber
Boerhavia diffusa L.	Pega-pinto	Herb	blood purifying, hepatitis and diarrhea	Atlantic forest	Cultivate field
Caryocar brasiliensis Camb.	Pequi	Tree	Anti-inflamatory	Cerrado	In situ
Chenopodium ambrosioides L.	Mastruz	Herb	fracture, gastritis, vermifuge	Atlantic Forest	Field
Copaifera langsdorffi Desf.	Copaiba	Tree	Oil, anti-inflamatory	Cerrado	In situ, cold chamber
Caesalpinia pyramidalis Tul.	Catingueira	Tree	Grippe	Caatinga	Field Caatinga
Cereus jamacaru	Mandacaru	Tree	Grippe, kidneys	Caatinga	In situ, field
Croton cajucara Benth.	Sacaca	Herb	Linalool	Amazon	Field collection
Croton zehntneri Pax et Hoff.	Cunha	Shrub	Anetol, eugenol	Caatinga	Field collection
Datura insignis B. Rodr.	Toe	Shrub	Escopolamina	Amazon forest	Cold chamber

(continued)

Table 2 (continued)

Species	Common name	Habit	Active substance/ pharmacological action	Region	Conservation form
Dimorphandra mollis Benth.	Faveiro	Tree	Rutin, anti-hemorragic	Cerrado	Cold chamber
Echinodorus macrophyllus(Kunth.) Mich	Chapeu de Couro Herb		Diuretic	Cerrado	Field collection, cold chamber
Erythrina verna Vell. Conc.	Mulungu	Tree	anxiolytics and anticonvulsants	Atlantic Forest	Field collection
Harrisia adscendens	Rabo-de-raposa	Shrub	Kidneys, prostate, toothache	Caatinga	In situ, field
Jatropha elliptica (Pohl) Baill.	Batat de Tiu Shrub		Jatrophone	Cerrado	In situ, field collection
Lippia spp.	Alecrim pimenta Shrub		Source of volatile oils, anti-microbial	Caatinga	Field collection
Luffa operculata (L.) Cogn	Cabacinha, buchinha	Climbing	Sinusitis	All Brasil	Field and plantations
Lychnophora ericoides Mart.*; L. salicifolia* Mart.	Arnica do Cerrado	Shrub	Volatile oils	Cerrado	Field collection, in situ
Mandevilla vellutina Mart.	Serra dos Órgãos	Shrub	Anti-inflamatory, bradykynin antagonist	Cerrado	In situ, field collection
Maytenus ilicifolia Mart. ex. Reiss; *M. aquifolium* Mart.	Espinheira Santa	Tree	Anti-ulceric	Meridional forest	Cold chamber, *in situ*
Melocactus zehntneri	Cabeça-de-frade, coroa-de-frade	Cactus 20 cm	Gripe, mulligrubs	Caatinga	In situ, field
Mikania glomerata Spreng.	Guaco	Herb	Bronchitis, coughs	Atlantic forest	Field collection
Mimosa tenuiflora (Willd) Poir	Jurema Preta	Tree	Anti inflammatory	Caatinga	Field collection
Ocotea odorifera (Vell.) Rohwer	Canela Sassafraz	Tree	Safrol, metileugenol	Atlantic forest	In situ
Operculina macrocarpa (L.) Farwel	Batata de Purga	Herb	Purgative	Caatinga	Cold chamber
Opuntia palmadora	Palmatoria do sertão	Shrub	Urethra problem	Caatinga	In situ, field
Piper hispidinervum DC.	Pimenta longa	Herb	Safrol	Amazon	Cold chamber, field collection

(continued)

Table 2 (continued)

Species	Common name	Habit	Active substance/ pharmacological action	Region	Conservation form
Pfaffia paniculata (Martius) Kuntze	Ginseng brasileiro	Herb	Antitumor compounds	Margins of Parana river	Cold chamber, field collection
Phyllanthus niruri L.	Quebra pedra	Herb	Hepatitis B, renal calculus	Ruderal	Cold chamber
Phyllanthus niruri L.	Quebra pedra	Herb	Kidney desease	Atlantic Field	Field collection
Pilosocereus gounellei F.A.C. Weber ex K. Schum.	Xique-xique	Shrub	Rheumatism, crowfoot	Caatinga	In situ, field
Pilocarpus microphyllus Stapf.	Jaborandi	Shrub	Pilocarpine	Amazon forest	Cold chamber, in situ
Psychotria ipecacuanha (Brot.) Stokes	Ipecac	Herb	Emetin, cefaline	Amazon and Atlantic forest	Cold chamber, in situ
Pterodon emarginatus Vogel	Sucupira	Tree	Analgesic, antinoceptive, cercaricide	Cerrado	In situ, cold chamber
Senna ocidentallis (L.) Link	Manjerioba, Fedegoso	Shrub	Lowering the blood pressure as well as the blood Cholesterol	All Brasil	Field
Solanum mauritianum Scopoli	Cuvitinga	Shrub	Solasodine	Ruderal, southeast and southern Brazil	Cold chamber
Stryphnodendron adstringens	Barbatimao	Tree	Tannin, anti-inflamatory	Cerrado	In situ, cold
(Mart.) Coville					chamber
Tabebuia avellanedae (Lor.) ex. Griseb.	Ipe roxo	Tree	Lapachol	Cerrado	In situ
Vanillosmopsis arborea(Aguiar) Ducke	Candeia	Shrub	Bisabolol	Caatinga	In situ, field Collection
Vitex gardneriana Schauer	Jaramataia	Tree	Vermicide, soothing and anti-inflammatory	Caatinga	Field Collection
Ximenia Americana L.	Ameixa da caatinga	Shrub	Anti-inflammatory	Caatinga	Field Bahia

After: Vieira (1999), Roque et al. (2010), and Andrade et al. (2006)

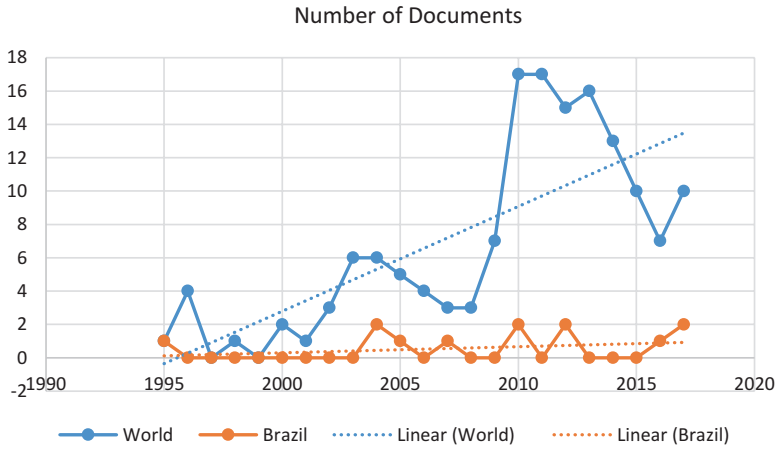


Fig. 3 Documents on the sustainable collection of MAPs in Brazil and the world (SCOPUS retrieved: 2018.02.24)

Table 3 Ten most frequently occurring type of documents by subject area in a SCOPUS search "sustainable collection of medicinal plants" (Retrieved: February 24, 2018)

No.	Subject area	Number of documents	
1.	Agricultural and Biological Sciences	82	54.3%
2.	Pharmacology, Toxicology and Pharmaceutics	46	30.5%
3.	Medicine	42	27.8%
4.	Social Sciences	30	19.9%
5.	Environmental Science	29	19.2%
6.	Biochemistry, Genetics and Molecular Biology	14	9.3%
7.	Engineering	6	4.0%
8.	Chemistry	3	2.0%
9.	Earth and Planetary Sciences	3	2.0%
10.	Energy	3	2.0%

9 Brazilian Medicinal Plants as Raw Materials for (Inter) National Trade

The world demand on medicinal plants has seen an exponential growth. There has been an increasing flow of medicinal plants from the southern hemisphere to developed countries, growing from 100 million dollars in 1979 to 35 billion dollars, in 2003. This increased interest in medicinal plants has put a dangerous pressure on the habitat of indigenous peoples (Caceres Guido et al. 2015).

Data on the international trade of medicinal and aromatic plants in Brazil are seemingly scarce. This fact is reflected by the SCOPUS search "medicinal plant

trade in Brazil" that has yielded 19 documents for the period 1999–2016. As a *quasi* contrast, the diversity of MAPs traded in the local markets of different areas of Brazil is quite common subject of studies (de Albuquerque et al. 2007; Lós et al. 2012; Roque et al. 2010) In one of the most recent studies Carvalho et al. (2018) published a critical survey in the Brazilian Health Regulatory Agency (ANVISA) database to verify HMPs (Herbal Medicine Product) licensed in Brazil in September 2016. Their data were compared with previously published similar surveys. The survey has established that there are 332 single, 332 single, and 27 combined Herbal Medicines (HM), totaling 359 HM licensed in Brazil. There are no Traditional Herbal Products (THPs) notified in the Brazilian Health Regulatory Agency's (ANVISA) system, yet. Remarkably, however, there are 214 HMs classified as non-prescription (OTC) products, while 145 are sold under prescription (one of them with prescription retention). There are 101 plant species licensed as active in HM in Brazil, 39 of which are native, adapted or cultivated species. The most frequently licensed plant species is *Mikania glomerata* Spreng., with 25 HM licenses.

According to the somewhat too critical conclusion of Carvalho et al. (2018), there are few licensed HMs in Brazil, and this number has been decreasing in recent years. They expected that their survey, together with the changes promoted in sanitary and environmental rules, will help to develop as well as regulate HMP chain in Brazil.

In Brazil, several exotic plants are also used in formal commercial consumption, partly due to the fact that they are authorized by laboratories in other countries. As established by Albuquerque et al. (2007) markets conserve their basic repertoire while act as open and dynamic systems that is enriched by adding new plants and their respective use-indications.

Endemic native plants are most commonly used in popular markets, in small shops or in street markets, called "raizeiros", where also medicinal, aromatic, and spices are sold. Wilma et al. (2012), in a study on "raizers", in Arapiraca, state of Alagoas (northeastern Brazil), identified 103 main commercialized species belonging to 47 families. The most represented families were: Fabaceae (21 species), Lamiaceae (6 species) and Asteraceae, Cucurbitaceae, (5 -5 spécies), Apiaceae and Euphorbiaceae (4 species). Most of the species (66%) was used in the form of tea prepared from leaves and seeds (24–24%). According to Goncalces De Lima et al. (1961) ca. 80% of the identified plants were native and the predominantly of arboreous habitus. This study also shed light on the local pattern of MAP production and marketing and underpinned the need of minimum quality standards and the implementation of public policies.

In a recent study Alves et al. (2016) analyzed the marketing of medicinal plants and products by the healers of free fair in the city of Guarabira state of Paraiba. In evaluating their results they also applied an *Index of Relative Importance* (IR). The ethnobotanical survey of plants sold by sales-men public market Guarabira-PB, it identified 85 plants "in natura" Commercialization of medicinal plants: ethnobotanical study in the province of Guarabira, Paraíba, northeastern Brazil. Three hundred

ninety-one sold dried, distributed in 44 families, totaling 246 citations of curative and preventive use of various diseases. Featured You are the plants used the bark, woody species such as Aroeira (*Myracrodruon urundeuva* Allemão) Barbatimão (*Stryphnodendron adstringens* (Mart) Coville.), purple Cashew (*Anacardium occidentale* L., Cumaru (*Amburana cearensis* (Allemão) AC Sm), Mulungu (*Erythrina verna*). Most represented botanical families – in terms of the number of species – were: Fabaceae (23%), Lamiaceae (19%), etc. The most frequently mentioned species were: chamomile (*Matricaria chamomilla* L.), Bilberry (*Plectranthus barbatus* Andrews), Rosemary (*Rosmarinus officinalis*).

Oliveira et al. (2013) – in a similar study – established that it was not the cultivation of medicinal plants but rather the purchase of their products that was characteristic of the markets of the city of Juazeiro do Norte and Fortaleza (Ceara). Medicinal plants marketed most, were: aroeira (*Myracrodruon urundeuva* Fr. All., Anacardiaceae), juazeiro (*Ziziphus joazeiro* Mart., Rhamnaceae and jatobá (*Hymenaea coubaril* L., Fabaceae).

10 Cultivation of Medicinal Plants in Brazil: Introduction and Domestication

In view of the complex and manifold possible implications (e.g.: biodiversity conservation, management and quality assurance), as well as sustainability issues, to date, MAP domestication and introduction into cultivation are increasing considered as methods that could secure the reliable raw material supplies (Máthé 2011). In the period 1989–2017. a total of 60 documents were published on “plant domestication in Brazil”. These publications deal mostly with fruit, vegetable and ornamental species. As a contrast, the search “on medicinal plant domestication in Brazil” has yielded only 4 documents and a slightly altered search phrase (i.e. “medicinal plant introduction in Brazil”) yielded 33 documents with an upward trend, to reach a maximum of 8 publications (in 2017.), during the last 10 years. Despite the encouraging trends it can be stated that in view of the vast MAP-diversity and -genetic potential of Brazil, these figures should denote only the beginnings of the huge tasks and opportunities ahead.

As the final aim of both introduction and domestication is to obtain a cultivated crop, we carried out a farther SCOPUS search on “medicinal plant production in Brazil”. For the period 1982–2018., the search phrase has yielded 271 documents according to the following major groups of disciplines: 38.6% agriculture and biological sciences, 48.7% pharmacology, 32.1% medicine, 14.4% biochemistry, Veterinary implications: 2.6% (Fig. 4). These data verify the complex multi-disciplinary character of MAP domestication/introduction.

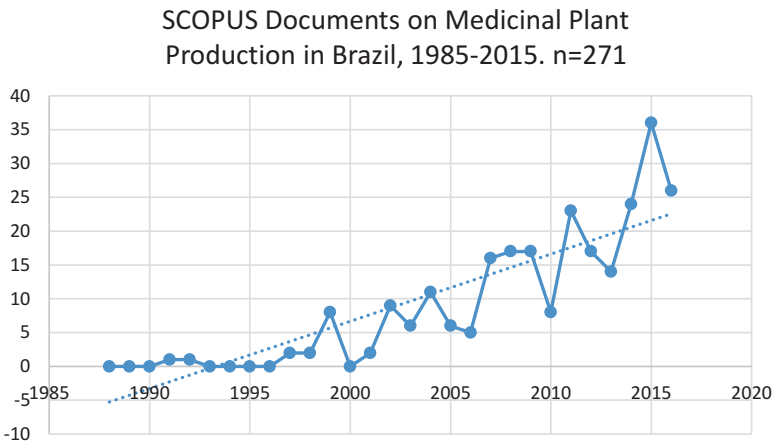


Fig. 4 SCOPUS documents on medicinal plant production in Brazil, 1985–2015

11 Medicinal Plants in the Brazilian Folk Medicine

Traditional medicines, including herbal medicines, have been, and continue to be, used in every country around the world in some capacity. In much of the developing world, 70–95% of the population rely on these traditional medicines for primary care. Developing countries, especially those in Asia, Africa, Latin America and the Middle East, use traditional medicine, including traditional and herbal medicines, for the management of health and as primary health care to address their health-care needs and concerns.

The use of Medicinal plants in folk (traditional) medicine has also long traditions in Brazil, where there is a still existing ancient tradition according to which plants are looked upon as divine sources of healing. According to Caceres Guido et al. (2015), it was marginalized for a long time. Due to the advancements in ethnobotanical and ethnomedical research, this situation has started to change at the end of the twentieth century. As such, especially, thanks to the important new contributions on traditional medicine, it is thus slowly being integrated into the clinical field.

Numerous interesting etnopharmacological studies have been published on various aspects of MAP usage. In 1994 (Elisabetsky and Shanley 1994) published a review of the ethnopharmacological and ethnobotanical studies that have been conducted in the Brazilian Amazon over the past 20 years. They discuss the role that ethnopharmacology can have in the discovery and development of new drugs from the Brazilian Amazon, a region hosting such enormous cultural and biological diversity.

A recent study by Mendes (2011) deals with species used as tonic, fortifier, aphrodisiac, anti-stress, among other uses that are similar to the indications of an adaptogen. Mendes provides a comparison of the main Brazilian plants used for such conditions, as follows: guarana (*Paullinia cupana* Kunth, family Sapindaceae),

muirapuama (*Ptychopetalum olacoides* Benth., Olacaceae), catuaba (*Anemopaegma arvense* (Vell.) Stellfeld & J.F. Souza, Bignoniaceae, and *Trichilia catigua* A. Juss., Meliaceae), nó-decachorro (*Heteropterys aphrodisiaca* O. Mach, Malpighiaceae), damiana (*Turnera diffusa* Willd. ex Schult., Turneraceae) and pfaffia or Brazilian ginseng (*Pfaffia* sp., Amaranthaceae).

A similar ethnobotanical study was carried out into the antimalarial plants in the middle region of the Negro River, Amazonas by Tomchinsky et al. (2017) and as a result they state that the in the population of Barcelos there exists an extensive knowledge on the use of a diverse array of antimalarial plants, and may contribute to the development of novel antimalarial compounds.

According to Lopes et al. (2014a) a search in the database of the Brazilian Health Surveillance Agency (ANVISA) revealed that 15 species of herbal medicines are approved for treatment of acute cough from a URTI. Of these, Public Health System (SUS) funding is available for two. In view of the fact that there are no systematic reviews available that address the benefits and harms of the herbal medication approved by ANVISA for URTI, they implemented "the first" systematic review to assess Brazilian medicinal plants approved by the Brazilian Health Surveillance Agency (ANVISA) to treat upper respiratory tract and bronchial illness associated with cough and sputum. It is expected that the results of this systematic review will help clinicians in making decisions in clinical practice and also help patients with cough and sputum seeking **effective and safe treatment** options.

Antonio et al. (2014) analyzed 53 original studies on actions, programs, acceptance and use of phytotherapy and medicinal plants in the Brazilian Unified Health System. They state that over the past 25 years, there was a small increase in scientific production on actions/programs developed in primary care. Including phytotherapy in primary care services encourages interaction between health care users and professionals. It also contributes to the socialization of scientific research and the development of a critical vision about the use of phytotherapy and plant medicine, not only on the part of professionals but also of the population.

Finally it should be mentioned that a SCOPUS search on "traditional medicine plants Brazil" for the period 1988–2017. has yielded 789 documents (Fig. 5), out of which the following main subject areas (10%+) were represented: Pharmacology, Toxicology and Pharmaceutics (70.6%), Medicine (30.4%), Biochemistry, Genetics and Molecular biology (17.0%), Agricultural and Biological Sciences (12.8%), Chemistry (10.1%). This steady upward trend clearly underpins the increasing acceptance as well as popularity of the old still in the form of integrative medicine renewed science of healing with medicinal plants.

12 The Dawn of Use of Integrative Medicine

As in in high-income countries, there is increasing public interest in the use of therapies that lie outside the mainstream of traditional Western medical practice. Complementary and alternative medicine (CAM) has been growing rapidly over the

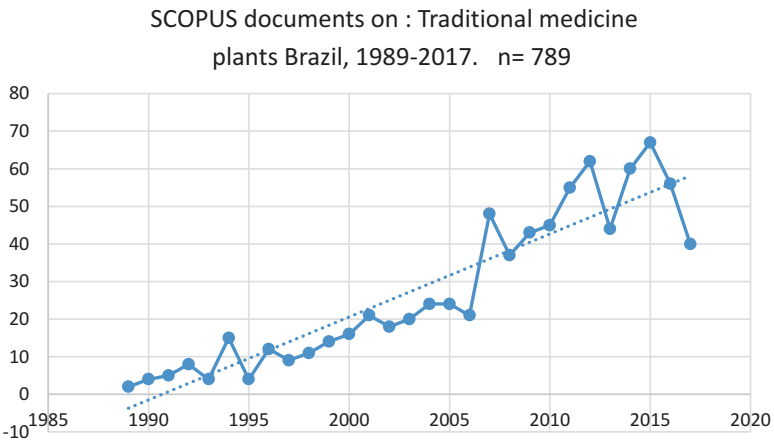


Fig. 5 SCOPUS documents on "traditional medicine plants Brazil" for the period 1989–2017

last decades (Lopes et al. 2014a). In the USA, an estimated 38% of adults and 12% of children are using some forms of CAM (Ekor 2014). Lopes et al. (2014b) cite that in Brazil, up to 25% of the total revenues of the pharmaceutical industry from sales of drugs, in the period from 1996 to 2014), came from preparations derived from plants. They also estimate that the government's decision to include herbal medicine in the list of publicly subsidized medicine in the Brazilian Health System (SUS) may have contributed to an increase in expenditures on herbal medicine in Brazil of 12% in 2012 over 2011, with a total of $1.147 billion.5.

In a recent review, entitled "The state of the integrative medicine in Latin America: The long road to include complementary, natural, and traditional practices in formal health systems" Caceres Guido et al. (2015) have estimated that more than 400 million people in Latin America use traditional/natural and/or complementary/alternative medicine (TN-CAM). The yearly expenditure on TN-CAM products of around 3 billion dollars illustrates that these practices have grown exponentially in this region as well. The quantity and quality of scientific studies on TN-CAM, although relatively scarce, has been steadily increasing. In Brazil, formal health systems - for different reasons - accept inclusion of TN-CAM. According to the authors, the immediate challenges are "how to improve multidisciplinary management, research, professional training, address legal/policy issues and a scientific approach to the extents and limitations of TN-CAM both in conventional health care and in the society as a whole."

13 Conclusions

Brazil, the largest country on the South American continent abounds in both diverse topographic conditions and diverse flora, including medicinal and aromatic plants.

MAPs have a long history in traditional medicine, and are still looked upon by certain ethnic groups (e.g. Tupis and Guaranis), as “divine sources of healing”.

In relation to extreme diversity and long, as well as rich traditions, the public knowledge on this special group of economic plants, is still relatively scarce, although much has been done to explore and utilize MAPs.

Two of the world’s diversity hotspots (the hottests of hotspots) can be found in the territory of Brazil. These are the Mata Atlantica (Atlantic Rainforest) and Cerrado (savannah). These territories have stood in the focus of especially intensive investigations with the aim to reveal the levels of habitat loss and the related rate of species extinction, ultimately to save their exceptional levels of plant endemism.

As for a long time in the past, there had been no reliable census of the plant species of Brazil flora, the estimates of diversity were frequently widely divergent. The first nationwide assessment of the naturalized flora of Brazil has, therefore, meant a scientific breakthrough, since it conveys important knowledge both for research and conservation prioritization. It was revealed by these studies that - also as a result of human presence and actions-, non-native species are widespread in all Brazilian biomes and regions.

It has been also recognized (Laurance 2000) that there are certain so called Mega-Developments taking place in certain domains of Brazil (e.g. the Amazon) that already have major implications on the Global Climate Change.

Traditional medicines, including herbal medicines, will continue to be used in Brazil to some capacity, similarly to several countries of the developing world, where 70–95% of the population rely on these traditional medicines for primary care.

It has been reported that Brazil is one of the few countries in the world that provides public support for the payment for herbal medicines approved only on the basis of long-standing and widespread prior use. Nowadays, Brazil has already a list of 12 such herbal medicines funded by the government (Lopes et al. 2014a).

The Ministry of Health of Brazil has presented a National Policy on Integrative and Complementary Practices (PNPIC), in 2008, in order to coordinate a Unified Health System (SUS) in Brazil and to establish policies that ensure integrality of health care, This policy, is based on public knowledge, support and incorporates as well as utilizes the rich experiences that had been developed in so far. It is to be hoped that it will also contribute to the farther exploration and modern utilization of medicinal plant resources of this vast country. As a consequence, it is expected to contribute to the safeguarding and/or sustainable use of natural resources in both Brazil and ultimately, in the world.

References

Akerele O, Heywood V (1991) Conservation of medicinal plants. Available at: https://books.google.com/books?hl=hu&lr=&id=mZZOAAAAIAAJ&oi=fnd&pg=PR11&dq=guidelines+on+the+conservation+of+medicinal+plants&ots=ouyFrvnIxh&sig=yxjNl3qyGK75bAgxlcK1hkWl9EE. Accessed 14 Feb 2016

Alves CAB et al (2016) Gaia Scientia. Gaia Scientia 10(4):390–407

Andrade CTS et al (2006) Utilização medicinal de cactáceas por sertanejos baianos. Rev Bras Pl Med 8(3):36–42. Available at: https://www.researchgate.net/profile/Daniela_Zappi/publication/283355113_The_use_of_medicinal_cacti_by_locals_at_the_semi-arid_in_Bahia_State_Brazil/links/5637425f08ae758841152285.pdf. Accessed 22 Feb 2018

Anon R (n.d.) Available at: http://floradobrasil.jbrj.gov.br/reflora/PrincipalUC/PrincipalUC.do?lingua=en. Accessed 5 Feb 2018

Antonio G, Tesser C, Moretti-Pires R (2014) Phytotherapy in primary health care. Rev Saude Publica 48(3):541–553. Available at: https://www.scopus.com/record/display.uri?eid=2-s2.0-84905911116&origin=resultslist&sort=plf-f&src=s&sid=422522a73e5092005f640fc52abe93ec&sot=b&sdt=cl&cluster=scosubtype%2C%22re%22%2Ct&sl=68&s=TITLE-ABS-KEY%28traditional+medicine+plants+Brazil%29+AND+PUBY

Assis MA, Morelli-Amaral VF, Pimenta FP (2015) Grupos de pesquisa e sua produção científica sobre plantas medicinais: um estudo exploratório no Estado do Rio de Janeiro. Research groups and their scientific literature on medicinal plants: an exploratory study in the state of Rio de Janeiro. Revista Fitos 9(1):1–72. Available at: https://www.arca.fiocruz.br/bitstream/icict/15933/2/19.pdf

Begossi A, Hanazaki N, Peroni N (2000) Knowledge and use of biodiversity in Brazilian hot spots. Environ Dev Sustain 2(3/4):177–193. Available at: http://link.springer.com/10.1023/A:1011409923520. Accessed 5 Feb 2018

Caceres Guido P et al (2015) The state of the integrative medicine in Latin America: the long road to include complementary, natural, and traditional practices in formal health systems. Eur J Integr Med 7(1):5–12. Available at: http://linkinghub.elsevier.com/retrieve/pii/S1876382014000961

Carvalho ACB et al (2018) The Brazilian market of herbal medicinal products and the impacts of the new legislation on traditional medicines. J Ethnopharmacol 212:29–35. Available at: http://linkinghub.elsevier.com/retrieve/pii/S037887411731797X. Accessed 6 Feb 2018

Craveiro AA et al (2007) Natural product chemistry in North-Eastern Brazil. Wiley, pp 95–105. Available at: http://doi.wiley.com/10.1002/9780470514634.ch7. Accessed 7 Feb 2018

da Silva Gomes ECB et al (2014) Evaluation of antioxidant and antiangiogenic properties of Caesalpinia echinata extracts. J Cancer 5(2):143–150. Available at: http://www.jcancer.org/v05p0143.htm

de Albuquerque UP et al (2007) Medicinal and magic plants from a public market in northeastern Brazil. J Ethnopharmacol 110(1):76–91. Available at: https://www.sciencedirect.com/science/article/pii/S0378874106004594. Accessed 26 Feb 2018

de Oliveira L, Martins ER (2002) A quantitative assessment of genetic erosion in ipecac (Psychotria ipecacuanha). Genet Resour Crop Evol 49(6):607–617

Ekor M (2014) The growing use of herbal medicines: issues relating to adverse reactions and challenges in monitoring safety. Front Pharmacol 4:177. Available at: http://journal.frontiersin.org/article/10.3389/fphar.2013.00177/abstract. Accessed 8 Feb 2018

Elisabetsky E, Shanley P (1994) Ethnopharmacology in the Brazilian Amazon. Pharmacol Ther 64(2):201–214. Available at: http://linkinghub.elsevier.com/retrieve/pii/0163725894900396. Accessed 6 Feb 2018

Forzza RC et al (2012a) New Brazilian floristic list highlights conservation challenges. Bioscience 62(1):39–45. Available at: http://reflora.jbrj.gov.br/downloads/FUNG1.pdf. Accessed 5 Feb 2018

Forzza RC et al (2012b) New Brazilian floristic list highlights conservation challenges. Bioscience 62(1):39–45. Available at: https://academic.oup.com/bioscience/article-lookup/doi/10.1525/bio.2012.62.1.8. Accessed 1 Mar 2018

Giacometti D (1990) Estrategias de coleta e conservacao de germoplasma horticola da America tropical. In: Proceedings of the Simposio Latinoamericano sobre recursos geneticos de especies horticolas, 1. Campinas/SP. Fundacao Cargill. pp 91–110

Giam X et al (2010) Future habitat loss and the conservation of plant biodiversity. Biol Conserv 143:1594–1602. Available at: https://pdfs.semanticscholar.org/650b/178fa829b06f163b6638bebe1c1a91d48f1b.pdf. Accessed 22 Feb 2018

Laurance WF (2000) Mega-development trends in the Amazon: implications for global change. Environ Monit Assess 61(1):113–122. Available at: http://link.springer.com/10.1023/A:1006374320085. Accessed 7 Feb 2018

Lewinsohn TL, Prado PI (2005) Quantas espécies há no Brasil? Megadiversidade 1:36–42

Lopes A et al (2014a) Brazilian medicinal plants to treat upper respiratory tract and bronchial illness: systematic review and meta-analyses—study protocol. BMJ 4(7):e005267. Available at: http://bmjopen.bmj.com/content/4/7/e005267

Lopes LC et al (2014b) Brazilian medicinal plants to treat upper respiratory tract and bronchial illness: systematic review and meta-analyses—study protocol. BMJ Open 4:e005267. Available at: http://dx.doi.org/ Accessed 8 Feb 2018

Lós DW d S, Barros RP, Neves JDS (2012) Comercialização de plantas medicinais: um estudo etnobotânico nas feiras livres do município de arapiraca–al. Revista de Biologia e Farmácia 7(2):38–51

Marini-Bettòlo GB (1977) Quimiotaxonomia e medicinia popular. Conferencia pronunciada na universidade federal de Alagôas, Maceio, Brazil. (Lecture delivered at the Federal University of Alagoas UFAL, Maceió, Brazil)

Máthé Á (2011) A new look at medicinal and aromatic plants. Acta Hortic 925:13–20.

Máthé A (2015) Medicinal and aromatic plants of the world: scientific, production, commercial and utilization aspects. Available at: https://books.google.com/books?hl=hu&lr=&id=LgqkCgAAQBAJ&oi=fnd&pg=PR5&dq=Medicinal+and+Aromatic+Plants+of+the+World:+Scientific,+Production,+Commercial+and+Utilization+Aspects&ots=V5eeol9FEj&sig=jW5qVfCCDHu6SQcSeQpT1noiz40. Accessed 8 Feb 2016

Mendes FR (2011) Tonic, fortifier and aphrodisiac: adaptogens in the Brazilian folk medicine. Rev Bras 21(4):754–763. Available at: http://www.scielo.br/scielo.php?script=sci_arttext&pid=S0102-695X2011000400028&lng=en&nrm=iso&tlng=en. Accessed 6 Feb 2018

Mitra R et al (2007) Medicinal plants of Brazil. Asia Pac Biotech News 11(11):689–743

Mittermeier RA, Robles Gil P, Hoffmann M, Pilgrim J, Brooks T, Mittermeier CG, Lamoreux J, da Fonseca GAB (2004) Hotspots revisited: Earth's biologically richest and most endangered ecoregions, 1st English edn. CEMEX, Mexico City, p 501

Mittermeier RA, Robles Gil P, Mittermeier CG (1997) Megadiversity: Earth's biologically wealthiest nations. CEMEX and Agrupación Sierra Madre, Mexico

Myers N (1988) Threatened biotas: "Hot spots" in tropical forests. Environmentalist 8(3):187–208. Available at: http://link.springer.com/10.1007/BF02240252 Accessed 6 Feb 2018

Myers N (1990) The biodiversity challenge: expanded hotspots analysis. Environmentalist 10(4):243–256. Available at: https://pdfs.semanticscholar.org/97ff/8edb8f2a51bd25e7113b7ed3b52a8f044ce6.pdf

Oliveira et al. (2013) Estudo etnobotânico sobre plantas medicinais nas feiras livres do município de limoeiro do norte. In: 64º Congresso Nacional de Botânica.2013. Belo Horizonte, 10–15 de Novembro de 2013. Available at: https://www.botanica.org.br/trabalhos-cientificos/64CNBot/resumo-ins18662-id5830.pdf

Roque AA, Rocha RM, Loiola B (2010) Uso e diversidade de plantas medicinais da Caatinga na comunidade rural de Laginhas, município de Caicó, Rio Grande do Norte (nordeste do Brasil). Rev Bras Pl Med 12(1):31–42. Available at: http://www.scielo.br/pdf/rbpm/v12n1/v12n1a06. Accessed 22 Feb 2018

Shanley P, Luz L (2003) The impacts of forest degradation on medicinal plant use and implications for health care in eastern Amazonia. Bioscience 53(6):573

Simberloff D et al (2013) Impacts of biological invasions: what's what and the way forward. Trends Ecol Evol 28(1):58–66 Available at: http://linkinghub.elsevier.com/retrieve/pii/S0169534712001747. Accessed 7 Feb 2018

Tomchinsky B et al (2017) Ethnobotanical study of antimalarial plants in the middle region of the Negro River, Amazonas, Brazil. Acta Amazon 47(3):203–212. Available at: http://www.scielo.br/scielo.php?script=sci_arttext&pid=S0044-59672017000300203&lng=en&tlng=en. Accessed 6 Feb 2018

van den Berg ME et al (1988) Contribuição à flora medicinal de Mato Grosso do Sul. Acta Amazon 18(suppl 1–2):9–22. Available at: http://www.scielo.br/scielo.php?script=sci_arttext&pid=S0044-59671988000500009&lng=pt&tlng=pt. Accessed 22 Feb 2018

Vieira R (1999) Conservation of medicinal and aromatic plants in Brazil. In: Janick J (ed) Perspectiv. ASHS Press, Alexandria. Available at: https://hort.purdue.edu/newcrop/proceedings1999/v4-152.html. Accessed 4 Feb 2018

Vieira RF (2002) Economic potential and conservation of medicinal and aromatic plants from Brazil | Conservaṃão de recursos genéticos de plantas medicinais e aromáticas brasileiras: Um desafio para o futuro

Wilma D et al (2012) Comercialização de plantas medicinais: um estudo etnobotânico nas feiras livres do município de arapiraca–al. BioFar 7(2):38–51. Available at: http://sites.uepb.edu.br/biofar/download/v7n2-2012/comercializacaodeplantasmedicinais.pdf. Accessed 26 Feb 2018

Zenni RD (2015) The naturalized flora of Brazil: a step towards identifying future invasive non-native species. Rodriguésia 66(4):1137–1144. Available at: https://books.google.hu/books?hl=hu&lr=&id=QzyBPA8SrN4C&oi=fnd&pg=PR5&dq=Invasive+species:+what+everyone+needs+to+know.+1ed&ots=88s8-8wWS-&sig=eKTGJ6lg1wbaxWnR6savhHDh0Dk&redir_esc=y#v=onepage&q&f=false. Accessed 6 Feb 2018