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Marcgrave and Piso's plants for sale: The presence of plant species and names from the *Historia Naturalis Brasiliae* (1648) in contemporary Brazilian markets

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ABSTRACT

Ethnopharmacological relevance: Parallelisms between current and historical medicinal practices as described in the seventeenth century treatise *Historia Naturalis Brasiliae* (HNB) provide us with an overview of traditional plant knowledge transformations. Local markets reflect the actual plant use in urban and rural surroundings, allowing us to trace cross-century similarities of ethnobotanical knowledge. Aims of the study: We aim to verify in how far the HNB, created in seventeenth-century northeastern Brazil, correlates with contemporary plant use in the country by comparing the plant knowledge therein with recent plant market surveys at national level. **Materials and methods:** We conducted a literature review on ethnobotanical market surveys in Brazil. We used the retrieved data on plant composition and vernacular names, together with our own fieldwork from the Ver-o-Peso market in Belém, to compare each market repertoire with the useful species in the HNB. We analyzed similarities among markets and the HNB with a Detrended Correspondence Analysis and by creating Venn diagrams. We analyzed the methods of the different markets to check whether they influenced our results. **Results:** Out of the 24 markets reviewed, the greatest similarities with the HNB are seen in northern Brazilian markets, both in plant composition and vernacular names, followed by the northeast. The least overlap is found with markets in the central west and Rio de Janeiro. Most of the shared vernacular names with the HNB belonged to languages of the Tupi linguistic family.

Conclusion: The similarity patterns in floristic composition among Brazilian markets and the HNB indicate the current wider distribution and trade of the species that Marcgrave and Piso described in 1648 in the northeast. Migration of indigenous groups, environmental changes, globalized and homogenous plant trade, and different market survey methods played a role in these results. The HNB is a reference point in time that captures a moment of colonial cultural transformations.

ABSTRACT (PORTUGUESE)

Relevância etnofarmacológica: Os paralelismos entre as práticas medicinais atuais e históricas, como aquelas descritas no tratado seiscentista *História Naturalis Brasiliae* (HNB), fornecem uma visão geral das transformações do conhecimento tradicional sobre plantas. Os mercados locais refletem o uso atual das plantas em ambientes urbanos e rurais, permitindo rastrear semelhanças de conhecimento etnobotânico em diferentes períodos históricos.

Objetivos do estudo: Nosso objetivo é verificar até que ponto o HNB, criado no nordeste do Brasil, carrega

abbreviations: WIC, (West India Company); HNB, (*Historia Naturalis Brasiliae*); IURNM, (*Indiae Utriusque Re Naturali et Medica*); MG, (Herbarium of the Museum Paraense Emílio Goeldi in Belém Pará); JS, (Jaccard Similarity Index); N, (North); NE, (Northeast); CW, (Central West); SE, (Southeast); RMB, Região Metropolitana de Belém; (DFS), Distrito Florestal Sustentável

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semelhanças com o uso contemporâneo de plantas no país, comparando seu conhecimento sobre plantas com pesquisas recentes de mercados de plantas a nível nacional.

Materiais e Métodos: Realizamos uma revisão de literatura sobre pesquisas etnobotânicas de mercados e feiras no Brasil. Utilizamos os dados recuperados sobre composição de plantas e nomes vernaculares, juntamente com nosso próprio trabalho de campo no mercado Ver-o-Peso em Belém, para comparar cada repertório de mercado com as espécies úteis do HNB. Analisamos semelhanças entre os mercados e o HNB usando Análise de Correspondência Destendenciada e criando diagramas de Venn. Analisamos os métodos dos diferentes mercados para verificar se eles influenciaram nossos resultados.

Resultados: As maiores semelhanças com o HNB são observadas nos mercados do norte do Brasil, tanto na composição das plantas quanto nos nomes vernaculares, seguido pelo nordeste. A menor correlação é encontrada nos mercados do centro-oeste e Rio de Janeiro. A maioria dos nomes vernáculos compartilhados com o HNB pertenciam a idiomas pertencentes ao tronco linguístico Tupi.

Conclusão: Os padrões de similaridade na composição florística dos mercados brasileiros e do HNB indicam uma atual distribuição e comércio mais amplo das espécies do que aqueles que Marcgrave e Piso descreveram em 1648 no nordeste. A migração de grupos indígenas, as mudanças ambientais, o comércio globalizado e homogêneo das plantas, e os diferentes métodos de pesquisa de mercado tiveram um papel nesses resultados. O HNB é um ponto de referência que captura um momento de transformações culturais coloniais em contexto colonial.

1. Introduction

Boosted by the Dutch colonial enterprise, an influential scientific account of Brazil's natural history was created from a relatively small, but highly biodiverse, territory of the vast country. The present-day state of Pernambuco in northeast Brazil was occupied by the Dutch West India Company (WIC) between 1630 and 1654. Count Johan Maurits van Nassau-Siegen was appointed as governor-general of the colony between 1637 and 1644. He commissioned a group of naturalists, artists and physicians to describe and illustrate the local diseases, flora and fauna of Dutch Brazil, generating one of the most comprehensive treatises of tropical natural history of the early modern period: the *Historia Naturalis Brasiliae* (HNB). The HNB was authored by the German naturalist George Marcgrave and the Dutch physician Willem Piso, and edited by the geographer and director of the WIC, Johannes de Laet, who published it in 1648. With great detail, De Laet systematized local knowledge on plants and animals as reported by Piso and Marcgrave, and added several illustrations, combining art and science in an encyclopedic format (Whitehead and Boeseman, 1989). He was influenced by other naturalists, explorers and religious chroniclers that travelled to the Americas, reflected in the many comparisons he wrote throughout the text, especially for plants (Francozo, 2010). Ten years later, after the deaths of Marcgrave and De Laet, the *De Indiae Utriusque Re Naturali et Medica* (IURNM) was published by Piso (1658), adding Marcgrave's notes on flora and fauna under his own name, after which he was accused of plagiarism by scholars such as Linnaeus (Whitehead and Boeseman, 1989; Ossenbach, 2017). Other contributors, not acknowledged but essential to create this book, were the diverse Tupi-speaking indigenous peoples, enslaved Africans and their descendants, and Portuguese and Dutch settlers in the colony, whose ecological knowledge was documented in the HNB (Furtado, 2007; Alcántara Rodríguez et al., 2019).

To what extent this knowledge is still present in Brazil was the subject of two recent historical revisions of the HNB (Medeiros and Albuquerque, 2014; Alcántara Rodríguez et al., 2019). Although this treatise was based on studies of the flora and fauna of the northeast of Brazil, most plant species and uses described here are widespread in the different regions and biomes of the country (Alcántara Rodríguez et al., 2019). To what extent these distributions are the result of pre-colonial, colonial, or post-colonial exchanges in ethnobotanical knowledge and plant trade in Brazil – or a combination of these – is still uncertain. In the pre-Columbian era, plant exchange and trade existed among diverse indigenous groups and, in Brazil, it was associated with Tupi-Guarani movements and settlements across the country (Noelli, 2008). Indigenous groups modified the Brazilian landscape to acquire plant and animal resources long before colonization, creating a corpus of

ecological knowledge over millennia (Heckenberger et al., 2007; Levis et al., 2018). This dynamic and adaptative knowledge was spread over the Brazilian regions by the local populations, interacting in contact zones with the Portuguese and other European colonists since 1500, and the enslaved Africans since the 1560s along the northeast coast (Fausto, 2014).

Our previous comparative study of the plant uses documented in the HNB (Alcántara Rodríguez et al., 2019) was mainly based on the research of the Brazilian botanist Pio Corrêa (1874–1934), whose work was published in six extensive volumes of useful native and exotic plants of Brazil (Corrêa, 1926–1984). The information on plant uses and names compiled by Corrêa stems from the beginning of the twentieth century or even earlier. This plant knowledge may have been transformed, disrupted or disappeared given the large-scale deforestation and land degradation by agribusiness and cattle industry (Gazzaneo et al., 2005; Sawyer, 2008), the “interculturalization” of plant practices, as defined by Tareau (2019), and the erosion in traditional knowledge due to industrialization and globalization in Brazil (Brandão et al., 2013; Aguiar, 2018). Here we use a more up-to-date approach, by comparing ethnobotanical information in the HNB to surveys of local plant markets in Brazil in the period 1984–2018, to analyze whether the plant species and their vernacular names, as documented by Piso and Marcgrave in the 1640s, are still present in Brazil today.

Local markets constitute places of acquisition and dissemination of natural resources, such as plants or plant-derived products and the information associated to them, between producers, vendors and consumers, and can promote the resilience of this dynamic knowledge over time (De Freitas et al., 2012). Local markets play a socio-economic role as they provide an important source of income for people in vulnerable sectors of the population, such as low-resource, illiterate people, migrants and women under forced or non-equal conditions (Macía et al., 2005; Van Andel et al., 2012; Lima et al., 2014). Medicinal plant markets offer alternative sources of health care that have earned the confidence of their users in terms of healing efficacy, and are less expensive than conventional medicinal treatments (Da Nóbrega-Alves et al., 2008).

Ethnobotanical market surveys reveal the pluricultural and intercultural context in which several pharmacopeias, botanical knowledge and beliefs co-exist (Pochettino et al., 2012) and intermingle (Tareau, 2019). They also inform about the plant diversity, species in highest demand, the most frequent diseases treated with herbal medicine and the relevance of medicinal plant use in a certain location (Parente and Da Rosa, 2001; Leitão et al., 2009; Pochettino et al., 2012; Van Andel et al., 2012). Markets also reflect socio-environmental activities, as vendors or intermediaries often gather their products from the wild, in forest or disturbed areas (Pinto et al., 2013), or cultivate them in their

yards or gardens (Alves, 2007), influencing the nearby landscape to a greater or lesser extent by the need for plant-based products (De Oliveira et al., 2014). Markets give us an overview of the most useful native plants (Pinto et al., 2013; Bitu et al., 2015), but also of introduced plants, reflecting human migration, trade between regions and globalization (Luz, 2001; Maioli-Azevedo and Da Fonseca-Kruel, 2007; Cajaliba et al., 2016; Tareau, 2019).

Most published market surveys in Brazil represent descriptive inventories focused on medicinal and ritual plants (Van den Berg, 1984; Stalcup, 2000), qualitative approaches on socio-economic aspects (Bitencourt et al., 2014; Santos et al., 2018) or quantitative studies on ethnopharmacological properties and species richness (De Almeida and Albuquerque, 2002; Carvalho, 2004; Lima et al., 2011). Only two studies in Brazil have investigated parallelisms between current and historical medicinal practices. Da Silva et al. (2004) compared animal-based products sold on medicinal markets in Recife with the animals used for healing described in the HNB. Pombo Geertsma (2019) compared useful plants from the Ver-o-Peso market in Belém with those described in the HNB. Here we present a comparison between plant knowledge from seventeenth century Dutch Brazil, as registered in the HNB, and recent ethnobotanical market surveys in the country. Surveys of local plant markets can be helpful in tracing cross-century change and retention of ethnobotanical knowledge, as they reflect the actual plant use in urban areas and their rural surroundings. By comparing useful plant species and vernacular indigenous and African names described by Marcgrave and Piso with recent data from local Brazilian markets, we can verify which areas show the greatest similarities with the traditional plant knowledge that was documented in 1648 in the northeast.

We posed the following research questions (Aguilar, 2018): Which plants are sold at local markets in several regions of Brazil (Albuquerque, 1997)? What are the similarities in species composition between these markets and the HNB (Albuquerque et al., 2007)? To which extent and where do we find similarities in Tupi plant names as documented in the HNB? We expected to find the greatest overlap in plant species composition and plant names in the northeast of Brazil, and in particular in Pernambuco, because the HNB was compiled there. Through this research we add new insights on plant knowledge correlations between historical sources and modern urban markets, and we analyze to which extent the HNB correlates with contemporary plant use in Brazil.

2. Materials and Methods

2.1. Data collection

We retrieved literature sources from Google Scholar in English, Portuguese and Spanish, using the following key words: (*urban*) (*local*) *markets*, *plants*, *ethnobotany*, *Brazil*, *Brasil*, *mercados*, *feiras*, *etnobotânica*, *plantas*, *comercializadas*, *medicinais*, and *comestíveis*. We completed this review with data obtained from our own fieldwork survey conducted at the Ver-o-Peso market in Belém (Amazon) in August 2018 (Pombo Geertsma, 2019). During our fieldwork we made voucher specimens and identified most of them at the herbarium of the Museu Paraense Emílio Goeldi (MG) in Belém. We labelled all vouchers with information on their taxonomical identification, vernacular name, location, perishable morphological characteristics, habit and plant parts sold and deposited them at the MG (Pombo Geertsma, 2019). For doubtful identifications or unknown plants, we compared the photographs of the specimens to the South American collections at the herbarium of Naturalis Biodiversity Center (L) in Leiden and consulted expert botanists at Naturalis. We also checked the Global Biodiversity Information Facility database-GBIF (www.gbif.org/), Flora do Brasil 2020 (www.floradobrasil.jbrj.gov.br/), Tropicos (www.tropicos.org/), and literature on medicinal plants in Brazil (Lorenzi, 2002; Lorenzi and Matos, 2008) and Surinam (Van Andel and Ruyschaert, 2011).

We organized all plant species reported in the market inventories in an Excel table, updated their scientific nomenclature by using The Plant List (www.theplantlist.org/) and then compared them with the useful species identified in the HNB by Alcántara-Rodríguez et al. (2019). These identifications were based in the plants described and often depicted in the fourth chapter of Piso on medicinal plants (*De Medicina Brasiliense*, 1648) and the three first chapters of Marcgrave (*Historia Rerum Naturalium*, 1648) on herbs, shrubs and trees. We also considered the IURNM (Piso, 1658), but as Piso copied most of the species from the HNB, we mainly refer to the HNB as the main reference, unless some specific plants were depicted only in the IURNM. We followed a conservative approach, as we excluded plants only identified to family or genus level from our analysis. However, we have taken into account the total number of species collected per market survey to consider species richness. To see whether (dis-) similarities among markets were caused by methodological differences in the surveys, we conducted an in-depth analysis of the methods in the reviewed literature. We checked whether the authors collected and identified vouchers, conducted free-listing or interviews with vendors, did their own observations, and/or verified the domestication status of plants.

2.2. Data analysis

We used descriptive statistics by simple tabulations after grouping all market species. We calculated for every market the number and percentage of species in common with the HNB. We calculated the most commonly sold species on all surveyed Brazilian markets (present in ≥ 10 locations), present in the HNB or not and added information on domestication status, habit and distribution (biomes) in Brazil according to the online Flora do Brasil 2020, Species link (www.splink.org.br/), and the Pl@nt Use (www.uses.plantnet-project.org/).

Of all species that overlapped with the HNB, we calculated for every market the proportion of vernacular names in Portuguese, African, Tupi-related or other languages shared with the HNB. We considered vernacular names ‘similar’ when they showed strong resemblance in structure, sound or meaning (Van Andel et al., 2014), as for example: “passion fruit” for *Passiflora edulis* Sims in Albuquerque et al. (2007) and “flor de paixão” in the HNB (Marcgrave, 1648: 71). We considered Tupi-related names those that originated from the macrolinguistic Tupi family, even if they were now borrowed into the Portuguese: e.g., *joão-barandí* for *Piper anisum* (Spreng.) Angely (De Azevedo and Silva, 2006) and *jaborandi* (Marcgrave, 1648: 69) for the same species.

We grouped market locations per geographic region (north, northeast, central west, and southeast) and by biome (Amazon, Atlantic Rainforest, Atlantic Coast, Caatinga, and Cerrado or Central Savannah), according to the Flora do Brasil 2020 (www.floradobrasil.jbrj.gov.br/). To assess similarities in species composition among markets and the HNB, we entered all plant species present at the markets and listed in the HNB into a presence-absence data matrix in Excel. We did a preliminary analysis of the data to test if the species response to markets showed a unimodal distribution using *vegan:decorana* in R version 3.6.2 (R Core Development Team, 2019), in which axis lengths should be greater than 4 (Oksanen et al., 2018). A unimodal distribution means that most species occurred only in subsets of markets and few are present uniformly. To minimize the effect of rare species, we opted for a Detrended Correspondence Analysis (DCA) in R. Finally, for each region, we calculated the overlap in species with the HNB by means of Venn Diagrams using FUNRICH software (Pathan et al., 2015: www.funrich.org). Within the shared species, we counted the number of vernacular plant names in common with the HNB and origin of their language.

Table 1
Overlap in species and vernacular plant names between the HNB and the 24 Brazilian markets.

Region	Biome	Municipality and state	Total nr species	Shared spp. with HNB (%) ^a	Shared names with HNB (%) ^b	Origin of shared name (language) ^c	References
North	Amazon	Belém, Pará	172	42 (24%)	34 (81%)	15 Tu, 2 Ar, 11 Po, 6 A	Pombo Geertsma, 2019 (Aguar, 2018)
North	Amazon	Boa Vista, Roraima	105	30 (29%)	24 (80%)	9 Tu, 2 Ar, 10 Po, 5 A	Luz, 2001 (Balée, 1993)
North	Amazon	Belém, Pará	158	30 (30%)	23 (77%)	11 Tu, 1 Ar, 6 Po, 5 A	Van den Berg, 1984 (Albuquerque, 1997)
Northeast	Atlantic Coast	São José, Recife, Pernambuco	107	26 (24%)	23 (88%)	7 Tu, 1 Ar, 9 Po, 2 A, 4 O	Albuquerque et al., 2007 (Barros, 2012)
Southeast	Atlantic Rainforest	Tijuca, Rio de Janeiro	145	24 (17%)	15 (63%)	6 Tu, 1 Ar, 6 Po, 2 A	Stalcup, 2000 (Da Nóbrega-Alves et al., 2008)
North	Amazon	Região Metropolitana de Belém (RMB), Pará	129	23 (18%)	16 (70%)	7 Tu, 1 Ar, 4 P, 4 A	Santos et al., 2018 (Alcantara Rodriguez et al., 2019)
Northeast	Atlantic-Caatinga	Caruaru, Pernambuco	74	21 (28%)	17 (81%)	8 Tu, 6 P, 3 A	De Almeida and de Albuquerque, 2002 (Bitencourt et al., 2014)
Southeast	Atlantic Rainforest	West, Rio de Janeiro	117	21 (18%)	12 (57%)	5 Tu, 5 P, 2 A	De Azevedo and Silva, 2006 (Cunningham, 2014)
Northeast	Caatinga	Crajobar Triangle-Cariri, Ceará	89	18 (20%)	15 (83%)	8 Tu, 4 P, 4 A	Bitu et al., 2015 (Burkill, 1997)
Southeast	Atlantic Rainforest	North/South, Rio de Janeiro	102	15 (15%)	12 (80%)	6 Tu, 4 P, 2 A	Maioli-Azevedo and Da Fonseca-Krue, 2007 (Cunha and De Almeida, 2000)
Central west	Cerrado	Guiabá, Mato Grosso	108	15 (14%)	8 (53%)	4 Tu, 2 P, 2 A	Pinto et al., 2013 (Carvalho, 2004)
North	Amazon	Guamá, Belém, Pará	125	14 (11%)	9 (64%)	2 Tu, 6 P, 1 A	Bitencourt et al., 2014 (Albuquerque et al., 2007)
North	Amazon	Boa Vista, Roraima	85	12 (14%)	9 (75%)	6 Tu, 2 P, 1 A	Da Costa-Pinto and Maduro, 2003 (Balée, 2000)
North	Amazon	Uruará, Pará	56	10 (18%)	10 (100%)	3 Tu, 6 P, 1 A	Cajaliba et al., 2016 (Araújo et al., 2015)
Northeast	Cerrado-Amazonia	Bacabal, Maranhão	31	9 (29%)	7 (78%)	3 Tu, 2 P, 2 A	Araújo et al., 2015 (Cajaliba et al., 2016)
Southeast	Atlantic Rainforest	Petrópolis/Nova Friburgo, Rio de Janeiro	92	9 (10%)	7 (78%)	1 Tu, 5 P, 1 A	Leitão et al., 2009 (Correia, 1926–1984)
Northeast	Atlantic Coast	Recife, Pernambuco	47	7 (15%)	5 (71%)	1 Tu, 3 P, 1 A	Albuquerque, 1997 (Bitu et al., 2015)
Southeast	Atlantic Rainforest	Barra do Piraí, Rio de Janeiro	66	7 (11%)	4 (57%)	3 Tu, 1 P	Parente and Da Rosa, 2001 (Da Costa-Pinto and Maduro, 2003)
Northeast	Caatinga	Campina Grande, Paraíba	23	6 (27%)	4 (67%)	3 Tu, 1 P	Alves, 2007 (Brandão et al., 2013)
Central west	Cerrado	Anápolis, Goiás	37	4 (11%)	3 (75%)	2 Tu, 1 P	Carvalho, 2004 (Chaddad and Jank, 2006)
Central west	Cerrado	Campo Grande, Mato Grosso do Sul	27	4 (15%)	3 (75%)	3 Tu	Nunes et al., 2003 (Casarões and Flenes, 2019)
North	Amazon	Distrito Florestal Sustentável (DFS), Pará	32	3 (9%)	2 (67%)	2 Tu	Lima et al., 2011 (Altieri et al., 2012)
North	Amazon	Itaituba, Pará	14	2 (14%)	1 (50%)	1 Tu	Lima et al., 2014 (Alves, 2007)
Central west	Cerrado	Goiânia, Goiás	24	0 (0%)	0 (0%)		Tresvenzol et al., 2006 (Clements and Fernandes, 2013)

^a Percentage of total number of identified species on that specific market.

^b Percentage of overlapping vernacular names for plant species in common with the HNB.

^c Indigenous: Tu (Tupi-related); Ar (Arawak-related); P (Portuguese); A (African/Arabic); O (Others).

3. Results

3.1. Plant diversity and similarity on Brazilian markets

Our literature review yielded 23 Brazilian market surveys, which combined with our own fieldwork (Pombo Geertsma, 2019), resulted in 24 surveys (Table 1). Most were carried out in the north of the country (9 surveys), followed by the northeast (Alves, 2007), southeast (Altieri et al., 2012) and central west (Alcantara Rodriguez et al., 2019) (Fig. 1). While 256 useful species were listed in the HNB, a total of 652 taxa identified to species level were recorded in these 24 surveys: most in the north (438 species), followed by the southeast (279), the northeast (203), and the central west (153) (Supplementary Table S1).

Of the 25 most commonly sold species (recorded in ≥ 10 surveys) less than a quarter (20%) are native plants, while the majority (80%) were introduced from Europe (mostly from the Mediterranean region), Asia or Africa, during the colonial trade started by the Portuguese in the sixteenth century (Walker, 2013), and from other regions of the continent (Table 2). Of these most frequently sold species 20% are also present in the HNB. Most of the introduced species (55%) are domesticated, the others (45%) are either cultivated or wild, as they have become naturalized over time. While few of the native plants are exclusively domesticated or gathered from the wild (each 20%), 60% can be found both cultivated and wild. Of those species in common with the HNB, more than half (60%) were introduced from the Old World and the rest (40%) are native Brazilian (Table 2). Most of these common market plants are herbs (52%), followed by trees (24%), shrubs (16%) and lianas (8%). Most of the shared species with the HNB are also herbs, followed by trees and shrubs.

The most commonly sold species in the Brazilian markets surveyed are widespread weeds, such as *Dysphania ambrosioides* (L.) Mosyakin & Clemants and *Petiveria alliacea* L. They grow in the wild, but people also cultivate them because of their medicinal value and high demand. Cultivated trees are also very popular, such as *Punica granatum* L. or the native *Amburana cearensis* (Allemão) A.C.Sm., which also grows wild. Cosmopolitan shrubs and herbs that are widely traded are *Ruta graveolens* L., *Cymbopogon citratus* (DC.) Stapf, *Luffa operculata* (L.) Cogn., *Rosmarinus officinalis* L., and *Zingiber officinale* Roscoe (Table 2).

3.2. Similarity in species between Brazilian markets and the HNB

Out of 256 useful species described in the HNB, 160 (63%) species

were not recorded by any of the recent market surveys in Brazil, while 96 (37%) were found on at least one market. The greatest overlap in commercialized species with the HNB was found in northern Brazil in the surveys of the Ver-o-Peso market in Belém by Pombo Geertsma (2019) and Van den Berg (1984), and the market in Boa Vista, Roraima (Luz, 2001). Although the HNB was produced in the northeast, much less overlap was found with the markets in Pernambuco and Ceará (Table 1). Typically, the least overlap (0 species in common) was surprisingly not found near Rio de Janeiro, located the furthest away from the northeast and having very different vegetation, but in Goiás in the central west region (Tresvenzol et al., 2006).

Species response to markets showed unimodal distributions. To visualize the results of the DCA we plotted it on the two axes that caused the distribution of the data. The results (Fig. 2) show how close in species composition the different markets are from the HNB, and from each other. Although the HNB has many species that are not found in any of the markets (because it has a much higher total number of species than other markets), the HNB shows most similarity in species composition with markets situated in the north of Brazil and least similarity with the markets located in the central west. The clustering of the markets in Rio de Janeiro suggest that in this region there are more species in common per market than among markets in the north, northeast and central west.

On the other hand, the greatest overlap in shared plant species between the markets in the north and the HNB was based on absolute numbers of shared species (Fig. 3). Greater percentage of overlapping species was found between the northeast and the HNB, followed by the north (Fig. 3). The greater number of plant species reported in northern markets (Table 1) could explain the overlap in number of shared plants species. However, these differences in number of species per market do not necessarily justify the results. Markets in Rio, with higher numbers of species than in the northeast, shared fewer species with the HNB than the northeastern markets, although the relative percentage of overlapping species was the same than in these later markets (Fig. 3).

3.3. Similarity in local names between Brazilian markets and the HNB

Regarding vernacular names, we found the greatest correlation with the HNB in the recent survey in Belém (Pombo Geertsma, 2019), with 34 plant names similar to those documented in the HNB, followed by the Boa Vista market (Luz, 2001). Fewer vernacular names were documented by Albuquerque et al. (2007) in Recife, although this was

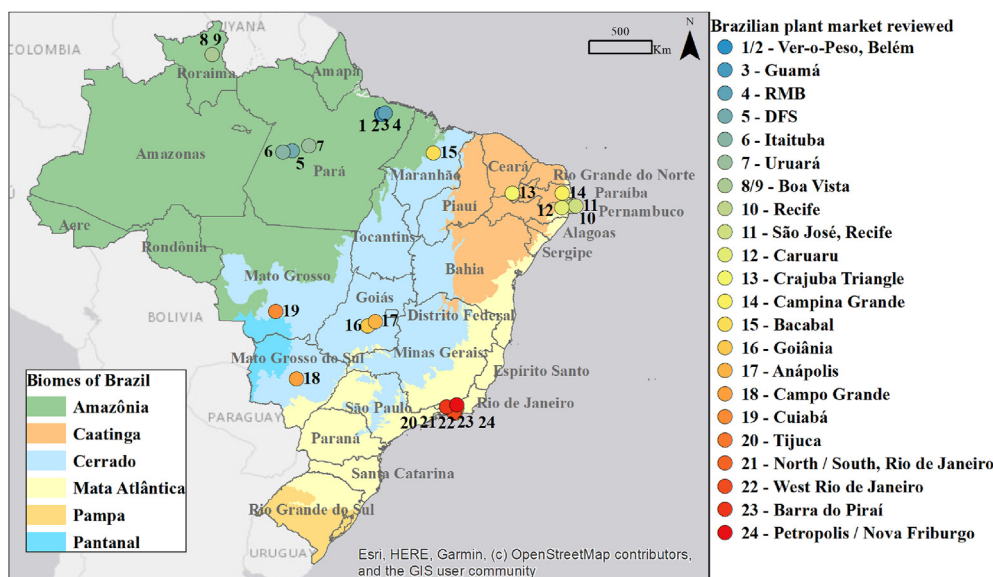


Fig. 1. Map depicting the 24 market survey locations and biomes. Numbers refer to references in Table 1.

Table 2
Most frequently sold species in the 24 Brazilian markets, their distribution, biomes, domestication status and presence in the HNB.

Species (Family)	Nr of markets (%)	Region	Domestication status	Distribution (biome)	Habit	Present in the HNB
<i>Petiveria alliacea</i> L. (Phytolaccaceae)	16 (67%)	All regions	Introduced (cultivated, wild)	Tropics worldwide	Herb	No
<i>Dysphania ambrosioides</i> (L.) Mosyakin & Clemants (Amaranthaceae)	15 (63%)	All regions	Introduced (cultivated, wild)	All biomes except Pampa and Pantanal	Shrub	No
<i>Punica granatum</i> L. (Lythraceae)	14 (58%)	All regions	Introduced (domesticated)	Tropics worldwide	Tree	No
<i>Ruta graveolens</i> L. (Rutaceae)	14 (58%)	All regions	Introduced (domesticated)	Worldwide	Herb	No
<i>Cymbopogon citratus</i> (DC.) Stapf (Poaceae)	13 (54%)	All regions	Introduced (domesticated)	Tropics worldwide	Herb	No
<i>Lippia alba</i> (Mill.) N.E.Br. ex Britton & P. Wilson	13 (52%)	All regions	Native (cultivated, wild)	All biomes except Pampa and Pantanal	Herb	Yes
<i>Luffa operculata</i> (L.) Cogn. (Cucurbitaceae)	13 (54%)	All regions	Introduced (domesticated)	Amazon, Cerrado, Atlantic Rainforest	Liana	No
<i>Ocimum gratissimum</i> L. (Lamiaceae)	13 (52%)	All regions	Introduced (cultivated, wild)	Tropics worldwide	Herb	No
<i>Rosmarinus officinalis</i> L. (Lamiaceae)	13 (54%)	All regions	Introduced (domesticated)	Worldwide	Shrub	No
<i>Zingiber officinale</i> Roscoe (Zingiberaceae)	13 (54%)	All regions	Introduced (domesticated)	Tropics worldwide	Herb	Yes
<i>Anacardium occidentale</i> L. (Anacardiaceae)	12 (50%)	All regions	Native (domesticated)	All biomes	Tree	Yes
<i>Momordica charantia</i> L. (Cucurbitaceae)	12 (50%)	All regions	Introduced (cultivated, wild)	Tropics worldwide	Vine	No
<i>Alpinia zerunbet</i> (Pers.) B.L.Burt & R.M.Sm. (Zingiberaceae)	11 (46%)	All regions	Introduced (domesticated)	All biomes except Pampa and Pantanal	Herb	No
<i>Amburana cearensis</i> (Allemão) A.C.Sm. (Leguminosae)	11 (46%)	N, NE, CW, SE	Native (cultivated, wild)	Caatinga, Cerrado, Atlantic Rainforest, Pantanal	Tree	No
<i>Carapa guianensis</i> Aubl. (Meliaceae)	11 (46%)	N, NE, SE	Native (wild)	Amazon	Tree	No
<i>Cinnamomum verum</i> J.Presl (Lauraceae)	11 (46%)	N, NE, SE	Introduced (domesticated)	Tropics worldwide	Tree	No
<i>Aloe vera</i> (L.) Burm.f. (Xanthorrhoeaceae)	10 (42%)	All regions	Introduced (domesticated)	Cerrado, Atlantic Coast/Rainforest, Caatinga	Herb	No
<i>Helianthus annuus</i> L. (Compositae)	10 (42%)	All regions	Introduced (domesticated)	Tropics worldwide	Herb	Yes
<i>Bidens pilosa</i> L. (Compositae)	10 (42%)	All regions	Introduced (cultivated, wild)	All biomes	Herb	No
<i>Bryophyllum pinnatum</i> (Lam.) Oken (Crassulaceae)	10 (42%)	All regions	Introduced (cultivated, wild)	Tropics worldwide	Herb	No
<i>Caesalpinia ferrea</i> C.Mart. (Leguminosae)	10 (42%)	All regions	Native (cultivated, wild)	Caatinga	Tree	No
<i>Jatropha gossypifolia</i> L. (Euphorbiaceae)	10 (42%)	All regions	Introduced (cultivated, wild)	Tropics worldwide	Shrub	No
<i>Ocimum basilicum</i> L. (Lamiaceae)	10 (42%)	All regions	Introduced (domesticated)	Worldwide	Herb	No
<i>Ricinus communis</i> L. (Euphorbiaceae)	10 (42%)	All regions	Introduced (cultivated, wild)	All biomes and regions	Shrub	Yes
<i>Matricaria chamomilla</i> L. (Compositae)	9 (38%)	All regions	Introduced (cultivated, wild)	Worldwide	Herb	No

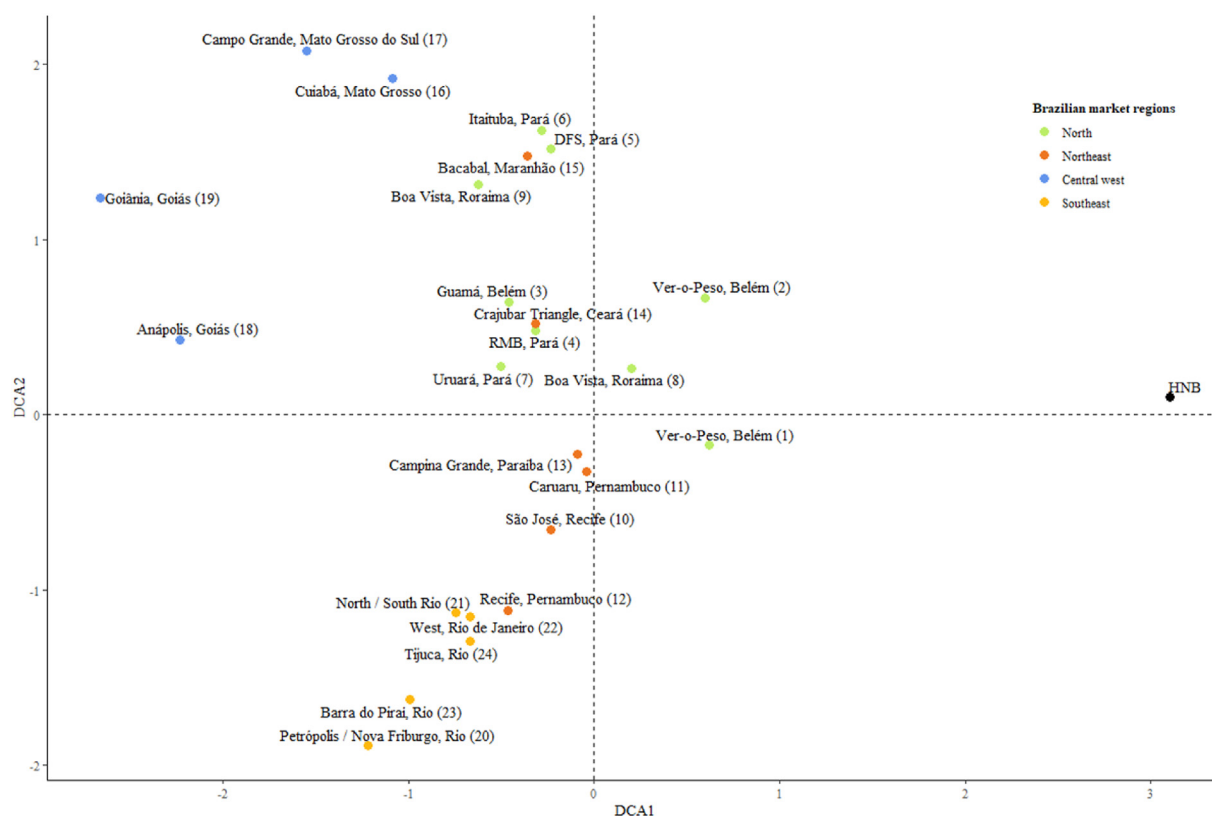


Fig. 2. DCA ordination diagram of 24 Brazilian markets and the HNB (black dot) based on presence-absence species matrix. Each dot represents a market: the closer dots are to each other, the more species they share. Axes do not represent variables, but standard deviations and serve to visualize variation and similarity in plant composition. Numbers refer to references in Table 1.

once the capital of Dutch Brazil. The greatest percentage overlap was found on the market in Uruará (Pará), where all 10 species had the same vernacular name as in the HNB, although the absolute number of vernacular names was much smaller (Table 1).

The greatest percentage overlap in vernacular names for the species in common among the HNB and the markets pooled per Brazilian region

was found with the northeast, followed by the north (Fig. 4). For all regions, the highest percentage (56%) of overlapping vernacular names was found for indigenous plant names, mostly belonging to the macro-linguistic Tupi family, except for three that belonged to Arawakan languages. Portuguese names were shared among 34% of the species in common, African or Arabic names for 15%. The remaining (6%) were

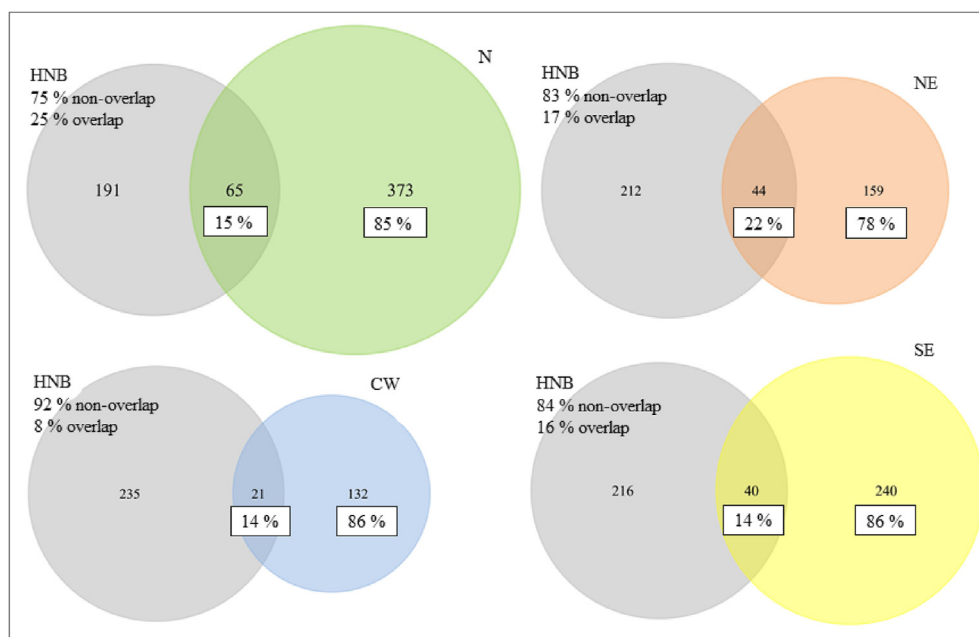


Fig. 3. Overlap in plant species (absolute numbers and percentages) between markets in the different geographic regions of Brazil (N: north; NE: northeast; CW: central west; SE: southeast) and the HNB.

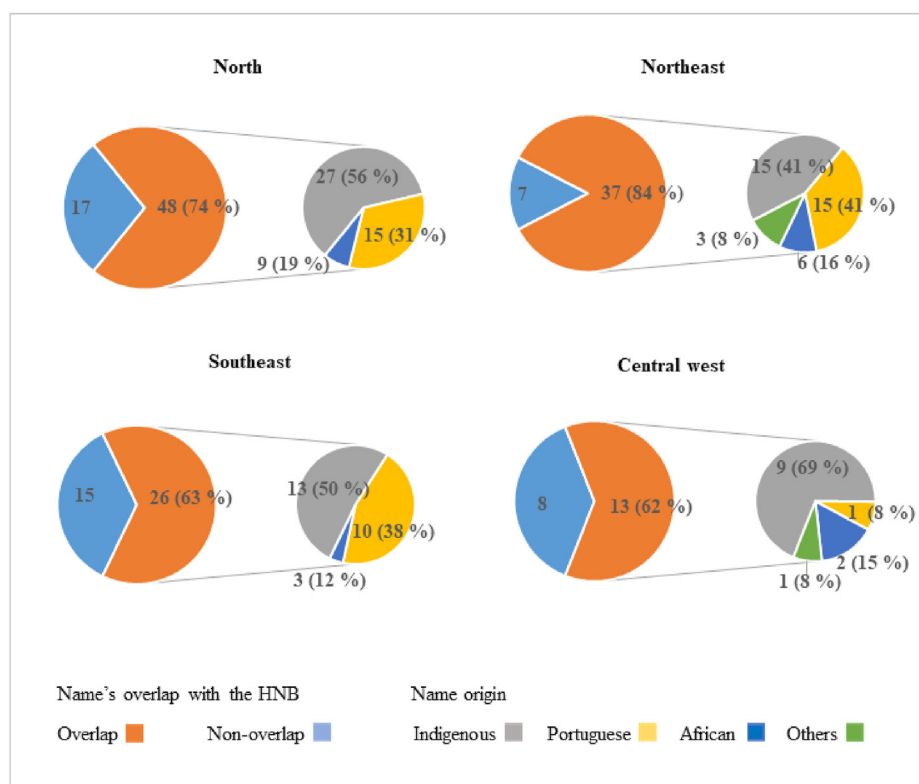


Fig. 4. Absolute and relative overlap in vernacular names between the vernacular names documented during market surveys in the different Brazilian regions and the HNB, expressed as language origins.

names that overlapped with HNB names in meaning (Supplementary Table S2).

Several plant species were documented in the HNB or the market surveys with more than one vernacular name, and sometimes names were compound by words in different languages. We found 73 vernacular names made out of two or more different languages in the 25 markets surveys, which correspond to 68 plant species of which the names overlap with those in the HNB (Supplementary Table 2).

In the north, the majority of overlapping plant names are indigenous, mostly Tupi-related (90%), while 10% are from the Arawakan linguistic family. An example of an Arawakan name is Batata for the sweet potato (*Ipomoea batatas* (L.) Lam.), while the name Batata de purga (*Operculina hamiltonii* (G. Don) D.F. Austin & Staples) is a compound name from an Arawakan word and the Portuguese term for 'purge', probably after its purgative properties (Piso, 1648: 93). Four of the African names are of Central African origin, such as Inhame (*Dioscorea alata* L.), and Quiabo (*Abelmoschus esculentus* (L.) Moench), which are Kimbundu names from Angola. The other are derived from Arabic names, such as Tamarindo (*Tamarindus indica* L.), and Alcaçuz (*Periandra mediterranea* (Vell.) Taub.) (Burkill, 1997; Barros, 2012).

In the northeast, the overlap in plant names is larger, but the proportion of indigenous and Portuguese names is the same (Fig. 4). Most of the indigenous names are Tupi-related and only Guava (*Psidium guajava* L.) has Arawakan roots (Góis and Martins, 2019). Half of the names with African roots are Afroasiatic, mostly of Arabic origin. Generally, name retentions occurred with one simple plant name per species, and therefore, in a unique language. Only few species kept two of the names reported in the HNB. *Cereus jamacaru* DC., a cactus characteristic of the Caatinga-Cerrado biome, has kept its Tupi name, written in the HNB as Iamacaru, and currently known with a slight modification as Mandacaru; but it has also retained the Portuguese name reported by Marcgrave (Cardon or Cardo), now Cardeiro.

In the central west, the relative proportion of indigenous names is the greatest and all are Tupi-related. *Mirabilis jalapa* L. was categorized

as 'others', because it was reported in the HNB by the Latin term *Mirabilis peruana* and known today as Cipó Maravilha in the market at Goiás (Carvalho, 2004), which in Portuguese means 'wonder', retaining its original meaning. In the southeast, the proportion of similar indigenous and Portuguese names are similar, while African names remain a minority, like in all regions. Plant cognates are sometimes compound names, such as the Tupi term Ambaiba in the HNB for *Cecropia hololeuca* Miq., now known as Embaúba branca in Rio de Janeiro (Maioli-Azevedo and Da Fonseca-Kruel, 2007), probably because of its leaves that are white below.

3.4. Differences in market survey methodologies

There was a large variation in the methods among the 24 market papers. While five surveys also included edible and handicraft plants (Van den Berg, 1984; Stalcup, 2000; Leitão et al., 2009; Santos et al., 2018; Pombo Geertsma, 2019), 19 studies surveyed only medicinal and ritual plants (Table 3). Tresvenzol et al. (2006) focused on the most cited plants, while Lima et al. (2011) paid more attention to plants gathered in extractive reserves. Only 15 of the 24 studies consulted botanists and/or collected herbarium vouchers, which made their identifications more reliable (Table 3). The identification methods of the nine other studies were unclear. Researchers who only interviewed vendors, asking them to free-list the specimens they sold (instead of surveying the stalls by themselves), probably ended up with smaller number of species. Although the methods of each survey may have been accurate to the specific aims of the author(s), for the purpose of our study, these possible underestimations of species richness resulted in less overlap with the HNB, which not necessarily reflected the true situation.

Table 3
Methodologies of the 24 Brazilian plant market surveys reviewed.

Market Location (Ref.) ^a	Taxa identified to species level (Total)	Indet. ^b	Fieldwork duration	Survey methods	Identification	Uses	Plant Origins and Market dynamics
Ver-o-Peso, Belém, Pará, N (Aguilar, 2018)	172 (204)	32	18 days (August 2018)	Free-listing, interviews, vouchers, own observation	Herbarium vouchers, photos, flora databases, taxonomic literature, botanical experts, by vernacular names	Medicinal, food, handicraft	Backyards of small producers, usually located in Outeiro/Mosqueiro (Belém)
Ver-o-Peso, Belém, Pará, N (Albuquerque, 1997)	158 (179)	21	18 years (1965–1983)	Own observation?	Herbarium vouchers, botanical experts, taxonomic literature	Medicinal, food, ritual, handicrafts, ornamental	Plants from N, NE, SE. 50% less species since 1965. Less vendors over time. Japanese migrants
Guamá, Belém, Pará, N (Albuquerque et al., 2007)	125 (180)	55	9 months (September 2013–May 2014)	Interview Inform consent	Herbarium vouchers, walk in the woods, photos, identification guides, vernacular names	Medicinal, magic-religious	From Ver-o-Peso, by intermediaries. cultivated (garden, backyards), wild (gathered in Pará/other states)
RMB, Pará, N (Alcantara Rodríguez et al., 2019)	129 (166)	37	10 months (January–October 2014)	Free listing, Interview. Species bought; fertile plants collected with the collector	Herbarium vouchers, macroscopic analysis (wood collection), vernacular names, botanical literature, photos	Medicinal, food, ritual-religious	Ver-o-Peso or from Cooperative, 2% cultivated, 2% collected. Migrants invigorate the local pharmacopeia
DFS, Pará, N (Altieri et al., 2012)	32 (Lima et al., 2011)	14	Nov. 2008–Sept. 2009	Free listing? Interview	Botanical literature, photographs, macroscopic analysis	Medicinal	Via intermediaries, extractivism, imported from NE
Itaituba, Pará, N (Alves, 2007)	14 (Da Costa-Pinto and Maduro, 2003)	9	Nov. 2008 May 2009	Free-listing, interview	Botanical literature, vernacular names	Medicinal	Agriculture, extractivism. Migrations adapted to the new flora, replacing/adding new plants
Uruará, Pará, N (Araújo et al., 2015)	56 (Oksanen et al., 2018)	7	Nov. 2014–March 2015	Free listing, Interviews	Photos, herbarium vouchers, botanists, botanical literature	Medicinal	Own cultivation, extractivism, brought from NE, SE. Many migrants brought their knowledge from other states
Boa Vista, Roraima, N (Balée, 1993)	105 (113)	8	January 1995 to April 1997	Interview	Botanical literature, herbarium vouchers	Medicinal	Gathered from the interior, cultivated. Many migrants (mostly NE) influenced plant diversity (many introduced). Native plants influenced by indigenous who migrated to the city.
Boa Vista, Roraima, N (Balée, 2000)	85 (99)	14	May to July 2001	Interview (questionnaire)	Herbarium voucher?	Medicinal	Heterogenous population (NE, SE, Amazonian) Mostly from other states, especially NE. Commerce organized and established, most vendors are migrants.
São José, Pernambuco, NE (Barros, 2012)	107 (164)	57	1993–1995; 2001–2002	Free listing, Interview, Own observation	Herbarium vouchers, botanical literature, wood analysis	Medicinal, magic-religious	Cultivated, gathered (Catinga, Cerrado vegetation). Strong Afro-Brazilian religion influence
Caruaru, Pernambuco, NE (Bitencourt et al., 2014)	74 (116)	42	Not specified	Free listing, Interview	Herbarium vouchers, botanical literature, botanists	Medicinal	Extractivism. Cultural selection of the plants sold
Recife, Pernambuco, NE (Bitu et al., 2015)	47 (Lima et al., 2014)	0	Not specified	Interviews	Usual tools used in taxonomy (?); species collected, analyzed and identified	Medicinal, Magic-religious	Most from Pernambuco, Mata and Agreste, few from Sertão/Serra. Gathered by intermediaries. Many vendors not knowledgeable on plant use, knowledge by intermediaries
Campina Grande, Paraíba, NE (Brandão et al., 2013)	23 (Da Silva and Alcides, 2002)	2	July 2004–February 2005	Free listing, Interview	Vernacular names, botanical literature, botanists	Medicinal	Many from extractivism (trees)
Crajabar Triangle, Ceará, NE (Burkill, 1997)	89 (Whitehead and Boesman, 1989)	1	March 2012–June 2014	Interview	Photos, herbarium vouchers	Medicinal	Many native from Cerrado (high local flora knowledge), exotics (38%)
Bacabal, Maranhão, NE (Cajaliba et al., 2016)	31 (De Oliveira et al., 2014)	0	December 2013–January 2014	Free listing, interviews	Not specified	Medicinal	Plants bought from Ceará, Piauí, and Bahia (many non-local species); very few cultivated
Cuiabá, Mato Grosso, CW (Carvalho, 2004)	108 (119)	11	September–October 2013	Interview, own observation	Not specified	Medicinal	Preference for native species (54%), mostly trees, from Cerrado: high local flora knowledge
Campo Grande, Mato Grosso do Sul, CW (Casarões and Fienes, 2019)	27 (Gibbons, 1990)	12	1992, 2002	Free listing, Interview	Herbarium vouchers, botanical literature	Medicinal	Not mentioned

(continued on next page)

Table 3 (continued)

Market Location (Ref.) ^a	Taxa identified to species level (Total)	Indet. ^b	Fieldwork duration	Survey methods	Identification	Uses	Plant Origins and Market dynamics
Anápolis, Goiás, CW (Chaddad and Jank, 2006)	37 (Leitão et al., 2009)	7	June–November 2001	Interviews, own observation	Not specified	Medicinal	Other cities/regions (via intermediaries), few cultivated. Knowledge transmitted from former vendors, family, indigenous peoples, or clients, TV, books
Goiania, Goiás, CW (Clements and Fernandes, 2013)	24 (De Azevedo and Silva, 2006)	4	Not specified	Most cited plants out of 235	Botanical experts (not specified)	Medicinal	Intermediaries, some come from other regions (e.g., Bahia). Deforestation obstructed plant collection nearby
Petrópolis, Nova Friburgo, Rio de Janeiro, SE (Correia, 1926–1984)	92 (113)	21	Not specified	Free listing, interviews, direct observation, plants bought	Botanical literature, voucher herbarium, botanists	Medicinal, food, ritual, ornamental	Cultivated, wild (50%)
North and South markets, Rio de Janeiro, SE (Cunha and De Almeida, 2000)	102 (106)	4	May 2003–June 2004	Free listing, interview, direct observation	Botanical literature, voucher herbarium, botanists	Medicinal, Ritual	Most bought in big markets, some from wild, 70% plants from Europe/Africa. Many ritual plants. Knowledge from media and oral stories
West markets, Rio de Janeiro, SE (Cunningham, 2014)	117 (127)	10	January–December 1999	Free listing, walk-in-the-woods, interview, open conversation	Botanical vouchers, analytic keys, botanists	Medicinal, Religious	Bought, cultivated, wild: mostly in Atlantic forest. Most Afro-Brazilian ritual plants.
Barra do Pirai, Rio de Janeiro, SE (Da Costa-Pinto and Maduro, 2003)	66 (94)	28	Not specified	Participant observation Walk-in-the-woods, interviews	Botanical literature, voucher herbarium, botanists	Medicinal	Most plants cultivated. Many Afro-Brazilian ritual plants
Tijuca, Rio de Janeiro, SE (Da Nóbrega-Alves et al., 2008)	145 (158)	13	August 1998–August 1999	Interview.	Botanical literature, voucher herbarium, botanists	Medicinal, magic-religious, food	Bought, cultivated, wild. Trend of urban people for 'natural' medicine. Afro-ritual plants (18%). Knowledge acquired via written and oral sources

^a Numbers refer to references in Table 1..^b Indet: Plants identified at genus or family level, or non-identified at all.

4. Discussion

4.1. Moving plants and people

We expected to find the greatest species similarities in the northeastern markets, because the HNB was mainly based on plant knowledge gathered during expeditions in Pernambuco, Paraíba, Rio Grande do Norte, and Ceará (Van den Boogaart and Brien, 2002); other regions in the northeast, such as Alagoas, Sergipe, Bahia and Maranhão, around the Itapicuru river (Von Martius et al., 1840-1906; De Sampaio and De Magalhães, 1942); and plants cultivated in the gardens of Johan Maurits in Recife (Da Silva and Alcides, 2002). As we found the greatest overlap in plant species and vernacular names in north Brazil, on the Amazonian markets of Belém and Boa Vista, we had to reject our initial hypothesis. Most matching vernacular names were found for those

belonging to the macro-linguistic Tupi family. These plant names, despite borrowings and exchanges with other ethnic groups, have remained practically unchanged over centuries -or even millennia, as those names associated to biocultural practices in the Amazon by contemporary Tupi-Guarani societies (Balée, 2000). The migrations of Tupi-speaking peoples from the northeast towards the Amazon after 1500 (Métraux, 1927; Monteiro, 1999; Neves et al., 2011) likely played an important role in these retentions, promoting a cultural continuity on plant knowledge through the maintenance of collective memory, not exempt of transformations, as occurs with cultural traits in contact zones with different populations by time (LaRocque et al., 2011; Tareau, 2019). Similarly, since the sixteenth century, European and Brazilian-born colonists had been learning about plant uses and plant names from indigenous populations. The transmissions of this corpus of plant knowledge do not necessarily reflect a northeastern origin. For



Fig. 5. *Spondias mombin* in: A. the HNB (Margrave, 1648: 129); B. the IURNM (Piso, 1658: 239); C. Marcgrave's herbarium (1638-44: 53), Botanical Garden-Univ. Copenhagen, Denmark, July 2014 (Photo: T. van Andel); D. *S. mombin* seeds sold at the Ver-o-Peso market in Belém, August 2018 (Photo: I. Pombo Geertsma).

example, cassava (*Manihot esculenta* Crantz) was cultivated in the Amazon more than thousand years ago, diversified by precolumbian migrations of Tupi-Guarani groups to northeastern regions (Gibbons, 1990; Nassar, 2002) and it was documented in the seventeenth century by the Dutch naturalists in the HNB (Marcgrave, 1648: 65; Piso, 1648: 52). These population expansions and demographic changes enabled the incorporation of indigenous, African and European plant knowledge, shaping the coastal part of Brazil as a highly multicultural place from the sixteenth century onwards and promoting the dissemination of floristic knowledge via migrations throughout the country.

The market surveys conducted in the Amazon commonly mentioned the high number of migrants from the northeast, bringing plants and associated knowledge with them (Van den Berg, 1984; Medeiros et al., 2012; Bitencourt et al., 2014; Santos et al., 2018). These movements of people and plants may be the underlying cause for the similarities in plant composition and local names with the HNB. Some species characteristic of the Caatinga, where Marcgrave and Piso worked, and the Central Brazilian Savannah, such as the cactus *Cereus jamacaru*, were found by Santos et al. (2018) on the markets around Belém. *C. jamacaru* could have been shifted from northeastern regions, where it is sold in the markets, although it also occurs in the wild in Pará (www.splink.org.br/). The introduction of new plants by migrants was also highlighted in Itaituba (Pará) by Lima et al. (2014). Certainly, human movements have influenced the flora of several regions, especially with regard to plants sold as medicine, food or as rituals in markets (De Oliveira, 2008; Pochettino et al., 2012; Van Andel et al., 2014). Markets act here as places of botanical exchange and reflect the intercultural mix caused by several populations in contact with different pharmacopeias (Tareau, 2019).

The markets in Rio de Janeiro showed considerable similarities in species composition with the HNB, comparable with some of the markets in the north and northeast. Many of these shared species, however, are exotics with European or African origin, currently cultivated for Afro-Brazilian rituals (Stalcup, 2000; Tijuca, 2000; Parente and Da Rosa, 2001; De Azevedo and Silva, 2006; Maioli-Azevedo and Da Fonseca-Kruel, 2007). Some of these plants of Old World origin (e.g., *Aloe vera*, *Cajanus cajan* (L.) Millsp., *Musa × paradisiaca* L., *Ricinus communis* L., *Zingiber officinale*) were already described by Marcgrave and Piso (1648) and Piso (1658), as they were introduced by the Portuguese and the Dutch via the transatlantic slave trade.

4.2. Different methods and resources

Even if the markets from the same region mostly shared the same biomes or environmental factors, the different methods used in the botanical surveys (Table 3) or the fact that they have been carried out in different states probably influenced the diversity of species composition (Fig. 2). Markets often share commercialized plants due to their geographical proximity (Lima et al., 2011), although other factors, such as connections with other markets and common commercial routes, influence the floristic composition as well (Santos et al., 2018). As the relative percentages of overlapping plant species and vernaculars were higher in the northeast, the small number of plants and names documented by the market studies in Pernambuco and surroundings showed great similarity with the HNB. Ethnobotanical market surveys are often considered “short lists” of a wider range of species that may be part of the market’s repertoires (Cunningham, 2014). If more funding would be dedicated to detailed markets surveys, the overlap with the HNB would probably increase. The same applies for all ethnobotanical research in Brazil to obtain more complete plant market repertoires.

4.3. Changing landscapes

Environmental factors have played an important role in our results as well. Some species are no longer sold on markets because of over-exploitation or loss of natural habitats due to deforestation or soil

degradation (Shanley et al., 2002). The high rates of deforestation and land degradation of the Caatinga, Cerrado and Atlantic Rainforest ecosystems since colonization (Myers et al., 2000; Gazzaneo et al., 2005; Sawyer, 2008; Rogers, 2010) could have caused the smaller overlap in species between northeastern markets and the HNB, as many plants sold at those markets were collected in nearby Atlantic rainforests (Table 3). *Schinus terebinthifolia* Raddi, also known as Brazilian pepper or Aroeira, and *Bowdichia virgilioides* Kunth, called Sucupira, are trees characteristic of the Caatinga and Atlantic Rainforest (www.splink.org.br/). Products from these trees are now found in Belém and Itaituba markets, brought by migrants or intermediaries from the northeastern regions, as they hardly occur naturally in the north (www.floradobrasil.jbrj.gov.br/). On the other hand, rainforest trees and palms that Marcgrave and Piso documented in the northeast in 1648 (e.g., *Caraipa densifolia* Mart., *Copaifera* sp., *Mauritia flexuosa* L.f. and *Spondias mombin* L.) were found in the markets in the north (Van den Berg, 1984; Luz, 2001; Da Costa-Pinto and Maduro, 2003; Pombo Geertsma, 2019) but not in the northeast. Although *S. mombin* has a wide distribution range, including the Atlantic coast (www.floradobrasil.jbrj.gov.br/), we did not find its fruit or medicinal bark in the market surveys from Pernambuco, Ceará, Paraíba and Maranhão. *S. mombin* was found in Belém with the names Taperebá and Cajá and reported in the HNB (Marcgrave, 1648: 129; Piso, 1658: 239) and Marcgrave’s herbarium (p. 53) under the indigenous names of Ibame-tara, Acaia, Acaja or Açaia (Fig. 5).

The loss of biodiversity due to habitat destruction in the northeast may also explain the fact that more than half of the useful plants reported in the HNB are not reported by the Brazilian market surveys. There are several useful species characteristic to the Caatinga/Atlantic biome (Giulietti et al., 2004) described in the HNB that were absent from the markets of northeastern regions, and from any of the other markets: *Abarema cochliocarpos* (Gomes) Barneby & J.W.Grimes, *Andira fraxinifolia* Benth., *Chloroleucon dumosum* (Benth.) G.P.Lewis, *C. foliolosum* (Benth.) G.P.Lewis, *Copernicia prunifera* (Mill.) H.E.Moore, *Dio-clea marginata* Benth., *Encholirium spectabile* Mart. ex Schult. & Schult.f., *Geoffroea spinosa* Jacq., *Indigofera microcarpa* Desv., *Manihot cartaginensis* subs. *glaziovii* (Müll.Arg.) Allem, and *Spondias tuberosa* Arruda. Likewise, some species now predominantly found in the Amazon (Balée, 1993), were reported in the HNB, but not found in any of the Brazilian market surveys (e.g., *Astrocaryum vulgare* Mart., *Jacaratia spinosa* (Aubl.) A.DC.).

4.4. Mega biodiverse country in a globalized world

The lack of many HNB species in the markets and the popularity of widely traded non-native species (Table 2) are likely related to the globalized plant trade. Although local markets reflect local demand, this demand is highly influenced by global economies based in agribusiness (Chaddad and Jank, 2006). This industrial model favors the homogeneity of global plant trade, which decreases plant crop diversity, and increases land grabbing to introduce monocultures (Altieri and Nicholls, 2012; Clements and Fernandes, 2013). However, HNB species not present in trade could be used for subsistence in local communities. Further research in these communities will add more insights on the presence of plant practices and knowledge as described by Marcgrave and Piso in the seventeenth century.

5. Conclusion

The *Historia Naturalis Brasiliae* reflects the flora that was used in the northeastern Atlantic Coast in the seventeenth century, under the mandate of the Dutch WIC and influenced by the Portuguese, enslaved Africans, and many indigenous groups living in the region. The HNB also carries the knowledge of all the naturalists, explorers and religious chroniclers that influenced De Laet’s work when he assembled the floristic and zoological knowledge to create this treatise. Our research

shows that the HNB not only represents the typical flora of northeast Brazil, but reflects ethnobotanical knowledge and practices with a much greater distribution range. The similarity patterns of plant composition among Brazilian markets and the HNB indicate the wider distribution and trade in the species that Marcgrave and Piso described in 1648.

The knowledge documented in the HNB can also derive from the expansion of indigenous peoples from the Amazon region into the northeast from pre-Columbian times until the 1640s. The lack of most of 'Marcgrave and Piso's plants' in current northeastern Brazilian markets could be explained by the methodological limitations in the published market surveys, but also result from the complex movements and displacements of Brazilian indigenous groups, the destruction of natural habitats due to economic interests and lack of proper social and environmental policies, and its associated globalized and homogenous plant trade. The displacement and decrease of indigenous population in Brazil, occurring since colonialism and perpetuated in the present with right-wing governmental policies (Cunha, 2000; Casarões and Flesmes, 2019), together with the destruction of the environment to fulfill economic purposes, does not favor the conservation of traditional plant knowledge among the Tupi or other indigenous groups and local communities.

Despite all odds, indigenous knowledge persists, as our study has shown with the retention of plant names derived from Tupi-linguistic family languages. The indigenous repertoire of plant knowledge and names was adopted and widely used by members of the multi-ethnic Brazilian colonial society, who expanded this knowledge in their migrations throughout the country and normalized these names into current Brazilian Portuguese vocabulary, as shown in the HNB and the market surveys. In one way or another, the HNB is a reference point in time that captures a moment of colonial cultural transformations. This body of plant knowledge, embedded in the intersection of art and science in the seventeenth century Dutch Brazil, partly remains for sale in Brazilian contemporary markets today.

Role of funding sources

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.jep.2020.112911>.

Supplementary data (Supplementary Tables S1 and S2)

Supplementary data associated with this article can be found, in the online version, at doi:

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