EXOTIC PLANTS IN THE CIBODAS BOTANIC GARDENS REMNANT FOREST: INVENTORY AND CLUSTER ANALYSIS OF SEVERAL ENVIRONMENTAL FACTORS

Inventarisasi Tumbuhan Eksotik di Lokasi Hutan Sisa Kebun Raya Cibodas dan Analisis Kluster Faktor-Faktor Lingkungannya

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Abstrak

Dilakukan inventarisasi tumbuhan eksotik di empat lokasi hutan sisa Kebun Raya Cibodas (KRC) dan analisis kluster untuk melihat peranan faktor lingkungan terhadap keberadaan spesies eksotik. Diperoleh sebanyak 26 spesies tumbuhan eksotik di dalam empat hutan sisa KRC. Spesies ini berasal dari 23 marga dan 14 suku. Analisis kluster menunjukkan bahwa pengelompokan nilai faktor lingkungan yang dianalisis bersinergi dengan kelimpahan populasi spesies eksotik tersebut di dalam hutan sisa KRC. Kesesuaian antara hasil analisis kluster dan kelimpahan populasi tumbuhan eksotik menunjukkan peranan faktor lingkungan terhadap keberadaan dan kelimpahan jenis tumbuhan eksotik di hutan sisa KRC. Hasil informasi inventarisasi tumbuhan eksotik di hutan sisa KRC merupakan informasi dasar yang dapat digunakan oleh pengelola KRC dalam rangka pengelolaan tumbuhan eksotik terutama yang bersifat invasif. Perlu dilakukan kajian lanjutan tentang tumbuhan eksotik di hutan sisa KRC untuk menentukan spesies eksotik mana yang harus diprioritaskan pengelolaannya untuk meminimalisasi dampak tumbuhan eksotik dan invasif terhadap ekosiostem alami di KRC.

Kata kunci: analisis vegetasi, hutan sisa, Kebun Raya Cibodas, konservasi, tumbuhan invasif

Abstract

Due to potential impact of invasive alien (exotic) species to the natural ecosystems, inventory of exotic species in the Cibodas Botanic Gardens (CBG) remnant forest area is an urgent need for CBG. Inventory of exotic species can assist gardens manager to set priorities and plan better responses for possible or existed invasive plants in the CBG remnants forest. The objectives of this study are to do inventory of the exotic species in the CBG remnant forest and to determine whether several environmental variables play role to the existence of exotic species in the CBG remnant forests. There are 26 exotic plant species (23 genera, 14 families) found and recorded from all four remnant forests in CBG. Cluster analysis of four environmental variables shows that clustering of environmental factors of exotic species correlates with the abundances of those exotic species. The relation between environmental factor clusters and the abundance of those exotics signify the role of environmental variables on the existence of exotic plant species. The information of exotic plant species in the remnants forest is the base information for gardens manager to manage exotic species in CBG remnants forest. The relation of several environmental factors with exotic species abundance could assist gardens manager to understand better the supportive and or suppressor factors of exotics in the CBG remnants forest. Further study on these species is needed to set priorities to decide which species should be treated first in order to minimize the impact of exotic plant species to native ecosystem of CBG.

Keywords: Cibodas Botanic Gardens, conservation, invasive plants, remnant forest, vegetation analysis

INTRODUCTION

Invasive plant species is one of threat to native biodiversity and may change the natural ecosystem (Gurevitch & Padilla, 2004; Brook *et al.,* 2008; Peltzer *et al.*, 2010). Botanic gardens play a role as sources and disperser of exotic plant species, including invasive plants (Dawson *et al.,* 2008; Heywood, 2011).

Cibodas Botanic Garden (CBG) preserves living collection of native and exotic plant species. Some parts of CBG area consist of native remnant forests which have similar vegetation composition with native forest of Gede-Pangrango National Park (GPNP) (Mutaqien and Zuhri, 2011) as *in situ* conservation area. The location of CBG that is adjacent to GPNP also very important in terms of potential escaped exotic collection of CBG to the GPNP. Gede-Pangrango National Park is an iconic and significant conservation area of Indonesia, and the adjacent ecosystem are considered as one of 200 priorities of global ecoregions for conservation (Olson & Dinerstein, 2002). Due to potential impact of invasive alien (exotic) species to the natural ecosystems, inventory of exotic species in the CBG remnant forest area is an urgent need for CBG. Inventory of exotic species can assist gardens manager to set priorities and plan. better responses for possible or existed invasive plants in the CBG remnants.

The objectives of this study were to do inventory of the exotic species in the CBG remnant forests and to determine whether several environmental variables play a significant role to the existence of exotic species in the CBG remnant forests.

METHODS

Study site

This study conducted in remnant forests of CBG which are located inside the area of CBG. Some parts of the remnants also located next to GPNP forest area. The altitude of CBG is between 1,300 m and 1,450 m above sea level, next to Gede-Pangrango National Park (GPNP). The general climate of CBG area is tropical wet climate (van Steenis, 1972). The average temperature is 20.6^{0}C. The average relative air humidity of CBG is 81%. The average of total precipitation is about 2,950 mm per year. CBG remnant forest consists of 137 tree species with tree density as much as 306 trees per hectares (Mutaqien and Zuhri 2011). The total sampling used in this study is 253 sub-plots that cover 2.53 hectares of remnant forest area. The details of the remnant forests presented in Table 1.

Table 1. All CBG remnant forests, its total area in hectares (Mutaqien and Zuhri, 2011), number of sampling sub-plots in every CBG remnant forests and the total area of sampling sub-plots.

CBG Remnant forest	Total remnant forest area (ha)	Number of sampling sub-plots	Total area of sampling sub-plots (ha)
Wornojiwo	3.934	147	1.470
Kompos	2.555	60	0.600
Jalan Akar	1.086	22	0.220
Lumut	0.855	24	0.240
TOTAL	8.430	253	2.530

Vegetation analysis

Vegetation analysis conducted in all remnant forests of CBG using Quadrat method (Mueller-Dumbois and Ellenberg, 1974) during December 2010. The size of each quadrat is 10 by 10 meters. In every quadrat, all exotic species listed and the environmental datasets collected. These data are: light intensity, air humidity, soil acidity, and soil humidity. The term 'exotic plants' refers to the species originated from outside Malesia-Southeast Asia. Therefore, plants from India, China and Japan considered as exotics. The edge of the remnant forest which is not covered by the sub-sampling plots analyzed using Quadrant method (Mueller-Dumbois and Ellenberg, 1974) along the remnant's edge that lies on the edge of the sub-plots area. Furthermore, this study excludes the exotic climber and exotic epiphyte species. The inventory also limited to trees, shrubs and herbs.

Cluster analysis of environmental factors

Due to incomplete datasets, the cluster analysis involves datasets from Wornojiwo only. Therefore, the exotic species involved in the cluster analysis were from Wornojiwo only. The environmental datasets consists of soil acidity (pH), soil relative humidity (%), air relative humidity (%) and light intensity (lux). All these data recorded for all exotic species found in sampling plots. Data from the same exotic species averaged and used for the cluster analysis. Distance matrix established from the differences of variable value for every exotic species. Cluster analysis conducted from distance matrix (Euclidean) with agglomerative hierarchical clustering and single linkage (Quinn and Keough, 2002) using MYSYSTAT 12. The exotic species which occurs in the remnant's edge did not considered for cluster analysis. The cluster analysis only involved exotic species in the interior part of the remnant forests.

RESULTS

There are 26 exotic plant species found and recorded from all four remnant forests in CBG. These species consists of 23 genus and 14 families. The list of exotic species listed in the vegetation analysis and the environmental factors datasets for every exotic species found in the remnants presented in the Table 2.

Table 2. List of exotic species found in Cibodas Botanic Gardens (CBG) remnant forests: Wornojiwo, Kompos, Jalan Akar and Lumut.

No	Species Name	Family
1	*Ageratina riparia* (Regel) R.M.King & H.Rob.	Asteraceae
2	*Austroeupatorium inulaefolium* (Kunth) R.M.King & H.Rob.	Asteraceae
3	*Bartlettina sordida* (Less.) R.M.King & H.Rob.	Asteraceae
4	*Brugmansia suaveolens* (Humb. & Bonpl. ex Willd.) Bercht. & J.Presl	Solanaceae
5	*Brugmansia x candida* Pers.	Solanaceae
6	*Calathea zebrina* (Sims) Lindl.	Marantaceae
7	*Calliandra calothyrsus* Meisn.	Leguminosae
8	*Camellia sinensis* (L.) Kuntze	Theaceae
9	*Celtis sinensis* Pers.	Ulmaceae
10	*Cestrum aurantiacum* Lindl.	Solanaceae
11	*Cestrum elegans* (Brongn. ex Neumann) Schltdl.	Solanaceae
12	*Chimonobambusa quadrangularis* (Fenzl) Makino	Poaceae

13	*Coffea canephora* Pierre ex A.Froehner	Rubiaceae
14	*Gleditsia fera* (Lour.) Merr.	Leguminosae
15	*Iris pseudacorus* L.	Iridaceae
16	*Malvaviscus arboreus* Cav.	Malvaceae
17	*Maranta lietzei* (E.Morren) C.H.Nelson, Sutherl. & Fern.Casas	Marantaceae
18	*Montanoa grandiflora* (DC.) Sch. Bip. ex Hems.	Asteraceae
19	*Montanoa hibiscifolia* Benth.	Asteraceae
20	*Myriocarpa longipes* Liebm.	Urticaceae
21	*Passiflora ligularis* Juss.	Passifloraceae
22	*Rubus fraxinifolius* Poir.	Rosaceae
23	*Sanchezia nobilis* Hook. f.	Acanthaceae
24	*Solanum aligerum* Schltdl.	Solanaceae
25	*Stobilanthes laevigata* C.B. Clarke	Acanthaceae
26	*Stromanthe thalia* (Vell.) J.M.A.Braga	Marantaceae

The list of exotic species found in Wornojiwo, its environmental datasets, and its relative frequency presented in Table 3. The cluster analysis conducted only for these species listed in Table 3.

Table 3. List of exotic species found in Cibodas Botanic Gardens (CBG) remnant forests Wornojiwo, its environmental data sets and its relative frequency of occurrence in Wornojiwo remnat forest. SPH: soil pH, SRH: soil relative humidity (%), ARH: air relative humidity (%), LI: light intensity (lux) and RF: relative frequency (%).

SPECIES NAME	SPH	SRH	ARH	LI	RF
Brugmansia x candida Pers.	6.8	75.5	81.9	14.0	11.2
Maranta lietzei (E.Morren) C.H.Nelson, Sutherl. & Fern.Casas	6.8	74.3	78.5	10.7	14.3
Calliandra calothyrsus Meisn.	7.0	72.0	65.0	6.0	0.3
Cestrum aurantiacum Lindl.	6.9	71.2	75.4	12.1	33.9
Chimonobambusa quadrangularis (Fenzl) Makino	6.8	71.9	69.2	7.3	5.1
Bartlettina sordida (Less.) R.M.King & H.Rob.	6.7	76.5	79.8	10.1	3.6
Iris pseudacorus L.	6.6	75.7	82.7	13.0	0.8
Myriocarpa longipes Liebm.	7.0	72.0	65.0	6.0	0.3
Sanchezia nobilis Hook. f.	6.8	90.0	80.3	9.0	0.8
Strobilanthes laevigata C.B. Clarke	6.8	70.2	77.1	12.4	29.8

The cluster analysis result of soil acidity shows that there is no significant cluster among the exotics due to soil acidity factors (Figure 1).

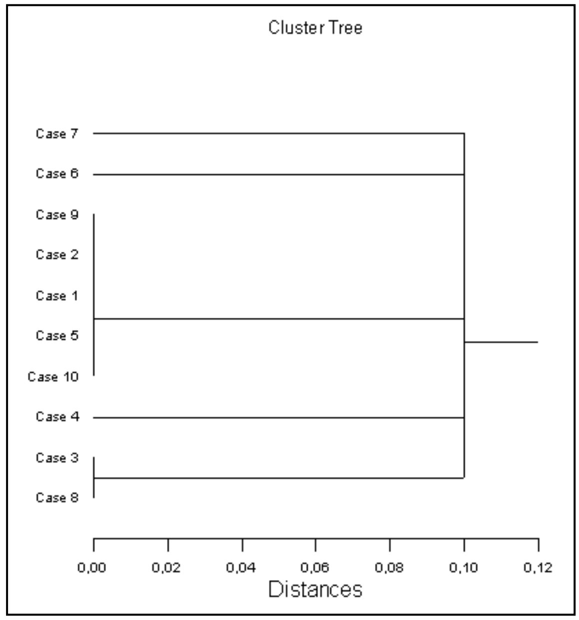

Figure 1. Cluster analysis tree of soil acidity (pH) of ten exotic species found in Wornojiwo. Case 1: *Brugmansia x candida,* case 2: *Maranta lietzei,* case 3: *Calliandra calothyrsus,* case 4: *Cestrum aurantiacum,* case 5: *Chimonobambusa quadrangularis,* case 6: *Bartlettina sordida,* case 7: *Iris pseudacorus,* case 8: *Myriocarpa longipes,* case 9: *Sanchezia nobilis,* case 10: *Strobilanthes laevigata.*

Cluster analysis of soil relative humidity shows that there are at least two clusters of exotic species in the remnant forests. Furthermore, *Sanchezia nobilis* (case 9) is different from other two clusters (Figure 2).

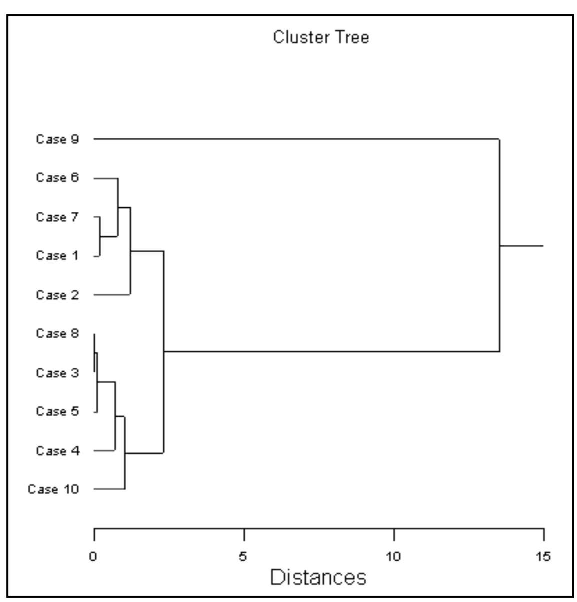

Figure 2. Cluster analysis tree of soil relative humidity (%) of ten exotic species found in Wornojiwo. Case 1: *Brugmansia x candida,* case 2: *Maranta lietzei,* case 3: *Calliandra calothyrsus,* case 4: *Cestrum aurantiacum,* case 5: *Chimonobambusa qaudrangularis,* case 6: *Bartlettina sordida*

Cluster analysis of air relative humidity shows that there are two clusters of exotic species (Figure 3). It is interesting to note that *Calliandra calothyrsus* (case 3) and *Myriocarpa longipes* (case 8) clustered in the same group and have small distance matrix value based on air relative humidity, similar to the clustering based on soil relative humidity.

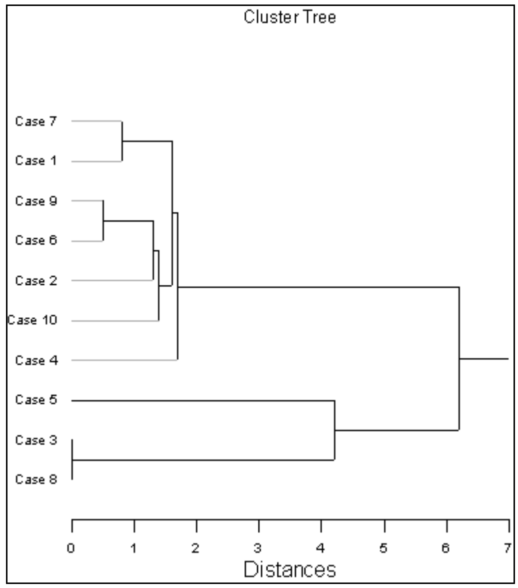

Figure 3. Cluster analysis tree of air relative humidity (%) of ten exotic species found in Wornojiwo. Case 1: *Brugmansia x candida,* case 2: *Maranta lietzei,* case 3: *Calliandra calothyrsus,* case 4: *Cestrum aurantiacum,* case 5: *Chimonobambusa quadrangularis,* case 6: *Bartlettina sordida,* case 7: *Iris pseudacorus,* case 8: *Myriocarpa longipes,* case 9: *Sanchezia nobilis,* case 10: *Strobilanthes laevigata.*

Cluster analysis of light intensity presented in Figure 4. Firstly, there are at least two clusters of exotic species based on light intensity. Secondly, *C. calothyrsus* (case 3) and *M. longipes* (case 8) also positioned in the same cluster with small distance matrix value. *Cestrum aurantiacum* (case 4) and *Strobilanthes laevigata* (case 10) have the same cluster with small distance matrix. Thirdly, if we compare the cluster result with the relative frequency data, species with the smallest frequency value (*C. calothyrsus* and *M. longipes*) clustered in the same cluster. Similarly, species with the largest frequency value (*C. aurantiacum* and *S. laevigata*) also grouped in the same cluster with small distance matrix value.

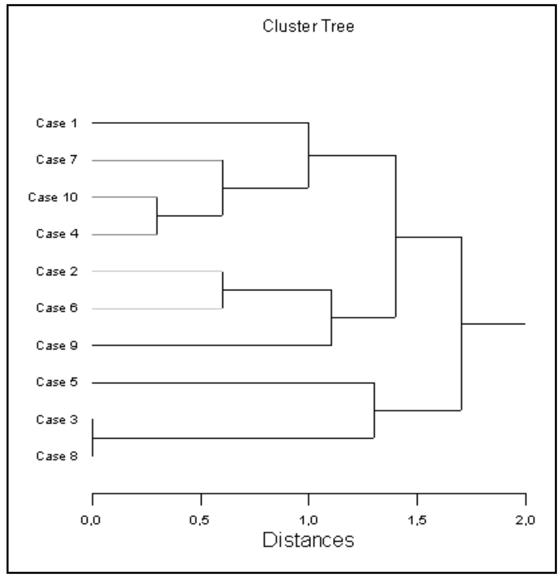

Figure 4. Cluster analysis tree of light intensity (lux) of ten exotic species found in Wornojiwo. Case 1: *Brugmansia x candida,* case 2: *Maranta lietzei,* case 3: *Calliandra calothyrsus,* case 4: *Cestrum aurantiacum,* case 5: *Chimonobambusa quadrangularis,* case 6: *Bartlettina sordida,* case 7: *Iris pseudacorus,* case 8: *Myriocarpa longipes,* case 9: *Sanchezia nobilis,* case 10: *Strobilanthes laevigata.*

DISCUSSIONS

Relative frequency of exotic plant species in the remnants reflects the distribution and population of exotics. *Cestrum aurantiacum* and *Strobilanthes laevigata* are the most common exotic species in the remnant forest. These two species relatively shade-tolerant compared to other exotics in CBG remnants. Cluster analysis of light intensity shows that these two species are on the same cluster. Moreover, cluster analysis of other three factors give similar results. Light intensity is a key factor for exotic species to establish and invade dense tropical forest (Gurevitch et al., 2008; Martin et al., 2010) such as CBG remnants.

Moreover, the establishment of exotic plant species in the remnant forest of CBG influenced by several factors. At least there are two factors: the characteristic of the exotic species itself and the condition of suitable environmental factors for the exotics to grow (including biotic factors). The dispersal of seeds of *C. aurantiacum* by birds possibly support the dominant existence of this species in the remnants. Therefore, *C. aurantiacum* have the biggest relative frequency value.

Moreover, the fact that the big value of relative frequency of *C. aurantiacum* and *S. laevigata* correspond with their same group in same cluster is the evidence of the role of environmental factors on the existence of exotics in the remnants. Either abundant exotics species or exotic with small population are correspond with their clustering in the cluster analysis. The cluster reflects the species needs for the environmental factors. The condition of exotic population may be influenced by many factors, but from this analysis at least we can conclude that environmental factor is one of the key-role.

CONCLUSION

There are 26 exotic species exist in the CBG remnant forests. Two of the most dominant exotics inside the remnants are *C. aurantiacum* and *S. laevigata*. Two of the smallest population are *C. calothyrsus* and *M. longipes*. Cluster analysis shows that the dominance of exotic species population correspond with the environmental condition. Therefore, environmental requirements is an important factor for exotic species establishment. By recognizing the environmental requirements of exotic species to establish, we can set priorities on managing exotic species in native ecosystem as well as minimizing exotic species impact to native ecosystem. Further study is needed to determine whether other environmental factors such as nutrient and competition with native species also play role and how is the relative role of those factors to the existed exotic species.

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