

Plant diversity and composition at three *Imperata* grasslands in Bogor, Katingan, and Kupang, Indonesia

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Research Center for Plant Conservation and Botanic Gardens, Indonesian Institute of Sciences. Jl. Ir. H. Juanda No. 13, Bogor 16122, West Java, Indonesia. Tel.: +62-251-8322187, 8321657, Fax.: +62-251-8322187, *email: didi.usmadi@gmail.com

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Abstract. *Usmadi D, Witono JR, Lestari R, Widyatmoko D, Magandhi M, Robiansyah I, Rachmadiyanto AN, Purnomo DW, Zulkarnaen RN, Rivai RR, Helmanto H, Yudaputra A, Damayanti F. 2020. Plant diversity and composition at three Imperata grasslands in Bogor, Katingan, and Kupang, Indonesia. Biodiversitas 21: 2804-2813.* *Imperata* grassland is among the largest proportions of marginal lands in Indonesia. Despite the dominance of *Imperata cylindrica* grass, certain plant species are able to compete and live together with this notorious species, suggesting window of opportunity that the grasslands can be restored. Yet, the existing diversity and composition of plants in *Imperata* grasslands may vary due to differences in climatic and soil conditions. This study aims to determine the plant diversity and composition at three *Imperata* grasslands in Bogor, Katingan, and Kupang, Indonesia. Data were collected using systematic sampling by establishing quadratic observation plots with size of each plot was 1 x 1 m². The total number of species found in *Imperata* grasslands in those three study sites was 81 species, belonging to 68 genera and 30 families. In the Bogor site, the dominant species were *Imperata cylindrica*, *Ageratum conyzoides*, and *Phyllanthus niruri*, while in the Katingan site was dominated by *I. cylindrica*, *Scleria ciliaris*, and *Cyanthillium cinereum*, and in the Kupang site was dominated by *I. cylindrica* and *Tridax procumbens*. The *Imperata* grassland in Bogor had low species richness, moderate species diversity, the abundance distribution of each species tends to be uniform, and the occurred species did not tend to dominate. The Katingan and Kupang *Imperata* grasslands had low species richness, low species diversity, the abundance distribution of each species tends to be uneven, and were more dominated by *I. cylindrica*. Controlling abundance of *I. cylindrica* is required in those three research sites in order to stimulate the growth of other plant species, which is in turn to maintain and restore biodiversity.

Keywords: Conservation, *Imperata* grassland, plant composition, plant ecology, species diversity

INTRODUCTION

Imperata grassland is a marginal land where the vegetation is dominated by alang-alang or cogon grass (*Imperata cylindrica* (L.) P. Beauv.). The grass belongs to the Poaceae family, it is widely distributed throughout the tropics and sub-tropics of Africa, Eastern Asia, China, Middle Asia, Western Asia, Indian Subcontinent, Southeast Asia, Eastern Asia, Australia, Northern and Southern America, Southeastern and Southwestern Europe, and Pacific (USDA 2020). It is considered as one of major invasive species. In 1997, Indonesia was a country with the largest area that was invaded by *I. cylindrica* in tropical Asia. The Indonesian area that has been invaded by *I. cylindrica* is c. 8.6 million ha or approximately 4.5% of the total land area of Indonesia with the largest distribution occurred in Kalimantan, Sumatra, and Nusa Tenggara (Garrity et al. 1997). In 2013, the area of critical land in Indonesia which had a risk to be invaded by *I. cylindrica* was around 24.2 million ha (Central Bureau of Statistics 2017).

Imperata grassland is the dominant land cover following deforestation (Yonekura 2009). The accelerated invasion of *Imperata* grass on deforested and degraded

lands is mainly caused by its physiological traits, including the extensive rhizome system, high adaptation to poor soils, drought tolerance, genetic plasticity, and fire adaptability (GISD 2020). On land where burning is continuous event, *I. cylindrica* is often the dominant species in the area, whereas, on protected areas disturbed by degradation, the grasslands often serve as a starting point in vegetation succession that will develop into secondary forests (Yassir and Arbainsyah 2014).

The negative impacts of *Imperata* invasion include reducing or displacing the diversity of native plants (Brewer 2008), increasing the intensity and frequency of fires (Lippincott 2000), and changing nitrogen and phosphorus cycles (Daneshgar and Jose 2009). Although, the presence of *I. cylindrica* gives negative impacts to the environment, various species of plants can still coexist and grow in the *Imperata* grasslands.

Some previous research on *Imperata* grasslands in relation to plant diversity include decreased plant species diversity due to the invasion of *Imperata* in the USA (Brewer 2008), the species diversity of *Imperata* grassland in India (Astapati and Das 2012), plant species diversity at the initial succession stage in the *Imperata* grassland of East Kalimantan, Indonesia (Yassir and Arbainsyah 2014),

and plant species diversity in post-fire succession in the Tegal Panjang grassland, Mount Papandayan (Sulistiyawati and Fitriana 2017). The fact that certain plant species are able to compete and live together with *I. cylindrica* as mentioned in above studies can provide information on how the diversity and structure of native plants in the *Imperata* grasslands can be increased and restored.

The structure and composition of a plant community are determined by abiotic conditions, biotic factors, and disturbances (Mitchell et al. 2017). In *Imperata* grassland, species diversity, structure, and composition are influenced by soil properties (Yassir et al. 2010). Therefore, it is important to study the diversity and composition of plant species in *Imperata* grasslands in different locations that have different climatic and soil conditions. This study aimed to determine plant diversity and composition at three *Imperata* grasslands in Bogor (West Java), Katingan (Central Kalimantan), and Kupang (East Nusa Tenggara), which represent climate and soil differences in Indonesia. Results of the research can be used as the scientific basis of *Imperata* grasslands management in Indonesia.

MATERIALS AND METHODS

Study period and locations

Data were collected from March to December 2016 at three locations of *Imperata* grasslands based on the

differences in climate and soil conditions. The research sites were as follows: (i) *Imperata* grassland in Bogor was located in Ecopark Cibinong, Cibinong Science Center and Botanic Gardens, Bogor District (6°29'18" S, 106°51'21" E) with an altitude of 150 m asl.; (ii) Katingan Botanic Gardens, Katingan District (1°53'21" S, 113°27'51" E) with an altitude of 45 m asl.; and (iii) Kupang District Government Complex, Kupang District (10°04'28" S, 123°51'57" E) with an altitude of 20 m asl. (Figure 1). The climatic and soil conditions at three research site are shown in Table 1.

Data collection procedures

Data were collected using systematic sampling by establishing quadratic observation plots. The observation plot size was 1 x 1 m² each with the distance between plots was 5 m (Figure 2). The number of observation plots at each *Imperata* grassland was 20 plots (i.e. 20 m²). Within each observation plot, all individuals of undergrowth plants and seedlings found were counted. Seedlings are the initial regeneration stage of trees with a height of less than 1.5 m, while undergrowth is a plant that cannot grow up to tree levels, such as grass, herbs, lianas, and ferns.

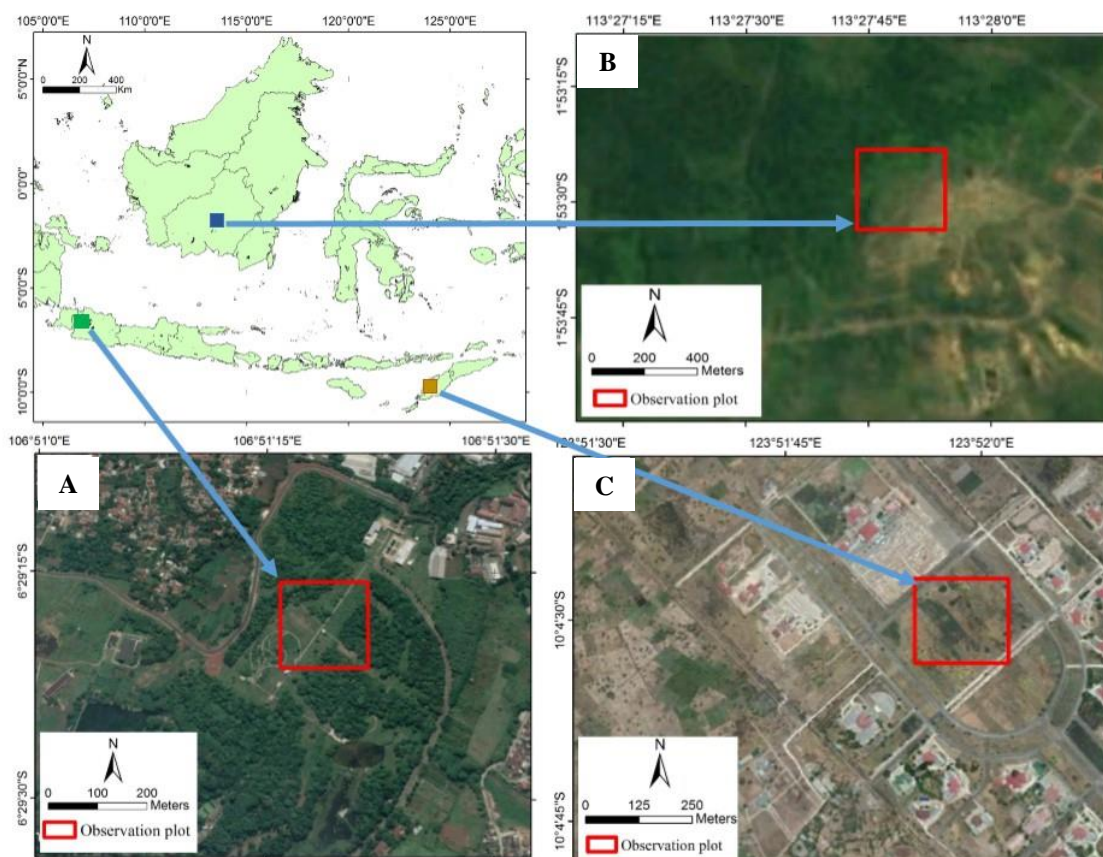


Figure 1. *Imperata* grassland research sites in Indonesia: A. Bogor, B. Katingan, C. Kupang (Source: Google.earth.com)

Table 1. Climatic and soil conditions in three research sites

Condition	Bogor	Katingan	Kupang
Climatic*			
Temperature (°C)	26.24 ± 0.77	27.61 ± 1.01	28.14 ± 1.18
Humidity (%)	84.71 ± 3.97	83.29 ± 4.57	76.50 ± 9.48
Monthly rainfall (mm)	387.08 ± 125.85	295.21 ± 98.73	103.31 ± 107.53
Climate type (Schmidt–Ferguson)	A (very wet)	B (wet)	E (almost dry)
Soil**			
pH H ₂ O	6.36 ± 0.23	6.32 ± 0.38	8.52 ± 0.09
C Organic (%)	2.21 ± 0.30	4.16 ± 0.99	1.51 ± 0.07
N Total (%)	0.04 ± 0.00	0.17 ± 0.04	0.10 ± 0.01
C/N Ratio	55.13 ± 7.60	25.50 ± 0.71	16.00 ± 0.00
Sand (%)	8.84 ± 0.52	88.00 ± 9.9	22.00 ± 2.83
Silt (%)	91.15 ± 0.51	2.50 ± 2.21	34.50 ± 3.54
Clay (%)	0.02 ± 0.00	9.50 ± 7.78	43.00 ± 1.41

Note: *climatic condition (BMKG 2019), **soil condition (soil analysis)

Data analysis

Vegetation composition and structure

The composition of plant species was analyzed using an Important Value Index (IVI) (Curtis and McIntosh 1950). IVI was calculated as the sum of relative density and relative frequency. Whereas, relative density and relative frequency were calculated using equation:

$$\text{Relative Density} = \frac{\text{Number of individuals of a species}}{\text{Total number of individuals of all species}} \times 100\%$$

$$\text{Relative Frequency} = \frac{\text{Frequency value of a species}}{\text{Total frequency value of all species}} \times 100\%$$

The level of similarity of the *Imperata* grassland at the three research sites was analyzed using the Sorensen similarity index (Magurran 2004).

$$SI = \frac{2w}{a + b}$$

Where: SI: Similarity index, w: number of species that appear in the communities a and b, a: number of species in community a, b: number of species found in community b.

Richness, diversity, evenness, and dominance of plant species

The species richness in each community was analyzed using Menhinick richness index (D_{mn}), the plant species diversity was analyzed using the Shannon diversity index (H'), the species evenness in each community was analyzed using the Pielou evenness index (J'), while the species dominance in each community was analyzed using the Simpson dominance index (D) (Magurran 2004). The three indices are formulated as follows:

$$D_{mn} = \frac{S}{\sqrt{N}}$$

$$H' = - \sum_{i=1}^n \left[\left(\frac{n_i}{N} \right) \ln \left(\frac{n_i}{N} \right) \right]$$

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

$$D = \sum_{i=1}^n \left(\frac{n_i}{N} \right)^2$$

Where; D_{mn} : Menhinick richness index, S: Number of all species, N: Total number of individuals of all species, H' : Shannon diversity index, n_i : Number of individuals of each species, J' : Pielou evenness Index, and D: Simpson dominance index.

Comparison between variables and correlation Imperata cylindrica abundance between other variables

Comparative analysis of the average value of the following variables across the three sites was conducted using One Way Anova: the abundance of *I. cylindrica*, number of species other than *I. cylindrica*, the abundance of species other than *I. cylindrica*, richness, diversity, evenness and dominance. While the relationship between the abundance of *I. cylindrica* with other variables using Pearson Correlation analysis. The statistical analysis is using Paleontological Statistics (PAST) version 4.0.

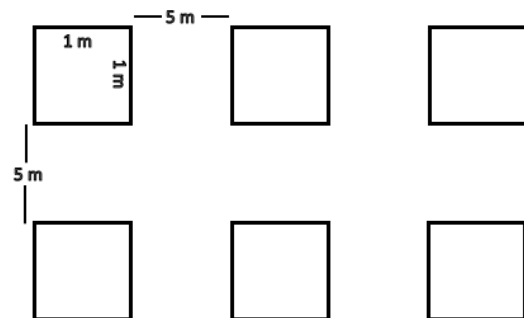


Figure 2. Research plot design

RESULTS AND DISCUSSION

Vegetation composition and structure

The total number of plant species occurred in the *Imperata* grasslands at the research sites in Bogor, Katingan, and Kupang was 81 species belonging to 68 genera and 30 families with the number of plant species varied across the three sites. *Imperata* grassland in Bogor had the highest species number (53 species) belonging to 45 genera and 19 families, followed by *Imperata* grasslands in Kupang with 26 species, included in 24 genera and 13 families, then *Imperata* grassland in Katingan which consisted of 17 species belonging to 16 genera and 13 families.

The three research sites were dominated by species from the family Compositae (16.05%), then followed by Poaceae (14.91%), Leguminosae (11.11%), Cyperaceae (7.41%), Rubiaceae (4.94%), Commelinaceae (4.94%), Oxalidaceae (3.70%), Phyllanthaceae (3.70%), and Acanthaceae (3.70%) (Figure 3). Compositae had the highest number of species in *Imperata* grassland in Bogor (12 species or 22.64% of the total species). The dominant family in *Imperata* grassland in Katingan was Cyperaceae (3 species or 17.65% of the total species), whereas *Imperata* grassland in Kupang was dominated by Poaceae (8 species or 30.77% of the number of species).

In comparison, a grassland in Brazil was generally dominated by plant species from the family Poaceae, Compositae (Asteraceae), Cyperaceae, and Leguminosae (Pinto et al. 2013). The dominance of Compositae, Poaceae, and Leguminosae in *Imperata* grassland was also found in India (Astapati and Das 2012). The Compositae grows generally on open area in which seed dispersal is generally aided by wind and it produces secondary metabolites, so that they can adapt and compete in these habitats (Döring 2019).

Poaceae had the highest importance value index (IVI) in the three research sites with 66.03% (Bogor), 113.15% (Katingan), and 127.99% (Kupang), followed by Compositae and Leguminosae (Figure 4). *Imperata cylindrica* had the highest abundance, were found in all observation plots, and was the most dominant species with the highest IVI. In the Bogor site, the species with the highest IVI was *I. cylindrica* (43.71%), then followed by *Ageratum conyzoides* (12.21%), and *Phyllanthus niruri* (11.82%) (Table 2). In Katingan site, species with the highest IVI was *I. cylindrica* (110.48%), followed by *Scleria ciliaris* (20.63%), *Cyanthillium cinereum* (17.05%), and *Vitex pinnata* (12.58%) (Table 3), whereas in Kupang, the highest IVI was *I. cylindrica* (110.04%), followed by *Tridax procumbens* (12.24%) (Table 4).

The dominant species other than *I. cylindrica* at the three research sites in this study are different from the Indian *Imperata* grassland. In India, besides *I. cylindrica*, the dominant species are *Borreria pusilla*, *Setaria glauca*, *Digitaria longiflora*, and *Chromolaena odorata* (Astapati and Das 2012). In the succession stage of *Imperata* grasslands in East Kalimantan, the dominant species other than *I. cylindrica* are *Nephrolepis biserrata*, *Bridelia glauca*, *Fordia splendidissima*, and *Scleria terrestris* (Yassir and Arbainsyah 2014). Whereas on a succession vegetation 6 months after a fire in West Java, the dominant species other than *I. cylindrica* are *Gonostegia hirta*, *Plectranthus teysmannii*, *Pteridium aquilinum*, *Eragrostis nigra*, and *Pteridium aquilinum* (Sulistyawati and Fitriana 2017). The success of a species to dominate an area is influenced by its adaptability to physical environmental factors, such as air temperature, light and humidity, biotic factors such as interactions among species, competition, and parasitism, and chemical factors such as availability of water, oxygen, pH, and nutrients in the soil (Krebs 1994).

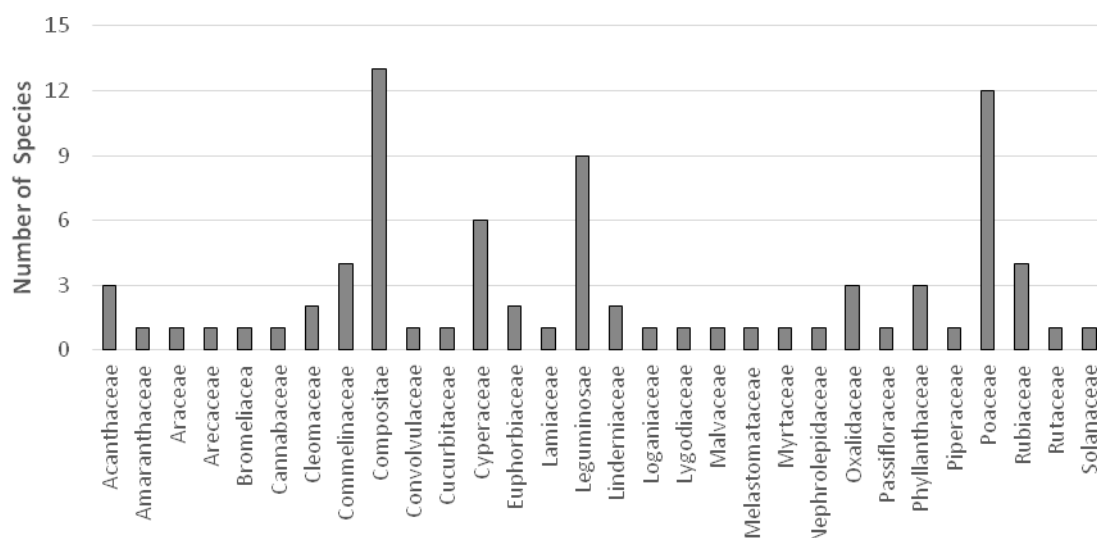


Figure 3. Number of plant species in each family found at the three research sites

Table 2. The importance value index (IVI) of each plant species in the Bogor site, Indonesia

Species	Family	Habitus	Invasive/ non-invasive	Native/ non-native	RD (%)	RF (%)	IVI (%)
<i>Imperata cylindrica</i> (L.) P.Beauv.	Poaceae	Herb	Invasive	Non-native	40.48	6.83	47.31
<i>Ageratum conyzoides</i> (L.) L.	Compositae	Herb	Invasive	Non-native	6.40	5.80	12.21
<i>Phyllanthus niruri</i> L.	Phyllanthaceae	Herb	Non-invasive	Non-native	7.38	4.44	11.82
<i>Panicum maximum</i> Jacq.	Poaceae	Herb	Non-invasive	Non-native	4.98	4.10	9.08
<i>Urochloa glumaris</i> (Trin.) Veldkamp	Poaceae	Herb	Non-invasive	Native	5.70	3.07	8.77
<i>Spermacoce alata</i> Aubl.	Rubiaceae	Herb	Non-invasive	Non-native	3.15	5.12	8.27
<i>Arachis</i> sp.	Leguminosae	Shrub	ni	ni	3.75	3.41	7.16
<i>Mimosa pudica</i> L.	Leguminosae	Shrub	Non-invasive	Non-native	2.63	4.44	7.07
<i>Centrosema</i> sp.	Leguminosae	Liana	ni	ni	2.13	4.44	6.57
<i>Emilia sonchifolia</i> (L.) DC. ex DC.	Compositae	Herb	Non-invasive	Native	0.91	4.78	5.69
<i>Oldenlandia corymbosa</i> L.	Rubiaceae	Herb	Non-invasive	Native	1.52	4.10	5.62
<i>Tridax procumbens</i> (L.) L.	Compositae	Herb	Non-invasive	Non-native	2.50	3.07	5.57
<i>Oxalis barrelieri</i> L.	Oxalidaceae	Herb	Non-invasive	Non-native	0.57	4.10	4.66
<i>Pachystachys</i> sp.	Acanthaceae	Shrub	ni	ni	0.84	3.41	4.26
<i>Murdannia nudiflora</i> (L.) Brenan	Commelinaceae	Herb	Non-invasive	Native	1.56	2.39	3.94
<i>Euphorbia hirta</i> L.	Euphorbiaceae	Herb	Non-invasive	Non-native	0.14	3.41	3.56
<i>Asystasia</i> sp.	Acanthaceae	Herb	ni	ni	1.17	1.71	2.88
<i>Rhynchospora colorata</i> (L.) H.Pfeiff.	Cyperaceae	Herb	Non-invasive	Non-native	0.48	2.39	2.87
<i>Axonopus compressus</i> (Sw.) P.Beauv.	Poaceae	Herb	Non-invasive	Non-native	1.07	1.71	2.77
<i>Wedelia</i> sp.	Compositae	Herb	ni	ni	1.23	1.37	2.59
<i>Lindernia crustacea</i> (L.) F.Muell.	Linderniaceae	Herb	Non-invasive	Non-native	1.35	1.02	2.38
<i>Chromolaena odorata</i> (L.) R.M.King & H.Rob.	Compositae	Shrub	Invasive	Non-native	0.60	1.71	2.31
<i>Synedrella nodiflora</i> (L.) Gaertn.	Compositae	Herb	Non-invasive	Non-native	0.57	1.71	2.28
<i>Asystasia gangetica</i> (L.) T.Anderson	Acanthaceae	Herb	Invasive	Non-native	1.34	0.68	2.02
<i>Cynodon dactylon</i> (L.) Pers.	Poaceae	Herb	Invasive	Native	0.97	1.02	1.99
<i>Digitaria fuscescens</i> (J.Presl) Henrard	Poaceae	Herb	Non-invasive	Native	1.47	0.34	1.82
<i>Cleome rutidosperma</i> DC.	Cleomaceae	Herb	Non-invasive	Non-native	0.08	1.71	1.79
<i>Torenia violacea</i> (Azaola ex Blanco) Pennell	Linderniaceae	Herb	Non-invasive	Native	0.30	1.37	1.67
<i>Cyperus rotundus</i> L.	Cyperaceae	Herb	Invasive	Native	0.58	1.02	1.60
<i>Ipomoea triloba</i> L.	Convolvulaceae	Liana	Non-invasive	Non-native	0.23	1.37	1.60
<i>Spilanthes iabadicensis</i> A.H.Moore	Compositae	Herb	Non-invasive	Non-native	0.50	1.02	1.52
<i>Spermacoce laevis</i> Lam.	Rubiaceae	Herb	Non-invasive	Non-native	0.14	1.37	1.51
<i>Borreria</i> sp.	Rubiaceae	Herb	ni	ni	0.14	1.37	1.51
<i>Aeschynomene americana</i> L.	Leguminosae	Shrub	Non-invasive	Non-native	0.73	0.68	1.41
<i>Fimbristylis quinqueangularis</i> (Vahl) Kunth	Cyperaceae	Herb	Non-invasive	Native	0.74	0.34	1.08
<i>Sida rhombifolia</i> L.	Malvaceae	Herb	Non-invasive	Non-native	0.04	1.02	1.06
<i>Murdannia spirata</i> (L.) G.Brückn.	Commelinaceae	Herb	Non-invasive	Native	0.33	0.68	1.01
<i>Phyllanthus urinaria</i> L.	Phyllanthaceae	Herb	Non-invasive	Native	0.29	0.68	0.98
<i>Commelina</i> sp.	Commelinaceae	Herb	ni	ni	0.20	0.68	0.89
<i>Oxalis dumetorum</i> Barnéoud	Oxalidaceae	Herb	Non-invasive	Non-native	0.09	0.68	0.77
<i>Mikania cordata</i> (Burm.f.) B.L.Rob.	Compositae	Herb	Non-invasive	Native	0.04	0.68	0.72
<i>Cyanthillium cinereum</i> (L.) H.Rob.	Compositae	Herb	Non-invasive	Native	0.02	0.68	0.70
<i>Syzygium polyanthum</i> (Wight) Walp.	Myrtaceae	Herb	Non-invasive	Native	0.02	0.68	0.70
<i>Commelina diffusa</i> Burm.f.	Commelinaceae	Herb	Non-invasive	Native	0.21	0.34	0.55
<i>Oxalis corymbosa</i> (DC.) Lourteig	Oxalidaceae	Herb	Non-invasive	Non-native	0.13	0.34	0.47
<i>Mimosa invisa</i> Colla	Leguminosae	Herb	Invasive	Non-native	0.09	0.34	0.43
<i>Blumea lacera</i> (Burm.f.) DC.	Compositae	Herb	Non-invasive	Native	0.05	0.34	0.39
<i>Clausena excavata</i> Burm.f.	Rutaceae	Shrub	Non-invasive	Native	0.04	0.34	0.38
<i>Erigeron sumatrensis</i> Retz.	Compositae	Herb	Non-invasive	Non-native	0.02	0.34	0.36
<i>Spigelia anthelmia</i> L.	Loganiaceae	Herb	Non-invasive	Non-native	0.02	0.34	0.36
<i>Celosia argentea</i> L.	Amaranthaceae	Tree	Non-invasive	Non-native	0.01	0.34	0.35
<i>Porophyllum ruderale</i> (Jacq.) Cass.	Compositae	Herb	Non-invasive	Non Native	0.01	0.34	0.35
<i>Peperomia pellucida</i> (L.) Kunth	Piperaceae	Herb	Non-invasive	Non-native	0.01	0.34	0.35

Note: ni: not identified, RD: Relative Density, RF: Relative Frequency, IVI: Important Value Index

The only species found at the three research sites was *I. cylindrica*, while the other plant species found at each study site were different. The similarity of the three *Imperata* grasslands analyzed using Sorensen similarity index varied from 0.05 to 0.20. It means that the vegetation

communities among the three research sites are not similar and show different plant species. The Sorensen similarity index value of the *Imperata* grasslands in Bogor and Katingan was 0.14 in which there were five species of plants found concurrently in the two locations, namely *I.*

cylindrica, *Cyanthillium cinereum*, *Spermacoce alata*, *Urochloa glumaris*, and *Oldenlandia corymbosa*. The similarity of the *Imperata* grasslands in Bogor and Kupang based on the Sorensen similarity index value was 0.20 in which eight similar plant species were found, namely *I. cylindrica*, *Cynodon dactylon*, *Cyperus rotundus*, *Digitaria fuscescens*, *Euphorbia hirta*, *Ipomoea triloba*, *Spigelia*

anthelmia, and *Tridax procumbens*. Whereas *Imperata* grassland in Katingan and Bogor have a Sorensen similarity index value of 0.05 and only one plant species was concurrently found, namely *I. cylindrica*. The differences in species composition occurred in the three *Imperata* grasslands are likely due to differences in climatic and soil conditions (Table 1).

Table 3. The importance value index (IVI) of each plant species in the Katingan site, Indonesia

Species	Family	Habitus	Invasive/ non invasive	Native/ non-native	RD (%)	RF (%)	IVI (%)
<i>Imperata cylindrica</i> (L.) P.Beauv.	Poaceae	Herb	Invasive	Non-native	76.58	33.90	110.48
<i>Scleria ciliaris</i> Nees	Cyperaceae	Herb	Non-invasive	Native	3.68	16.95	20.63
<i>Cyanthillium cinereum</i> (L.) H.Rob.	Compositae	Herb	Non-invasive	Non-native	11.96	5.08	17.05
<i>Vitex pinnata</i> L.	Lamiaceae	Tree	Non-invasive	Native	0.72	11.86	12.58
<i>Trema orientalis</i> (L.) Blume	Cannabaceae	Tree	Non-invasive	Non-native	0.61	5.08	5.70
<i>Scleria triglomerata</i> Michx.	Cyperaceae	Herb	Non-invasive	Non-native	0.31	3.39	3.70
<i>Spermacoce alata</i> Aubl.	Rubiaceae	Herb	Non-invasive	Non-native	1.94	1.69	3.64
<i>Ananas comosus</i> (L.) Merr.	Bromeliaceae	Herb	Non-invasive	Non-native	0.20	3.39	3.59
<i>Breynia racemosa</i> (Blume) Müll.Arg.	Phyllanthaceae	Tree	Non-invasive	Native	0.20	3.39	3.59
<i>Urochloa glumaris</i> (Trin.) Veldkamp	Poaceae	Herb	Non-invasive	Native	0.20	3.39	3.59
<i>Bulbostylis pseudoperennis</i> Goetgh.	Cyperaceae	Herb	Non-invasive	Non-native	0.92	1.69	2.62
<i>Nephrolepis biserrata</i> (Sw.) Schott	Nephrolepidaceae	Fern	Non-invasive	Native	0.92	1.69	2.62
<i>Melastoma malabathricum</i> L.	Melastomataceae	Shrub	Non-invasive	Non-native	0.72	1.69	2.41
<i>Acacia mangium</i> Willd.	Leguminosae	Tree	Invasive	Non-native	0.41	1.69	2.10
<i>Oldenlandia corymbosa</i> L.	Rubiaceae	Herb	Non-invasive	Native	0.41	1.69	2.10
<i>Lygodium microphyllum</i> (Cav.) R. Br.	Lygodiaceae	Fern	Invasive	Native	0.10	1.69	1.80
<i>Passiflora foetida</i> L.	Passifloraceae	Liana	Invasive	Non-native	0.10	1.69	1.80

Note: RD: Relative Density, RF: Relative Frequency, IVI: Important Value Index

Table 4. The importance value index (IVI) of each plant species in the Kupang site, Indonesia

Species	Family	Habitus	Invasive/ non invasive	Native/ non-native	RD (%)	RF (%)	IVI (%)
<i>Imperata cylindrica</i> (L.) P.Beauv.	Poaceae	Herb	Invasive	Non-native	84.70	25.33	110.04
<i>Tridax procumbens</i> (L.) L.	Compositae	Herb	Non-invasive	Non-native	1.57	10.67	12.24
<i>Synedrella nodiflora</i> (L.) Gaertn.	Compositae	Herb	Non-invasive	Non-native	0.41	9.33	9.74
<i>Flemingia congesta</i> W.T.Aiton	Leguminosae	Shrub	Non-invasive	Native	1.03	5.33	6.36
<i>Cynodon dactylon</i> (L.) Pers.	Poaceae	Herb	Invasive	Native	3.15	2.67	5.81
<i>Paspalum scrobiculatum</i> L.	Poaceae	Herb	Invasive	Native	4.31	1.33	5.64
<i>Mucuna pruriens</i> (L.) DC.	Leguminosae	Liana	Non-invasive	Non-native	0.25	5.33	5.58
<i>Corypha utan</i> Lam.	Arecaceae	Tree	Non-invasive	Native	0.09	5.33	5.42
<i>Passiflora foetida</i> L.	Passifloraceae	Liana	Invasive	Non-native	0.09	4.00	4.09
<i>Sacciolepis myosuroides</i> (R.Br.) A.Camus	Poaceae	Herb	Non-invasive	Native	2.19	1.33	3.52
<i>Paspalum conjugatum</i> P.J.Bergius	Poaceae	Herb	Non-invasive	Non-native	0.43	2.67	3.10
<i>Euphorbia hypericifolia</i> L.	Euphorbiaceae	Herb	Non-invasive	Non-native	0.32	2.67	2.99
<i>Digitaria</i> sp.	Poaceae	Herb	ni	ni	0.27	2.67	2.94
<i>Brachiaria mutica</i> (Forssk.) Stapf	Poaceae	Herb	Non-invasive	Non-native	0.11	2.67	2.78
<i>Cucumis sativus</i> L.	Cucurbitaceae	Liana	Non-invasive	Non-native	0.09	2.67	2.76
<i>Euphorbia hirta</i> L.	Euphorbiaceae	Herb	Non-invasive	Non-native	0.07	2.67	2.74
<i>Oryza rufipogon</i> Griff.	Poaceae	Herb	Non-invasive	Non-native	0.62	1.33	1.95
<i>Cyperus rotundus</i> L.	Cyperaceae	Herb	Invasive	Native	0.07	1.33	1.40
<i>Sonchus arvensis</i> L.	Compositae	Herb	Non-invasive	Non-native	0.07	1.33	1.40
<i>Amorphophallus</i> sp.	Araceae	Herb	Non-invasive	Native	0.02	1.33	1.36
<i>Cleome viscosa</i> L.	Cleomaceae	Herb	Non-invasive	Native	0.02	1.33	1.36
<i>Chromolaena odorata</i> (L.) R.M.King & H.Rob.	Compositae	Shrub	Invasive	Non-native	0.02	1.33	1.36
<i>Ipomoea triloba</i> L.	Convolvulaceae	Liana	Non-invasive	Non-native	0.02	1.33	1.36
<i>Vigna umbellata</i> (Thunb.) Ohwi & H. Ohashi	Leguminosae	Liana	Non-invasive	Native	0.02	1.33	1.36
<i>Physalis angulata</i> L.	Solanaceae	Herb	Non-invasive	Non-native	0.02	1.33	1.36
<i>Spigelia anthelmia</i> L.	Loganiaceae	Herb	Non-invasive	Non-native	0.02	1.33	1.36

Note: ni: not identified, RD: Relative Density, RF: Relative Frequency, IVI: Important Value Index

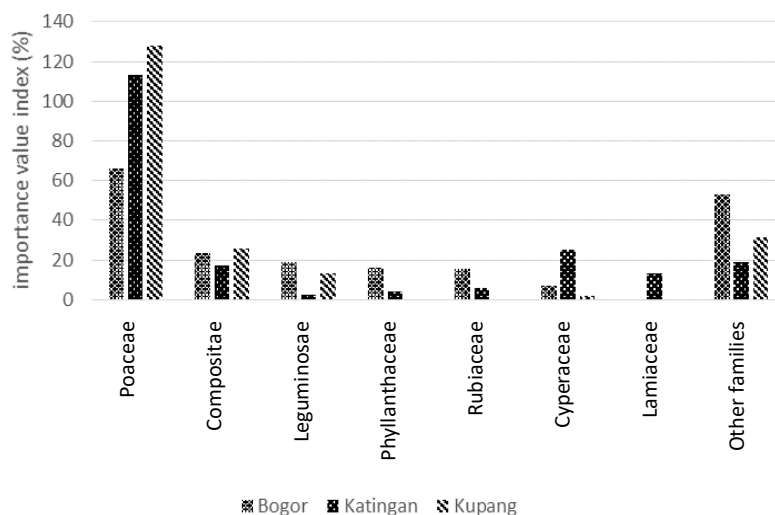


Figure 4. The importance value index (IVI) of the dominant families in three research sites

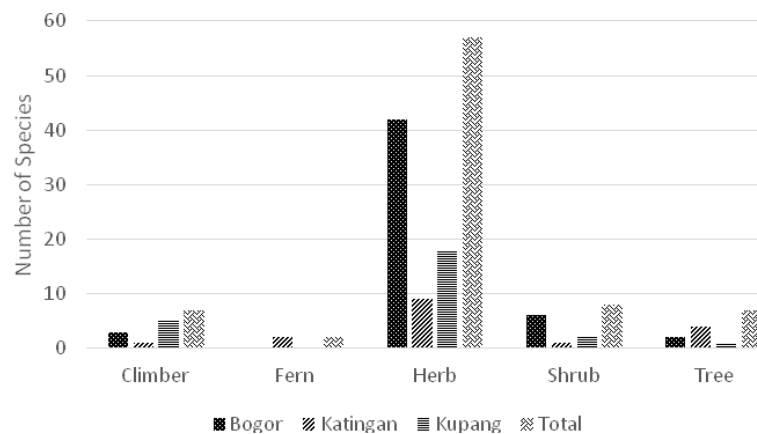


Figure 5. The habitus of plants found in the three *Imperata cylindrica* grasslands

Based on plant habitus, it is revealed that the three research sites were dominated by herbs species (70.37%), followed by shrubs (9.88%), and the remainder were trees, lianas, and ferns (Figure 5). Tree species found in the three research sites included *Acacia mangium*, *Breynia racemosa*, *Celosia argentea*, *Corypha utan*, *Syzygium polyanthum*, *Trema orientalis*, and *Vitex pinnata*. The species of lianas found were the members of Leguminosae, Cucurbitaceae, Convolvulaceae, and Passifloraceae. The fern species found were *Nephrolepis biserrata* and *Lygodium microphyllum*.

Across the three research sites, understory shrubs, herbs, and ferns were found. However, in Katingan, *Melastoma malabathricum* (shrub), *Vitex pinnata* and *Acacia mangium* (tree) were found in a high number of individuals. The presence of *M. malabathricum* and *V. pinnata* is an indicator of the succession process from *Imperata* grassland to secondary forest, where both species become the dominant species (Yassir and Arbainsyah 2014). *Acacia mangium* is a fast-growing tree and

continuously produces seeds in large quantities, so that the species can compete strongly with other species in the *Imperata* grasslands (Richardson and Rejmánek 2011; Aguiar et al. 2014). In the *Imperata* grassland in Kupang, *Corypha utan*, a native plant species were found.

Based on the Global Invasive Species Database (<http://www.iucngisd.org/gisd> 2019), at least 11 invasive plant species were found in the three *Imperata* grasslands. Seven species were found in the Bogor site, four species in Katingan, and six species in Kupang. The invasive plants' species found were mostly herbs, namely *I. cylindrica*, *Ageratum conyzoides*, *Asystasia gangetica*, *Cynodon dactylon*, *Cyperus rotundus*, *Mimosa invisa*, and *Paspalum scrobiculatum*. The other invasive plant species were shrub (i.e. *Chromolaena odorata*), tree (i.e. *Acacia mangium*), liana (i.e. *Passiflora foetida*), and fern (i.e. *Lygodium microphyllum*). Of the 11 invasive plant species, only *I. cylindrica* and *Ageratum conyzoides* were the most dominant species in the *Imperata* grasslands.

Imperata cylindrica was the dominant species in the three research sites, however, several species were able to compete with this noxious weed, i.e. *Ageratum conyzoides*, *Phyllanthus niruri*, *Scleria ciliaris*, *Cyanthillium cinereum*, *Vitex pinnata*, and *Tridax procumbens*. *A. conyzoides* is a herb species that can adapt to various environmental conditions, has a high reproduction and excellent seed dispersal by wind and livestock, and also has allelopathic substances that can inhibit the germination and growth of other undergrowth species (Isda et al. 2013; Wardani et al. 2018). *P. niruri* is known to have allelopathic substances in the roots, leaves, and stems (Mishra 2017). *S. ciliaris* can grow in various environmental conditions and the seeds can germinate well, so that this plant often becomes dominant weed and is difficult to control (Wahyuni et al. 2015). *V. pinnata* is a fast-growing tree in an open area and is effective in spreading seeds (Hashim and Hughes 2010). *T. procumbens* has strong allelopathic activity and can inhibit the growth of other plant species (Andriana et al. 2018).

Plant species that can compete with *I. cylindrica* (i.e. *Ageratum conyzoides*, *Phyllanthus niruri*, *Scleria ciliaris*, *Cyanthillium cinereum*, *Vitex pinnata*, and *Tridax procumbens*) have some characteristics, such as high reproductive ability, adaptive to various environmental conditions, possessing allelopathy and can carry out generative reproduction through seeds and vegetative through high rhizomes. *Imperata* is capable of producing c. 3,000 seeds per individual and can be regenerated at a radius of 15 to 100 m by wind (Dozier et al. 1998; MacDonald 2004). Reproduction through rhizomes is the main way in the spread of *Imperata*, and the sprouting shoots at each node and the sharp edges of the rhizome can cause physical damage to the roots of the surrounding plants. *Imperata* rhizomes can withstand fire, soil disturbance, and can penetrate the soil as deep as 1.2 m (Dozier et al. 1998).

Richness, diversity, evenness, and dominance of plant species

Plant diversity in *Imperata* grasslands at plot area of 1 m² in the three research sites tends to vary which can be seen from the value of the richness index, diversity index, evenness index, and dominance index (Table 5). The results of statistical analysis using the One Way ANOVA show very significant differences among the three research sites in term of richness ($F_{2,57} = 20.146$, $P = 0.00$), diversity ($F_{2,57} = 104.668$, $P = 0.00$), evenness ($F_{2,57} = 23.941$, $P = 0.00$), and dominance ($F_{2,57} = 64.900$, $P = 0.00$). Species richness in *Imperata* grasslands at the three research site has a Menhinick richness index (D_{mn}) value of 0.28-0.67 and can be categorized as low richness. *Imperata* grassland in Bogor has the highest value of species richness with an average Menhinick richness index value of 0.67 and found an average of 14.65 species in each plot.

Using the Shannon index value (H'), the level of species diversity can be categorized into three, i.e. low ($0 < H' < 1$), moderate ($1 \leq H' \leq 3$), and high ($H' > 3$) (Fitriani et al. 2017). Plant diversity in *Imperata* grasslands at the three research sites has Shannon diversity index value of 0.37-1.80 and can be categorized as low to moderate diversity. *Imperata* grassland in Bogor is the most diverse community with an average Shannon diversity index value of 1.80, while Kupang has the lowest diversity with a Shannon diversity index value of 0.37.

Pielou evenness index (J') can be categorized into three: i.e. low ($J' < 0.4$), moderate ($0.4 \leq J' < 0.6$), and high ($J' \geq 0.6$) (Fitriani et al. 2017). The evenness of plant communities in *Imperata* grasslands in the three research sites has an average value of 0.24-0.68 and this can be categorized as low to high. In terms of species evenness, *Imperata* grassland in Bogor has the most uniform species abundance with an average Pielou evenness index of 0.68, while Kupang *Imperata* grassland has low species evenness with an average value of 0.24.

Table 5. The richness, diversity, evenness and dominance index of plant species in the three research sites

Variables	Bogor	Katingan	Kupang	F	P
Menhinick richness index	0.67 ± 0.11	0.47 ± 0.28	0.28 ± 0.15	20.146**	0.000
Shannon diversity index	1.80 ± 0.39	0.43 ± 0.40	0.37 ± 0.27	104.668**	0.000
Pielou evenness index	0.68 ± 0.13	0.34 ± 0.30	0.24 ± 0.17	23.941**	0.000
Simpson dominance index	0.27 ± 0.14	0.77 ± 0.22	0.84 ± 0.14	64.900**	0.000

Note: Value = Average ± Standard Deviation, ** significant in 1% level

Table 6. *Imperata cylindrica* abundance, number of species other than *I. cylindrica*, and species abundance other than *I. cylindrica* in three research sites

Variables	Bogor	Katingan	Kupang	F	P
<i>I. cylindrica</i> abundance	199.15 ± 133.15	37.45 ± 21.23	185.80 ± 121.69	14.652**	0.000
Number of species other than <i>I. cylindrica</i>	13.65 ± 2.98	1.90 ± 1.74	2.75 ± 1.97	163.089**	0.000
Abundance of species other than <i>I. cylindrica</i>	292.80 ± 115.63	14.45 ± 31.02	33.55 ± 51.61	85.352**	0.000

Note: Value = Average ± Standard Deviation, ** significant in 1% level

Table 7. Pearson Correlations between *Imperata cylindrica* abundance with several other variables at the three research sites

<i>Imperata cylindrica</i> abundance with	Bogor		Katingan		Kupang	
	R	P	r	P	r	P
Abundance of species other than <i>I. cylindrica</i>	-0.400*	0.470	-0.057	0.811	-0.41	0.088
Number of species other than <i>I. cylindrica</i>	0.020	0.934	-0.247	0.293	0.001	0.998
Menhinick richness index	-0.463*	0.400	-0.606**	0.005	-0.476*	0.034
Shannon diversity index	-0.777**	0.000	-0.586**	0.007	-0.387	0.092
Pielou evenness index	-0.860**	0.000	-0.552*	0.012	-0.407	0.075
Simpson dominance index	0.872**	0.000	0.577**	0.008	0.355	0.124

Note: * significant in 5% level, ** significant in 1% level

The Simpson dominance index range from 0 to 1, with high values indicating strong dominance of a species in the community (Odum and Barrett 2004). The Simpson dominance index (D) in the three research sites has a value of 0.27-0.84. *Imperata* grasslands in Katingan and Kupang have high dominance index values of 0.77 and 0.84, respectively. *Imperata* grassland in Bogor has moderate to high species diversity, the distribution of the abundance of each species tends to be uniform, and the *Imperata* does not dominate the vegetation. The *Imperata* grasslands in Katingan and Kupang have low species diversity, species abundance is uneven, and *Imperata* tends to be more dominant.

In comparison, *Imperata* grasslands in India have an average Shannon diversity index of 0.7-1.38 and an evenness index of 0.46-0.48 (Astapati and Das 2012). The diversity and evenness of *Imperata* grassland in Bogor has higher value than that of the *Imperata* grassland in India, but the Katingan and Kupang sites have lower species diversity and evenness. Plant community in timber plantations in South Sumatra dominated by *I. cylindrica* has a low diversity ($H' = 0.78-0.83$) (Kunarso and Azwar 2013). Compared to these plantations, the diversity of the Katingan and Kupang grasslands is lower, but it should be noted that *Imperata* grasslands in Bogor have higher diversity. *Imperata* grassland in Bogor has higher plant diversity, and this can prevent a wider invasion of *I. cylindrica* at that location. However, this is not the case with the Katingan and Kupang grasslands which have low species diversity, so that the possibility of the location being invaded by weeds will be even higher in the future.

Comparison between variables and correlation

Imperata cylindrica abundance between other variables

Using One Way Anova's statistical analysis, there were significant differences across the three sites in terms of *I. cylindrica* abundance ($F_{2,57} = 14.652$, $P = 0.00$), the number of species other than *I. cylindrica* ($F_{2,57} = 163.089$, $P = 0.00$), and the abundance of species other than *I. cylindrica* ($F_{2,57} = 85.352$, $P = 0.00$) (Table 6). Bogor grassland has the highest abundance of *I. cylindrica* and number of species other than *I. cylindrica* compared to the other two research sites.

Based on the Pearson Correlation analysis between the abundance of *I. cylindrica* and the species other than *I. cylindrica*, the abundance of species other than *I.*

cylindrica, richness, diversity, evenness and dominance index in the three research sites have varying values. The relationship between *Imperata* grassland abundance and other plant species abundance in *Imperata* grassland in Bogor tends to be negative, while the *Imperata* grassland vegetation in Katingan and Kupang has no significant relationship (Table 7). The abundance of *Imperata* also negatively affects species richness, species diversity and evenness of species, and has a positive correlation with species dominance in the *Imperata* grasslands in Bogor and Katingan. Whereas in Kupang, the abundance of *I. cylindrica* only has negatively affects species richness and does not significantly influence other variables.

Correlation between than *I. cylindrica* abundance and number of species other than *I. cylindrica* has insignificant correlation. In Katingan has a negative correlation ($r = -0.247$) while Bogor and Kupang are positive correlations ($r = 0.020$ and $r = 0.001$). Based on the analysis, it is revealed that the increasing abundance of *I. cylindrica* causes a decrease in the abundance of other plant species. The decrease in the abundance of other species causes the reduction in the level of species richness, species diversity and evenness of species, and increases the dominance of *I. cylindrica* in the research sites. The results of Brewer (2008.) showed the invasion of *I. cylindrica* in longleaf pine (*Pinus palustris*) communities, Mississippi, United States causes a decrease in the number of native species between 2-4 individuals in plots 0.25 m² in a period of 3 years, whereas in the next 2 years there was no relative decline in the number of native species. Increase in the abundance of *I. cylindrica* that dominates the competition, the abundance of species other than *I. cylindrica* was diminished and this might have resulted in the reduction of species that grew in the community.

In conclusion, *I. cylindrica* was the dominant species in the *Imperata* grasslands in Bogor, Katingan, and Kupang, but other species were also found in which some of them were invasive species. The presence of species other than *I. cylindrica* suggests that these species can grow and compete with *Imperata*. However, efforts to control *I. cylindrica* and the other invasive species populations should not inhibit the growth of other species, so that the succession process of *Imperata* grasslands into forest vegetation runs well and could even restore the biodiversity.

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