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The influence of edaphic factors on bamboo population in Mount Baung Nature Tourism Park, Pasuruan, East Java, Indonesia

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Abstract. *Sofiah S, Setiadi D, Widyatmoko D. 2018. The influence of edaphic factors on bamboo population in Mount Baung Natur Tourism Park, Pasuruan, East Java. Trop Drylands 2: 12-17.* There are 1250 bamboo species in the world with 161 of them are in Indonesia. Mount Baung Natural Tourist Park (MBNTP) is an important bamboo habitat in East Java. The purpose of this research was to study the influence of edaphic factors on the occurrence of bamboo. This research was carried out from September 2011 to May 2012. The principal component analysis (PCA) was performed to determine the relationships between edaphic components and bamboo occurrences. Six species of bamboo were found in MBNTP, namely, *Bambusa blumeana*, *Bambusa vulgaris*, *Dendrocalamus asper*, *Schizostachyum iraten*, *Gigantochloa atter,* and *Gigantochloa apus*. The edaphic factors affected the presence of bamboo in MBNTP. Phosphor (P) contributed significantly to *B. blumeana, B. vulgaris*, *D. asper*, and *S. iraten* presence in MBNTP. These bamboos grow in soil with high P levels of up to 27 ppm. The existence of *G. apus* was influenced by Manganese (Mn) and Sodium (Na) elements. This bamboo in this area was more commonly found in soil environments with low levels of Na (< 0.02 (cmol (+) kg^{-1})) and Mn (≤ 24 ppm). *G. apus* and *G. atter* populations were affected by solar radiation. The species of bamboo with the densest population in Mount Baung, namely *B. blumeana,* was influenced by environmental factors, i.e., the slope. The results of this study imply that each bamboo species has specific environmental factor(s) that affect its presence.

Keywords: Bamboo, edaphic, Mount Baung

INTRODUCTION

Bamboo is one of the high-value plants in Indonesia because it has a high diversity and a range of usability in the country. There are about 1250 species of bamboo in the world and Indonesia has 161 species that belong to 21 genera (Widjaja 1997). Bamboo has many benefits and utilities for human life (Dransfield and Widjaja 1995) and so many materials are produced from bamboo. Almost all parts of the bamboo can be used, from the roots to the leaves.

Bamboo also plays essential role in delivering ecosystem services particularly for soil and water conservation (Zhou et al. 2005). No wonder if this plant is often found along streams (riparian) and springs. The biological characteristics of bamboo make it a perfect tool for solving many environmental problems such as erosion control and CO_2 sequestration. Bamboo has rhizome-root system, wide and thick leaf litter, which enable them to mitigate erosion, with widespread roots that can absorb and store more water in the soil. Type of root in bamboo, the fibrous root, also makes the bamboo can bind the soil well. Based on the previous observations, it was known that bamboo is capable of holding up to 84.63% of rainfall. Sikumbang (2010) stated that compared to trees that absorb only 35-40% of rainwater, bamboo absorbs more rainwater of up to 90%.

Despite the great importance of bamboo, various human activities such as forest clearance, road and housing construction, agricultural activities affect the biogeographical distribution and population of bamboo (Holtum 1985). Several sources of information and studies suggest that certain bamboo species are rare in Indonesia. However, the species of bamboo in Indonesia are not listed in the International Union for the Conservation of Nature and Natural Resources (IUCN). Therefore, it is essential to study the ecology of Indonesian bamboo species, given that bamboo is often used by the community.

Distribution of endemic bamboo in Java Island is unique because some species are limitedly found in certain parts of the island (Widjaja 1987). In East Java, Indonesia, Mount Baung Nature Tourism Park (*Taman Wisata Alam Gunung Baung*/MBNTP) is considered an important habitat of bamboo on Java. Results of an inventory work by the Indonesian Ministry of Forestry (1998) showed that there were six species of bamboo in MBNTP, including *Bambusa blumeana*, *B. vulgaris*, *Dendrocalamus asper*, *Schizostachyum iraten*, *Gigantochloa atter* and *Gigantochloa apus*.

Studies indicating the effect of soil factors on plant populations are still rare. Widyatmoko (2006) said that edaphic variables are important determinants of the abundance and distribution of palm lipstick (*Chyrtostachys renda*). The C/N ratio of soils appears to influence the palm densities and sizes. The relationships between plant communities and environmental factors are among the most fundamental questions contributing to understanding plant species composition and structure in a particular habitat, landscape, and region, as well as understanding the ecological character of plants in their environment (Zhang et al. 2013). About a century back, Brandis (1899) rightly stated that "each species has its particularities and its requirements." In this regard, studies on the effect of edaphic factors on the growth of bamboo population are still insufficient. This research aimed to study the influence of edaphic factors on bamboo's growth in Mount Baung Nature Tourism Park, East Java, Indonesia.

MATERIALS AND METHODS

Study area

This study was conducted in Mount Baung Nature Tourism Park, East Java, Indonesia (Figure 1). Geographically, MBNTP is located between 7°49'9"-7°47'23" South Latitude and 112°16'23"-112°17'17" East Longitude. The altitude in this area ranges from 200-501 m above sea level. The average annual rainfall was 2654.10 mm, with an average number of rainy days was 141.05 days.

Vegetation sampling of bamboo

The abundances and densities of bamboo were expressed as importance value index, namely the resultant of the sum of Relative Density, Relative Frequency, and Relative Abundance. Two hundred plots of different sizes were made; 20 m x 20 m plots for trees, 40 m x 5 m plots for saplings, and 5 m x 5m plots for understory. Category of trees and saplings were determined by the size of diameter at breast height (DBH) of woody plants; tree (DBH > 30 cm) and saplings (DBH 5-30 cm). An understory plant is groundcover plant growing on the forest floor which is typically herbs. The observation of bamboo was done to explain the bamboo in the context of the individual that forms the population. Measurement or observation activities undertaken included the number of clumps that were carried out on individual plant and diameter of the bamboo clump.

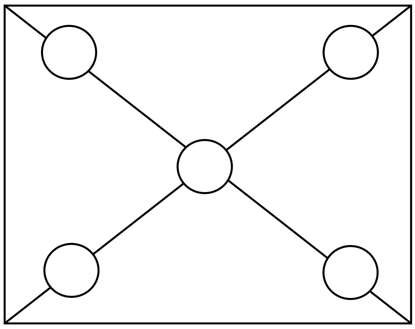

Figure 2. Map of soil sampling points at the research site

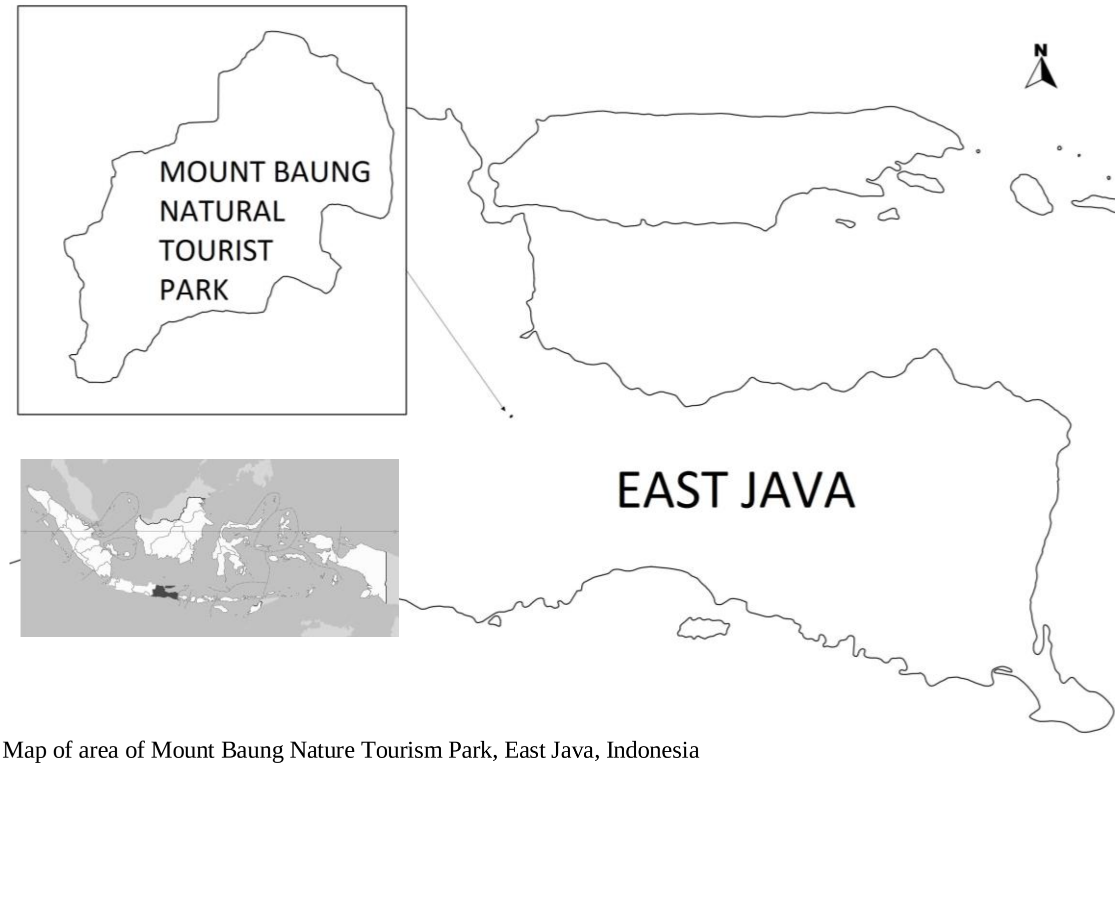

Figure 1. Map of area of Mount Baung Nature Tourism Park, East Java, Indonesia

Soil sampling

Soil sampling was conducted at five points in the form of a diagonal; soil sample from each point was then ground as a composite. Soil samples for analysis of soil physical and chemical properties were taken from the topsoil layer (0-30 cm) and subsoil layers (30-60 cm). The soil physicochemical properties were assessed in the soil science laboratory of Research Center for Soil and Agroclimate, Bogor and were analyzed through the drying stage temperature of 105°C. Soil physical property analyzed included soil texture (sand, silt, and clay), while the chemical properties included Potassium (K), Calcium (Ca), Magnesium (Mg), Sodium (Na), Soil-Cation Exchanges Capacity (CEC), Aluminum (Al), Forums (Fe), Manganese (Mn) and Zinc (Zn). Soil texture analysis was conducted by separation of sand, silt, and clay particles by a quantitative method through the mechanical analysis process. This process consisted of spreading the aggregated soil into single grains, followed by sedimentation. Soil acidity (pH) was measured in soil and water mixture extracts with a ratio of 1: 5, C content was analyzed by Walkley & Black method, while total N was determined by the Kjeldahl method.

Data analysis

The relationship between bamboo and edaphic factor was analyzed using Principal Component Analysis (PCA). The PCA analysis was performed using Minitab 14.

RESULTS AND DISCUSSION

Soil chemical property

The results of soil chemical property analysis are presented in Figure 3. Figure 3 shows bamboo populations were found in soil conditions with soil acidity (pH) ranging from 5.6 to 6.5. This data showed that bamboo could grow on soil conditions with pH levels slightly acidic (Hardjowigeno 2003). The C-organic content of the research area varied from 0.83 to 1.76% which fell into the low category, while soil nitrogen ranged from 0.07-0.18% which was also classified into the low category. C/N ratio was 9-12. According to Tisdale et al. (1993), C/N ratio of <20 indicates that the decomposition process is imminent. The cation exchange capacity (CEC) shows the soil's ability to bind, and exchange between the cation elements controls the availability of several nutrients in cation form and regulates the mobilization of hydrogen ions (pH actual) and Al-dd (potential pH). The content of CEC in the research area was between 10.90-18.52 cmol kg^{-1} which was classified in the medium category. The Ca, Mg, K and Na values in this area were, respectively. 12.40%, 4.66%, 1.23%, 0.09%. Even for potassium was very high.

Soil physical property (texture)

Soil texture was the only soil physical property observed in the present study (Table 1). Table 1 shows soil texture in MBNTP. The study results of soil physical property of soil samples taken from the Gunung Baung area indicate that the average soil texture class belongs to silty clay loam. This soil texture contains more dust, but also a considerable amount of clay content, while the sand content is minimal.

Results of PCA analysis

The Principal Component Analysis (PCA) results on the observed parameters are presented in Figure 4. This figure shows that there were two groups of soil factors that naturally affected the growth of bamboo. The first factor is soil chemical elements such as Al, Ca, Mg, Zn, pH, and Mn which affected the growth of *G. apus*, and especially the Na. The second group of soil chemical element consists of CEC, phosphorus, K_2O, K-Morgan, while the most naturally occurring effect on the growth of some bamboo are: phosphorus. *G. atter* was not affected by any soil chemical properties.

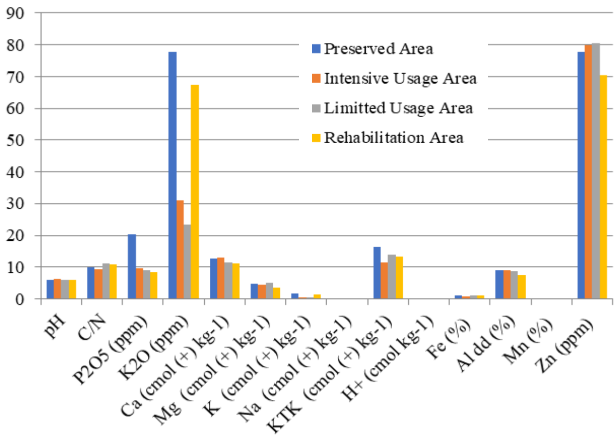

Figure 3. Soil chemical properties of the research area

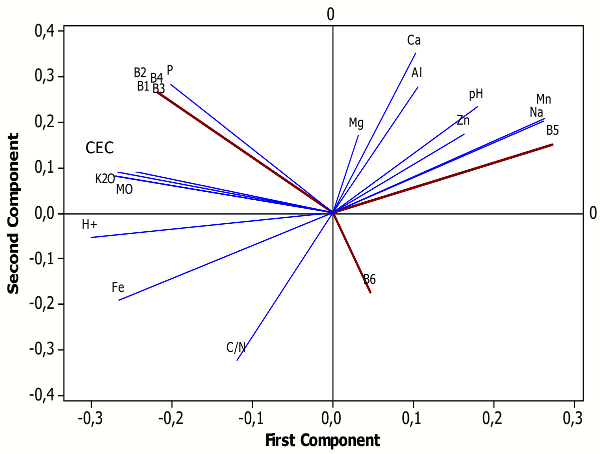

Figure 4. Results of Principal Component Analysis (PCA) of soil chemical properties on bamboos habitat in Mount Baung Nature Tourism Park. Soil chemical properties included soil acidity (pH), Phosphorus (P), C/N ratio, Potassium (K_2O), Potassium-K_2O Morgan (MO), Calcium (Ca), Sodium (Na), Cation Exchange Capacity (CEC), Hydrogen (H^+), Aluminum (Al), Manganese (Mn) and Zinc (Zn). Biotic environmental factors included the number of bamboo clumps: B1 (*B. blumeana*), B2 (*B. vulgaris*), B3 (*D. asper*), B4 (*S. iraten*), B5 (*G. apus*), and B6 (*G. atter*)

Table 1. Soil texture characteristics in MBNTP

Research area (replicates)	Soil layer (cm)	Sand (%)	Silt (%)	Clay (%)	Soil texture
Preserved area	0-30	14	51	35	Silty clay loam
Preserved area	30-60	13	59	28	Silty clay loam fine
Preserved area	0-30	12	51	37	Silty clay loam
Preserved area	30-60	12	47	41	Silty clay loam
Preserved area	0-30	8	61	31	Silty clay loam
Preserved area	30-60	8	67	25	Silty clay loam fine
Intensive usage area	0-30	16	52	32	Silty clay loam
Intensive Usage area	30-60	15	51	34	Silty clay loam
Limited usage area	0-30	7	49	44	Silty clay
Limited usage area	30-60	5	53	42	Silty clay loam
Rehabilitation area	0-30	12	58	30	Silty clay loam
Rehabilitation area	30-60	18	52	30	Silty clay loam

Table 2. The abiotic characteristics of bamboo habitat in MBNTP

Species of bamboo	Slope	Soil pH	Temp.	Solar radiation	Humidity	Altitude
B. blumeana	√					√
B. vulgaris					√	
D. asper			√			
S. iraten		√				
G. atter				√		
G. apus				√		

Abiotic characteristics

Characteristics of abiotic factors influencing bamboo growth are presented in Table 2. Data in Table 2 shows several variations of abiotic factors that affect bamboo species in MBNTP. Each bamboo has its own uniqueness in its growth. *B. blumeana was* affected by slope and altitude while *B. vulgaris* was affected by humidity, and *D. asper* was more affected by air temperature. *B. blumeana* and *B. vulgaris* have locally adapted to sloping/hilly terrain areas. The growing conditions of *D. asper* and *S. iraten* were on a slight slant. Gigantochloa genus, i.e., *G. apus* and *G. atter* are in place to grow in fall within the ramps criteria.

Discussion

Data in Figure 3 shows that the bamboo grew in the conditions of land with soil acidity (pH) ranging from 5.6 to 6.5, indicating that this plant can grow in soil with a slightly acid condition (Hardjowigeno 2003). In general, bamboo survives in a variety of soil conditions with a high degree of adaptability, which is indicated by the spread of bamboo, either naturally or intentionally planted, that can be found in flat areas, valleys, hills, and plateaus except for dessert and swamp areas (Pratiwi 2006). The soil pH is assessed either in water: soil mixture (pH H_2O) or in other electrolytes with different ionic strength, like $CaCl_2$ (pH $CaCl_2$) or KCl (pH KCl) (Gavriloiei, 2012). Based on the content of pH (KCl), the soil in MBNTP has a clay content dominated by the negative-colloidal charge. Due to the result of the reduction (ΔH) values against pH KCl and pH H_2O has a positive relationship, it can be concluded that the soil colloids charge is dominated by the negative charge, meaning that the soil has a high sequestering power of elements in soil, especially cations, so the absorption of soil nutrient can be adequate.

Values of C/N ratio in MBNTP ranged from 9-12, which was classified in a medium category. According to Tisdale et al. (1993), the C/N value of < 20 indicates the decomposition process to occur. It is also influenced by the nature of the soil colloids and cations sequestered in the soil. The organic matter quality is related to the provision of N, which is determined by the number of high nitrogen content, low lignin, and polyphenol concentrations. C/N ratio is an indicator to describe the speed of the reform process in the form of organic matter decomposition and mineralization of nutrients that are chemically bound in the form of complex compounds in the body of an organism. Bamboo is a plant species that have high silicate content in leaves as compared to other plant species (Lu et al. 2007); thus decomposition and mineralization of organic matter in this plant species are running very slow.

For Poaceae species, phosphorus is required for the elongation of segment and the development of stem diameter. Moreover, it can strengthen the stem so as not to fall down easily. Figure 3 shows that phosphorus content in the Preserved Area of MBNTP was the highest. In Preserved Area, soil phosphorus content was included in a medium category with an average value of 20.33 ppm, while that in other areas was classified in a low category. The P element in the soil is bound in the form of a phosphate compound, a readily available compound for plants. P, N, and K elements are classified as the primary element, but the P element is absorbed in small amounts as compared to the other two elements (N and K). *D. asper* is a bamboo species with a large stick character. Therefore, this species would require large amounts of phosphorus for its growth. Figure 4 shows that *G. atter* did not have the variety of data variation (indicated by a line on the short axis), so it is not enough to provide information about the chemical elements that are most influencing this bamboo species growth.

Tiongco (1997) said that positive logarithmic relationships occurred between the culm/biomass production and culm height/soil pH/available P/exchangeable cations (K+, Ca++, Mg++)/CEC. The content of each of Ca, Mg, K and Na in the area of Mount Baung was respectively, 12.40%, 4.66%, 1.23%, and

0.09%, which were classified in high category. Soil base cations are closely related to soil pH. Generally, the soil with high pH has high alkaline content. In MBNTP, although soil acidity was close to neutral, the content of base saturation was very high. The presence of soil pH content that was acidic could have come from the slow decomposition of bamboo litter so that when they are exposed to water, they will experience decay that is also running slowly. The high content of silicates in bamboo leaves causes the litter to decompose slowly so that the reshuffle of cellulose from bamboo litter leaves is also running slowly. Thus, this litter can cover the ground for a long time.

Results of Principal Component Analysis performed on 15 essential macronutrients showed that the soil chemical properties of the growing environment of bamboo can be grouped into two main components (Figure 4). Eigenvalues of > 1 indicate this. The two components can explain about 81.4% (i.e. 46.8% by the first component and 34.6% by the second component) of all variability in soil elements observed in the present study. Relatively, the first component had greater information than the second component, although the two components were not substantially different. Based on the analysis of the above components, the followings are the eigenvalue of each component.

Eigenvalues of Bamboo Habitat Index are as follows: PC1 = 0.17 pH- 0.12 C/N-0.2 phosphorus-0.27 Molibdenum + 0.11 Calsium + 0.04 Magnesium-0.27 Pottasium + 0.27 Natrium-0.28 CEC-0.26 Manganese + 0.17 Zinc-0.22 Clumps of *B. blumeana*-0.22 clumps of *B. vulgaris*-0.22 clumps of *D. asper*-0.22 clumps of *S. iraten* + 0.27 *G. apus* + 0.05 clumps of *G. atter*. PC2 = 0.23 pH-0.32 C/N + 0.29 phosphorus + 0.09 Pottasium + 0.08 Molibdenum + 0.35 Calsium + 0.21 Natrium + 0.11 CEC-0.05 hidrogen-0.19 Zinc + 0.28 Alumunium + 0.21 Manganese + 0.18 Zinc + 0.27 clumps of *B. blumeana* + 0.27 clumps of *B. vulgaris* + 0.27 clumps of *D. asper* + 0.27 clumps of *S. iraten* + 0.15 clumps of *G. apus*-0.17 clumps of *G. atter*.

Nonetheless, based on Figure 4, the phosphorus element is an element that was strongly influenced the bamboo habitat, especially for almost all species of bamboo, except *G. apus* which was very strongly affected by the elements such as sodium (Na) and manganese (Mn). Manganese is microelement, which is taken little in plant growth, but it is essential. The effect of phosphorus on the presence of bamboo in MBTNP was highly significant and positive.

Bamboos are planted for hedges and landscaping. Bamboo groves also act as a windbreaker and to prevent soil erosion (Alam 1992). Generally, bamboo growth is affected by temperature (Uchimura 1981) and altitude. Some bamboo is affected by light intensity; however, sometimes the soil factors influence more specific for some particular types of bamboo. Uchimura (1981) said that growth of bamboo was highly correlated with temperature when it overlapped by an annual rainfall of more than 1000 mm $year^{-1}$. For information, *G. atroviolaceae* can intercept rainwater approximately 84.63% (Sofiah 2011). Additionally, Sikumbang (2010) mentioned that compared to trees that absorb only 35-40% of rainwater, bamboo could absorb rainwater up to 90%. Plant canopy layer that fills the room stems dimensions will be an essential factor in determining microclimate/local bamboo plants. It is important to note that area of leaf blade also affects the amount of interception of rainwater through rain run-off detention.

Bamboos are plants that display rapid biomass growth after long periods of exclusively vegetative growth (Griscom and Ashton 2003), culminating in explosive flowering followed by widespread population death. The size of new culm was determined by the nutrient supply from the rhizome (Ueda 1960). The agronomy/silvicultural trials were conducted on four bamboo species. Four bamboo species responded differently to treatment not only because of their genetic traits but also because of their relative ages. The mature *D. asper* (giant bamboo) produced few shoots, on average c. 1 stalk per standing culm, but they were large if harvested for consumption (reaching 4.5 kg). In contrast, the young (3-7 years old during the trial) *B. blumeana* at the Capiz site produced very few stalks, although the poor soil or some other factors may have had an overriding effect, as average shoot number per clump did not increase during the 5-year course of the experiment (Midmore 2009).

The influence of slope on soil, especially in soil texture, partly determines the levels of available mineral nutrients, and consequently the establishment and spatial distribution of vegetation (Widyatmoko 2010). Based on Table 1, the pattern of bamboo population distribution in MNBTBP was influenced by environmental factors. The slope more specifically determined the dominant species of bamboo in the region, namely *B. blumeana*. Soils on slopping areas tended to be coarser and better drained than those on flat ground where run-off creates accumulations of small soil particles (House 1984; Kessler 2000; Costa et al. 2008). Several studies have shown that soil factors influenced the floristic plant in bamboo-dominated forests. Significant intercorrelations were found between Ca, Mg and organic matter for eleven species of *S. agittaria* (Wooten 1986). Salinity was the most crucial edaphic factor for the distribution and density of *C. americanum,* and the higher its value, the higher its population density. The other elements analyzed seemed to have little or no influence over the population density of *C. americanum*. The analysis did not highlight any edaphic factor as the determinant factor for the height of the individuals of this species in the Massaguacu River estuary (Ribeiro 2011). Meanwhile, the texture of soil in the average research area was silty clay loam (Table 2). This texture soil shows the proportion of soil particle content that contains more dust, but also a considerable amount of clay content, while the sand content is minimal. Based on the analysis, the soil base saturation of the entire area of MNBTBP was of high value. The high value of soil base saturation content is thought to be related to soil texture properties, where, in silty clay loam type, soil colloids are readily bonded within the soil tracking complex, due to adhesion and cohesion between the cations in the soil.

Edaphic constraints may play a role in the floristic of bamboo-dominated forests by shifting the competitive balance in favor of tree species tolerant of excessive moisture and/or drought or of other characteristics of soils occurring in bamboo-dominated soils, such as reduced soil cations exchange capacity (Griscom 2003). Forest is highly dynamic and its structure and composition change in time and space. Bamboo dominance could be foreseen as a step in this process (Vinha 2011). Studies investigating these topics, as well as the effect of different bamboo species dominance on the abundance and survival of tree species, are of prime importance for understanding the impact of other bamboo species on tropical forest regeneration and the implications for forest management. Further research on ecophysiological characteristics of species regarding edaphic constraints, shade tolerance, growth rate, and traits affecting tolerance for mass-loading is needed to improve our understanding of the bamboo-dominated plant community.

Bamboo is one of the plant species that have high adaptability. Based on research results, one of the edaphic factors that influenced the growing environment of *B. blumeana*, *B. vulgaris*, *D. asper* and *S. iraten* species was the phosphorus element. The phosphorus element affects the existence of bamboo as it plays a vital role in growth activity. Phosphorus can strengthen the culm so as not to fall easily, which is vital for Poaceae family. The presence of *G. apus* was influenced by Manganese (Mn) and Sodium (Na) elements. In soil, manganese dissolves at low soil pH. The higher the soil pH, the solubility of manganese in the soil decreases. The slightly acid soil-pH in Mount Baung Nature Tourism Park may be one factor leading to the high solubility of manganese in the soil. Bamboo species with the densest population in Mount Baung, i.e., *B. Blumeana,* was influenced by environmental factors such as slope. Each bamboo has its uniqueness in its growth. Growths of *G. apus* and *G. atter* were affected by solar radiation.

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