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EFFECT OF ECOLOGICAL FACTORS ON VEGETATION AND CARBON STOCK ON SAMAESAN ISLAND, CHON BURI PROVINCE, THAILAND

ผลของปัจจัยเชิงนิเวศต่อสังคมพืชและการกักเก็บคาร์บอนในพื้นที่เกาะแสมสาร จังหวัดชลบุรี ประเทศไทย

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Abstract

This study aims to classify this littoral evergreen forest and to analyze the environmental factors that determine its composition and structure and evaluate the potential of carbon stock of each vegetation community. Seventy-five plots were sampled, the plant cover was measured, and the importance value index was calculated. Thirty-seven soil samples were analyzed, and cluster analysis was employed to classify the vegetation communities. Floristic and environmental data were evaluated and ordered using the canonical correspondence analysis (CCA). THEOS was applied to classify the vegetation boundary. Allometric equations were used to calculate the aboveground biomass.

The results revealed that the vegetation communities could be divided into five types: 1) the Flatland Flacourtia indica, 2) the Memecylon plebejum with Atalantia monophylla, 3) the Sloping land Memecylon plebejum; 4) the Upland Memecylon plebejum, 5) and the Flatland Dipterocarpus obtusifolius. The aboveground carbon content is controlled by the type of vegetation. The highest potential for carbon stocks per hectare is the Memecylon plebejum with Atalantiam onophylla plant community. CCA result showed that the belowground carbon content appears to be controlled by the slope and type of vegetation. The results of this study indicate that Samaesan Island has high biological diversity and it shows the potential for greenhouse gas mitigation.

Keywords: ecological factors, aboveground biomass, Samaesan Island, carbon stock

บทคัดย่อ

การศึกษานี้มีจุดประสงค์เพื่อศึกษาความสัมพันธ์ระหว่างปัจจัยทางสิ่งแวดล้อมที่ส่งผลต่อลักษณะของสังคมพืชที่แตกต่างกันไปและประเมินศักยภาพในการกักเก็บคาร์บอนของเกาะแสมสาร ชนิดของสังคมพืชและขอบเขตของแต่ละสังคมโดยการวางเส้นสำรวจและวาง

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แปลงเก็บตัวอย่างสังคมพืชและนำมาทำการจัดสังคม โดยวิธีCluster analysis และทำการกำหนดขอบเขตของแต่ละชนิดสังคมโดยการแปรภาพถ่ายดาวเทียม THEOS โดยวิธี visual interpretation เก็บตัวอย่างดินบนเส้นสำรวจหลักสี่เส้นและวิเคราะในห้องปฏิบัติการ ความสัมพันธ์ระหว่างปัจจัยสิ่งแวดล้อมและสังคมพืช วิเคราะห์โดยวิธี canonical correspondence analysis (CCA) โดยมีผลการศึกษาดังนี้ สังคมพืชถูกแบ่งออกเป็นห้าสังคมย่อยได้แก่ Memecylon plebejum with Atalantia monophylla community จะกระจายตัวอยู่ในบริเวณระดับความสูงต่ำกว่า 70 เมตรจากระดับน้ำทะเลระดับความลาดชันต่ำ ระดับความชื้นในดินสูง พื้นที่ส่วนใหญ่ของ Sloping land Memecylon plebejum community และ Upland Memecylon plebejum community จะกระจายตัวในระดับความสูงและระดับความลาดชันที่มากกว่า Memecylon plebejum with Atalantia monophylla community และเป็นสังคมพืชที่มีช่วงของปัจจัยทางดินที่กว้าง Flatland Flacourtia indica community กระจายตัวในบริเวณที่ราบระดับความสูงต่ำรอบเกาะ Flatland Dipterocarpus obtusifolius community กระจายตัวอยู่บนพื้นที่เฉพาะยอดเขาทางทิศใต้ของภูเขาทางเหนือและสัมพันธ์กับคุณสมบัติดินที่มีร้อยละของอนุภาคทรายในดินและคาร์บอนในดินสูง การสะสมของคาร์บอนในดินจะถูกควบคุมโดยระดับความลาดชันและชนิดของสังคมพืชที่ปกคลุม ความลาดชันระดับต่ำและความหนาแน่นของพืชที่ปกคลุมต่ำเช่นสังคมของ Flatland Dipterocarpus obtusifolius community ส่งผลให้ปริมาณการสะสมคาร์บอนในดินสูงและในทำนองเดียวกันในสังคมพืชอื่นๆ การสะสมของคาร์บอนเหนือดินจะเป็นไปตามชนิดพืชที่ปกคลุม Memecylon plebejum with Atalantia monophylla community เป็นสังคมพืชที่มีศักยภาพในการกักเก็บคาร์บอนต่อพื้นที่สูงสุด

คำสำคัญ: ปัจจัยเชิงนิเวศ, มวลชีวภาพ เหนือพื้นดิน, เกาะแสมสาร, การกักเก็บคาร์บอน

Introduction

Thailand consists of a northern part (the Indochina province) and a southern part (the Sundar Province). Hundreds of costal islands exist in the Gulf of Thailand and in the Andaman Sea, and Thailand has no islands located in the open sea far from the coast. During the Pleistocene epoch [1,2], large sea level fluctuations caused the sea level to lower between 50 and 150 m, creating land bridge connections. After this time, the sea level increased and the low places were covered with water forming many islands separated from the mainland. Various fossils confirm these events during this period [3]. Therefore, biological species found on the mainland may also be found on the islands. No records show how long the islands in Thailand have been inhabited; however, in recent times, many islands have been developed into tourist resorts. Over the past decade, there has increasing interest in the function of the ecosystem[4-7], including forest structure[8-9], species composition[10-11], and environment factors. Several recent studies have been conducted the research on mainland; however, little is currently understood regarding the island ecosystems. Such changes in the environmental gradient can significantly affect on the ecological components. Indeed, island terrestrial ecosystems in Thailand are restricted and isolated, which makes them very unique.

Area or size and distance from mainland of the island has important effects on the interactions among organisms and inorganic materials[(12)], and, thus, is a major determinant of the biological species composition[(13)]. Furthermore, islands are natural laboratory because they are isolated. Moreover, islands often accommodate communities that have evolved under less competitive conditions[(14)]. Many Islands in Thailand have been used for tourist activities[(15-16)], which have caused changes in the ecological system due to the introduction of invasive species. Only few groups of islands have been conserved for ecological purposes. This paper aims to determine the relationship between environmental factors and vegetation community and evaluate the potential of carbon stock of each vegetation community. Knowledge of these relationships may be critically important for the planning of appropriate adaptations when this island experiences climate changes.

Materials and Methods

Study Area

Samaesan Island is located in Eastern Thailand, in the Satahip district, Chon Buri province at 100°57’E, 12°34’N. The total land area is approximately 5 km^2, and the distance from the island to the mainland is 8 km (Figure 1). The soil type is gravel. The topographical features consist of two small mountains; the highest peak is approximately 167 m above sea level (asl) and lies in the north, and the other is approximately 159 m asl and is found in the south of the island.

Since 1998, the local community has cooperated with the Thai Royal Navy to promote the conservation of Samaesan Island for the Plant Genetic Conservation Project under the Royal Initiative of Her Royal Highness Princess MahaChakriSirindhorn, and these people immigrated to settle on the Ban Chong Samaesan [(17)]. Without baseline data for the tree communities on Samaesan Island, however, the trees are currently small in size. The climate conditions are influenced by northeast and southwest Asian monsoons; the former bring dry air to Thailand during November through April, and the latter bring moisture from May through October. The mean annual rainfall is 980 mm, and the average temperature is range from 25.6-29.4 °C (data from Navy meteorological station at Samaesan Island from 1994-2010).

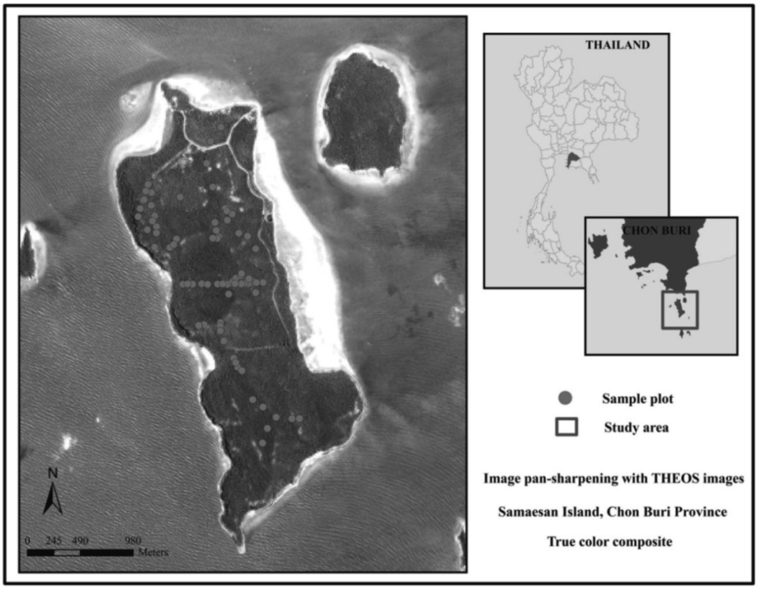

Figure 1 Study area with the plots sampling in Samaesan Island.

Sampling

A quantitative survey of the vegetation was conducted on the two mountains on the island (northern and southern). Two intersecting survey lines were created in north-south and east-west directions at the top of each mountain. Each line began at an altitude of 30 m, and the sample plots were divided with every 20 m change in altitude until the end of the survey line was reached on the other side at 30-m altitude. The total of 75 point samples were divided within the four major survey lines. All sample points were collected in year 2009. The point-centered quarter method was used in each sample plot, as described previously[18]. A transecting line was created within a square survey to set five sample points, and each sample point measured 3 m apart. For this study, a minimum trunk diameter at breast height (DBH) of 10 cm was required for a plant to be considered a tree. Floristic lists, distances between each tree, heights were recorded to analyze a particular plant's community characteristics. The elevation for each sample plot was extracted using Chon Buri' s Topography Map, and the slope inclination and aspect for each sample were also calculated from digital elevation data obtained from the ArcGIS program. The geographical coordinates of samples were recorded using the global positioning system.

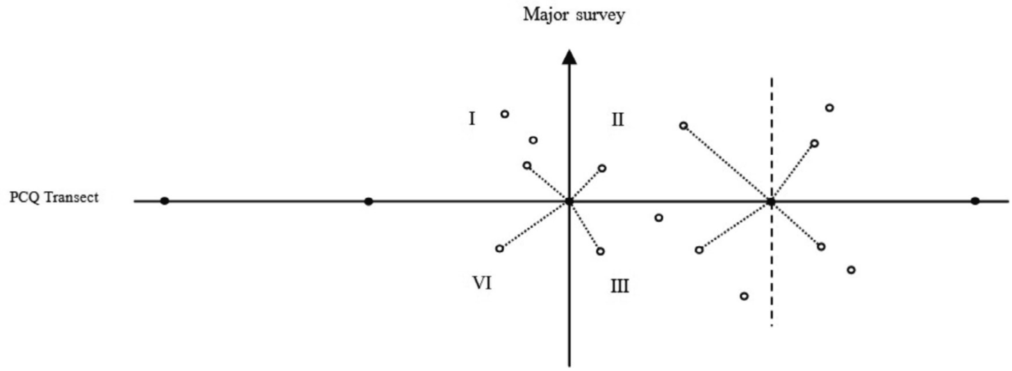

Figure 2 Sample points with the nearest trees in each quarter

Soil samples were random collected 37 points from 75 points in the four major survey lines correlating with the aspect and altitude change. For each site, two interval soil depths were collected separately at 0-15 and 15-30 cm endorganic layers. These soil samples were air dried and passed through a 2 mm sieve to remove coarse gravels, roots and debris. The soil texture, bulk density, soil moisture, pH value, soil organic carbon, total nitrogen, available phosphorus, and exchangeable potassium were subsequently analyzed in these samples.

Vegetation Analysis, Classification and Ordination

The species list was created to more simply identify species diversity. We also determined three values for each tree species in a given community, including the relative density, relative frequency and relative dominance (dominance was defined as the mean basal area per tree times the number of trees of the species)[18]. Next, the three values were summed to obtain an importance value index (IVI) for each species.The diversity within a community was calculated using the Shannon-wiener index (H) [19].

Both classification and ordination techniques were applied to reveal similarities and differences between plant communities and to analyze the relationship between a species and the environmental factors. Multivariate data analysis were performed on the floristic data matrices, and all species with an importance value of less than 5% were eliminated. The classification of plant communities was performed using a cluster with the PC-ORD program[20]. Seventy-five plots of plant communities were classified based on community characteristics. The relationship between plant community and environmental variables were analyzed using canonical correspondence analysis (CCA), as described previously [21-22].

Vegetation Area Interpretation

Samaesan THEOS satellite images were used in this study (Panchromatic, Multispectral on December 30, 2008). We compared different targets based on several visual elements, including tone, shape, size, pattern, texture, shadow, and association[23] using in visual interpret method. The vegetation characteristics and topographic data for each plot were used to more accurately adjust the vegetation boundaries and area. An accuracy assessment at a level greater than 80% was proposed using a confusion matrix by comparing the results of the classification system with the ground truth data. Accuracy assessment was carried out using an output map of logical operation using the ground truth data.

Aboveground and Belowground Carbon Content

An allometric relation equation was applied to calculate the aboveground and belowground biomass of tree stands. The biomass of upper-layer stands (DBH greater than or equal to 14 cm) in the dry evergreen forest was calculated using the allometric equation described by Tsutsumi et al.,[24].

DBH less than 14 cm was calculated using the allometric equation of Issaree[25] and Dipterocarpdeciduous forest was calculated using the allometric equation of Ogawa et al.[26]. The aboveground carbon content was calculated as 50% of the total aboveground biomass[27]. The soil organic carbon was tested using the Walkley and Black method[28]

Results and Discussion

Vegetation Characteristics and Cluster Analysis

The list of vegetation names and Importance value of each species (IVI) from the 75 sampled points is presented in Table 1. The structure of the forest is highly dense with vines of small circumference and a closed canopy (~70% of the crown projection)[29-30]. The Samaesan tree species are composed primarily of evergreen trees as the major species, such as *Memecylon plebejum* and *Diospyros filipendula.* Variable numbers of deciduous trees make up the miner species. Twenty-nine species in 18 families were recorded in the study area.

Cluster analysis, Euclidean distance measure and Ward's Linkage techniques were used to classify the 75 stands for dominant types based on the importance value of each species and the topographic factors (slope and altitude). The results showed that the vegetation in the study could be classified into three communities and three sub-communities with 30% of this information was remaining after this classification (Figure 3).

1. *Memecylon plebejum* community, which consisted of three sub-communities:

- *Memecylon plebejum* with *Atalantiamonophylla* (10 sample plots)
- *Memecylon plebejum* community I (34 sample plots)
- *Memecylon plebejum* community II (24 sample plots)

2. Flacourtia indica community (3 sample plots)

3. Dipterocarpus obtusifolius community (3 sample plots)

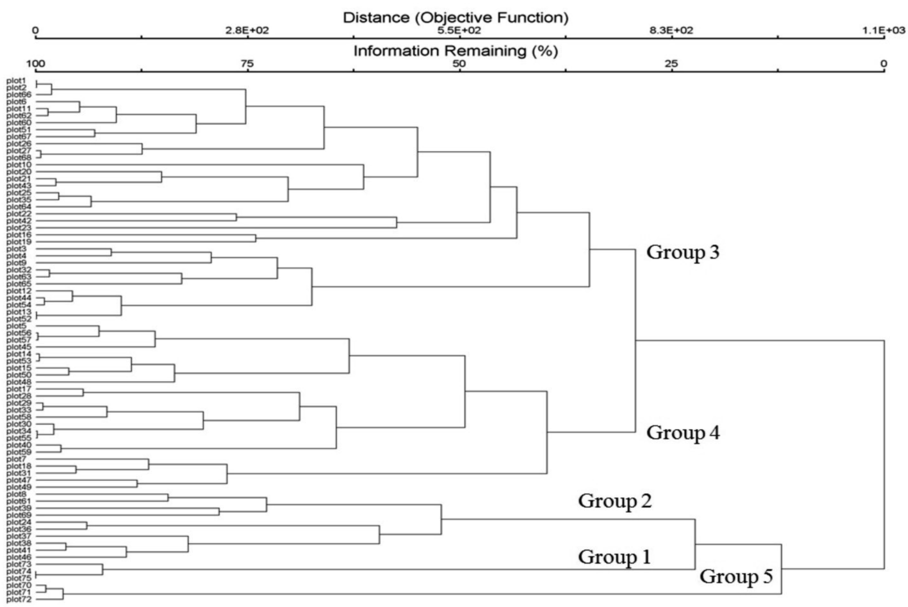

Figure 3 Cluster analysis and Relative Sorensen distance based on the importance value of tree species and the percentage of slope and altitude (m). Data was cut off at 30 % information remaining. Key: 1 *Flacourtia indica* community, 2 *Memecylon plebejum* with *Atalantia monophylla,* 3 *Memecylon plebejum* community I, 4 *Memecylon plebejum* community II, 5 *Dipterocarpus obtusifolius* community.

Describe from sub-community 1: *Flacourtia indica* and *Memecylonovatum:* It consisted of 5 sample point and Fifteen tree species were found in the *Flacourtiaindica* community. The calculations for the top 3 most important tree species for *Flacourtia indica, Diospyros filipendula* and *Vitex limnonifolia* were 56.74, 32.80 and respectively. The Shannon-wiener index for diversity was 3.26 (high species evenness and richness) and the absolute density was 0.16 tree m^{-2}. The average tree height was 3.71 m, and the average girth at breast height was 19.37 cm.

Table 1 List of vegetation in the sampling points and importance value of each species.

Scientific name	Groups				
	1	2	3	4	5
Atalantia monophylla (DC.) Corrêa	25.15	17.33	1.55	2.59	-
Buchanania arborescens Blume	-	0.97	-	0.76	-
Canthium glabrum Blume	15.48	-	-	1.18	-
Cleistanthus hirsutulus Hook.f	-	-	0.70	0.61	-
Cratoxylum formosum (Jack) Dyer	12.42	8.06	6.26	6.60	-
Croton poitanei Gagnep.	-	10.72	11.36	18.89	-
Dialium cochinchinense Pierre	-	12.42	26.19	8.68	-
Diospyros filipendula Pierre ex Lecomte	32.80	29.56	41.03	44.15	-
Dipterocarpus obtusifolius Teijsm. Ex Miq.	-	-	-	2.03	263.09
Eurycoma longifolia Jack	-	0.85	0.61	-	6.85
Flacourtia indica (Burm.f.) Merr.	56.74	-	-	-	-
Ganophyllum falcatum Blume	16.01	1.08	-	0.63	-
Garcinia speciosa Wall.	-	4.56	3.27	-	-
Jasminum Adenophyllum Wall. Ex C.B.Clarke	7.24	0.82	-	-	-
Lagerstroemia cuspidata Wall.	-	9.32	-	-	-
Lagerstroemia balansae Koehne	24.77	-	-	1.96	-
Maerua siamensis (Kurz) Pax	5.52	22.01	8.79	9.51	-
Mallotus philippensis Müll.Arg.	-	-	2.16	5.73	-

Table 1 List of vegetation in the sampling points and importance value of each species. (cont.)

Scientific name	Groups				
	1	2	3	4	5
Manikara hexandra (Roxb.) Dubard	6.24	10.30	1.39	4.68	-
Memecylon sp.	20.69	90.04	102.96	97.35	-
Morinda coreia Ham.	-	-	2.72	1.90	-
Ochna integerrima (Lour.) Merr.	19.46	15.37	24.28	17.68	30.07
Pavetta indica L.	-	11.87	18.92	14.82	-
Polyalthia cerasoides (Roxb.) Benth. Ex Bedd.	24.15	2.23	-	-	-
Pterospermum littorale Craib ver.	7.07	5.41	-	-	-
Sindora siamensis Teijsm. &Miq.	-	2.23	9.51	15.10	-
Vitex limnonifolia Wall.	26.26	44.86	38.30	45.16	-

Describe from sub-community 2: Twenty different tree species were discovered in *the Memecylon plebejum* with *Atalantia monophylla* community. The calculations for the top 3 most important tree species for *Memecylon plebejum*, *Vitex limnonifolia* and *Diospyros filipendula* were 90.04, 44.86 and 29.56, respectively. The Shannon-wiener index was 3.41, the absolute density was 0.29 tree m^{-2}, the average tree height was 5.22 m, and the average girth at breast height was 21.04 cm.

Describe from sub-community 3: In the *Memecylon plebejum* community I, there were 17 different tree species. The calculations for the top 3 most important tree species for *Memecylon plebejum, Diospyros filipendula* and *Vitex limnonifolia* were 102.96, 41.03 and 38.30, respectively. The Shannon-wiener index was 3.05, the absolute density was 0.31 tree m^{-2}, the average tree height was 5.31 m, and the average girth at breast height was 19.88 cm.

Describe from sub-community 4: Twenty different tree species were recorded for the *Memecylon plebejum* community II. The calculations for the top 3 most important tree species for *Memecylon plebejum, Vitex limnonifolia* and *Diospyros filipendula* were 97.35, 45.16 and 44.15, respectively. The Shannon-wiener index was 3.19, the absolute density was 0.29 tree m^{-2}, the average tree height was 4.51 m, and the average girth at breast height was 20.79 cm.

Describe from sub-community 5: *Dipterocarpus obtusifolius* community contained only three different tree species. The calculations for the importance of *Dipterocarpus obtusifolius, Ochna integerrima,* and *Eurocoma longifolia* were 263.09, 30.07, and 6.85, respectively. The Shannon-wiener index was 0.62, the absolute density was 0.19 tree m^{-2}, the average tree height was 3.64 m, and the average girth at breast height was 31.40 cm.

Ordination Analysis

Topographic factor

From 3 factors, altitude, slope and aspect, of 5 sub-community clustering from 75 sample points, the Monte-Carlo test indicated statistical significance for two ordination axes, axis 1 and 2, ($P< 0.05$). The eigenvalues of the first and second ordination axes were 0.247 and 0.092 (Table 2). From the CCA analysis, the vegetation ordination and topographic factors indicated statistical significance for two ordination axes, The vector lines representing the environmental variables, which indicate the direction of maximum change of that variable across the diagram. The length of the vector is proportional to the rate of change. In Figure 4-a, the five different communities have been correlated with altitude and slope percentage. The percentage of the slope line begins at the origin point and increases to the upper left. The Table 3 indicates, the percentage of the slope varied directly with axis 2 ($r = 0.357$, $p < 0.05$) and indirectly with axis 1 ($r = -0.44$, $p < 0.05$). In Figure 4-a, the altitude variable begins at the origin point and increases to the lower left. The altitude varied indirectly with axes 1 and 2 ($r = -0.672$ and -0.188, $p < 0.05$ respectively). From inter-set correlations for the altitude values on axis 1, the altitude was the topographic factor with the strongest effect on the distribution of vegetation on Samaesan Island.

Most of the *Memecylon plebejum* community II (group 4) is distributed within the upland (mean altitude asl> 100 m) area to the top of the mountain with steep slopes. the *Memecylon plebejum* community I (group 3) is primarily distributed at middle level of slope and altitude. The *Memecylon plebejum* with *Atalantia monophylla* community (group 2) is distributed within areas with similar slopes to those of the *Memecylon plebejum* community I (group 3); however, they are limited to low altitudes. The *Flacourtia indica* (group 1) and the *Dipterocarpus obtusifolius* communities (group 5) are distributed on flat slopes, as shown by the CCA ordination and on site plots (Figure 4-a), but they spread at different altitudes.

Table 2 Summary statistics for the CCA ordination of topographic and environmental factors

	Topographic factors			Environmental factors		
	Axis 1	Axis 2	Axis 3	Axis 1	Axis 2	Axis 3
Eigenvalue	0.247	0.092	0.04	0.243	0.207	0.115
Variance in species data						
% of variance explained	6.6	2.4	1.1	7.5	6.4	3.5
Cumulative % explained	6.6	9	10.1	7.5	13.9	17.4
Pearson Correlation, Spp-Envt	0.744	0.455	0.449	0.8	0.751	0.576
Kendall (Rank) Corr., Spp-Envt	0.561	0.433	0.421	0.592	0.589	0.45

Environmental factors

From 37 points of soil samples were presented in 5 sub-community, 1 sample in *Flacourtia indica* community, 10 samples in *Memecylon plebejum* with *Atalantia monophylla,* 13 samples in *Memecylon plebejum* community I, 12 samples in *Memecylon plebejum* community II (Upland) and 1 sample in *Dipterocarpus obtusifolius* community. The spatial distribution pattern of communities was recognized by CCA, and the communities were separated into distinct groups along the CCA axis. The Monte-Carlo test indicated statistically significant differences between the first and second ordination axes and environmental variables ($P < 0.05$). The eigenvalues for the first and second axes were 0.243 and 0.207, respectively (Table 2).

Table 3 Inter-set correlations for three factors

Correlations	Topographic factors			Environmental factors					
	Altitude	Slope (%)	Aspect	Sand (%)	Silt (%)	pH (0-15 cm)	moisture (0-15 cm)	Altitude	Slope
Axis 1	-0.672*	-0.44*	0.036	0.264	-0.244	-0.094	-0.373*	0.430*	0.125
Axis 2	-0.188	0.357*	0.053	0.298*	-0.251*	-0.184	-0.148	-0.036	-0.416*
Axis 3	-0.035	-0.045	-0.374*	-0.004	-0.105	-0.01	0.203	-0.357*	-0.235

*sig. p <0.05

The CCA biplot showed a separation of environmental variables and vegetation. The graph indicated that six environmental variables (from 19 trial factors) are related to vegetation (Table 3). These related properties were organized by the strength of their relationships, which were the percentage of slope, altitude, percentage of sand, percentage of silt, soil reaction (pH) in the 0 to 15 cm sample depth, and soil moisture in the 0 to 15 cm sample depth, respectively. In contrast, the percentage of clay, exchangeable potassium, bulk density, soil organic carbon, total nitrogen in both sample depths and also soil pH in the 15 to 30 cm sample depth and soil moisture in the 15-30 cm sample depth were not associated with the growth of plants.

As seen in Figure 4-b, the soil reaction (pH) in the 0 to 15 cm sample depth, the soil moisture in the 0 to 15 cm sample depth and the percentage of silt showed slight differences in the relationship direction, which started from the middle to lower left. These directions were indicated dependence variables. The percentage of sand also increased in relationship strength from the middle to upper right. Furthermore, this was an independent variable with the percentage of silt. The ordination of vegetation was distributed significantly along the environmental gradient but many plots aggregated together because the community structures were similar in both species composition and environmental gradients. Axis 1 of the CCA showed a positive association for altitude and a negative association for soil moisture in the 0 to 15 cm sample depth. The axis 2 of CCA, the percentage of sand showed a positive tendency, and the percentage of silt, slope, and soil pH showed a negative association.

In Figure 4-b, the flatland of the *Flacourtia indica* community (group 1) plot is shown in the upper left of diagram. This community was distributed in a habitat with a low altitude and low slope, but variable conditions in soil particle, soil pH and percentage of slope.

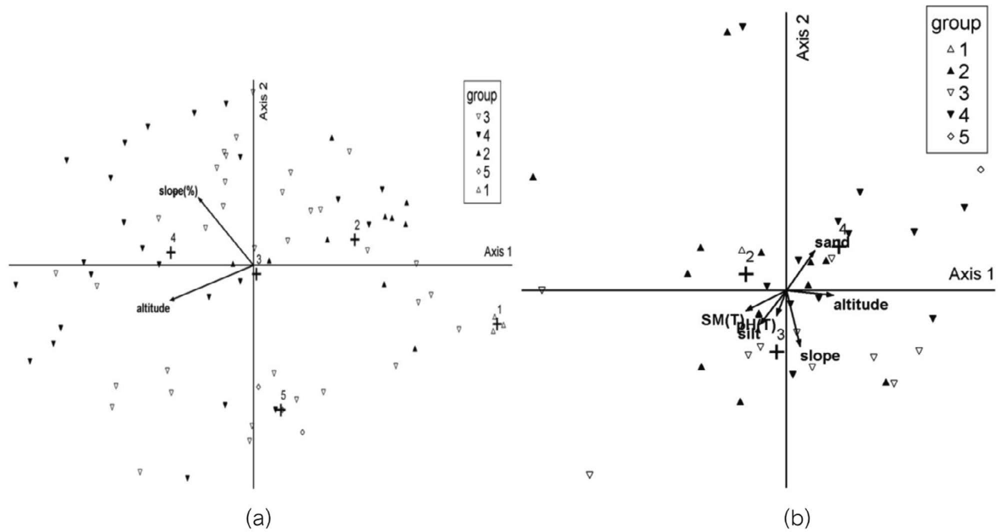

Figure 4 Ordination biplot for the first two axes of CCA that (a) is CCA between 75 points and topographic factors (b) is CCA between 37 points and environmental factors. Key: 1 *Flacourtia indica* community, 2 *Memecylon plebejum* with *Atalantia monophylla,* 3 *Memecylon plebejum* community I, 4 *Memecylon plebejum* community II, 5 *Dipterocarpus obtusifolius* community.

In Figure 4-b, most of the *Memecylon plebejum* with *Atalantia monophylla* community (group 2) plots are shown in the left part of diagram and are distributed along axis 2 from upper to lower. Thus, it appears that altitude and soil moisture are important factors to this community. Indeed, as seen in Table 3, the altitude was the most important factor (correlation with axis 2 is 0.430, $p< 0.05$). This community was explained in a habitat with low altitude and a high percentage of soil moisture, but variable conditions in soil particle, soil, pH and percentage of slope existed in this environment.

The *Memecylon plebejum* community I (group 3) plots are in the lower right and left parts of the diagram (Figure 4-b). Based on the data in Table 3, it may be concluded that slope represents the most important factor (correlation with axis 2 is -0.416, $p < 0.05$). These communities were explained in a habitat with a high slope percentage and variable altitudes.

The *Memecylon plebejum* community II (group 4) plots are distributed from the middle to upper right (Figure 4-b). This community positively correlated with percentage of sand, and spread a habitat high in altitude.

The *Dipterocarpus obtusifolius* community (group 5) plot is on the upper right part of diagram (Figure 4-b). The results indicated that the percentage of sand and altitude were important variables for this community, which was distributed in a habitat with a high altitude and high sand percentage.

Thus, the altitude and slope percentage play the most important role in vegetation characteristics, distribution and soil properties. The topographic characteristics of Samaesan Island can be divided into three types: flatland at low altitude, steeply sloping land, and flatland at high latitude. Naturally, the steeper slopes lead to greater soil loss from water or wind erosion. Soil erosion by water also increases as the slope length increases due to greater runoff and sedimentation. The consolidation of small fields into larger ones often results in longer slope lengths with greater erosion potential due to increased water velocity, which permits a larger degree of scouring. For this reason, the percentage of silt on steeply sloping lands is often lower than in flatlands at low altitudes.

In the upland areas (flatland at high altitudes), wind is one factor causing the low percentage of silt and clay. Very fine particles can be suspended by the wind and transported great distances. Fine and medium size particles can also be lifted and deposited, while coarse particles can be blown along the surface. The resulting abrasions can reduce soil particle sizes and further increase the soil erosion. Wind can also cause a loss in soil moisture. A lack of windbreaks (trees, shrubs, residue, etc.) allows the wind to put soil moisture directly out of the soil and increases evapotranspiration rates leading to reduce water uptake.

In contrast to our results, research by Tamartash et al.[31] showed that different plant communities exhibited different correlations to physiographic variables. For example, shrubs correlated more with altitude than grasses, but did not significantly correlate with the slope. Leul et al.[32] examined the relationship between vegetation in Ethiopia and environmental factors. This group found 102 species belonging to 83 genera and 50 families, and five community types were classified. The analysis of the vegetation communities and environment did not show significant differences, except for altitude and slope. Ozakan[33] described the environmental factors that influence vegetation communities in the Acipayam district, Turkey. The results showed two vegetation gradients related to factor complexes of altitude-landform and the parent material-land surface smoothness. The study research results differed from previous results in that a particular aspect variable did not show significance for the vegetation community. Ozakan explained that this was likely due to the dominant winds affecting the Acipayam district. These findings are similar to our results, in which that aspect also did not show a significant correlation with the other axes. The latter discovered that the distribution of four ecological groups was associated with aspect, content of clay, total nitrogen, organic matter, phosphorus and exchangeable bases. Our research collected soil samples for only the half of the sampled vegetation. Therefore, additional research with more soil samples per vegetation group and more soil parameters, such as micronutrient and cation exchange capacity measurements, will be necessary to fully assess the parameters in this region.

Area of Vegetation

Samaesan panchromatic and multispectral THEOS satellite images (December 30, 2008) were pansharpenedand bounded for different areas using a visual interpretation technique (Table 4 and Figure 5). Five classes were identified. We separated human buildings, roads, abandoned areas, gaps, beaches, and water bodies from the forest area and grouped them into the "Other" class. The "*Memecylon plebejum* with *Atalantia monophylla* community" class (Group 2), "Sloping land and Upland *Memecylon plebejum* community" class (consist of Groups 3 and 4), "Flatland *Flacourtia indica* community" class (Group 1), and "Flatland *Dipterocarpus obtusifolius* community" class (Group 5) were bounded by texture on the satellite image, including the to pographic characteristic data for each community (such as altitude, slope and aspect) and field check. The results showed that the Sloping land and Upland *Memecylon plebejum* communities represent 1.906 km^2, or 44.35% of the total area. The second, third, and fourth largest are the *Flacourtia indica* community (1.095 km^2 or 25.47%), *Memecylon plebejum* with *Atalantia monophylla* community (0.901 km^2 or 20.96%), and the "Other" class (0.381 km^2 or 8.86%). The class with the least area is the Flatland *Dipterocarpus obtusifolius* community (0.0157 km^2 or 0.36%). However, it is important to note that THEOS imaging cannot distinguish between Sloping land and Upland *Memecylon plebejum* communities. Thus, this technique is markedly different from the plot sampling along the transect line. Therefore, the calculations for the carbon content of these two vegetation communities were averaged and multiplied by the area.

A total of 79 points around Samaesan Island were selected from ground truth data, recorded on September 18, 2010, and were used to verify the classification accuracy. The results showed the percentage of accuracy for each classification stage: 100%, 50%, 96%, 100%, and 80%, respectively. The accuracy report was generated to calculate the percentage of accuracy based on the error matrix and showed an overall accuracy of approximately 85%

Table 4 Description of vegetation and the appearance on the THEOS image (December 30, 2008)

Type	Interpretation remark	Area(km^2)	Area(%)
Memecylon plebejum with *Atalantia monophylla*	Smoother texture than "Flatland *Flacourtia indica*" Distributed at altitudes lower than 60 m	0.901	20.96
Sloping land and Upland *Memecylon plebejum*	Smoother texture than "*Flacourtia indica*"	1.906	44.35
Flatland *Flacourtia indica*	Rough texture Flat slope at low altitude	1.095	25.47
Flatland *Dipterocarpus obtusifolius*	Smoother texture than "*Flacourtia indica*" Flat slope at high altitude	0.016	0.36
Other	Geometric shape Light tone Can interpret with naked eye	0.381	8.86

Carbon Stock of Samaesan Island

As shown in Table 5 the *Memecylon plebejum* with *Atalantia monophylla* community contained the highest biomass per square meter (8.67 kg m^{-2}). This would suggest that this community contains the highest aboveground carbon content (43.34 tC ha^{-1}); however, the organic carbon in the soil from this community was lower than other communities. However, the *Memecylon plebejum* with *Atalantia monophylla* community had the highest absolute density (0.29 tree m^{-2}), and high-density trees take up more carbon stock from the ground as biomass. The flatland of the *Dipterocarpus obtusifolius* community had the highest soil organic carbon per ha^{-1} (67.56 tC ha^{-1}) from the highest soil carbon stock, but the soil particles from this community contain a high percentage of sand. Hassink [34] observed a close relationship between the proportions of primary particles (<20 μm) in the soil (10-cm depth). The amount of soil organic carbon (SOC) in the >20-μm fraction was not correlated with texture, and cultivation decreased the amount of SOC in the >20-μm fraction more than in the <20-μm fraction, indicating that SOC associated with the <20-μm is better protected against decomposition. However, quantity and quality of the biomass returning to the soil of the flatland of the *Dipterocarpus obtusifolius* species with a flat slope, low tree density (less uptake), and strongly acid soil (decomposition inhibitor) has a greater effect on the potential of below-ground carbon sequestration than the proportion of primary particles[35]. The total carbon stocks of the sloping land and upland of the *Memecylon plebejum* communities were the greatest from this large area (15372.92 tC ha^{-1} or 52.77%), followed by the *Memecylon plebejum* with *Atalantia monophylla* community (7118.39 tC ha^{-1} or 24.43%), the flatland of the *Flacourtia indica* community (5360.81 tC ha^{-1} or 22.30%), and the flatland of the *Dipterocarpus obtusifolius* community(145.55 tC ha^{-1} or 0.50%).

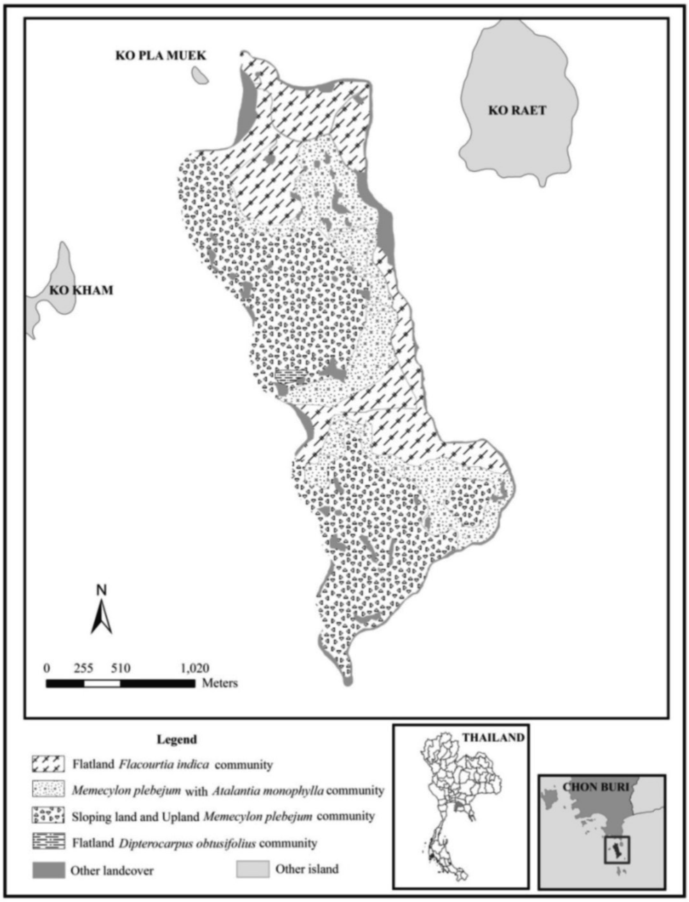

Figure 5 Boundary of vegetation at Samaesan Island based on the THEOS satellite image.

Table 5 Aboveground biomass for each type of vegetation

Vegetation	Absolute Density (tree m^{-2})	WS	WB	WL	WR	WT	Biomass content (kg m^{-2})
		kg/tree^{-1}					
Flatland *Flacourtia indica* (Group 1)	0.16	7.93	1.93	0.56	2.60	13.02	2.07
Memecylon plebejum with *Atalantia monophylla* (Group 2)	0.33	16.77	4.61	0.79	4.46	26.62	8.67

Table 5 Aboveground biomass for each type of vegetation (cont.)

Vegetation	Absolute Density (tree m^{-2})	WS	WB	WL	WR	WT	Biomass content (kg m^{-2})
		kg/tree^{-1}					
Sloping land *Memecylon plebejum* (Group 3)	0.36	9.51	2.36	0.61	2.99	15.46	5.53
Upland *Memecylon plebejum* (Group 4)	0.36	11.16	2.84	0.66	3.36	18.02	6.45
Flatland *Dipterocarpus obtusifolius* (Group 5)	0.19	20.58	5.53	0.97	-	27.08	5.05

WS = Stem biomass; WB = Branch biomass; WL = Leaf biomass; WR = Root biomass; WT = Total biomass

The aboveground biomass and soil organic carbon were different in each vegetation community [36-39]. The carbon content (tC ha^{-1}) in each vegetation community was measured from the largest to the smallest: *Memecylon plebejum* with *Atalantia monophylla,* sloping land and upland of the *Memecylon plebejum*, flatland of the *Dipterocarpus obtusifolius*, and flatland of the *Flacourtia indica*, respectively. However, the soil organic carbon (tC ha^{-1} in soil depth of 30 cm) is not related to the amount of aboveground carbon content. The organic carbon in the soil was measured in the communities as follows (the highest to the lowest): flatland of the *Dipterocarpus obtusifolius*, sloping land and upland of the *Memecylon plebejum*, flatland and *Flacourtia indica,* and *Memecylon plebejum* with *Atalantia monophylla* with the lowest. The total soil properties on Samaesan Island are particularly low in % OC and % total N, while the available phosphorus is high only in the surface soil (0-15 cm), indicating low fertility. Generally, the absolute quantity of soil carbon stock is derived from three basic parameters: the depth of the soil layer, the bulk density, and the carbon concentration [40]. Our aboveground carbon stock research results compare to other research in Thailand, such as Terakunpisut et al.[41], who investigated the carbon sequestration potential in the aboveground biomass of the Thong PhaPhum National Forest, Thailand. This group found that the carbon stock in evergreen forests is the highest followed by dry evergreen forests and mixed deciduous forests (137.73, 70.29 and 48.14 tons C/ha, respectively). However, because of the variability in tree size class, the authors concluded that the greatest carbon sequestration is in mixed deciduous forests followed by tropical rain forests and dry evergreen forests. Similarly, Kaewkrom et al.[42] reported that primary mixed deciduous forests had a higher level of carbon stock in the biomass than secondary mixed deciduous forests. The pattern of organic matter production and accumulation in secondary tropical forests showed a higher aboveground biomass in wet reforest tropical systems than in moist or dry zones. Lugo et al.[43] discovered that tree plantation and natural forest stands in Puerto Rico were able to acquire nutrients from soil, return nutrients via litter fall, and accumulate soil nutrients. Furthermore, the rate of decomposition was species-specific.

When land degradation is extreme, tree planting is necessary and the selection of species is particularly important because tree species differ in their water-and nutrient-use efficiencies. Hughes et al.[44] demonstrated that tropical secondary forests in Mexico have the capacity to function as large carbon and nutrient sinks. They showed that the aboveground biomass increased with increasing site age. In addition, the mean annual aboveground biomass accumulation in the secondary forest was strongly and inversely related to the duration of prior land use.

In the current research study, soil samples were collected only once during the beginning of the rainy season. Thus, it is possible that low moisture caused a decrease in decomposition processes. The primary soil type is sandy clay loam, except in the flatland of the *Flacourtia indica* community, where sandy loam is prevalent. The average soil pH was 5-6, except in the sloping land and upland of the *Memecylon plebejum* communities, where it was 3.5-3.9. Thus, the soil is somewhat acidic. The soil organic carbon is complex and is affected by many factors [45]. Generally, the main factors controlling aboveground and belowground carbon content in tropical and subtropical regions are land use cover and climatic data[46-47]. However, based on the current research, the soil is particularly shallow, and some parts contain rocks, indicating that soil formation occurs rather slowly. Together with less rainfall (compared to the average rainfall in the Chon Buri province), this may have caused low decomposition rates and lower soil nutrient turn-over rates compared to other rainforests[48]. Jobbagy & Jackson[49] found that the SOC content was the highest in wet and cold conditions and in fine-textured soils. The study concluded that the SOC content with precipitation and temperature is the closest in the top 20 cm. In addition, the sand content was negatively correlated with SOC content across all soil depths. This finding research result is the first to attempt the relation between vegetation communities and environmental variables at Samaesan Island further research should adding more soil properties and nutrient in the model to analyses.

Table 6 Carbon content for each vegetation type

Vegetation	Area (ha)	Area (%)	Aboveground Carbon Content		Belowground Carbon Content	
			Carbon content ($tC\ ha^{-1}$)	Total carbon content (tC)	Carbon content until 30 cm depth ($tC\ ha^{-1}$)	Total carbon content (tC)
Memecylon plebejum with *Atalantia monophylla* community (Group 2)	90.07	20.96	43.34	3909.72	35.69	3214.67
Sloping land and Upland *Memecylon plebejum* community (Group 3, 4)	190.61	44.35	29.95	5708.85	50.70	9664.07
Flatland *Flacourtia indica* community (Group 1)	109.49	25.47	10.37	1135.45	48.96	5360.81
Flatland *Dipterocarpus obtusifolius* community (Group 5)	1.57	0.36	25.25	39.60	67.56	105.95

This pioneer knowledge can be used as a baseline for further island ecosystem studies in Thailand. The limitation of this study is about soil properties. Further studies should add information about soil parameter such as nutrient in the soil and nutrient from rainfall which is the main input nutrient for island ecosystem.

Conclusion

Seventy-five plots in literal evergreen forest at Samaesan Island consist of twenty-nine species in 18 families. Vegetation communities are classified as 1) Flatland *Flacourtia indica* community, 2) *Memecylon plebejum* with *Atalantia monophylla* community, 3) Upland *Memecylon plebejum* community, 4) Sloping land *Memecylon plebejum* community and 5) Flatland *Dipterocarpus obtusifolius* community based on physical and biological factors using cluster analysis. CCA biplot showed the partition of environmental variables and vegetation communities. There are only six environmental variables that show significant relationship with vegetation communities. They are the percentile of slop, altitude, percentile of sand, percentile of silt, soil reaction (pH) in the 0-15 cm depth, and soil moisture in the 0-15 cm depth. Other variables are not statistically significant. THEOS image analysis was used to classify the boundary of vegetation area. Unfortunately, the analysis can classify the differences only among 4 vegetation communities. And THEOS could not distinguish the categories between Sloping land and Upland *Memecylon plebejum.* THEOS classification was used to estimate carbon content in each vegetation community. The highest to the lowest amount of carbon stock was found in the *Memecylon plebejum* with *Atalantia monophylla* community, Sloping land and Upland *Memecylon plebejum* community, Flatland *Dipterocarpus obtusifolius* community and Flatland *Flacourtia indica* community respectively. The carbon stock in vegetation communities is not correlated with soil organic carbon at 30-cm depth. This can be explained that trees on Samaesan Island are mainly evergreen not deciduous trees. Therefore there is a small amount of litter that falls into the soil and decomposes as nutrient. On the other hand the turnover rate of nutrient consumed by evergreen forest is very fast. The amount of soil organic carbon content are found from the highest to the lowest as following: 1) Flatland *Dipterocarpus obtusifolius* community, 2) Sloping land and Upland *Memecylon plebejum* community, 3) Flatland *Flacourtia indica* community and 4) *Memecylon plebejum* with *Atalantia monophylla* community. Our study at this small Samaesan Island has revealed essential environmental variables that have significant relationship with vegetation communities. This pioneer knowledge can be used as a baseline for further island ecosystem studies in Thailand. The limitation of this study is about soil properties. Further studies should add information about soil parameter such as nutrient in the soil and nutrient from rainfall which is the main input nutrient for island ecosystem.

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