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Floristic Variation of Tree Communities and Their Association with Soil Properties in Pulau Jerejak, Penang, Peninsular Malaysia

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ABSTRACT

This study was conducted at Pulau Jerejak, Penang to determine the floristic variation of its tree communities. A 0.5-hectare study plot was established and divided into 11 subplots. A total of 587 trees with diameter at breast height (DBH) of 5 cm and above were measured, identified and recorded. The tree communities comprised of 84 species, 63 genera and 32 families. The Myrtaceae was the most speciose family with 10 recorded species while *Syzgium glaucum* (Myrtaceae) was the most frequent species. The Myrtaceae recorded the highest density of 306 individuals while *Syzgium glaucum* (Myrtaceae) had the highest species density of 182 individuals. Total tree basal area (BA) was 21.47 m^2/ha and family with the highest BA was Myrtaceae with 5.81 m^2/ha while at species level, *Syzgium glaucum* (Myrtaceae) was the species with the highest total BA in the plot with value of 4.95 m^2/ha. The Shannon-Weiner Diversity Index of tree communities showed a value of 3.60 (H'max = 4.43) and Evenness Index of 0.81 which indicates high uniformity of tree species. The Margalef Richness Index (R') revealed that the tree species richness was 13.02. Myrtaceae had the highest Importance Value of 20.4%. The Canonical Correspondence Analysis (CCA) showed that *Diospyros buxifolia* (Ebenaceae) and *Pouteria malaccensis* (Sapotaceae) were strongly correlated to low pH. *Dysoxylum cauliflorum* (Meliaceae) and *Eriobotrya bengalensis* (Rosaceae) were correlated to phosphorus (P) and calcium ion (Ca^{2+}), respectively. Therefore, the trees species composition at Pulau Jerejak showed that the biodiversity is high and conservation action should be implemented to protect endangered tree species.

Keywords: *Floristic variation; Tree communities; Trees composition; Pulau Jerejak; Species diversity*

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INTRODUCTION

Tropical forest has high tree diversity and species richness. The tree diversity varies due to difference in biogeography, habitat and disturbance [1]. Many studies have reported that floristic variation is due to environmental factors especially in tropical forests. Environmental factors such as edaphic and topography are associated with tree distribution [2]. The difference in ecosystems and mechanisms become limitation to the researchers to study about tree species composition and floristic pattern [3].

Due to geographical isolation, island ecosystems have become model systems to study evolutionary processes, ecological and biogeographic theories [4,5]. Island are influenced by interacting natural and anthropogenic factors because their ecosystems are limited to includes only the land and surrounding water [6]. The remote island ecosystem is an area of biodiversity, with the impact of anthropogenic activities and extinction of native species, and thus gives significant challenges on biodiversity conservation. It also offers the most appropriate situation for better understanding human relationships with nature and conservation strategies [7].

Island ecosystems have different tree species composition compared to mainland ecosystem due to geographical isolation [8]. The environmental factors at islands contribute major factor towards unique and different tree species. Environmental factors such as soil composition [9], weather [10] and altitude [11] cause variation in tree communities' structure. This paper gives insights into the floristic variation patterns and its relationship to soil parameters at Pulau Jerejak so that the findings can be used for further conservation action.

EXPERIMENTAL

Study Area

Pulau Jerejak (5.31667° N, 100.3000° E) is an island that is located between Penang Island and Seberang Perai. It has an area amounting to 3.62 km^2 and is located at the south-eastern coast of Penang Island [12]. Pulau Jerejak is only minutes away from Penang city and has its own jetty which is located Bayan Lepas. The island is a virgin jungle with rich species diversity of flora and fauna. It consists of different tree communities such as lowland dipterocarp, mangrove, riverine coastal forests and weedy species [12]. The altitude of the island ranges from 115 to 210 m above the sea level. The island is mostly covered by a lowland dipterocarp forest and important timber species can be found here [13].

Tree species enumeration

11 study plots with a total area of 0.5 hectare were established at the study area. In each plot, all woody plants with diameter at breast height (DBH) of 5 cm were counted and identified. A measuring tape was used to measure the DBH of the trees at a height of 1.3 m from the ground surface [14]. Species identification was done after drying process with the help of expert plant taxonomists from Selangor Forestry Department. The morphological characteristics were compared to herbarium specimens and the nomenclature were obtained using keys in Tree Flora of Malaya [15-18] and Malaysia Planet Red List [19].

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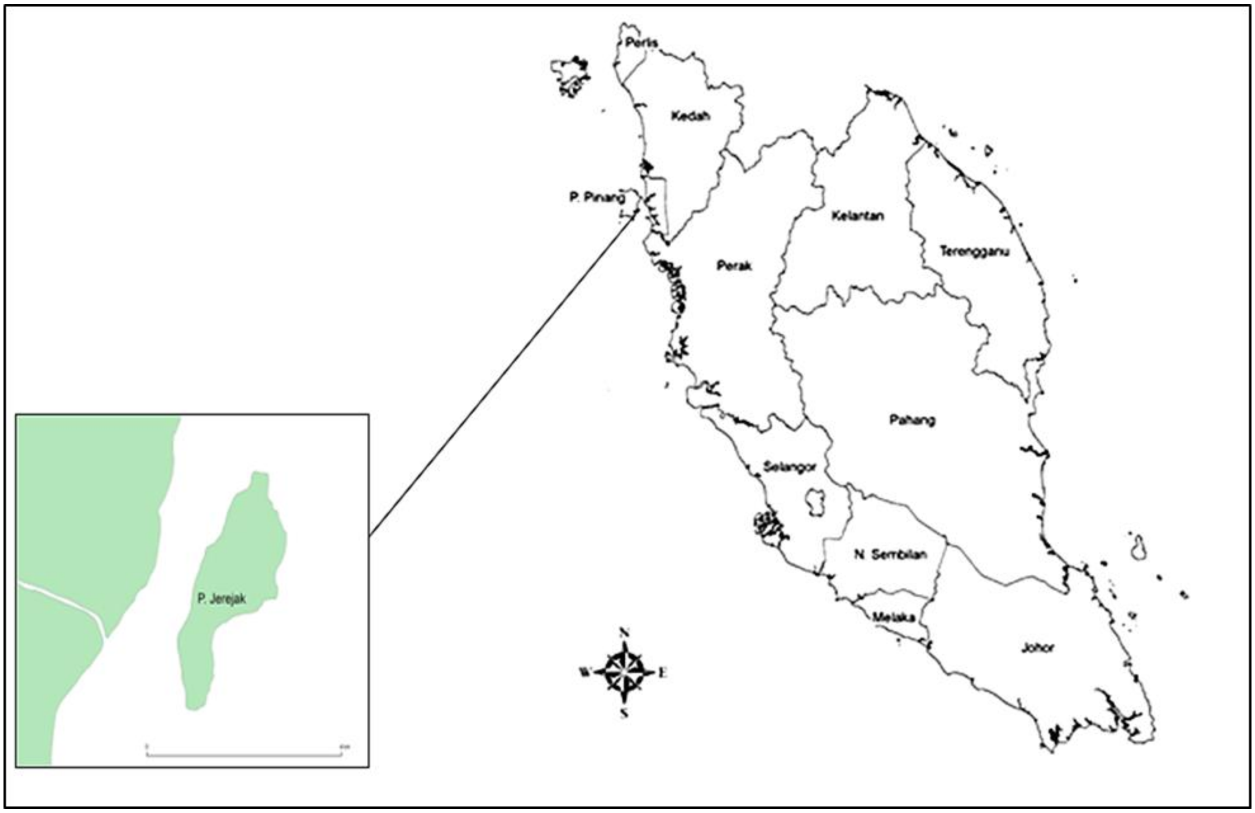

Figure 1: Map of Peninsular Malaysia showing the location of Pulau Jerejak

Soil sampling and analysis

The soil samples were gathered from all 11 plots in order to determine the physical and chemical properties. The leaf litter were removed, and three topsoil samples were taken from each plot at the depth of 0-20 cm. Later, the soil samples were air dried and further analysis were performed. The analysis for physical and chemical properties were conducted to determine the soil particle size distribution [20,21], soil pH [22,23], soil texture [24], base cation, electrical conductivity, exchangeable base cation [25-28], cation exchange capacity (CEC) [29, 30], organics matter (OM) content [31] and available nutrients (Mg, P, K, N and Ca^{2+}) [32].

Data analysis

The data collected from the study plots were tabulated and summarized to determine floristic variations and was used to calculate density, basal area and Importance Value Index (IVi) of trees species. IVi was calculated to determine family or species importance by adding up the values of relative density (R_D), relative dominance (R_B) and relative frequency (R_F), [$IVi = (R_D + R_B + R_F)/3$] [33]. Shannon-Weiner Diversity Index, Margalef Richness Index and Evenness Index was used to determine species diversity and evenness [34,35]. Detrended Correspondence Analysis (DCA) was conducted to determine the

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appropriateness of the data as unimodal by determining the eigen values before proceeding with Canonical Correspondence Analysis (CCA) [36,37]. CCA was performed by using CANOCO version 5.0 to analyse the pattern of tree species distribution in relation to edaphic factors [38].

RESULTS AND DISCUSSION

Floristic composition

A total of 587 trees with diameter at breast height (DBH) of 5 cm and above were enumerated in all plots at Pulau Jerejak. The taxonomic composition of trees consisted of 84 species from 63 genera and 32 families. The number of tree species recorded at Pulau Jerejak was compared to the previous studies from different locations [39-41] (Table 1).

The most speciose family at the study area was the Myrtaceae (10 species) followed by Dipterocarpaceae (9 species) while 15 families were represented by only one species (Bignoniaceae, Chrysobalanaceae, Fagaceae, Flacourtiaceae, Juglandaceae, Lauraceae, Ochnaceae, Opiliaceae, Rhizophoraceae, Rosaceae, Sapindaceae, Simaroubaceae, Sterculiaceae, Tiliaceae and Verbenaceae). The Myrtaceae were also the most speciose family at Endau Rompin State Park, Pahang [42].

Table 1: Number of tree species at Pulau Jerejak with comparison to island studies

Study	Location	Number of tree species recorded
Present study	Pulau Jerejak (0.5 ha)	84
Siti Sofiah (2012)	Pulau Tinggi Forest Reserve (1 ha)	182
Khairil et al (2012)	Pulau Redang (0.2 ha)	98
Ghollasimod et al (2011)	Sungai Pinang Permanent Forest Reserve, Pulau Pangkor (1 ha)	181

The smallest tree diameter was measured at 5.0 cm and the largest diameter was at 80.0 cm. 59.6% of the trees (350 trees) recorded a DBH size ranging from 5.0 cm to 14.9 cm and only 0.34% of the trees (2 trees) had a DBH size of more than 75.0 cm. Of these, *Dialium platysepalum* (Leguminosae) recorded the largest diameter measuring 80.0 cm. A reversed J-shaped curve was plotted showing the number of trees decrease as tree DBH increase which is similar when compared to other studies at forested islands in Peninsular Malaysia [43,44]. The reversed J-shaped curve is commonly found in primary rain forest with many small trees and few large trees [45] where implies the development of stand structure and the occurrence of tree regeneration [46].

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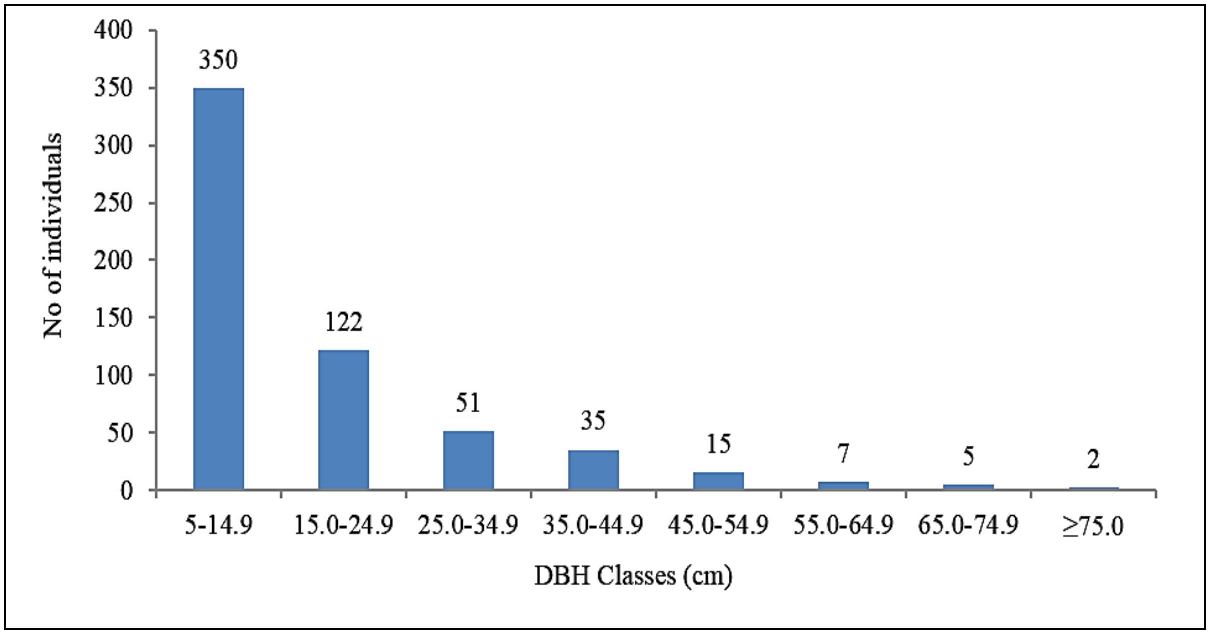

Figure 2: Tree stand structure of different DBH classes in study plots at Pulau Jerejak

Tree diversity

The Shannon-Weiner Diversity Index at Pulau Jerejak showed a value of 3.60 (H'max = 4.43) in which the forest has high diversity if H' value exceeds 5 [47]. Other study at Langkawi Archipelago showed the H' value ranges from 3.6 to 4.34 [48]. The Evenness Index of 0.81 showed that the study area has high uniformity and equal abundance of tree species as it approaches the value of 1 [49] while the Margalef Richness Index (R') of 13.02 indicated high species richness as the index varies according to the species abundance [50].

Abundance and species importance

The total density of trees in all plots was 1174 trees/ha of which Myrtaceae contributed the highest density with 306 trees/ha (26.1%) followed by Anacardiaceae with 130 trees/ha (11.1%). *Syzygium glaucum* (Myrtaceae) with 182 trees/ha recorded the highest species density followed by *Rhodamnia cinerea* (Myrtaceae) with 74 trees/ha (Table 2). The total tree basal area (BA) was 21.47 m^2/ha of which Myrtaceae dominated the highest BA with 5.81 m^2/ha followed by Ixonanthaceae with 2.83 m^2/ha (Table 2). At the species level, *Syzygium glaucum* (Myrtaceae) recorded the highest total BA with a value of 4.95 m^2/ha followed by *Ixonanthes reticulata* (Ixonanthaceae) with a value of 2.61 m^2/ha (Table 2). Bukit Bauk Urban Forest, Terengganu also recorded Myrtaceae with the highest BA of 6.29 m^2/ha [51].

The Myrtaceae recorded the highest family IVi (20.40%) followed by Anacardiaceae (8.44%). High IVi at the family level was also reported for the Myrtaceae in the Bukit Bauk Urban Forest, Terengganu [51]. *Syzygium glaucum* (Myrtaceae) recorded the highest IVi of 14.47%, followed by *Ixonanthes reticulata* (Ixonanthaceae) with an IVi of 2.61% (Table 2). The current study did not demonstrate absolute

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dominance for any tree species or family as an IVi of more than 10% and 40%, respectively is suggestive of dominance [52].

The tree species were also categorized based on the criteria used in the taxon assessment by International Union of Conservation of Nature (IUCN). The species were classified under nine categories; Extinct (EX), Extinct in the Wild (EW), Critically Endangered (CR), Endangered (EN), Vulnerable (VU), Near Threatened (NT), Least Concern (LC), Data Deficient (DD) and Not Evaluated (NE). For example, *Anisoptera scaphula* (Dipterocarpaceae) and *Dipterocarpus grandiflorus* (Dipterocarpaceae) are listed as endangered species under threatened categories according to IUCN Red List Version 2019-2.

Table 2: Summary of tree density, basal area (BA) and Importance Value (IVi) of two leading families and species at Pulau Jerejak

	Family		Species	
Density (trees/ha)	Myrtaceae	306	*Syzygium glaucum*	182
	Anacardiaceae	130	*Rhodamnia cinerea*	74
Basal Area (m^2/ha)	Myrtaceae	5.81	*Syzygium glaucum*	4.95
	Ixonanthaceae	2.83	*Ixonanthes reticulata*	2.61
IVi (%)	Myrtaceae	20.40	*Syzygium glaucum*	14.47
	Anacardiaceae	8.44	*Ixonanthes reticulata*	2.61

Species-area curve

In the study plots, the first plot with an area of 0.05 ha recorded 29 species and accumulated to 43 species in a 0.1 ha plot with addition of 14 other species (Table 3). A gradual accumulation was observed from 0.15 ha to 0.42 ha, where the species number increased from 52 to 83 species. Increment in plot size to 0.50 ha only recorded an increase in two species.

Table 3: Total numbers of species and the increase in tree species (≥ 5cm DBH) a crossed 0.05-ha intervals in the 11 plots at Pulau Jerejak

		No. of species at Pulau Jerejak	
Plot	**Size (ha)**	**Total sp.**	**Total sp. increase**
1	0.05	29	0
2	0.1	43	14
3	0.15	52	9
4	0.2	60	8

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5	0.25	66	6
6	0.3	72	6
7	0.34	76	4
8	0.38	79	3
9	0.42	82	3
10	0.46	83	1
11	0.5	84	1

The mean cumulative numbers of species per 0.05 ha in the study sites was 7.6 species, while the total additional number of species of 0.50 ha in the present study was 84 species. Figure 3 showed that as the size of study area increase, the number of species increase. However, the graph did not show the optimum size. The species richness was not captured because the graph did not reach a plateau and no clear asymptote is noted. Studies in Pulau Pangkor also did not demonstrate species-area curve reaching a plateau [41] but [53,54] suggests that a sampling area between 1-3 ha maybe required for the species richness to achieve plateau.

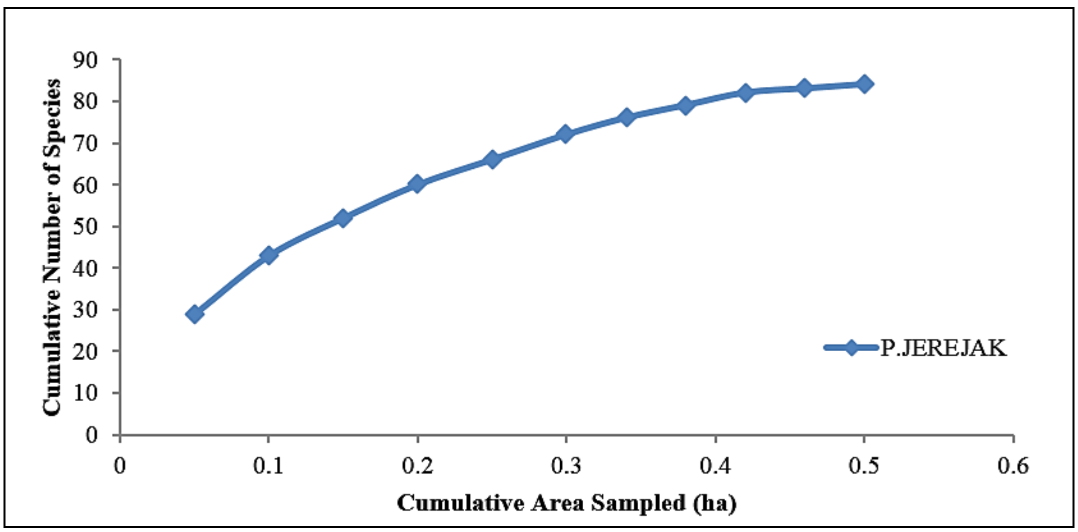

Figure 3: Species-area curve of the study plots at Pulau Jerejak

Relationship of soil factors with tree communities

The Detrended Correspondence Analysis (DCA) (Figure 4) ordination shows that tree species are clustered based on similarities in habitat and species composition. The distance between points among species represents their similarity [55] and the tree species were listed as in Table 6. Species that are closed together such as *Dialium platysepalum* (7), *Madhuca laurifolia* (20) and *Santiria laevigata* (23) had similar position in the ordination are influenced by similar environmental factors. On the contrary, the points that are further away from each other do not share the same environmental factors.

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For example, *Ixonanthes icosandra* (17), *Gynotroches axillaris* (67) and *Licania splendens* (71) are remoted from other points and can be inferred that these species are distributed to different environmental factors.

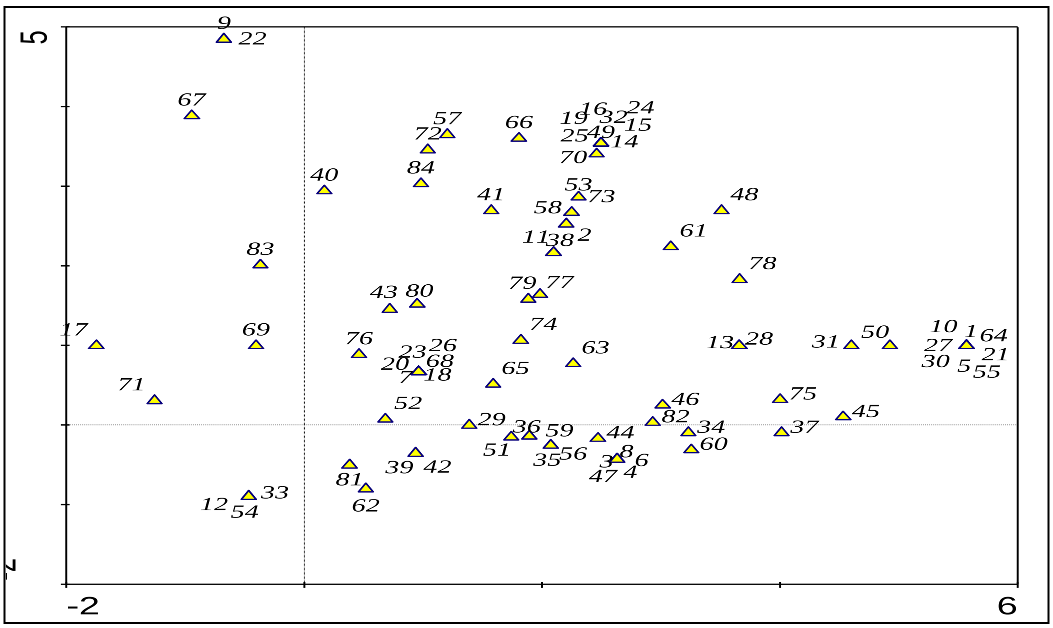

Figure 4: DCA ordination of tree species at Pulau Jerejak

The CCA of the vegetation and soil composition (Table 5) shows that the species-environment correlation is 1.000 for axis 1 (eigen value = 0.641) and axis 2 (eigen value = 0.568), and this indicates a strong relationship between tree species and soil. The cumulative percentage variation for the first three axes was 46.6% and this also suggest that the other factors may have influenced the floristic pattern.

Table 5: Summary of CCA on the tree species and soil composition at Pulau Jerejak

Axes	1	2	3	4	Total inertia
Eigen values	0.641	0.568	0.420	0.397	3.496
Species-environment correlations	1.000	1.000	1.000	1.000	
Cumulative percentage variance of species data	18.3	34.6	46.6	57.9	
Cumulative percentage variance of species-environment relation	18.3	34.6	46.6	57.9	
Sum of all eigenvalues					3.496
Sum of all canonical eigenvalues					3.496

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Tree species such as *Diospyros buxifolia* (43) and *Pouteria malaccensis* (80) were influenced by soil pH; *Dysoxylum cauliflorum* (9) and *Pentace curtisii* (22) showed positive correlation with phosphorus (P) while *Eriobotrya bengalensis* (12) and *Gardenia tubifera* (33) were positively correlated with calcium ion (Ca^{2+}); *Adenanthera pavonina* (1), *Syzygium* sp4 (38) and *Swintonia floribunda* (78) were negatively correlated with calcium ion, magnesium and phosphorus, respectively (Figure 5). As for comparison, trees species distribution at the Endau Rompin State Park, Pahang was influenced by soil parameters in which *Lophopetalum pachyphyllum* (34), *Syzygium palembanicum* (57) and *Xylopia caudata* (63) are strongly correlated with soil pH while *Hydnocarpus woodii* (31), *Pternandra echinata* (43) and *Saurauia pentapetala* (45) are influenced by potassium (K) and ammonium-N [42].

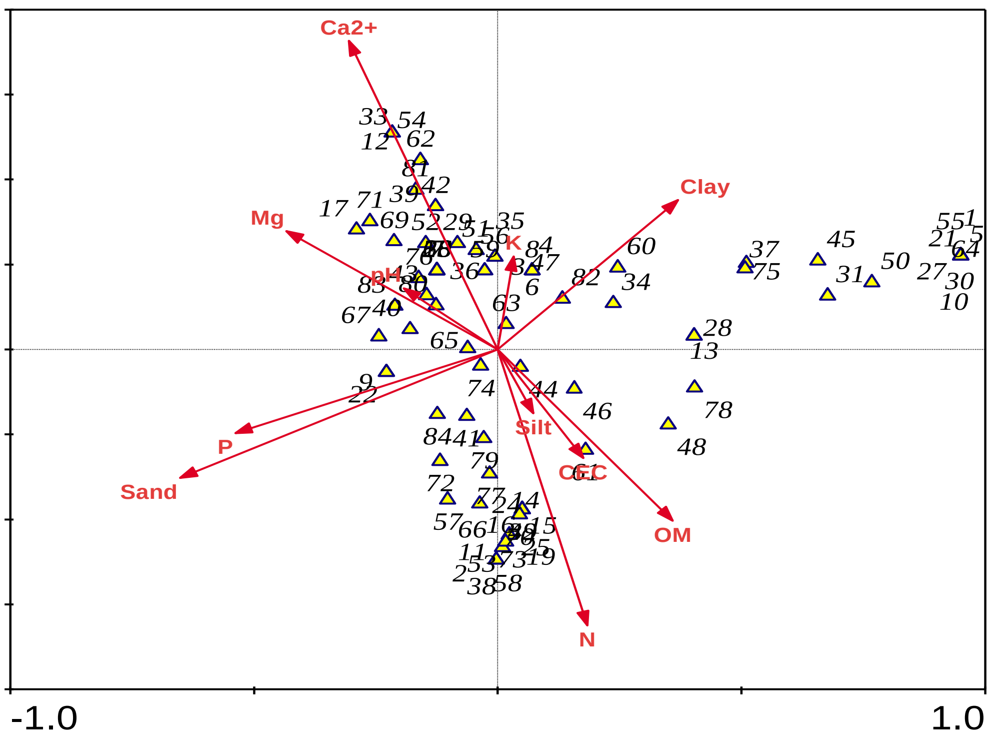

Figure 5: CCA ordination showed species occurrence in relation to edaphic factors at Pulau Jerejak

With respect to plots and edaphic factors, plot 2 and 6 were strongly correlated to calcium ion (Ca^{2+}); plot 4 is strongly correlated to phosphorus (P); plot 5 was highly correlated to potassium (K). The ordination diagram also showed the gradient of variables move toward the lower part than upper part of diagram which favours towards cation exchange capacity (CEC), organic matter content (OM), phosphorus (P), nitrogen (N), silt and sand texture. It showed that the presence of environmental factors influenced the variation in floristic patterns at specific study plots. N, P and K are limited macronutrients at tropical forests in which P helps to increase the production of fine litter while N and K increase the small trees development [56].

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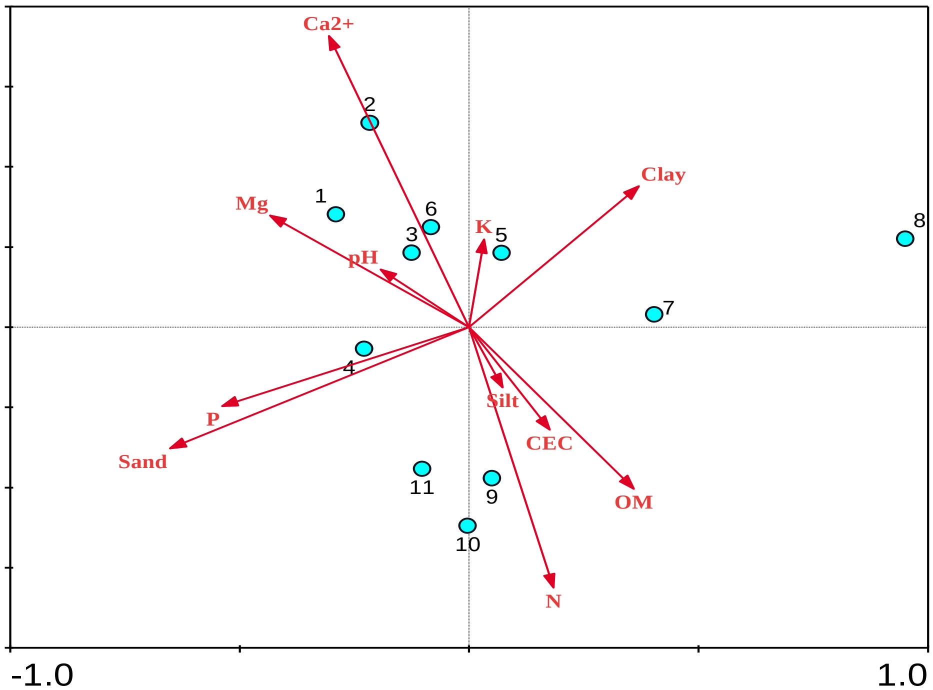

Figure 6: CCA ordination showed location of plots and direction of edaphic factors at Pulau Jerejak

Table 6: List of tree species and its number

No	Species	No	Species	No	Species
1	*Adenanthera pavonina*	29	*Artocarpus kemando*	57	*Timonius compressicaulis*
2	*Agrostistachys gaudichaudii*	30	*Drypetes pendula*	58	*Tristaniopsis merguensis*
3	*Alstonia angustiloba*	31	*Endocomia canarioides*	59	*Xanthophyllum vitellinum*
4	*Beilschmiedia madang*	32	*Ficus fulva*	60	*Aidia densiflora*
5	*Bouea macrophylla*	33	*Gardenia tubifera*	61	*Calophyllum rubiginosum*
6	*Castanopsis inermis*	34	*Horsfieldia brachiate*	62	*Pternandra echinata*
7	*Dialium platysepalum*	35	*Knema intermedia*	63	*Syzygium* sp3

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8	*Dolichandrone spathacea*	36	*Shorea parvifolia*	64	*Vatica pauciflora*
9	*Dysoxylum cauliflorum*	37	*Syzygium* sp1	65	*Endospermum diadenum*
10	*Dysoxylum* sp.1	38	*Syzygium* sp4	66	*Palaquium maingayi*
11	*Engelhardtia roxburghiana*	39	*Adenanthera malayana*	67	*Gynotroches axillaris*
12	*Eriobotrya bengalensis*	40	*Allophylus cobbe*	68	*Dipterocarpus kerrii*
13	*Garcinia atroviridis*	41	*Campylospermum serratum*	69	*Syzygium* sp2
14	*Garcinia eugeniifolia*	42	*Dacryodes longifolia*	70	*Hopea dryobalanoides*
15	*Homalium longifolium*	43	*Diospyros buxifolia*	71	*Licania splendens*
16	*Hopea ferrea*	44	*Diospyros wallichii*	72	*Garcinia hombroniana*
17	*Ixonanthes icosandra*	45	*Dipterocarpus grandiflorus*	73	*Alstonia macrophylla*
18	*Knema hookeriana*	46	*Eurycoma longifolia*	74	*Canthium confertum*
19	*Macaranga hypoleuca*	47	*Ficus variegate*	75	*Teijsmanniodendron coriaceum*
20	*Madhuca laurifolia*	48	*Hullettia dumosa*	76	*Timonius corneri*
21	*Mallotus oblongifolius*	49	*Payena lucida*	77	*Lijndenia laurina*
22	*Pentace curtisii*	50	*Scutinanthe brunnea*	78	*Swintonia floribunda*
23	*Santiria laevigata*	51	*Buchanania arborescens*	79	*Ixonanthes reticulata*
24	*Syzygium* sp5	52	*Champereia manillana*	80	*Pouteria malaccensis*
25	*Syzygium* sp6	53	*Cratoxylum formosum*	81	*Gluta elegans*

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26	*Vatica cuspidata*	54	*Croton argyratus*	82	*Streblus elongatus*
27	*Xanthophyllum affine*	55	*Dacryodes costata*	83	*Rhodamnia cinerea*
28	*Anisoptera scaphula*	56	*Pterospermum javanicum*	84	*Syzygium glaucum*

CONCLUSIONS

Floristic variation patterns showed that Pulau Jerejak has high species diversity and richness due to the environmental gradient that influence the floristic patterns. The stand structure of tree communities in the study site showed that trees with ≥ 5 cm DBH dominated the forest and demonstrated a reverse J-shaped pattern. Threatened tree species such as *Anisoptera scaphula* (Dipterocarpaceae) and *Dipterocarpus grandiflorus* (Dipterocarpaceae) were found at the study area and this requires consideration in order to conserve the unique species. Therefore, it is important to take the initiative by performing *in-situ* conservation at Pulau Jerejak for any species of interest and thus allow us to provide sufficient protection for this valuable island forest ecosystem to ensure its sustainability.

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