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LE THANH QUANG

STUDY ON THE RELATIONSHIP BETWEEN THE GROWTH OF *SONNERATIA ALBA* PLANTATIONS AND THE COASTAL ENVIRONMENT OF THUA THIEN HUE

Specialization: **Soil and Water Environment**

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SUMMARY OF TECHNICAL DOCTORAL THESIS

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THESIS WAS COMPLETED AT
THE SOUTHERN INSTITUTE OF WATER RESOURCES RESEARCH

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Scientific Supervisor: Assoc. Prof. Dr. Thai Thanh Luom

Reviewer 1: Professor. Doctor. Nguyen Thi Kim Cuc

Reviewer 2: Doctor. Truong Van Vinh

Reviewer 3: Associate. Professor. Doctor. Hoang Cong Tin

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INTRODUCTION

1. Background

Forests and their environment are inextricably linked (Kimmins, 1998; Nguyen Van Add, 2002). The impact of mangroves (*Sonneratia alba*) on the environment is of concern not only to ecologists, environmental managers and conservators, but also meteorologists, hydrologists, irrigators and foresters. Information about the relationship between forests and the environment helps foresters develop principles for the application of silvicultural methods. Environmental managers and protectors use this information to develop any necessary remediation measures, and irrigators to develop measures to prevent floods and waves damaging irrigation works, and to limit erosion and landslides in riverine and coastal areas.

Previous authors have studied the distribution of mangroves in coastal areas (Thai Van Trung, 1999; Phan Nguyen Hong et al., 1999), Others have investigated the characteristics of soil under the canopy (Do Dinh Sam et al., 2005), the geography (Ngo Dinh Que, 2003), biomass (Vien Ngoc Nam, 1998; Nguyen Hoang Tri, 1999), and growth and cultivation techniques (Dang Cong Buu, 2006) of mangroves. However, these studies have not yet clarified the dynamics of the relationship between soil, water, and mangrove growth. This information is required to assist in making decisions on mangroves planting, and for developing measures to protect and improve riparian and marine environments.

Stemming from the above, this thesis analyzes the relationship between soil and water characteristics and mangrove growth in the central coastal region. There are many species of mangroves. This study focuses on the relationship between soil and water characteristics and the growth of plantations of the mangrove *Sonneratia alba* in the coastal area of Thua Thien Hue province. Four main questions are addressed. 1. How does site type affect the growth of the *S. alba* plantations? 2. How different are the characteristics of soil and water under the canopy of *Sonneratia alba* plantations compared to non-forested land (hereinafter referred to as bare land)? 3. How do soil and water characteristics relate to *Sonneratia alba* plantations? 4. The growth of *Sonneratia alba* plantations depends mostly on which characteristics of soil and water?

2. Research objectives

2.1. General objectives

Provide scientific bases for choosing sites for *Sonneratia alba* plantations and for developing measures to protect and improve the estuarine and marine environment

2.2. Specific objectives

(1) Analysis of the growth of *Sonneratia alba* plantations on different forms of site.

(2) Identification of soil and water characteristics under the canopy of *Sonneratia alba plantations* and bare land.

(3) Analyze and determine the relationship between some characteristics of soil and water with the growth of *Sonneratia alba plantations.*

3. Scope of research

The scope of the thesis is the relationship between soil and water characteristics and the growth of *S. alba* plantations. The research content is: (1) Growth of *S. alba* plantations*;* (2) Characteristics of soil and water under the canopy of S. alba plantations and bare land; (3) The relationship between soil and water characteristics and the growth of *S. alba* plantations. The research site type is located in the Con Te area in the mouth of Thuan An Sea in Thua Thien Hue province. The study period was from 2016 to 2020.

4. Significance of the thesis (Scientific significance and practical significance of the thesis)

Scientific significance of the thesis: The thesis provides information to analyze the relationship between mangroves and the characteristics of soil and water.

Practical significance of the thesis: The project not only provides information on site selection for *S. alba* plantations, but also on measures to protect and improve the environment such as limiting the harmful effects of floods, high winds and waves, and riverine erosion and coastal landslides.

5. New findings of the thesis

(1) The thesis demonstrated that *S. alba* plantations are best adapted to grow on Site type II, and poorly adapted to Site type III. Planting on Site type II is recommended.

(2) The thesis showed that the characteristics of the soil under the canopy of *S. alba* plantations varied according to their complexity. Increased complexity led to a marked increase in pH-H_2O, humus content, nitrogen, phosphorus, potassium, and clay ratio, and reduced the (toxic) content of Al^{3+}, Fe^{2+}, SO_4^{2-} in the 0-50 cm-depth soil layer.

(3) The thesis has shown that increased complexity of *S. alba* plantations led to a marked decrease in salinity, contents of Al^{3+}, Fe^{2+} and SO_4^{2-} in the aquatic environment.

(4) The growth of *Sonneratia alba* plantations is strictly dependent on the characteristics of the soil and water. An increase in the content of N, P and Al^{3+} in the 0-50 cm-depth soil layer leads to an increase in the complexity of *S. alba* plantations. On the contrary, an increase in Fe^{2+} content leads to a decline in their complexity. An increase in the content of salts, Al^{3+} and Fe^{2+} in water also leads to a decline in their complexity*;* on the contrary, an increase in the content of SO_4^{2-} leads to an increase in complexity.

6. Layout of the thesis

The layout of the thesis consists of an introduction, 3 chapters and a conclusion. Chapter 1: Overview. Chapter 2: Research subjects, contents, and methods. Chapter 3: Research Findings and Discussion. Conclusions and recommendations. The thesis consists of 144 pages; 76 tables; 9 Figures; 18 Graphs; 13 Appendixes. The thesis references 50 domestic and foreign documents.

Chapter 1: OVERVIEW

From 53 references, the thesis reviewed the distribution, species composition, structure and growth of mangroves, and mangrove settings, cultivation and cultivation techniques, yield, and material cycling. Issues to be discussed were stated.

1) Most of the previous research on mangroves in Vietnam has focused on determining their distribution, species composition, structure and growth, eccentricity, incubation and cultivation techniques, yield, and material cycling. In this study, this research base is further developed for planting *Sonneratia alba* plantations in the coastal area of Thua Thien Hue province.

2) Previous research on mangroves in Vietnam has not yet clarified the dynamics of soil and water characteristics under mangroves, and the interrelationship between environmental factors and mangrove growth. In this study, this thesis analyzes the variability of some soil and water characteristics under mangrove plantations, and the relationship between soil and water characteristics and mangrove growth.

Chapter 2: SUBJECTS, CONTENTS, RESEARCH METHODS

2.1. Subjects of study

(1) The object of study was the relationship between soil and water characteristics and the growth of 4-year-old *S. alba* plantations.

2.2. Research content

(2) Growth of *S. alba* plantations on different sites.
(3) Characteristic of the soil under the canopy of *S. alba* plantations
(4) The relationship between the soil and the growth of *S. alba* plantations
(5) The relationship between water and the growth of *S. alba* plantations
(6) The relationship between of *S. alba* plantations and soil and water.

2.3. Research methodology

2.3.1. Methodology bases

This research is based on 5 basic theses. **One is** that the forest is an ecosystem in which the components are closely related. **The second** is that forests consist of many different characteristics which are difficult to accurately measure. To simplify the analysis of the relationship between forests and the environment, the thesis analyzed the influence of the forest structure index (SCI) on the soil and water environment. **Third**, forest habitats consist of many different elements, and they interact with each other in a complex way. For simplicity, foresters divide forest habitats into different formations. According to the 3rd methodology base, this thesis analyzes the influence of site type on the growth of *S. alba* plantations*;* **Fourth**, the growth and development of forests changes with age. In this study, the thesis analyzed the growth of *S. alba* plantations over a period of 4-year-old. **Fifth,** the relationship between soil and water characteristics and forest growth can be determined by a variety of methods. In this study, this problem was identified by the method of correlation analysis.

From the above 5 theses, the research direction was to use experimental ecological methods to analyze the relationship between soil and water with the growth of *Sonneratia alba* plantations. The research sequence consists of 4 steps. **Step 1**: Arrangement of *S. alba plantations;* experiments on different sites. **Step 2**: Analyze the growth of *S. alba* plantations by age on three different sites. **Step 3:** Determine the characteristics of the soil and water under the canopy of *S. alba* plantations. **Step 4**: Analyze the relationship between some characteristics of soil and water with the growth of *S. alba* plantations. The results of step 1 are the basis for analysis of the growth of *S. alba plantations* and the relationship between the forest and the environment. The results of step 2 are used to provide the evidence to answer question 1 that the thesis specifies. The results of steps 3 and 4 are the evidence to answer questions 2 and 3 that the thesis specifies.

2.3. 2 . Research hypotheses

Hypothesis 1: Geography form has a negligible effect on the growth of *S. alba* plantations. This hypothesis is clarified through a comparative analysis of the growth of *S. alba* plantations across three different geographical forms.

Hypothesis 2: The characteristics of soil and water under the canopy of *S. alba* plantations and non-forested open land are the same. This hypothesis is clarified through comparative analysis of the characteristics of soil and water in bare land with soil and water under the canopy of *S. alba* plantations

Hypothesis 3: Increased structural complexity of *S. alba* plantations has a subtle effect on soil and water characteristics. This hypothesis is clarified through analysis of the relationship between some characteristics of soil and water and the growth of *S. alba* plantations

Hypothesis 4: The growth of *Sonneratia alba* plantations does not depend on soil and water characteristics. This hypothesis is clarified through analysis of the relationship between *S. alba* plantations and the characteristics of soil and water.

2.3.3. Methods of experimental layout and data collection

2.3.3.1 Identify suitable sites for planting S. alba plantations

Divide the 3 types of sites based on the following criteria (I) drying time, tidal flooding level (h/day), (II) average salinity (‰), and (III) mechanized composition and soil maturity.

This section identifies the evidence to support hypothesis 1. To determine the influence of sites on *S. alba plantations*, the thesis follows 2 steps.

Step 1. *Sonneratia alba* plantation afforestation on three sites. Site type consists of three forms (I, II and III) according to the classification of Ngo Dinh Que (2003). *Sonneratia alba* plantations were grown from 6-month-old seedlings. Seedlings are sown in 25 × 30 cm polyethylene gourd bags. The selected seedlings were plants that would grow well, with straight stems and were free from pests and diseases; the root diameter (D_0) and height (H) were > 0.5 cm and 50 cm respectively. The time of planting was the middle of March, and the time of a daywas when the tide was lowest. Seedlings were planted in rows. The trees were arranged in a direction perpendicular to the coast. The initial afforestation density was 3,300 trees per hectare (spacing 1.5 ×2.0 m). To help seedlings counter high waves and winds, each seedling was firmed with 3 bamboo poles with a diameter of 2 – 3cm and a height of 100 – 150 cm. The stakes were inserted to 40-60 cm depth; then the seedlings were tied to the stakes at 2/3 stem height. The surroundings of the test plot were protected by bamboo fences against large waves

and moss. There were three replications of each site type. Each experimental plot was rectangular in shape with an area of 300 m^2 (15 ×20 m).

Step 2. Collecting growth data. The response of *S. alba plantations* to site type was assessed at age 6 months and 1-4 years after planting. Growth of *Sonneratia alba* plantations per site type was measured on 30 trees in a 100 m^2 (10 m × 10 m) sample plot; where each iteration of measurement form was 10 trees. The sample plots were located in the center of the experimental batch. The impact of site type was assessed through measurements of survival rate (SR%), growth, quality, and stability of the plantations 4 years after planting. The research variables were existing density (N, tree), root diameter (D_0, cm), whole body height (H, cm), canopy diameter (Dcanopy, cm), biomass (B, kg), plant quality (good, average, bad).

2.3.3.2. Determination of soil and water characteristics under the canopy

This section identifies the evidence to support hypotheses 2 and 3. The characterization of bare soil before afforestation and soil under the canopy of *Sonneratia alba* plantations aged 1 – 4 years on each type was determined from 3 soil profiles, where each soil profile represents 1 replication. The soil profiles were arranged in the center of the experimental batches. The size of the soil area is 70 × 150 cm (*length*, *width*). Because the plantations were young and the root system shallow, 0.5 – 1.0 kg soil samples were only collected in the soil depths 0 – 20 cm and 20 – 50 cm-depths.

The characteristics of bare land and land under the plantation canopy were assessed through 10 indicators: pH-H_2O, pH-KCl, humus (%), total nitrogen (N%), phosphorus (P_2O_5%), potassium (K_2O%), Al^{3+}(me/100 g), Fe2+(me/100 g), SO_4^{2-} (me/100 g), mechanized composition (% of clay, silt and sand, %). pH-H2O extracted by water, soil and water ratio 1:5, measured by pH meter, pH-KCl 1N, soil ratio and KCl solution by ratio 1:5, measured by pH meter according to TCVN 5979: 2007 (Standards of Viet Nam, TCVN). Humus content was determined by the Walkley-Black method, oxidation by concentrated H_2SO_4 mixture - $K_2Cr_2O_7$, titration by $FeSO_4$ 0.5 N according to TCVN-8726-2012, total nitrogen (%N) determined by Kjeldhall's method according to TCVN 6645:2000, total phosphorus (%P_2O_5) inorganic soil sample by H_2SO_4 and $HClO_4$. Show color with phosphomolybdate with reducing agent ascorbic acid. Color measurement by spectrograph at wavelength 880 nm according to TCVN 8940: 2011. Total potassium (% K_2O) inorganic soil samples by H_2SO_4 and $HClO_4$ and is measured by flame photometer according to: TCVN 8660: 2011. Three toxic components

Al^{3+}, Fe^{2+} and SO_4^{2-} were measured by UV-Vis colorimeters according to TCVN 4403: 2011, Fe2+: according to TCVN 12202-8: 2018 and SO_4^{2-} according to TCVN 8727: 2012. The mechanized composition of soil was determined by the composition (% clay, % Silt, and % sand) using the Robinson straw method according to TCVN 8567: 2010 Water sampling method: pH: TCVN 5979: 2007, dissolved oxygen (DO): TCVN 7325: 2016, salinity: TCVN 9167: 2012, Fe^{2+}: TCVN 6177: 1996, Al^{3+} Total: TCVN 6657: 2000, SO_4^{2-}: TCVN 6656: 2000.

The effect of forests on water characteristics was only analyzed for *Sonneratia alba* plantations aged 1-4 years on site type II. This is the form of site type that ensures the best growth. Each subject collected 3 water samples. Analysis criteria were pH_{H2O}, dissolved oxygen content (DO, mg/l), salinity, ‰), Al^{3+}content (me/100g), Fe^{2+}content (me/100g) and SO_4^{2-} content (me/100g). The pH-$_{H2O}$ was determined by a pH meter. The DO content was determined by electrode measurement. Water salinity was measured with a salinity meter (refractometer). The three components Al^{3+}, Fe^{2+} and SO_4^{2-} were determined by colorimetry. All these indicators were measured on the 15^{th} lunar day of every month; then averaged out the year. Water samples were analyzed at the soil and water environment laboratory of the Forestry Sciences Institute of South Vietnam.

2.3.4 Data processing methods

2.3.4.1. Growth analysis of Sonneratia alba plantations

The data processing method for the growth of *Sonneratia alba* plantations was carried out in 8 steps. **Step l.** Calculate the survival rate (SR%). **Step 2.** Aggregate measurements D_0, H, D_T by age (A = 6 months and 1 – 4 years) across three site types. **Step 3.** Calculate the SCI index across site types. **Step 4**. The level of between-tree competition. **Step 5**. Analysis of wood reserves. **Step 6**. Analysis of tree biomass. **Step 7**. Analysis of the stability of the plantations across the three site types. **Step 8**. Set up suitable site type for planting *Sonneratia alba*. The appropriate location was selected according to the Max standard (Survival rate, D_0, H, M, B).

2.3.4.2. Analysis of soil and water characteristics under the canopy of

Determine the statistics describing the characteristics of soil and water under the canopy of *Sonneratia alba* plantations and bare land. Then compare the differences between soil and water characteristics by plantations age across three sites.

2.3.4.3. Analyze the *relationship between soil and water with the growth of Sonneratia alba plantations*

The relationship between soil and water characteristics and the SCI index of *Sonneratia alba plantations* was analyzed according to Spearman's grade correlation coefficient

2.3.4.4. Analyze the relationship between Sonneratia alba plantations of soil and water

The relationship between *Sonneratia alba plantations* and soil characteristics was described by the model (2.1).

$SCI = f(N, P, K, Al, Fe, SO_4)$ (2.1)

The relationship between *Sonneratia alba* plantations and water characteristics was described by the model (2.2).

$SCI = f(Salinity, Al, Fe, SO_4)$ (2.2)

The role of each soil and water characteristic in *Sonneratia alba* plantations growth was assessed according to the regression coefficient. The order of role contribution from large to small was determined through the absolute value of the normalized regression coefficient.

All descriptive statistical calculations, hypothesis testing and graphing were performed using Excel software and STATGRAPHICS Centurion version XV.I

Chapter 3 : RESEARCH FINDING AND DISCUSSION

3.1. Growth of *Sonneratia alba plantations* on different sites

3. 1. 1. Growth in diameter and height

Statistical characteristics of the diameter and height of *Sonneratia alba* plantations *on* the three-site type are summarized in Table 3. 1 - 3. 5.

Table 3. 1. Diameter growth of *Sonneratia alba plantations* on three site types.

A (year)	D_{0Bq} (cm)	Min	Max	±SEE	CV%	N (tree/ha	Survival rate N (%)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Site type I							
6 months	0.9	0.8	1.1	0.10	10.7	3.082	93.39
1	1.8	1.5	2.0	0.16	8.9	2,987	90.52
2	2.6	2.1	3.2	0.36	13.5	2.914	88.30
3	4.5	4.3	4.6	0.13	2.8	2.864	86.79
4	7.0	6.7	7.3	0.21	2.9	2.828	85.70
Site type II							
6 months	1.0	0.8	1.1	0.10	10.5	3.145	95.30

1	2.0	1.7	2.2	0.16	8.0	3.059	92.70
2	2.9	2.3	3.4	0.31	10.9	2,987	90.52
3	7.2	6.7	7.6	0.36	5.0	2.914	88.30
4	10.7	10.2	11.1	0.32	3.0	2.871	87.00
Site type III							
6 months	0.9	0.8	1.1	0.11	11.4	2.492	75.52
1	1.5	1.2	1.7	0.17	11.4	2.386	72.30
2	2.4	1.8	2.9	0.34	14.1	2.264	68.61
3	3.3	3.1	3.6	0.15	4.7	2.053	62.21
4	6.3	6.1	6.4	0.15	2.4	1,993	60.39

Table 3. 2. The height growth of *Sonneratia alba* plantations on three site type.

A (year)	H (cm)	Min	Max	±SEE	CV%
(1)	(2)	(3)	(4)	(5)	(6)
Site type I					
6 months	57.4	48	66	5.4	9.5
1	96.0	92	99	2.1	2.2
2	123.0	115	131	4.7	3.8
3	154.8	152	158	2.1	1.4
4	284.7	275	294	6.1	2.1
Site type II					
6 months	59.3	56	63	2.1	3.5
1	102.1	62	106	5.2	5.1
2	136.8	129	145	4.7	3.5
3	179.7	177	183	2.0	1.1
4	326.8	317	336	5.9	1.8
Site type III					
6 months	57.8	48	66	5.6	9.6
first	89.3	86	93	2.5	2.8
2	112.6	105	121	4.7	4.2
3	134.8	130	140	3.2	2.3
4	211.4	174	240	22.4	10.6

Analysis of the growth process of the *Sonneratia alba* plantations in the period of 4 years (Table 3. 3 – 3.5) shows two quantities ZD_0 and ΔD_0 (what do these variables mean? – you should perhaps provide a definition in the Table legend or as a Table footnote) on the three-site type all increased with age.

Compared with the average ZD_0 and D_0 on site type III (1.5 cm and 1.3 cm respectively), these two quantities on site type I (1.7 cm and 1.5 cm respectively) are larger respectively 15.4% and 19.5%. Similarly, these two quantities on site type II (2.7 cm and 2.0 cm respectively) are 83.1% and 60.3% larger, respectively. The two quantities ZH and ΔH on the three-site type also increase with age. Compared with the average ZH and H on site type III (47.8 cm and 60.2 cm respectively), these two quantities on site type I (63.5 cm and 67.9 cm respectively) are 32 .7% and 12.9%. Similarly, these two quantities on site type II (73.9cm and 75.2cm respectively) are 54.5% and 25.0% larger, respectively. In general, the plantations of Sonneratia alba plantations on site type II grow faster than on site type I and III.

Table 3.3. Growth in diameter and height of *Sonneratia alba* plantations on site type I.

A (year)	Amount of growth in diameter:				Amount of height growth:			
	D_0 (cm)	ZD_0	D_0	Pd(%)	H (cm)	ZH	H	Ph(%)
(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*	*(9)*
1	1.3	1.3	1.3	100.0	74.0	74.0	74.0	100.0
2	3.0	1.7	1.5	55.5	137.1	63.1	68.5	46.0
3	4.8	1.8	1.6	37.8	196.6	59.5	65.5	30.3
4	6.7	1.9	1.7	28.6	253.9	57.3	63.5	22.6
Medium		1.7	1.5			63.5	67.9	

Table 3. 4. Growth in diameter and height of the *Sonneratia alba* plantations on site type II.

A (year)	Amount of growth in diameter:				Amount of height growth:			
	D_0 (cm)	ZD_0	D_0	Pd(%)	H (cm)	ZH	H	Ph(%)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1	1.3	1.3	1.3	100.0	77.0	77.0	77.0	100.0
2	3.8	2.4	1.9	64.7	150.9	73.9	75.4	49.0
3	6.9	3.2	2.3	45.6	223.6	72.7	74.5	32.5
4	10.7	3.7	2.7	35.1	295.6	72.0	73.9	24.4
Medium		2.7	2.0			73.9	75.2	

Table 3.5. Growth in diameter and height of the *Sonneratia alba* plantations on site type III.

A (year)	Amount of growth in diameter:	Amount of height growth:

	D_0 (cm)	ZD_0	D_0	Pd (%)	H (cm)	ZH	H	Ph(%)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1	1.1	1.1	1.1	100.0	78.5	78.5	78.5	100.0
2	2.5	1.4	1.2	57.5	122.6	44.0	61.3	35.9
3	4.1	1.6	1.4	39.4	159.0	36.5	53.0	22.9
4	5.8	1.7	1.5	29.9	191.3	32.3	47.8	16.9
Medium		1.5	1.3			47.8	60.2	

3.1.2. Growth of canopy diameter and canopy length of the plantations of *S. alba plantations*

The average canopy diameter of the *Sonneratia alba* plantations at the age of 1 - 4 years was the lowest on the site type III (respectively 0.51; 0.65; 0.78 and 1.22m), the highest on the site type II (0.70; 0.93; 1.13 and 2.23m, respectively). The average canopy length at the age of 1 - 4 years is lowest on-site type I (0.60; 0.76; 0.91 and 1.43m respectively), the highest on site type II corresponding to 0.80; 1.07; 1.41 and 2.57m). In general, D_canopy and L_canopy of the *Sonneratia alba* plantations at the age of 4 on 3 different site type (corresponding to F = 4 1.9 with P < 0.0 1; F = 38.1 with P < 0.01).

3. 1. 3. Complexity and competitiveness index of Sonneratia alba plantations

The SCI and CCI scores of the *Sonneratia alba* plantations varied with age and site type. On site type I, the SCI index increased from 5.2 at the age 1 y to 56.4 at age 4 y, on site typeII from 6.2 at the age 1 y to 100.4 at age 4 y, and on site type III, from 3.2 at the age year 1 to 26.5 at age years 4. At age 4yaes, the SCI index of *Sonneratia alba* plantations on site type II (100.4) was 1.8× and 3.9× larger than on site types I and III, respectively,. At the age of 4 years, the canopy area of the *Sonneratia alba* plantations on site types I, II and III were 0.68×, 1.12× and 2.30× times, respectively, of the ground area.

3. 1. 4. Wood and biomass reserves of Sonneratia alba plantations

Wood and biomass reserves of *Sonneratia alba* plantations on three site type are shown in Table 3.6 – 3.11.

Table 3.6. Growth of timber reserves in the *Sonneratia alba* plantations on site type I.

A (year)	M (m^3/ha)	ZM (m^3/ha/year)	ΔM (m^3/ha/year)	PM%
(1)	*(2)*	*(3)*	*(4)*	*(5)*
1	0.01	0.01	0.01	100.0
2	0.61	0.60	0.31	98.6
3	4.09	3.48	1.36	85.0
4	12.72	8.63	3.18	67.8

Table 3.7. Growth of timber reserves in the *Sonneratia alba* plantations on site type II.

A (year)	M (m^3/ha)	ZM (m^3/ha/year)	ΔM (m^3/ha/year)	PM%
(1)	(2)	(3)	(4)	(5)
1	0.01	0.01	0.01	100.0
2	1.94	1.92	0.97	99.4
3	13.93	11.99	4.64	86.1
4	40.56	26.63	10.14	65.7

Table 3.8. Growth of timber reserves in the *Sonneratia alba* plantations on site type III.

A (year)	M (m^3/ha)	ZM (m^3/ha/year)	ΔM (m^3/ha/year)	PM%
(1)	*(2)*	*(3)*	*(4)*	*(5)*
1	0.01	0.01	0.01	100.0
2	0.10	0.09	0.05	89.5
3	1.79	1.70	0.60	94.7
4	9.48	7.69	2.37	81.1

Table 3.9. Biomass of *Sonneratia alba* plantation*s* on site type I.

A (year)	Biomass components (tonne /ha) :				
	B_{T0}	$B_{BILLION}$	B_{OLD}	LOTS _	B_{CL}
(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*
1	0.42	0.38	0.02	0.01	0.04
2	1.06	0.91	0.10	0.05	0.16
3	4.13	3.31	0.52	0.30	0.82
4	13.89	10.65	1.91	1.34	3.25

Table 3.10. Biomass of *Sonneratia alba* plantations on site type II.

A (year)	Biomass components (tonne /ha) :				
	B_{T0}	$B_{BILLION}$	B_{OLD}	LOTS _	B_{CL}
(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*
1	0.57	0.51	0.04	0.02	0.06
2	1.41	1.19	0.15	0.08	0.22
3	15.44	11.80	2.13	1.51	3.64
4	50.58	37.43	7.22	5.94	13.15

Table 3.11. Biomass of *Sonneratia alba* plantations on site type III.

A (year)	Biomass components (tonne /ha) :				
	B_{T0}	$B_{BILLION}$	B_{OLD}	LOTS _	B_{CL}
(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*

1	0.18	0.17	0.00	0.00	0.01
2	0.71	0.59	0.08	0.04	0.12
3	1.67	1.36	0.21	0.11	0.32
4	9.89	7.60	1.38	0.92	2.30

The timber reserves of the *Sonneratia alba* plantations varied markedly with age and site type. Compared with the timber volume of the *Sonneratia alba* plantations on site type III (100%), times larger, respectively. In general, the timber reserves of the Sonneratia alba plantations are highest on-site type II and lowest on-site type III.

Total biomass on site type I, increased from 0.42 tons /ha at age 1 to 13.89 tons /ha at age 4 year, in site type II, total biomass increased from 0.57 tons /ha at the age of 1 to 50.58 tons /ha at the age 4 years, in site type III, total biomass increased from 0.18 tons /ha at the age of 1 to 9.89 tons /ha at the age of 4 .

stock in the biomass of *Sonneratia alba* plantations received the highest value in site typeII, the lowest in site type III. Compared with the above 4-year-old conifer plantations on site type III, carbon storage in biomass and CO_2 absorption capacity of Sonneratia alba plantations s on site typeI and II is 1.4 times greater, and 5.1 times.

3. 1. 5. The influence of the site type on the stability of the *Sonneratia alba* plantations

The stability of the plantations of *Sonneratia alba* is assessed through the H/D ratio and the quality of the trees. The shape of the trunk of the white cypress tree on the three-site type tends to decrease with age. The ratio of H/D at all ages is less than 0.80, showing that *Sonneratia alba* plantations is developing stably. The trees that form the plantations of the *Sonneratia alba* plantations from 1 to 4 years old are clearly differentiated in terms of quality. In general, the percentage of 4-year-old conifers of good and medium quality was highest on site type II (90.1%), the lowest in site type III (70.9%).

3. 2. Characteristics of the soil under the canopy of *Sonneratia alba plantations*

The characteristics of soil under the canopy of 1 - 4-year-old cypress plantations on three site type are summarized in Table 3. 12 - 3.14.

Table 3. 12. Changes in soil characteristics under the canopy of *Sonneratia alba plantations* from 1 to 4 years old on-site type I.

Soil characteristics	Forest age (years):				
	Bare land l	1	2	3	4

(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*
pH $_{H2O}$	5.9	6.1	6.3	6.5	6.5
pH $_{KCL}$	5.8	5.9	5.7	5.9	6.0
Humus (%)	1.20	1.79	2.05	2.18	2.44
Nitrogen (%)	0.056	0.099	0.113	0.110	0.122
Phosphorus (%)	0.050	0.082	0.081	0.073	0.091
Potassium (%)	0.129	0.181	0.221	0.215	0.262
Al^{3+} (me/100g)	1.68	1.27	1.17	0.97	1.02
Fe^{2+} (me/100g)	113.7	92.0	79.6	66.6	51.6
SO_4^{2-} (me/100g)	0.099	0.081	0.070	0.061	0.067
Clay (%)	12.8	14.3	15.5	14.3	18.0
Silt (%)	8.0	9.7	10.0	7.0	8.1
Sand (%)	79.2	76.0	74.5	78.7	73.9

Table 3. 13. Changes in soil properties under the canopy of *Sonneratia alba* plantations from 1 to 4 years old on-site type II.

Soil characteristics	Forest age (years):				
	Bare land	1	2	3	4
(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*
pH $_{H2O}$	6.1	6.6	6.8	6.8	6.5
pH $_{KCL}$	5.9	6.0	5.9	6.0	5.9
Humus (%)	1.20	0.72	0.96	1.04	1.09
Nitrogen (%)	0.056	0.064	0.074	0.101	0.123
Phosphorus (%)	0.050	0.065	0.065	0.069	0.078
Potassium (%)	0.129	0.142	0.182	0.195	0.234
Al^{3+} (me/100g)	1.681	0.539	0.749	0.775	0.562
Fe^{2+} (me/100g)	113.7	65.3	65.5	60.6	45.5
SO_4^{2-} (me/100g)	0.097	0.059	0.051	0.042	0.045
Clay (%)	12.8	12.7	12.0	12.5	12.5
Silt (%)	8.0	7.4	7.7	5.8	5.5
Sand (%)	79.3	79.9	80.4	81.7	82.0

Table 3. 1 4. Changes in soil characteristics under the canopy of *Sonneratia alba* plantations from 1 to 4 years old on-site type III.

Soil characteristics	Forest age (years):				
	Bare land	1	2	3	4
(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*
pH $_{H2O}$	6.1	6.3	6.5	6.5	6.8

pH $_{KCL}$	5.9	6.0	5.9	6.0	6.0
Humus (%)	1.20	1.43	1.69	1.94	2.28
Nitrogen (%)	0.056	0.083	0.094	0.088	0.178
Phosphorus (%)	0.051	0.080	0.079	0.083	0.092
Potassium (%)	0.129	0.182	0.220	0.233	0.256
Al^{3+} (me/100g)	1.681	0.787	0.852	0.677	0.835
Fe^{2+} (me/100g)	113.7	112.0	79.9	86.9	73.6
SO_4^{2-} (me/100g)	0.099	0.084	0.070	0.074	0.062
Clay (%)	14.3	15.4	16.6	17.2	18.0
Silt (%)	6.4	6.9	7.1	5.3	5.5
Sand (%)	79.3	77.8	76.4	77.5	75.9

The data in Table 3. 12 show that 6 soil characteristics on site type I increased with the increase in age of *Sonneratia alba* plantations, namely $pH_{H2O,}$ humus content, nitrogen, phosphorus, potassium, and percentage lighting. On the contrary, 5 characteristics that decrease gradually with the increase of age of the plantations are Al^{3+}, Fe^{2+}, SO_4^{2-}, ratio of Silt (%) and sand. pH value $_{KCL}$ tends to be stable, only fluctuating in the range of 5.8 - 6.0. At the age of 4, compared with bare soil, 6 characteristics (pH_{H2O}, humus content, nitrogen, phosphorus, potassium, and percentage of clay) of the soil under the forest canopy increased by 10.2 %, 103, respectively. 3%, 117.9%, 82.0%, 103.1% and 40.6%. In contrast, 4 properties (Al $^{3+}$, Fe $^{2+}$, SO_4^{2-}, percentage of sand) was lower than 39.3%, 54.6 %, 32.3% and 6.7% respectively.

The data in Table 3.13 show that 4 characteristics (pH $_{H2O}$, nitrogen, phosphorus, potassium) of soil on site type II increased markedly with the increase of age of *Sonneratia alba* plantations. In contrast, 5 characteristics (humus content, Al^{3+}, Fe^{2+}, SO_4^{2-}, Silt (%)) decreased markedly with the increase in age of the *Sonneratia alba* plantation*s*. Value of pH-$_{KCL}$ tends to be stable, fluctuating in the range of 5.9 - 6.0. At the age of 4, compared with bare soil, the 4 characteristics (pH_{H2O}, nitrogen, phosphorus, potassium) of the soil under the canopy of the forest increased by 6.6%, 119.6%, 56.0% and respectively. 81.4%. In contrast, 4 properties (Al^{3+}, Fe $^{2+}$, SO_4^{2-}, Silt (%) was lower than 66.6%, 60.0 %, 53.6% and 31.3% respectively.

The data in Table 3. 1 4 show that 6 characteristics (pH_{H2O}, humus, nitrogen, phosphorus, potassium, and clay content) of soil on site type III increased markedly with the increase of forest age. Plant white coriander. In contrast, 4

properties (Al^{3+}, Fe^{2+}, SO_4^{2-}, silt (%) decreased markedly with the increase in age of the *Sonneratia alba* plantations. pH value $_{KCL}$ tends to be stable, only fluctuates in the range of 5.9 - 6.0. At the age of 4, compared with bare soil, the 6 characteristics (pH_{H2O}, humus, nitrogen, phosphorus, potassium, and clay) of the soil under the canopy of the forest increased by 11.5 %, 90.0%, respectively. 217.9%, 80.4%, 98.4% and 25.9%. In contrast, 4 properties (Al^{3+}, Fe^{2+}, SO_4^{2-}, Silt (%)) was lower than 50.3%, 35.3%, 37.4% and 14.1% respectively. Statistical analyzes show that 9 soil properties (pH-H2O , pH-KCL , humus , phosphorus , Fe^{2+}, SO_4^{2-}, proportion of clay, flesh and sand) under the canopy of the *Sonneratia alba* plantations s from 1 to 4 years old on three distinct site type ($P < 0.05$). In contrast, the components (N, K and Al) were not significantly different ($P > 0.05$).

3.3. The relationship between soil characteristics and growth of *Sonneratia alba* plantations

The growth of the plantations of *Sonneratia alba* significantly affects the soil properties on the three-site type (Table 3. 15 – 3.17).

Table 3. 15. Relationship between soil and growth of *Sonneratia alba* plantations on site type I.

Soil characteristics	r	P_α	K (sample)
(1)	*(2)*	*(3)*	*(4)*
pH_{H2O}	0.483	0.007	30
pH_{KCL}	0.560	0.001	30
Humus (%)	0.829	0.000	30
Nitrogen (%)	0.676	0.000	30
Phosphorus (%)	0.546	0.002	30
Potassium (%)	0.808	0.000	30
Al^{3+} (me/100g)	-0.204	0.279	30
Fe^{2+} (me/100g)	-0.855	0.000	30
SO_4^{2-} (me/100g)	-0.638	0.000	30
Clay (%)	0.661	0.000	30
Silt (%)	-0.552	0.002	30
Sand (%)	-0.355	0.054	30

Table 3. 16. Relationship between soil and growth of *Sonneratia alba* plantations on site type II.

Soil characteristics	r	P_α	K (sample)
(1)	*(2)*	*(3)*	*(4)*

pH $_{H2O}$	0.277	0.138	30
pH $_{KCL}$	-0.006	0.976	30
Humus (%)	0.046	0.808	30
Nitrogen (%)	0.688	0.000	30
Phosphorus (%)	0.649	0.000	30
Potassium (%)	0.796	0.000	30
Al^{3+} (me/100g)	-0.406	0.026	30
Fe^{2+} (me/100g)	-0.752	0.000	30
SO_4^{2-} (me/100g)	-0.686	0.000	30
Clay (%)	-0.042	0.825	30
Silt (%)	-0.665	0.000	30
Sand (%)	0.418	0.021	30

Table 3. 17. Relationship between soil and growth of *Sonneratia alba* plantations on site typeIII.

Soil characteristics	r	P $_{\alpha}$	K (sample)
(1)	*(2)*	*(3)*	*(4)*
pH $_{H2O}$	0.501	0.005	30
pH $_{KCL}$	0.145	0.444	30
Humus (%)	0.760	0.000	30
Nitrogen (%)	0.515	0.004	30
Phosphorus (%)	0.620	0.000	30
Potassium (%)	0.767	0.000	30
Al^{3+} (me/100g)	-0.240	0.202	30
Fe^{2+} (me/100g)	-0.754	0.000	30
SO_4^{2-} (me/100g)	-0.676	0.000	30
Clay (%)	0.714	0.000	30
Silt (%)	-0.370	0.044	30
Sand (%)	-0.266	0.156	30

On site type I, seven characteristics (pH-H_2O, pH-KCL, humus content, N, P, K and clay ratio) had a clear positive relationship ($P < 0.01$) with the SCI of the site. *Sonneratia alba* plantations. In contrast, four characteristics (Fe^{2+} content, SO_4^{2-} and Silt (%) were negatively related with ($P < 0.01$) with the SCI index of the Whitewood plantations. On site type II, 4 characteristics of soil (N, P, K and ration of clay) have a positive relationship ($P < 0.01$), while four characteristics (Al^{3+}, Fe^{2+}, SO_4^{2-} and silt (%) has a negative relationship with ($P < 0.01$) with the SCI

index of the plantations of *Sonneratia alba* plantations on site type III, seven characteristics of soil (pH-H_2O, pH-KCL, humus, N, P, K, and clay (%) in the soil) have a positive relationship ($P < 0.01$), while the remaining five characteristics of soil (Al^{3+}, Fe^{2+}, SO_4^{2-}, ratio of silt (%) and sand) has a negative relationship with ($P < 0.01$) with the SCI index of *Sonneratia alba* plantations.

Regression analyzes show that the soil properties can be approximated based on the age of the mangrove plantations. The estimation functions exist at a very high significance level ($P < 0.01$) and the coefficient of determination (r^2) ranges from 74 to 99%. On site type I, 6 soil characteristics (humus content, N, P, K, Fe^{2+}, SO_4^{2-}) under the canopy of *Sonneratia alba* plantations can be estimated according to the function 3.1 – 3.6 (Table 3.18). On site type II, 6 soil properties (N, P, K, Al^{3+}, Fe^{2+}, SO_4^{2-}) under the canopy of *Sonneratia alba* plantations can be estimated according to the function 3.7 – 3.12 (Table 3.19). On site type III, 6 characteristics of soil (humus content, N, P, K, Fe^{2+}, SO_4^{2-}) under the canopy of *Sonneratia alba* plantations can be estimated according to the function 3.13 – 3.18 (Table 3.20)

Table 3. 18. Estimating functions of soil characteristics by age of *Sonneratia alba* plantations on site type I.

TT	Function	
1	$Humus = (1.10024 + 0.228186* \sqrt{A})^2$	3.1
2	$N = \sqrt{0.00359117 + 0.00565127*\sqrt{A}}$	3.2
3	$P = 1/(18.7432 - 3.98414* \sqrt{A})$	3.3
4	$K = \exp(-2.04343 + 0.337414* \sqrt{A})$	3.4
5	$Fe^{2+} = (10.5822 - 0.839019*A)^2$	3.5
6	$SO_4^{2-} = \sqrt{0.00957254 – 0.00299218*\sqrt{A}}$	3.6

Table 3. 19. Estimating functions of soil characteristics by age of *Sonneratia alba* plantations on site type II.

TT	Function	
1	$N = \sqrt{0.00306812 + 0.00075658*A^2}$	3.7
2	$P = 1/(19.6885 - 3.31256* \sqrt{A})$	3.8
3	$K = \exp(-2.0598 + 0.150819*A)$	3.9
4	$Al^{3+} = \sqrt{2.37241 – 1.18256*\sqrt{A}}$	3.10
5	$Fe^{2+} = (10.4608 - 1.77942* \sqrt{A})^2$	3.11

6	$SO_4^{2-} = \exp(-2.37032 - 0.416317 * \sqrt{A})$	3.12

Table 3. 20. Functions for estimating soil properties according to age of *Sonneratia alba* plantations on site type III.

TT	Function	
1	$Humus = (1.0936 + 0.102606 * A)^2$	3.13
2	$N = \sqrt{0.00358122 + 0.00288369 * \sqrt{A}}$	3.14
3	$P = \sqrt{0.00286209 + 0.00264951 * \sqrt{A}}$	3.15
4	$K = (0.358129 + 0.0736772 * \sqrt{A})^2$	3.16
5	$Fe^{2+} = (10.7029 - 0.542894 * A)^2$	3.17
6	$SO_4^{2-} = \sqrt{0.00975687 - 0.002881 * \sqrt{A}}$	3.18

3. 4. The relationship between water with of the *Sonneratia alba* plantations

3. 4.1. Characteristics of water under the canopy of Sonneratia alba plantations

Research results show that the composition of pH- $_{H2O}$. The water content varies very slightly with the age of the *Sonneratia alba* plantations on site type II, ranging from 6.3 to 6.4 with CV < 2.5%. Similarly, the DO. component also varies very slightly with the age of the *Sonneratia alba* plantations, ranging from 5.4 on bare land to 5.5 under the canopy of the *Sonneratia alba* plantations; average 5.4 with CV = 2.6%. Compared with bare land (100%), the salinity of water under the canopy of the *Sonneratia alba* plantations from 1 to 4 years old is lower, respectively, by 6.6%, 12.6%, 14.9% and 17.7%; Al^{3+} content was lower, respectively, 5.9%, 16.1%, 28.2 % and 29.5%; Fe^{2+} content was lower, respectively, 4.1%, 12.6%, 22.4 % and 24.2%; SO_4^{2-} content was lower than 25.3%, 42.2%, 46.1% and 50.0%, respectively. In general, the characteristics of water change markedly with the age of the *of Sonneratia alba* plantations.

3. 4.2. Relations between countries with the growth of Sonneratia alba plantations

The results of the study showed that the growth of the *Sonneratia alba* plantations significantly affects the characteristics of the water (Table 3.21). The increase in the age of the plantations of the White spp. led to an increase in pH $_{H2O,}$ DO content, salinity, Al^{3+}, Fe^{2+} and SO_4^{2-} . However, the change in the SCI index of the plantations of the *Sonneratia alb* plantations a only resulted in a marked decrease in salinity ($r = -0.982$; $P < 0.01$), Al^{3+} content. ($r = -0.977$; $P < 0.01$), Fe^{2+} content ($r = -0.951$; $P < 0.01$) and SO_4^{2-} ($r = -0.932$; $P < 0.01$). Regression analysis

showed that the salt, Al^{3+}, Fe^{2+} and SO_4^{2-} contents could be estimated according to the age of the Sonneratia alba plantations (Table 3.22). These 4-component estimators exist at a very high significance level ($P < 0.01$) and the coefficients of determination ($r^{2)}$ range from 96% to 98%.

Table 3. 21. Relationship between water and *Sonneratia alba* plantations.

Soil characteristics	r	P_α	K (sample)
(1)	(2)	(3)	(4)
pH_{H2O}	-0.061	0.828	15
DO (mg/l)	-0.141	0.617	15
Salinity ($\%_0$)	-0.982	0.000	15
Al^{3+} (me/100g)	-0.977	0.000	15
Fe^{2+} (me/100g)	-0.951	0.000	15
SO_4^{2-} (me/100g)	-0.935	0.000	15

Table 3. 22. Model for estimating water characteristics according to age of *Sonneratia alba* plantations on site type II.

No	Function	
1	Salinity = $\sqrt{515.384 - 84.321*\sqrt{A}}$)	3.19
2	$Al^{3+} = 0.2962 - 0.024*A$	3.20
3	$Fe^{2+} = 0.2054 - 0.0136*A$	3.21
4	$SO_4^{2-} = (0.225664 - 0.0334785*\sqrt{A})^2$	3.22

3.5. *The relationship between the Sonneratia alba plantations and the characteristics of soil and water*

3.5.1. The relationship between the Sonneratia alba plantations and the characteristics of soil

The results of the study in Section 3.3.2 show that the SCI index of *Sonneratia alba* plantations on site type II has a relationship with 6 soil characteristics (N, P, K, Al, Fe, SO_4). The regression analysis shows that the SCI index only has a close relationship ($R^2 = 56.8\%$) with 5 factors (N, P, K, Al, Fe) (Function 3.23).

SCI = 1.49875 + 35.2979*N + 30.9501*P + 150.295*K + 3.62515*Al - 0.266977*Fe - 7.7071*(N*P*K*Al*Fe) (3.23)

$R^2 = 56.8\%$; SEE = ±13.1.

The SCI index of *Sonneratia alba* plantations depends the most on Fe content (Standardized Regression Coefficient |-0.843|); next is aluminum content (Standardized regression coefficient |0.341|); The lowest is the P content (Standardized regression coefficient |-0.008|.

3.5 . 2. The relationship between the Sonneratia alba plantations and the characteristics of water

The results of the study in Section 3.4.2 show that the SCI index of *Sonneratia alba* plantations *s* is closely related to 4 characteristics of water (Salinity, Al, Fe, SO_4). The regression analysis shows that the change of SCI index of *Sonneratia alba plantations* s according to 4 factors (N, P, K, Al, Fe) has the form as Function 3.24.

SCI = 417,239 - 8,8789*Saline -372,895*Al - 839,412*Fe + 646,916*SO_4 + 387,745*(Saline*Al*Fe*SO_4) (3.24)

R^2 = 66.3%; SEE = ±25.3.

The change in the SCI index of the white coniferous forest depends the most on Fe content (Standardized Regression Coefficient |-1,416|); next is salinity (Standardized regression coefficient |-1,276|); The lowest is Al content (Standardized regression coefficient |0.704|.

3.6. Proposal to apply research results

***3.6. 1* . Choose the location of the *Sonneratia alba* plantations**

The growth of *Sonneratia alba* plantations is the worst in site type III, the highest in site type II. Therefore, site type II is a suitable environment for growing white thorns. In order to help the *Sonneratia alba* plantations to live well on site typeIII, the method of afforestation by creating canals to bring tidal water deep into the trees is a necessary measure.

***3.6. 2* . The technique of *Sonneratia alba* plantations**

S. alba plantations can be planted can be planted from 6-month-old seedlings. Seedlings need to be nursed in pots with the size of 25 * 30cm. The seedlings brought planted are good growing trees , straight stems and free from pests and diseases ; where the root diameter (D_0) and height (H) are greater than 0.5cm and 50cm respectively. Seedlings are planted in rows. The rows of white pine are planted in the direction at right angles to the riverbank and the sea. The initial planting density was 3,300 trees per hectare (1.5*2.0m). In order to help the seedlings after planting not to fall when encountering waves and strong winds , each tree is fixed by 3 bamboo poles with a diameter of 2-3cm and a height of 100-150cm. The stakes are inserted 40 – 60 cm deep; then the seedling is tied to the

stake at two-third of the stems. Around the experimental plot is protected by a fence bamboo to reduce of big waves and clinging of moss.

3.6.3. Planting *Sonneratia alba* plantations to protect the environment along estuaries and sea

The estuary and coastal land can be improved by planting mangroves. In order to improve and protect the estuary and coastal environment of Thua Thien Hue province, the thesis proposes to plant *Sonneratia alba* plantations. This forest type is only well adapted to site type I and II. Forest planting and protection techniques are implemented the same way as Section 3.6.2. After planting, the white tree canopy closed, no thinning and no pruning. The strong growth of trunks and branches in *Sonneratia alba* plantations s has the effect of preventing large waves from crashing into structures along rivers and the sea. In addition, the plantations of *Sonneratia* alba plantations. also have the effect of improving soil and water properties, increasing soil accretion.

CONCLUSIONS AND RECOMMENDATIONS

1. Conclusion

(1) *Sonneratia alba* plantations are well adapted to the sites in the coastal area of Thua Thien Hue province. They grow best on-site type II, then site type I and site type III. Site type II is the most suitable plante4d *Sonneratia alba*.

(2) The characteristics of the soil under the canopy of *Sonneratia alba* plantations differ markedly from bare land to the structural complexity of *Sonneratia alba*. The increase in the complexity of *Sonneratia alba* plantations leads to an increase in pH-H_2O, humus content, nitrogen content, phosphorus content, potassium content and clay rate in the soil layer from 0 – 50cm. On the contrary, the increase in the structural complexity of *Sonneratia alba* plantations leads to a very marked decrease in Al^{3+}, Fe^{2+} and SO_4^{2-} content, the ratio of silt and sand in the soil layer is from 0 – 50cm.

(3) The characteristics of water change very markedly with the development of *Sonneratia alba*. The increase in the complexity of *Sonneratia alba* plantations leads to a very marked reduction in salinity, the content of Al^{3+}, Fe^{2+} and SO_4^{2-}.

(4) The growth of *Sonneratia alba* plantations is strictly dependent on the characteristics of the soil. An increase in the content of N, P and Al^{3+} in the soil layer of 0-50 cm leads to an increase in the complexity of *Sonneratia alba* plantations. On the contrary, an increase in Fe^{2+} content leads to a decline in the complexity of *Sonneratia alba* plantations.

(5) The growth of *Sonneratia alba plantations* is strictly dependent on the characteristics of the water. The increase in the content of salts, Al^{3+} and Fe^{2+} in water leads to a decline in the complexity of *Sonneratia alba* plantations. On the contrary, an increase in the content of SO_4^{2-} leads to an increase in the complexity of *Sonneratia alba* plantations.

2. Recommendations

This thesis has shown that the *Sonneratia alba* plantations is well adapted to the sites in the coastal area of Thua Thien Hue province. At the same time, it shows that *Sonneratia alba* plantations grow best on-site type II, worst on site type III. The author proposes that forestry authorities in Thua Thien Hue province could use the results of this thesis to plant *Sonneratia alba* plantations on saltwater wetlands in estuarine areas and coastal mudflats. Because of the effect of improving the properties of soil and water. The research results are also the scientific basis for leaders and environmental management agencies in Thua Thien Hue province to use to plant *Sonneratia alba* plantations on saltwater wetlands in estuarine areas and coastal mudflats to limit the adverse effects of wind and waves, provide shelter and food sources for marine life, sightseeing tourism

THESIS RELATED PUBLICATION

1. **Le Thanh Quang**, Thai Thanh Luom, Akihiro Itai, Hoang Van Thoi, Kieu Tuan Dat, Nguyen Khac Dieu and Kieu Manh Ha, 2022. Influence of site typeon growth of S. alba plantations in the coastal area of Thua Thien Hue province. Journal of Forestry Science. ISSN 1859 – 0373. Number 1/2022, pages 177 - 184.
2. **Le Thanh Quang**, Thai Thanh Luom, Akihiro Itai, Hoang Van Tho, Kieu Tuan Dat, Nguyen Khac Dieu and Hoang Anh Tuan, 2022. Characteristics of Soil under the canopy of S. alba plantations in the coastal area of Thua Thien Hue province. Forest and Environment Journal. ISSN 1859 -1247. Number 110 +111 in 2022, pages 17 - 22.
3. Hoang Van Thoi, Nguyen Thi Hai Hong, **Le Thanh Quang**, Nguyen Khac Dieu, Vo Hoang Anh Tuan, 2020. Species and provenance trial of some mangrove species at Con Dao and Binh Son in central Vietnam. Journal of Agriculture & Rural Development. ISSN 1859-4581 No. 19/2020, Pages 86-92.
4. Hoang Van Thoi, **Le Thanh Quang,** Nguyen Khac Dieu. Research on planting mangroves in the central coastal by techniqe improving the sites and plant protection fences; Proceedings of the forestry science, technology and innovation conference, Agricultural publishing house, 2023, ISBN: 978-604-60-3831-3, p. 376-387.
5. **Le Thanh Quang**, Thai Thanh Luom. Impact of Water and Soil Compositions on the Growth of *Sonneratia alba* in ThuaThien Hue, Vietnam; International Journal of Research Studies in Agricultural Sciences (IJRSAS). Volume 10, Issue 3, 2024, PP 15-26. ISSN No. (Online) 2454–6224. DOI: http://dx.doi.org/10.20431/2454-6224.1003002. www.arcjournals.org.

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