Structure and Diversity in a Permanent Plot of *Melaleuca* forest in Rayong Botanical Garden, Thailand

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Abstract

Swamp forest is important the ecosystem because it is a habitat for many different types of organisms. Moreover, swamp forests are considered as an important sink for carbon storage. This is particularly important for controlling global warming. In this study we studied the structural and floristic diversity of *Melaleuca* forest over a 5-year period in a hectare the permanent plots at Rayong Botanical Garden, Thailand. Floristic characters included stem density, basal area, species composition, species diversity, and morality rate were compared between 2016 and 2020. The soil samples were systematic random sampling from 20 points in a 100 square meter for chemical analysis of soils. A total of 1,127 individual, belonging to four species were measured. Most plants had DBH more than 100 cm (56%). During the five year-peroid, there was a change Shannon diversity index (H). The species with the highest IVI value are *Melaleuca cajuputi* (294.18=98.06 %). The forest structure consists of a two-story tree layer and the top canopy is 10 meter height or higher with means annual increment about 4.26 % per year. The soil fertility in the permanent plot is relatively low with calcium (Ca^{2+}) as the most concentrated element. The soil was loam, sandy loam mixed with silt loam and is strongly acid soils (pH 5.14). There were about 3% of organic matter content. The mean values of electrical conductivity of soil was (27.76 μs/cm) and cation exchange capacity was (CEC) 2.12 me/soils 100g. Although, the soil fertility is very low but the number of *M. cajuputi* was increased, additional 127 individual were found in 2020. Moreover, the tree basal area had increased from 16.65 to 29.88 cm during five year-period. This demonstrated that *Melaleuca* forest is an important sink of carbon.

Keywords: Structural, Diversity, *Melaleuca* forest, Rayong botanical garden, Swamp forest, *Melaleuca cajuputi*

Introduction

The Botanical Gardens Organization has realized the importance of plants preservation in different regions of the country. Rayong Botanical Garden (RBG) is one of the satellite garden along with the main garden, Queen Sirikit Botanic Garden (QSBG) in Chiang Mai, Thailand. RBG has an area of about 3,800 Rai of wetland. The RBG is one of the national heritages with ancient forest, primary old-growth area of the wetlands. One of the important ecosystems in RYG is *Melaleuca* forest, a forest dominated by *M. cajuputi*. This ecosystem contributes important ecological services such as protecting soil and water; habitat for mammals, birds and fish (Tran & Matusch, 2017).

The genus *Melaleuca* consists of about 260 species and distributed mostly in Southeast Asia to Australia (Tran, Dargusch, Moss, & Hoang, 2013).

In Thailand, only a species, *Melaleuca cajuputi* Powell is a member of the Myrtaceae family (Craven & Barlow, 1999). *Melaleuca cajuputi* is a small to medium sized tree with spreading branches. It is usually about 8-15 m tall and could spread about 5-10 m. However, it could be 25 m tall. This plant is tolerant to strong acid soil. Moreover, its leaves have essential oil which possess antioxidant and antibacterial activities. (Nazeh et al., 2015). Moreover, Melaleuca forests are considered as an important carbon sink that

helps reduce global warming. Plants have the ability to capture atmospheric CO_2, through the process of photosynthesis. The carbon stocks are estimated by multiplying C concentration by biomass (dry weight) (Yeboah, Burton, Storer, & Opuni, 2014).

Forest structure refers to the way in which the attributes of trees (species, sizes) are in the forest (Szmyt, 2016). Trees are sessile, but they are living things that propagate, grow and die. In a forest ecosystem, diversity that determines the heterogeneity within a community of trees, including the diversity of tree sizes. Structure and diversity are important features which characterize a forest ecosystem (Myers & Harms, 2009).

However, there are little researches on the ecology of swamp forest. Hence, the objective of this study was to assess structure and diversity in a permanent plot of *Melaleuca* forest in Rayong Botanical Garden, Thailand. For the conservation and sustainable management, it is essential to evaluate.

Materials and methods

Study areas and permanent plot establishment

The study area is located in Rayong Botanical Garden, in the east coast of Thailand, at the coordinates 12°38′57″ N, 101°32′55″ E. The permanent plots of 100 x 100 m^2 (1 hectare) was established and monitored in 2016 and 2020 (Figure 1).

Figure 1 The *Melaleuca* forest in RBG, comparing the different level of water in rainy season and summer.

Plant Data collection and Analysis

All trees with a circumference at breast height (DBH = 1.3 m from ground level) larger than 14 cm in the permanent plot were identified to the species level. Plant identifications were performed in the field. Plant specimens were collected and deposited in the Herbarium of Queen Sirikit Botanic Garden (QBG). For each tree individual, these data were collected: the circumference at DBH, height (H), height to the lowest living branch (Hb), and the crown radius. The circumference and crown radius were measured by measuring tape while H and Hb were measured by hypsometer (Haglof Vertex IV). Then the ecological indices were calculated by following formulas:

- Ecological Important Value Index (IVI) (Pagare, 2007) : Density = $\frac{\text{Number of a species}}{\text{Total area sampled}}$

Relative density = $\frac{\text{Density of a species}}{\text{Total density of all species}} \times 100$

Frequency = $\frac{\text{Area of plots in which a species occurs}}{\text{Total area sampled}} \times 100$

Relative frequency = $\frac{\text{Frequency of a species}}{\text{Total frequency of all species}} \times 100$

Dominant area = $\frac{\text{Total basal area of a species}}{\text{Total area sampled}}$

Relative dominant = $\frac{\text{Basal of a species}}{\text{Basalarea of all species}} \times 100$

Tree basal area (TBA) (m^2) = 3.142 x $(DBH/200)^2$ Where DBH is the diameter at breast height in centimeters

IVI = Relative density + Relative frequency + Relative dominant

- Shannon-Wiener index: (Shannon & Weaver, 1949)

$$H = -\sum_{i=1}^{S} Pi \ln Pi$$

H = Shannon-Wiener Index Diversity

Pi = proportion of total sample represented by species

S = number of species

- Dynamics of Plant Community

These parameters were used to calculate the mortality and means of annual increment of DBH as the following formula

- Mortality = $\frac{(\ln No - \ln Ni)}{t} \times 100$

No = Number of initial tree

Ni = Number of surviving trees

t = Number of years the measurement was repeated

- Mean annual increment (%)

= $\frac{(dbh_2 - dbh_1)}{(n \times dbh_1)} \times 100$

dbh_1 and dbh_2 = Initial of Girth at Breast Height: G.B.H. (t_1) and tracking period (t_2)

n = Duration of study (years)

Soil Analysis

Soil samples were collected from the permanent plot in the swamp forest using systematic random sampling. The samples were collected in different 20 points per 100 sq. meters. Soils were collected from each sampling point at 15 cm depth. The soil sample was kept in a plastic bag. Soil analysis was carried out by Central Laboratory (Thailand) Co., Ltd. The methods for soil analysis were provided in Table 1.

Table 1 Physical and chemical properties of dried soil samples analyzed in this study

Mineral nutrients available and Soil properties	Methods of analysis
1. Total Nitrogen (N)	Total Kjedahl Nitrogen : TKN
2. Available Phosphorus of Soil	Spectrophotometric method
3. Exchange Potassium	Flame photometer method
4. Calcium (Ca)	ICP
5. Magnesium (Mg)	ICP
6. Electrical Conductivity (EC)	Electrochemical at 1:5 soil : water ratio
7. pH	Electrochemical at 1:10 soil : water ratio
8. Organic Matter	Walkley & Black's wet oxidation method

Results

Plant Diversity and Species Composition

There were four species found in the permanent plot, included: *Melaleuca cajuputi*, *Antidesma ghaesembilla*, *Acacia mangium* and *Spondias pinnata*. A total of 1,000 and 1,127 plant individuals were found in 2016 and 2020, respectively. *Melaleuca cajuputi* is the dominant species, contributed to about 99% of total individuals. During the intervals of 5 years, there was a change of basal area and Shannon-wiener index. The basal area of white same, black currant tree, brown salwood and ma-kok were increased from 16.65, 0.12, 0.02 and 0.005 m^2/ ha in 2016 to 29.88, 0.18, 0.06 and 0.008 m^2/ ha in 2020 respectively. The diversity indices of Shannon-wiener index was increased from 0.08 in 2016 to 0.18 in 2020.The species with the highest IVI value is *Melaleuca cajuputi* (294.18=98.06 %) (table 2). During the five year-periods the mortality rate is 0.62% . The species that contributed most to the mortality rate were *Melaleuca cajuputi*. The total basal area increase was due to the growth of surviving individuals.

Forest structure

This forest structure consists of a two story tree layer and the top canopy height of 10 meters (Figure 2-3). The mean annual increment of 4.26 % per year (table 2). *Melaleuca cajuputi* was dominant in the size class >100 cm.

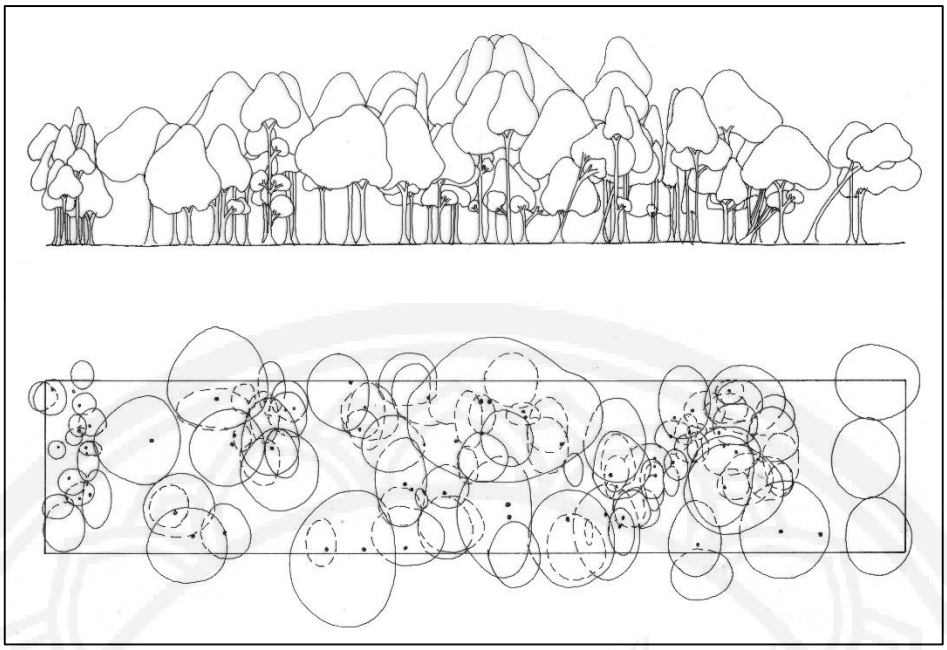

Figure 2 Crown cover diagram (above) and profile diagram (below) of *Melaleuca* forest at rayong botanical garden, Thailand (North-south direction)

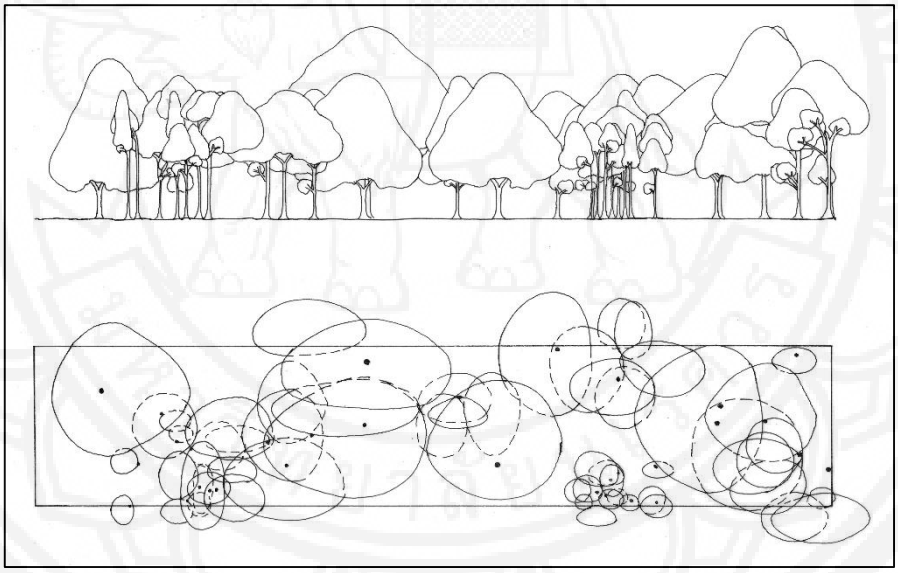

Figure 3 Crown cover diagram (above) and Profile diagram (below) of *Melaleuca* forest at rayong botanical garden, Thailand (East-west direction)

Table 2 Quantitative characteristics of tree in *Melaleuca* forest

Quantitative characteristic	Sampling time 1 (2016)	Sampling time 2 (2020)
Species	4	4
Relative frequency	White same tree (95 %)	White same tree (95 %)
	Black currant tree (3%)	Black currant tree (3%)
	Brown salwood (1%)	Brown salwood (1%)
	Ma-kok (1%)	Ma-kok (1%)

Table 2 (Cont.)

Quantitative characteristic	**Sampling time 1 (2016)**	**Sampling time 2 (2020)**
Species	**4**	**4**
Relative frequency	White same tree (95 %)	White same tree (95 %)
	Black currant tree (3%)	Black currant tree (3%)
	Brown salwood (1%)	Brown salwood (1%)
	Ma-kok (1%)	Ma-kok (1%)
Density	Total 1,000 individual/ha	Total 1,127 individual/ha
(individual/ha)	White same tree = 987	White same tree = 1,114
	Black currant tree = 9	Black currant tree =9
	Brown salwood = 3	Brown salwood =3
	Ma-kok = 1	Ma-kok =1
Basal area (m^2)	White same tree = 16.65	White same tree = 29.88
	Black currant tree = 0.12	Black currant tree = 0.18
	Brown salwood = 0.02	Brown salwood =0.06
	Ma-kok = 0.005	Ma-kok =0.008
IVI	White same tree (292.27 = 97.42%)	White same tree (294.18=98.06 %)
	Black currant tree = (3.87= 1.29%)	
	Brown salwood = (1.76=0.59%)	Black currant tree (3.32= 1.11 %)
		Brown salwood = (1.42= 0.47 %)
Shannon-Wiener Index	0.08	0.18
Morality rate (%)	-	0.62
Distribution of Size class (cm)		
> 14 cm.	-	2
14-30 cm.	322	115
30-50 cm..	211	18
50-100 cm.	350	358
>100 cm.	107	634

The soil in the permanent plot has relatively low fertility. Most of the soil is loam or sandy loam mixed with silt loam, with strongly acidity (pH 5.14). The organic matter content (3 %). The mean values of electrical conductivity of soil (27.76 μs/cm) and cation exchange capacity (CEC) 2.12 me/soils 100g.

Among mineral nutrients available in the soil, Ca has the highest concentration, 116.2 mg/kg. Other minerals contents included: K (28.68 mg/kg), Mg (21.33 mg/kg), P availability (18.73 mg/kg), NH_4^+-N (6.37 mg/kg) and NO_3^--N (1.02 mg/kg) (Figure 4).

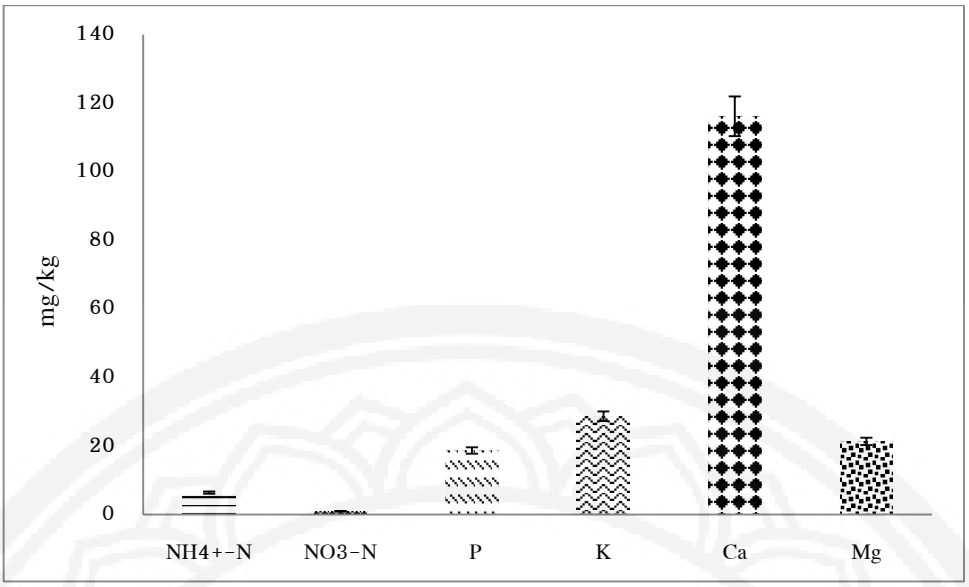

Figure 4 the concentration of mineral elements in soil in a permanent plot of *Melaleuca* forest

Discussion

The freshwater swamp forest ecosystem in the Rayong Botanical Garden, Thailand is an ecologically important biome with unique floristic composition. However, unlike other tropical forest ecosystems with higher species richness, it was dominated by a species *Melaleuca cajuputi*. It has highest IVI value (292.27, 97.42 %) contributed to 99% of plant individual found in the forest. This plant could grows along streams, fringing tidal estuaries and frequently forms pure stands in freshwater swamps. It often occurs close to the beach and could tolerate to wind-blown salt. Moreover, *M. cajuputi* can grow in high acid soil (Thien, Xuan, & Buu, 2019). *M. cajuputi* was the most abundant family, a common finding in many other freshwater swamp forests. (Theilade, Schmidt, Chhang, & McDonald, 2011).The changes observed in relation to the number of species, basal area and diversity were low when compared with reported for others *Melaleuca* forest (Truong & Hong, 2019.). The diversity index in *Melaleuca* forest is low, 0.18 because there were only four species and was nearly completed dominated by a species. During the five year-periods the mortality rate is 0.62% which is mainly caused by forest fires. *M. cajuputi* is a species with high resistance to effects of flames, particularly the mature trees which the fibrous bark offers insulation heat.

The structural intervals and a healthy juvenile/middle class tree population size are very few. This is not suitable for recruitment and replacement in the future. Because the soil is sandy loam, they dry out quickly. Moreover, plant nutrients could be quickly washed out by rain. Therefore, the soil nutrients in *Melaleuca* are extremely low. The nutrient cations plants use in the largest amounts are ammonium (NH_4^+), potassium (K^+), calcium (Ca^{2+}) and magnesium (Mg^{2+}) etc. These nutrients essential for plant growth. Additionally, high acidity in soil (pH 5.14) also caused low nutrient absorption. This is another factor affecting the plant diversity. Similarly, it was reported that *M. cajuputi* species adapted well to low pH soils (Osaki et al., 1998). The high CEC values mean that peat has a good capacity to store cationic nutrients for plants. In this study, the cation exchange capacity (CEC) 2.12 me/soils 100 g, that is able to bind more cations such as calcium (Ca^{2+}) with a high concentration.

Conclusion

In this study we studied the structural and floristic diversity of *Melaleuca* forest over a 5-year period in a hectare the permanent plot at Rayong Botanical Garden, Thailand. There were four species found in the permanent plot, included: *Melaleuca cajuputi*, *Antidesma ghaesembilla*, *Acacia mangium* and *Spondias pinnata*. A total of 1,000 and 1,127 plant individuals were found in 2016 and 2020. The diversity indices of Shannon-wiener index was increased from 0.08 in 2016 to 0.18 in 2020. *Melaleuca cajuputi* was dominant in the size class >100 cm. *M. cajuputi* is able to grow in a wide range of environment especially high acid soil, waterlogged soil and low fertility. Areas of swamp forest are potential for crediting wetland conservation as carbon sinks.

Suggestion for future research

The carbon stored in the swamp forest was then estimated using field measurements to the assess potential for crediting swamp forest conservation as carbon sinks.

Reference

Craven, L., & Barlow, B. A. (1997). New Taxa and New Combinations in Melaleuca (Myrtaceae). *Novon, 7*(2), 113-119. https://doi: 10.2307/3392182

Myers, A., & Harms, K. E. (2009). Seed arrival, ecological filters, and plant species richness: a meta-analysis. *Ecology Letters, 12*(11), 1250-1260. https://doi.org/10.1111/j.1461-0248.2009.01373.x.

Nazeh, M., Al-Abd, N., Mohamed Nor, Z., Mansor, M., Azhar, F., Hasan, M.S., Kassim, M. (2014). Antioxidant, antibacterial activity, andphytochemical characterization of *Melaleuca cajuputi* extract. *BMC Complementary and Alternative Medicine, 15*, 385. https://doi.org/10.1186/s12906-015-0914-y

Osaki, M., Watanabe, T., Ishizawa, T., Nilnond, C., Nuyim, T., Sittibush, C, & Tadano, T. (1998). Nutritional characteristics in leaves of native plants grown in acid sulfate, peat, sandy podzolic, and saline soils distributed in Peninsular Thailand. *Plant and Soil, 201,* 175-182.

Pagare, P. K. (2007). *Medicinal Plants.* U.S.A.: APH Publishing.

Shannon, C. E., & Weaver, W. (1949). The mathematical theory of communication. Urbana: University of Illinois Press.

Szmyt, J. (2016). Structural diversity of selected oak stands (*Quercus robur* L.) on the Krotoszyn Plateau in Poland. *Forest Research Papers, 78* (1), 14-27. https://doi.org/10.1515/frp-2016-0002

Theilade, I., Schmidt, L., Chhang, P., & McDonald, J. A. (2011). Evergreen swamp forest in Cambodia: Floristic composition, ecological characteristics, and conservation status. *Nordic Journal of Botany*, *29*(1), 71-80. https://doi.org/10.1111/j.1756-1051.2010.01003.x

Tran, D. B., Dargusch, P., Moss, P., & Hoang, T. V. (2013). An assessment of potential responses of *Melaleuca* genus to global climate change. *Mitig Adapt Strateg Glob Chan*, *18*, 851-86. https://doi.org/10.1007/s11027-012-9394-2

Tran, D.B., & Matusch, T. (2017). Restoration of Melaleuca Swamp Ecosystem for Bird Diversity in the Mekong Delta of Vietnam. *MOJ Ecology Environmental Science*, *2*(6), 1-9. https://doi.org/10.15406/mojes.2017.02.00040

Truong, K., & Hong, N. (2019). Plant Species Diversity in the Melaleuca Forest Ecosystem of Lower U Minh National Park in Vietnam. *The International Journal of Engineering and Science (IJES)*, *8*(3), 60-68. https://doi.org/10.9790/1813-0803026068

Yeboah, D., Burton, A. J., Storer, A. J., & Opuni-Frimpong, E. (2014). Variation in wood density and carbon content of tropical plantation tree species from Ghana. *New Forests*, *45*, 35-52. https://doi.org/10.1007/s11056-013-9390-8