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Research Article

Autecology of *Castanopsis argentea* (Blume) A.DC. in Telaga Warna Nature Reserve Area, Bogor Regency

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ABSTRACT
The red list of the International Union for the Conservation of Nature and Natural Resources (IUCN) reported *Castanopsis argentea* as an endangered species. Studies about autecology on its natural habitat become important to perform species conservation. This study aimed to analyze the population structure, distribution pattern, and environmental factors that influence the presence of *C. argentea* in the Telaga Warna Nature Reserve. Data was collected in September 2020 by making 21 plots with a single plot. The purposive sampling method was used based on *C. argentea* representatives to determine plot location. Measurement of environmental factors, including soil sampling was carried out on each plot. Population structure was analyzed based on plant density, and Morisita index determined the distribution pattern. Environmental data were analyzed using PCA with Minitab 19 programs. Our field observation showed that *C. argentea* seedling has the highest density (1071 ind/ha) and decreased in the mature phase. *C. argentea* was found to have a clumped distribution pattern with an Id value of 1.03. PCA analysis showed differences in environmental factors that were thought to influence the presence of *C. argentea* individuals in four growth phases. The highest population structure of *C. argentea* was found in the growth phase of seedlings and saplings at an altitude of 1400 m asl. The spread population distribution of *C. argentea* was clumped. The influences of environmental variables on the existence of *C. argentea* were Mg, Ca, CEC, pH, and soil moisture.

INTRODUCTION

Castanopsis argentea (saninten) is a woody plant from the Fagaceae family. This plant is distributed naturally in Assam, India, Myanmar, Indonesia, and Thailand (POWO 2022) and is a native plant from Indonesia that grows in Borneo, Sumatra, and Java (Soepadmo 1968; POWO 2022). On Java Island, *C. argentea* is found in primary forest at an altitude of 150-1750 m asl (Zuhri et al. 2018). Ecologically, this tree species is a place for wildlife, especially birds and mammals, used for foraging, resting, and nesting. *C. argentea* seeds are food for wild animals such as wild boars and other primates (Heriyanto et al. 2007). This species can be used to reforest rocky mountainous land (Wibowo 2006) and become one of the plant species that have the potential for revegetation activities of ex-mining land as well as to repair damaged ecosystems (Ahmad et al. 2013). In other fields, the wood of this plant can be used as a building material, the fruit can be used as a stomach ache medicine, and the peel of the fruit can be used as a dye (Setyawati 2010).

Since 2018, *C. argentea* has been listed as an endangered species and added to the red list according to the International Union for the Conservation of Nature and Natural Resources (IUCN) (Barstow & Kartawinata 2018). As the case in Sumatra, *C. argentea* in nature is disrupted due to land conversion, such as forest clearing into plantations of palm oil. This species habitat loss has led to a population decline of approximately 50% over the last three decades (Handayani & Hidayati 2020). The most significant impact of *C. argentea* declinine in the population is the existence of anthropogenic activities. The anthropogenic activity threat to this species is the reduced ability of natural regeneration caused by fruit over-harvesting and the wood being cut down for timber (Barstow & Kartawinata 2018).

The Telaga Warna Nature Reserve Area is one of the remaining natural habitats of *C. argentea* in West Java. Based on an initial scoping study, *C. argentea* trees are commonly found growing in the Telaga Warna Nature Reserve Area. That makes the Telaga Warna Nature Reserve considered effective for obtaining data related to the interaction of *C. argentea* species on environmental factors and other plant species in the area. Therefore, a study is needed on the autecology of the *C. argentea* species in its natural habitat. The information obtained can be used as a reference for conservation and added to the biodiversity database in the Telaga Warna Nature Reserve Area. The purposes of this study were to analyze the population structure, distribution pattern, and environmental factors that influence the presence of *C. argentea* in the Telaga Warna Nature Reserve Area.

MATERIALS AND METHODS

Materials

The study was conducted in September 2020 in the Telaga Warna Nature Reserve, Bogor Regency (Figure 1). Biotic and abiotic data were collected at three different altitudes (1400, 1500, and 1600 m asl). The separation of elevation range 100 meters impacted the growth of *C. argentea* (Dewi et al. 2019). The materials used in this study were field-collected plant specimens and soil samples from three different altitudes.

Methods

The population structure of *C. argentea* and community structure at the study site was carried out by collecting biotic data on four growth phases (seedling, sapling, pole, and tree) with a total sampling area of 0.84 hectares. Seedlings are young trees from sprouts to < 1.5 m high; saplings are young trees that have 1.5 m high and < 10 cm of diameter breast height (dbh); poles are young trees with dbh range from 10 cm to < 20 cm, while trees are adult individuals with a > 20 cm dbh (Wahyudi et al. 2014). The purposive

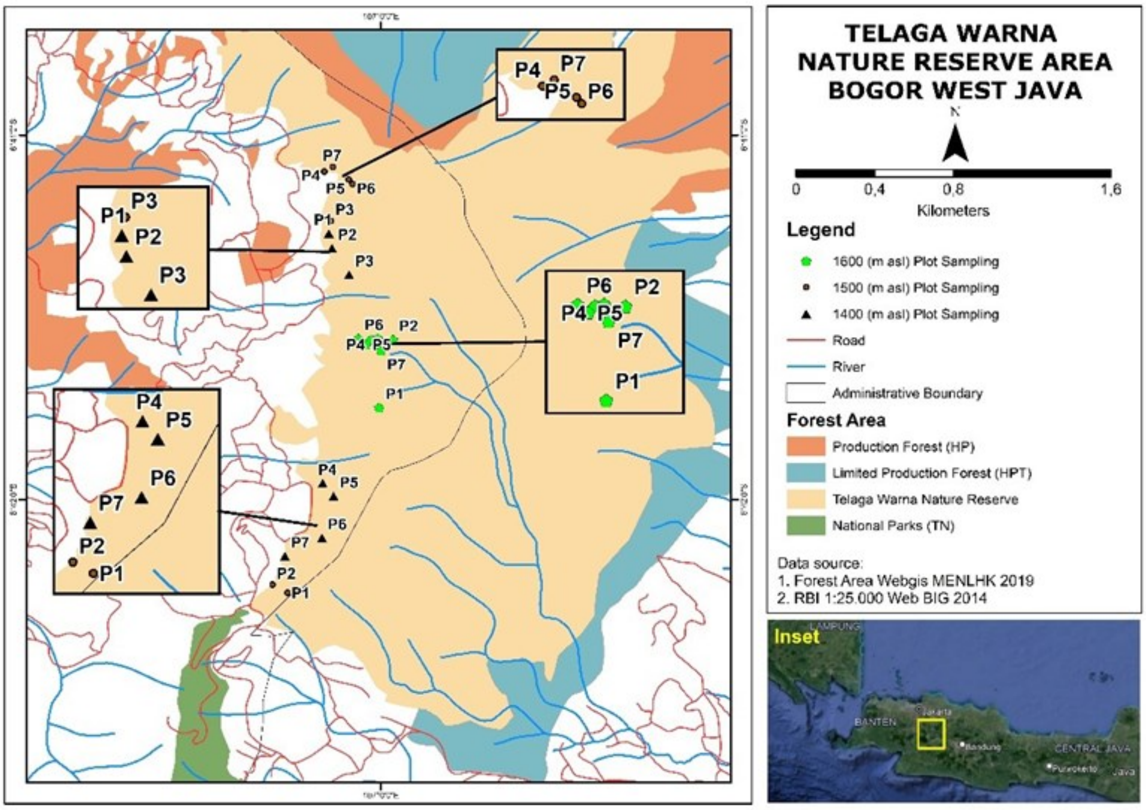

Figure 1. A map of the research location and plot sampling in the Telaga Warna Nature Reserve Area, Bogor Regency.

sampling method was used based on *C. argentea* representatives to determine plot location. The total number of plots is 21, divided by three based on each elevation (1400, 1500, and 1600 m asl). A Single quadrat plot of 20 m x 20 m was used for vegetation analysis, modified from Metananda et al. (2015). The sample plot size was used as 20 m x 20 m for the tree phase sampling. In plot 20 m x 20 m, sub-plots were made for other phases of sampling; 2 m x 2 m is made for the seedling phase, 5 m x 5 m for the sapling phase, and 10 m x 10 m for the pole phase.

Plant data inventory was obtained by recording each individual plant contained in each plot, then calculating the number of individuals for each species. Population structure was measured by dbh (diameter at breast height). For this method, the dbh level (1.3 m above the ground) was measured for each species present within the quadrat (Pradhan et al. 2018). The identification method was done by taking photography and herbarium preparation. A sample of leaves, flowers, and fruit for herbarium preparation was brought to the Laboratory of Ecology and Plant Resources to be identified and verified through various websites such as Plants of Southeast Asia, GBIF, and Plants of the World.

Environmental factors measured by using a 4-in-1 environmental meter (Lutron LMB8000A) were air humidity, air temperature, light intensity, and wind speed. The topographic factors measured were altitude by using GPS and altimeter, whereas the slope of the place was measured with a clinometer. In contrast, edaphic factors such as pH and soil moisture were measured using a soil tester. Determination of soil sampling following the location of vegetation plot created to test chemical properties. Soil samples were taken with a sample ring of 2 inches in diameter and stored in sealed plastic. For each altitude, seven sampling points were taken based on the presence of a study plot, and then the soil was composited (Risna 2009).

Data on plant abundance at each growth phase in each sample plot was obtained by calculating the Important Value Index (IVI). In contrast, population structure data was obtained by calculating the density value (D). The Important Value Index (IVI) for the seedling and sapling phases was obtained based on the sum of relative density (RD) and relative frequency (RF). In contrast, the IVI for the pole and tree phases was obtained based on the sum of relative density (RD), relative frequency (RF), and relative dominance (RDo) (Gonçalves et al. 2018). Data on the basal area (BA) is needed to determine the dominance of a species. Basal area (BA) is calculated using a formula $\frac{1}{4}\pi\,(dbh)^2$ (Yahya et al. 2019). Density (D), relative density (RD), frequency (F), relative frequency (RF), Dominance (Do), and relative dominance (RDo), were calculated as follows:

$$D = \frac{\text{Number of individuals of each species}}{\text{Sample plot area (ha)}}$$

$$RD = \frac{\text{Density of each species}}{\text{Total density of all species}} \times 100\ \%$$

$$F = \frac{\text{Number of study plots found for each species}}{\text{Total number of study plots created}}$$

$$RF = \frac{\text{Frequency of each species}}{\text{Total frequency of all species}} \times 100\ \%$$

$$Do = \frac{\text{Basal area of each species}}{\text{Sample plot area (ha)}}$$

$$RDo = \frac{\text{Dominance of each species}}{\text{Total dominance of all species}} \times 100\ \%$$

The Morisita index was used to determine the distribution pattern of *C. argentea* in the study area (Krebs 1989). The Morisita index was calculated as follows:

$$I_\delta = n\left[\frac{\sum x^2-\sum x}{(\sum x)^2-\sum x}\right]\ ;\ M_u = \frac{\chi^2_{0.975};df^1-n+\sum xi}{(\sum x^2)-1}\ ;\ M_c = \frac{\chi^2_{0.025};df^1-n+\sum xi}{(\sum xi)-1}$$

where:

I_δ = Morisita index

M_u = uniform distribution pattern index

M_c = aggregate distribution pattern index

n = number of plot

Σx = total number of plot

Σx^2 = sum of the squares of the number of plot

Σxi = number of each individual plant in a plot i (i = 1,…n)

$\chi^2_{0.975}$ = Chi-squared in db (n-1), 97.5%

$\chi^2_{0.025}$ = Chi-square in db (n-1), 2.5%

The observed plant distribution pattern was determined using the following criteria:

a) If the value of $I_\delta \geq M_c \geq 1.0$, then $I_p = 0.5 + 0.5\left(\frac{I\delta - Mc}{n - Mc}\right)$

b) If the value of $M_c > I_\delta \geq 1.0$, then $I_p = 0.5\left(\frac{I\delta - 1}{Mc - 1}\right)$

c) If the value is $1.0 > I_\delta > M_u$, then $I_p = 0.5\left(\frac{I\delta - 1}{Mu - 1}\right)$

d) If the value is $1.0 > M_u > I_\delta$, then $I_p = 0.5 + 0.5\left(\frac{I\delta - Mu}{Mu}\right)$

The distribution pattern of the species is random when $I_p = 0$; clumped when $I_p > 0$; and uniform when $I_p < 0$ (Krebs 1972).

Environmental and soil chemical data from each research plot were analyzed using Principal Component Analysis (PCA) with the Minitab 19 program. Principal Component Analysis (PCA) was used to determine the effect of environmental factors on the presence of *C. argentea*.

RESULTS AND DISCUSSION

Overview of Research Sites and Population Structure of *Castanopsis argentea*

The Telaga Warna Nature Reserve Area study site has dense vegetation conditions (Figure 2). Some tree species with a diameter > 50 cm were found growing in this location, such as *Castanopsis argentea*, *Castanopsis tunggurut*, *Castanopsis acuminatissima*, and *Lithocarpus indutus* from the Fagaceae family, *Cinchona succirubra* (Rubiaceae), *Schefflera polybotrya* (Araliaceae), *Turpinia sphaerocarpa* (Staphyleaceae), *Ficus elastica* (Moraceae), *Sloanea sigun* (Elaeocarpaceae), *Manglietia glauca* (Magnoliaceae), *Villebrunea rubescens* (Urticaceae), *Schima wallichii* (Theaceae), and *Neolitsea javanica* (Lauraceae).

The results of the vegetation analysis showed that the *C. argentea* tree dominated the study area. Trees of this species had the highest IVI of 59.95 with values of relative density, relative frequency, and relative dominance, 12.40, 12.74 , and 34.81% respectively (Table 1).

The number of individuals per hectare was used as a parameter to study the population structure of *C. argentea* at the study site. The results showed that each study site in the Telaga Warna Nature Reserve had a

Table 1. Important Value Index of *Castanopsis argentea* in all study sites in the Telaga Warna Nature Reserve.

Growth phases	D (ind/ha)	RD (%)	F	RF (%)	Do	RDo (%)	IVI
Seedling	1071.43	1.01	0.19	3.25	-	-	4.27
Sapling	323.81	6.23	0.52	7.97	-	-	14.20
Pole	38.10	5.44	0.38	7.41	0.66	5.55	18.40
Tree	36.90	12.40	0.94	12.74	21.49	34.81	59.95

Notes: ind = individuals; ha = hectare; D = density; RD= relative density; F = frequency; RF = relative frequency; Do = dominance; RDo = relative dominance; IVI = Important Value Index.

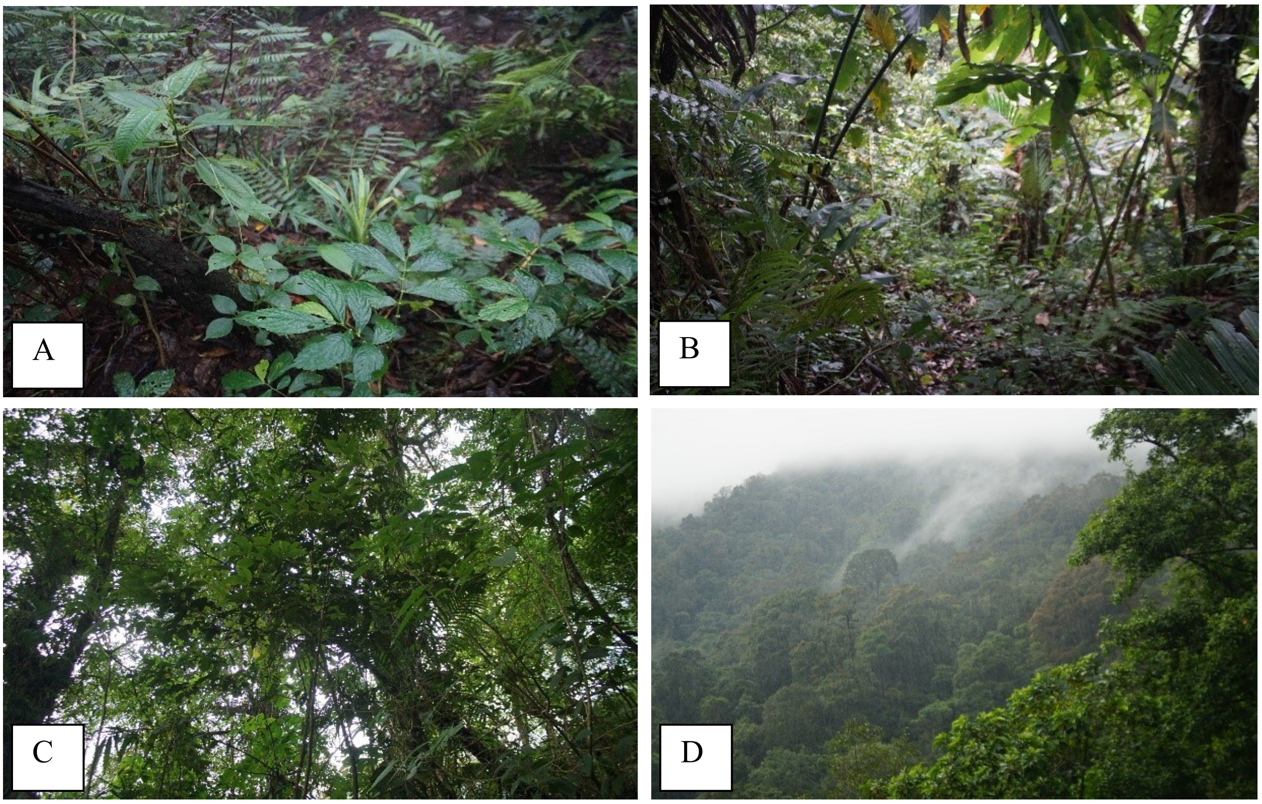

Figure 2. Vegetation conditions in the Telaga Warna Nature Reserve. A-B: forest floor condition; C-D: tree vegetation cover.

different population structure of *C. argentea* (Figure 3). The rejuvenation of *C. argentea* in seedling and sapling phases was more commonly found at an altitude of 1400 m asl, which indicates the environmental conditions of 1400 m asl were suitable for the growth of rejuvenation *C. argentea*. Seedlings of *C. argentea* grow very well at an altitude of 1400 m asl, indicated by the high value of seedling density (Heriyanto et al. 2007).

Meanwhile, at an altitude of 1600 m asl, no individual seedlings were found in the study plots. The individual density of the seedling level tends to decrease with increasing altitude (Hilwan 2012). Although the density of the tree phase at this location is greater than in the other two locations, the abundance of trees is not always a parameter in terms of increasing the success of seeds in growing into seedlings. Most seeds cannot survive due to unfavorable growing environment conditions (Yang et al. 2015). A growing environment with enough high light intensity can increase the seed density and viability of seedling life compared to a growing environment with low light intensity (Zhao et al. 2021). Given that *Castanopsis* is a tree species with a wide canopy cover, the number of trees in this location can withstand light from entering the forest floor (low light intensity value is 242 lux). That can affect seed germination to grow into seedlings and develop into sapling phase. *C. argentea* saplings at this location had a lower population density than the other two locations (Figure 3). Danková & Saniga (2013) found that 6 out of 8 species of saplings had low specific densities in locations with large canopy cover so that only a small amount of light entered the forest floor through the canopy gap.

The existence of competition also affects the development of the *C. argentea* seedling phase. As time passes, individuals in the seedling phase require much energy to compete among plants for sunlight and nutrients used for growth and development (Waskitaningtyas et al. 2018). Slow seedling growth can also be caused by competition between individuals of the same or different species in terms of struggle nutrients, water, growth space, and sunlight, causing some *C. argentea* seedling individuals to be defeated.

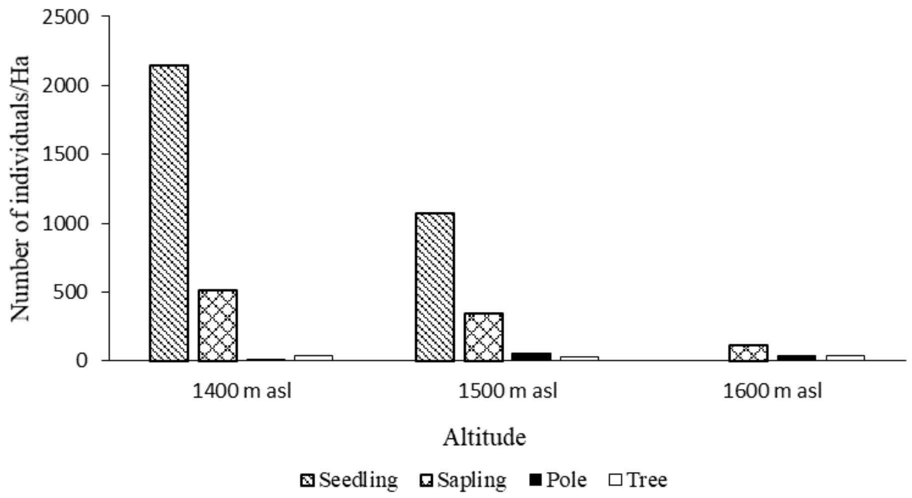

Figure 3. Population structure of *C. argentea* at three altitudes in the Telaga Warna Nature Reserve.

Several dominant plant species in the seedling and understorey phases were found around *C. argentea* (Table 2). *Elastostema strigosum* was the dominant understorey species at three altitudes. *E. strigosum* could grow well and even dominate previously disturbed forest park areas (affected by landslides) (Raihandhany et al. 2019). In addition, this alleged competition showed that the state of seedlings at an altitude of 1500 m asl decreased due to other dominant plant species besides *E. strigosum*, namely *Cliemia hirta*. At that altitude, *C. hirta* has the second-highest IVI. *C. hirta* is an invasive plant that can threaten and harm the ecosystem. In addition, this species also can spread fast because it has a high germination ability and is shade tolerant (Nursanti & Adriadi 2018). *C. hirta* also has allelopathic compounds that can inhibit seed germination, roots, and stems from other plant seedlings (Ismiani 2015). The dominance of this species is feared to change the condition of the forest floor and even inhibit the growth of other plant species such as *C. argentea* seedlings which are native plants in the area.

Distribution Pattern of *Castanopsis argentea* at the Study Site

The calculation of the Morisita dispersion index (Table 3) showed that the population of *C. argentea* in the Telaga Warna Nature Reserve has a clumped distribution pattern ($I_p > 0$). Hilwan & Irfani (2018) research in the Gede

Table 2. Dominant plant species in the seedling and understorey phases found around *Castanopsis argentea* at three altitudes.

No.	Species Name*)	Altitude		
		1400	1500	1600
1	*Elatostema strigosum* Hassk.*	√	√	√
2	*Cyrtandra grandis* Blume*	√	-	-
3	*Clidemia hirta* (L.) D.Don*	-	√	-
4	*Strobilanthes filiformis* Blume*	√	-	√
5	*Elatostema acuminatum* (Poir.) Brongn.*	√	-	-
6	*Costus* sp.*	√	-	-
7	*Cyathea contaminans* (Hook.) Copel.	-	-	√
8	*Psychotria montana* Blume	-	-	√

Notes: *) Plant species with INP ≥ 10; * understorey**;** √ = found; - = not found.

Pangrango National Park area showed similar results. Random plant distribution patterns rarely occur in nature, and between plants usually have a clumped pattern (Rayburn et al. 2011).

Differences in the distribution pattern of a plant species are influenced by various biological factors and environmental conditions available in an ecosystem, such as the presence of wind, water flow, light intensity, animals, characteristics possessed by a plant species (Duman et al. 2016), environmental heterogeneity (Perry et al. 2009), seed dispersal (Schurr et al. 2004), and the presence of certain disturbances (Rayburn & Monaco 2011). The clumped distribution pattern in fruit plants, including *C. argentea* is influenced by reproductive factors (Sumihadi et al. 2019). Naturally, the fruit of *C. argentea* will not fall too far from the mature plant. However, because trees of this species are found growing on relatively steep land, some individual trees are found growing in steep places, causing the regeneration of *C. argentea* to be found quite far from the mature plant. This situation allows *C. argentea*, who are relatively the same age, to live in groups. Therefore, it was rare to find seedlings growing together in the same plot with mature individuals during the research.

The different characteristics of *C. argentea* at various growth phases are related to this species distribution pattern in nature. Judging from the seed or fruit distribution mechanism, *C. argentea* can grow well if the seeds or fruit of *C. argentea* are carried to a particular place in a suitable environment to support its growth process. The process of growing from seed dispersal is influenced by high light intensity and the steep slope affects the success of tree phase growth. Different habitat conditions, such as elevation and slope, cause tree species to have different distribution patterns (Mirmanto 2014).

Table 3. The value of the standardized Morisita index and the distribution pattern of *C. argentea* at the study site.

Morisita dispersion index (I_δ)	Uniform index (M_u)	Clumped index (M_c)	Standardized Morisita index (I_p)	Distribution pattern
1.03	0.84	1.22	0.07	Clumped

Habitat Characteristics Affecting the Presence of *Castanopsis argentea*

Based on the analysis of environmental factors (Table 4 and Table 5), two components can describe the habitat characteristics of *C. argentea* in the Telaga Warna Nature Reserve Area, namely edaphic factors and climatic factors. PCA analysis of environmental data obtained from three different study sites showed that altitude affected the presence of *C. argentea* individuals (Figure 4A). At an altitude of 1400 m asl, there were 26 individuals of *C. argentea* starting from the seedling phase to the tree phase, an altitude of 1500 m asl as many as 22 individuals, and an altitude of 1600 m asl as many as 17 individuals. That means the number of *C. argentea* individuals in the four growing phases decreased with increasing altitude.

Altitude has an essential role in the process of plant growth and development. The difference in altitude has affected the amount of sunlight received, water absorption, and the availability of soil nutrients (Zhu et al. 2019). These varying factors can cause an increase or decrease in the presence of a plant species along an altitude gradient (Körner 2007). Therefore, some plants can grow well in high lands while others can only grow in low to medium lands. *C. argentea* found at the study site could grow well at an altitude of 1400 m asl. Because at that altitude, there were environmental factors that were favorable for the existence of this species, namely the high content of Mg, Ca, Cation Exchange Capacity (CEC), pH, and soil moisture (Table 4).

Table 4. Analysis of soil chemical properties at the study site.

Parameters	Altitude (m asl)					
	1400		1500		1600	
	Value	**Criteria***	**Value**	**Criteria***	**Value**	**Criteria***
pH H_2O	5.41	Acidic	4.97	Acidic	4.84	Acidic
C (%)	8.88	Very high	10.25	Very high	4.84	High
N (%)	1.01	Very high	1.16	Very high	2.08	Very high
C/N ratio	8.79	Low	8.84	Low	13.69	Medium
P_2O_5 (ppm)	14.85	Very high	16.40	Very high	44.06	Very high
Ca ($cmol_c$/kg)	17.97	High	7.96	Medium	1.23	Very low
Mg ($cmol_c$/kg)	4.14	High	2.63	High	0.67	Low
K ($cmol_c$/kg)	1.26	Very high	8.28	Very high	2.62	Very high
Na ($cmol_c$/kg)	0.30	Low	0.32	Low	0.32	Low
CEC ($cmol_c$/kg)	63.33	Very high	50.94	Very high	54.21	Very high
BS (%)	37.39	Medium	37.67	Medium	8.91	Very low

Notes: *soil fertility criteria follow Eviati & Sulaeman (2009).

Table 5. Average microclimate at the study site.

Parameters	Altitude (m asl)		
	1400	**1500**	**1600**
Soil moisture (%)	58	57	56
Air humidity (%)*	62	70	73
Air temperature (^{o}C)	24.4	24.4	21.8
Light intensity (lux)	968	904	242
Wind speed (m/s)	0.04	1.70	0.30

Notes: *air humidity data is an absolute value.

C. argentea in the four growth phases had different tendencies in PCA biplots. All seedlings and saplings of *C. argentea* (Figure 4B) collected at location 1 (1400 m asl) were influenced by the high availability of macronutrients (Ca and Mg), cation exchange capacity, base saturation, pH, and microclimates such as air temperature, the intensity of light and soil moisture. The seeds must be in favorable environmental conditions to grow and develop into a more mature phase to increase the chances of survival. The rejuvenation of *C. argentea*, especially in the seedling phase at an altitude of 1400 m asl was growing in a slightly shaded environment. It can be said that the seedling of this species is a light-demanding plant. The light intensity at this location is also higher than in the other two locations. This study's results align with the research by Handayani et al. (2019), which showed that *C. argentea* seedlings planted in the open area experienced a rapid increase in height.

In the pole phase, the presence of individual *C. argentea* at location 2 (altitude 1500 m asl) was more influenced by the availability of macronutrients K and Na as well as microclimates such as wind speed and humidity. In contrast to its regeneration, *C. argentea* in the pole phase required higher macronutrients K and Na concentrations than the other two macronutrients (Ca and Mg). This condition was supported by the high value of CEC (> 40) at the study site. CEC plays an essential role in retaining soil nutrients (Luo et al. 2015) and controlling the supply of exchangeable cations, namely Ca^{2+}, Mg^{2+}, K^{+}, Na^{+}, Al^{3+}, and Fe^{3+} (Mueller et al. 2012), so the soil with a high CEC able to absorb and provide sufficient nutrients for plant growth (Siburian et al. 2020).

C. argentea trees were dominant at an altitude of 1600 m asl (location 3). That can explain the growing *C. argentea* trees were heavily influenced by soil macronutrients such as N, C-organic, C/N ratio, and phosphate. The high C/N ratio (13.69) indicated that the mature phase of *C. argentea* required fewer nutrients than the younger phase. Meanwhile, high nitrogen availability can help maximize nutrient absorption and play an essential role in mature plants' flowering and fruit formation process (Pescie et al. 2018). That can also answer why the number of trees in this location was abundant.

Different altitudes affect soil formation, which can determine soil texture and vegetation composition. The Telaga Warna Nature Reserve Area has an andosol soil type with a dusty to clay texture (Effendi et al. 2019). The finer the texture of the soil, the greater its ability to hold water used for plant growth (Fitriani et al. 2018). The research by Rukhmi et al. (2017) at three altitudes shows that soil with a clay texture has a larger surface area than sandy loam so that, it stores more nutrients, providing sufficient water content for air circulation in the soil. The soil condition could be another supporting factor for discovering *C. argentea* in the Telaga Warna Nature Reserve Area.

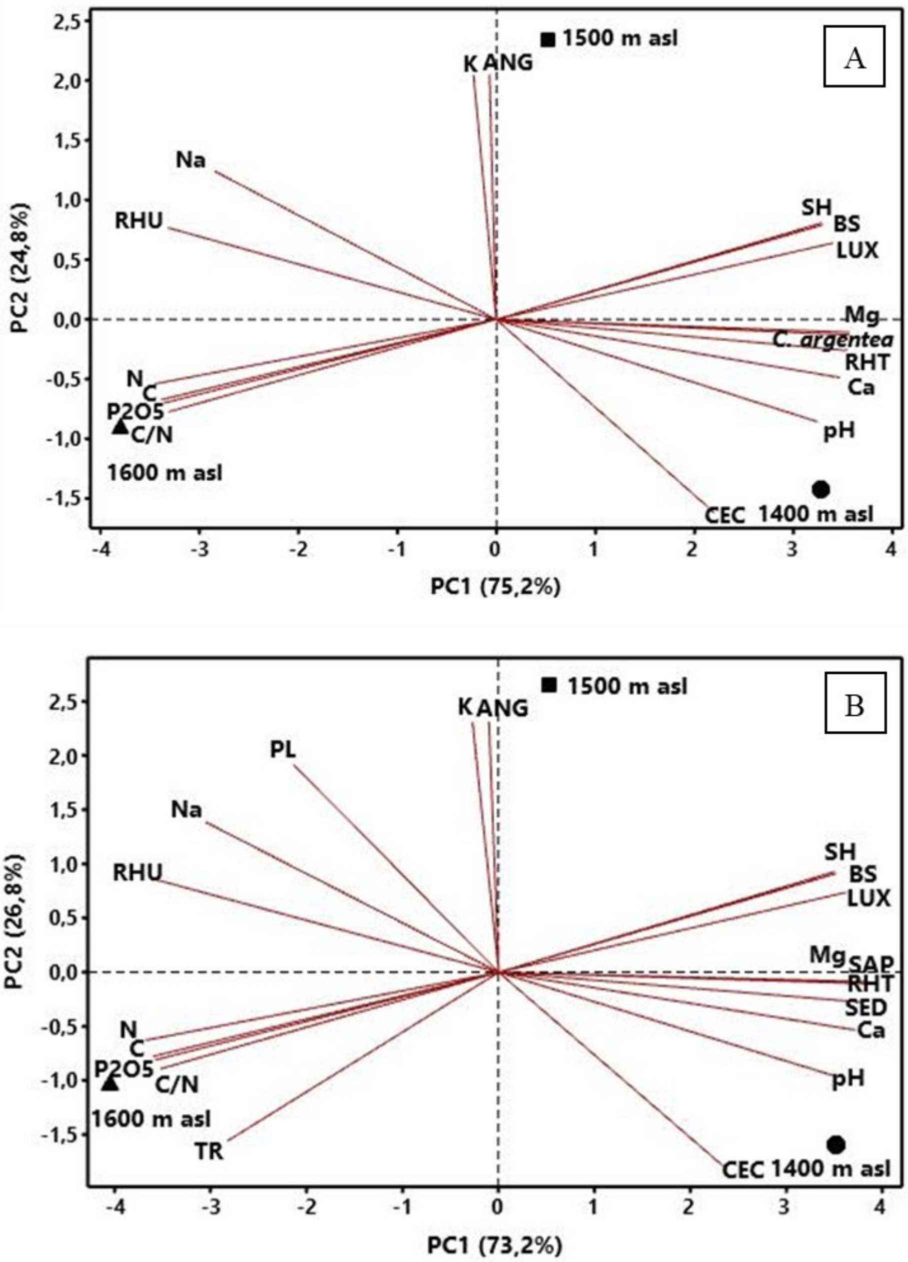

Figure 4. Results of PCA analysis of environmental factors determining the presence of *C. argentea* in the Telaga Warna Nature Reserve. (A) All phases; (B) four growth phase. SED: seedling; SAP: sapling, PL: pole; TR: tree; ANG: wind speed; SH: air temperature; LUX: light intensity; RHT: soil moisture; RHU: air humidity, BS: base saturation; CEC: cation exchange capacity.

CONCLUSION

The highest population structure of *C. argentea* was found in the growth phase of seedlings and saplings at an altitude of 1400 m asl, decreasing population with ever-increasing elevations. The population of *C. argentea* spreads clumped in the Telaga Warna Nature Reserve. Meanwhile, PCA analysis showed differences in environmental factors, namely edaphic and climatic factors, that were thought to influence the presence of *C. argentea* individuals in four growth phases. *C. argentea* could grow well at an altitude of 1400 m asl because environmental factors were favorable for the existence of this species, namely the content of Mg, Ca, CEC, pH, and soil moisture.

AUTHORS CONTRIBUTION

D.M.P. contributed to design the research concept, data collection, analyzed the data, and authored the manuscript. S. and N.R.D. contributed equally to this manuscript, developed the research concept, examined the data, authored, reviewed, and approved the final manuscript.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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