ASSESSMENT OF THE CURRENT DISTRIBUTION, DISPERSAL TRENDS AND IMPACTS OF INVASIVE SPECIES IN BANA - NUI CHUA NATURE RESERVE, VIETNAM

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Abstract - Invasive species threaten the biodiversity and the function of ecosystems. Drone image, satellite images, and image analysis software were used to create the map of invasive distribution and the potential spreading of invasive plants. 13 most invasive plants were identified with 11 species listed as invasive species in Southeast Asia and 5 of them in the 100 world's invasive species by IUCN. Three species *Merremia boisiana* (Gagn.) van Ooststr., *Ipomoea eberhardtii* Gagn. and *Mimosa pigra* were identified as the species with high-ranking impacts on biodiversity and ecosystem biodiversity in Ba Na - Nui Chua Nature Reserve (BNNR). *Ipomoea eberhardtii* Gagn shows the highest spreading rate at 0.65 ± 0.06 ha/month, followed by *Merremia boisiana* (Gagn.) van Ooststr) and *Mimosa pigra* at 0.12 ± 0.01 ha/month and 0.01 ± 0.001 ha/month respectively. Fresh biomass of *Ipomoea eberhardtii* Gagn; *Merremia boisiana* (Gagn.); *Mimosa pigra* and *Sphagnetola trilobata* (L.) Pruski in BNNR are 15.67; 14.9; 8.1 and 6.8 ton/ha. The database of invasive plant distribution and potential spreading will be used to monitor strategies and invasive weeds management in BNNR.

Key words - Ba Na - Nui Chua Nature Reserve; biodiversity; impact; invasive

1. Introduction

Ba Na - Nui Chua Nature Reserve (BNNR) has a total area of 26.8 ha [1]. It is located on the border between Da Nang city and Quang Nam province, Vietnam. Lowland evergreen forest and evergreen lower mountain forest are 2 main types of natural vegetation. There are 793 species in the flora, divided into 487 genera and 134 families. 19 species are listed in the Red Book of Vietnam [2] The fauna of BNNR has 256 species, of which there are 61 mammals, 179 birds, and 17 reptiles (belong to 8 families)

Recently, Da Nang's ecology has been negatively impacted by a variety of causes, one of which is environmental weeds. Since 1999, thousands of hectares of special-use forest in Da Nang City have been reported to be overwhelmed by invasive liana species. In the nearby BNNR, about 300 ha of forest has been affected by invasive woody vine (*Merremia boisiana*.). In all locations these woody vines are climbing and covering the forest canopy, killing hosts and understorey plants by preventing them from absorbing sunlight. These invasive plants often increase the likelihood of forest fires because their big, dense leaves quickly catch fire, even though they are green [3]. BNNR is in danger by the rapid spread of invasive species. Many of them have covered a large area of the natural forest in the Reserve and had an impact on native biodiversity. In addition, forest loss and degradation due to the rapid development of construction such as hotels, resorts, traffic roads in BNNR have created favorable conditions for invasive plants to thrive.

The database of invasive species has an important role in controlling their impacts. However, there is no comprehensive research to determine the impacts of the invasive species in BNNR, especially new exotic species, which have occupied only a small area but are potential threats to forest and agricultural ecosystems. In this research, we identify the invasive species, assess their presence, dispersal trends, and impacts on the local biodiversity in BNNR by an invasive species assessment protocol and using satellite images, drone image, and image analysis software.

2. Materials and methods

2.1. Transect-Method and Quadrat Sampling

14 transects (3 to 18 km in length) were set up and investigated from July to November 2018, crossing over different habitats: planted forests, natural forests, forest sides, alongside streams, roadsides, cropland, grasslands, orchards, vacant lands, and swamp in BNNR.

The line-intercept transect-method [1] with quadrat of (5×5m) and (1x1m) was used in the survey transects. Quadrat size depends on the type of species (tree, vine, or herb…). Inside the quadrat's perimeter, invasive plants were established, and the total number of individuals of each was registered. Transect locations and lengths are shown in Figure 1

- A comprehensive list of invasive species was documented based on the creation of a system of symbols and annotations.

- Exporting maps to PDF or PNG formats.

References such as An Illustrated Flora of Vietnam [5], Vietnam Forest Trees [6] as background data for field observers. For unknown weed species, herbarium specimens were collected to identify in the laboratory [4].

2.2. Invasive Species Assessment Protocol

The species were identified as Invasive Alien Species (IAS), Likely Invasive (L.IAS), or Potentially Invasive (P.IAS) based on the criteria described by the Massachusetts Invasive Plant Advisory Group [7], IAS in South-Southeast Asia by Global Invasive Species Programme [8] and the Circular N35/2018-BTNMT by the Ministry of Natural Resources and Environment, Vietnam.

The methodology for surveillance of invasive alien plant species was based on an Invasive Species Assessment Protocol: Evaluating Non-Native Plants for their Impact on

Biodiversity, Version 1, [9] We redesigned the protocol for applying in our study area condition. 13 assessment-weighted multiple-choice questions were grouped into five sections that addressed five major aspects of an invasive species' total impact:

1. Ecological impact (4 questions);
2. Current distribution and abundance (2 questions);
3. Trend in distribution and abundance (3 questions);
4. Management difficulty (2 questions);
5. Impact on production and human activities and other factors (2 questions).

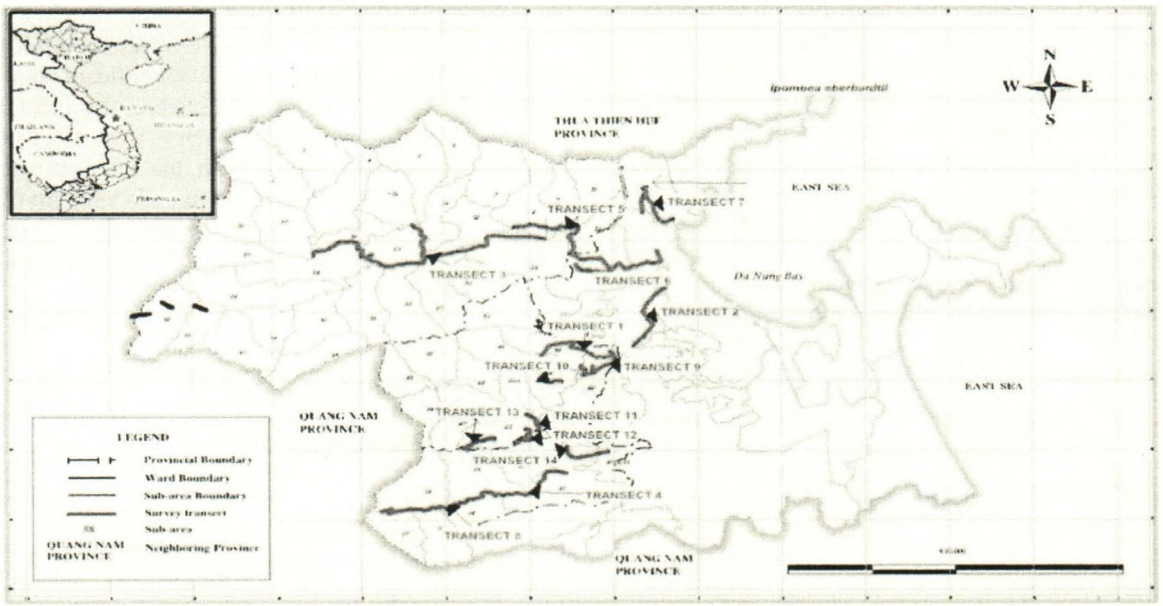


Figure 1. *The location of 14 surveys transects in BNNR*

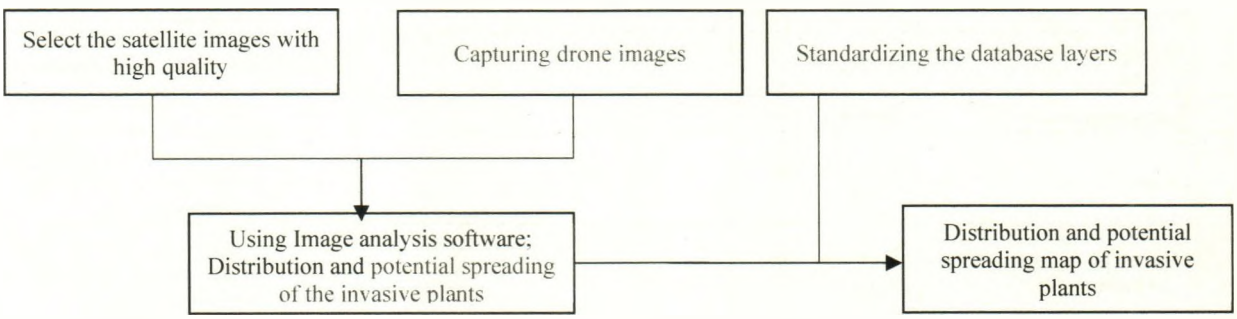


Figure 2. *The diagram illustrates the steps for generating a distribution map of invasive species by using drone image and image analysis software*

2.3. Making the invasive species distribution map by using drone image and image analysis software

In this study, one of the popular drones (DJI Mavic Ari) was used. Drone images were taken during the automatic flight using a smartphone application provided by (DJI GO 4). Images were taken in BNNR and buffer zone with total of 165 points.

The steps for creating a distribution map of invasive species by using satellite images, drone image, and image analysis software were described below:

(1) Collecting data

- Collecting Background maps of Danang city.
- Collecting drone images of invasive species in the field.
- Using Vtool packages in MapInfo software to analyse satellite images (from Google Earth, Sentinel-2, and Landsat 8) and drone images. Comparing drone images with aerial images provided by National Geographic Information Institute.

(2) Building the database

- Standardizing the content layers.
- Selecting the satellite images with the best quality, then comparing the resolution of the layers based on drone image coordinates collected.
- Checking and fixing database errors.
- Exporting a relevant datasheet.

(3) Building the map of invasive plant distribution and the potential spreading of the invasive plants.

- Overlapping layers and editing maps according to different contents.

3. results and discussions

3.1. Diversity of Invasive Species in BNNR

The composition of invasive plant species in BNNR was listed in (Table 1). A total of 13 invasive plant species have been explored, among which 5 species are listed in

100 of the world's worst invasive alien species by IUCN [10], 11 species in the list of invasive species in Southeast Asia, and 6 species are ranked as invasive alien species according to Circular #35/2018TT-BTNMT by the Ministry of Natural Resources and Environment[13].

The appearance of few "super invaders" can be a consequence of increased resource availability and altered disturbance regimes associated with human activities [11]. The roads cross the natural forest and the other habitats provide sufficient photosynthetic conditions for the invasive species growing when most of them are light-demanding plants. The better light conditions and less competition in space enhance the invasion of non-native plants over mountain vegetation. More than 90 percent of invasive species can be found along the roads to the forest. In addition, the roads and constructing activities have contributed to the rapid spread and reproduction of invasive species. Indeed, their seeds can be dispersed through long distances by floodwaters, and distributed along the riverside. After that, they will be taken and transported to other locations by the sand exploitation process in the river for material building that accidentally spread the invasive species in BNNR.

3.2. Evaluating Impacts of Invasive Plants on Biodiversity

In order to assign each Invasive Species Impact Rank (IRank) of High, Medium, Low or Insignificant on natural biodiversity within the study area, the protocol includes 13 questions were used. Each species was assessed by considering these questions, with the answers used to calculate a subrank for each of the five sections. An overall I-Rank was then calculated from the subranks. The results of the Invasive Species Impact Rank (I-Rank) in BNNR are shown in Table 2.

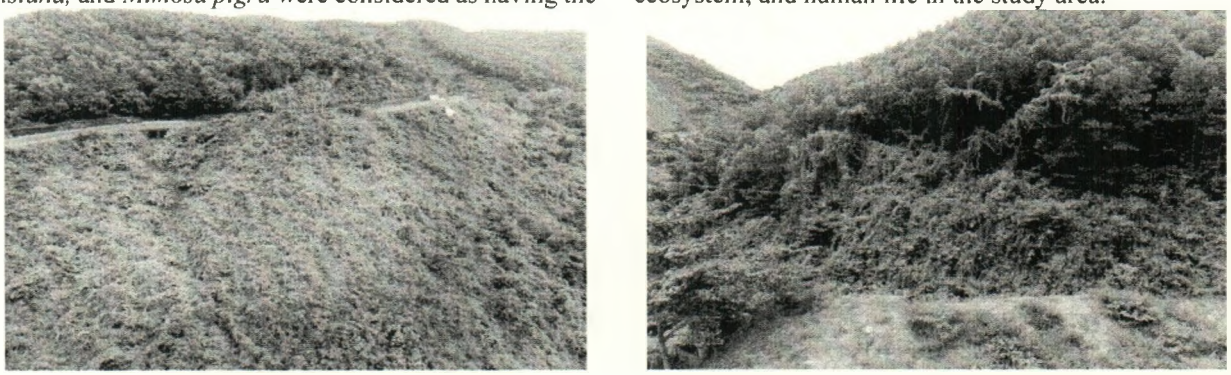
Table 1. *List of invasive species in study areas*

No	*Family/species*	*Local name*	*List of 100 world's invasive species*	*List of invasive species in Southeast Asia*	*List of invasive species in Circular 27/2013*	*Habitat*
I	***Asteraceae***	***Ho Cuc***				
1	*Ageratum conyzoides* L.	Cut lon	+	+		Roadside, orchards, vacantlands, grasslands
2	*Bidens pilosa* L.	Don buot		+		Roadside, vacantlands, grasslands
3	*Chromolaena odorata* (L.) King & H. Rob	Co lao	+	+	+	Roadside, orchards, vacantlands
4	*Sphagneticola trilobata* (L.) Pruski	Cuc bo		+		Roadside, vacantlands
II	**Convolvulaceae**	**Bim bim**				
5	*Ipomoea eberhardtii* Gagn.	Bim bim hoa trang		+		Forestsides, Planted forests, nature forests, alongside stream, roadsides
6	*Merremia boisiana* (Gagn.) van Ooststr.)	Bim bim hoa vang		+		Forestsides, Planted forests, nature forests, alongside stream, roadsides.
III	**Commelinaceae**	**Ho Thai Lai**				
7	*Callisia fragrans* (Lindl.) Woodson	Luoc vang			+	Orchards, vacantlands
IV	**Fabaceae**	**Ho dau**				
8	*Leucaena leucocephala* (Lamk.) De Wit.	Keo dau	+	+		Roadside, vacantlands, grasslands
9	*Mimosa diplotricha* C. Wright var. Diplotricha Sauvalle	Trinh nu moc		+	+	Roadside, vacantlands, grasslands
10	*Mimosa pigra*	Trinh nu than go/Mai duong	+	+	+	Roadside, vacantlands, grassland, cropland, orchards, swamp.
11	*Mimosa pudia* L.	Xau ho/ Trinh nu bo		+		Roadside, vacantland, grassland, swamp.
V	**Pontederiaceae**	**Ho Luc binh**				
12	*Eichhornia crassipes* (Mart.) Solms	Beo Nhat Ban/ Beo Tay/ Luc binh			+	Swamp
VI	**Verbenaceae**	**Ho roi ngua**				
13	*Lantana camara* L.	Ngu sac	+	+	+	Roadside, vacantland, grassland

Table 2. *The Invasive Species Impact Rank (I-Rank) in BNNR*

No	*Species*	*Point*	*The Invasive Species Impact Rank (I-Rank)*			
			High significance	*Moderate significance*	*Low significance*	*Insignificance*
I	***Terrestrial plants***					
1	*Merremia boisiana* (Gagn.) van Ooststr.)	**90**				
2	*Ipomoea eberhardtii* Gagn.	**90**				
3	*Mimosa pigra*	**85**				
4	*Sphagneticola trilobata* (L.) Pruski	**75**				
5	*Chromolaena odorata* (L.) King & H. Rob	**55**				
6	*Lantana camara* L.	**40**				
7	*Callisia fragrans* (Lindl.) Woodson	**0**				
8	*Mimosa pudia* L.	**20**				
9	*Mimosa diplotricha* C. Wright var. Diplotricha Sauvalle	**35**				
10	*Leucaena leucocephala* (Lamk.) De Wit.	**0**				
11	*Ageratum conyzoides* L.	**35**				
12	*Bidens pilosa* L.	**20**				
II	**Aquatic plants**					
13	*Eichhornia crassipes* (Mart.) Solms	**50**				

3 species namely *Ipomoea eberhardtii*, *Merremia boisiana,* and *Mimosa pigra* were considered as having the highest-ranking impact on the natural biodiversity, ecosystem, and human life in the study area.



(a) *(b)*

Figure 3. (a) *Merremia boisiana covers the nature forest and (b) planted forest canopy*

Acacia auriculiformis planted forests were threatened by *Merremia boisiana*. Vines are climbing and covering the forest canopy, killing the trees below by preventing them from the sunlight. Most native trees cannot compete with these species.

Most of *Pinus kesiya* Royle ex Gordon in the study area was covered by *Ipomoea eberhardtii* Gagn. Pinus mixed with broad-leaved trees is the main forest type of Nam Hai Van forest types and BNNR buffer zone.

Ipomoea eberhardtii Gagn and *Merremia boisiana* (Gagn.) van Ooststr were growing very fast. According to the Phuong Vo [12], the growth rate of *Ipomoea eberhardtii* Gagn was 6.4cm/day by marking and measuring treetops length at least once every 2 days. The growth rate of *Ipomoea eberhardtii* Gagn was higher than that of *Merremia boisiana* (Gagn.) van Ooststr by 0.45cm/day in the Son Tra Nature Reserve. *Merremia boisiana* (Gagn.) can be found from 300 m to 900m above sea level [12].

In this research, the growth rate of *Merremia boisiana* (Gagn.) and *Ipomoea eberhardtii* Gagn were 2.0 and 2.4 cm/day, *Ipomoea eberhardtii* Gagn distributed at higher 300m hight of sea level (in Nam Hai Van area.). *Merremia boisiana* (Gagn.) distributed almost all of differents elevation from 15m to 1031m above sea level.

Mimosa pigra can be found commonly along roadsides, vacant lands, grasslands, croplands, orchards, swamps. This species has a high potential to harm the farmland by reducing the cultivating area and the corresponding carrying capacity. *Miosa pigra* reproduces easily by means of buoyant seed pods that can be spread long distances by floodwaters; the seeds can also be widely distributed via agriculture, construction and traffic activities.

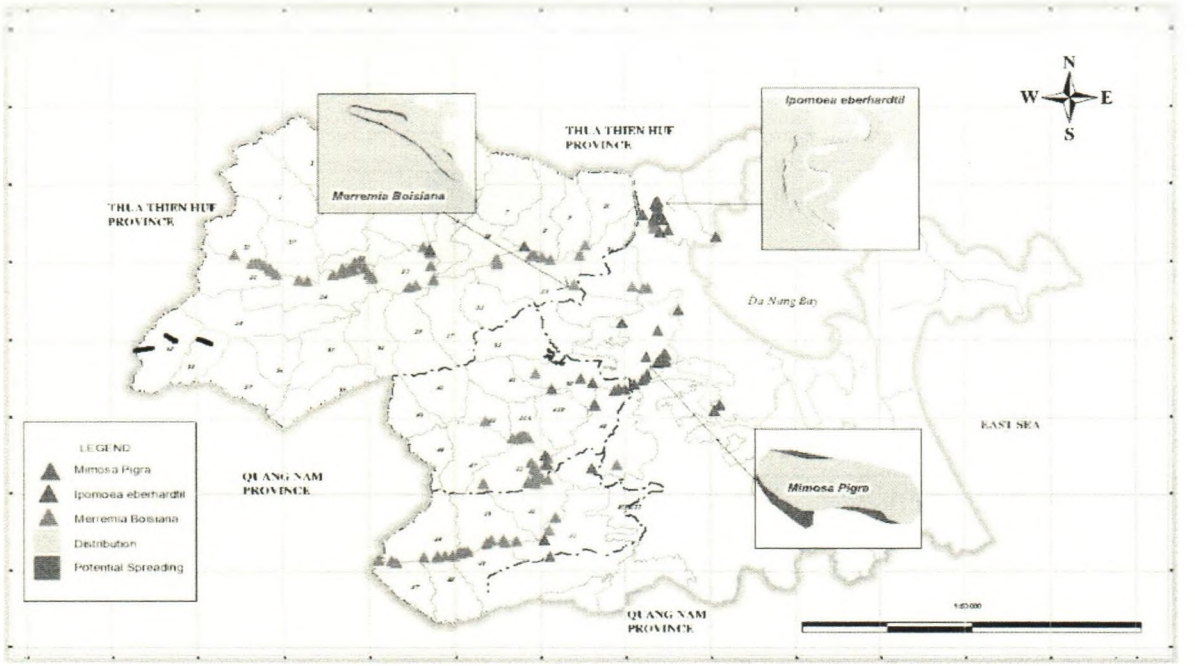


Figure 4. *Database and map of Ipomoea eberhardtii Gagn. Merremia boisiana (Gagn.) van Ooststr and Mimosa pigra distribution and potential spreading*

Fresh biomass of *Ipomoea eberhardtii* Gagn and *Merremia boisiana* (Gagn.) in BNNR were respectively 15.67 ton/ha and 14.9 ton/ha that are lower than the results from the research in Son Tra Nature Reserve (25 and 21 (ton/ha) respectively) [12]. However, these species in BNNR are growing very fast and covering a larger forest canopy. The fresh biomass of invasive plants is shown in Table 3.

Table 3. *Assessing fresh biomass of invasive plants in BNNR*

No	Species	Fresh biomass (kg/4m² of plot)	Average (ton/ha)	Note
1	*Ipomoea eberhardtii* Gagn.	8.2	15.67	Leaf 30 cm x 40 cm
		3.8		Leaf 15 cm x 17 cm
		6.8		Leaf 20 cm x 24 cm
2	*Merremia boisiana* (Gagn.) van Ooststr.)	1.9	14.9	Leaf 14 cm x 16 cm
		2.3		Leaf 20 cm x 24 cm
		9.2		Leaf 30 cm x 40 cm
		10.8		Leaf 19 cm x 22 cm
		5.6		Leaf 16 cm x 18 cm
3	*Mimosa pigra*	11.5	8.1	Plot ($1m^2$)
		4.7		
4	*Sphagneticola trilobata* (L.) Pruski	9.27	6.8	plot ($1m^2$)
		4.5		

Sphagneticola trilobata (L.) Pruski was introduced as ornamental plants and street trees. This species is increasing in abundance, competing with other common wild plants. Fresh biomass in each plot was high at 6.8 (ton/ha).

3.3. Assessment of The Potential Spread of Invasive Plants in BNNR

Drone images were taken in 3 consecutive months and combined with field measurement results. These then were compared with satellite images to create the map of invasive species distribution and potential spreading of the invasive plants. Based on 120 points of monitoring, the results show that the spreading rate of *Ipomoea eberhardtii* Gagn.was the highest at 0.65±0.06 ha/month, followed by *Merremia boisiana* (Gagn.) van Ooststr.) and *Mimosa pigra.* If there are no invasive control methods, nearly 8ha of the forest will be covered by only *Merremia boisiana* (Gagn.) each year. Assess the potential spreading of the 3 most invasive plants is presented in Table 4.

The research suggests that 2 species *Merremia boisiana* (Gagn.) van Ooststr) and *Ipomoea eberhardtii*Gagn should be listed in Vietnam's invasive species [13].

Table 4*: Assess the potential spreading of 3 most invasive plants (ha/month)*

Invasive plants	*Ipomoea eberhardtii* Gagn.	*Merremia boisiana* (Gagn.) van Ooststr.)	*Mimosa pigra*
Points of field observation	120	24	21
Current Range Size (ha) investment	52.06	7.53	5.8
The average range size was changed after 1 month (ha)	52.7	7.6	5.8
Potential spreading of invasive plant (ha/month)	0.65±0.06	0.12±0.01	0.01±0.001

4. Conclusion

13 most invasive species were identified in BNNR, of those, 5 species are listed in 100 world's invasive species, 11 species in the list of invasive species in southeast Asia, and 6 species are ranked as invasive alien species according to Circular N°35/2018-BTNMT. Three species

Merremia boisiana (Gagn.) van Ooststr, *Ipomoea eberhardtii* Gagn, and *Mimosa pigra* are listed in high ranked impact on biodiversity and ecosystem. *Sphagneticola trilobata* (L.) Pruski was considered at medium ranked. Fresh biomass of *Ipomoea eberhardtii* Gagn and *Merremia boisiana* (Gagn.) in BNNR were 15.67 and 14.9 ton/ha. *Merremia boisiana* (Gagn.) growth rate was very high around 2.0 to 2.4 cm/day, distributed almost all of differents elevation from 15m to 1031m hight of sea level. The spreading rate of *Ipomoea eberhardtii* Gagn. was highest at 0.65 ± 0.06 ha/month, followed by *Merremia boisiana* (Gagn.) van Ooststr.) and *Mimosa pigra* at 0.12 ± 0.01 ha/month; 0.01 ± 0.001 ha/month respectively. Controlling the potential spreading of these plants should also be emphasized.

Ethics statement: This research is unique and has never been published before. During this review, no animals were treated or given any kind of care. Any of the data was gathered in an unobtrusive and passive manner.

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