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A STUDY OF MANGROVE FORESTS IN THE KHANH HOA PROVINCE OF VIETNAM*

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In the Socialist Republic of Vietnam, mangrove forests grow in the foreshore of the sea coast and in the river mouths. Mangrove forests play an important role in the coastal tropical ecosystem. They protect the coastline from destroying by tides, fix the soil with root systems and prevent its flushing into the sea, preserve the diversity of species of flora and fauna. With the development of industry in the agrarian country mangrove forests began to be harvested intensively. High level of disturbance of mangrove forests is typical for the Khanh Hoa province. The reduction of forest area has led to a deterioration of the ecological situation in the region; a decrease in the number of species of coastal plants and animals increased the amount of salt in the soil. The primary task for forestry specialists is the study of mangrove forests and the development of methods for their regeneration. We have conducted a research on the mangrove forests in the Khanh Hoa province for 2 years. Two experimental areas were investigated in the mangrove forests formed naturally: the Nhaphu (November, 2017) and Dambay (May, 2018) and in artificially created forests in 2007 in other place of Dambay.
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Introduction

Mangrove forests are common in the humid tropics, mainly along the coasts of East Africa, South Asia, Australia and Oceania [14]. They grow in the zone between the lowest water level at low tide and the highest at high tide – littoral.

They can be found in 118 countries; however, about 75 % of the world's mangrove forests are growing in 15 countries [9]. Asia has the largest area (42 %) of mangrove forests, America (26 %), Africa (21 %), and Australia (12 %). Such a wide spread of these forests around the world is connected with the feature of the seeds of mangrove trees. The seeds ripened on the trees fall off and are carried away by the flow of water to the future place of germination. Seeds of mangrove trees are able to maintain germination for a long time (up to a year) and cross the seas and oceans until they find their harbor, where they take root [5]. Totally there are about 54 species of mangrove trees, and their greatest diversity is found on the coast of Southeast Asia.

*The research has been done under the supervision of professor V.F. Kovyazin.

Mangrove forests – a unique ecosystem that creates favorable conditions for the habitat of various species of flora and fauna [11]. The root system, which grows under the water, slows down the flow, so that in coastal waters there is a high diversity of invertebrates and fish; mangrove forest is the habitat for the larvae of many species of insects [8, 13, 15]. The important role of mangrove forests is to prevent soil flushing and protect the shores from the destructive effects of the ocean. The roots of mangrove forests retain precipitation and strengthen the soil, thereby constraining erosion. In addition, mangrove ecosystems are very important for reproduction of fish, creation of habitats for small animals of the continental shelf, nesting places of birds [3, 4, 12]. According to some data, mangrove ecosystems are more or less associated with the life cycle of up to 90 % of all tropical commercial fish [1]. Mangrove forests reduce the destructive effects of hurricanes and tsunamis, they protect from natural disasters more effectively than artificial protective structures built in the places earlier occupied by mangrove forests [18].

Research methods

Two experimental objects, where natural mangrove forests are growing, were established far from the settlements of Nhaphu and Dambay, so there is no anthropogenic impact on the state of plantations (Fig. 1).

a

b

Fig. 1. Location of experimental areas: *a* – near by Nhaphu, *b* – near by Dambay. Objects are highlighted in red

The third experimental object, where young mangrove forests were artificially created, is located in 20 km to the South from Dambay. The area of each object is 1.0 ha. At each object, inventory of plantations was carried out, with the follow-up calculation of the main inventory parameters. The studies were carried out according to the well-known forestry methodology [4, 19]. Each object was divided into squares with sides of 10 m. Inventory of stands was carried out according to the received squares. In natural mangrove forests (objects 1 and 2) the species composition of stands was determined [10, 16, 17]; in artificial forest plantations the density of planting and inventory parameters of plants were determined [19]. The research results were processed using MS Excel.

Results of research

The analysis of statistical data shows that the area of mangrove forests in Vietnam has been decreasing over the last years. In 1943 there were 408,500 hectares of the forests, and in 1999 there left only 156,608 hectares. Almost 62 % of the mangrove forests were destroyed by human. The Khanh Hoa province has the highest degree of degradation of mangrove forests. Until 1975 the province had about 3,000 hectares of mangrove forests. During 1990–2000 many mangroves were cut down for the construction of pond aquaculture and in 2000 only 100 hectares of mangrove forests remain in the province [2]. As a result of anthropogenic impact, the tree species composition of forests has also changed. At present the province's priority is the study and development of technology of mangrove forests restoration.

According to the study of the tree species composition of mangrove forests, it was found that 11 species of mangroves are found in the stands of the natural origin. The following species dominate: *Rhizophora apiculata* Blume, *Rhizophora mucronata* Lam., *Avicennia officinalis* L., *Aegiceras floridum* Roemer and Schults (Table 1). In the primary mangrove forests of Vietnam there were 37 mangrove species, and more than 30 secondary species [6, 7].

Table 1

The tree species composition of authentic mangroves in the studied mangrove forests

No	Family, species	Experimental plots near by	
		Nhaphu	Dambay
	Avicenniaceae		
1	*Avicennia marina* (Forssk.) Vierh.	+	+
2	*Avicennia officinalis* L.	+	–
	Combretaceae		
3	*Lumnitzera racemosa* Willd.	+	+
	Myrsinaceae		
4	*Aegiceras floridum* Roemer and Schultes	+	+
5	*Aegiceras corniculatum* L.	+	–
	Rhizophoraceae		
6	*Bruguiera gymnorrhiza* (L.)	+	+
7	*Rhizophora apiculata* Blume	+	+
8	*Rhizophora mucronata* Lam.	+	+
	Euphorbiaceae		
9	*Excoecaria agallocha* L.	+	+
	Rubiaceae		
10	*Scyphiphora hydrophylacea* C.F.Gaertn	+	–
	Sonneratiaceae		
11	*Sonneratia alba* Sm.	+	–

Note: here and later on in Table 2, "+" – found species; "–" – absent species.

The species composition of mangrove forests near by settlement Nhaphu is richer than near by Dambay. On the first experimental area the floor includes 11 authentic mangrove species from 7 families, and on the second one only 7 species from 5 families.

In addition to the main species in the mangrove forests there are secondary species (Table 2).

Table 2

Secondary species composition in the studied mangrove forests

No	Family, species	Experimental plots near by	
		Nhaphu	Dambay
	Verbenaceae		
1	*Clerodendron inerme* (L.) Gaertn	+	+
	Asteraceae		
2	*Wedelia biflora* (L.)	+	–
	Malvaceae		
3	*Hibiscus tiliaceus* L.	+	–
4	*Thespesia populnea* (L.) Sol. ex Corrêa	–	+

Secondary species composition in the studied mangroves represented only by 4 species (in Nhaphu – 3 and in Dambay – 2). In general, it can be concluded that these objects of study have a low diversity of mangrove species composition. This is due to their natural origin and violation of the tree species composition of stands in the 90's of the 20th century as a result of uncontrolled felling.

Nowadays in the area near by Nhaphu the mangrove forests' area is about 30 ha; large part of which is artificially restored. The forests are located in the North and West of the Nhaphu village. Here mangroves are being grown in order to reduce the influence of sea waves and wind. In the area of Tuanle 8 ha were reforested; the main species are: *Sonneratia alba* Sm., *Avicennia* sp., *Rhizophora mucronata* Lam.; about 40 ha of mangroves are grown in the Tandao area, the main species of mangroves is *Rhizophora mucronata* Lam.; and in the Mika planting area there are 10 ha of forests; the main planted species are *Sonneratia alba* Sm., *Avicennia* sp., *Rhizophora mucronata* Lam., *Aegiceras corniculatum* L.

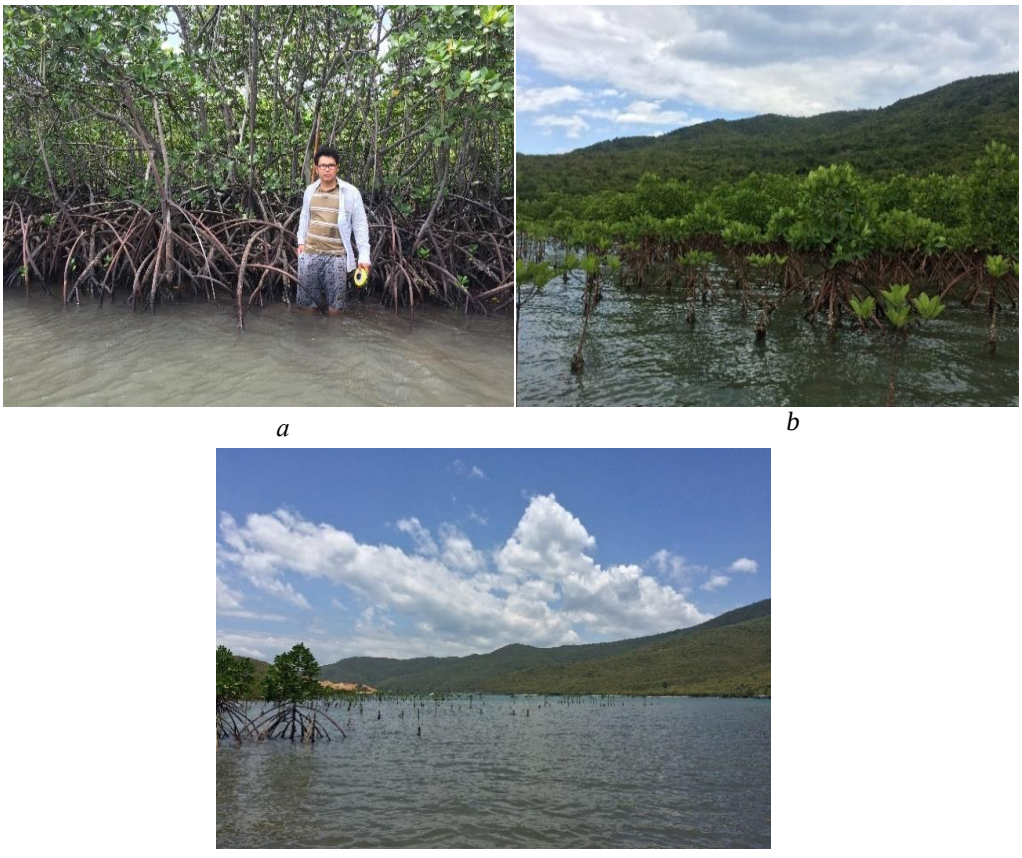
In the Dambay area only 3.4 ha of natural mangrove forests are preserved, which are located in the East, the main species are *Rhizophora apiculata* Blume and *Aegiceras floridum* Roemer and Schultes. At the present in the North and East of the Dambay, mangrove forests are being restored by planting (object 3). Planting was carried out in 2004, 2007 and 2013. Planted species of the mangroves is *Rhizophora apiculata* Blume.

It is planned to plant 400 ha of mangrove forests in the Khanh Hoa province by 2025 and 61 hectares of artificial forests around the city Nhatrang, village Bichdam (11 ha), and other areas in the river of Quantruong basin.

Mangroves that were planted in 2004 and 2007 are well developed and have formed dense thickets (Fig. 2 *a*, *b*), and planted in 2013 are still small and did not form a crown (Fig. 2 *c*). Last year we carried out an inventory of mangroves planted in 2007.

There are 9 investigated squares in total (of 10×10 m size); the first 3 squares were located on the edge of water in the sea; and the following were located closer to the land. The measurement of inventory parameters was carried out during high

tide, so in the squares 1, 2 and 3 the plants are deeply immersed in water (more than 1 m), so we could not measure the diameter of the trunk, which is recommended to measure at a height of 15 cm from the root neck. These plants we classified as the I category. The II category included plants that are flooded with water at 0.5–1 m. These are squares 4, 5, and 6. The diameter of the trunk was measured in mangroves that were flooded with water less than 0.5 m. The III category included plants that were located at the highest place; these are squares 7, 8, and 9. The diameter of the trunk of these plants was determined according to the requirements of forestry research.



a *b*

c

Fig. 2. Artificial mangrove forests in Dambay: *a* – plantations of 2004, *b* – plantations of 2007, *c* – plantations of 2013

The processed results of the plant inventory are given in Table 3.

The results of the studies presented in Table 3 show that the success of the formation of artificial mangrove forests is influenced by the level of flooding of plants during tides. Sea waves in the deep flooding of mangroves shake them and disrupt the root systems and cause mechanical damages of the trunks, which leads to the death of some samples. The greatest density fixed at 11 year old plants (82.33 pcs/0,01 ha) is observed in the plantations without flooding them with sea water (Fig. 3). Salt excess in sea water slows down the physiological processes inside the plants, which leads to a decrease in the growth rate of height and diameter.

Table 3

Inventory parameters of mangroves planted in Dambay in 2007

Parameter	Number of square								
	1	2	3	4	5	6	7	8	9
Density of plants, pcs/0.01 ha	45	53	42	50	57	65	75	89	83
Mean density of plants by category, pcs /0.01 ha		46.67			57.33			82.33	
Height of plants, m	1.7	1.5	1.7	1.7	1.6	1.7	3.5	3.5	3.6
Height of plants, minimum, m	1.15	1.2	1.15	1.2	1.2	1.2	1.5	1.5	1.6
Mean height of plants, m	1.32	1.31	1.33	1.33	1.35	1.32	2.76	2.70	2.66
Mean height of plants by category, m		1.31			1.33			2.7	
Trunk diameter, maximum, cm	–	–	–	2.5	2.6	2.6	5.1	5.2	5.2
Trunk diameter, minimum, cm	–	–	–	2.0	2.0	2.0	2.0	2.0	2.0
Mean trunk diameter of plants, cm	–	–	–	2.10	2.21	2.11	3.54	3.48	3.42
Mean trunk diameter by category, cm		–			2.17			3.47	

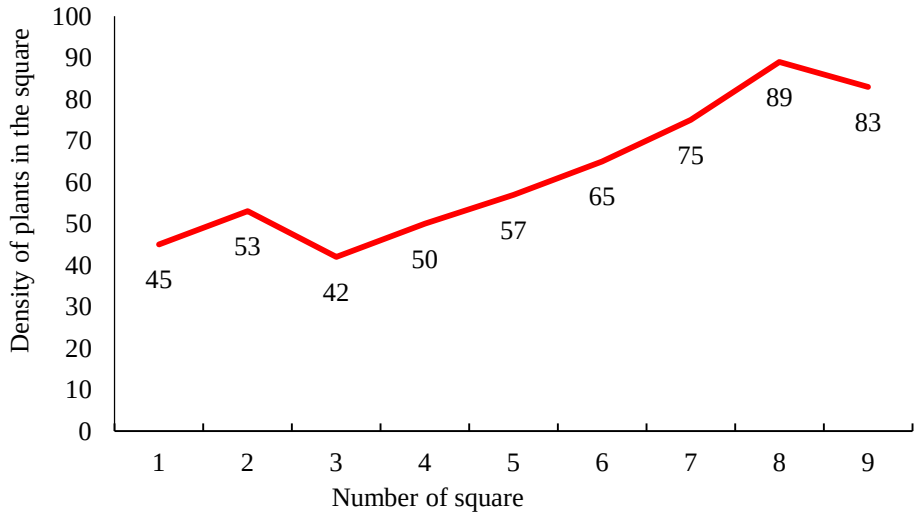


Fig. 3. Density of mangroves in the studied squares

For this reason, the habitus (height and diameter) of plants planted in the tidal zone (squares 1–6) is significantly smaller than the size of mangroves planted outside the zone of the sea waves (squares 7–9) (Fig. 4). ANOVA single factor criterion was used to estimate the reliability of the average values of taxation parameters of plantations. There are no significant differences between inventory indicators of stands ($F<F_{cr}$) of the first two categories of forming forests. If we compare the III category of mangrove forests formation with the II category and especially with the I category, there is a significant difference in the size of inventory indicators ($F>F_{cr}$).

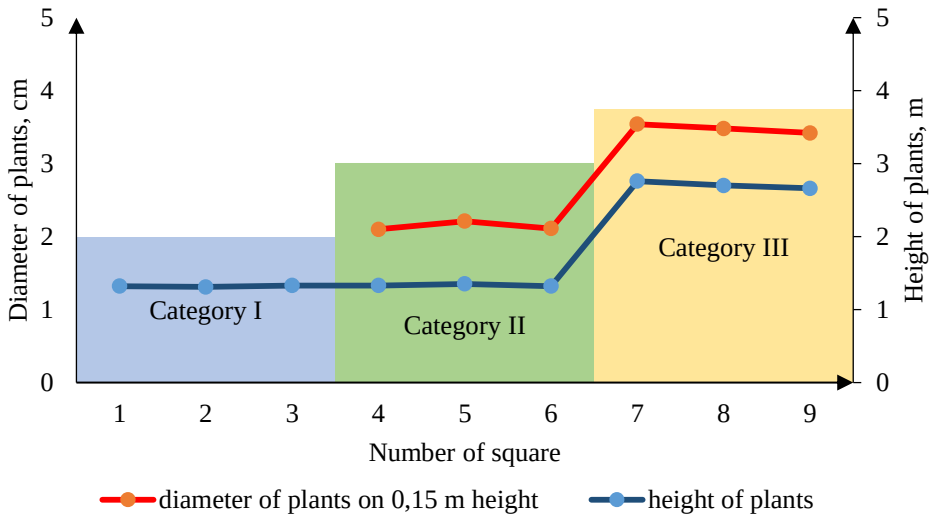


Fig. 4. Inventory indicators of mangroves growing at different water flooding levels

Summary

1. Natural mangrove forests growing close to the settlements Nhaphu and Dambay are characterized by low diversity of plant species. This is due to their intensive exploitation in the late 20th century. In the Khanh Hoa province of Vietnam there are minor areas of natural mangrove forests, and most of them cut down. There are 11 authentic mangrove species and 4 secondary species. The dominant species are *Rhizophora apiculata* Blume, *Rhizophora mucronata* Lam, *Avicennia officinalis* L., *Aegiceras floridum* Roemer and Schultes.

2. Mangrove forests are a unique ecosystem that creates conditions for the habitat of various species of flora, fauna and even invertebrates and fish. The root systems of plants slow down the water flow, prevent erosion, washing away the fertile soil layer, protect the coast from destruction by the ocean waves, hurricanes and tsunamis. In Vietnam, a large area of mangroves has been planted. Comparison of the results showed that the survival of mangrove trees planted in Dambay is not high.

3. In the last decade there has been a trend of artificial reforestation of mangrove forests cut down in the end of the 20th century in Vietnam. The survival of plantations is influenced by many factors; for mangroves – the height of flooding of plantations with the sea water. It has been found that with periodically flooding of forest plantations with water of the sea tide, the growth rate of plants in height and diameter is lower than that of plants constantly growing in the ground. Moreover, the flooding level does not affect the efficiency of formation of plants' inventory indicators. In case of plants flooding by 0.5 and 1.0 m, the inventory indicators remain the same for the 11 forest plantations of mangroves. Plantations grown on land without tides in habitus differ almost 2 times in comparison with tidal areas. The reason for this is the negative impact of sea waves on plants. This fact should be taken into account in the planning of artificial mangroves plantations.

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Исследование мангровых лесов в провинции Кханьхоа во Вьетнаме*

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Мангровые леса Вьетнама растут в приливной полосе морского побережья и в устьях рек. Они играют важную роль в прибрежно-тропической экосистеме и защищают береговую линию от разрушения приливами, закрепляют почву своими корневыми системами и предотвращают ее смыв в море, сохраняют разнообразие видов флоры и фауны. С развитием промышленности во Вьетнаме началась интенсивная вырубка мангровых лесов. Высокий уровень разрушения мангровых лесов характерен для провинции Кханьхоа. Сокращение площади лесов приводит к ухудшению экологической ситуации в регионе, уменьшению числа видов прибрежных растений и животных, увеличению солей в почве. Основной задачей специалистов лесного хозяйства является изучение мангровых лесов и разработка методов их восстановления. Проводятся исследования мангровых лесов в провинции Кханьхоа в течение 2 лет. Изучены два экспериментальных лесных участка, образованных естественным путем: Няфу (ноябрь 2017 г.) и Дамбай (май 2018 г.), а также участки в искусственных лесах Дамбая, посаженные в 2007 г.
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