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Biomass Productivity of Invasive Mantangan (*Merremia peltata*) under Various Canopy Covers

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ABSTRACT

Mantangan (*Merremia peltata*) is the most important invasive species in Bukit Barisan Selatan National Park (BBSNP) due to its fast-growing and spreading that potentially damage and threat biodiversity conservation. The objectives of this study were to determine the biomass stock and productivity of mantangan and the nutrient content of mantangan biomass grown in various classes of canopy cover. Stratified sampling was employed as a sampling method on three classes of canopy cover, i.e., sparse (light intensity > 70%), medium (light intensity 40 -70%), and dense (light intensity < 40%). A destructive method was used to collect biomass samples. The biomass harvesting was conducted twice. The first was conducted to determine biomass storage and nutrient content, and the second was conducted a month later to measure biomass productivity. The macronutrient content (N, P, K, and C-Organic) of mantangan was analyzed at the Soil Science Laboratory, Faculty of Agriculture, University of Lampung. The results showed that the biomass stock and productivity differed in each canopy cover class. The highest biomass stock was found in sparse canopy cover (192 kg/ha), followed by medium (188 kg/ha) and dense (179 kg/ha). Biomass productivity was highest in sparse canopy cover (93 kg/ha/month), followed by medium (79 kg/ha/month) and dense (83 kg/ha/month), respectively. Surprisingly, the nutrient content and nutrient productivity of mantangan grown on medium canopy cover were higher than that of dense and sparse.

1. Introduction

Bukit Barisan Selatan National Park (BBSNP) is a conservation area aimed at protecting the tropical rainforests of Sumatra Island and its biological natural wealth. In 2004, UNESCO designated the BBSNP, Gunung Leuser National Park, and Kerinci Seblat National Park as World Heritage Sites for the Tropical Rain Forest of Sumatra. This status has confirmed that BBSNP is an important conservation area for the world, so it must be protected from all forms of damage. Furthermore, protecting biodiversity for future development is one of the commitments of the Indonesian Government under the 1992 UN Convention on Biological Diversity (CBD) and ratified by the Indonesian Government in 1994.

One of the causes of natural damage that occurs in conservation areas is the presence of invasive plants that endanger and harm other plant species (Tjitrosoedirdjo et al. 2016). Invasive alien species are foreign species brought or taken by accident into an ecosystem unnaturally. The species adapt and reproduce in new habitats and widely affect their habitat. The invasive alien species can cause environmental damage, economic loss, and human harm (CBD-UNEP 2014). In addition, invasive alien species affect native ecosystems by altering the hydrological and nutrient cycles (Kohli et al. 2009). Indonesia has around 1,936 alien plant species, some of which are invasive and can cause ecosystem damage (Tjitrosoedirdjo 2005). Sayfulloh et al. (2020) found several types of invasive foreign plants in BBSNP, such as sembung rambat (*Mikania micrantha*), klibadium (*Clibadium surinamense*), kirinyuh (*Chromolaena odorata*), daun tanah (*Austroeupatorium inolifolium*), irengan (*Ageratina riparia*), sintrong (*Crassocephalum crepidioides*), and mantangan (*Merremia peltata*).

As an invasive plant, mantangan can grow very fast, thus becoming a serious threat to biodiversity conservation (Whistler and Arthur 2002). Currently, 2% of the total area of the BBSNP area is invaded by mantangan (Master et al. 2013). Mantangan is a plant with elongated stems, smooth, hairless, semi-woody, creeping up to 20 m high, twisting on the shoots, and having tuberous roots (Stone 1970). This species has wide heart-shaped to round leaves, smooth leaf texture, cyme wreath-type flowers, large bell-shaped petals, white or yellow, with a total of 5 crowns, five green petals, and frayed and hairy anther (Staples 2010). In addition, Mantangan is a dicotyledonous plant with complex and hairy seed covers (Mardiati 2014). Mantangan is a liana plant member of the Convolvulaceae family, which has been declared an invasive alien plant species that can cause environmental damage (Thapa et al. 2018).

The mantangan invasion will severely threaten native species in the BBSNP area due to its invasive nature if it does not get serious attention. The dangers caused by mantangan are disturbances in the plant's growth as a source of forage and animal habitat, causing habitat succession and disrupting plant and animal associations (Putra 2022). Master et al. (2013) explained that the competitors for native species; disrupt the food web; and potentially reduce biodiversity by suffocating or killing native species. As a vine, mantangan can grow fast and densely; it can close the canopy of other plants, block the plants from getting sunlight, and ultimately disrupt the photosynthesis process (Putra 2022). The presence of mantangan results in the death of native species by losing the competition for space and obtaining sunlight. The loss of native species shows a decrease in habitat quality due to the loss of food sources. Land cover by mantangan also prevents the mobility of large fauna in BBSNP (Master et al. 2013). Associated with all these adverse properties, and due to their fast growth and highly dispersible nature, they are the most important invasive plants in the BBSNP area.

Mantangan is a severe threat to biodiversity conservation in BBSNP due to its fast growth and straightforward spread (Whistler and Arthur 2002). It can potentially cause environmental damage (Thapa et al. 2018). It is estimated that around 2% (7.110 ha) of the BBSNP area is currently invaded by mantangan (Master et al. 2013). Mantangan is a pioneer plant that requires full sunlight for growth and reproduction. Therefore, it will climb and acquire the canopy of its host plant to get light. The danger is caused by the symbiosis of parasitism for the native species, disrupting the food web and potentially reducing biodiversity by suffocating or killing native species. The invasion of mantangan will change the structure and composition of species in natural ecosystems. The presence of mantangan will make other plants unable to compete and ultimately reduce biodiversity and the extinction of native plants (Tjitrosoedirdjo 2016). The existence of mantangan can also reduce habitat quality due to the loss of food sources for various animal species and inhibit the mobility of large fauna in BBSNP (Master et al. 2013).

Behind all the destructive properties, mantangan has the potential to produce biomass related to its growth rate. Biomass is organic matter produced through the process of photosynthesis. Plants with high biomass productivity have the potential as a source of energy, organic fertilizer, or soil enhancer (Herlambang et al. 2017). Due to its fast growth, the mantangan has economic potential as a source of income for BBSNP managers. Mantangan also has the potential to be used as organic fertilizer. Organic fertilizers contain organic compounds, including proteins or amino acids and other substances that increase plant growth and yield (Silalahi et al. 2020). This potential utilization is one of the invasive plant control efforts carried out in BBSNP. This method was taken because apart from the ability of invasive plants to acquire places to grow, mantangan biomass that is not managed properly is feared to harm the environment. Some of these adverse effects include low seed growth due to nutrient immobilization, allelopathy, and as a breeding ground for pathogens (Setyorini et al. 2006).

Mardiati (2014) reported that the growth of mantangan is strongly influenced by the intensity of the light received. Carbon fixation rate, relative growth rate, leaf weight ratio, net assimilation rate, leaf nitrogen, and photosynthetic nitrogen use efficiency would increase align with increasing light intensity received. Forest tree canopy cover will create shade which will affect the speed of growth and productivity of mantangan biomass. Plants that obtain less light intensity than necessary will grow faster than those that obtain enough light, but the plants turn pale because they lack chlorophyll, are thin, and the leaves do not develop (Magfiroh et al. 2017). The study aimed to determine mantangan biomass's content and productivity and the nutrient content of various classes of tree canopy cover (sparse, medium, and dense) in the BBSNP area.

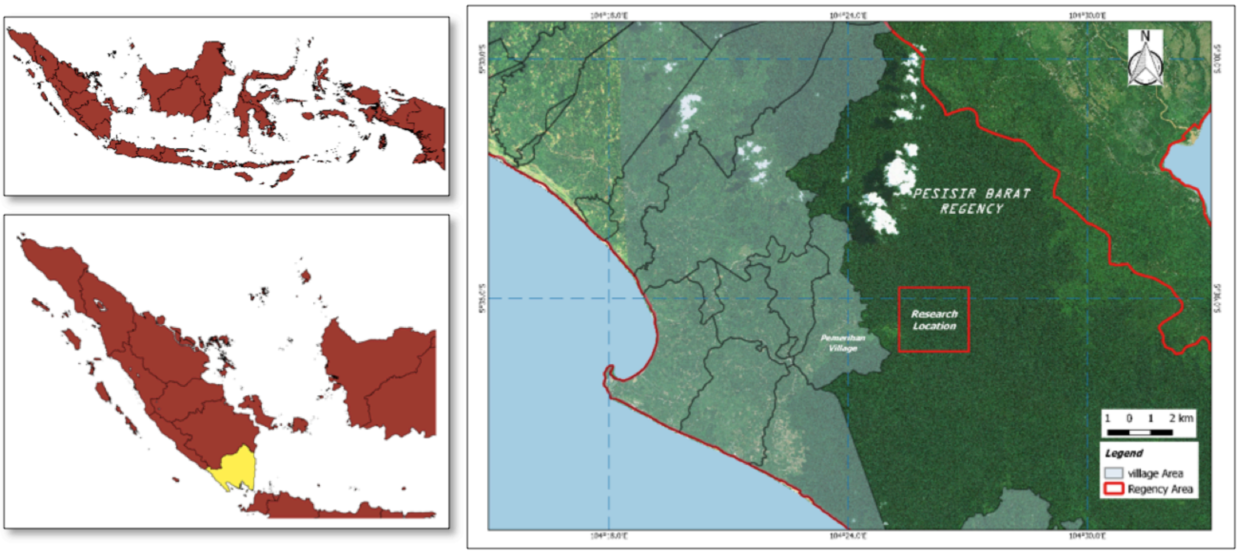
2. Materials and Methods

2.1. Time and Place

This research was conducted from October 2020 – July 2021 at Bukit Barisan Selatan National Park, Pemerihan Resort, National Park Management Section (SPTN) Region II Bengkunat, National Park Management Division (BPTN) Region I Semaka, Pesisir Barat Regency, Lampung Province, Indonesia (**Fig. 1**). According to Schmidt and Ferguson's classification, the site has Type A climate, with rainfall of 2,500–3,000 mm per year and an average temperature of around 31°C. The altitude ranges from 20–500 masl, and the slope is predominantly flat (0–8%) of 43.35% of the area (BBSNP 2017). Soil types are dominated by red-yellow-podzolic and alluvial (Wardani et al. 2016).

2.2. Sampling

A stratified sampling was carried out by dividing the population into several strata, selecting samples from each stratum, and combining them to interpret the parameters of a population (Ulya et al. 2018). This method was chosen because mantangan at the Pemerihan Resort in BBSNP grows in three classes of canopy cover, namely sparse canopy cover (accepted light intensity > 70%), medium (accepted light intensity 40–70%), and dense (accepted light intensity < 40%).



Map sources: Attachment to the Decree of the Minister of Forestry and Plantations No. 256/KPTS-II/2000, processed (Bappeda Provinsi Lampung 2022); Potensi Desa Map 2020 (BPS 2021); SPOT 6 Imagery (Bappeda Provinsi Lampung 2018).

Fig. 1. Research location of Pemerihan Resort, Bukit Barisan Selatan National Park, Sumatra, Indonesia.

The total area invaded by mantangan in the Pemerihan Resort area was 27 ha. From the area, 30 sample plots measuring 2 m × 2 m were drawn. The sample plots were distributed proportionally based on the area portion of each class of canopy cover where the mantangan grew. The area of mantangan growing on sparse, medium, and dense canopy cover was 19 ha, 3 ha, and 5 ha, respectively. Therefore, the number of sample plots in each canopy cover class was determined proportionally based on the area: 19/27 × 30 = 21 plots, 3/27 × 30 = 3 plots, and 5/27 × 30 = 6 plots.

2.3. Methods

Mantangan biomass was sampled using the destructive method by harvesting all plant parts in a 2 m × 2 m sample plot. The parameters measured in the study were the total gross and the oven-dry weight of mantangan tissue per plot. Harvesting of mantangan tissue was performed twice. The first was conducted to determine the biomass stock and nutrient content of mantangan, and the second harvesting was carried out one month later to measure the productivity of mantangan biomass for one month.

The nutrient content of mantangan tissue was analyzed at the Laboratory of Soil Science, Faculty of Agriculture, University of Lampung. Nutrient analysis was carried out for the macronutrients N, P, K, and C-organic, where the N nutrient content was analyzed using the Kjeldhal method (Mlangeni et al. 2013). The sample was destructed using sulfuric acid and catalyzed with the appropriate catalyst to produce ammonium sulfate. After liberation with a strong alkali, the ammonia formed was steam distilled quantitatively into the adsorption solution and determined by titration. The P nutrient content was analyzed using the Olsen method (Umaternate et al. 2014). The Olsen method measures phosphorus content using the principle of colorimetry (difference in blue) by using a spectrophotometer. Potassium (K) nutrient content was determined using a 25% HCl extractor (Sudjadi et al. 1971). The mantangan tissue was extracted with 25%

HCl solution, left to stand for 24 hours, then evaporated at 100°C until the solution became clear. Then the standard series of potassium solution was measured using a flame photometer. C-organic levels were measured using the Walkley and Black method (Sholikah et al. 2013). The principle of this method is that Cr_2O_7 given in excess, was then reduced when reacting with mantangan tissue, considered equivalent to C-Organic in the sample tissue.

Biomass content was measured twice to determine the stock and productivity in each canopy cover class. Biomass content is the total organic material content of a living organism at a particular place and time (Lodhiyal and Lodhiyal 2003). The gross weight content of plant tissue must first be measured to calculate plant biomass. The following calculation formula of the gross weight content per hectare of mantangan was used:

$$Gross\ weight\ (kg/ha) = Bb\ per\ plot\ (kg)/sample\ plot\ area\ (0.0004\ ha) \quad (1)$$

Biomass content for undergrowth plants was calculated using Equation 2 (Brown 1997):

$$Biomass = Bb/ha \times (Bk/Bb) \quad (2)$$

where *Bb/ha* is the gross weight per hectare (kg/ha), *Bk* is the dry weight (kg), and *Bb* is the gross weight (kg).

The number of nutrients in mantangan biomass was calculated quantitatively by multiplying the weight of mantangan biomass/ha in each canopy cover class with the nutrient content obtained from laboratory analysis. Analysis of K, N, and C content is expressed in percentage (%), while P nutrients are expressed in units of mg/kg.

3. Results and Discussion

3.1. Biomass Content of Mantangan

Biomass is the total dry weight of an organic matter expressed in kilograms or tonnes (Irawan et al. 2020). The results showed that the mantangan biomass in the sparse canopy cover class was higher than that of medium and dense cover and indicated that sunlight affects the growth and production of mantangan biomass. As a pioneer plant, mantangan likes the site with high-intensity sunlight or not shaded (Sukmasari et al. 2019). Previous studies explained that sunlight's intensity is related to photosynthesis (Simangunsong et al. 2016). Photosynthesis produces photosynthate, which is stored in biomass or total dry weight. The greater the value of the total dry weight (BKT), the greater the biomass value. The complete content of mantangan biomass in each canopy cover class is presented in **Table 1**.

Table 1. Mantangan biomass content in various canopy cover classes in TNBBS

No.	Canopy cover class	Bb/plot (kg)	Bb/ha ($kg.ha^{-1}$)	Bk/sample (kg)	Biomass/ha ($kg.ha^{-1}$)
1	Sparse	0.705	1,763	0.077	192
2	Medium	0.529	1,321	0.076	188
3	Dense	0.660	1,649	0.072	179

Notes: Bb = gross weight, and Bk = dry weight.

The results indicated that it is interesting that the gross weight of mantangan tissue in dense canopy cover was higher than in medium ones. This condition is thought to occur due to the high concentration of the hormone auxin in the tissues that receive less light, so the cells in these tissues grow longer and produce a high plant gross weight. Mutryarny and Lidar (2018) explained that auxin is a phytohormone that keeps away from light. This hormone is found at the tips of stems, roots, and flower shoots which functions as a regulator of cell enlargement and triggers cell elongation in the area behind the end meristem. Light intensity is closely related to plant physiological processes, and this condition is evident in the morphological state of the plant. If the received light intensity is high, the leaf cells will be smaller in size, have less chlorophyll, and have lumpy thylakoids. This condition causes the leaves to be smaller and thicker, the number of leaves on the plant to be more significant, and the stem segments are shorter growth (Buntoro et al. 2014). Sunlight is a source of energy needed for the process of photosynthesis. Light also plays a role in the process of forming chlorophyll. However, light can act as an inhibitor in the growth process because light can stimulate the diffusion of auxin to parts that are not exposed to light (Wiraatmaja 2017).

Another interesting fact is that although the gross tissue weight in dense canopy cover is higher than that in medium one, the biomass content shows the opposite growth and thriving. Plants will only grow well if they obtain enough sunlight. Plants will grow fast, but the color of the plants will look paler because the chlorophyll content of these plants decreases. Light is the main factor as energy in photosynthesis. Lack of light will interfere with the process of photosynthesis and growth. Plants that grow with sufficient light will grow slower with relatively harsh conditions, are more expansive, greener, and look fresher, and the stems of the sprouts are stronger (Wiraatmaja 2017).

The biomass contained in the tissues (0.179–0.192 tons/ha) of mantangan was much lower than that of lianas of the leguminous cover crop (LCC) type. *Mucuna bracteata* is an LCC with an average biomass content of 9–12 tons/ha if planted without shade (Ma'ruf et al. 2017). Therefore, the results indicated that the mantangan does not have the potential to be utilized as an LCC.

3.2. Biomass Productivity of Mantangan

Biomass production is the development and increase of plant tissue, such as the number of leaves, leaf area, and plant height, which are influenced by the water content and nutrient content in the plant tissue cells (Manuhuttu et al. 2014). The results showed that the highest productivity of mantangan biomass was produced in sparse canopy cover and indicated that mantangan is a pioneer plant that is intolerant and requires high-intensity sunlight to grow and reproduce. The response of plants to low light conditions is to optimize their photosynthetic abilities (Ruberti et al. 2012). However, it is interesting that the productivity of mantangan biomass in dense canopy cover is slightly higher than in medium ones. This condition is thought to occur as a form of adaptation to light intensity. The complete productivity of mantangan biomass for various classes of canopy cover in BBSNP is presented in **Table 2**.

Table 2. Productivity of mantangan biomass at various canopy cover classes

No.	Canopy cover class	MTP (kg.plot^{-1}.month^{-1})	PTP (kg.ha^{-1}.month^{-1})	MB (g)	BP (kg.ha^{-1}.month^{-1})
1	Sparse	0.342	855	0.109	93
2	Medium	0.223	557	0.145	79
3	Dense	0.306	765	0.108	83

Notes: MTP = mantangan tissue production, PTP = plant tissue production/month, MB = the content of mantangan biomass/kg of gross tissue, BP = biomass production.

The leaf area ratio (LAR) of shaded plants will usually increase, as will their chlorophyll content. It aims to increase the ability of plants to harvest light (light-harvesting) (Ridwan et al. 2018). Lianas generally have good adaptability to changes in light intensity. According to Toledo et al. (2008), lianas have much higher survival characteristics than other plants in the ecosystem. Mantangan can quickly grow vegetatively through stems that can take root on the part of the nodus that touches the ground. Even Irianto and Tjitrosoedirdjo (2010) revealed that a stem that has been cut could bring roots back to where the cut was. This ability is thought to be the cause of the difficulty of eradicating mantangan stems through eradication processes by mechanical means, such as cutting/pruning. Furthermore, pruned stems were also able to regrow with a percentage of 46.67% (stem diameter of 5 cm), 40% (stem diameter of 3 cm), and 20% (stem diameter of 1 cm).

Apart from having extraordinary adaptability, they also have a fast growth rate. Pengembara et al. (2014) reported that mantangan shoots grown from stem cuttings had a growth rate of up to 16 cm/week with an increase in stem diameter of 0.07 cm/week and an increase in the number of leaves reaching one leaf/week. The high growth rate of mantangan in the Pemerihan Resort area is also supported by a site that is very suitable for the needs of mantangan. The mantangan grows well in the temperature of > 26°C (Master 2012), altitudes 0–600 masl (SPREP 2000), and land slopes that tend to be flat (Hermawan 2017). These growth requirements follow the Pemerihan Resort site status, which has a Type A climate, with rainfall of 2,500–3,000 mm per year with an average temperature of around 31°C. The altitude ranges from 20–500 masl, and the slope is predominantly flat (0–8%) of 43.35% of the area (BBSNP 2017).

3.3. Nutrient Content of Mantangan

The continuous addition of organic matter to the soil is a cheap and easy way to increase land productivity. In addition, organic matter can increase the availability of several nutrients, such as N, P, and K (Muliatiningsih et al. 2019). Generally, the macro-nutrient content (N, P, K, and C) of mantangan biomass growing in medium canopy cover was higher than that in the dense and sparse canopy covers. The difference in macronutrient content is likely due to the influence of light intensity, impacting the rate and duration of photosynthesis in mantangan. The complete nutrient content of mantangan in various classes of canopy cover in BBSNP is presented in **Table 3**.

Physiologically light influences plants directly or indirectly. Directly the influence of light occurs through photosynthesis and indirectly through plant growth and development due to direct metabolic responses (Fitter and Hay 1991). Sunlight is the primary energy source in the photosynthesis reaction. The leaves will absorb 1–5% of the received solar energy, and the rest will be released through transpiration and emitted/reflected (Taiz and Zeiger 2010). Therefore, low light intensity in dense canopy covers will produce fewer photosynthetic products.

Table 3. Nutrient content of mantangan vegetation on various canopy cover classes

No.	Canopy cover class	Laboratory test results			
		N (%)	P (mg/kg)	K (%)	C-organic (%)
1	Sparse	1.28	179.79	2.14	54.85
2	Medium	1.71	231.94	2.38	53.28
3	Dense	1.24	76.45	2.00	53.56

Meanwhile, light intensity that is too high will affect the activity of leaf stomata cells in reducing transpiration, resulting in inhibition or reduced nutrient content in mantangan biomass. Furthermore, the high light intensity can reduce the rate of photosynthesis due to the fast photo-oxidation of chlorophyll, which damages chlorophyll. In addition, high light intensity reduces air humidity, so transpiration occurs more quickly (Treshow 1970).

The nutrients in the mantangan tissue were also not as high as those in the LCC plant species. Mantangan had an N concentration of 1.24% if it grew under dense shade and 1.28% if it grew in light shade. In comparison, the LCC-type *Mucuna bracteata* has an N content of 2.03% if it grows in the shade and 1.96% in an open area (Ma'ruf 2017). In addition to lower biomass productivity, it turns out that the nutrient content of mantangan is also lower compared to *M. bracteata*. This study indicates that mantangan does not have the potential to be used as a cover crop.

3.4. Nutrient Productivity of Mantangan

Nutrients are the essential chemical elements needed by plants to achieve optimal growth, provided that other factors are under normal conditions (Rajiman 2020). The productivity of mantangan nutrients in medium canopy covers was higher than that of dense and sparse canopy covers. This result is presumably because, apart from sunlight, water availability is an environmental factor that also plays a significant role in the growth of mantangan. Mantangan requires large amounts of water and nutrients due to its fast-growing nature. Marsudi et al. (2018) stated that canopy stratification is closely related to groundwater availability. On land with low canopy cover, groundwater availability may be limited due to high evaporation. In total, nutrient productivity per month by mantangan plants in BBSNP is presented in **Table 4** below.

Table 4. Productivity of mantangan nutrients in BBSNP on various canopy cover classes

No.	Canopy cover class	Biomass ($kg.ha^{-1}.month^{-1}$)	Nutrient productivity/month ($kg.month^{-1}$)			
			N (kg)	P(kg)	K (kg)	C-organic (kg)
1	Sparse	192	2.46	34.54	4.10	105.3
2	Medium	188	3.21	43.60	4.47	100.2
3	Dense	179	2.22	13.68	3.58	95.87

Water is essential for plant growth as a nutrient, nutrient solvent, and part of plant cells (Firmansyah et al. 2018). As a type of plant with high-speed growth, Mantangan requires an ample supply of water and nutrients. This result is in line with a report by Master (2012) that mantangan in the forest areas that are invaded prefer locations with a higher nutrient content than areas that are less/not invaded.

Based on the measurement results of several parameters where it grows, the TNBBS area is highly vulnerable to disturbance by mantangan as an invasive species. This result indicated the parameters of the site quality in BBSNP, especially at the Pemerihan Resort, which is very suitable for the growth and reproduction of mantangan. Pemerihan Resort TNBBS has an average temperature of 27°C with an average light intensity of 76.24 lux. These conditions are ideal for the growth of most lianas; where Mukti et al. (2016) stated that lianas generally live in the site where the air temperature ranges from 15–32°C, pH ranges from 5.6–7, humidity ranges from 70–80%, and light intensity ranges from 70–1,500 lux.

4. Conclusions

The content and productivity of mantangan biomass differed for each canopy cover class in the Bukit Barisan Selatan National Park area. The lower the canopy cover indicates the higher the intensity of sunlight received by mantangan. This condition impacts the content and productivity of mantangan biomass, which tends to be higher. However, it does not occur in the macronutrient content (N, P, and K). The mantangan tissue grown in the medium canopy cover had a higher macronutrient content than the two other canopy covers. Meanwhile, the C-organic content of mantangan tissue grown in the three canopy cover classes showed no significant difference. The productivity of macronutrients from the medium canopy cover class was higher than the other two classes. Meanwhile, C-organic productivity in the sparse canopy cover class was higher than in the other two.

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