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Vegetation Stratification in Semarang Coastal Area

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Abstract

The coastal region is a dynamic area as a transition between the land and the sea. The ecological function of the coastal area is affected mainly by the structure and composition of vegetation factors. This study aims to analyze the vegetation stratification of terrestrial to marine ecosystems in the coastal area of Semarang City, Central Java Indonesia as an effort to manage a sustainable ecosystem. A striped path combined with nested plots were applied in this research. The plots were placed by systematic purposive sampling based on the homogeneity of vegetation found along with the topographic conditions of the research location. Analysis of qualitative data used by way of inventorying plants and identifying plants based on morphological characteristics that can be observed. Data analysis was performed based on the results of an inventory of the structure and composition of vegetation obtained including the index of diversity, evenness, and species richness. The results of plant identification found in the three locations recorded 51 plant species consisting of 29 families. The different types of vegetation in Taman Lele, Tapak, and Tirang Beach affect the diversity, richness, and evenness index of vegetation in all three locations. Therefore, it can be concluded that different environmental factors contribute to the vegetation stratification from the land to the sea. This is the first report on the Semarang coastal area vegetation stratification. The results can have a positive impact on the coastal area conservation strategy for sustainable management, as well as to be a media for environmental education purpose.

How to Cite

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INTRODUCTION

The coastal area as a transition between the land and the sea has the unique and dynamic characteristics including the high biodiversity. Semarang City is the capital city of Central Java Province, Indonesia with 373.70 km^2 in width and coastal line length at approximately 36.63 km (Statistical Bureau of Semarang, 2017). There are four sub-districts in Semarang coastal area, i.e., Tugu, West Semarang, North Semarang, and Genuk. Among that area, the environmental factors are varied such as salinity, pH, temperature, light intensity and soil type, which can affect the structure and composition of the vegetation growing on it.

The vegetation structure elements are in the form of growth, stratification and canopy closure (Hidayat et al., 2017). Stratification is a profile diagram that describes the layers (strata) of trees, poles, stakes, and herbs as compilers of that vegetation (Fachrul, 2007). There is the fact that various environmental factors which are interconnected, combined, and have an interdependence among the factors can affect the structure and composition of vegetation in the particular region, which also influence the ecological function of coastal areas. Vegetation in ecological terms is the whole plant community in a particular place, including both the community mix of the types of its constituent flora and the ground cover (Wijana, 2014).

Semarang coastal area has different vegetation in different environmental conditions. The differences in topography and environmental factors can be observed from Taman Lele (Ngaliyan Sub-District) to Tirang Island in Tugurejo Village, Tugu Sub-District. Taman Lele is a terrestrial ecosystem, while Tapak, Tugurejo is a type of brackish ecosystem, and Tirang Island is a coastal ecosystem to the sea. Those three sites have distinct soil characteristics. Taman Lele has silt soil type, while the type of soil in Tapak is muddy, and Tirang Beach has a sandy soil type. The nature of the soil significantly affects the ability of the soil to support plant life. The existence of different physical properties of the soil will affect the growth and production of plants because it will determine the penetration of roots in the soil, the ability of soil to hold water, drainage, soil aeration and the availability of soil nutrients (Holilullah et al., 2015).

Data and information on vegetation structure and composition are essential as the basis for the use and conservation of biodiversity and other natural resources. Vegetation data is collected not only for scientific purposes, but also for various practical purposes, such as forest products collection, land use, land protection, water management, grazing, and mining. A thorough understanding of vegetation and interactions with the environment allows land use planners to determine the best use of resources in the context of sustainable development (Kartawinata, 2013).

There have been many studies on the diversity of vegetation types in various regions in Indonesia; however, there is information related to vegetation stratification from terrestrial to marine ecosystems in the coastal area of Semarang, Central Java. The scientist has never done the stratification process. Therefore, a study on the vegetation stratification from terrestrial to marine ecosystems in the coastal area of Semarang is necessary to be conducted as an effort to manage a sustainable ecosystem. The purpose of this study is to determine vegetation stratification from terrestrial to marine ecosystems in the coastal area of Semarang sustainable ecosystem management. Thus, it helps the management of coastal area conservation, for example as a guidance for choosing the suitable type of plants in coastal region.

METHODS

Field data in the form of the plant, vegetation types and their environmental factors were taken in Tamam Lele (Ngaliyan Sub-District, Tapak), Tirang Island (Tugu Sub-District), Semarang. The plant identification was carried out in the field and the Laboratory of Plant Taxonomy, Universitas Negeri Semarang, while the analysis of soil items was carried out at the Land Mechanics Laboratory, Civil Engineering, Diponegoro University. The study was conducted in April-October 2018.

Vegetation at the growth stages of herbs, seedlings, saplings, poles, and trees was recorded in the observation plot. Taman Lele area was divided into two observation lines with each observation track consisting of 2 plots. Tapak mangrove area was divided into five stations with 10 sample plots, while Tirang Beach was divided into 6 plots.

A survey was conducted in the initial stage to determine the field conditions. Then, the determination of the location for data retrieval by the method specified. A layered path combined with a nested plot and laying a plot by systematic purposive sampling based on the homogeneity of vegetation found in the field was employed in this study. The three main activities carried out in this

Figure 1. Research location: (a) Taman Lele, (b) Tapak, and (c) Tirang Beach (Source: Google maps, 2018).

study were (a) vegetation inventory; (b) measurement of environmental factors (temperature, air humidity, light intensity, salinity, soil texture, and soil pH); and (c) analysis of vegetation structure and composition data.

The data taken for vegetation analysis were location, type name, growth stage, and the number of individuals. The data was then processed to obtain several parameters as a reference in determining the location conditions. The parameters include species diversity index, evenness index, and species richness index. Each vegetation inventory was based on its growth stage, and it was divided into several squared sizes. The squares were divided based on a) a type of understory consisting of regeneration of trees, grass, herbs, and shrubs; b) seedlings in the form of tree seedlings from sprout to <1.5 m high; c) stake was in the form of saplings with height of ≥1.5 m and diameter <10 cm; and d) the pole was a young tree with a diameter of 10-20 cm. Trees were mature stands with a diameter of ≥20 cm (Wijana, 2014).

The qualitative and quantitative approach was performed to analyze the structure and composition of vegetation from terrestrial to marine ecosystems in the coastal area of Semarang. Analysis of qualitative data was used in the field by way of inventorying plants and identifying plants based on the observable morphological characteristics. Identification of plant species names was carried out directly with field guides and identification keys from families to species level. While literature studies performed the identification of local names of plants, methods of interviewing managers or communities that have been considered experts.

Analysis of quantitative data from the results of the inventory of structure and composition of vegetation obtained included: Shannon-Wiener Diversity Index, Equity Type Index, and Type Richness Index.

RESULTS AND DISCUSSION

The results of plant identification obtained in three research locations (Taman Lele, Tapak, and Tirang Beach) indicate that 51 plant species consisting of 29 families (Table 1) were found. The vegetation data can be used to determine the vegetation stratification of terrestrial to sea ecosystems in the coastal area of Semarang City to manage a sustainable ecosystem.

The results of diversity, evenness, and richness of vegetation in three research sites are presented in Table 2.

Table 2. Recapitulation of diversity, evenness, and richness of vegetation in Taman Lele, Tapak, dan Tirang Beach

Index	Taman Lele	Tapak	Tirang Beach
H’	2.355	0.792	2.184
E	0.85	0.411	0.825
R	3.27	0.999	3.007

Keterangan:

H’ = Species diversity index

E = Species evenness index

R = Species richness index

Table 1. Floristic vegetation of Taman Lele, Tapak, and Tirang Beach

Lele Park	Tapak	Tirang Beach
Microcos paniculata	*Avicennia marina****	*Avicennia marina****
Arenga pinnata	*Rhizophora mucronata****	*Rhizophora mucronata****
Caesalpinia pulcherrima	*Rhizophora stylosa****	*Rhizophora stylosa****
Moringa oleifera	*Rhizophora apiculata*	*Casuarina junghuhniana*
*Leuchaena glauca**	*Bruguiera gymnorrhiza*	*Terminalia catappa**
Sweitenia mahagoni	*Excoecaria agallocha*	*Hibiscus tiliaceus***
Pterocarpus indicus	*Xylocarpus moluccensis*	*Leuchaena glauca**
*Terminalia catappa**	*Morinda citrifolia*	*Clerodendrum inerme****
Pometia pinnata	*Cerbera manghas*	*Phempis acidula*
Hibiscus-rosa sinensis	*Leuchaena glauca**	*Wedelia biflora****
Sauropus androgynus	*Terminalia catappa**	*Ipomoea pes-caprae****
*Hibiscus tiliaceus***	*Cyperus pilosus*	*Canavalia maritima*
Dracaena sp.	*Ipomoea pes-caprae****	*Spinifex littoreus*
Cyathula prostata	*Pluchea indica****	*Fimbristylis cymosa*
Asystasia gangetica	*Clerodendrum inerme****	*Panicum repens*
Brachiaria reptans	*Wedelia biflora****	*Agrostis capillaris*
Peristrophe hyssopifolia		*Issachne pulchella*
Lantana camara		*Pluchea indica****
*Bidens pilosa***		*Calotropis gigantea*
Aglaonema crispum		*Bidens pilosa***
Althernanthera brasiliana		*Imperata cylindrica*
Commelina diffusa		*Sesuvium portulacastum*
Costus speciosus		*Chloris barbata*
Euphorbia tithymaloides		
Chromolaena odorata		

Description:

*	=	Vegetation similarity in Taman Lele, Tapak, and Tirang Beach
**	=	Vegetation similarity in Taman Lele and Tirang Beach
***	=	Vegetation similarity inTapak and Tirang Beach

Vegetation in Taman Lele showed 25 species consisting of 19 families (Table 1). Wijana (2014) reported that the species diversity including species evenness and richness in a community with a particular index in each component. If both components have similar or same index value, then the species evenness and richness that determines the diversity index have the same or balanced contribution.

The results of species diversity analysis showed that the diversity index of vegetation in Taman Lele was in the moderate category (1 <H '<3), with H' = 2.38, the richness index (R) of Taman Lele vegetation was 3.28. The richness index of the medium category (2.5> R> 4). Species evenness index (E) vegetation in Taman Lele was 0.85 (Table 2). Factors influencing the high and low diversity of vegetation in Taman Lele are habitat conditions such as microclimates and also natural disturbances or due to human activities (Table 3).

The successful vegetation growth cannot be separated from environmental factors where the vegetation grows. For example, the results of temperature measurement in three different research sites showed varied results. The lowest air temperature was in Taman Lele at 29 °C. Temperature is an essential factor for plants because temperature determines the speed of reactions and chemical activities in the life process. Temperature is also a climate factor that contributes to the existence of vegetation because the tem-

Table 3. Environmental factors of Taman Lele, Tapak, and Tirang Beach

Environmental Parameters	Taman Lele	Tapak	Tirang Beach
Temperature (°C)	29	32	38
Light intensity (lux)	540	612	765
Humidity (%)	66	62	59
Salinity (‰)	0	7	18
pH	6.4	6.2	7.2
Gravel (%)	0.59	0.37	0.19
Rough sand (%)	9.16	6.14	27.06
Fine sand (%)	29..69	50.05	70.05
Silt (%)	93.58	44.9	2.79
Clay (%)	16.5	23.6	0
Substrate type	Silt	Muddy	Sandy

perature influences the metabolic process (Nursal et al., 2013). The low temperature in Taman Lele is related to the vegetation form that is dominated by dense trees with canopies. The existence of these vegetation plays an important role in determining of microclimate in the ecosystem (Hilwan et al., 2013). Based on research by Evert et al. (2017), each tree density of 1 tree/ha can reduce the temperature by 0.000989 °C.

Taman Lele protected area is located on the hill with silt soil and with a salinity of 0 ‰. Due to the presence of canopies of large and tall plants, the light intensity in the area was smaller (540 lux) (Figure 3), compared to Tapak (612 lux) and Tirang (765 lux). Vegetation in the form of trees and shrubs grows most dominating in the protected forest of Taman Lele.

Figure 3. Vegetation structure in Taman Lele

The results of vegetation identification in Tapak, Tugurejo area showed that 16 plant species consisting of 12 families (Table 2). Mangrove vegetation showed species diversity index (H') at 0.79 (Table 2). Most of the mangroves found in Tapak were planted in aquaculture areas; only a few locations were found as natural mangroves. The research result revealed that the diversity of mangrove species in Tapak was moderate because it was influenced by human intervention; for example, they planted mangroves for rehabilitation of this area. Therefore the types and numbers of mangroves found were not too diverse (Martuti et al., 2018). The richness index of the mangrove species found in Tapak was 0.999 (Table 2). Based on the Margalef criteria for the type of richness showed that the mangrove species richness in Tapak was low (R <2.5). However, the presence of mangrove ecosystems in Tapak has an important role in absorbing CO_2 as can be observed from the amount of biomass and carbon stock stored (Martuti et al., 2017).

The temperature range at ± 32 °C in Tapak, Tugurejo showed a supportive environment for mangrove growth. According to Hastuti et al. (2012), temperature is one of the critical factors that influence the growth of mangrove seedlings. Each type of mangrove has a tolerance limit that varies to the temperature of the environment. For instance, *Rhizophora* has a maximum temperature tolerance limit of 38 °C (Numbere & Camilo, 2017). The adaptive mechanism of mangrove species such as wax layers, hair, and regulation of stomata on the leaves can avoid excessive water loss due to transpiration process (Noor et al., 2015). Besides the temperature factor, salinity is also an important factor for mangrove growth in Tapak area with a moderate level (brackish water) with an average salinity of 7 ‰ (Table 3). As stated by Nthunya et al. (2018), fresh water has a salinity of 0-0.5 ‰, brackish water has a salinity of 0.5-17 ‰, and seawater has a salinity of more than 17 ‰. According to Hastuti et al. (2012), the most crucial factor for the development of mangroves is salinity in case of *Avicennia* species growth have a positive correlation, as indicated by the increase in salinity which can stimulate its growth. Proper salinity for Avicennia growth is 5-30 ‰.

The vegetation evenness index in Tapak showed a value of 0.411 (Table 2). The low evenness index of the mangrove species indicated the symptoms of dominance, the concentration of communities by certain types of plants. It is by the results of the analysis of the structure and composition of mangrove vegetation in Tapak (Table 1) which showed that R. mucronata and A. marina species dominated *Tapa*k mangrove *forest ar*eas. According to Amaliyah et al. (2018), *Rhizophora* has been planted, and it is the dominant type of mangrove in coastal forest area and also is widely planted in coastal area rehabilitation programs (Figure 4).

Figure 4. Tapak mangrove area

According to Noor et al. (2008), mangroves generally grow in four zones, i.e., open area, central area, brackish water to almost river area, and land freshwater area. The condition of the substrate is one of the factors that play a role in the formation of mangrove zonation (Muzaki et al., 2012). It is by the opinion of Hossain & Nuruddin (2016), zoning is closely related to soil type, salinity, and tidal influences. The presence of physicochemical properties of the soil can significantly affect ecophysiology, species composition, and mangrove forest structure.

The zoning pattern of mangroves in the Tapak, Tugurejo can be seen in Figure 5. The front zone, the zone closest to the sea, is dominated by mangrove species which have pneumatophores, i.e., *Avicennia*, then behind them are zones of *Rhizophora, Xylocarpus, Excoecaria, Bruguiera*, and mangroves association. It is by the study of Martuti (2013), where the ideal zoning for mangroves are : 1) the area closest to the sea is planted with *Avicennia* sp. and *Sonneratia* sp.; 2) the more landward area, it is suitable to be planted with *Rhizophora* sp. and *Xylocarpus* sp.; 3) the next zone is appropriate for *Bruguiera* sp.; and 4) the transition zone between mangrove forest and land near the coast is planted with *Nypa fruticans* and several other palm species.

The frontier zone in Tugurejo Tread has a type of sandy mud substrate, with high salinity, and is always flooded even when it is low tide. The high frequency of flooding and salinity affect the mangrove plants that grow in this zone to have adaptations in the form of breath roots (pneumatophores) to be able to survive. Such conditions make the frontier zone suitable for the growth of *A. marina*. It was supported by Halidah and Kama (2013) who conveyed that *A. marina* and *S. alba* were mangrove species that could be used in the rehabilitation of mangrove forests with nutrient-poor sand substrates, with high salinity and growing conditions that remained exposed to low tide; whereas Irpan et al. (2017) said that *A. marina* was found on a line near the sea with a salinity of 10-34 ‰ with a type of mud substrate to sand.

The second zone behind the *Avicennia* zone is the zone of *Rhizophora* and *Xylocarpus*. This zone consists of *R. mucronata*, *R. stylosa*, *R. apiculata*, and *X. molluccensis*. The condition of the substrate in this zone is muddy with salinity lower than the front zone; this is because in this zone there is a phenomenon of seawater mixing with river water. Therefore, the salinity of the water to drop to brackish. It is by the opinion of Mughofar et al. (2018), Rhizophora species usually dominate the *middle zo*ne and sometimes *Xylocarpus* species are also found. *Rhizophora* and *Xylocarpus* grow better on mud substrates that are rich in organic matter (Muzaki et al., 2012).

The third zone behind the *Rhizophora* and *Xylocarpus* zone is *Excoecaria* and *Bruguiera* zones. This third zone is located towards the mainland, has a rather hard muddy substrate (clay). The measured salinity in this zone is almost the same as the second zone because in this zone it is near the river. Following the opinion of Kaliu (2018), *Bruguiera* usually develops behind *Rhizophora* on the type of dry muddy substrate towards the land. Generally living on the banks of the river to the land that still has enough tidal water.

The backmost zone is occupied by mangrove associations such as *Morinda citrifolia*, *Cerbera manghas, Pluchea indica, Leucaena glauca, Terminalia catappa, Cyperus pilosus*, and *Wedelia biflora*. In this zone, the salinity is very low compared to the previous zones and has a hard soil texture and is less affected by tides. The lower salinity leads to land due to the supply of freshwater from the river, causing differences in the type of mangrove between the zones with one another. It is following the opinion of Annisa et al. (2017), mangrove associations are vegetation that grows inland behind the mangrove zone, less affected by tides, with drier substrate conditions, low salinity fluctuations, and high temperatures. According to Muzaki et al. (2012), the back zone is generally dominated by *Acanthus, Sesuvium*, and various other types of mangrove associations.

The results of identification of vegetation on Tirang Beach found 23 species of plants consisting of 15 families. The diversity index of vegetation on Tirang Beach showed the value of H '= 2.18 (Table 1). Based on the Shannon-Wiener species diversity index criteria, the diversity of vegetation types in Tirang Beach was in the moderate category (1 <H '<3). Unlike in Taman Lele and Tapak, the vegetation on Tirang Beach was dominated by common coastal herbs (Figure 5). Although the diversity index of Tirang Beach was classified as a medium category, the existence of this type of vegetation that forms the coastal forest plays an important role as a "green belt" in coastal areas. It can withstand coastal abrasion from tidal waves, also as a nursery or hatching area of various types of shorebirds and another aquatic biota.

Figure 5. Tirang Island

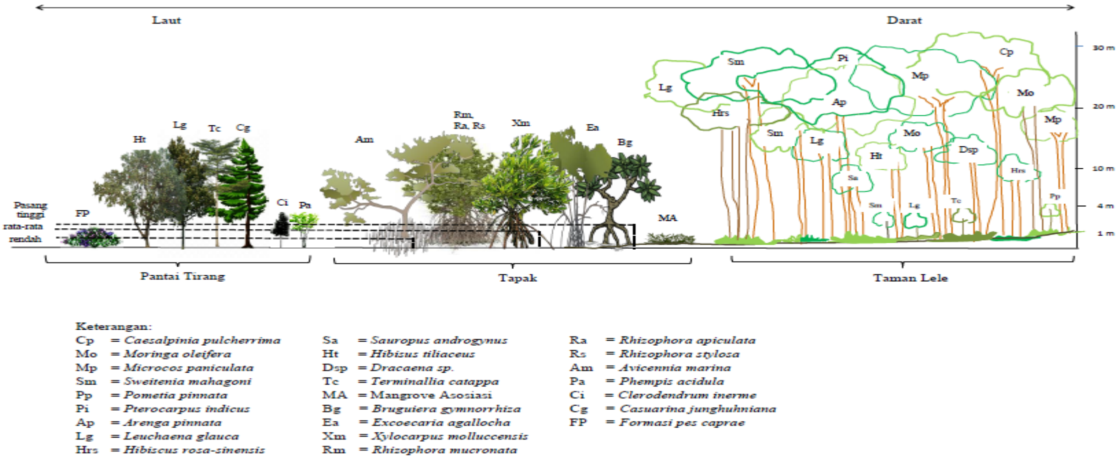
The richness index of vegetation type in Tirang Beach showed the value of R = 3.007, and it was categorized as moderate based on the criteria for the Margallef type richness index (2.5 <R <4). The species evenness index in Tirang Beach showed the value of E = 0.825 (Table 2). Evenness values of low vegetation types indicate the existence of symptoms of the dominance of certain species. Vegetation of Tirang Beach was dominated by herbs which form the formation of *pes-caprae*. The *pes-caprae* formation as shown in Figure 5 was occupied by plants that can grow in high salinity, have the adaptability to dry sand conditions, high wind strength, poor soil nutrient content, and high temperature.

The physical condition of Tirang Beach is mainly influenced by strong winds, high salinity (18 ‰), sea tides, and high air temperature (38 °C), and substrate in the form of sand has high porosity where it is difficult to hold water. Because of such physical conditions, plants that live on sandy beaches can be said to grow in a dry environment (xerophytes). Plants that live in a sandy beach environment are very prone to drought due to high transpiration. Living plants tend to propagate on the sand and take root in their books, as can be seen in *Ipomoea pes-caprae*.

The formation of *pes-caprae* has an important role in the coastal ecosystem as a natural protective coastline against erosion (Martinez et al., 2016). The name of the *pes-caprae* formation is taken from the name of the dominant plant species in the coastal region, namely *I. pes-caprae*. Beside *I. pes-caprae* there are also other plant species found in the *pes-caprae* formation including *Spinifex littoralis, Ischia pulchella, Agrostis capillaris, Fimbristylis cymosa, Wedelia biflora, Panicum repens, Imperata cylindrica, Chloris barbata, Sesuvium portulacastrum, Bidens pilosa,* and *Canavalia maritima*. *Ipomoea pes-caprae* has a stature of herb that spreads and serves as a sand binder and protects the beach from abrasion. *Ipomoea pes-caprae* is an extremophilic halophyte plant with good adaptability to seawater and drought. This plant is widely used in improving coastal areas and tropical islands in the tropics and subtropics (Zheng et al., 2018).

The figure in the following section is the pattern of plant stratification in the coastal area of Semarang City, which shows the pattern of stratification of plants from land (Taman Lele) to the sea area (Tirang Island) (Figure 6).

In contrast to Taman Lele and Tapak, the results of soil analysis using the sieve analysis method showed that Tirang Beach had sandy soil types (Table 3). Sandy soil has a sand content of >70%, porosity <35%, with the low ability to store water and plant nutrients (Pratama et al., 2017). This type of soil is an important factor that influences the physical, chemical and biological properties of the soil, which can affect soil productivity (Tale and Ingole, 2015). The results of this research can contribute as the guidelines for farmer on choosing the appropriate and suitable plants for coastal area conservation management. It can be also a media for educational purposes for teacher, students, and academicians for vegetation stratification technique, especially for coastal plant identification, characterization and classification.



Tirang Beach	Tapak	Taman Lele
Cp : *Caesalpinia pulcherrima*	Sa : *Sauropus androgynus*	Ra : *Rhizophora apiculata*
Mo : *Moringa oleifera*	Ht : *Hibiscus tiliaceus*	Rs : *Rhizophora stylosa*
Mp : *Microcos paniculata*	Dsp : *Dracaena sp*	Am : *Avicennia marina*
Sm : *Swietenia mahagoni*	Tc : *Terminalia catappa*	Pa : *Phempis acidula*
Pp : *Pometia pinnata*	MA : Mangrove Asosiasi	Ci : *Clerodendrum inerme*
Pi : *Pterocarpus indicus*	Bg : *Bruguiera gymnorrhiza*	Cg : *Casuarina junghuhniana*
Ap : *Arenga pinnata*	Ea : *Excoecaria agallocha*	FP : Formasi pes caprae
Lg : *Leuchaena glauca*	Xm : *Xylocarpus moluccensis*	
Hn : *Hibiscus-rosa sinensis*	Rm : *Rhizophora mucronata*	

Figure 5. Vegetation stratification in Semarang coastal area

CONCLUSION

Vegetation from terrestrial to marine ecosystems in the coastal area of Semarang City shows a distinct variety of plants, due to different environmental factors. The results of identification of vegetation in the Taman Lele showed 25 species of plants consisting of 19 families, with the dominance of the *Caesalpinia pulcherrima* tree. Vegetation in Tapak, Tugurejo was dominated by 16 species of plants consisting of 12 families, with the predominance of mangrove species *Avicennia marina* and *Rhizophora mucronata*. While the vegetation found in Tirang Beach was 23 species consisting of 15 families, which were dominated by *Ipomoea pes-caprae.*

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