Exotic invasive flora evaluation on different environments and preservation conditions from a caatinga area, Petrolina, PE

Jasciane da Silva Alves[1], Juliano Ricardo Fabricante[2]

1 Federal University of Vale do São Francisco, Petrolina, Pernambuco, Brazil.
2 Federal University of Sergipe, Itabaiana, Sergipe, Brazil
** Corresponding author: jasciane.alves@outlook.com*

Recebido em 14 de maio de 2018. Aceito em 29 de julho de 2019. Publicado em 05 de agosto de 2019.

Abstract - Biological invasions are increasingly common worldwide due to continuous transformations that environments have been undergoing. Thus, this study aimed to catalog the exotic invasive species from different environments at the Agricultural Sciences Campus from the Federal University of Vale do São Francisco, Petrolina-PE and to measure the distribution of the species diversity in the evaluated environments. The study area was initially divided into six environments. By walking through them (active search), all exotic invasive species were collected and herborized. Overall, 29 species were sampled, distributed into 16 genera and 12 families. From all catalogued species, 18 were herbs, four trees, four climbing plants and three bushes. Regarding their origin, 13 were from African continent, one from Europe, two from Asia, two from India, one from Madagascar and four from Central America. Some species still have natural occurrence at more than one continent. The ruderal environments showed greater similarity to each other, with a percentage of exotic invasive species in common, equal or greater than 75%. This study suggests that modified environments (degraded) facilitate biological invasions.

Keywords: Anthropic Action; Bioinvasion; Steppe Savanna.

Avaliação da flora exótica invasora em distintos ambientes e condições de conservação de uma área nos domínios da caatinga, Petrolina, PE

Resumo - As invasões biológicas são cada vez mais comuns em todas as partes do mundo devido as continuas transformações que os ambientes vêm sofrendo. Assim, o presente trabalho teve como objetivo inventariar as espécies exóticas invasoras que ocorrem em distintos ambientes do Campus de Ciências Agrárias da Universidade Federal do Vale do São Francisco, Petrolina-PE e ponderar sobre a distribuição da riqueza de espécies exóticas invasoras nos ambientes avaliados. A área de estudo foi inicialmente dividida em seis ambientes. Por meio de caminhadas (busca ativa) por esses ambientes, todas as espécies exóticas invasoras foram coletadas e herborizadas. Ao todo foram amostradas 29 espécies, distribuídas em 16 gêneros e 12 famílias. Do total de espécies inventariadas, 18 eram ervas, quatro árvores, quatro trepadeiras e três arbustos. Em relação à origem das espécies, 13 eram do continente africano, uma da Europa, duas da Ásia, duas da Índia, uma de Madagascar e quatro da América Central. Algumas espécies ainda possuem ocorrência natural em mais de um continente. Os ambientes ruderais apresentaram uma maior similaridade entre si, com uma porcentagem de espécies exóticas invasoras em comum, igual ou superior a 75%. Esse estudo sugere que ambientes modificados (degradados) são facilitadores das invasões biológicas.

Palavras-chave: Ação Antrópica; Bioinvasão; Savana Estépica.

Evaluación de la flora exótica invasora en distintos ambientes y condiciones de conservación de un área en los ámbitos de la caatinga, Petrolina, PE

Resumen - Las invasiones biológicas son cada vez más comunes en todas partes del mundo debido a las continuas transformaciones que han sufrido los ambientes. Así, el presente trabajo tuvo como objetivo inventariar las especies exóticas invasoras que ocurren en distintos ambientes del Campus de Ciencias Agrarias de la Universidade Federal do Vale do São Francisco, Petrolina-PE y reflexionar sobre la distribución de la riqueza de especies exóticas invasoras en los ambientes evaluados. El área de estudio fue inicialmente dividida en seis ambientes. Por medio de caminatas (búsqueda activa) por esos ambientes, todas las especies exóticas invasoras fueron recolectadas y herborizadas. En total fueron muestreadas 29 especies, distribuidas en 16 géneros y 12 familias. Del total de especies inventariadas, 18 eran hierbas, cuatro árboles, cuatro trepadoras y tres arbustos. En cuanto al origen de las especies, 13 eran del continente africano, una de Europa, dos de Asia, dos de India, una de Madagascar y cuatro de Centroamérica. Algunas especies todavía tienen ocurrencia natural en más de un continente. Los ambientes ruderales presentaron una mayor similitud entre sí, con un porcentaje de especies exóticas invasoras en común, igual o superior al 75%. Este estudio sugiere que los ambientes modificados (degradados) son facilitadores de las invasiones biológicas.

Palabras clave: Acción Antrópica; Bio invasión; Sabana estépica.

Introduction

Biological invasions are increasingly common worldwide due to continuous transformations that environments have been undergoing (Chaffin et al. 2016). This global phenomenon has caused serious effects over biodiversity and different society sections (Vitousek et al. 1996). According to Pimentel et al. (2001), biological invasions result in a loss corresponding to 5% of global economy.

The success of a species into biological invasion process requires dispersion, establishment and survival (Kolar and Lodge 2001). Opportunities are introduced mostly by human interference in natural environments, either by intentional or accidental introduction, as well as by changes in the physical environment (Kolar and Lodge, 2001; Pimentel et al. 2001).

Among the theories that explain a successful biological invasion, the one that stands out is the environment characteristics (Hobbs and Huenneke 1992). According to Ziller (2001), degraded environments with low diversity are more susceptible to invasion by exotic species, since these sites have vague ecological niches. Therefore, ruderal environments, for example, harbor a high diversity of alien invasive species (Vila and Pujadas 2001). In contrast, preserved environments with high biodiversity work as a barrier to alien species (Fine 2002; Vitule and Prodocimo 2012).

Land use, combined to socioeconomic factors, directly influence the introduction and propagation of exotic species (Jenkins 1996). In the Brazilian semi-arid region, extensive cattle farming, shifting agriculture and logging are the main ways of degradation and biodiversity loss (Andrade et al. 2010).

A total of 205 exotic invasive species occur in the Caatinga biome (Almeida et al. 2014), however, studies on biological contamination are still scarce in this region, despite increasing last years (Andrade et al. 2009; Andrade et al. 2010; Gonçalves et al. 2011; Fabricante and Siqueira-Filho, 2012a; Fabricante et al. 2013; Fabricante et al. 2016; Pegado et al. 2006; Sousa et al. 2016). It is worth highlighting that most of the studies are intended to some exotic invasive species, being rare to map exotic flora from a certain place.

In this scenario, this work aimed to catalog exotic invasive species that occur on different environments at the Agricultural Sciences Campus of the Federal University of Vale do São Francisco, Petrolina-PE, and to measure the distribution of the species diversity in the evaluated environments.

Material and Methods

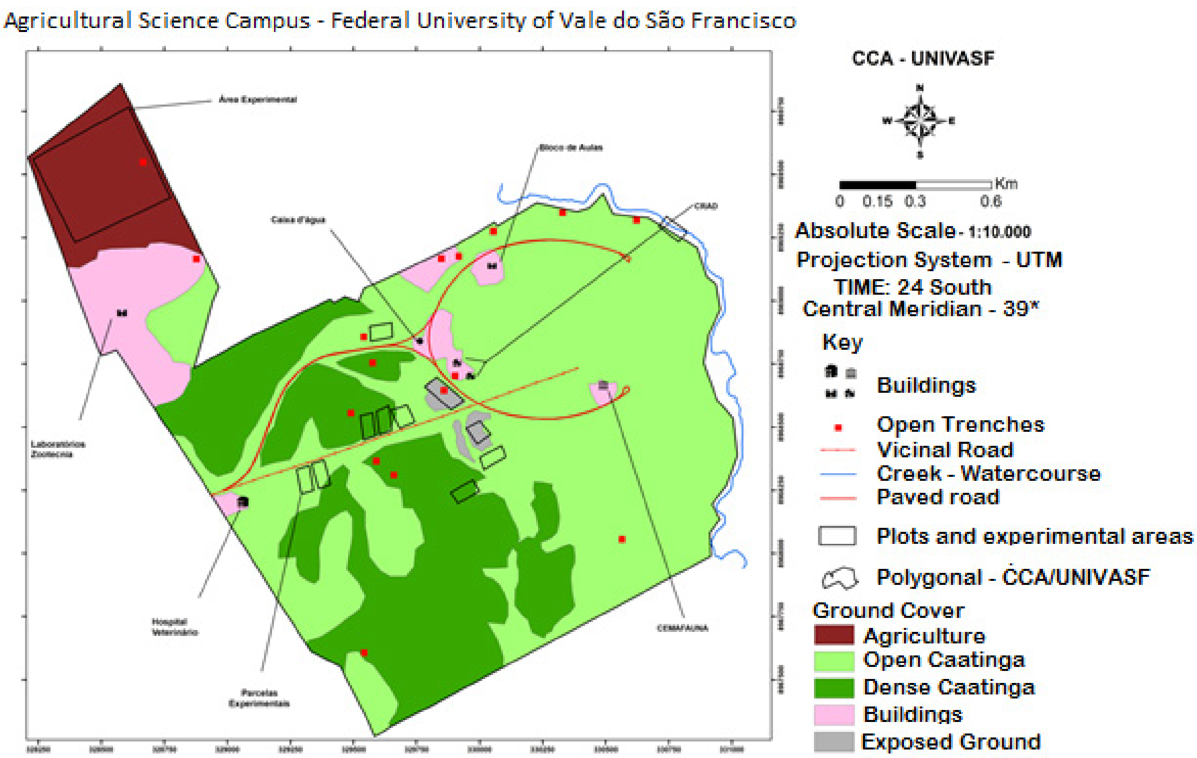
Study site

The research was performed at the Agricultural Science Campus from the Federal University of Vale do São Francisco (UNIVASF) Petrolina, PE (9º19'44,2" S and 40º33'30,1" W), experimental area corresponds to 3.6 km² (Figure 1), from October 2016 to January 2017. The region climate is Bsh (Hot semi-arid climate) according to the Koppen-Geiger classification, with seven to eight dry months, 612 mm of annual precipitation and 26.3 ºC of average temperature (Leal et al. 2003).

The predominant soils are Quartzarenic Neosols and the vegetation is Forested Steppe Savanna (Ta) (IBGE 1992), under different conservation conditions (Souza et al. 2013b).

The Agricultural Sciences campus was built in an area donated by the São Francisco and Parnaíba Valley Development Company (Codevasf) (UNIVASF 2017). There was partial removal of native vegetation, during the campus construction, leaving only fragments of its original vegetation, distributed irregularly (Souza et al. 2013b).

Figure 1. Agricultural Science Campus from the UNIVASF.



Methodology

Initially the study area was divided into six different environments, namely: Environment 1: ruderal environments (roads and trails); Environment 2: ruderal environments (constructions); Environment 3: ruderal environments (agricultural sites - environments with crops and animal husbandry); Environment 4: preserved natural Caatinga sites (Caatinga areas in intermediary/advanced stage of ecological succession - characterized by bushes and trees predominance); Environment 5: degraded Caatinga sites (Caatinga areas on initial stage of ecological succession - characterized by herbs and bushes predominance); Environment 6: Ciliary environments and floodplain.

Active searches were conducted and all exotic invasive species were collected, then herborized and deposited at the herbarium of the Nucleus of Education and Environmental Monitoring (NEMA). The taxonomic classification was made according to APG III System (2009) and the authors name spelling according to the List of Species of the Brazilian Flora (2017).

It was considered to be an exotic invasive those species that are able to reproduce in an effective way to maintain a viable population, and that is able to disperse for areas far from its original introduction location and to establish there, invading the new region (Moro et al. 2012). This classification was done through field observations and consulting to scientific articles (Almeida et al. 2014; Fabricante et al. 2015; Fabricante and Siqueira-Filho 2012b; Horowitz et al. 2013), as well as consulting databases on the subject (Bionet-Eafrinet 2017; Cabi 2017; I3N Brasil 2017; ISSG Global Invasive Species Database 2017). The species were also classified according to their habit (herbs, bushes, climbers and trees) and to their origin. In order to realize this last one, the same listed above databases were consulted.

To evaluate the floristic similarity between the environments, the Jaccard coefficient (Sj) was used (Müller-Dombois and Ellemberg 1974), and the evaluation of clusters adjustment degree was verified by the Cophenetic Correlation Coefficient (ccc), as proposed by Sokal and Rohlf (1962). The cluster method used was the *Arithmetic Average Clustering* (Sneat and Sokal 1973). An analysis of Non-Metric Multidimensional Scheduling was also performed (NMDS) (Melo and Heep 2008).

Results and Discussion

Overall, 29 species were sampled, distributed in 16 genera and 13 families (Table 1). The Poaceae family was the most representative with 13 species (44.8%), followed by Cucurbitaceae with three species (10.3%) and Apocynaceae and Fabaceae, both with two species (6.8%). The other families were represented by a single species (3.4%).

The high representativeness of the families Poaceae and Fabaceae is common in surveys of exotic flora (Almeida et al. 2014; Fabricante et al. 2015; Fabricante et al. 2012b; Horowitz et al. 2013) although in a survey of exotic trees, the number of species are well distributed among all families (Santana and Encinas 2008). However, because they are tree, it excludes grasses that have the greatest representativeness in the other studies.

Table 1. Exotic invasive species list sampled at Agricultural Sciences Campus from Federal University of the São Francisco Valley (UNIVASF).

Family	Species	Origin	Habit	Voucher
Amaranthaceae	*Amaranthus viridis* L.	Central America	Herb	4482
Apocynaceae	*Calotropis procera* (Aiton) W.T.Aiton	Africa and Asia	Shrub	4476
	Catharanthus roseus (L.) Don	Madagascar	Subshrub	4480
Asteraceae	*Emilia sonchifolia* (L.) DC. ex Wight	Africa and Asia	Herb	4484
Convolvulaceae	*Ipomoea wrightii* A.Gray	Americas	Climbing Plant	2404
Cucurbitaceae	*Citrullus vulgaris* Schrad.	Africa	Climbing Plant	4487
	Cucumis melo var. *momordica* (Roxb.) Cogn.	Africa	Climbing Plant	4498
	Momordica charantia L.	Africa and Asia	Climbing Plant	4488
Cyperaceae	*Cyperus rotundus* L.	India	Herb	4499
Euphorbiaceae	*Ricinus communis* L.	Africa	Shrub	4496

Family	Species	Origin	Habit	Voucher
Fabaceae	*Leucaena leucocephala* (Lam.) de Wit	Central America	Tree	4490
	Prosopis juliflora (Sw.) DC.	America	Tree	4489
Meliaceae	*Azadirachta indica* A.Juss.	Asia	Tree	4479
Myrtaceae	*Psidium guajava* L.	Central America	Tree	4495
Nyctaginaceae	*Boerhavia diffusa* L.	India	Herb	4491
Oxalidaceae	*Oxalis corniculata* L.	Europa	Herb	4497
Poaceae	*Aristida adscensionis* L.	Africa	Herb	4481
	Cenchrus ciliaris L.	Africa, India e Indonesia	Herb	4478
	Cenchrus echinatus L.	Central America	Herb	4486
	Cynodon dactylon (L.) Pers.	Africa	Herb	4501
	Dactyloctenium aegyptium (L.) Willd.	Africa	Herb	4485
	Digitaria ciliaris (Retz.) Koeler	Asia	Herb	4494
	Enneapogon cenchroides (Roem. and Schult.) C.E. Hubb.	Africa	Herb	4493
	Eragrostis tenella (L.) P.Beauv. ex Roem. and Schult.	Africa	Herb	4483
	Eragrostis ciliaris (L.) R.Br.	Africa	Herb	4500
	Melinis repens (Willd.) Zizka	Africa	Herb	4477
	Sorghum bicolor subsp. *Arundinaceum* (Desv.) de Wet & J.R.Harlan	Africa	Herb	4492
	Tragus berteronianus Schult.	Africa	Herb	4503
	Urochloa mollis (Sw.) Morrone & Zuloaga	Africa	Herb	4502

The high representativeness of the families Poaceae and Fabaceae suggest the existence of a pattern when certain families are present in surveys with exotic invasive flora. Grasses, for example, have several invasive species across the country, especially the species that are used as forage (Matos and Pivello 2009). This type of purpose is the main cause for this family to dominate invasions in relation to others (Almeida et al. 2014).

In general, exotic invasive plants are introduced because of some economic value characteristics (Pegado et al. 2006). The drought resistance, the facility to establish (William and Baruch 2000) and the large biomass production in dry seasons led to the introduction of these species in the country (D'Antonio and Vitousek 1992; Williams and Baruch 2000); However, these same characteristics, combined to other attributes such as anemochory and large seed production, make these potential invasive species, for example *Cenchrus ciliaris* L. (Williams and Baruch 2000; Ziller 2001).

In this research, was sampled 10% of the total exotic invasive species found by Almeida et al. (2014) in a compilation of data evaluating the profile of exotic invasive species from Caatinga flora. This number becomes significant when considers the scales used by both studies: the experimental area corresponds to 3.6 km², while the total area of the Caatinga is equal to 800,000 km² (Almeida et al. 2014).

Almeida et al. (2014) do not list eight species: *Catharanthus roseus* (L.) Don, *Cenchrus echinatus* L., *Citrullus vulgaris* Schrad., *Cucumis melo* var. *momordica* (Roxb.) Cogn., *Emilia sonchifolia* (L.) DC. ex Wight, *Eragrostis ciliaris* (L.) R.Br., *Eragrostis tenella* (L.) P.Beauv. ex Roem. and Schult, *Urochloa mollis* (Sw.) Morrone & Zuloaga. By then, only

Catharanthus roseus, *Cenchrus echinatus* and *Eragrostis tenella* were listed in other surveys in the region (Fabricante et al. 2015; Fabricante and Siqueira-Filho 2012b).

From the catalogued species, 19 were sampled by Fabricante et al. (2015). The proximity among the areas should be the main reason for the high species number in common, added the fact that most of the species are widely distributed in the Brazil Northeaster and many in whole country (List of Species of the Brazilian Flora, 2017).

The exotic species diversity observed was similar to that found by Fabricante et al. (2015) in a survey performed in São Francisco river islands, which was superior to the values found in other similar works (Martins et al. 2007; Santana and Encinas 2008). However, it was lower than that found in a floristic catalog realized under the São Francisco River Integration Project (PISF) (Fabricante and Siqueira-Filho, 2012b).

From total catalogued species, 18 were herbs (62%), four were trees (13.8%), four were climbing plants (13.8%) and three were bushes (10.4%) (Table 1). The high representativeness of herbaceous plants was also observed in similar studies carried out in the São Francisco valley region (Fabricante et al. 2015; Fabricante and Siqueira-Filho 2012b). This high representativeness may be related to anthropic activities developed in the region for pasture production, since most of them are used as forage.

Regarding the species origin, 13 are from the African continent (44.8%), from that 76% were grasses. African grasses were introduced in Brazil aiming pasture farming (Pivello 2011), however, they often naturalize and propagate rapidly and widely (Parsons 1972). The species from this plant group are considered extremely aggressive and great competitors (Martins et al. 2007), have higher photosynthetic rates and better uses of resources, especially in arid and semi-arid ecosystems (D'Antonio and Vitousek 1992). The grasses aggressiveness from African continent is superior when compared to other continents (e.g. Asia), probably due to differences in biophysical conditions among the continents, not allowing an uncontrolled expansion, as with the African ones (Pivello 2011)

For the other species, four have their origin in Central America, two in Asia, two in India, one in Madagascar and one in Europe. Some species still have a natural occurrence in more than one continent such as *Calotropis procera* (Aiton) W.T.Aiton, *Emilia sonchifolia* (L.) DC. Ex Wight and *Momordica charantia* L. occurring in Africa and Asia, *Cenchrus ciliaris* L. in Africa, India and Indonesia and *Ipomoea wrightii* A.Gray and *Prosopis juliflora* (Sw.) DC., in the Americas (Table 1).

At first, the exotic species introduction was associated with agricultural and forestry needs, however, the ornamental plants business is responsible for the most widely disseminated species around the world (Ziller 2001; Binggeli 2001). Over time, about 50% of recorded situations from ornamental plant introduction have become exotic invasive species (Binggeli 2001). Human activities are considered to be responsible for species introduction into new locations, whether accidental or intentional (D'Antonio and Vitousek 1992).

The reason for the Brazilian introduction of the species sampled in this work is quite variable. Species such as Cenchrus ciliaris L., Prosopis sp., Leucaena leucocephala (Lam.) de Wit. and Sorghum bicolor subsp. Arundinaceum (Desv.) from Wet & J.R.Harlan were brought to be used as forage (Evangelista et al. 2005; Rodrigues et al. 2004; Vasconcelos et al. 2012), Psorium guajava L. was brought for agricultural use (Siqueira et al. 2012), others, such as Catharanthus roseus (L.) Don, Azadirachta indica A.Juss., Cynodon dactylon (L.) Pers., for use in landscaping (Christoffoleti and Aranda 2001; Menezes and Hardoim 2013, Souza et al. 2013a). There are still examples of species that were probably introduced accidentally, as Enneapogon cenchroides (Roem. and Schult.) C.E. Hubb. (Silva et al. 2013).

The ruderal environments presented the highest number of species. Environment 2 (buildings) presented 27 species from the total (89.6%), while Environment 1 (roads and trails) and Environment 3 (agricultural sites) presented 23 species each (79.3%). Environments 5 (degraded Caatinga sites) and Environment 6 (ciliary environments and floodable sites) presented 13 and 15 species (44.8% and 51.7%), respectively (Table 2). *Cenchrus ciliaris and Enneapogon cenchroides* are present in all environments, while *Azadiracthta indica, Digitaria ciliaris* and *Ipomoea wrightii* were sampled in a single environment each.

Table 2. Exotic Invasive species sampled at Agricultural Science Campus from the Federal University of Vale do São Francisco (UNIVASF) per environment. Being: Environment 1 - ruderal environments (roads and trails); Environment 2 - ruderal environments (constructions); Environment 3 - ruderal environments (agricultural sites); Environment 4 - preserved Caatinga sites; Environment 5 - degraded Caatinga sites; Environment 6 - Ciliary environments and floodplain sites.

Species	Environments					
	1	2	3	4	5	6
Amaranthus viridis L.	1	1	1	0	1	1
Aristida adscensionis L.	1	1	1	0	1	1
Azadirachta indica A.Juss.	0	1	0	0	0	0
Boerhavia diffusa L.	1	1	1	0	0	1
Calotropis procera (Aiton) W.T.Aiton	1	1	1	0	1	0
Catharanthus roseus (L.) Don	0	1	0	0	0	0
Cenchrus ciliaris L.	1	1	1	1	1	1
Cenchrus echinatus L.	1	1	1	0	0	1
Citrullus vulgaris Schrad.	1	1	1	0	1	0
Cucumis melo var. *momordica* (Roxb.) Cogn.	1	1	1	0	0	0
Cynodon dactylon (L.) Pers.	1	1	0	0	0	0
Cyperus rotundus L.	1	1	1	0	0	0
Dactyloctenium aegyptium (L.) Willd.	1	1	1	0	1	1
Digitaria ciliaris (Retz.) Koeler	0	0	0	0	1	0
Emilia sonchifolia (L.) DC. ex Wight	1	1	1	0	0	1
Enneapogon cenchroides (Roem. and Schult.) C.E. Hubb.	1	1	1	1	1	1
Eragrostis ciliaris (L.) R.Br.	1	1	1	0	0	0
Eragrostis tenella (L.) P.Beauv. ex Roem. and Schult.	1	1	1	0	0	0
Ipomoea wrightii A.Gray	0	1	0	0	0	0
Leucaena leucocephala (Lam.) de Wit	1	1	1	0	0	1
Melinis repens (Willd.) Zizka	1	1	1	0	1	1
Momordica charantia L.	1	1	1	0	1	1
Oxalis corniculata L.	0	1	1	0	0	1
Prosopis juliflora (Sw.) DC.	1	1	1	0	1	1
Psidium guajava L.	0	1	1	0	0	0
Ricinus communis L.	1	1	1	0	0	1
Sorghum bicolor subsp. *Arundinaceum* (Desv.) de Wet & J.R.Harlan	1	0	1	0	1	1
Tragus berteronianus Schult.	1	1	1	0	0	0
Urochloa mollis (Sw.) Morrone & Zuloaga	1	0	0	0	1	0

Anthropogenic changes such as high levels of urbanization, simplification of the environment and changes in land use and cover, work as facilitators in the entry process, establishment and colonization by exotic invasive species, bearing in mind that these environments have low resilience, and these species, generally, present competitive advantages in relation to native species (Mack et al. 2000). Furthermore, a plant community becomes more susceptible to invasion as there is an increase of unused resources, since they do not find resident species (Davis et al. 2000).

According to Sher and Hyatt (1999), disorders that change the environment susceptibility to biological invasion are characterized by the increase or decrease in resource availability as light, space and nutrients. The increase in resource availability can also be caused by other exotic invasive species, in which they work as facilitators to establish new exotic species, by inhibiting the native plant community (Flory and Bauer 2014). As native species are being regionally eliminated through their habitat destruction, exotic invasive species increase their populations due to provoked disorders (Fabricante and Siqueira-Filho 2012b).

The relative communities' vulnerability to biological invasion process is explained through vague or underutilized niches (Mack et al. 2000). The vague niche hypothesis suggests that relatively poor communities in number of native species do not offer "biological resistance" to non-native species (Holle et al. 2003)

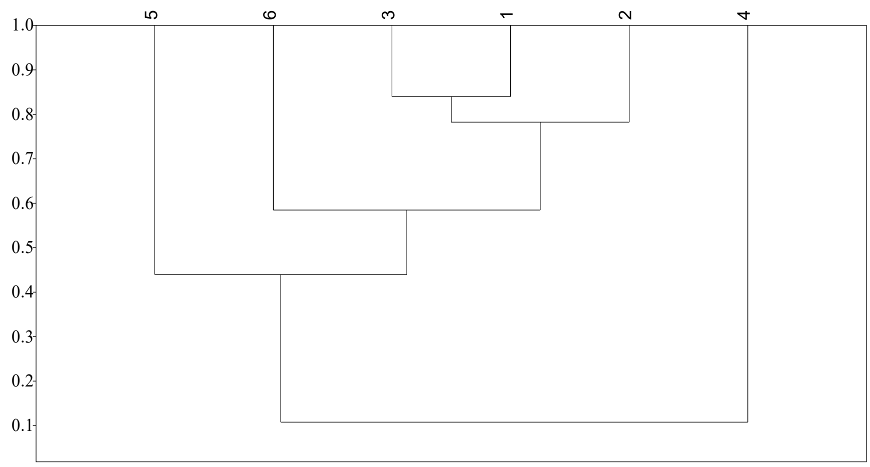
Environment 4 (natural sites of preserved Caatinga) presented only two exotic invasive species. According to Elton (1958), community resistance to biological invasions is related to the number of native species present in the community, so preserved environments are more stable, since it is unlikely that the community has vague niches that cannot be defended.

However, some species can overcome these barriers, such as Enneapogon cenchroides (Roem and Schult.) C.E. Hubb and Cenchrus ciliaris L. Enneapogon cenchroides that still presents its restricted distribution to Caatinga environments (Silva et al. 2013), where it was pointed out for the first time in the country recently (Fabricante and Siqueira-Filho 2012b; Silva et al. 2013). Cenchrus ciliaris, popularly known as buffel grass, is known for impacts it causes on environments that it invades, especially on the herbaceous stratum. Much attention must be paid to the eradication of these species, since they can also occupy degraded sites, they can invade preserved sites, corroborating with the idea that exotic invasive species can replace autochthonous species, besides causing negative effects on the ecosystem (Fabricante and Siqueira-Filho 2012a; Fabricante and Siqueira-Filho 2012b).

A research with C. ciliaris demonstrated its ability to form dense populations and eliminate native species, in addition to establishing negative relationships with them. Its effects act over the structure, composition and diversity on the Caatinga herbaceous stratum (Alves et al. 2017).

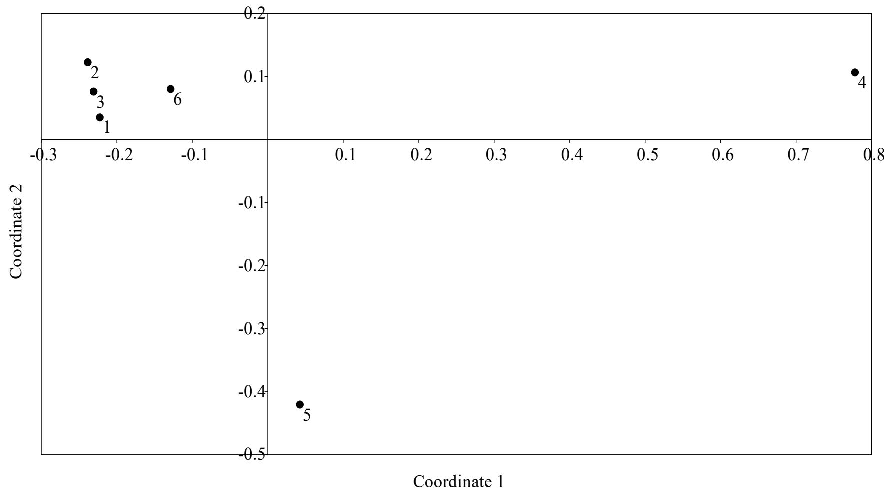
The ruderal environments showed a greater similarity to each other, with a percentage of exotic invasive species in common equal to or greater than 75%. Among these environments and Environments 5 (sites of degraded Caatinga) and 6 (ciliary environments and floodable sites), the similarity ranged from 34% to 65%, being greater to Environment 6. Between Environments 5 and 6 the percentage of common species was 47%. However, for Environment 4 (Caatinga preserved sites), similarity results were lower than 16% for all crosses (Figure 2).

Figure 2. Jaccard similarity dendrogram of the studied environments. Being: Environment 1 - ruderal environments (roads and trails); Environment 2 - ruderal environments (constructions); Environment 3 - ruderal environments (agricultural sites); Environment 4 - preserved Caatinga sites; Environment 5 - degraded Caatinga sites; Environment 6 - Ciliary environments and floodplain sites.



Environment 6 (ciliary environment and floodable sites) that presents a lower disorder degree when compared to ruderal environments, was close to these and distant from degraded Caatinga sites, suggesting that water presence makes the environment susceptible to invasion as well as a ruderal environment. In the NMDS analysis it is possible to graphically observe a more consistent clusters formation between ruderal environments (Environments 1, 2 and 3) and Environment 6 (ciliary environment and floodable sites) and the separation of Environments 4 (conserved Caatinga sites) and 5 (degraded Caatinga sites) to this cluster and each other (Figure 3).

Figure 3. Non-Metric Multidimensional Scheduling Analysis (NMDS) for the studied environments. Being: Environment 1 - ruderal environments (roads and trails); Environment 2 - ruderal environments (constructions); Environment 3 - ruderal environments (agricultural sites); Environment 4 - preserved Caatinga sites; Environment 5 - degraded Caatinga sites; Environment 6 - Ciliary environments and floodplain sites.



Although it is degraded, environment 5 (degraded natural Caatinga sites) differs from ruder environments and environment 6 (ciliary environment and floodable sites) demonstrating that the resistance offered by the environment may be present in early stages of ecological succession.

Conclusion

The results of this study are concern due to the high quantity of exotic invasive species catalogued and the recognized presence of aggressive taxon. They also suggest that degraded environments facilitates biological invasions and that environments in early ecological succession stages are already resistant to biological contamination, at least for most species. For that matter, it is necessary to warn public about the exotic invasive species risk over invaded environments, in addition, a strict regulation to use these species for any purpose.

References

Almeida WR, Lopes AV, Tabarelli M, Leal IR. 2014. The alien flora of Brazilian Caatinga: deliberate introductions expand the contingent of potential invaders. **Biological invasions**, 17(1): 51-56.

Alves JS, Fabricante JR, Reis LBO, Moraes GS, Silva EKC. 2017. Biological invasion by *Cenchrus* ciliaris l.: is there an impact on caatinga composition and diversity of herbaceous stratum? **Revista de Biologia Neotropical**, 14(2): 101-110.

Andrade LAD, Fabricante JR, Oliveira FX. 2009. Invasão biológica por Prosopis julifl ora (Sw.) DC.: impactos sobre a diversidade e a estrutura do componente arbustivo-arbóreo da caatinga no estado do Rio Grande do Norte, Brasil. **Acta bot. bras.**, 23(4): 935-946.

Andrade LAD, Fabricante JR, Oliveira FX. 2010. Impactos da invasão de Prosopis juliflora (sw.) DC.(Fabaceae) sobre o estrato arbustivo-arbóreo em áreas de Caatinga no Estado da Paraíba, Brasil. **Acta Scientiarum. Biological Sciences**, 32: 249-255.

APG. **An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG III.** Botanical Journal of the Linnean Society. 2009.

Bionet-Eafrinet. **Invasive Plants**. Disponível em: <http://keys. lucidcentral.org/keys/v3/eafrinet/plants.htm>. Acesso em: 7 de abril 2017.

Binggeli, P. 2001. **The human dimensions of invasive woody plants. The great reshuffling: human dimensions of invasive alien species. Gland and Cambridge: IUCN**, p. 145-159, 2001.

CABI. 2014. Invasive Species Compendium. Disponível em: <http://www. cabi.org/isc/>. Acesso em: 7 de maio 2017.

Chaffin BC, Garmestani AS, Angeler DG, Herrmann DL, Stow CA, Nystr€om M, Sendzimir J, Hopton ME, Kolasa J, Allen CR. 2016. Biological invasions, ecological resilience and adaptive governance. **Journal of Environmental Management**, 183:399-407.

Christoffoleti PJ, Aranda N. 2001. Seletividade de herbicidas a cinco tipos de gramas. **Planta Daninha**, 19(2): 273-278.

D'Antonio CM, Vitousek P. 1992. Biological invasions by exotic grasses, the grass/fire cycle, and global change. **Annual review of ecology and systematics**, 23: 63-87.

Davis, MA, Grime JP, Thompson K. 2000. Fluctuating resources in plant communities: a general theory of invasibility. **Journal of Ecology**, 88:528-534.

Elton, C. S. 1958. **The ecology of invasions by animals and plants Methuen**. London, UK: Methuen.

Evangelista AR, Abreu JG, Amaral PNC, Pereira RC, Salvador FM, Lopes J, Soares LQ. 2005. Composição bromatológica de silagens de sorgo (*Sorghum bicolor* (L.) MOENCH) aditivadas com forragem de leucena (*Leucaena leucocephala* (LAM.) DEWIT). **Ciênc. agrotec.**, 29(2): 429-435.

Fabricante JR, Ziller SR, Araújo KCT, Furtado MDG, Basso FA. 2015. Non-native and invasive alien plants on fluvial islands in the São Francisco River, northeastern Brazil. **Check List**, 11(1): 1535.

Fabricante JR, Araújo KCT, Castro RA, Cotarelli VM. 2016. Estudo do banco de sementes do solo em uma área de caatinga invadida por Parkinsonia aculeata L. **Scientia Plena**, (12).

Fabricante JR, Oliveira NA, Siqueira-Filho JA. 2013. Aspectos da ecologia de Calotropis procera (Apocynaceae) em uma área de Caatinga alterada pelas obras do Projeto de Integração do Rio São Francisco em Mauriti, CE. **Rodriguésia-Instituto de Pesquisas Jardim Botânico do Rio de Janeiro**, 34(3): 647-654.

Fabricante JR, Siqueira-Filho JA. 2012a. Mudanças nas paisagens das caatingas e as invasões biológicas. **Boletín de la Red Latinoamericana para el Estudio de Plantas Invasoras Volumen**, v. 2.

Fabricante JR, Siqueira-Filho JA. 2012b. Plantas Exóticas e Invasoras das Caatingas do Rio São Francisco. In: SIQUEIRA-FILHO, J. A. (Org.) **A flora das Caatingas do Rio São Francisco: história natural e conservação**, Rio de Janeiro: Andrea Jakobsson, p.367-393.

Fine PVA. 2002. The invasibility of tropical forests by exotic plants. **Journal of Tropical Ecology**, 18:. 687–705.

Flory SL, Bauer T. 2014. Experimental evidence for indirect facilitation among invasive plants. **Journal of Ecology**, 102: 12–18.

Flora do Brasil. Lista de espécies da flora do Brasil. Jardim Botânico do Rio de Janeiro. Disponível em: < http://floradobrasil.jbrj.gov.br/reflora/listaBrasil/PrincipalUC/PrincipalUC.do#CondicaoTaxonCP>. Acesso em: 10 de abril 2017.

Gonçalves GS, Andrade LA, Xavier KRF, Oliveira LSB, Moura MA. 2011. Estudo do banco de sementes do solo em uma área de caatinga invadida por Parkinsonia aculeata L. **Revista Brasileira de Biociências**, 9: 428.

Hobbs RJ, Huenneke F. 1992. Disturbance, diversity, and invasion: implications for conservation. **Conservation biology**, 6(3): 324-337.

Holle BV, Delcourt R, Simberloff, D. 2003. The importance of biological inertia in plant community resistance to invasion. **Journal of Vegetation Science**, 14: 425-432.

Horowitz C, Martins R, Walter MT. 2013. Flora Exótica no Parque Nacional de Brasília: Levantamento e classificação das espécies. **Biodiversidade Brasileira**, 3(2): 50-73.

IBGE. 1992. Manual Técnico da Vegetação Brasileira. Série Manuais Técnicos em Geociências**.**, Rio de Janeiro, n.1.

Instituto Hórus de Desenvolvimento e Conservação Ambiental. Base de dados I3N Brasil de espécies exóticas invasoras. Disponível em:< http://i3n.institutohorus.org.br>. Acesso em: 10 de maio 2017.

ISSG Global Invasive Species Database. 2010. Ecology. Disponível em: <http://interface.creative.auckland.ac.nz/database/welcome/>. Acesso em: 10 de maio de 2017.

Jenkins PT. 1996. Free Trade and Exotic Species Introductions. **Conservation Biology**, 10(1): 300-302.

Kolar CS, Lodge M. 2001. Progress in invasion biology: predicting invaders. **TRENDS in Ecology & Evolution**, 14(4):199-204.

Leal, I.R.; Tabarelli, M.; Silva, J.M.C. **Ecologia e conservação da Caatinga**. Editora Universitária, Universidade Federal de Pernambuco, Recife, 2003. p. 822.

Mack RN, Simberloff D, Lonsdale WM, Evans H, Clout M, Bazzaz FA. 2000. Biotic invasions: causes, epidemiology, global consequences, and control. **Ecological Applications**, 10(3): 689–710, 2000.

Martins CR, Vall Hay JD, Valls JFM, Leite LL, Hemriques RPB. 2007. Levantamento das gramíneas exóticas do Parque Nacional de Brasília, Distrito Federal, Brasil. **Natureza & Conservação**, 5(2): 23-30.

Matos DMS, Pivello VR. 2009. O impacto das plantas invasoras nos recursos naturais de ambientes terrestres: alguns casos brasileiros. **Ciência e Cultura**, 61(1): 27-30.

Melo AS, Hepp LU. 2008. Ferramentas estatísticas para análises de dados provenientes de biomonitoramento. **Oecoligia Brasiliensis,** 12(3): 463-486.

Menezes CR, Hardoim L. 2013. Identificação, seleção e caracterização das espécies vegetais destinadas ao Jardim Sensorial Tumucumaque, município de Serra do Navio, AP/ Brasil. **Biota Amazônia (Biote Amazonie, Biota Amazonia, Amazonian Biota)**, 3(1): 22-30.

Moro MF, Souza VC, Oliveira-Filho AT, Queiroz L P, Fraga CN, Rodal MJN, Araújo FS, Martins FR. 2012. Alienígenas na sala: o que fazer com espécies exóticas em trabalhos de taxonomia, florística e fitossociologia? **Acta Botanica Brasilica**, 26(4): 991-999.

Muller-Dombois D, Ellemberg H. 1974. **Aims and methods of vegetation ecology**. New York: John Wiley & Sons, p. 547.

Parsons JJ. 1972. Spread of African Pasture Grasses to the American Tropics. **Journal of Range Management**, 25(1): 12-17.

Pegado CMA, Andrade LA, Féliz LP, Pereira IM. 2006. Efeitos da invasão biológica de algaroba-Prosopis juliflora (Sw.) DC. sobre a composição e a estrutura do estrato arbustivo-arbóreo da caatinga no Município de Monteiro, PB, Brasil. **Acta bot. bras.,** 20:887-898.

Pimentel D, Mcnair S, Whigtman JJ, Simmonds C, O'Connell C, Wong E, Russel L, Zern J, Aquino T, Tsomondo T.2001. Economic and environmental threats of alien plant. **Agriculture, Ecosystems and Environment**, 84: 1-20.

Pivello VR. 2011. Invasões Biológicas no Cerrado Brasileiro: Efeitos da Introdução de Espécies Exóticas sobre a Biodiversidade**.** Ecologia, 2011. Disponivel em: <http://ecologia.info/cerrado.htm>. Acesso em: 20 Fevereiro 2017.

Rodrigues A LP et al. 2004. Degradabilidade in situ da matéria seca de forrageiras tropicais obtidas em diferentes épocas de corte. **Arq. Bras. Med. Vet. Zootec**, 56(5): 658-664, 2004.

Santana AO, Encinas I. 2008. Levantamento das espécies exóticas arbóreas e seu impacto nas espécies nativas em áreas adjacentes a depósitos de resíduos domiciliares. **Biotemas**, 21(4) 29-38.

Sher AA, Hyatt A. 1999. The Disturbed Resource-Flux Invasion Matrix: a new framework for patterns of plant invasion. **Biological Invasions**, 1: 107-114.

Silva ACCP, Castro RA, Fabricante JR, Araújo KCT, Siqueira-Filho JA. 2013. *Enneapogon cenchroides*. In: Fabricante, J. R. (Org.). **Plantas Exóticas e Exóticas Invasoras da Caatinga**. v. 2. p.27-34.

Siqueira KMM, Kiill LHP., Martins CF, Silva LT. 2012. Ecologia da polinização de *Psidium guajava* L. (Myrtaceae): riqueza, frequência e horário de atividades de visitantes florais em um sistema agrícola. **Magistra**, 24:150-157.

Sneath A, Sokal RR. 1973. **Numerical taxonomy. The principles and practice of numerical classification**. WH Freeman.

Sokal RR, Rohlf FJ. 1962. The comparison of dendrograms by objective methods. **Taxon**, 11:33-40.

Sousa FQD, Andrade LA, Xavier RF. 2016. Cryptostegia madagascariensis Bojer ex Decne.: impactos sobre a regeneração natural em fragmentos de caatinga. **Revista Brasileira de Ciências Agrárias (Agrária)**, 11:39-45.

Souza DIMD, Costa LR, Gurgel MT, Soares SRF. 2013a . Arborização do Bairro Peixe-gordo na cidade de Icapuí-Ce. **Revista Verde de Agroecologia e Desenvolvimento Sustentável**, 8(4):238 – 242.

Souza KD, Coelho RDF, Sobrinho CP, Nascimento JPB, Gogliath M, Ribeiro LB. 2013b. Fauna de lagartos de hábitats de Caatinga do Campus Ciências Agrárias da Universidade Federal Do Vale Do São Francisco, Petrolina-Pe, Brasil. **Revista Brasileira de Zoociências**, 15:253-265.

Vasconcelos WAD, Andrade AP, Santos EM, Marin AM P, Tinôco LBM, Edvan RL. 2012. Produção de fitomassa e composição químico-bromatológica do capim buffel adubado com digesta bovina sólida. **Revista Trópica – Ciências Agrárias e Biológicas**, 6(2):94.

Vila M, Pujadas J. 2001. Land-use and socio-economic correlates of plant invasions. **Biological Conservation**, 100: 397-401.

Vitousek PM. et al. 1996. Biological invasions as global environmental. **American scientist**, 84: 468.

Vitule JRS, Prodocimo V. 2012. Introdução de espécies não nativas e invasões biológicas. **Estudos de Biologia: Ambiente e Diversidade**, 34: 225-237.

Williams, D. G.; Baruch, Z. African grass invasion in the Americas: ecosystem consequences and the role of ecophysiology. **Biological Invasions**, v. 2, p. 123–140, 2000.

Ziller SR. 2001. Plantas exóticas invasoras: a ameaça da contaminação biológica. **Ciência Hoje**, v. 30(178): 77-79.