Overview of Invasive Plants in Natural Areas of Brazil: A Systematic Review.

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Overview of Invasive Plants in Natural Areas of Brazil: A Systematic Review.

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Abstract

Invasive plants pose biological, structural, and economic threats to the different ecosystems where they have been introduced. Historically, they exhibit high anthropogenic dispersal, whether intentional or not, and proliferate synergistically with human impacts. In Brazil, invasive plants are present in all biomes of the country. However, studies on the biology of invasive plants in Brazilian natural areas, their impacts, and management remain insufficient. To provide an overview of plant invasions in Brazil's natural areas, a systematic review was conducted of all documents that reported invasive plants in these environments. Using the world's two largest scientific databases (Web of Science and SCOPUS) and the Brazilian database (SciELO), 234 scientific documents published between 1982 and 2023 were analyzed. A total of 48 botanical families were recorded, with Poaceae and Fabaceae being the most represented in terms of invasive species. The main invasive plant species identified were *Melinis minutiflora*, *Urochloa eminii*, *Pinus elliottii*, *Leucaena leucocephala*, *Prosopis juliflora*, *Urochloa brizantha*, *Cryptostegia madagascariensis*, *Hovenia dulcis*, *Urochloa arrecta*, and *Hedychium coronarium*. The Atlantic Forest and Cerrado biomes were the regions with the highest occurrence of invasive plants. The Neotropical biogeographic region contributed the most to invasive plants in the country, highlighting the need for public policies that classify plant invasions based on a biogeographic rather than a geopolitical approach. The results consolidate a significant amount of information that supports the prioritization of future studies in the field, not only filling knowledge gaps about invasive plants in Brazil but also providing subsidies for decision-making in the conservation of natural areas.

Keywords: biological invasion; invasive plants; plant habit; Brazilian biomes; conservation.

Introduction

Biological invasions are caused by exotic species—those introduced outside their natural distribution range—which threaten different components of native populations, species communities, and ecosystems where they have been established (Simberloff et al., 2005; Simberloff & Rejmánek, 2011; Pyšek et al., 2012; Lihle et al., 2017; Sagoff, 2018; Pyšek et al., 2020). The ecological, social, and economic conflicts generated by invasive species are complex and vary according to the biology of the species and their interactions with the environments being invaded (Mack et al., 2000; Pimentel et al., 2001; Traveset & Richardson, 2006; Richardson & Pyšek, 2012; Castro-Díez et al., 2019; Shackleton et al., 2019; Monnet et al., 2020; Zenni et al., 2021). In natural environments, invasive species can impact local native biodiversity through different invasion mechanisms (i.e., interspecific competition, alteration of food webs, and changes in community successional dynamics) (Cadotte & Colautti, 2005; Simberloff & Rejmánek, 2011; Simberloff et al., 2013).

Plants constitute one of the best-known groups of invasive species (Pyšek et al., 2020). They are constantly introduced into exotic environments at a higher rate than other groups, such as animals. This occurs due to the ease with which seeds or vegetative propagules are transported by humans, both intentionally and accidentally (Bonnamour et al., 2021). Human activities generate impacts on natural environments, which invasive plants exploit to establish themselves and compete with native species for resources (Simberloff et al., 2013). Through strategies such as phenotypic plasticity, vegetative propagation, high reproduction and dispersal rates, invasive plant species increase their success and place native species at a disadvantage (Vilà et al., 2011; Keser et al., 2013; Roiloa et al., 2015). They promote processes such as altering nutrient cycling (Currie et al., 2014), suppressing native plant recruitment (Dairel & Fidelis, 2020; Barbosa et al., 2021), and releasing allelochemicals that inhibit the growth of other plant species (Patnaik et al., 2017). For these reasons, they also represent an economic problem, due to the high costs required for their management (Pimentel et al., 2001; Zenni et al., 2021) and their negative impacts on ecosystem services (Simberloff et al., 2013).

Brazil harbors important biomes within its national territory, such as the Amazon, Atlantic Forest, Cerrado, Caatinga, Pampa, and Pantanal (Flora do Brasil 2020, 2024), which together contain some of the highest biodiversity levels in the world (Myers et al., 2000). However, throughout the post-colonial period, the country has experienced numerous introductions of exotic species (Zenni, 2014; Almeida et al., 2014), whether for ornamental, commercial, or accidental cause (Mayer et al., 2017). Many of these species initially became casual, later naturalized, and eventually invasive (Richardson et al., 2000; Zenni, 2015; Xavier et al., 2021).

In this context, several studies have been conducted with different approaches, aiming to gather sufficient information to understand the characteristics of these species (Matos & Pivello, 2009; Zenni & Ziller, 2011; Dias et al., 2013; Dechoum et al., 2018) and the invasion process (Fulgêncio-Lima et al., 2021; Xavier et al., 2021). Such information is fundamental to support strategies for control, eradication, and the development of relevant public policies. However, knowledge about plant invasions remains insufficient, particularly in a country of continental dimensions and marked by numerous environmental conflicts (Frehse et al., 2016).

To address these knowledge gaps, systematic reviews have proven to be valuable tools in the study of invasive species (Qiu & Chen, 2009; Dias et al., 2013; Khapugin, 2019; Fachinello et al., 2022). By carefully analyzing existing studies, these reviews allow for the synthesis of information on patterns of occurrence, ecological impacts, and management strategies for exotic invasive species. Moreover, they assist in identifying understudied geographic areas and taxonomic groups, guiding future research and conservation policies (Pinto et al., 2020). Systematic reviews have contributed to understanding the distribution of invasive species in both urban and natural environments, as well as to developing more effective strategies for control and eradication (Khapugin, 2019; Yu et al., 2016).

The objective of this study was to provide an overview of plant invasions in Brazil's natural areas by addressing the following questions: (1) Which invasive plant species are most frequently reported in studies conducted in natural areas of Brazil? (2) What are the most common growth forms of these species? (3) Which Brazilian biomes show the highest occurrence of these species? (4) What is the origin of invasive plants in the country? (5) What is the temporal trend of publications in this field of study? (6) What are the most frequent keywords in the literature?

Materials and Methods

A database was created to compile scientific articles on plant invasions in Brazil, using journals indexed in Web of Science (WoS); SciELO, and SCOPUS.

The search strategy included the relevant terminologies (plant invasion and locality) (Table 1). Logical operators were applied: "AND" (to intersect terms), "OR" (to combine terms), and "()" (to establish search order). To enhance the search, truncation symbols were used: "*" (to retain the word root) and “?” (to substitute any letter). Searches were conducted in the title, abstract, and keyword fields across the three databases. The query was set to retrieve all articles published up to December 2023, in both English and Portuguese.

Table 1. Search combinations used for data collection in Web of Science (WoS), Scientific Electronic Library Online (SciELO), and SCOPUS.

Theme	Term	Combination
Biological scope	Invasion/Invasive/ Weed/Alien/Non-native/Non-Indígenous/Vegetal/Plant	(invas* OR daninha OR alien* OR non-indigenous OR nonindigenous OR nonnative OR non-native OR exotic* OR invader) AND (plant* OR vegetal) AND (bra?il*)
Locality	Brazil	

The reference lists of the retrieved studies were exported in .csv format and then integrated into a single table of the same format. Article eligibility criteria were applied following the recommendations of the PRISMA - 2020 (Page et al., 2021) method for systematic reviews (Box 1).

Box 1. Inclusion and exclusion criteria used to select the articles included in the database for analysis.

(a) Redundancies among references from the three databases were checked, and duplicate articles were removed using Microsoft Excel tools.
(b) Works not categorized as articles were excluded through the automatic tools of the platforms.
(c) The remaining studies were manually analyzed by reading the “title” and “abstract” fields. The following inclusion criteria were applied during this filtering: (i) studies that explored Brazilian territory; (ii) studies that considered the plant species as invasive; and (iii) studies that mentioned the invaded location.
(d) To refine the database, the following exclusion criteria were applied: (i) studies categorized as literature reviews or invasive species lists, to avoid duplicated studies; and (ii) studies primarily focused on highly disturbed environments or artificial ecosystems (e.g., crops, hydroelectric plants, water reservoirs, urban fragments, forest edges in early successional stages, riparian forests with high levels of disturbance), since the study focused on natural environments.
(e) After this filtering, the documents were grouped into two categories: (i) studies that, based on title and abstract, met the eligibility criteria: fully or partially satisfying the inclusion criteria and not exhibiting any of the exclusion criteria; and (ii) studies that, based on title and abstract, did not meet the eligibility criteria: either failing to meet any inclusion criteria or exhibiting at least one exclusion criterion.
(f) For studies that fully or partially met the inclusion criteria and did not exhibit any exclusion criteria (Group I), the following information was extracted from the main text: (a) Plant species considered invasive and (b) the biome or phytogeographic domain in which the invaded site is located. Studies that did not report this information, either directly or indirectly, were excluded from the results.

Using this information, a final database was constructed with the following categories: invasive plant species studied in each work (aimed at creating a list of the most studied species in natural areas of Brazil); botanical family; origin (to identify the biogeographic regions of invasive plant species in the country); common name in Portuguese for one or more regions of Brazil; growth form (basic pattern of plant growth); and the biome in which the invaded site is located (to establish which biomes should be prioritized for management and control of invasive plant species in Brazil). Species with natural distributions in Brazilian biomes but reported as invasive in other biomes were included under the contribution of the Neotropical region. Information such as botanical family, common name, standardization of synonyms (e.g., *Urochloa decumbens* = *Urochloa eminii*), growth form, and origin was supplemented using the Flora do Brasil 2020 platform (2024), the database of the Instituto Hórus de Desenvolvimento e Conservação Ambiental (2024), and the Global Compendium of Weeds (Randall, 2012). Scientometric data (year of publication, article keywords) were obtained from the databases themselves (WoS, SciELO, and SCOPUS). Keyword relationship analyses were generated using the VOSviewer platform (van Eck et al., 2010). Establishing relationships between publication years allows visualization of the temporal trend in invasive species research. The analysis of keyword relationships highlights the most frequent topics and knowledge gaps in studies on invasive plant species in Brazil.

Results

The database comprised documents published between 1982 and 2023. A total of 1,345 documents were found in SciELO, 2,073 in SCOPUS, and 1,925 in WoS, totaling 5,343 documents. After removing duplicate documents (868) and works not categorized as articles by the platforms (941), 3,534 studies remained. Among these, 528 documents met the inclusion criteria fully or partially and did not exhibit any exclusion criteria based on their title and abstract (Group I). Following a manual review of the full text of these studies, 234 documents met the eligibility criteria (Figure 1). The information extracted from these documents formed the final database used for the analyses in this study.

Fig. 1 PRISMA 2020 flowchart for systematic reviews including database searches.

The 234 documents reported a total of 460 records of 160 plant species. Records were found in all Brazilian biomes. A total of 48 botanical families were recognized, with Poaceae and Fabaceae being the families with the highest number of species (41 and 25, respectively). Of the 160 species, 93 were reported only once, representing 58.1% of the species and 20.2% of the records in the publications. Similarly, 30 species were studied in two documents, representing 18.8% of the total species and 13.0% of the records. Eighteen species were reported in three to five articles, accounting for 11.3% of the total species and 14.8% of the records in the publications. Conversely, only 10 species (6.25%) accounted for 36.7% of the total records in the publications and appeared in more than ten articles. All information collected for these 10 species is summarized in Table 2.

Table 2. Most studied invasive plant species in Brazil, according to a survey of academic articles published between 1982 and 2023 in Web of Science (WoS), Scientific Electronic Library Online (SciELO), and SCOPUS.

Number of studies	Species/Family	Common name (Brazil)[1]	Origin[2]	Growth form	Biome[3]
36	*Melinis minutiflora* P.Beauv. **Poaceae**	capim-catingueiro, capim-gordo, capim-gordura	Africa	Herb	Caatinga Cerrado Atlantic Forest
26	*Urochloa eminii* (Mez) Davidse **Poaceae**	braquiária-decumbens, capim-brachiaria-decumbens	East Africa	Herb	Cerrado Atlantic Forest Pampa
17	*Pinus elliottii* Engelm. **Pinaceae**	pinheiro, pinus	North America	Tree	Cerrado Atlantic Forest Pampa

15	*Leucaena leucocephala* (Lam.) de Wit **Fabaceae**	leucena	Central America	Tree	Amazon rainforest Caatinga Cerrado Atlantic Forest
14	*Prosopis juliflora* (Sw.) DC. **Fabaceae**	algaroba	Northern South America/Central America/Mexico/ Caribbean	Tree	Caatinga Atlantic Forest
14	*Urochloa brizantha* (Hochst. ex A.Rich.) R.D.Webster **Poaceae**	capim-brachiaria-brizantha, braquiária-brizanta	Africa	Herb	Caatinga Cerrado Atlantic Forest
12	*Cryptostegia madagascariensis* Bojer **Apocynaceae**	videira-de-borracha-roxa	Madagascar	Shrub	Caatinga Cerrado
12	*Hovenia dulcis* Thunb. **Rhamnaceae**	uva-japonesa, chico-magro, caju-japonês, uva-do-japão, tripa-de-galinha	East Asia	Tree	Amazon rainforest Cerrado Atlantic Forest Pampa
12	*Urochloa arrecta* (Hack. ex T.Durand & Schinz) Morrone & Zuloaga **Poaceae**	capim-tanner-grass, braquiária-do-brejo, capim-braquiária-do-brejo, braquiária-de-banhado, brachiaria-do-brejo	Africa	Herb	Amazon rainforest Cerrado Atlantic Forest
11	*Hedychium coronarium* J.Koenig **Zingiberaceae**	lágrima-de-moça, narciso, lírio-do-brejo	Asia	Herb	Cerrado Atlantic Forest

[1]Flora do Brasil 2020 (https://floradobrasil.jbrj.gov.br), Instituto Hórus (https://bd.institutohorus.org.br/); [2]Instituto Hórus (https://bd.institutohorus.org.br/), *A global compendium of weeds*. (Randall, 2012); [3] Regarding the invaded location.

Of the total species considered invasive in the publications, 83 (51.9%) have a herbaceous growth form, 45 (28.1%) are trees, and 32 (20.0%) are shrubs (Figure 2).

Fig. 2 Growth form of species considered invasive in the publications.

Regarding the origin or natural distribution of the analyzed species, species from all biogeographic regions were found (Figure 3). The largest contribution came from the Neotropical region (including Brazil), with 69 species, representing 43.1% of the total invasive species reported in the documents. The Ethiopian region contributed 26 species (16.3%), the Palearctic region 27 species (16.9%), the Oriental region 22 species (13.8%), the Australian region 10 species (6.3%), and the Nearctic region 6 species (3.8%).

Fig. 3 Contribution of biogeographic regions to the species considered invasive in the analyzed documents.

Articles were found studying plant species considered invasive in all Brazilian biomes (Figure

4), distributed as follows: Atlantic Forest (113), Cerrado (74), Caatinga (37), Pampa (15), Pantanal (6), and Amazon (5).

Fig. 4 Distribution of study sites in the articles where the species are reported as invasive.

Regarding the temporal trend of publication of the articles included in this study, 85.0% were published in the last ten years (2014–2023). During this period, the average publication rate was 19.9 articles per year. Between 2008 and 2013, the average publication rate was 4.5 articles per year. Prior to 2008, eight articles were retrieved from the period between 1982 and 2004, with no consistent annual publication pattern (Figure 5).

Fig. 5 Temporal distribution of publication of the analyzed articles.

The main keywords, appearing at least seven times in the selected documents (present in at least 3% of the selected studies), are shown in Figure 6. Most of the articles included the terms "biological invasion" (37 occurrences), "invasive species" (29 occurrences), "exotic species" (20 occurrences), "competitions" (11 occurrences), "biological invasions" (11 occurrences), "alien species" (10 occurrences), "plant invasion" (9 occurrences), and "invasive alien species" (9 occurrences), reflecting key concepts in the field of study. Regarding keywords referring to the location of the studies or the areas invaded by the species, the Cerrado biome (24 occurrences) and Caatinga (15 occurrences) stand out. The Atlantic Forest biome, which concentrates the majority of studies (Figure 4), does not appear among the listed keywords.

Fig. 6 Keyword network of the analyzed studies.

Discussion

The results indicated a considerable number of scientific documents compared to other similar studies, which limited research to terrestrial environments (Zenni, Dechoum & Ziller, 2016), did not delimit the study to a specific ecosystem (Dias et al., 2013), or even did not specify the anthropogenic state of the invaded environments (Fachinello et al., 2022). Invasive species tend to occupy human-impacted environments (Jauni et al., 2014; Dodonov et al., 2020; Sena et al., 2021) and primary stages of ecological succession following disturbances (Davis et al., 2000; Novoa et al., 2020; Weidlich et al., 2020). This study focused exclusively on invasive plant species in natural environments in Brazil. This approach highlights the invasiveness of exotic species in preserved environments (Zenni & Ziller, 2011), allowing the intrinsic competitive potential of the invader to be observed in stable environments (Fulgêncio-Lima et al., 2021).

Based on this study, *Melinis minutiflora* P.Beauv., *Urochloa eminii* (Mez) Davidse, *Pinus elliottii* Engelm., *Leucaena leucocephala* (Lam.) de Wit, *Prosopis juliflora* (Sw.) DC., *Urochloa brizantha* (Hochst. ex A.Rich.) R.D.Webster, *Cryptostegia madagascariensis* Bojer, *Hovenia dulcis* Thunb., *Urochloa arrecta* (Hack. ex T.Durand & Schinz) Morrone & Zuloaga, and *Hedychium coronarium* J.Koenig are the most important invasive plant species in natural environments in Brazil. These 10 species were studied in 169 documents as invaders of natural areas across the Brazilian biomes Amazon, Caatinga, Cerrado, Atlantic Forest, and Pampa, demonstrating their high invasiveness and the risks they pose to the economy, society, and native biodiversity.

Melinis minutiflora, *Urochloa eminii*, *Urochloa brizantha*, and *Urochloa arrecta* are native to African savannas, herbaceous in growth form, and belong to the family Poaceae (Randall et al., 2012), which is also the most represented family in our results (41 species). Poaceae occurs in almost all ecosystems worldwide and is one of the richest families among Angiosperms (Soreng et al., 2017). Their phenotypic plasticity and effective dispersal strategies make them highly successful invaders in various regions of the globe (Linder et al., 2017). They propagate by seeds or vegetatively (Lorenzi, 2008), which enhances the invasion process. These African grasses were introduced to Brazil to increase pasture productivity (Bosi et al., 2014) and quickly spread through the country's natural ecosystems, displacing native species due to their strong competitive power (Rossi et al., 2014). They increase litter biomass, which affects soil temperature and moisture, consequently altering processes such as nutrient cycling (Hoffman & Haridasan, 2008), and impacting the composition and dynamics of the seed bank (Dairel & Fidelis, 2020). In the Cerrado, where numerous occurrences of these species are reported, the accumulation of dry biomass also modifies natural fire regimes (Aires et al., 2013). These African grasses were introduced throughout the tropical Americas, including the Caribbean, and spread to occupy numerous habitats across the continent (Williams & Baruch, 2000).

Pinus elliottii is a gymnosperm tree belonging to the Pinaceae family, native to the Nearctic region (Randall et al., 2012). Like other pines, it was introduced in several South American countries and worldwide (e.g., South Africa and Australia) for timber and urban landscaping purposes (Simberloff et al., 2010). It is recognized as an invasive species in Brazil in the Cerrado grasslands (Brewer et al., 2018), Atlantic Forest restingas (Bechara et al., 2013), and coastal Pampa fields (Da Silva Rodrigues-Corrêa et al., 2017).

Leucaena leucocephala (Fabaceae) is a small tree native to Central America, widely recognized as one of the most widespread arboreal invasive species in tropical and subtropical regions (Richardson & Rejmánek, 2011). Its high reproductive capacity significantly contributes to its invasive success: the species predominantly reproduces by self-fertilization, allowing seed production even from isolated individuals (De Melo-Silva et al., 2014). In addition, it also reproduces via cross-pollination by a wide variety of generalist insects (De Melo-Silva et al., 2014). The environments most susceptible to invasion by *L. leucocephala* are those with low-acidity soils, even when degraded, explaining its occurrence along roadsides, abandoned pastures, degraded agricultural areas, rock outcrops, and sensitive ecosystems such as restingas and mangroves (Zenni & Ziller, 2011). The species was introduced in Brazil and elsewhere for forage, nitrogen-fixation potential, and timber use (Machado et al., 2020; Bageel et al., 2019). However, these introductions have caused significant ecological impacts: *L. leucocephala* forms dense clusters, monopolizes resources, and prevents the establishment of native species, negatively affecting local plant diversity (Zenni et al., 2016). Allelopathic activity also limits native plant regeneration, hindering ecological restoration (Alvim et al., 2023). Its presence in Brazilian natural areas, particularly in already compromised biomes like the Atlantic Forest and Cerrado, is therefore concerning.

Prosopis juliflora is a xerophytic tree capable of adapting to resource-poor environments (Patnaik et al., 2017). Belonging to the Fabaceae family, it is naturally distributed in Mexico, Central America, and northern South America (Randall et al., 2012). *P. juliflora* was introduced in northeastern Brazil for timber production and spread along the coastal zones of Caatinga and Atlantic Forest (De Andrade et al., 2010). It tolerates a wide range of climatic conditions such as temperature and humidity, exhibits rapid vegetative growth, and releases allelopathic substances (Patnaik et al., 2017). Besides its threat in Brazil, *P. juliflora* is also a major invader in Ethiopia (Sintayehu et al., 2020), Kenya (Swallow & Mwangi, 2008), and Middle Eastern countries (Hussain et al., 2021).

Cryptostegia madagascariensis is a shrub or climbing species, used as an ornamental plant, for rubber production, and biofuel generation from biomass. This exotic invader colonizes savannas and riparian forests, forming dense populations, especially in disturbed areas near rivers and close to the native palm *Copernicia prunifera* (carnaúba) (Araújo et al., 2017). It relies on neighboring plants, covering their canopies and generating intense shading, which can lead to their death (Araújo et al., 2017). This impact is particularly evident on palms in the Caatinga. Under its canopy, no recruitment of native species or its own seedlings occurs. Shading and allelopathic compound release inhibit establishment of other species, significantly reducing plant diversity in invaded areas (Araújo et al., 2017). A study in the Caatinga indicated that the invader can alter arbuscular mycorrhizal composition to its advantage (Souza et al., 2016). *C. madagascariensis* competes directly with *C. prunifera*, reducing its occurrence. The carnaúba palm has high socioeconomic importance, providing income through handicrafts and other products, closely tied to rural community livelihoods (Vieira et al., 2004).

Hovenia dulcis is a deciduous tree native to Asia (China, Japan, and Korea), occurring as an occasional component of the intermediate stratum in oak deciduous forests (Randall, 2012). Beyond Brazil, it is considered invasive in countries such as Tanzania, Paraguay, and Argentina (Randall, 2012). In Brazil, it invades forests (secondary strata and gaps), roadsides, and vacant lots (Gerber et al., 2018). Its uses include ornamental purposes, windbreaks, shading for poultry and pig pens, and consumption of the fruit peduncle for sweets, jams, and honey. *H. dulcis* competes with native species for space, light, and nutrients, reducing resource availability (Dechoum et al., 2014). In Araucaria forests, it occupies the upper stratum, gradually replacing characteristic mature-phase species such as cedar, cinnamon trees, *Canjerana*, *Ipê*, and *Miguel-pintado* (Gerber et al., 2018). Currently, it is considered one of the most aggressive exotic invaders in the Uruguay River basin, especially in Seasonal and Mixed Ombrophilous Forests (Lazzarin et al., 2015).

Hedychium coronarium is a rhizomatous herb native to humid forest understories of Nepal (Himalaya region), India, and Indonesia (Randall, 2012). In Brazil, it invades marshes, wetlands, and forest understories, being highly adapted to lake margins, water bodies, channels, and shallow streams (Chiba De Castro et al., 2016). It is considered invasive in several countries, including South Africa, Samoa, Cook Islands, Micronesia, Fiji, French Polynesia, New Caledonia, Australia, Hawaii, Galápagos Islands, Cuba, and Japan (Randall, 2012). Ecological impacts include the release of toxic compounds affecting competitors and associated organisms, altering trophic dynamics in invaded aquatic ecosystems. Dense clumps hinder or prevent ecological succession of native vegetation in wetlands and forest understories (Chiba De Castro et al., 2016).

The study included documents that considered a plant species as invasive, without evaluating the definition of “invasive species” used. It is important to emphasize that many documents do not provide clear definitions of biological invasions, present little theoretical-ecological basis to classify a species as invasive, and/or consider a species invasive merely because it is exotic (Fachinello et al., 2022). The lack of clear definitions generates knowledge gaps in biological invasion studies, hindering communication and mapping of research on invasive species (Pereyra, 2016). For example, Moraes & Leal (2015) consider *Habenaria repens* Nutt. (Orchidaceae) invasive due to its broad distribution in the Neotropics. Being an orchid, *H. repens* has a highly specific niche in natural communities (Ackerman, 2015; García-González et al., 2018) and, like many Orchidaceae groups, is part of species complexes often resulting from natural hybridization, possibly making it non-invasive as described (Lau et al., 2021).

In this study, herbaceous species were the most frequent among invasive plants (51.9%), followed by arboreal (28.1%) and, to a lesser extent, shrub species (20.0%). These results differ from Zenni, Dechoum and Ziller (2016), who found that for invasive plants across all terrestrial environments in Brazil (regardless of disturbance level), arboreal species predominated (65.3%) over shrubs (2.8%) and herbaceous species (31.9%), including lianas and pteridophytes. Conversely, Weidlich et al. (2020) report a higher proportion of invasive herbaceous plants in ecological restoration areas. Native herbaceous species contribute to natural ecological succession (Kozera et al., 2020), and when replaced by invaders, can alter nutrient cycling (Chiba de Castro et al., 2019), release allelopathics (Barbosa et al., 2008), and affect recruitment of arboreal and shrub species (Barbosa et al., 2021). Habit variability also helps understand the dispersal potential of invasive plants (Rojas et al., 2019). Understanding the implications of higher proportions of invasive herbaceous plants is important for establishing ecological restoration and conservation protocols.

An asymmetric distribution of studies across Brazilian biomes was observed. The number of vegetation invasion records is higher in the Atlantic Forest, Cerrado, and Caatinga compared to the Amazon, Pantanal, and Pampa. This aligns with previous studies (Dias et al., 2013; Frehse et al., 2016; Dechoum et al., 2021) showing that invasive species studies in Brazil concentrate in the Southeast and South regions, mainly covering the Atlantic Forest and Cerrado. This variation can be explained by the proximity and higher number of research institutions, environmental agencies, universities, and road access facilitating visits to these areas (Young & Larson, 2011). Remote areas like the Central Amazon require external factors, adequate funding, and infrastructure for study (Wilson et al., 2007).

A critical point identified is the discrepancy between the most studied biomes and keywords used in articles. Despite the Atlantic Forest having the highest number of invasion records, the term “Atlantic Forest” does not appear among the most frequent keywords, unlike terms such as “Cerrado” and “Caatinga.” This may relate to inconsistent indexing practices by authors and journals, reducing visibility and systematic retrieval of scientific information (Derbyshire et al., 2023). Well-defined keywords are essential for organizing knowledge, especially in interdisciplinary and strategic fields such as biological invasions, where quick access to information supports environmental management and policy-making (Wilson et al., 2007; Zenni & Ziller, 2011). In Brazil, specifying the affected biome in keywords allows identification of vulnerable areas and a coherent overview of scientific efforts across regions (Dechoum et al., 2021; Zenni et al., 2016). Lack of keyword standardization may underrepresent certain ecosystems in specialized literature even if they are heavily studied. Thus, good editorial and research practices are reinforced, including controlled vocabulary and precise geographic and ecological descriptors, promoting transparency, accessibility, and effective biodiversity conservation and management actions (Soto et al., 2024).

Our results show that the Neotropical region contributes the highest number of invasive plants in Brazil. Climate, anthropogenic flows, and invasive species strategies largely explain invasion processes in tropical regions (Irl et al., 2021). Similarity between invaded environments and the species’ native habitat contributes to invasion success (Rejmánek et al., 2005; Jaksic & Castro, 2021). Weak customs enforcement across South America facilitates the dispersal of potentially invasive species to Brazil (Oliveira & Machado, 2009). Internal flows from other Brazilian biomes may also drive new plant invasions (Davis et al., 2009). Additionally, tropical species have specific physiological traits and faster growth rates than temperate species (Kleunen et al., 2010), possibly explaining the lower number of invasive species from temperate regions.

The findings reinforce the need for public policies defining plant species classifications (native, exotic, or invasive) based on biogeographic perspectives. Delimitations should reflect species reality, such as natural barriers or distant phytogeographic regions and ecoregions, disregarding political boundaries (Bevilaqua, 2013). Brazil’s large geographical extent and diverse climates (Cavalcanti, 2016) encompass contrasting phytogeographic regions, from dense forests like the Amazon to semi-arid areas like the Caatinga (IBGE, 2012). Several species considered native to one biome are invasive in another, e.g., the allelopathic *Clitoria fairchildiana* R.A.Howard, native to the Amazon and invasive in the Atlantic Forest (Xavier et al., 2021), and *Vochysia divergens* Pohl, native to the Amazon Basin and invasive in the Pantanal (Haase & Haase, 1995; Dalmolin et al., 2012; Dalmagro et al., 2013).

Temporal publication trend analysis shows substantial growth in studies on invasive plants in Brazil’s natural areas, particularly from 2014 onwards, contrasting previous periods. This expansion aligns with the consolidation of biological invasions as a significant field within biological and environmental sciences (Simberloff et al., 2013; Pyšek et al., 2020). In recent decades, conceptual and methodological maturity has been driven by research networks, increased funding, and inclusion of the topic in public policy and conservation agendas (Dechoum et al., 2021). Growing concern about ecological, economic, and social impacts of invasive species has further stimulated scientific interest, especially in highly anthropized biomes (Fachinello et al., 2022). The COVID-19 pandemic (2020–2022), although initially limiting fieldwork, appears not to have reduced scientific output; instead, it may have encouraged reviews, data analyses, and theoretical reflections, maintaining or accelerating publications (Li et al., 2025). The absence of consistent publications in earlier decades (1982–2004), with only eight retrieved articles, indicates the topic was nascent in Brazilian academia, often embedded within broader ecological or conservation studies. The recent growth highlights greater specialization and institutionalization of biological invasion research in Brazil, essential for effective prevention, control, and management policies (Dechoum et al., 2021).

Conclusions

The results consolidate a substantial amount of information that can contribute to the prioritization of future research in the field. Identifying which species are invasive in a given region can help establish priority zones for conservation (Novoa et al., 2020; Weidlich et al., 2020). Similarly, knowledge of the origins of invasive species can aid in their identification during environmental inspections, especially in transit areas where introductions may occur. The large number of invasive plants reported in Brazil poses a significant challenge for researchers, managers, and public agencies (Abrahams et al., 2019; Bonnamour at al., 2021). Collaboration among these stakeholders is essential to create robust and sophisticated knowledge bases, compendia, and national or regional catalogs, as well as effective mechanisms for environmental monitoring to prevent the establishment of invasive species in the country.

Finally, this study demonstrates the importance of systematic reviews and scientometric analyses for synthesizing knowledge, in this case regarding plant invasions in Brazil. In addition to the extensive coverage of academic articles in the WOS and SCOPUS databases, the use of regional databases (Khapugin et al., 2019) such as SciELO should also be encouraged. Although these may have smaller coverage, they often provide more region- or country-specific information.

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