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SPATIAL DISTRIBUTION OF INVASIVE PLANTS IN BANDUNG, WEST JAVA, INDONESIA

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ABSTRACT

The urban area is a source of invasive plants that enter through human activities such as agriculture and land-use conversion. Studying the invasive plant in urban areas is essential to understanding the city's ecosystem health condition. Therefore, this study aims to inventory invasive plants, map their distribution, and explain the relationship between land use with the community diversity and species richness of invasive plants in Bandung. The vegetation analysis was performed using line-transect in 22 study sites distributed using a systematic random sampling method in Bandung to observe the plant species composition. The study plots were placed based on the land-use type. The species name, individual number, frequency, and sampling site locations were noted and analyzed to calculate the important value index (IVI) and the invasive species distribution pattern using the principal component analysis (PCA). The dominant invasive species was spatially mapped. Six types of land use were used in this study, i.e., settlements, street green lanes, gardens, paddy fields, urban parks, and urban forests. There were 187 species found in Bandung, which can be categorized into alien invasive species (39%), invasive native plants (25%), non-invasive alien species (18%), non-invasive native species (15%), and unidentified plants (3%). The most common invasive plants found were *Eleusine indica* (IVI=10.50%), *Trimezia martinicensis* (IVI=7.22%), and *Cyperus rotundus* (IVI=6.74%). Based on the plant community similarity index, the study area with the highest similarities were paddy fields with gardens (50.5%), settlements with road lanes (44.4%), urban parks with road lanes (26.2%), and urban forests with road lane (17.5%). PCA showed *Swietenia macrophylla* as the most common invasive plant found in urban forests, urban parks, and road lanes, with air humidity as the most influencing environmental factor. *Trimezia martinicensis* is the most common species in the settlement area affected by high air humidity. *Bidens pilosa* is an invasive plant commonly found on paddy fields, gardens, settlements, road lanes, and urban park edges. This species can easily and rapidly reproduce with a high survival rate. The many invasive plants found in Bandung must be managed to maintain the urban ecosystem's health.

Keywords: Bandung, interpolation, invasive species, species mapping, urban area

INTRODUCTION

Alien species are brought or accidentally brought into an ecosystem unnaturally. Invasive species are native or alien species that can widely impact their habitat, causing environmental damage, economic loss, or harm to humans (Tjitrosoedirdjo 2017). Dominating their habitat is the main characteristic of invasive species. They can cause a decrease in biodiversity through the loss of native species and disturbance in the ecosystem functioning (Sunaryo 2015). Urban areas create multiple habitats that accommodate plant species diversity, and invasive species can often develop in such habitats (Štajerová *et al.* 2017). Mainly, anthropogenic disturbances introduce invasive species into the new habitat, such as the land-use change to establish agricultural areas of paddy fields and gardens or newly built settlements. Settlement areas can be a focal point of the species' invasive movement from spreading to the surrounding landscape (Chytrý *et al.* 2005). The diverse land use in urban areas caused the difference in the invasive species composition in each land-use type. Bandung is one of Indonesia's major cities with vastly developed and diverse land use. So far, studies

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on invasive species have mainly been done in conservation areas with limited knowledge in urban areas.

Many alien plant species were introduced to urban areas to provide, augment or restore specific ecosystem services. However, some species negatively impact existing ecosystem services and create novel ecosystem disservices within urban areas (Potgieter *et al.* 2017). For example, the alien invasive *Acacia mangium* found in the highway green lanes and urban parks was first introduced as street tree shade. Besides, this plant was also planted on eroded soil to repair the soil structure due to its robust, extensive rooting system (Environmental Management Agency 2014). On the other hand, *A. mangium* can change the soil composition through nitrogen fixation, competing on water and light resources with surrounding native species due to its deep rooting system and dense shade, producing allelopathic substances that can hamper the germination of surrounding plant seeds (Datiles & Rodriguez 2017). A study of invasive species in urban areas must be carried out to manage invasive species to reduce the negative impact on ecosystem services and prevent their spread to the natural areas. Therefore, this study aims to inventory invasive species and map their distribution. Data gathered (invasive species number and composition on each land use type, relations between invasive species with the land use, and distribution map of the ten most dominant invasive species in Bandung) can serve as early detection of the invasiveness of each species. It can also provide information for policymakers to determine further steps.

MATERIALS AND METHODS

Study Area

This study was done in 22 sampling sites (Figure 1) placed with systematic random sampling in Bandung (6°50'20"-6°58'3" SL, 107°32'44"-107°44'15" EL). The sampling sites were determined by 22 coordinates systematically set in the thematic map of Bandung on ArcGIS 10.4.1. These selected coordinates were then exported from ArcGIS to the GPS essential application for the location survey. Monitoring plots were randomly assigned based on the land use in those coordinate points.

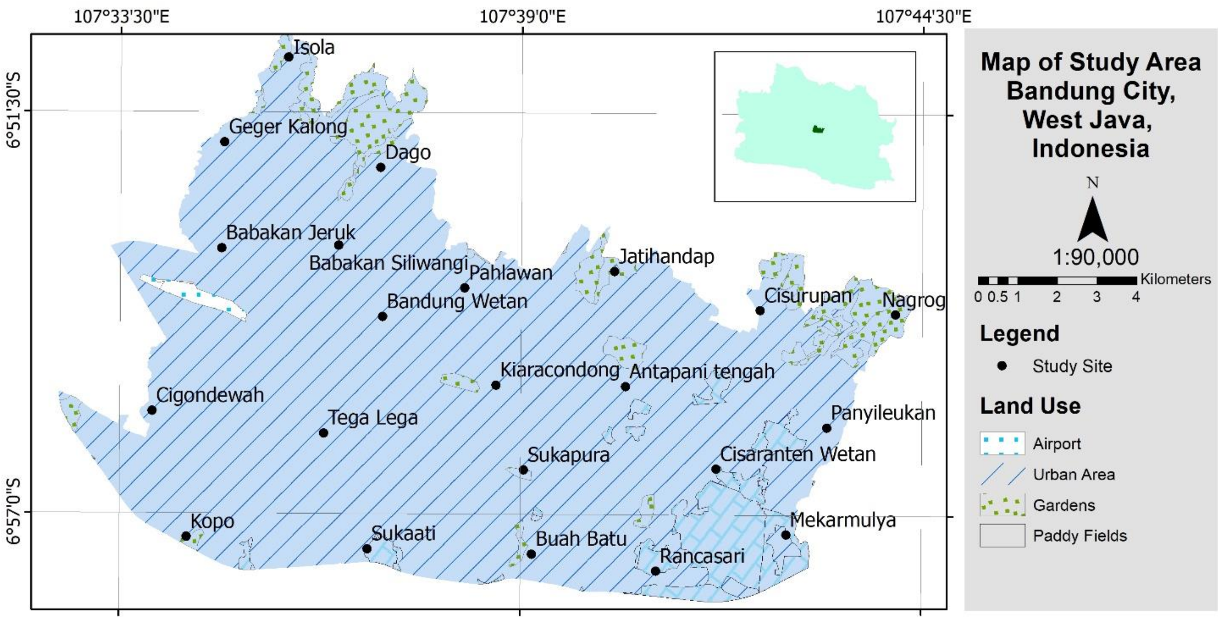


Figure 1 Location of the study site

Land-use paddy fields were found in six areas, i.e., Sukaati, Buahbatu, Rancasari, Mekarmulya, Sukapura, and Kopo. Gardens were found in five sampling areas, i.e., Isola, Cigondewah, Nagrog, Cisurupan, and Jatihandap. The street green lanes were found at five points, i.e., Cigondewah, Mekar Mulya, Cisaranten Wetan, Kiaracondong, and Pahlawan. There were nine points of settlements, i.e., Geger Kalong, Babakan Jeruk, Rancasari, Buahbatu, Sukaati, Panyileukan, Dago, Antapani Tengah, and Pahlawan. Last, urban parks were found at Tegalega and Bandung Wetan. Meanwhile, the urban forest was only found in the area point of Babakan Siliwangi.

Vegetation Survey

The vegetation survey was done from April 2021 to January 2022. Depending on the environmental situation, a twenty-eight-line transect was installed for 100 or 150 meters. The plant species' name with their life form (i.e., tree, shrub, liana, or herb) found in the line transect area and their number was written in the monitoring data sheet. The plants were directly identified in the field. Unidentified plants were sampled from the field to be further identified using the identification book *Main Weeds of Rice in Asia*. Identified plants were then grouped into four types, i.e., invasive alien species, invasive native, non-invasive alien, and non-invasive native, based on the guidebook provided by Biotrop, Convention of Biological Diversity (CBD), Center for Agriculture Biosciences International (CABI) and Guide Book to Invasive Species in Indonesia, Forest in Southeast Asia-Indonesia Program (FORIS-INDONESIA).

Measurement of Environmental Climatic Condition

Environmental and climatic conditions were measured to support the making of invasive species distribution prediction maps. Measured data were temperature and air humidity using a thermo hygrometer. Light intensity was also measured using a light meter. Measurements were done triplicate on each transect at the transect's start, middle, and endpoint, 50 to 100 cm above the ground.

Calculation of Importance Value Index (IVI), Diversity and Habitat Similarity

The Importance Value Index (IVI) was calculated for each species by summing up the relative density (1) and relative frequency (2) as follows:

$$\text{Density (D)} = \frac{\textit{Species individual number}}{\textit{Length of line transect}}$$

$$\text{Relative Density (RD)} = \frac{\textit{D of species}}{\textit{Total D of all species found}} \times 100\% \quad (1)$$

$$\text{Frequency (F)} = \frac{\textit{Number of plots where species was found}}{\textit{Total plot number}}$$

$$\text{Relative Frequency (RF)} = \frac{\textit{F of species}}{\textit{Total F of all species found}} \times 100\% \quad (2)$$

The IVI was calculated twice. The first was done for each land-use type for community analysis, where each land-use type was assumed to represent a specific vegetation community, totaling six vegetation communities. The second calculation was the IVI of the overall study sites.

The calculation of Shannon Wiener diversity index H' (3) on each community was done with the following formula,

$$H' = -\sum pi \;\; ln\,(pi) \quad (3)$$

with pi = proportion of species' individual number to overall species.

The Sorensen similarity index (4) was calculated for every combination pair of land use to find the most similar vegetation communities. The calculation of the Sorensen similarity index used the following formula,

$$S = \frac{2C}{A+B} \times 100\% \quad (4)$$

with
A = Species number in community A
B = Species number in community B
C = Species number in communities A and B

Statistical Analysis

Density values from 20 plant species with high IVI scores (>2.06%), average temperature, average air humidity, and average light intensity in each community were analyzed with PCA. PCA is used to extract meaningful information from a multivariate data table and to express this information as a set of a few new variables called principal components. These new variables correspond to a linear combination of the originals (Kassambra 2017). The number of principal components is less than or equal to the number of original variables. Using R studio version 4.2.0, package FactoMineR, only 15 plant species with the highest contribution of the principal component were shown on the PCA plot. Graphs from the analysis were visualized using the package Factoextra. PCA analysis was used to choose ten invasive species in making the invasive species distribution prediction map.

Invasive Species Distribution Mapping

Ten species with the highest score were mapped for their distribution in the Bandung area. The score indicates that those species highly influence study sites (Kassambara 2017). The plant distribution map in Bandung was based on the data of the individual number of each species and the mean climatic factor measured on each coordinate point (study sites). Climatic data were adjusted from the PCA results, where only one to two climatic data influence that species.

The distribution map was made using the interpolation method on the application ArcGIS 10.4.1. Spatial interpolation is a procedure for estimating the variable value in the field that is not included in study samples and located inside an area of the sampling location (Aswant 2016).

RESULTS AND DISCUSSION

Vegetation Composition in Bandung

The total number of species found in all study sites was 187, comprising 47 tree species, 21 shrub species, 3 liana species, and 116 herb species. Invasive species, whether alien or native, have a higher proportion than non-invasive species, with a total ratio of 64% (Figure 2). The presence of invasive species is supported by disturbance and human activities. These two phenomena are pervasive in urban areas. Thus, the presence and frequency of invasive species are relatively high in urban areas (Gulezian & Nyberg 2010).

The proportion of alien invasive species found was higher than the native ones. Most alien invasive species were initially brought to the urban areas to provide, add, or recover a specific ecosystem service. However, besides giving ecosystem services needed by humans, the alien invasive species may negatively impact the available ecosystem services (Potgieter *et al.* 2017).

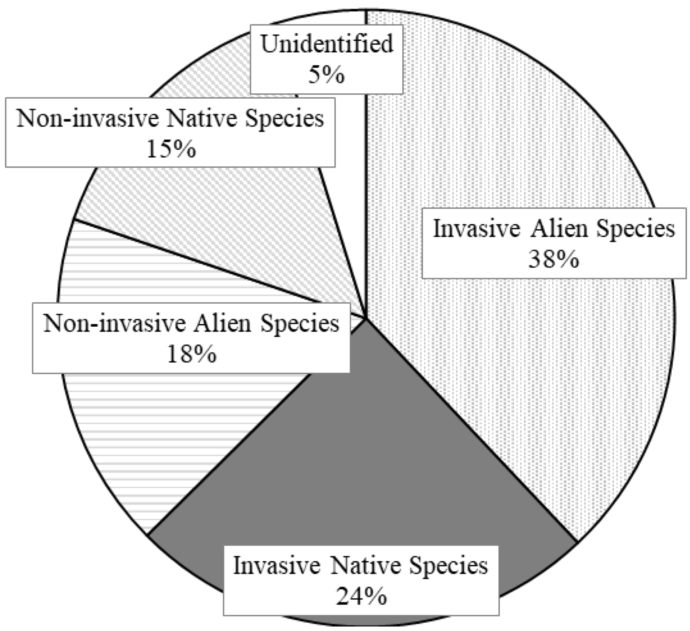


Figure 2 The proportion of invasive and non-invasive species in Bandung

Table 1 Ten species with the highest importance value index (IVI) on all study sites

Nr	Species name	Native	Family	IVI (%)
1	*Axonopus compressus*	Tropical America	Poaceae	11.46
2	*Eleusine indica*	India	Poaceae	10.50
3	*Asystasia gangetica*	India, Ceylon	Acanthaceae	7.87
4	*Alternanthera philoxeroides*	Tropical America	Asteraceae	7.46
5	*Trimezia martinicensis*	Mexico	Iridaceae	7.22
6	*Cyperus rotundus*	India, Africa	Cyperaceae	6.74
7	*Bidens pilosa*	South Africa	Asteraceae	5.42
8	*Cynodon dactylon*	Africa	Poaceae	5.12
9	*Swietenia macrophylla*	South America, Central America	Meliaceae	4.36
10	*Synedrella nodiflora*	South America, Central America	Asteraceae	4.23

The calculation of IVI in Table 1 shows that ten plants with the highest IVI were invasive species. Invasive species tend to have a high IVI due to their characteristics of the high tolerance range, enabling them to adapt well to various environments.

Axonopus compressus is the most abundant species in street green lanes, settlements, and urban parks. Annual plant *A. compressus* can grow vegetatively well with stolon and produce many seeds. *E. indica* was abundant in paddy fields and found in gardens, street green lanes, and settlements. *E. indica* can grow well in high light intensity and has a high adaptation level (Setyawati *et al.* 2015). Meanwhile, *A. gangetica* was abundant in gardens and found in paddy fields, streets, and urban forests. *A. gangetica* is a climber plant that can form a highly dense population (Sandoval & Rodriguez 2012).

Vegetation Composition in Six Communities

IVI calculation in each community (Table 2) shows three species with the highest value in communities' settlements, street green lanes, and urban parks, i.e., *A. compressus*, *Rivina humilis*, and *Syngonium podophyllum*. The three species are dominant and co-dominant in the urban forest community. Dominant species are defined as species with a higher ability to utilize their environment more efficiently than other species (Smith 1977). Invasive species tend to have a high IVI due to their wide tolerance range. Thus, they can adapt very well to various environments.

Table 2 Three species with the highest importance value index (IVI) were found on six land-use types/communities

Land-use	Species name	Family	IVI (%)
Paddy fields	*Eleusine indica*	Poaceae	29.66
	Cynodon dactylon	Poaceae	17.22
	Bidens pilosa	Asteraceae	13.90
Gardens	*Asystasia gangetica*	Acanthaceae	19.71
	Alternanthera philoxeroides	Amaranthaceae	14.94
	Galinsoga parviflora	Asteraceae	12.76
Street green lanes	*Axonopus compressus*	Poaceae	32.63
	Trimezia martinicensis	Iridaceae	25.49
	Swietenia macrophylla	Meliaceae	11.57
Settlements	*Axonopus compressus*	Poaceae	15.20
	Trimezia martinicensis	Iridaceae	9.03
	Arachis pintoi	Fabaceae	8.55
Urban parks	*Axonopus compressus*	Poaceae	37.56
	Arachis pintoi	Fabaceae	18.47
	Hymenocalis speciosa	Amaryllidaceae	14.51
Urban forests	*Rivina humilis*	Phytolaccaceae	29.54
	Syngonium podophyllum	Araceae	27.37
	Xanthosoma violaceum	Araceae	13.89

Table 3 Mean climatic factors measured in six communities

Land-use	Light intensity (lux)	Temperature (°C)	Air humidity (%)
Urban forests	191	23	90
Settlements	17 074	30	84
Gardens	58 037	30	78
Paddy fields	54 687	30	79
Street green lanes	7 030	29	78
Urban parks	2 030	27	85

Dominating species in the paddy field community were mainly plants from the family Poaceae, with leaf characteristics resembling ribbon and fibrous root and reproducing vegetatively with stolon. Grasses tend to grow optimally in areas exposed to sunlight. The paddy field community has a relatively high light intensity (Table 3), allowing this plant group to grow optimally and reproduce well or widely spread.

The garden community was dominated by three invasive species, i.e., *A. gangetica, A. philoxeroides,* and *G. parviflora*. The habitat suitability of invasive species developing in the garden community is affected by several factors, e.g., species commodity planted and spatial variations such as microclimate, soil character, and human presence (Wang & Wan 2020). Five garden communities in this study comprised two cauliflower gardens, a bok choy garden, and two mixed cassava and sweet potato gardens. Various commodities planted in those five study sites also influenced the invasive species found.

R. humilis and *S. podophyllum* were two invasive species dominating the urban forest community. *R. humilis* is a tropical plant commonly found in forests, scrubs, street edges, and disturbed sites at a wide range of altitudes from 0 to 1700 masl. This species proliferates, mainly under shade. Due to those characteristics, this species can significantly change its habitat and harm the native vegetation (Parker 2013). Meanwhile, *S. podophyllum* is a climber that can rapidly grow, invading the forest's floor into canopies, covering huge trees to understory vegetation underneath (Pacific Islands Ecosystems at Risk 2012).

Species *A. compressus* dominated the settlements, street green lanes, and urban parks, while *T. martinicensis* was a co-dominant species in the street lanes and settlements. The third dominant plant in the green street lanes community was *S. macrophylla*. The ornamental plant *A. compressus* is mainly used in domestic gardens and parks. This species adapts to humid and warm environments and is also adequately tolerant to shade, even though it can grow well in areas exposed to sunlight (CABI 2019). Climatic conditions in settlements, urban parks, and street lanes support the optimal growth of *A. compressus*. Light intensity in settlements, urban parks, and street lanes was lower than in paddy fields and gardens. Even though the settlement temperature was the same as those in the garden and paddy fields, the settlement had higher humidity.

T. martinicensis is also intentionally introduced as an ornamental plant. Almost 40% of invasive plants in the United States were initially introduced as ornamental plants (Lehan *et al.* 2013). Ornamental plants can quickly grow and resist pests and pathogens (Guo *et al.* 2019). These characteristics support most ornamental plants developing into invasive species. *S. macrophylla* is a fast-growing tree with a high tolerance to low light intensity. A study by Norghauer *et al.* (2011) suggests that the abundance of *S. macrophylla* is negatively correlated to the abundance of plants under their shade. When *S. macrophylla* grows as the landscape canopy, a dense shade forms, limiting sunlight penetration to understory plants under its shade. Therefore, the germination of understory plants can be disturbed, and the mature individual does not grow optimally.

The highest invasive species richness (Table 4) was found in the community of settlements, followed by gardens, paddy fields, street green lanes, and urban parks. Decker *et al.* (2012) also report a similar result, mentioning that the richness of invasive species positively correlates to the percentage of public area use, human population, and agricultural area use. The settlement vegetation community has the highest diversity and richness of invasive and

Table 4 The Shannon Wiener diversity index (H') calculated in six communities

Land-use	H'	Invasive species richness	Non-invasive species richness
Settlements	3.71	60	55
Street green lanes	2.6	39	17
Gardens	3.03	45	3
Paddy fields	2.74	39	4
Urban parks	2.4	18	10
Urban forests	2.31	10	13

non-invasive species. The presence of humans is the most influencing factor in invasive species introduction. The settlement area has the highest human population of the other five land uses. Factors influencing the high diversity and abundance of invasive species in settlement areas are human population, trading activity, nutrition source, warm and protected microclimate, and the potential of herbivore or competitor absence (Francis & Chadwick 2015).

The vegetation community in settlements, street green lanes, and urban parks, including urban and suburban areas, had more invasive species than non-invasive ones (Table 4). The settlements- green street lanes and urban parks-street green lanes communities had a high similarity of vegetation composition (Table 5). Human-made ecosystems have often supported the establishment and development of alien species (Hulme, 2003). Besides the high similarity of vegetation composition, those four communities mentioned (i.e., settlements, urban parks and forests, and green street lanes) also belong to the same cluster in the PCA results (Figure 3). These four communities are located in quadrant 1 with *A. compressus, T. martinicensis*, *S. macrophylla,* and *Mangifera indica*, with a particular characteristic of climatic factor being air humidity. The four species had a high presence in the community with high humidity, indicating that high humidity is a suitable climatic condition for the growth of the four species. The intensity of human existence is high in this land use compared to gardens and paddy fields. Species found in quadrant 1 are invasive species, mainly introduced with the intention of ornamental plants, food sources, and street shade trees.

The paddy fields and garden communities had a high similarity index (50.5%). Both of these communities are included in the suburban area. Meanwhile, the urban forest community had a species composition that tends to be unique, indicated by the low value of the similarity index with other communities. In addition, the urban forest also had different climatic conditions from other communities, such as low light intensity and low temperature with high humidity.

Other invasive species found in these four communities were *Tagetes erecta* and *Cosmos sulphureus* as ornamental plants, *Artocarpus heterophyllus* and *Psidium guajava* as consumable plants, *Delonix regia* and *Albizia saman* as shade trees. The presence of these species depends on human preference. Human plays a vital role in managing invasive species. People often tend these species by pruning or splitting them, directing their growth without disturbing their aesthetics. Thus, it can be concluded that anthropogenic factor has a more considerable influence than climatic factors on determining the presence of invasive species in urban areas. Humans, through their preferences, control the presence and dominance of invasive species in urban areas without reducing the number of invasive species.

Table 5 Sorensen Index calculated in six paired communities

	Paddy fields	Gardens	Street green lanes	Settlements	Urban parks	Urban forests
Paddy fields	-	50.5	30.3	22.8	16.9	6.0
Gardens	-	-	32.7	25.8	7.9	5.6
Street green lanes	-	-	-	44.4	26.2	17.5
Settlements	-	-	-	-	21.0	14.4
Urban parks	-	-	-	-	-	11.5
Urban forests	-	-	-	-	-	-

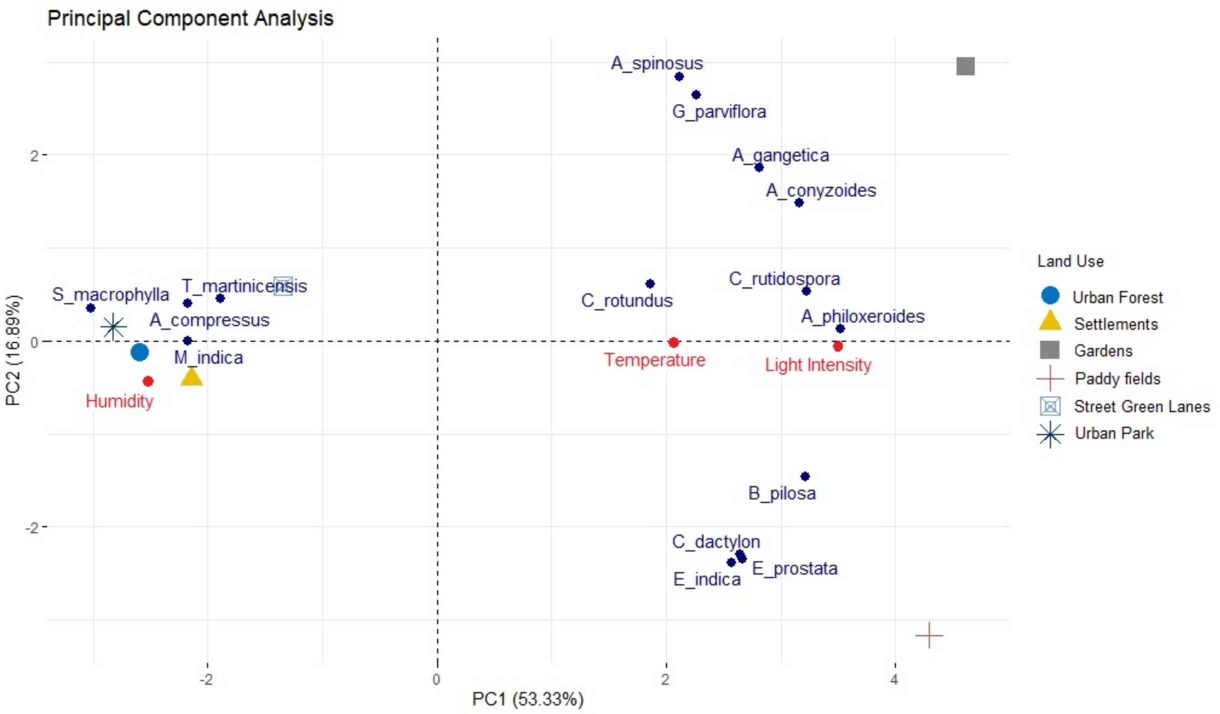


Figure 3 PCA results

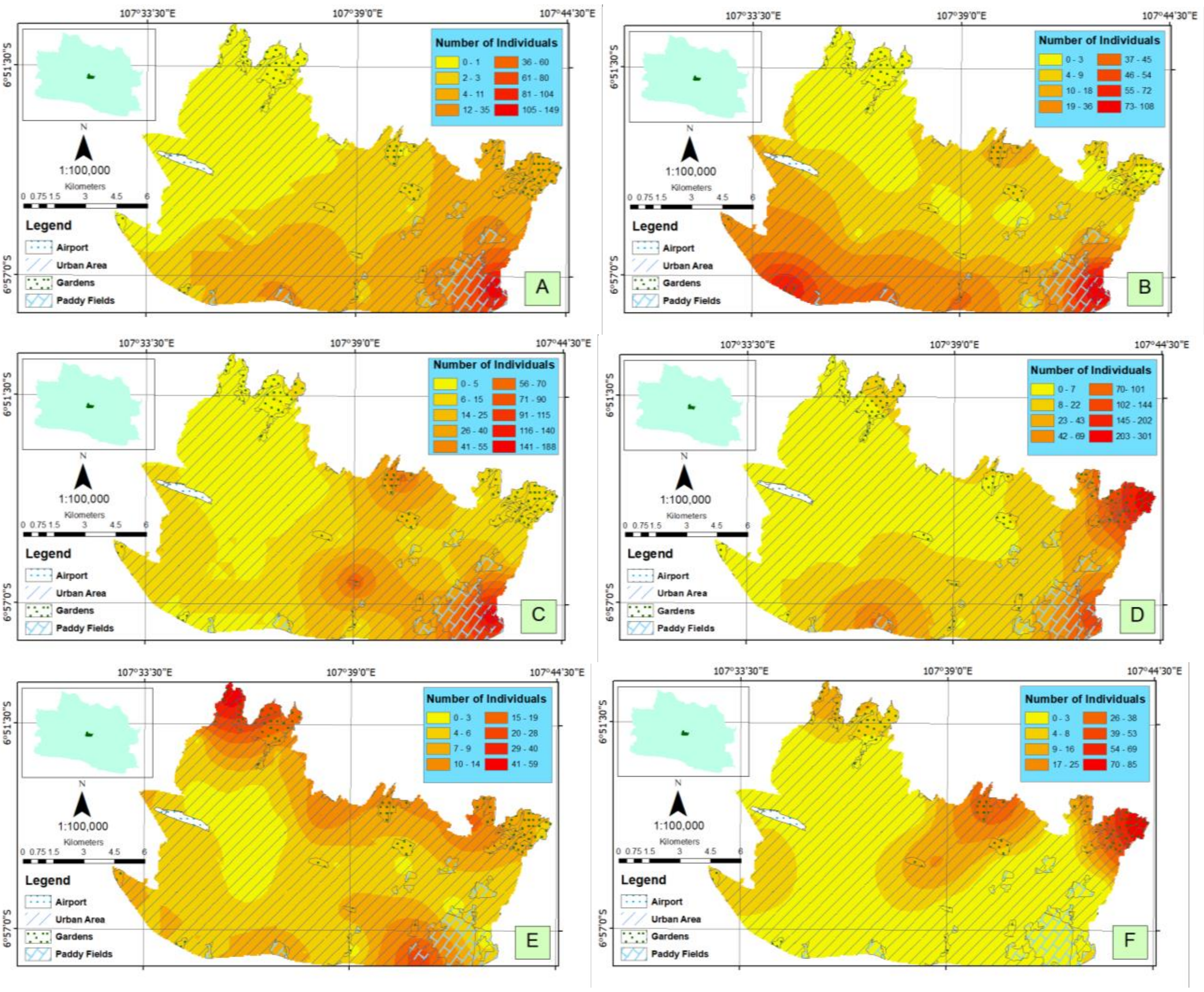
On the contrary, findings in the urban forests show that although non-invasive species had a higher species number, this community had the lowest diversity index of others. Apart from discussing species' invasiveness in urban forests, species richness was lower than species richness in other communities. Several factors affect small-scale species richness, including geographic factors such as the regional species pool, dispersal distance and ease of dispersal, biological factors such as competition, facilitation, and predation, as well as environmental factors such as resource availability, environmental heterogeneity, and disturbance frequency and intensity (Brown *et al.* 2016). Urban Forest's climatic conditions differ from other communities, such as low light intensity, temperature, and high humidity. This condition causes limited species that can survive in urban forests, and the low diversity of species in the urban forest can be caused by management areas related to its function as a recreation facility. When viewed from an ecological perspective, it is also included as an ecosystem disturbance that causes a decrease in species richness.

Based on the PCA results, paddy fields and gardens belong to different quadrants, even though they share similarities in their vegetation composition. Gardens were placed in quadrant 2, while paddy fields at quadrant 3. Both quadrants were influenced by the same climatic factors, i.e., light intensity and air temperature. It indicates that an abundance of *Amaranthus spinosus, Ageratum conyzoides, Cleome rutidosperma, Cyperus rotundus, G. parviflora, A. gangetica, A. philoxeroides*, *Eclipta prostrata, E. indica, C. dactylon,* and *B. pilosa* is influenced by light intensity and air temperature, whereas the abundance of *A. compressus, T. martinicensis, S. macrophylla, and M. indica* is influenced by humidity. Quadrant 2 is occupied by species, i.e., *A. spinosus, A. conyzoides, C.rutidosperma, C. rotundus, G. parviflora, A. gangetica,* and *A. philoxeroides*. These species were initially introduced as contaminants to propagules planted in the garden and managed to "escape" to the surrounding areas. These species were then able to adapt and invade the surrounding garden areas. Most species can survive in intense light exposure and grow optimally in warm temperatures. For example, *A. gangetica* is dispersed by seeds and rhizomes. The seeds are dispersed from explosive capsules, but long-distance dispersal is affected by humans. The risk of introducing rhizome material as a contaminant of soil and compost remains high in those countries where the plant is well established (Sandoval & Rodríguez 2012).

Meanwhile, quadrant 3 is occupied by *Eclipta prostrata, E. indica, C. dactylon,* and *B. pilosa.* In the paddy field community, in our observation, species such as *C. rotundus, A. gangetica,* and *A. philoxeroides* had relatively high frequency but low density. Due to the inter-species interaction, their density was lower than *E. indica, C. dactylon,* and *B. Pilosa.* Interspecific interactions, including competition, interference, and facilitation, determine the natural community's composition, distribution, and species abundance (Belote & Weltzin 2006).

Invasive Species Distribution in Bandung

The distribution pattern of *E. prostrata* shares similarities with *C. dactylon* (Figure 4). *C. dactylon* belongs to the C4 plant group that can adapt well and grow optimally in high light intensity. Although occupying the same PCA quadrant, *B. pilosa* has a different distribution pattern from *E. prostrata* and *C. dactylon.* Instead, *B. pilosa* distribution tends to be similar to *A. philoxeroides* and *A. conyzoides.* The three species (i.e., *B. pilosa, A. philoxeroides,* and *A. conyzoides)* are abundant in paddy fields, gardens, and settlements. They produce abundant seeds with a wide dispersal range, allowing them to be present in various land-use types. On average, seeds of *A. conyzoides* are 3.4 mm in length and 0.33 mm in width, equipped with pappus that enables them to attach to garments or animal body parts. This species is widely considered a weed in agricultural and anthropogenic areas and its natural habitat (United States Department of Agriculture 2019). Meanwhile, *B. pilosa* can produce up to 6000 seeds per year that can easily be dispersed by attaching to animals, birds, human clothes, wind, and water. Their propagules can remain viable for 5-6 years (Sandoval 2018).



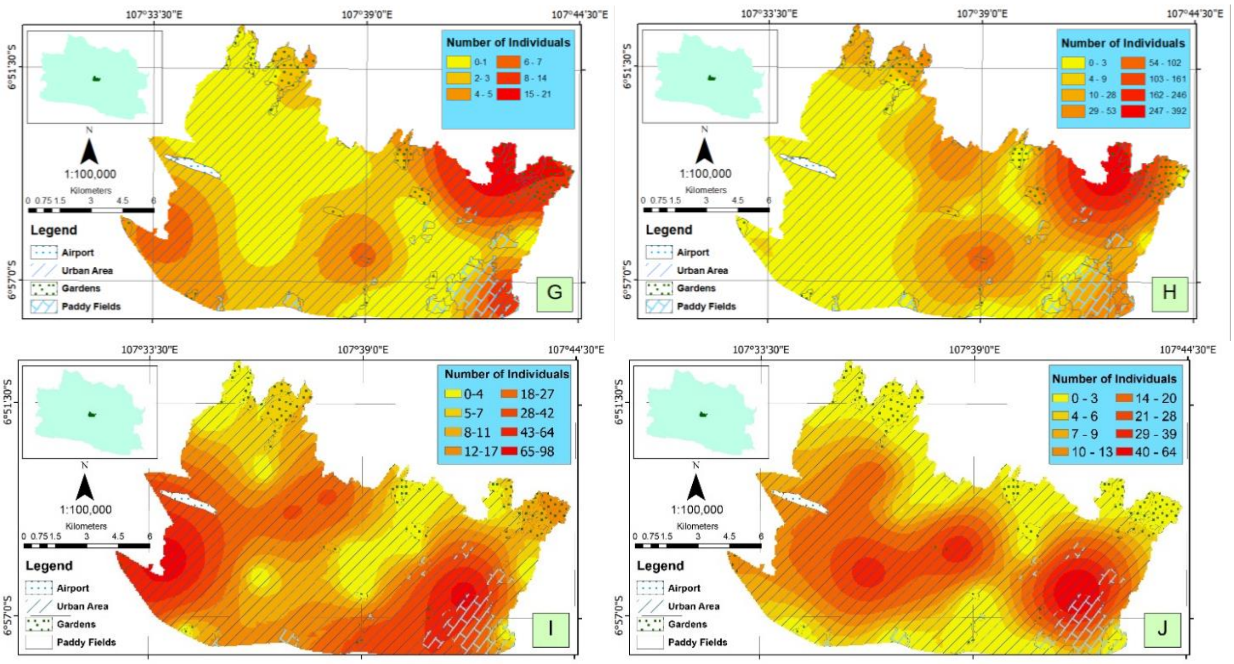


Figure 4 Distribution map of invasive species in Bandung: A. *E. prostrata*; B. *C. dactylon*; C. *B. pilosa*; D. *A. philoxeroides*; E. *A. conyzoides*; F. *A. spinosus*; G. *C. rutidosperma*; H. *A. gangetica*; I. *T. martinicensis*; J. *S. macrophylla*

A. conyzoides and *A. spinosus* are frequently found in gardens. There is no specific distribution pattern of *A. gangetica,* but it can be commonly found in paddy fields, settlements, and green street lanes. This species propagates through rhizomes and dehiscent capsules. Furthermore, the dehiscent capsule explodes and disperses the seeds in the surrounding areas. Humans can assist in its long-distance dispersal. The rhizome of this species can contaminate the soil, and it can spread further when present in compost used as planting media (Sandoval & Rodríguez 2012).

Two species, i.e., *S. macrophylla* and *T. martinicensis,* are introduced in urban areas such as parks, settlements, and streets with an initial specific purpose. The shape of *S. macrophylla* resembles a huge umbrella. Thus, it can provide broad shade areas and decorate the road due to its pleasant form (Environmental Management Agency 2014). Therefore, it is unsurprising that this species is widely found in urban parks, forests, and green street lanes. On the contrary, *T. martinicensis* is abundant in settlements since it is widely planted as ornamental.

CONCLUSION

There were 187 species found in Bandung that can be grouped into invasive alien species (39%), invasive native plants (25%), non-invasive alien species (18%), non-invasive native species (15%), and unidentified plants (3%). Species with the highest individual found on the edge of urban areas and were absent in the city's center were *Eclipta prostrata, C. dactylon, B. pilosa, A. philoxeroides, A. conyzoides, A. spinosus, C. rutidosperma,* and *A. gangetica*. Meanwhile, *S. macrophylla* and *T. martinicensis* had the highest number of individuals in the city center.

Paddy fields and gardens have similar vegetation composition but differ in dominant and co-dominant species. Invasive species found in paddy fields and gardens were agricultural weeds. Meanwhile, ornamental plants were invasive in urban parks, street green lanes, and settlements. Forest had the lowest number of invasive species, corresponding with its function to maintain biodiversity.

Further research on the distribution map of invasive species in Bandung can focus only on one or several species by analyzing the relationship between plant populations and distance to the city center, distance to main roads, edaphic factors, and human population. This information is vital for determining how to control invasive species properly. Experimental research can be used to determine interactions between invasive species in one community. In addition, it is essential to carry out a risk analysis to study further the risks posed and the management of each species. Thus, the subsequent steps can be more focused.

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