LIGHT INTENSITY AND THE SPREAD OF *Cestrum aurantiacum* Lindl. IN A SECONDARY MOUNTAINOUS REMNANT FOREST*
[Intensitas Cahaya dan Penyebaran *Cestrum aurantiacum* Lindl. di Hutan Remnan Sekunder]

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ABSTRACT

Penyebaran *Cestrum aurantiacum* Lindl. di hutan remnant sekundair Wornojiwo Kebun Raya Cibodas (KRC) dianalisis dalam penelitian ini menggunakan Nearest Neighbor Method. Peranan (korelasi) faktor lingkungan terhadap pola penyebaran *C. aurantiacum* dibandingkan dengan jenis pohon asli dan dilakukan dengan menggunakan cluster analysis. Faktor-faktor lingkungan yang digunakan dalam cluster analysis ini yaitu: intensitas cahaya, keasaman tanah, kelembapan tanah dan kelembapan udara. Hasil analisis penyebaran menunjukkan bahwa jarak penyebaran *C. aurantiacum* hampir lima kali lebih besar daripada penyebaran yang diasumsikan terjadi secara acak. Hasil cluster analysis menunjukkan bahwa intensitas cahaya berhubungan secara nyata dengan penyebaran *C. aurantiacum* di hutan Wornojiwo. Intensitas cahaya rata-rata di plot dengan *C. aurantiacum* lebih besar dibandingkan dengan plot tanpa *C. aurantiacum*. Contoh pengaplikasian hasil penelitian ini adalah memprioritaskan eradikasi *C. aurantiacum* yang ada di pinggir hutan daripada yang ada di bagian tengah. Hasil penelitian ini juga mempertegas pentingnya memelihara tegakan hutan alami untuk memelihara naungan hutan.

Kata Kunci: Tumbuhan invasif, *Cestrum aurantiacum*, Lindl. Cibodas, cluster analysis, hutan remnant pegunungan sekunder, Wornojiwo

ABSTRAK

The dispersion of *Cestrum aurantiacum* Lindl. in Cibodas Botanic Gardens (CBG) mountainous remnant Wornojiwo forest was studied and analyzed. The roles of several environmental factors in the distribution pattern of *C. aurantiacum* were also analyzed. Vegetation analysis methods were used to record *C. aurantiacum* tree meta-population. The nearest Neighbor Method was used to analyze the dispersion of C. aurantiacum. Cluster analysis was operated to determine the roles of four environmental factors observed (light intensity, soil pH, soil relative humidity and air humidity) in affecting the dispersion of *C. aurantiacum* trees. The results show that the dispersion of *C. aurantiacum* is nearly five times longer in distance than the random dispersion assumption. The cluster analysis results show that light intensity received by *C. aurantiacum* is different from that of native species in the Wornojiwo forest. The average light intensity at the plots where *C. aurantiacum* occurs is higher than the plots where *C. aurantiacum* is absent. An example of practical application of this founding is to set eradication priority action for C. aurantiacum trees occur in the forest edge rather than in the middle part of the forest. This result is a strong argument for the importance of maintaining natural forest cover.

Key words: invasive plant, *Cestrum aurantiacum* Lindl., Cibodas, cluster analysis, mountainous remnant Wornojiwo forest, Wornojiwo

Introduction

Invasive plant species contribute to natural ecosystem disturbance and may threat native biodiversity (Andersen *et al.*, 2004; Gurevitch dan Padilla, 2004; Ens dan French 2008; Brook *et al.*, 2008; Peltzer *et al.*, 2010). Invasive plant is an important issue in Indonesia due to the ratification of Convention on Biological Diversity (CBD) by Indonesia. CBD includes invasive plant species as an important issue to be managed (Convention on Biological Diversity, 2012).

Cibodas Botanic Garden (CBG) is an *ex situ* plant conservation area where is located in high-elevation area and maintains exotic plant species as living collection specimens. The issue of invasive plant species in CBG becomes important because CBG is situated next to Gede-Pangrango National Park (GPNP) native forest ecosystem and yet CBG still has a remnant native ecosystem inside its garden area. Invasive plant species in CBG remnant forest may have spreaded further to the native forest of GPNP which is directly located next to CBG. The spread could potentially affect the biodiversity and community of GPNP native forest which possesses high significance in global conservation constituting one of important 200 eco-regions in the world for global conservation prority (Olson dan Dinerstein, 2002).

Invasive plants are defined by spatio-temporal scales. Richardson *et al.* (2000) define in-

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vasive plants based on the dispersal rate (i.e. amount of time needed for dispersion to reach certain distances). This definition is closely related to the plant spatial analysis. Spatial analysis or distribution analysis suggests plant distribution models which can predict plant distribution in larger scales (Clark dan Evans, 1954). On the other hand, plant distribution is not as simple as spatial patterns. Environmental factors, such as light, nutrient and disturbance, may contribute to plant distribution patterns, including invasive plant distribution mechanisms (Gurevitch *et al.*, 2008; Martin *et al.*, 2009; Martin *et al.*, 2010).

Cestrum aurantiacum Lindl. is one of invasive plants occured in CBG remnant forest. *Cestrum aurantiacum* is one of well-known ornamental plants. *Cestrum aurantiacum* is also known for the pharmacological and chemical prospectus for its organic compounds (Beckett, 1987; Prema dan Raghuramulu, 1994; Backhouse *et al.*, 1996; Haraguchi-Mitsue *et al.*, 2000). This species is native to Central America (Benitez dan D'Arcy, 1998; Ye Shiang, 1994) and is considered as weed and alien species in several countries, including South Africa (Henderson, 2007). Some other members of *Cestrum* are also recorded as invasive species e.g. *C. auriculatum* (Renteria dan Buddenhagen, 2006).

This study analyses the dispersion of *C. aurantiacum* in the CBG remnant forest elucidating a possible example of exotic plant species spreading to a mountainous native remnant forest. This study also analyses the clustering of exotic invasive species and native species based on several environmental factors (i.e. light intensity, soil pH, soil relative humidity and air humidity).

METHODS

Research Site

This study located in the remnant forest of Cibodas Botanic Gardens (CBG), namely Wornojiwo forest. CBG is situated in Cipanas District, Cianjur Regency, West Java Province, Indonesia located at 1300 m to 1450 m asl on the slope of the Mount Gede. Remnant forest Wornojiwo is naturally part of Mount Gede-Pangrango ecosystem. Wornojiwo forest consists of more than two hectares of secondary forest area representing a typical Javanese secondary mountainous forest. The average relative air humidity of CBG is 81 % and the average temperature is 20.6^{0}C. The yearly average precipitation is 2950 mm (Mutaqien and Zuhri, 2011).

Vegetation Analysis

The vegetation analysis was conducted at the Wornojiwo forest using a quadrat method (Mueller-Dumbois dan Ellenberg, 1974). Total sampling was 173 quadrat plots and the size of each quadrat was 10 by 10 meters. The data of tree diameter at breast height (dbh) and tree heights of the tree population occurred in all quadrats were then recorded. Environmental data were collected for every tree recorded, including light intensity, air humidity, soil acidity, and soil humidity.

Dispersion type analysis

All *C. aurantiacum* trees were recorded and their positions were tagged. All individual plants were categorized into different life-stages based on their trunk diameters and plant heights. Dispersion type was analyzed using the Nearest Neighbor Method (Clark dan Evans, 1954). The bias due to inaccuracies caused by unrecorded individual plants occurred outside the plots was coped by recording all individual the plants occurred in Wornojiwo forest, either inside or outside the plots.

Cluster Analysis

All *C. aurantiacum* tree data (29 individual trees in total) obtained from vegetation analysis were then averaged (totally 29 trees). The native tree data used for cluster analysis were only those with similar average height and dbh with *C. aurantiacum* (with 5 meters in height) (consisting of 121 individual native trees recorded from the vegetation analysis). Native trees with average dbh and height outside the + 5 meters height range from *C. aurantiacum* average were excluded from the analysis. This data reduction was implemented in order to avoid biases from the

Table 1. Plant species used in the cluster analysis. Total species used in the analysis were 15 species (1 invasive *C. aurantiacum,* 1 exotic non-invasive *C. cassia* and 13 selected native species).

Species Code (Case Number)	Species Name	Family	Average Tree Height (meters)
1	*Cestrum aurantiacum* Lindl.	Solanaceae	5.48
2	*Cinnamomum cassia* (Nees dan T.Nees) J.Presl[#]	Lauraceae	10.00
3	*Dysoxylum nutans* (Blume) Miq.	Meliaceae	8.67
4	*Ficus fistulosa* Reinw. ex Blume	Moraceae	9.25
5	*Ficus ribes* Reinw. ex Blume	Moraceae	7.40
6	*Ficus variegata* Blume	Moraceae	5.00
7	*Macropanax concinnus* Miq.	Araliaceae	6.50
8	*Macropanax* sp.	Araliaceae	5.15
9	*Oreocnide* sp.	Urticaceae	8.00
10	Rutaceae*	Rutaceae	8.00
11	*Saurauia pendula* Blume	Actinidiaceae	8.17
12	*Saurauia reindwardtiana* Blume	Actinidiaceae	7.11
13	*Saurauia* sp.	Actinidiaceae	6.25
14	*Turpinia Montana* (Blume) Kurz	Staphyleaceae	3.73
15	*Villebrunea* sp.	Urticaceae	5.95

[#]Exotic species, but not invasive; *Unidentified genus

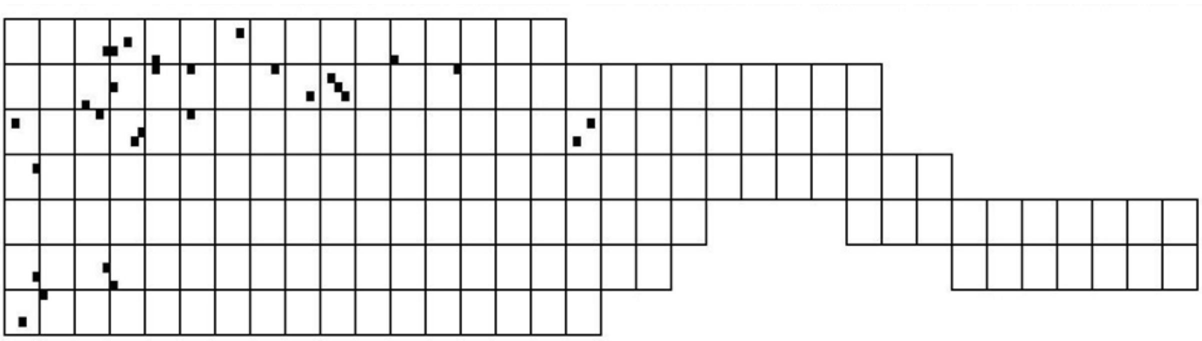

Figure 1. Distribution map of *C. aurantiacum* trees in all established quadrat plots in Wornojiwo forest. One square represents 1 quadrat plot with a 10 m by 10 m in size. Trees were defined by the diameter at breast height (dbh) $\geq$ 10 centimeters. Each black small-square represents an area of 2 m x 2 m in size where a *C. aurantiacum* tree occurs. All plots occupy more than 80 % of the total Wornojiwo forest area. The edge of the Wornojiwo forest is approximately 5 to 10 meters from the edge of the outer quadrat plots.

light intensity factor.

Data reduction includes 13 native tree species and one exotic species but non-invasive (Table 1). Cluster analysis was conducted for all invasive *C.aurantiacum* and the selected native species for all of four measured environmental variables: air relative humidity, soil relative humidity, soil acidity, and light intensity.

Distance matrix was established from the differences of variable value for every species observed (invasive *C. aurantiacum*, exotic non-invasive *C. cassia* and 13 native species). Cluster analysis was then conducted from the distance matrix (Euclidean) using the agglomerative hierarchical clustering and single linkage analysis (Quinn dan Keough 2002) using MYSYSTAT 12.

RESULTS

Based on the nearest neighbor method, the R value of *C. aurantiacum* is 4.65. This R figure shows that the distance of *C. aurantiacum* tree to its nearest neighbor tree in actual condition is almost 5 (4.65) times longer than the hypothetical random condition. The distribution map of *C. aurantiacum* tree in Wornojiwo is presented in Figure 1.

Environmental factors may contribute to the plant distribution patterns, including the invasive plant distribution pattern. Light intensity (LI), soil relative humidity (SRH), soil acidity (SA), and air relative humidity (ARH) have been analyzed as potential factors that correlate to the spread of *C. aurantiacum* in the Wornojiwo forest.

Average environmental data of the 13 native species, invasive *C. aurantiacum* and exotic non-invasive *C. cassia* are presented in Table 2.

There are several interesting results revealed from the cluster analysis. Firstly, light intensity received by *C. aurantiacum* is totally different from all native species except the exotic *Cinnamomum cassia* (Figure 2). Secondly, soil acidity (soil pH) of *C. aurantiacum* is similar to the two native species (*Dysoxylum nutans* and *Ficus ribes*) and the exotic *C. cassia* (Figure 3). Thirdly, the relative air humidity (RH) and soil RH of the *C. aurantiacum* habitat is similar to those of the most native species (Figure 4 and Figure 5).

From totally 173 plots established, *C. aurantiacum* trees only occur in 24 plots. Most of these occurring plots are located in the edge part of the forest (Figure 1). The average light intensity within 24 plots where *C. aurantiacum* occurs is 15.1 lux. This figure is significantly higher than the average light intensity within the 149 plots where *C. aurantiacum* is absent (9.564 lux).

Eventhough the pH differences is not more than 0.2, but the cluster analysis shows that *C. aurantiacum* has lower soil acidity than the native tree species (Figure 3).

The result of cluster analysis for soil relative humidity presented in Figure 4.

The cluster analysis of air relative humidity shows that *C. aurantiacum* occurs in similar air relative humidity environment to the most of native species (Figure 5).

DISCUSSION

A longer distance to the nearest neighbor reflects high capabilities of populations to disperse. This findings show a potential invasiveness of *C. aurantiacum* in Wornojiwo forest because it can reach a relatively wide area and is not distributed clumpy (Figure 1). However, this figure should be concluded carefully due to the unknown disturbance rate in the Wornojiwo secondary forest. Based on Richardson *et al.* (2000), a species can be considered as invasive plant if it can reproduce consistently

Table 2. Tree species used in cluster analysis and its average environmental data: air relative humidity (ARH, in %), soil relative humidity (SRH, in %), soil acidity (SA, in pH), and light intensity (LI, in lux).

Species name	ARH	SRH	SA	LI
Cestrum aurantiacum Lindl.	81.00	72.62	6.69	15.10
Cinnamomum cassia (Nees & T.Nees) J.Presl	83.00	90.00	6.50	15.00
Dysoxylum nutans (Blume) Miq.	82.83	73.33	6.53	9.00
Ficus fistulosa Reinw. ex Blume	74.38	69.88	6.89	12.38
Ficus ribes Reinw. ex Blume	72.50	74.15	6.72	7.92
Ficus variegata Blume	59.50	70.00	7.00	8.50
Macropanax concinnus Miq.	64.00	74.00	6.90	9.50
Macropanax sp.	69.55	63.61	6.95	9.97
Oreocnide sp.	58.00	80.00	6.88	6.50
Rutaceae*	64.00	60.00	7.00	1.00
Saurauia pendula Blume	79.00	84.17	6.90	5.67
Saurauia reindwardtiana Blume	78.89	81.11	6.90	11.11
Saurauia sp.	68.00	64.25	6.98	10.25
Turpinia Montana (Blume) Kurz	63.38	63.38	6.98	9.85
Villebrunea sp.	76.52	70.71	6.88	10.87

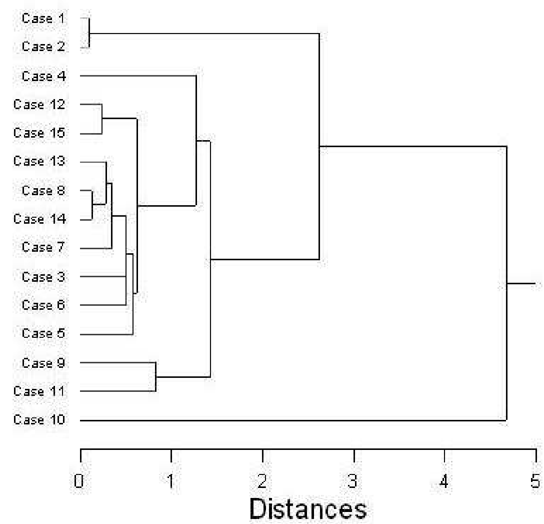

Figure 2. Cluster analysis result for light intensity of *C. aurantiacum* and other 14 tree species in Wornojiwo remnant forest. Every case number represents a tree species. Case 1:*Cestrum aurantiacum,* 2:*Cinnamomum cassia,* 3: *Dysoxylum nutans*, 4: *Ficus fistulosa*, 5: *Ficus ribes*, 6: *Ficus variegata*, 7: *Macropanax concinnus*, 8: *Macropanax* sp., 9: *Oreocnide* sp., 10: Rutaceae, 11: *Saurauia pendula*, 12: *Saurauia reindwardtiana*, 13: *Saurauia* sp., 14: *Turpinia Montana*, 15: *Villebrunea* sp. The numbers in the lower part of the diagram represent the 'distance' (light intensity differences). Software used: MYSYSTAT 12.

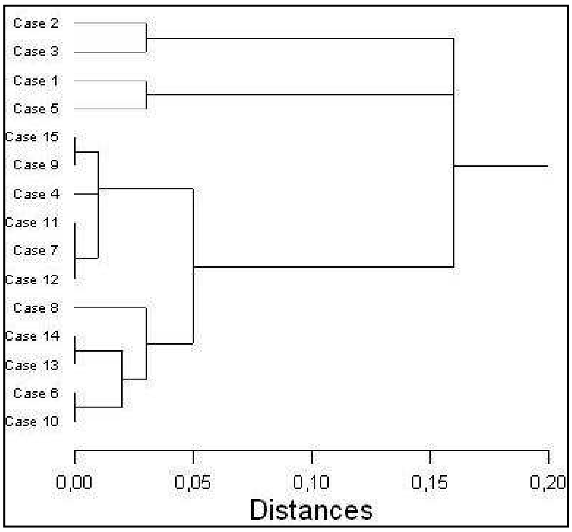

Figure 3. Cluster analysis results for soil acidity of *C. aurantiacum* and other 14 tree species in the Wornojiwo remnant forest. Each case number represents a tree species. Case 1: *Cestrum aurantiacum,* 2: *Cinnamomum cassia,* 3: *Dysoxylum nutans*, 4: *Ficus fistulosa*, 5: *Ficus ribes*, 6: *Ficus variegata*, 7: *Macropanax concinnus*, 8: *Macropanax* sp., 9: *Oreocnide* sp., 10: Rutaceae, 11: *Saurauia pendula*, 12: *Saurauia reindwardtiana*, 13: *Saurauia* sp., 14: *Turpinia Montana*, 15: *Villebrunea* sp. The numbers in the lower part of the diagram represent the 'distance' (soil acidity differences). Software used: MYSYSTAT 12.

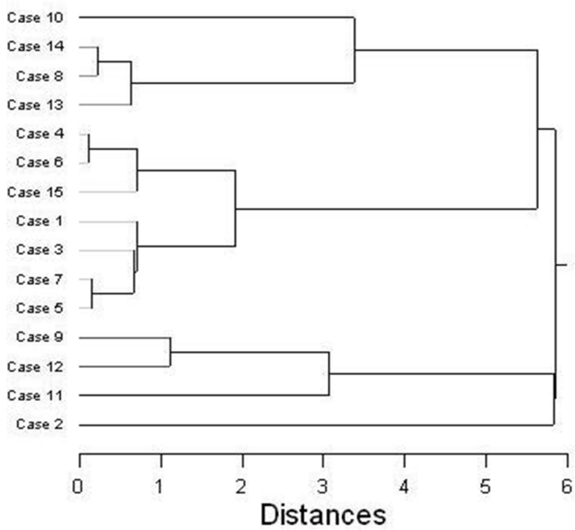

Figure 4. Cluster analysis results for soil relative humidity of *C. aurantiacum* and other 14 tree species in Wornojiwo remnant forest. Each case number represents a tree species. Case 1:*Cestrum aurantiacum,* 2:*Cinnamomum cassia*, 3: *Dysoxylum nutans*, 4: *Ficus fistulosa*, 5: *Ficus ribes*, 6: *Ficus variegata*, 7: *Macropanax concinnus*, 8: *Macropanax* sp., 9: *Oreocnide* sp., 10: Rutaceae, 11: *Saurauia pendula*, 12: *Saurauia reindwardtiana*, 13: *Saurauia* sp., 14: *Turpinia Montana*, 15: *Villebrunea* sp. The numbers in the lower part of the diagram represent the 'distance' (soil relative humidity differences). Software used: MYSYSTAT 12.

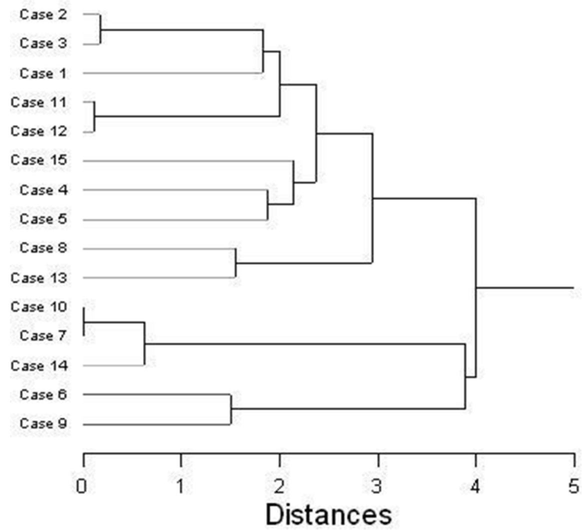

Figure 5. Cluster analysis results for air relative humidity of *C. aurantiacum* other 14 tree species in Wornojiwo remnant forest. Each number represents a tree species. Case 1:*Cestrum aurantiacum,* 2:*Cinnamomum cassia*, 3: *Dysoxylum nutans*, 4: *Ficus fistulosa*, 5: *Ficus ribes*, 6: *Ficus variegata*, 7: *Macropanax concinnus*, 8: *Macropanax* sp., 9: *Oreocnide* sp., 10: Rutaceae, 11: *Saurauia pendula*, 12: *Saurauia reindwardtiana*, 13: *Saurauia* sp., 14: *Turpinia Montana*, 15: *Villebrunea* sp. The numbers in the lower part of the diagram represent the 'distance' (air relative humidity differences). Software used: MYSYSTAT 12.

without interference from human and reached more than 100 meters from its initial location or parent tree inside natural forest. *C. aurantiacum* fruits are dispersed by birds and may be bats due to its juicy berry fruit (Benitez dan D'Arcy, 1998). *Cestrum aurantiacum* may have potential abilities to spread all over remnant forest area. Based on the collected data, the population of *C. aurantiacum* exists in a range of 1.19 hectares within the Wornojiwo forest area while the longest distance between two trees of *C. aurantiacum* is more than 170 meters.

The cluster analysis result of light intensity reveals interesting phenomena of *C. aurantiacum* in this forest. Even though *C. aurantiacum* is a dominant invasive species in Wornojiwo, but the amount of light intensity in the forest limits the invasiveness of this species. A consequence of fast growing rate of *C. aurantiacum* is the higher demand of energy sources, including sunlight. Gurevitch *et al.* (2008) stated that plant invasion in the forest is more sensitive to light rather than to other environmental factors, i.e. nutrient. However, Martin *et al.* (2009) argued that the percentage of successful invaders from shade-tolerant species in the forest is relatively high. *C. aurantiacum* is a member of Solanaceae that commonly tolerates shades but requires a certain amount of light (Benitez dan D'Arcy, 1998). Martin *et al.* (2010) stated that even though light availability limits the exotic plant species survivorship in the forest, but certain species with different life history trade-off pattern may become invasive in low light environment in the forest.

Based on the cluster analysis, *C. aurantiacum* possesses different soil acidity properties (relatively lower than native tree) in their habitat. Soil acidity is one of plant-soil feedback aspect. On the other hand, soil chemistry properties such as soil acidity can be a result of invasive plant exudates released to invade soil (Weidenhamer dan Callaway, 2010).

There is a similar soil relative humidity requirement between *C. aurantiacum* and the native trees. *C. aurantiacum* is basically a riparian zone plant in its natural habitat. *C. aurantiacum* need high soil relative humidity (Benitez and D'Arcy, 1998). This requirement is similar to native mountainous rainforest habitat that requires high soil relative humidity (Yamada, 1975; 1976).

The air relative humidity does not reflect habitat preference differences between *C. aurantiacum* and the native trees. However, exotic non-invasive species *C. cassia* is also closely related to *C. aurantiacum* as shown by the light intensity and soil acidity cluster results in Figure 2 and 3. The relative humidity around Cibodas is relatively high and never reaches below 70% (Yamada, 1975). The recent average relative air humidity in Cibodas was around 81 % (Mutaqien dan Zuhri 2011).

The cluster analysis result of light intensity and soil acidity is a significant supportive figure for *C. aurantiacum* management to be considered. *C. aurantiacum* needs higher light intensity and more acidic soil compared to native tree's habitat requirements. A certain condition (i.e. higher light intensity and lower soil pH), can assist *C.aurantiacum* invasion. On the other hand, a condition of lower light intensity and higher soil pH can limit the invasiveness of this species. An example of practical application of this finding is to set an eradication priority action for *C. aurantiacum* trees occur in the forest edge rather than in the middle part of the interior part. This finding is also an argument for the importance of maintaining natural forest cover. Forest cover can assure there will not enough light for light-demanding exotic invasive tree such as *C. aurantiacum* to grow further and become more invasive. Managing environmental condition to cope with invasive species is one of the important management strategy (Catford *et al.*, 2011).

In conclusion, the dispersion analysis result of *C. aurantiacum* shows an evidence of potential invasiveness of this species. Moreover, light intensity and soil acidity are two important factors that determine the occurrence of *C. aurantiacum* in Wornojiwo forest. Further studies are needed to examine the rate of invasiveness, the autecology of *C. aurantiacum* and the quantitative analysis on the ecological impact of this species occurrence to the native forest and native plants biodiversity.

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