Jurnal Penelitian Hutan dan Konservasi Alam, (2022), 19(2): 207-218
http://ejournal.forda-mof.org/ejournal-litbang/index.php/JPHKA
pISSN: 0216 – 0439 eISSN: 2540 – 9689
Akreditasi Kemenristekdikti Nomor 200/M/KPT/2020

Inventory and Risk Analysis of Naturalized Exotic Species from the Cibodas Botanical Garden Collection Recorded in the Remnant Forest of Cibodas *(Inventarisasi dan Analisis Resiko Jenis Eksotik Ternaturalisasi Koleksi Kebun Raya Cibodas yang Ditemukan di Hutan Sisa Cibodas)*

Dadang Suherman[1], Dadang Sunandar[1], Decky Indrawan Junaedi[2], Dwinda Mariska Putri[2*], Muhammad Efendi[1], Risha Amilia Pratiwi[1], and Vandra Kurniawan[1]

[1]Research Center for Plant Conservation and Botanical Gardens, National Research and Innovation Agency. Jl. Kebun Raya Cibodas. Cipanas, Cianjur 43253, West Java, Indonesia. Telp. +62263 512233
[2]Research Center for Ecology and Ethnobiology, National Research and Innovation Agency. Jl. Raya Jakarta-Bogor Km.46, Cibinong, Bogor 16911, West Java, Indonesia. Telp. +6221 87914511

Article's info:

Keywords:
Cibodas remnant forest,
naturalized plant collections,
tropical botanical garden

Article history:
Received:
15 December 2021;
Revised:
28 June 2022;
Accepted:
20 December 2022

ABSTRACT

Botanic Gardens cultivates exotic species for the purpose of ornamental plants. Moreover, these exotic species have the probability to escape the garden area and naturalized in adjacent forests. Cibodas Botanical Garden (CBG) is adjacent to four remnant forests: Jalan akar, Bengkel, Lumut, and Wornojiwo forests. There are several reports of naturalized CBG collections in Wornojiwo, thus this study does the inventory of naturalized exotic CBG collections in Cibodas remnant forests and perform Tropical Weed Risk Assessment Protocol (TWRAP) of these species. We found 26 CBG exotic species naturalized in remnant forests and more naturalized exotic species in Lumut and Jalan Akar forests than Wornojiwo and Bengkel forests. We presumed the topographic condition in Bengkel forest inhibit the spread of exotic species, meanwhile Jalan akar forest was located in the center area of CBG therefore holds the greatest number of naturalized exotic species. We found the domination of Chimonobambusa qudrangularis in Wornojiwo forest inhibiting other exotic species growth. The largest figure of the naturalized species belong to the family of Asteraceae, followed by Solanaceae, Marantaceae, Fabaceae, and Acanthaceae. The TWRAP assessment score results of the 81% naturalized species were above 10. Therefore TWRAP can be used as an early screening for botanic gardens exotic species naturalization probability. CBG commits to support the post-2020 biodiversity CBD target, with this inventory CBG can monitor the spread of CBG exotic plant collections that threaten native plant diversity and prevent future spreading of other exotic species.

1. Introduction

Cibodas Botanical Garden (CBG) plant living collections contain an economic potential value such as ornamental plants and medicinal plants. These collections are utilized for plant research and support CBG for tourism purposes. Indonesian botanic gardens including CBG introduced exotic plant species intentionally in the past, particularly during the colonial period (Hulme, 2011). Botanical garden as an ex-situ conservation organization plays a critical role in preventing extinction (Cibrian-jaramillo et al., 2013; Wyse Jackson & Sutherland, 2017; Chen & Sun, 2018). Somehow, botanical gardens also have some limitations that the adaptations with ex-situ environment addressed trait changes. Furthermore, these changes might trigger invasive traits of exotic species (Volis, 2017).

The plant collections of CBG consist of native and exotic plant species. These exotic species are introduced during the colonial era and become economically cultivated plants in Indonesia (Galera & Sudnik-

Editor: Dr. Henti Hendalastuti Rachmat
Korespondensi penulis: Dwinda Mariska Putri* (E-mail: dwinda.mariska@gmail.com)
Kontribusi penulis: **DS and DS**: contribute data collections; **DIJ**: contribute in study design, and data analysis; **DMP**: contribute in study design, data analysis, and data collection; **ME**: contribute in data collections and data analysis; **RAP**: contribute in data analysis and **VK**: contribute in data collections and data analysis.

https://doi.org/10.20886/jphka.2022.19.2.207-218

Wójcikowska, 2010; Galbraith & Cavallin, 2021). Some of the exotic species may have the ability to "escape" and spread outside the botanical garden territory. It is expected of a botanical garden to reduce the risk of alien plants escaping from cultivation (Galera & Sudnik-Wójcikowska, 2010). Preventive management is the ideal approach to managing invasive species and has been practiced in many geographical contexts, such as the regional level (Pritekel et al., 2006; Foxcroft, Richardson, & Wilson, 2008), the national level (Williams & West, 2000) and the continental level (Brunel et al., 2010). Technically, preventive management could include early detection, reconnaissance, and implementation of a designated risk assessment framework for potentially invasive alien species (Leung et al., 2012). CBG answers this invasion issues by performing several studies, including tropical weed assessment of CBG exotic collections (Junaedi, Putri, & Kurniawan, 2021). CBG also already conducted important studies as part of preventive action for invasion risk management at CBG. First, inventory studies of naturalized species outside the CBG area (Zuhri & Mutaqien, 2013) and in the remnant forests in the CBG area (Mutaqien, Tresnanovia, & Zuhri, 2011; Junaedi, 2014) were implemented. Second, studies on developing prediction systems for the naturalized exotic collection were conducted based on a scoring-framework system (Junaedi, 2011) and a trait-based system (Junaedi et al., 2021). CBG management has built small ditches along the remnant forests border to prevent the spreading of exotic collections.

There are four stages of exotic species overcoming environment barrier to become invasive. The steps are transport-introduction-establishment-spread. CBG's collections passed the stages of transport and introduction after collected and domesticated inside the gardens area. Afterwards, it passed establishment steps after producing several offspring. Later, it passed the spread stages after it overcomes the environmental barrier and grows outside the gardens area (Blackburn et al., 2011).

Apart from the botanical gardens collection display area, the CBG area also consists of several forest patches that were assumed as remnant forests of the Gede Pangrango National Park (GPNP) forests area. These forest patches covered 5-10% of CBG's total area and managed by CBG as natural forests. CBG remnant forests contain many native plant species and are considered native forest research site (Zuhri & Mutaqien, 2013). The existence of these remnant forests also supports the uniqueness of CBG that contain ex-situ plant collection and resemble in-situ plant conservation site that similar to GPNP native forests (Rozak, Astutik, Mutaqien, Widyatmoko, & Sulistyawati, 2016).

Previous studies found that several CBG collections are detected in adjacent native forests. The research conducted by Mutaqien et al. (2011) found 10 naturalized exotic CBG collections in the Wornojiwo forest, while research conducted by Zuhri & Mutaqien (2013) found 4 exotic CBG collections exist in the GPNP forest area. Junaedi (2014) found 26 exotic species in Cibodas remnant forests, but these species are general and may include exotic species from non-CBG plant collections. While Padmanaba, Tomlinson, Hughes, & Corlett (2017) found 5 naturalized exotic species of CBG collections in GPNP. From these previous researches, we found there was no inventory of CBG exotic plant collections that specifically grow in Cibodas remnant forests. Monitoring of escaping exotic CBG collections is important to conduct in preventing further spreading. A regular inspections could give early warning of new escaped species. Therefore, this research aims to discover CBG exotic

plant collections that have been grown and or naturalized in Cibodas remnant forest areas, and conduct Tropical Weed Risk Assessment Protocol (TWRAP) to assess the potential invasiveness of these species.

2. Methodology

This research was conducted in Cibodas remnant forest, Cianjur, West Java. CBG has a wet submontane climate, the average rainfall is 4000-5000 mm/year (Whitten, Whitten, Soeriaatmadja, Soeriaatmadja & Afiff, 1996). CBG remnant forests mainly consist of four areas: Wornojiwo (3.934 Ha), Lumut (0.855 Ha), Bengkel (2.555 Ha), and Jalan Akar (1.086 Ha) (Mutaqien et al., 2011). These four forests are laid in different areas and thus have different topography. Jalan Akar is located in the middle of CBG, the slope is gentle and gradually steeper at the border. Lumut is adjacent to Jalan Akar with a gentle hill and interlock canopy. While Bengkel is situated at the lower hill of Jalan Akar, separated by a 4 m road, the slope is steep with a creek running through. Wornojiwo which is located apart from the other remnant forest is adjacent to the CBG area and has a gentle slope.

Samplings were conducted in March 2021, inside Cibodas Remnant Forests using the Quadrat method (Ellenberg & Mueller-Dumbois, 1974). First, we inspected the exotic plants in the remnant forest. We identified each detected and recorded exotic species' presence. We collected herbarium specimens for the unidentified exotic species. The herbarium was later identified by comparing it with herbarium specimens in Cianjur Hortus Tjibodasensis (CHTJ). Following the identification of all species, the detected exotic species were then shortlisted based on CBG exotic plant collections list. Afterward, we collected the exotic species data in each remnant forest inside 2 x 2 m square plots along the remnant forests' edge, with ten plots in each forest. The plot size and number were determined after calculating the species number found in the previous inspection, after seven plots the species number tend to be stagnant (Figure 1). We placed the plots near the border of the forest after the first inspection that exotic species were mostly found on the border. Species presence and species density data were collected from the sampling plots. Densities and Frequencies of exotic species were calculated according to Krebs, (1987):

$$Density = \frac{Total\ number\ of\ individual\ species}{Total\ sampled\ area}$$

$$Frequency = \frac{Number\ of\ sampled\ areas\ where\ species\ occured}{Number\ of\ total\ sampled\ areas}$$

$$Important\ Value\ Index\ (IVI) = Relative\ Density + Relative\ Frequency$$

Risk assessment of the naturalized species followed the Weed Risk Assessment (WRA) (Pheloung, Williams & Halloy, 1999) protocol. The dataset provided by Pacific Island Ecosystem at Risk (PIER) can be accessed through the link http://www.hear.org/pier/index.html. The question set later was modified following Tropical Weed Risk Assessment Protocol (TWRAP) (Junaedi & Mutaqien, 2018).

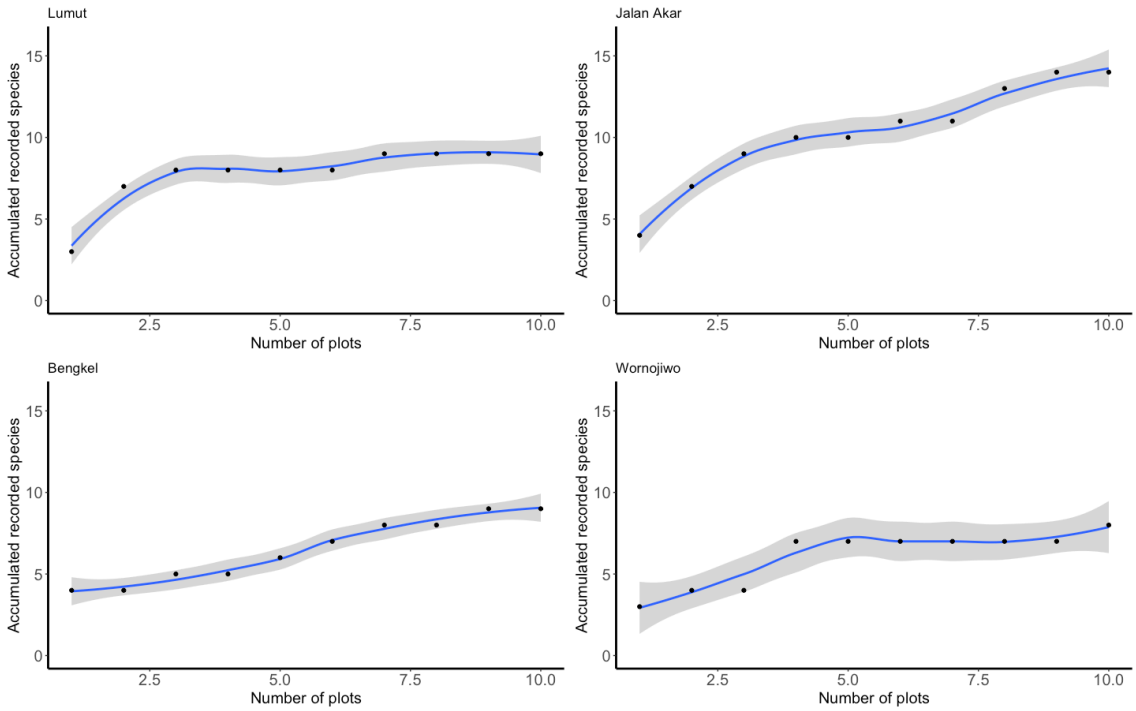

Figure 1. Species number accummulation vs number of sampling plots in Cibodas remnant forests

3. Results and Discussions

We collected 26 species (Table 1) of CBG exotic plant collections in Cibodas remnant forests. These figures belong to 17 families (Figure 2). This number was higher than the last inventory (Mutaqien et al., 2011). The increasing number of naturalized exotic species is presumably due to exotic species requiring residence time to adapt to the new environment. There are exotic species that have not been reported in previous studies (Table 1). These species are *Calliandra tetragona, Gleditsia sinensis, Iresine herbstii, Pavonia spinifex, Podachaenium eminens, Salvia splendens,* and *Tithonia diversifolia*. Some of these species are found alongside Cibodas brooks and found only by the waterside. This finding indicates that invasive species tend to invade by water dispersal (Bottollier-Curtet, Planty-Tabacchi, & Tabacchi, 2013).

Results show that Asteraceae contribute the greatest number of CBG exotic species naturalized in remnant forests, there are four species. The research of Tjitrosoedirdjo et al. (2015) listed Asteraceae as the most common IAS found in Indonesia with 162 species, Poaceae with 120 species, and Papilionaceae with 103 species, respectively. They also mentioned that 57 species of Asteraceae are listed as weeds and raising the cost of horticulture maintenance. Asteraceae are also commonly cultivated by Indonesian people, there are 77% of Asteraceae utilized as an ornamental plants and commonly found in the home yard.

CBG Asteraceae collections found in Cibodas remnant forest are *Bartlettina sordida, T. diversifolia, Montanoa grandiflora*, and *Podachaenium eminens*. *B. sordida* also known as *Eupatorium sordidum*, contain allelopathy that hinders *Brassica rapa* germination, root length, and dry mass (Lailaty, 2015). *Bartlettina sordida* also reportedly naturalized outside the CBG area, it was found in Gede-Pangrango National Park (GPNP) (Kudo, Mutaqien, Simbolon, & Suzuki, 2014). *Tithonia diversifolia* or

Mexican sunflower was introduced as an ornamental plants, and later become invasive. This plant is tolerant to heat and dry stress, fast-growing, and produce lightweight seeds that can easily blow away by wind and follow the water flow. The dormant seeds are also viable for a long period of about four months. This species also has the ability to overcome native species by releasing allelopathy (Rojas-Sandoval, Tremblay, Acevedo-Rodríguez, & Díaz-Soltero, 2017). *Montanoa grandiflora* is also reportedly found in Wornojiwo although its density did not contribute much to the forest community (Mutaqien et al., 2011). *Podachaenium eminens* is a broad leaves plant and has reportedly been found in GPNP. *Tithonia diversifolia* and *P. eminems* together with *C. calothyrsus, Chimonobambusa quadrangularis, Lantana camara, Passiflora ligularis,* and *Strobilanthes hamiltoniana* are the most familiar exotic plants in Indonesia (Tjitrosoedirdjo et al., 2015). Further, *L. camara* is considered as the worst 100 invasive species worldwide (Lowe, Browne, Boudjelas, & De Poorter, 2000).

Amongst the four CBG remnant forests, the Jalan Akar forest contains the largest number of naturalized exotic species, meanwhile, the Bengkel forest holds the smallest number of naturalized exotic species (Figure 2). Jalan Akar is located in the center of the CBG, and thus contains the most escaped exotic species. While the Bengkel forest is located on the steep hillside of CBG, therefore it creates a natural barrier for exotic species. The composition of exotic species in Wornojiwo is different from the other three remnant forests (Table 1). The reported species of exotic escaped species found in the latest publication by Mutaqien et al. (2011) are 11 species, while we found 8 species in Wornojiwo.

We found the domination of *C. quadrangularis* inhibiting other species, therefore it is most likely decreasing the number of species in Wornojiwo. Further, there are three species present in all four forests, they are *B. sordida*, *Cestrum auranticaum* and *Chimonobambusa quadrangularis. Cestrum aurantiacum* is also listed as invasive species for its potentials to invade Java Mountain forests. Currently, *C. aurantiacum* invades the natural forests of the GPNP, especially around the CBG border area. However, there is no record of this species in other areas (Mutaqien et al., 2011). These species have become an issue for CBG management. CBG has performed several treatments to prevent these species from spreading deeper into the adjacent forests by constructing a small ditch between Wornojiwo and CBG area, and also eradication. Naturalized exotic species are supported by the presence of suitable habitats, adequate water resources, and the relatively rapid growth rate of naturalized species (Junaedi et al., 2021).

The TWRAP scoring shows the highest score is 19, which belongs to *C. zebrina*, and the lowest score is 4 belongs to *C. sinensis*. On the contrary, the RD of *C. zebrina* is very low which is 1.33 (Figure 3). *C. zebrina* and *C. quadrangularis* both have the ability to grow vegetatively and fast growing, in which one of the most anticipated traits of exotic species. These traits correlated to the ability of species in dominating an area and outcompeting native species. Some species like *B. sordida* and *L. camara* produce enormous light-weight seeds, that are easily dispersed by wind. Invasive species are related to more efficient use of resources and effective reproduction (Dyderski & Jagodziński, 2019). Therefore, exotic species with these traits should be put on the high priority for monitoring.

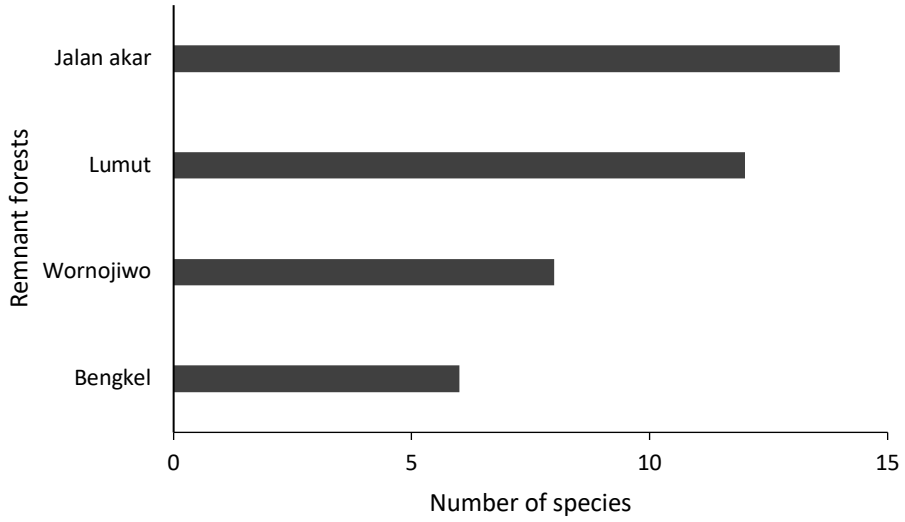

Figure 2. Number of exotic species of CBG plant collections naturalized in Cibodas remnant forests

TWRAP score shows there are 21 of 26 species that have above ten scores, meanwhile only five species score lower than ten. Furthermore, as we can expect in the future, TWRAP can be used to assess exotic species before it plant in the garden as garden collections. We also calculated the correlation between the vegetation parameter and the TWRAP score (Figure 4). The correlation between TWRAP and RD is 0.11, therefore the use of TWRAP is presumably fit for the early plans of choosing exotic species as garden collections but not related to the actual distributions of the species.

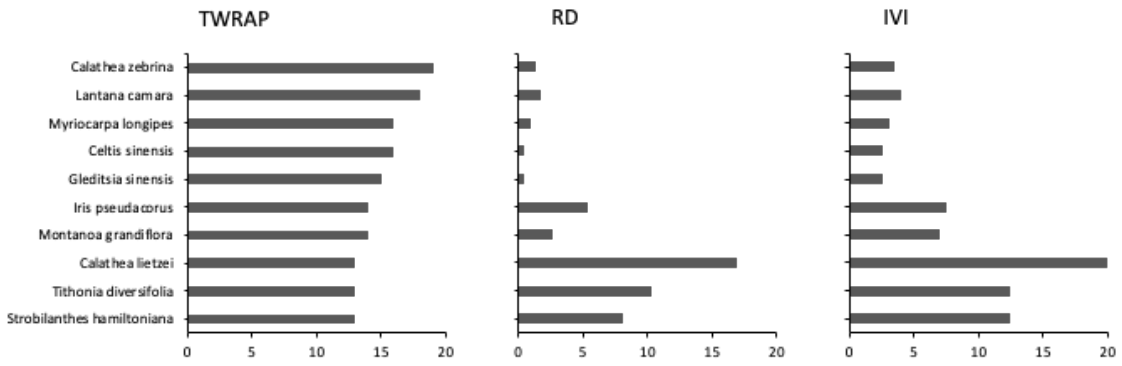

Figure 3. The TWRAP score (left), Relative Density (center) and Important Index Value (IDI) (right) of the ten highest score

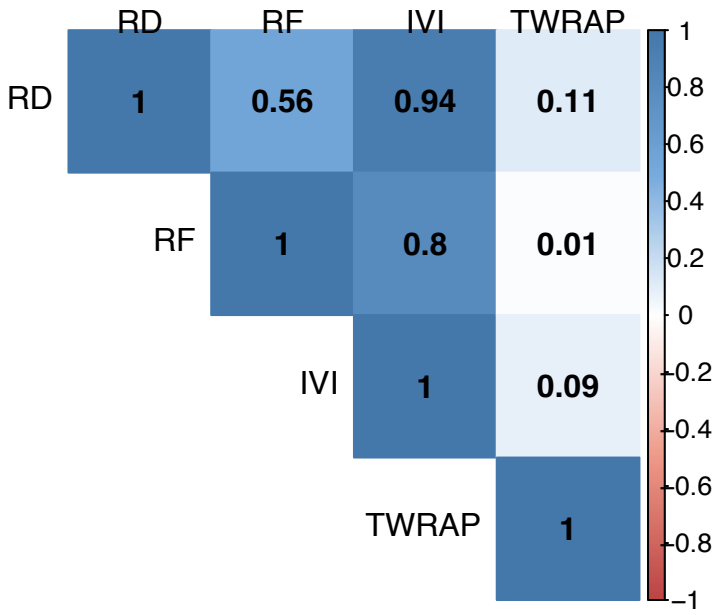

Figure 4. The correlation between Relative Density (RD), Relative Frequency (RF), Important Index Value (IVI), and Tropical Weed Risk Assessment (TWRAP)

Botanic gardens play role in the introduction pathway for horticulture (Hulme, 2014; Xu et al., 2014; Asih, Letari, Warseno & Iryadi, 2018; Ni & Hulme, 2021;). We found 26 CBG collections naturalized in remnant forests that set the alarm for future improvement in handling exotic collections. Our results corroborate previous findings showing there is an increasing number of naturalized exotic species, thus better management of garden exotic collections is necessary to prevent further invasions. This study supported the CBG commitment as ex-situ conservation institutions, botanic gardens need to perform acts continuously addressing invasive plant issues (Reichard, 2011).

4. Conclusions

Cibodas Botanical Garden collections have reportedly escaped and naturalized in adjacent forests. Our study in four Cibodas remnant forests shows 26 species of *Cibodas Botanical Garden* (CBG) exotic collections have been naturalized. Asteraceae contribute the largest number of species, followed by Solanaceae, Marantaceae, Fabaceae, and Acanthaceae. Therefore, CBG needs to set the alarm for Asteraceae collections to be assessed first. Jalan Akar holds the most exotic naturalized species, followed by Lumut, Wornojiwo, and Bengkel forests. *Tropical Weed Risk Assessment Protocol* (TWRAP) scoring shows 81% of the naturalized species have a score above ten, therefore TWRAP can be performed as an early screening of choosing garden collections. Overall, CBG needs to commit to performing risk analysis and monitoring its exotic collections. Monitoring in the following years is necessary to maintain diversity, monitor forest dynamics, and the spread of invasive CBG plant species. Further actions are applied according to monitoring results, whether digging small ditch or eradication.

Acknowledgments

This research was funded by *In-House Research* 2021 held by Research Center for Plant Conservation and Botanic Gardens – LIPI.

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Appendix. TWRAP framework question list

1. INVASIVENESS TRACK RECORD - Is this species known to be invasive elsewhere (outside assessed area)?	**SCORE**
Yes, in the same region as the assessed area	2
Yes, in different region as the assessed area or different country	1
No	0
2. CLIMATE OF NATURAL DISTRIBUTION – Is the climate of the natural distribution ranges of the species similar to the susceptible "invaded" habitat?	**SCORE**
Yes	2
No	0
3. SHADE TOLERANT – Is the species shade tolerant?	**SCORE**
Yes	2
To some extent	1
No	0
4. PREDATOR/PARASITE/DISEASE– Does a predator/parasite/disease of the species exist among the natural biodiversity of susceptible invaded habitat?	**SCORE**
No	1
Yes	0
5. MINIMUM JUVENILE PERIOD - What is relative measurement of minimum juvenile period of the species compared to the minimum juvenile period of native species with the same life form (or closely related taxa)?	**SCORE**
Shorter than native species	2
Similar to native species	1
Longer than native species	0
6. SEED THEORY - What seed characteristics are attributed to the species?	**SCORE**
The species seed properties have all following characteristics (Rejmanek & Richardson 1996; Gordon et al. 2010): (A) relatively small seed size (< 1 cm) (B) relatively high number seed per production (>5000-10000/m/year for non woody and > 1000 /m/year for woody species) (C) relatively short term between large seed crop (1-4 years) (D) relatively small seed mass (< 50 mg)	4
The species seed properties have three out of four characteristics	3
The species seed properties have two out of four characteristics	2
The species seed properties have one out of four characteristics	1
The species seed properties have none of four characteristics	0
7. POLLINATOR - Is the native pollinator available for the species?	**SCORE**

Yes, and relatively general, does not need specific species	2
Yes, and relatively specific, need particular species	1
No	0
8. VEGETATIVE REPRODUCTION – Does the species reproduce vegetatively?	**SCORE**
Yes, and the species is a fast growing species	2
Yes, and the species is not a fast growing species	1
No	0
9. DISPERSAL - What is/are the agent(s) of dispersal of the species? (if more than one, the score is the cumulative score)	**SCORE**
Animal	1
Wind	1
Water	1
Human	1
Others	1
None	0