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COMPOSITION AND DISTRIBUTION OF INVASIVE SPECIES IN THE PESON SUBAH I NATURE RESERVE, BATANG DISTRICT, CENTRAL JAVA PROVINCE

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Abstract

This research was conducted to analyze the composition and distribution of invasive plant species in the Peson Subah I Nature Reserve (PSINR), a conservation area located in Kuripan Village, Subah District, Batang Regency, Central Java Province. The present study, carried out from April 17 to 20, 2023, aimed to identify invasive plants in PSINR and map their spatial distribution. A double-plot method was employed, with plots selected purposively at a sampling intensity of 10%. Data analysis utilized a quantitative descriptive approach based on vegetation analysis parameters. As a result, the observations identified 80 plant species, of which 43 (53%) were classified as invasive. The species with the highest Importance Value Index (IVI) at each growth stage were as follows: at the tree level, Acacia (*Acacia auriculiformis*) (IVI: 66.44); at the pole level, *Klampis* (*Flacourtia indica*) (IVI: 91.46); at both the sapling and the seedling levels, *Lampeni* (*Ardisia elliptica*) (IVI: 55.16). The plant diversity index for PSINR at all growth levels was categorized as medium, while the evenness index ranged from medium to high.

Keywords: *Nature Reserve, Invasive Species, Peson Subah I Nature Reserve*

Introduction

Peson Subah I Nature Reserve (PSINR) is a conservation area managed by the Central Java Natural Resources Conservation Agency (BKSDA Jateng, 2023). Located in Kuripan Village, Subah District, Batang Regency, Central Java Province, PSINR was designated as a conservation area by Indonesia's Minister of Forestry through Decree No. 82/Menhut-II/2004 on March 10, 2004. The reserve covers an area of 10.4 hectares and is part of the Subah Forest within the Kendal Forest Management Unit (*KPH Kendal*), maintaining its designation as a Nature Reserve forest. During the reform period, PSINR was occupied by the local community, resulting in changes to its land cover. At that time, the community utilized the area for agricultural and farming activities. However, after these activities ceased, PSINR underwent natural succession, shaping its current ecological state.

Throughout its management history, PSINR has encountered various dynamics and significant ecological challenges. These issues have affected biodiversity, ecosystems, and local ecological functions, threatening the sustainability of the PSINR area. One notable challenge is the entry and proliferation of invasive species, both from within and outside the region.

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The impact of invasive species on PSINR is not merely a local concern but a global issue requiring serious attention due to its far-reaching consequences. Invasive species spread from their native habitats to new locations and threaten biodiversity and ecosystems (Almeida, 2013). This is affirmed by Tjitrosoedirdjo et al. (2016), who state that invasive plants are species that threaten the integrity of natural and semi-natural communities, causing significant impacts on biodiversity within ecosystems.

An invasive species is defined as any species, whether native or non-native, that has colonized a habitat and caused ecological, economic, and social harms. Invasive alien species include plants, animals, microorganisms, and other non-native organisms that can damage ecosystems and the environment, resulting in economic losses or negatively impacting biodiversity and human health (Tjitrosoedirdjo et al., 2016). The presence of invasive species in PSINR has been a pressing concern. However, to date, no data exists on invasive species within the area. This research aimed to (1) identify the composition and structure of invasive plant vegetation in PSINR and (2) spatially map the distribution. The findings were expected to provide valuable insights for area managers to set management priorities for invasive species and identify priority areas for invasive species management within the PSINR.

Research Methods

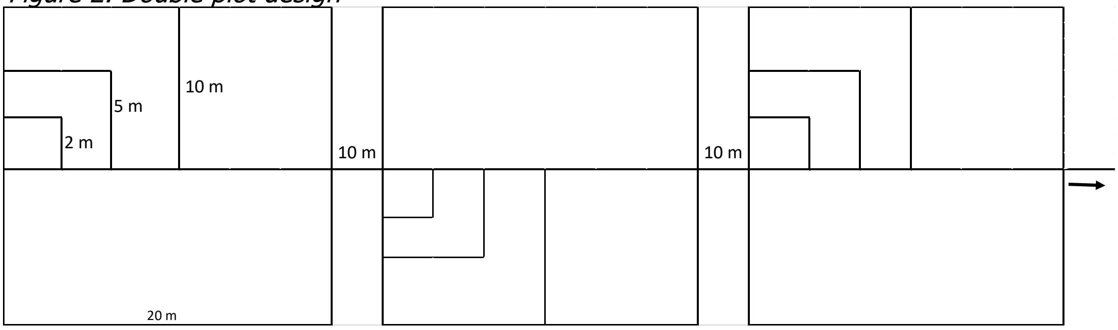
The research was conducted at PSINR, located in Kuripan Village, Subah District, Batang Regency, Central Java Province (see Figure 1), from April 17 to 20, 2023.

Figure 1. Sampling location

Data collection was carried out employing the multiple plot method, which was determined purposively (see Figure 2). The sampling intensity was 10%, with 25 measuring plots created. Data collection was based on growth levels, categorized as follows: a) Seedling measuring plot (2 m x 2 m): for seedlings with a height of <1.5 m; b) Stake measuring plot (5 m x 5 m): for saplings with a height of >1.5 m and a diameter of <10 cm; c) Pole measuring plot (10 m x 10 m): for stems with a diameter between 10 cm and 19.9 cm; and d) Tree measuring plot (20 m x 20 m): for trees with a diameter of ≥20 cm.

The locations where invasive species were found were marked using a Global Positioning System (GPS). The classification of invasive species was based on criteria from the Ministry of Environment and Forestry Regulation No. 94/2016, the Invasive Species Guide (Setyawati et al., 2015), the CABI Invasive Species Database (CABI, 2024), and the IUCN Global Invasive Species Database (IUCN, 2024). In addition, the tools used in this research included the PSINR map, GPS, ArcGIS 10.6 software, stationery, a

Figure 2. Double plot design



camera, length measuring tools, plastic ropes, a compass, a phi band, and tally sheets.

Data analysis employed a descriptive quantitative approach, focusing on the results of vegetation analysis. For spatial data, overlay analysis was conducted using a Geographic Information System (ArcGIS 10.6). The analysis parameters included Relative Density (RD), Relative Frequency (RF), and Relative Dominance (RDo). The Importance Value Index (IVI) was calculated to identify and describe the dominance of species in the community. The IVI is the sum of Relative Density, Relative Frequency, and Relative Dominance.

$$\text{Density (ind/ha)} = \frac{Number\ of\ individuals\ of\ a\ type}{Total\ plot\ area}$$

$$\text{Relative Density (\%)} = \frac{DM\ of\ species}{DM\ total\ of\ all\ species} \times 100$$

$$\text{Frequency} = \frac{\sum a\ subplot\ determined\ by\ species}{\sum Total\ of\ subplot}$$

$$\text{Relative Frequency (\%)} = \frac{F\ of\ a\ species}{F\ of\ total\ of\ all\ species} \times 100$$

$$\text{Dominance} = \frac{Basal\ area\ of\ a\ species}{Total\ plot\ area}$$

$$\text{Relative Dominance (\%)} = \frac{Dominance\ of\ a\ type}{Total\ of\ dominance} \times 100$$

Importance Value Index = RD+RF+RDo

The Shannon-Wiener Index was used to calculate the level of plant diversity. This diversity index is a variable that helps determine the condition and stability of an ecosystem by assessing the types and abundance of living organisms within it (Odum, 1996).

$$H' = -\sum_{ni}^{n} pi \text{ In } pi$$

Notes: H' = Shannon-Wiener diversity index; pi = the proportion of a species (calculated as the number of individuals of a species divided by the total number of individuals); ni = the number of individuals of the *i-th* species; *n* = the total number of individuals in the ecosystem.

The level of evenness of plant species was assessed using the species evenness index, which provided insight into the distribution of ndividuals across different species. The evenness index was defined as follows:

$$E = \frac{H'}{\ln (S)}$$

Notes: H' = Shannon-Wiener diversity index; S = Number of species; E = Species evenness index. The value ranges from 0 to 1. A value of 0 indicates a very uneven distribution of species, while a value close to 1 suggests that nearly all species have a similar abundance (Magurran, 2013).

Research Results and Discussion

Type of Composition

Visually, invasive species occupied most of the area, as evidenced by the proliferation of several types of lianas growing in towering structures and wrapping around trees in PSINR (see Figure 3). Based on observations, 80 plant species from 34 families were identified in PSINR. The most abundant families were *Fabaceae*, *Arecaceae*, *Poaceae*, *Euphorbiaceae*, and *Moraceae*. Of these 80 species, 43 plant species (53%) were classified as invasive plants. Among the 43 invasive species, 9 met the criteria outlined in the Ministry of Environment and Forestry Regulation No. 94 of 2016. Additionally, 36 species were categorized as invasive based on Setyawati et al. (2015), and 37 species were classified as invasive according to IUCN (2024) and CABI (2024) (see Table 1).

Based on their growth habits, these invasive species originated from 18 families and were categorized as 21 herbaceous species, 19 shrub species, and 3 liana species. In PSINR, herbaceous undergrowth and shrubs were the most commonly found types. Understory plants, which grew easily in open environmental conditions with high sunlight intensity, thrived in PSINR (Sahira, 2016). The relatively open conditions in some parts of PSINR allowed these understory plants to grow abundantly, often overpowering native species. Invasive alien plants exhibited several distinctive characteristics, including rapid growth and reproduction, effective dispersal mechanisms, strong environmental adaptability, and the ability to thrive on various nutrients (Wahyuni et al., 2016).

Vegetation analysis in PSINR, conducted across various growth levels—trees, poles, saplings, and seedlings—identified the five plant species with the highest Importance Value Index. These included Acacia (*Acacia auriculiformis*) at the tree level, *Klampis (Flacourtia indica*) at the pole level, and *Lampeni* (*Ardisi elliptica*) at both the sapling and seedling levels (see Table 2).

Table 1. Invasive plant species in PSINR

No	Local name	Scientific name	MoEF Regulation No. 94/2016	Setyawati (2015)	CABI & IUCN (2024)
1	*Akasia 1*	*Acacia auriculiformis*			√
2	*Akasia 2*	*Acacia mangium*		√	√
3	*Randha lenguk*	*Ageratina riparia*		√	√
4	*Bandotan 1*	*Ageratum conyzoides*		√	√
5	*Bandotan 2*	*Ageratum houstonianum*		√	√
6	*Bayam tahun*	*Amaranthus hybridus*		√	√
7	*Lampeni*	*Ardisia elliptica*			√

No	Local name	Scientific name	MoEF Regulation No. 94/2016	Setyawati (2015)	CABI & IUCN (2024)
8	*Rumput paitan*	*Axonopus compressus*		√	√
9	*Bunga kupu-kupu*	*Bauhinia purpurea*	√	√	√
10	*Ajeran*	*Bidens pilosa*		√	√
11	*Rumput kebo*	*Brachiaria eruciformis*		√	
12	*Gambiran*	*Breynia cernua*		√	
13	*Kacang asu*	*Calopogium muconoides*		√	
14	*Anggur-angguran*	*Cayratia trifolia*		√	
15	*Rumput rhodes*	*Chloris gayana*		√	√
16	*Kirinyu*	*Chromolaena odorata*	√	√	
17	*Enceng-enceng*	*Cleome rutidosperma*		√	√
18	*Harendong*	*Clidemia hirta*	√	√	√
19	*Tali putri*	*Cuscuta sp*			√
20	*Lidah anjing*	*Cyanthillium cinereum L*		√	√
21	*Tuba laut*	*Derris trifoliata*		√	√
22	*Patikan kebo*	*Euphorbia hirta*		√	√
23	*Klampis*	*Flacourtia indica*			√
24	*Wowo*	*Flagellaria indica*			√
25	*Alang-alang*	*Imperata cylindrica*	√	√	√
26	*Sukem blembem*	*Ishachaemum rugosum salisb.*		√	
27	*Tembelekan*	*Lantana camara*	√	√	√
28	*Lamtoro*	*Leucaena leucocephala*	√	√	√
29	*Sikejut besar*	*Mimosa diplotricha*		√	√
30	*Baret*	*Mimosa pigra*	√	√	√
31	*Putri malu*	*Mimosa pudica*		√	√
32	*Blimbing tanah*	*Oxalis barrelieri*		√	
33	*Rambusa*	*Passiflora foetida*	√	√	√
34	*Rumput gajah*	*Pennisetum purpureum*	√	√	√
35	*Naga buana*	*Phyllanthus pulcher*		√	
36	*Meniran*	*Phyllantus urinaria*		√	
37	*Bluntas*	*Pluchea indica*		√	√
38	*Jambu biji*	*Psidium guajava L.*		√	√
39	*Rumput branjangan*	*Rottboelia cochinchinensis*		√	
40	*Glagah*	*Saccharum spontaneum*			√
41	*Pecut kuda*	*Stachytarpheta indica*		√	
42	*Amplesan*	*Tetracera scandes*			√
43	*Srunen*	*Tridax procumbens*		√	√

Table 2. Importance Value Index on PSINR

No	Type	Relative Frequency	Relative Density	Relative Dominance	IVI
	Trees				
1	*Acacia auriculiformis*	18.75	24.29	23.41	66.44
2	*Macaranga rhizinoides*	14.58	18.57	19.3	52.46
3	*Nauclea orientalis*	12.5	8.57	16.54	37.61
4	*Ternimalia catappa*	14.58	11.43	10.71	36.72
5	*Protium javanicum*	10.42	12.86	8.86	32.14
	Poles				
1	*Flacourtia indica*	16.67	34.21	40.58	91.46
2	*Protium javanicum*	16.67	23.68	14.03	54.38
3	*Morinda citrifolia*	12.5	7.89	7.98	28.38
4	*Ternimalia catappa*	8.33	5.26	7.57	21.17
5	*Acacia auriculiformis*	8.33	5.26	7.22	20.81
	Saplings				
1	*Ardisia elliptica*	22.54	32.63		55.16
2	*Flagellaria indica*	28.17	24.51		52.68
3	*Tetracera scandes*	16.9	21.16		38.07
4	*Flacourtia indica*	4.23	7.23		11.46
5	*Saccharum spontaneum*	5.63	4.94		10.57
	Seedlings				
1	*Ardisia elliptica*	22.54	32.63		55.16
2	*Flagellaria indica*	28.17	24.51		5.68
3	*Tetracera scandes*	16.9	21.16		38.07
4	*Flacourtia indica*	4.23	7.23		11.46
5	*Saccharum spontaneum*	5.63	4.94		10.57

Notes: *IVI = Importance Value Index*

At the tree level, the analysis revealed that the dominant invasive species was Acacia (*Acacia auriculiformis*), with an IVI of 66.44. Apart from this species, no other invasive species were found at the tree growth level. Acacia's presence in PSINR resulted from planting activities carried out by the local community after the area was occupied in 1966 (BKSDA Jateng, 2023). The distribution of Acacia is extensive, and it can adapt to a wide range of environments, from the coastline to altitudes of up to 800 meters above sea level. Acacia is a fast-growing species capable of thriving in extreme conditions. Due to its adaptability and rapid growth, Acacia is often used for reforestation or the reclamation of degraded land. However, while it benefits land rehabilitation, caution is necessary because it can outcompete native species (Sagar et al., 2014). Acacia is categorized as an invasive species in Category I in several regions, including Asia (Bangladesh and Singapore), Africa

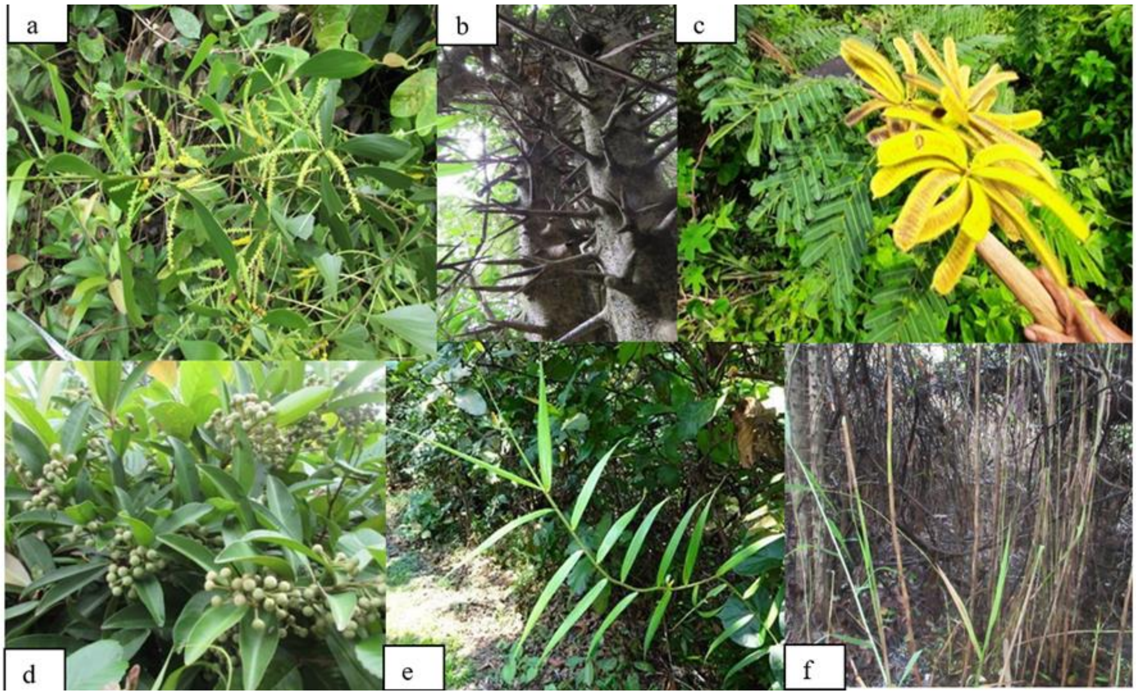
(Comoros, Mayotte, and Tanzania), North America (Florida and USA), the Caribbean (Bahamas), and Oceania (Cook Islands, Federated States of Micronesia, and Guam) (CABI, 2024). This aligned with the findings of Kueffer et al. (2010), who noted that dominant invasive species comprised 57% trees, 28% herbs or succulents, 10% grasses, and 5% vines.

Analysis of vegetation at pole level in PSINR, the invasive species that dominates at pole level is Klampis (*Flacourtia indica*) with an IVI of 91.46. *Flacourtia indica* is a species of small tree or shrub native to Africa and Asia. According to CABI, this type is quite widely known and is considered a major invasive plant. This species attacks disturbed areas, forest edges or clearings and riparian zones. It has been most widely recorded as invasive on islands in the Western Indian Ocean to varying degrees. *Flacourtia indica* is considered very invasive and must be monitored (Kueffer & Vlos, 2004). This species can dominate several types of habitats in India along with Melochia corchorifolia and Amaranthus spinosus. Flacoutia indica can form dense, impenetrable thickets that can inhibit the growth of native plant species (Sagar et al., 2014). Other invasive types are Acacia (*Acacia auriculiformis*) with an IVI value of 32.90, Lamtoro (Leucaena leucocephala) with an IVI of 16.08 and Lampeni (*Ardisia elliptica*) with an IVI of 15.37. Lamtoro (*Leucaena leucocephala*) is a type of plant that contains allelopathic substances which can inhibit other types from growing around it (Junaedi et al., 2006).

At the sapling level, the dominant invasive species was *Lampeni (Ardisia elliptica)*, with an IVI of 61.61. *Ardisia elliptica* is listed among the world's 100 worst invasive alien species (Hejda et al., 2009). This ornamental shrub, native to Southeast Asia, has been widely introduced to tropical and subtropical areas, where it has become a problematic weed, particularly in South Florida, the Everglades, and Hawaii. It has also become naturalized in Australia, Puerto Rico, and possibly other countries. Birds and some mammals are the primary agents of local dispersal, spreading seeds through berry consumption. *Ardisia elliptica* is shade-tolerant and capable of forming monotypic stands in moist areas, displacing native vegetation (CABI, 2024). The cultivation of *Ardisia elliptica* has been banned in some areas, although its *spontaneum* had an IVI of 28.38, and *Klampis* (*Flacourtia indica*) had an IVI of 20.81 (see Table 2).

Figure 3. a) PSINR conditions in the northern part of the area, showing several trees entangled with lianas; b) PSINR conditions in the northern part of the area, showing several trees entangled with lianas.

Figure 4. Types of invasive plants dominating PSINR: a) Acacia (*Acacia auriculiformis*); b) *Klampis* (*Flacourtia indica*); c) *Lamtoro* (*Leucaena leucocephala*); d) *Lampeni* (*Ardisia elliptica*); e) *Wowo* (*Flagellaria indica*); f) *Glagah* (*Saccharum spontaneum*).

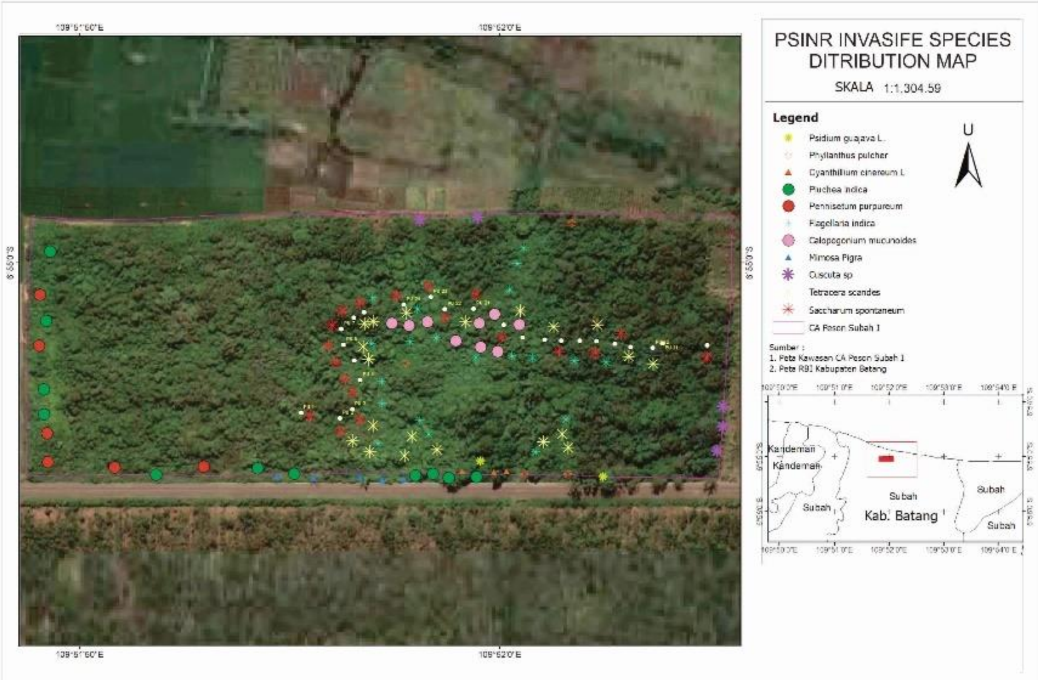


Based on the results of vegetation data processing on seedling growth levels, the dominant invasive species were *Lampeni* (*Ardisia elliptica*) with an IVI of 55.16, *Wowo* (*Flagellaria indica*) with an IVI of 52.68, *Ampelasan* (*Tetracera scandes*) with an IVI of 38.07, *Klampis* (*Flacourtia indica*) with an IVI of 11.46, and *Glagah* (*Saccharum spontaneum*) with an IVI of 10.57 (see Table 2 and Figure 4). *Wowo* (*Flagellaria indica*) can grow up to 15 meters and even 20 meters in height and is known as a tree climber. These plants grow by climbing on other plants, which impacts competition for nutrient sources and photosynthesis of the surrounding vegetation. The infestation of this plant is also quite dense, making it difficult to pass through due to its high density and scattered stems. Meanwhile, *Glagah* (*Saccharum spontaneum*) is a plant from the *Poaceae* family. This plant can reach a height of 1 to 4 meters. Its growth is quite aggressive in heavy soil, resistant to moisture, and adaptable to sandy soil (CABI, 2024), such as that found in the PSINR. Furthermore, this plant can become invasive in areas often flooded with water or in fields, forming pure stands in colonies. *Acacia* sp. is another type of plant that contains allelopathic substances, which can inhibit the growth of other species around it (Junaedi et al., 2006).

Diversity and Evenness of Species

The data processing results using the Shannon-Wiener index at each PSINR growth level showed that species diversity fell within the medium category (see Table 3). This finding aligned with Odum (1996), who states that a Shanon-Wiener index

Figure 5. Map of distribution of invasive species in PSINR



value in the range of 1<H'<3 is classified as medium. Species diversity refers to the degree of variation in species within an ecosystem (Baderan et al., 2021). A higher H' value indicates greater species variety in an ecosystem, accompanied by lower species dominance. Accordingly, the H' value observed in PSINR suggested that the area exhibited moderate species diversity, moderate individual distribution, and the stability of a moderately polluted ecosystem. The geographical location of PSINR, situated on the north coast of Java, might influence soil nutrient conditions. Additionally, the puddles in PSINR were saline in nature. The species distribution was influenced by both edaphic and climatic factors in the environment. The climatic factors included temperature, light, and wind speed, while edaphic factors pertained to soil fertility, encompassing texture, chemical composition, acidity, moisture, and living organisms (Desmukh, 1992).

The evenness of plants in PSINR ranged from high to medium (see Table 3). At the tree level, evenness was high, indicating that the five tree species with the highest IVI (see Table 2) were evenly distributed across PSINR. According to Ismaini et al. (2015), the Equity Index has a value range of 0-1. Values closer to 1 indicate a more even distribution, whereas values closer to 0 suggest an uneven distribution of plant species. This implies that invasive species in the research area were relatively evenly distributed throughout the region.

The evenness of plant species reflects the degree of abundance of individuals across different species. Evenness reaches its maximum value when each species has an equal number of individuals. Based on the Equality Index equation, the index value will decrease when certain species exhibit high dominance within a community. The evenness value highlights the extent of dominance exhibited by each species in the community. As observed in PSINR, high evenness suggested the absence of a dominant species within the community (Nahlunnisa et al., 2016).

Spatial Distribution

The mapping of invasive species revealed that invasive plants in PSINR were partially spread (see Figure 5). The collected spatial data on invasive plants were mapped using an overlay mechanism. On a larger scale, several locations appeared quite complex due to the proximity of species. Notably, although the distribution appeared even along the edges of the area, the spread of invasive plants was significantly more pronounced in the eastern and southern regions. The spatial distribution patterns identified included both local and foreign invasive plant species in easily accessible locations, which could potentially facilitate effective control measures. However, the accuracy of the mapped data might be limited by minor errors in recording spatial data and inaccuracies in documenting invasive species in the area (Turbelin et al., 2017).

Table 3. Diversity and Evenness Index of Invasive Species in PSINR

No.	Growth Level	H' (Diversity Index)		E (Evenness Index)	
		Value	Category	Value	Category
1.	Tree	2.23	Medium	0.87	High
2.	Pole	2.07	Medium	0.67	Medium
3.	Sapling	1.57	Medium	0.57	Medium
4.	Seedling	1.81	Medium	0.52	Medium

Conclusion

The identification of invasive species in PSINR revealed the presence of 43 invasive species among 80 recorded plant species. The species with the highest Importance Value Index at the tree level was Acacia (*Acacia auriculiformis*), at the pole level was *Klampis* (*Flacourtia indica*), and at both the sapling and seedling levels was *Lampeni* (*Ardisia elliptica*). According to the Shannon-Wiener diversity index, the diversity at each growth level fell within the medium category, while the evenness index ranged from medium to high. Furthermore, the mapping results showed that invasive plants in PSINR were partially distributed.

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