Indian Journal of Plant Sciences ISSN: 2319–3824
An Open Access, Online International Journal Available at http://www.cibtech.org/jps.htm
2020 Vol. 9, pp.48-56/ Thảo
Research Article

FLORAL CHARACTERISTICS AND DIVERSITY OF TREES AND SHRUBS OF ANGIOSPERM IN NATURAL VEGETATION ON COASTAL SANDY AREA OF GIO LINH, QUANG TRI, VIET NAM

Hoàng Xuân Thảo*
Department of Biology of Hue University - University of Education, Viet Nam
**Author for Correspondence*: *hoangxuanthao@dhsphue.edu.vn*

ABSTRACT
The study aimed to identify, describe floral characteristics of trees and shrubs of angiosperm, and to compare species composition, diversity indices (richness and Simpson's diversity index) among 3 major habitats in coastal sandy area of Gio Linh district, Quang Tri province, Viet Nam.
A total of 45 quadrats 100 m^2 were laid randomly in natural communities in coastal mobile dunes, seasonal wetlands and stable dunes. The comparison of species composition and diversity indices among habitats were performed with PERMANOVA, SIMPER and ANOVA post hoc test Tukey, respectively. Some 55 species belonging to 45 genera and 22 families were identified. Myrtaceae (7 species - 12.7%), Lauraceae and Phyllanthaceae (both 6 species - 10.9%), Rubiaceae (5 species - 9.1%) were the most dominant families. The main phytogeographical elements were both Indochina endemic and Tropical Asia element, each element had 12 species, accounted for 21.8%; Viet Nam endemic had 10 species and the proportion reached to 18.2%. Species composition was remarkably different among 3 habitats, and overall average dissimilarity was 97.5%. Species richness and Simpson's diversity index increased from coastal mobile dunes (2 species - 0.40) to seasonal wetlands (13 species - 0.75) and then stable dunes (53 species - 0.96). Mean of Simpson's diversity index per quadrat showed significant difference among 3 habitats. Mean of species richness per quadrat of stable dunes revealed noticeable difference between seasonal wetlands and coastal mobile dunes, but the difference was not clearly between seasonal wetlands and coastal mobile dunes. The natural vegetation distributed in study area was fragmented and reduced in size. This study provides some basic data for the conservation and restoration of vegetation in coastal sandy areas of Gio Linh district, Quang Tri, Viet Nam.

Keywords: *Flowering plants, species composition, diversity, sandy area*

INTRODUCTION
Coastal sandy ecosystems show the dynamic of abiotic factors. The change of environmental factors from coast to inland gradient has created many different habitats. The progression of formation and development of sand dunes are associated with the succession of vegetation (Carboni *et al.,* 2010; Doing 1985; Lichter 1998, 2000; Frederiksen *et al.,* 2006; Miller *et al.,* 2010; Peyrat & Fichtner, 2011; Poyyamoli *et al.,* 2012). The interaction of environmental factors of habitats and plants during the succession has formed many types of plant communities with different species composition from coast to inland (Avis & Lubke, 1996). The diversity of habitats also plays a vital role for biodiversity in these ecosystems.
Vegetation of coastal sandy areas are natural barriers to reduce affection of waves, tides, winds, storms, and slow down and then fix the mobility of sandy. Plants also provide several good services for ecosystem and human life. Vegetation give foods, shelter for animals and habitats for other living things in coastal sandy ecosystems. In addition, plants supply a source of medicinal materials, fuel and construction materials to humans. However, natural vegetation of coastal sandy area have being affected by many human impacts such as conversion of land use to agriculture, aquaculture, building houses, roads, tourism that has reduced the area of natural vegetation.
The coastal sandy area of Gio Linh district, Quang Tri province in central Viet Nam where is diversity of habitat types such as mobile dunes, fixed dunes and seasonal wetlands. However, natural vegetation is

strongly influenced by humans. Natural vegetation area has been decreasing and fragmenting that is the reasons of biodiversity loss (Wu, 2013).

Studies on vegetation classification in coastal sandy region in central Viet Nam as well as in Quang Tri had been conducted by Nguyễn *et al.*, (2004) and Nguyễn, (2007). These studies performed representative sampling at some delegate points. These studies showed basically the diversity of plant community types as well as the species composition in central Viet Nam and Quang Tri. There have not been detailed studies for this local area.

Identification of plant species composition, measurement of species richness and diversity in different habitat types play a key role for ecosystem management. Besides, the composition of natural plant species in this ecosystem is a core suggestion in selecting local species for vegetation restoration. This study aimed to investigate the composition of trees and shrubs of flowering plants in the natural vegetation of sandy coastal area of Gio Linh district, Quang Tri province, Viet Nam in different habitats to provide more information for the management and restoration of this sensitive ecosystem.

MATERIALS AND METHODS

Study area

Gio Linh coastal sandy area is located in Quang Tri province, in central Viet Nam. This sandy area has the coordinates of 17.012477° - 16.906389° North latitude, 107.111372° -107.191291° East longitude (figure 1). The sandy soil lengthens from the estuary of Ben Hai River to the Hieu River. The coastline is about 14 kilometers, from the northwest to the southeast. Sandy soil extends to inland about 5.5 km. The topographic is relatively flat and less than 15 meters above sea level in the height.

Climate characteristic of the study area is tropical monsoon. There are two main seasons a year. The rainy season lasts from August to December and from January to August is the dry season. The sum of average rainfall of the in the dry season was 441.8 mm; in the rainy season was 1840.2 mm. In low-lying areas, it is often flooded in the rainy season forming seasonal wetland habitat. The temperature average of a month in the dry season was 25.26°C and the rainy season was 24.92°C (Nguyễn, 2015).

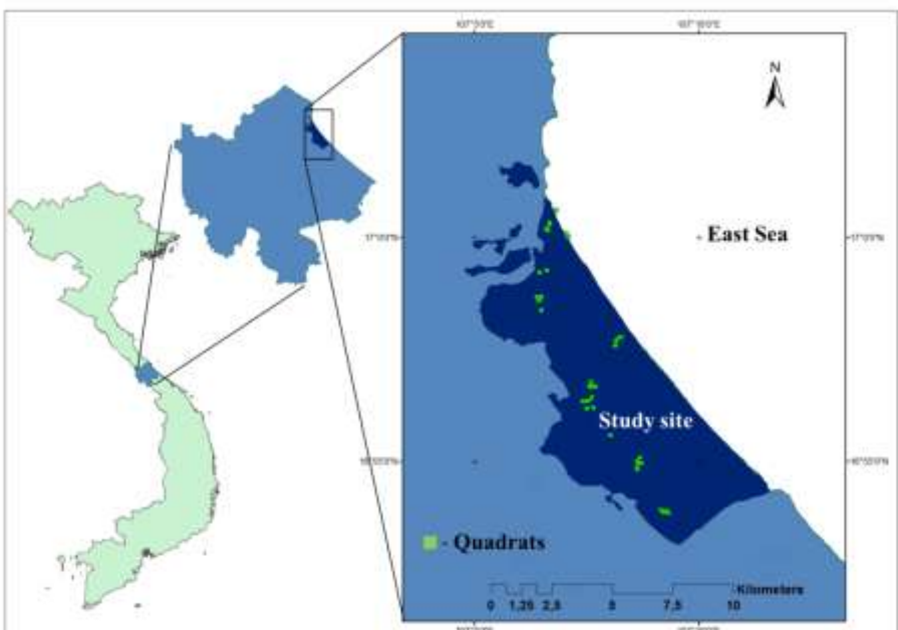

Figure 1: Coastal Sandy area of Gio Linh district, Quang Tri province, Viet Nam

Data collection

A total of 45 random quadrats 10 ×10 m^2 (10 m × 10 m) was set in natural plant communities. The species composition and the number of individuals of trees and shrubs, be higher than 0.5 m, were collected. Habitat conditions, mobile and flooded properties of sandy soil, were defined at each quadrat. The survey period was conducted from March to September 2018.

Data analysis

The geographical elements of trees and shrubs were determined by the guidance of Le *et al.*, (1999). Species richness was defined as the total number of species; Simpson's diversity index (1-D) was used in this study. In each habitat, the individual and number of species in quadrats were made a pool to calculate the diversity indices. Mean of species richness and diversity index per quadrat in each habitat were compared by ANOVA (Magurran 2004) with post-hoc test of Tukey. The Comparison of species composition among habitats was carried out by PERMANOVA (Anderson 2001) and SIMPER (Clarke 1993) was used to estimate the role of species in the difference among habitats. PERMANOVA and SIMPER used abundance data and with Bray-Curtis' dissimilarity index. Data analysis was performed by PAST v3 software (Hammer et al. 2001).

Nomenclature: Following an Illustrated Flora of Viet Nam, vol. 1 to 3 (Phạm, 1999 & 2003) and Flora of Viet Nam vol. 1 to 11 (Viet Nam Academic of Scicence and technology, 2002-2007).

RESULTS AND DISCUSSION

Floral characteristics

Trees and shrubs of angiosperm in study area included 55 species belonging to 45 genera and 22 families (table 1). The richest family was Myrtaceae (7 species - 12.7%), Lauraceae and Phyllanthaceae with the same 6 species (10.9%), Rubiaceae (5 species - 9.1%). Myrsinaceaea and Rutaceae each family had 4 species (7.3%); Euphorbiaceae and Fabaceae had the same 3 species (5.5%); three families including 2 species (3.6%) were Flacourtiaceae, Melastomataceae and Verbenaceae. There were 11 families with only 1 species (Annonaceae, Fagaceae, Clusiaceae, Sapotaceae, Thymelaeaceae, Memecylaceae, Simaroubaceae, Rhizophoraceae, Oleaceae, Pandanaceae, and Poaceae). *Syzygium* consisted of 3 species, three genera had 2 species (*Cinnamomum*, *Embelia* and *Phyllanthus*), and the remaining genera had only 1 species.

Table 1. List of trees and shrubs of angiosperm species

Botanical name	Habits	Phytogeographical elements	Habitats
Annonaceae			
Meiogyne hainanensis (Merr.) Tien Ban	Tree	Indochina endemic	S
Lauraceae			
Litsea glutinosa (Lour.) C. B. Rob.	Tree	Tropical asia element	S
Actinodaphne pilosa (Lour.) Merr.	Tree	Southern China endemic	S
Cinnamomum burmannii (Ness et. T. Nees) Blume	Shrub	Indonesia-Malaysia element	S
Cinnamomum melastomaceum Kost.	Tree	Viet Nam endemic	S
Lindera myrrha (Lour.) Merr.	Shrub	Viet Nam endemic	S
Neolitsea merrilliana C. K. Allen	Shrub	Southern China endemic	S
Fagaceae			
Lithocarpus concentricus (Lour.) Hjelmq.	Tree	Viet Nam endemic	S
Clusiaceae			
Garcinia ferrea Pierre	Tree	Indochina endemic	S

Botanical name	Habits	Phytogeographical elements	Habitats
Sapotaceae			
Planchonella obovata (R. Br.) Pierre	Tree	Indochina endemic	S
Myrsinaceae			
Ardisia splendens Pit.	Tree	Viet Nam endemic	S
Rapanea linearis (Lour.) Moore.	Tree	Southern China endemic	S, W
Embelia picta A. DC.	Tree	India element	S
Embelia henryi Walker.	Shrub	Southern China endemic	S
Flacourtiaceae			
Homalium cochinchinensis (Lour.) Druce.	Tree	Viet Nam endemic	S
Scolopia spinosa (Roxb.) Warb.	Tree	Tropical asia element	S
Thymelaeaceae			
Wikstroemia indica (L.) C. A. Mey.	Shrub	Viet Nam endemic	S
Phyllanthaceae			
Breynia ruticosa (L.) Hook. F.	Shrub	Tropical Asia element	S, W
Cleistanthus pierrei (Gagn.) Croiz.	Shrub	Viet Nam endemic	S
Phyllanthus thaii Thin.	Shrub	Viet Nam endemic	S
Phyllanthus fasciculatus (Lour.) Mull. Arg.	Shrub	Unidentified	S
Aporosa dioica (Robx.) Muell.-Arg.	Tree	Malaysia element	S
Antidesma bunius (L.) Spreng	Shrub	Tropical Asia element	S
Euphorbiaceae			
Alchornea rugosa (Lour.) Mull. Arg.	Shrub	Hainam-Taiwan-Philippines element	S
Croton heteocarpus Mull. Arg.	Shrub	Indonesia-Malaysia element	S
Briedelia monoica (Lour.) Merr.	Shrub	Tropical Asia element	S
Memecylaceae			
Memecylon umbellatum Burm. F.	Shrub	Viet Nam endemic	S
Melastomataceae			
Melastoma affine D. Don	Shrub	Tropical Asia element	S, W
Osbeckia stellata Buchanan-Hamilton ex Kew Gawler	Shrub	Indochina endemic	S, W
Myrtaceae			
Baeckea frutescens L.	Shrub	India element	W
Melaleuca cajuputi P.	Tree	Indochina endemic	S, W
Rhodomyrtus tomentosa (Ait.) Hassk.	Shrub	Tropical Asia element	S
Rhodamnia dumetorum (DC.) Merr.& L. M. Perry	Tree	Indochina endemic	S
Syzygium zeylanicum (L.) DC.	Tree	India element	S, W
Syzygium mekongensis (Gagn.) Merr. Perry.	Shrub	Indochina endemic	S
Syzygium bullockii (Hanc.) Merr. & L.M. Perry	Shrub	Hainan-Taiwan-Philippines element	S, W
Fabaceae			
Ormosia henryi Prain	Tree	Southern China endemic	S
Archidendron bauchei (Gagnep.) I. C. Niels.	Shrub	Indochina endemic	S
Mischocarpus poilane Gagn.	Shrub	Unidentified	S

Botanical name	Habits	Phytogeographical elements	Habitats
Rutaceae			
Acronychia pedunculata (L.)Miq.	Shrub	Tropical Asia element	S, W
Euodia lepta (Spreng.) Merr.	Tree	India element	S, W
Glycosmis pentaphylla (L.) Tan.	Shrub	Tropical Asia element	S
Severinia monophylla (L.) Tan.	Shrub	Tropical Asia element	S
Simaroubaceae			
Eurycoma longifolia Jack.	Tree	Indochina endemic	S
Rhizophoraceae			
Carallia brachiata (Lour.) Merr.	Tree	Malaysia element	S
Rubiaceae			
Fagerlindia scandens (Thunb.) Tirveng.	Tree	Indochina endemic	S
Gardenia angusta (L.) Merr.	Tree	Southern China endemic	S, W
Ixora coccinea L.	Shrub	Viet Nam endemic	S
Pavetta cambodiensis Brem.	Shrub	Indochina endemic	S
Psychotria rubra (Lour.) Poir.	Shrub	India element	S
Verbenaceae			
Clerodendrum paniculatum L.	Shrub	Tropical Asia element	S
Vitex rotundiflora L.	Shrub	Tropical Asia element	M
Oleaceae			
Olea dioica Robx	Shrub	India element	S
Pandanaceae			
Pandanus tectorius Parkinson ex Zucc.	Shrub	Unidentified	M, S, W
Poaceae			
Bambusa bambos (L.) Voss	Tree	Indochina endemic	W

S = Stable dunes, W = Seasonal wetlands, M = Mobile dunes

In total of 55 species, there were 23 species of trees and 32 species of shrubs. The species were distributed on 3 major habitat types: mobile dunes, stable dunes and seasonal wetlands. 10 species distributed on both stable dunes and seasonal wetlands, only 1 species distributed on 3 habitats. The species distributed in only habitats including 1 species only distributed on mobile dunes, 2 species in seasonal wetlands and 41 species in stable dunes.

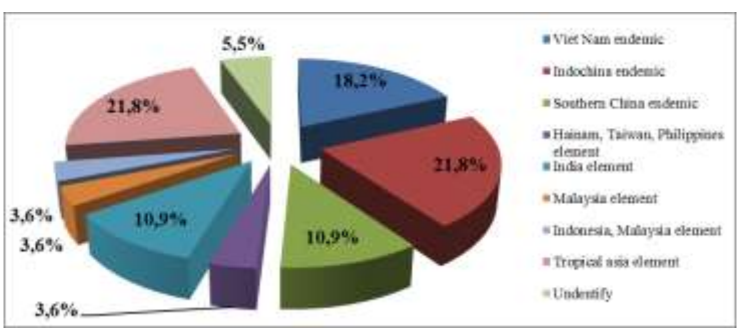

Figure 2: Trees and shrubs of angiosperm species' phytogeographical elements

Trees and shrubs of angiosperm flora at the study site were composed of 8 geographical elements. Viet Nam endemic had 10 species (18.2%); Indochina endemic and Tropical Asia element had both 12 species

(21.8%); Southern China endemic and India element had the same 6 species (10.9%); Hainan-Taiwan-Philippines element, Malaysia element, and Indonesia-Malaysia element had 2 species (3.6%), each; and 3 unspecified species (figure 2). At present, there are no specific studies on phytogeographical elements of this sandy area. Research showed that the trees and shrubs of Viet Nam endemic in this sandy soil were quite high rate.

Species compositions and diversity

Species compositions: Species composition among 3 main types of habitat was significantly different (PERMANOVA, F = 7.349, p = 0.0001) (table 2). The result also revealed remarkable difference between each pair of 3 habitats: Stable dunes - Mobile dunes (F = 4.067, p = 0.0001), Seasonal wetlands - Mobile dunes (F = 4.612, p = 0.0024) and Stable dunes - Seasonal wetlands (10.97, p = 0.0001). The result of SIMPER showed that the overall average dissimilarity of 3 habitats was 97.5%, 3 and 9 species made up 51.46% and 70.04% of cumulative differences, respectively (table 3). Environmental factors changing from coast to in land formed many different habitat types so that plant composition varies among habitats (Moreno-Casasola & Espejel 1986; Munoz-Reinoso & Novo 2005; Van Der Maarel 2003; Martínez 2004). The result of research showed clearly the difference in composition of shrubs and trees in these three main habitat types.

Table 2: The result of PERMANOVA among 3 major habitats

	F	p
Overall habitats	7.349	0.0001
Stable dunes - Mobile dunes	4.067	0.0001
Seasonal flooded -Mobile dunes	4.612	0.0024
Stable dunes - Seasonal flooded	10.97	0.0001

Table 3: The result of SIMPER with 7 species consist of 70.04% of accumulation of overall average dissimilarity

Taxon	Average dissimilarity (%)	Contribution (%)	Cumulation (%)	Mean - Mobile dunes	Mean - Stable dunes	Mean - Seasonal wetlands
Melaleuca cajuputi	22.66	23.24	23.24	0	0.323	24
Osbeckia stellata	14.16	14.53	37.77	0	0.516	16.4
Melastoma affine	13.35	13.69	51.46	0	0.806	19.5
Pandanus tectorius	4.173	4.28	55.74	2.67	0.645	1.82
Syzygium zeylanicum	3.528	3.619	59.36	0	2.1	0.0909
Phyllanthus thaii	3.259	3.342	62.7	0	2.71	0
Cleistanthus pierrei	2.528	2.593	65.3	0	1.61	0
Rapanea linearis	2.379	2.44	67.74	0	1.26	0.182
Euodia lepta	2.25	2.308	70.04	0	0.194	2.91

Species richness and Simpson's diversity index: Species richness among habitats ranged from 2 to 53 species. In each quadrat, species richness fluctuated from 1 to 17 species. Simpson's diversity index among habitats ranged from 0.4 to 0.96 and from 0 to 0.92 in each quadrat. Species richness and diversity index increased from mobile dunes (species richness = 2, Simpson index = 0.4) to seasonal wetland (species richness = 13, Simpson index = 0.75), and then stable dunes (species richness = 53, Simpson index = 0.96) (table 4). The result of ANOVA performed remarkable difference of average species richness and diversity index (ANOVA, F = 21.76, p = 0.0000003). Considering each habitat pair, the average species richness was not noticeably different between the seasonal wetlands and mobile dunes (p

= 0.42), the mean value of the remaining pair of habitats differed clearly. The mean of average diversity index of each habitat pair showed remarkably difference (table 5).

Table 4: Species richness, Simpson's diversity index

Habitat	Number of quadrat	Average number of individual per quadrat	Species richness			Simpson index		
			Range of quadrat	Mean of quadrat	Habitat	Range of quadrat	Mean of quadrat	Habitat
Mobile dunes	3	3.67	1-2	1.33	2	0-0.24	0.08	0.40
Seasonal wetlands	11	71.08	2-7	4.00	13	0.05-0.71	0.50	0.75
Stable dunes	31	27.74	1-17	10.13	53	0-0.92	0.81	0.96
Overalls	45	37.48	1-17	7.91	56	0-0.92	0.68	0.92

Table 5: The result of ANOVA and post-hoc test Tukey of mean species richness, Simpson's diversity index per quadrat

		Mean difference	**p**	**F**
ANOVA			**0.0000003**	**21.76**
Stable dunes - Mobile dunes	Species richness	8.8*	0.0001	
	Simpson index	0.73*	0.00000002	
Seasonal flooded -Mobile dunes	Species richness	2.67	0.42	
	Simpson index	0.42*	0.0009	
Stable dunes - seasonal flooded	Species richness	6.13*	0.00001	
	Simpson index	0.31*	0.00001	

**. The mean difference is significant at the 0.05 level.*

The research results revealed the species richness and diversity index of trees and shrubs was the highest in the stable dunes, followed by seasonal wetlands and then mobile dunes. Environmental factors such as mobility of sand, wind, soil salinity and salt spray made the coastal mobile dunes became a harsh environment (Maun 2009). In addition, in the coastal mobile dunes at the study site, *Casuarina equisetifolia* was planted to create barriers for reducing against the moblility of sand, so that the natural plant communities in mobile sand dunes were strongly impacted and scattered distribution. Therefore, the species of shrubs here were not only poor but also very low in number of individuals. In seasonal wetlands, flooding changed during the year also creates instability in this habitat. The flooding also leads to anaerobic and oxygen-poor environment (Cherry 2011) during the rainy season. These features created the cycling disturbance in seasonal wetland batbitat, therefore, only species adapted to this condition could be distributed. Species richness and diversity index increased from mobile dunes to seasonal wetlands and then fixed sandy areas, where there was less disturbance in the environment. The diversity of communities in stable environment was higher than disturbing environment that was showed by previous studies (Stankeviciute 2001; Isermann 2011).

Conclusions

Tree and shrubs of angiosperm in the study site was quite diversity. The proportion of endemic species in Viet Nam was rather high. Species richness and diversity showed the highest in the stable dunes, followed by seasonal wetlands and then mobile dunes. Species composition and diversity differed significantly among 3 major habitat types. This result revealed the influence of habitat on species composition and diversity indirectly. This research was intended to provide basic information for conservation and restoration.

ACKNOWLEDGEMENT
The author thanks heads of Department of Biology, Hue University - University of Education for their permission to use the botanical laboratory to identify plant species. Thanks to the local committee for supporting in my sampling.

REFERENCES

Anderson MJ (2001). A new method for non-parametric multivariate analysis of variance. *Austral ecology* **26**(1) 32-46.

Avis AM and Lubke RA (1996). Dynamics and succession of coastal dune vegetation in the Eastern Cape, South Africa. *Landscape and Urban Planning* **34**(3-4) 237-253.

Carboni M, Santoro R and Acosta ATR (2010). Are some communities of the coastal dune zonation more susceptible to alien plant invasion? *Journal of Plant Ecology* **3**(2) 139-147.

Cherry JA (2011). Ecology of Wetland Ecosystems: Water, Substrate, and Life. *Nature Education Knowledge* **3**(10) 16.

Clarke KR (1993). Non-parametric multivariate analyses of changes in community structure. *Australian journal of ecology* **18**(1) 117-143.

Doing H (1985). Coastal fore-dune zonation and succession in various parts of the world. In *Ecology of coastal vegetation* (Springer, Dordrecht) 65-75.

Frederiksen L, Kollmann J, Vestergaard P and Bruun HH (2006). A multivariate approach to plant community distribution in the coastal dune zonation of NW Denmark. *Phytocoenologia* **36**(3) 321-342.

Hammer Ø, Harper DA and Ryan PD (2001). PAST: Paleontological statistics software package for education and data analysis. *Palaeontologia electronica* **4**(1) 9.

Isermann M (2011). Patterns in species diversity during succession of coastal dunes. *Journal of Coastal Research* **27**(4) 661-671.

Lê TC, Trần T, Nguyễn HT, Huỳnh N, Đào TP and Trần TV 1999. *Some basic characters of Vietnam flora* (Science and Technology Publishing House, Hanoi) 46-307.

Lichter J (1998). Primary succession and forest development oncoastal Lake Michigan sand dunes. *Ecological Monographs* **68**(4) 487-510.

Lichter J (2000). Colonization constraints during primary succession on coastal Lake Michigan sand dunes. *Journal of Ecology* **88**(5) 825-839.

Magurran AE (2004). *Measuring Biological Diversity* (Blackwell Publishing company, United Kingdom) 151.

Maun AM (2009). *The biology of coastal dunes sand* (Oxfrod University Press, The United States) 1-37.

Martínez ML, Psuty NP and Lubke RA (2004). A perspective on coastal dunes. In: Martınez ML, Psuty NP (eds) *Coastal dunes. Ecology and conservation* (Springer, Heidelberg) 3-10.

Miller TE, Gornish ES and Buckley HL (2010). Climate and coastal dune vegetation: disturbance, recovery, and succession. *Plant ecology* **206**(1) 97.

Moreno-Casasola P and Espejel I (1986). Classification and ordination of coastal sand dune vegetation along the Gulf and Caribbean Sea of Mexico. *Vegetatio* **66**(3) 147-182.

Munoz-Reinoso JC and Novo FG (2005). Multiscale control of vegetation patterns: the case of Donana (SW Spain). *Landscape Ecology* **20**(1) 51-61.

National Center for Natural Sciences and Technology (2002-2007). *Flora of VietNam*, vol. 1 to 11(Science and Technology Publishing House, Ha Noi).

Nguyễn HT, Huỳnh N, Trần TV and Nguyễn VL (2004). *Research on the overall solution, rational use of coastal sand strips in central region from Quang Binh to Binh Thuan (KC 08-21)* (Institute of Geography - Vietnam Academy of Science and Technology, Ha Noi).

Nguyễn HT (2007). *Quang Tri province vegetation* (Science and Technology Publishing House, Ha Noi) 6.
Nguyễn TL (2015). *Study on climate and hydrological changes in Quang Tri province in the period of 1993 - 2013 under the impact of climate change to serve socio-economic development in the province*, Final report of scientific research topic, Department of Science and Technology of Quang Tri Province.
Peyrat J and Fichtner A (2011). Plant species diversity in dry coastal dunes of the southern Baltic coast. *Community ecology* **12**(2) 220-226.
Phạm HH (1999 & 2003). *An Illustrated Flora of Vietnam*, I to III (Tre Publishing House, Ho Chi Minh).
Poyyamoli G, Padmavathy K and Balachandran N (2011). Coastal Sand Dunes–Vegetation Structure, Diversity and Disturbance in Nallavadu Village, Puducherry, India. *Asian Journal of Water, Environment and Pollution* **8**(1) 115-122.
Stankeviciute J (2001). Correlation between species number and homogeneity in plant communities of the Lithuanian seacoast. *Biologija* **2** 105-107.
Van Der Maarel E (2003). Some remarks on the functions of European coastal ecosystems. *Phytocoenologia* **33**(2-3) 187-202.
Wu J (2013). Key concepts and research topics in landscape ecology revisited: 30 years after the Allerton Park workshop. *Landscape ecology* **28**(1) 1-11.