

**COMPARATIVE ANALYSIS ON ECONOMIC RETURN
INCLUDING CARBON STORAGE VALUE FROM
RHIZOPHORA APICULATA PLANTATIONS FOR
CONSERVATION AND COMMERCIAL PURPOSES
IN PATTANI PROVINCE**



TANAPOOM CHANPRAPAI

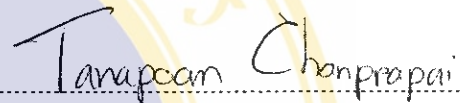
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Thesis

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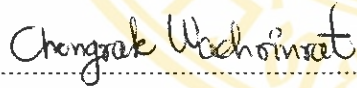
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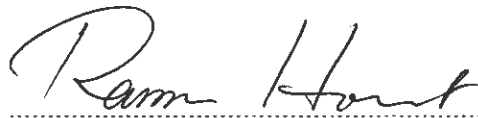
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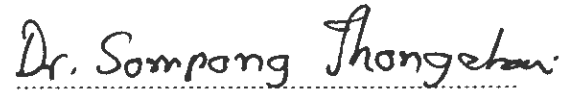
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Tanapoom Chanprapai

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IN PATTANI PROVINCE

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ABSTRACT

The objective of this research was to carry out the comparative analysis on economic return from *Rhizophora apiculata* (*R.apiculata*) plantations for conservation and commercial purposes. The *R.apiculata* plantation for conservation purposes provided benefits only from carbon storage value but *R.apiculata* plantation for commercial purposes provided benefit from 3 patterns of wood use: 100% charcoal production, 99% charcoal production plus 1% construction materials, and 100% construction materials, including carbon storage value.

The result of this research showed that the *R.apiculata* plantation for conservation purposes had a net economic return of less than for commercial purposes. The *R.apiculata* plantation for conservation purposes had the minimum and maximum present value of net economic return in the 30th year at -33,030 to -6,905 bath/ha. and -28,917 to 29,581 baht/ha. respectively. The benefit came mainly from the carbon storage value. For commercial purpose, benefit depended on patterns of wood use and carbon storage value. The present value of net economic return in the 30th year varied according to the pattern of wood use: 100% charcoal production, between 96,864 and 186,256 bath/ha., 99% charcoal production and 1% construction material, the minimum was 135,878 to 262,943 bath/ha. and the maximum was 153,046 to 296,689 baht/ha.; and 100% construction material, the minimum was 900,321 to 1,765,511 bath/ha. and the maximum was 1,358,105 to 2,665,357 baht/ha..

The *R.apiculata* plantation for commercial purposes (100% construction material) had the highest carbon storage at 138.78 tc./ha.. The carbon storage value of *R.apiculata* plantation for conservation purposes was 104.78 tc./ha., and *R.apiculata* plantation for commercial purposes (99% charcoal production and 1% construction material) was 1.23 tc./ha.. *R.apiculata* plantation for commercial purposes (100% charcoal production) had no carbon storage.

In conclusion, if Thailand would like to participate in solving the climate change problem by mangrove management, *R.apiculata* plantation may be considered because it gives a considerable economic return.

KEY WORDS: COMPARATIVE ANALYSIS / CARBON STORAGE VALUE /

ECONOMIC RETURN / *RHIZOPHORA APICULATA*

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การวิเคราะห์เปรียบเทียบผลตอบแทนทางเศรษฐกิจของสวนป่าโกงกางใบเล็กแบบอนุรักษ์และแบบเศรษฐกิจในจังหวัดปัตตานี โดยคิดรวมมูลค่าการสะสมคาร์บอน (COMPARATIVE ANALYSIS ON ECONOMIC RETURN INCLUDING CARBON STORAGE VALUE FROM *RHIZOPHORA APICULATA* PLANTATIONS FOR CONSERVATION AND COMMERCIAL PURPOSES IN PATTANI PROVINCE)

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บทคัดย่อ

การศึกษานี้มีวัตถุประสงค์เพื่อวิเคราะห์เปรียบเทียบผลตอบแทนทางเศรษฐกิจของสวนป่าโกงกางใบเล็กแบบอนุรักษ์และแบบเศรษฐกิจ โดยแบบอนุรักษ์จะมีรายได้เพียงอย่างเดียวคือ มูลค่าการสะสมคาร์บอน แต่แบบเศรษฐกิจ รายได้ขึ้นอยู่กับการใช้ประโยชน์จากไม้ ซึ่งมี 3 รูปแบบคือ 1. การใช้ผลิตถ่านทั้งหมด 2. การใช้ผลิตถ่าน 99% และไม้สำหรับการก่อสร้าง 1% และ 3. ทำไม้สำหรับการก่อสร้างทั้งหมด และนำมูลค่าการสะสมคาร์บอนมาคิดรวมเป็นรายได้ เพื่อหาผลตอบแทนทางเศรษฐกิจ

จากการศึกษาพบว่า การปลูกสวนป่าโกงกางใบเล็กแบบอนุรักษ์ มีผลตอบแทนทางเศรษฐกิจน้อยกว่าการปลูกแบบเศรษฐกิจ โดยค่าปัจจุบันสุทธิของผลตอบแทนในปีที่ 30 ของแบบอนุรักษ์ ขึ้นต่ำอยู่ระหว่าง -33,030 ถึง -6,905 และระดับสูงที่ -28,917 ถึง 29,581 บาทต่อเฮกแตร์ เนื่องจากมีรายได้เพียงมูลค่าการสะสมคาร์บอนเท่านั้น ในขณะที่การปลูกแบบเศรษฐกิจ รายได้ขึ้นอยู่กับการใช้ประโยชน์จากไม้และมูลค่าการสะสมคาร์บอน มีค่าปัจจุบันสุทธิของผลตอบแทนในปีที่ 30 ตามการใช้ประโยชน์จากไม้ดังนี้ 1. การใช้ผลิตถ่านทั้งหมด มีค่า 96,864 ถึง 186,256 บาทต่อเฮกแตร์ 2. การใช้ผลิตถ่าน 99% และไม้สำหรับการก่อสร้าง 1% มีรายได้ขั้นต่ำ 135,878 ถึง 262,943 บาทต่อเฮกแตร์ และรายได้ระดับสูง 153,046 ถึง 296,689 บาทต่อเฮกแตร์ และ 3. ทำไม้สำหรับการก่อสร้างทั้งหมด มีรายได้ขั้นต่ำ 900,321 ถึง 1,765,511 บาทต่อเฮกแตร์ และรายได้ระดับสูง 1,358,105 ถึง 2,665,357 บาทต่อเฮกแตร์

ส่วนการสะสมคาร์บอนจากการปลูกสวนป่าโกงกางใบเล็กแบบอนุรักษ์และแบบเศรษฐกิจนั้น แบบเศรษฐกิจที่มีการใช้ประโยชน์จากไม้เพื่อทำไม้สำหรับการก่อสร้างทั้งหมด จะมีการสะสมคาร์บอนสูงสุด เท่ากับ 138.78 ตันคาร์บอนต่อเฮกแตร์ รองลงมาคือการปลูกแบบอนุรักษ์ เท่ากับ 104.78 ตันคาร์บอนต่อเฮกแตร์ และการปลูกแบบเศรษฐกิจที่มีการใช้ประโยชน์จากไม้เพื่อผลิตถ่าน 99% และไม้สำหรับการก่อสร้าง 1% เท่ากับ 1.23 ตันคาร์บอนต่อ เฮกแตร์ ส่วนการปลูกแบบเศรษฐกิจที่มีการใช้ประโยชน์จากไม้เพื่อการใช้ผลิตถ่านทั้งหมด จะไม่มีมูลค่าการสะสมคาร์บอน

ดังนั้น หากประเทศไทยต้องการเข้าร่วมโครงการแก้ปัญหาโลกร้อน โดยการจัดการพื้นที่ป่าชายเลน ให้เกิดประโยชน์ทั้งฝ่ายรัฐและประชาชน การปลูกสวนป่าชายเลนน่าจะมีโอกาสประสบผลสำเร็จ ด้วยผลตอบแทนทางเศรษฐกิจที่ดีและการดำรงอยู่ของป่าชายเลนที่มีประโยชน์ด้านอื่นๆ ต่อชุมชน

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CHAPTER 1

INTRODUCTION

1.1 Background and Justification

According to the present global change and global warming situation, the United Nations accomplished the United Nations Framework Convention on Climate Change (UNFCCC) in 1992 at Rio Dejanero, Brazil, influencing countries which produced greenhouse gases to stop. However, it seemed rather difficult because there was no clarified amount of greenhouse gases needed to reduce and no legal enforcement. At the third Conference of Parties (COP-3) in Kyoto, Japan, the Kyoto Protocol was introduced dealing with reduction of greenhouse gases e.g., carbon dioxide, methane, nitrous oxide, hydrofluorocarbon, perfluorocarbon and sulfer hexafluoride.

The Kyoto Protocol provides 3 major mechanisms for greenhouse gases reduction: Clean Development Mechanism (CDM), Joint Implementation (JI) and Emission Trading (ET). CDM is the only mechanism that opens for participation to reduce greenhouse gases between Annex I Parties and Non-Annex I Parties.

An activity of CDM involves with forest, especially forest plantation that can absorb greenhouse gases. Mangrove plantation, for example *Rhizophora apiculata*, can be harvested in 10 or 15 years and wood can be sold for use as firewood and construction materials, creating benefit by reducing the cost of plantation and offering the benefit on investment. If the value of carbon storage was counted as a benefit, *Rhizophora apiculata* plantation would make even more benefit. In addition, communities which established *Rhizophora apiculata* plantation, could have job opportunity and earn direct and indirect benefits from *Rhizophora apiculata* plantation. *Rhizophora apiculata* plantation is not only a source of wooden goods but

also a source of construction materials, agriculture, paper production, household goods, clothes, tourist attraction, food resources, traditional medicines and fisheries that support people's livelihood (1).

Therefore, the researcher aimed at studying and analyzing the cost and benefit from trading *Rhizophora apiculata* including value of carbon storage for determining the benefit on investment of *Rhizophora apiculata* plantations for conservation and commercial purpose. The results may be useful for decision on greenhouse gases control project or negotiation on carbon trading in the world market. Furthermore, the derived data may help proper decision on forest plantation and management as sources of energy, construction materials, foods and income for the communities and their sustainable development.

1.2 Conceptual Framework

The cost and benefit of *Rhizophora apiculata* (*R.apiculata*) plantation, for the conservation and commercial purposes, may be different. In this study, commercial plantation is considered to provide benefit in 3 forms: firstly, 100% charcoal production (selling charcoal and carbon storage value); secondly, 99% charcoal production (selling charcoal and carbon storage value) and another 1% of wood as construction materials (selling woods and carbon storage value); and thirdly, 100% construction materials (selling woods and carbon storage value). Meanwhile, conservation plantation provides income in the form of carbon storage value only. A comparative study on the economic return from these 2 types of *Rhizophora apiculatal* plantation, will provide better understanding about the values of mangrove conservation and utilization. See Figure 1-1.

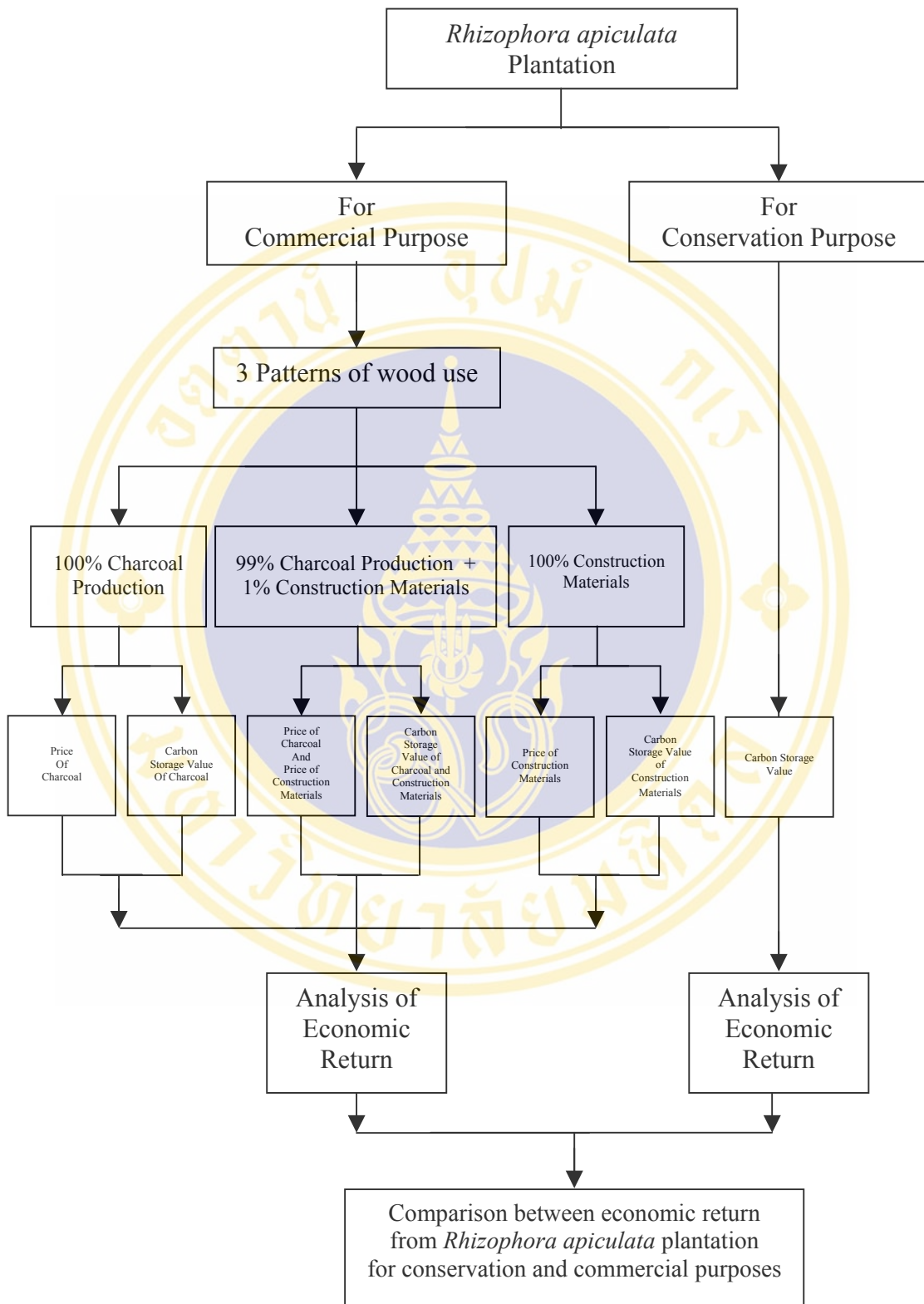


Figure 1-1 Conceptual Framework

1.3 Research Objectives

1. To compare the net economic return from two types of *R.apiculata* plantation: conservation and commercial plantations.
2. To compare the potential of carbon storage of two types of *R.apiculata* plantations.

1.4 Hypothesis

1. *R.apiculata* plantation for conservation purpose gives the lower net economic return (baht / ha.) than for commercial purpose.
2. *R.apiculata* plantation for conservation purpose has the lower amount of carbon storage (tons / ha.) than for commercial purpose.

1.5 Scope of Research

1. The cost, benefit and net economic return of *R.apiculata* plantations were compared, between conservation and commercial types.
2. The study area of *R.apiculata* plantations for conservation and commercial purposes was at Yaring district, Pattani Province.
3. The age of conservation plantation was 30 years. The age of commercial plantation was 15 years for 1 cycle. For comparison, 2 cycles of commercial plantation were analysed.
4. The total cost of plantation include fixed cost and variable cost.
5. The benefit includes the carbon storage value, charcoal and wood selling values.
6. The carbon storage value was calculated from the surface biomass only.

1.6 Research Expectations

1. Comparative result between the net economic return from *R.apiculata* plantations for conservation and commercial purposes.
2. Comparative result between the carbon storage potential of *R.apiculata* plantations for conservation and commercial purpose.
3. Better understanding of the *R.apiculata* plantation for commercial purpose (a concession).

1.7 Definitions

For the purpose of this study, the following definitions were used:

Cost: All expenses of *R.apiculata* plantation for conservation and commercial purpose i.e. fixed cost and variable cost.

Net present cost value: The present value of cost deducted with discount rate.

Benefit: It is income from selling product of *R.apiculata* i.e. wood product, carbon storage value.

Net present benefit value: The present value of benefit deducted with discount rate.

Net economic return: The net present benefit value deducted with the net present cost value.

***Rhizophora apiculata* plantation for conservation purpose:** The *R.apiculata* plantation with no cutting for 30 years.

***Rhizophora apiculata* plantation for commercial purpose:** The *R.apiculata* plantation with systematical maintenance and cutting.

Carbon storage value: The value of carbon storage in above ground biomass, quantity of carbon storage multiplied by price of carbon.

CHAPTER 2

LITERATURE REVIEW

2.1 Kyoto Protocol

The Kyoto Protocol was adopted at the third Conference of the Contracting Parties (COP-3) of the UNFCCC on December 11, 1997 in Kyoto, Japan, and was an initial step to have legal binding of climate change in greenhouse gases release of Annex I countries. If the perfect implementation was done according to the yielded volume of greenhouse gases under legal binding (2008-2012), greenhouse gases from Annex I countries under the ratification would be decreased by 5.2% from 1990. Non-annex countries were not under the ratification so they had no need to follow the rules. Common but different responsibility offered an opportunity to non-annex countries to develop without any limit on greenhouse gases (2).

From the legal binding on greenhouse gases for Annex I countries, the Kyoto Protocol has 3 mechanisms to control and assist those countries as follows:

1. Joint Implementation (JI) (Article 6) is a mechanism that Emission Reduction Units (ERUs) can be transferred from projects among Annex I countries. Some countries, which received ERUs, would add ERUs with greenhouse gases volume but some countries, which transferred ERUs would reduce it from greenhouse gases volume instead.

2. Emission Trading (ET) (Article 7) is a mechanism that Assigned Amount Units (AAUs) can be traded among Annex B countries. Annex I country list is in the UNFCCC. Annex B countries are listed in the Kyoto Protocol.

3. Clean Development Mechanism (CDM) (Article 12) is a mechanism that Certified Emission Reduction Units (CERs) can be transferred from projects among Annex I countries and non-annex I countries (2).

2.2 The Clean Development Mechanism (CDM)

The CDM allows Annex I Parties to implement projects that reduce emissions in the territory of a Non-Annex I Party. The certified emission reduction units (CERs) generated by such projects can be used by Annex I Parties to help meet their emission targets while the projects also help Non-Annex I Parties to achieve sustainable development and contribute to the ultimate objective of the Convention.

The modalities and procedures for the CDM focus on projects that reduce emissions. Definitions and modalities are to be developed, for adoption at COP 9, for including afforestation and reforestation activities in the CDM for the first commitment period. However, Annex I Parties are limited in how much they may use CERs from such sink projects towards their targets (up to 1% of the Party's emissions in its base year, for each of the five years of the commitment period).

A CDM project might then involve, for example, a rural electrification project using solar panels or the reforestation of land. As with joint implementation projects, Annex I Parties are to refrain from using CERs generated through nuclear energy to meet their emission targets.

The CDM is expected to generate investment in developing countries, especially from the private sector, and promote the transfer of environmentally and friendly technologies in that direction. However, the finance and technology transfer commitments of Annex II Parties under the Convention and Kyoto Protocol are separate and remain valid. Furthermore, public funding for CDM projects must not result in the diversion of official development assistance. (3)

For joint implementation (JI) and emissions trading (ET), Thailand cannot involve with both mechanisms.

2.3 Price of Traded Carbon

A computerized multi-objective programming approach and a Leontief inter-industry model were used to investigate the impact of mitigating CO₂ emissions on Taiwan's economy. The result showed that Taiwan's GDP would drop 34% off the targeted GDP growth rate for the year 2000 and Taiwan's economy would be seriously weakened if the annual CO₂ emissions were stabilized at the 1990 level. If Taiwan maintained CO₂ emissions at 128% of the 1990 level, then Taiwan's economy would have 5.37% average annual growth rate up to the year 2000. The 157% CO₂ emission level would mean 5.92% annual GDP growth rate; and the 213% CO₂ emission level would mean 6.58% annual GDP growth rate. In addition, policy implications were presented in order to assist policy makers in economic planning (4).

The possible market values of carbon ranged from as low as \$50 per ton to as high as \$100 per ton or more. The result indicated that at a low price of carbon of \$10 per ton, the per hectare values would range from \$1 per hectare per year in temperate and tropical dry regions, to a high value of \$8 per hectare per year in tropical wet regions. At a relatively high price of carbon of \$100 per ton, the per hectare values would range from \$10 to \$80 per hectare per year. At a middle-range carbon price of \$50 per ton, the per hectare values for tropical regions would range from \$10 to \$40 per hectare per year (5).

Therefore, this study will use the market price of carbon between the minimum \$50 per ton and the maximum \$100 per ton or the minimum 2,000 baht / ton to the maximum 4,000 baht / ton.

2.4 The Emission of the GHGs in Thailand

In Thailand, there are various activities releasing greenhouse gases. Major greenhouse gases are carbon dioxide (CO₂), methane (CH₄) and Nitrous oxide (N₂O). Carbon dioxide was released most in 1990 (164 million tons,; percentage of total

emission was 73%). Methane and nitrous oxide were released at 2.8 million tons and 0.01 million tons or 25% and 2% respectively (Table 2-1).

In 1994, the release of greenhouse gases carbon dioxide, methane and nitrous oxide was increased to 202, 3.1 and 0.55 million tons or 70.69%, 23.25% and 6.06% respectively (Table 2-2).

Greenhouse gases were obviously increased in the atmosphere due to human activities. In Thailand (1990), combustion generated carbon dioxide at the level of 79 million tons or 36% of total activities. Changes of land use and forestry, agriculture, industrial process and waste management released CO₂ 78, 54, 10 and 3 million tons or 35%, 24%, 4% and 1%, respectively (Table 2-3).

In 1994, combustion released most carbon dioxide at the level of 130 million tons or 45.45% of total activities. Agriculture, changes of land use and forestry, industrial process and waste management released carbon dioxide 78, 62, 16 and 0.7 million tons or 27.3%, 21.67% and 5.6%, respectively (Table 2-4). Although the percentage of greenhouse gases released in 1994 was reduced but the equivalent carbon dioxide value was increased from 79 to 130 million tons. Carbon dioxide released from agriculture was elevated from 54 to 78 million tons. Change of land use and forestry was decreased from 78 to 62 million tons (Table 2-4).

Table 2-1 The emission of the three most significant GHGs in Thailand in 1990

Gases	Emission (Million Tons)	Global Warming Potential (GWP)	Emission in CO₂ equivalent (Million tons)	Percentage of Total Emissions
CO ₂	164	1	164	73
CH ₄	2.8	21	58	25
N ₂ O	0.01	310	3	2
Total				100

Source: (6)

Table 2-2 The emission of the three most significant GHGs in Thailand in 1994

Gases	Emission (Million Tons)	Global Warming Potential (GWP)	Emission in CO₂ equivalent (Million tons)	Percentage of Total Emissions
CO ₂	202,458.05	1	202,458	70.69
CH ₄	3,157.57	21	66,598	23.25
N ₂ O	55.86	310	17,317	6.06
Total			286,373	100

Source: (6)

Table 2-3 Sources of GHGs emission in Thailand in 1990

Production sector	Emission in CO₂ equivalent (Million tons)	Percentage of Total Emissions
All Energy	79	36
Industrial process	10	4
Agriculture	54	24
Land use change & Forestry	78	35
Waste management	3	1
Total	225	100

Source: (6)

Table 2-4 Sources of GHGs emission in Thailand in 1994

Production sector	Emission in CO₂ equivalent (Million tons)	Percentage of Total Emissions
All Energy	130	45.4
Industrial process	16	5.6
Agriculture	78	27.3
Land use change & Forestry	62	21.7
Waste management	0.7	
Total	286.7	100

Source: (6)

2.5 Mangrove Forest

2.5.1 The Importance and Value of Mangrove

According to Sanit Aksornkaw et al. (1999), mangroves are very important resources and play a very significant role in human life and Thailand's economy as a source of fuel and food. Three main values of mangroves are forestry, fisheries and conservation of environmental balance. Forestry values are derived from charcoal, firewood, pole tannin extraction, wood distillation, wood-chips, medicines, construction materials and land use for agriculture. Fisheries values are important as food sources, shelters and nurseries, capture fisheries and maintaining natural ecological balance. Conservation values are important as ecotone between terrestrial and marine ecosystems, being habitats for aquatic animals, birds and wildlife and food resources for living organisms. In addition, mangroves help protect shoreline from storms, tidal waves and erosion (7).

2.5.2 Mangrove Forest and Climate

Mangroves are significant to climate as a source of carbon dioxide absorption. According to Thailand Development and Research Institute (1989), the annual amount of carbon dioxide absorption of mangroves per area throughout Thailand was 77 million tons (8). Under the current greenhouse effect, the LANDSAT data showed that the mangrove area of Thailand in 1996 was 1,047,390 rai

or 0.33% of the total country area with a potential of future decrease (7). According to the research on carbon sink in mangrove (1990), the carbon absorption was decreased to 35.11 tons carbon because of the reduction of mangrove forest. It illustrated that carbon released to the atmosphere would be about 2 tons within 5 years (9).

2.5.3 Distribution of Mangroves in Thailand

In Thailand, mangrove forest areas are distributed on the east and west coasts of the peninsula but mostly found on the west coast region about 934,220 rai or 89.2%. On the east coast region, mangrove areas remain only about 79,112 rai or 7.5% and along the upper part of the Gulf of Thailand about 34,056 rai or 3.3% (7).

2.5.4 Mangrove research and Carbon Absorption

Khamnung Chindanuch studied the carbon dioxide (CO₂) absorption and release in Phang-Nga area, Phang-Nga Province. The rates of carbon dioxide absorption and emission in the daytime and the night time were nearly the same in summer. In rainy season, the carbon dioxide absorption rate in the daytime was 9 times higher than at night. The study on carbon dioxide accumulation in the coastal mangrove in Chumporn Province indicated that mangrove ecosystem kept 1,208 tons carbon / hectare (tc./ha.) and the soil kept 281 tc./ha. The carbon was kept in mangrove forest more than in the soil (10).

Phaisan Thanapermpul studied the production of *Rhizophora apiculata* at Pattani Province and showed that the total biomass (dry weight) of planted mangrove at age 5-20 years was 22.81-234.30 tons/hectare. The maximum biomass incremental rate was at 14 years old and the biomass increased 20.92 tons/hectare/year (11).

The mangrove aged 5-20 years had the volume of 12.56 – 184.87 cubic meters/hectare and the growth rate was 22.61 cubic meters/hectare/year (11).

The change of land use and forestry area in Thailand, i.e. pine forest, mangrove forest, evergreen forest, deciduous forest and dry evergreen forest affected the amount of carbon dioxide absorbed in the forest. In 1990 and 1996, the mangrove area was

256.31 and 242.51 hectare and the carbon accumulation was 37.11 and 35.11 ton of green carbon (TgCO₂). If the mangrove area decreased, the amount of carbon dioxide absorbed in the mangrove would also decrease (9).

In 1990, the change of forest area to other land uses caused the carbon dioxide emission of 33.65 TgCO₂/yr and carbon dioxide absorption 4.98 TgCO₂/yr. In 1994; the total carbon dioxide released was 10.65 TgCO₂/yr and carbon dioxide absorbed was 7.23 TgCO₂/yr. In 1994, although the natural forest area decreased, but the forest plantation area increased (9).

2.6 *Rhizophora apiculata* Plantation

2.6.1 Characteristics of *Rhizophora apiculata*

Rhizophora apiculata (Bl.). Family *Rhizophoraceae*, is strongly associated with soft muds under tidal influence and spring tides. *R.apiculata* can be an important and conspicuous mangrove species along tidal riverbanks, creeks and even seaward areas. In undisturbed pristine sites, *Rhizophora apiculata* trees can reach 25 m in height. The foliage is distinctive, the leaves are markedly smaller than those of the common sister species, *R. mucronata*. *R.apiculata* leaves have a characteristic of color distribution. The leaf tips are sharp, elongate and dark green, giving an almost black tipped appearance from a distance. The mid rib on the lower part of the leaf is pink, the color fades as the lamina flattens. The undersurface of the leaves is a more uniform dark green. *R.apiculata* bark too, is distinctive, being rather dark and smooth externally and orange red to red beneath. Reddish young stilts or prop roots often arising close to the main trunks, are prominent features. From a distance these impressive and massive prop root systems provide a touch of design amidst a tangled sophistication above the soft muddy *Rhizophora*'s amazing habitat (12).

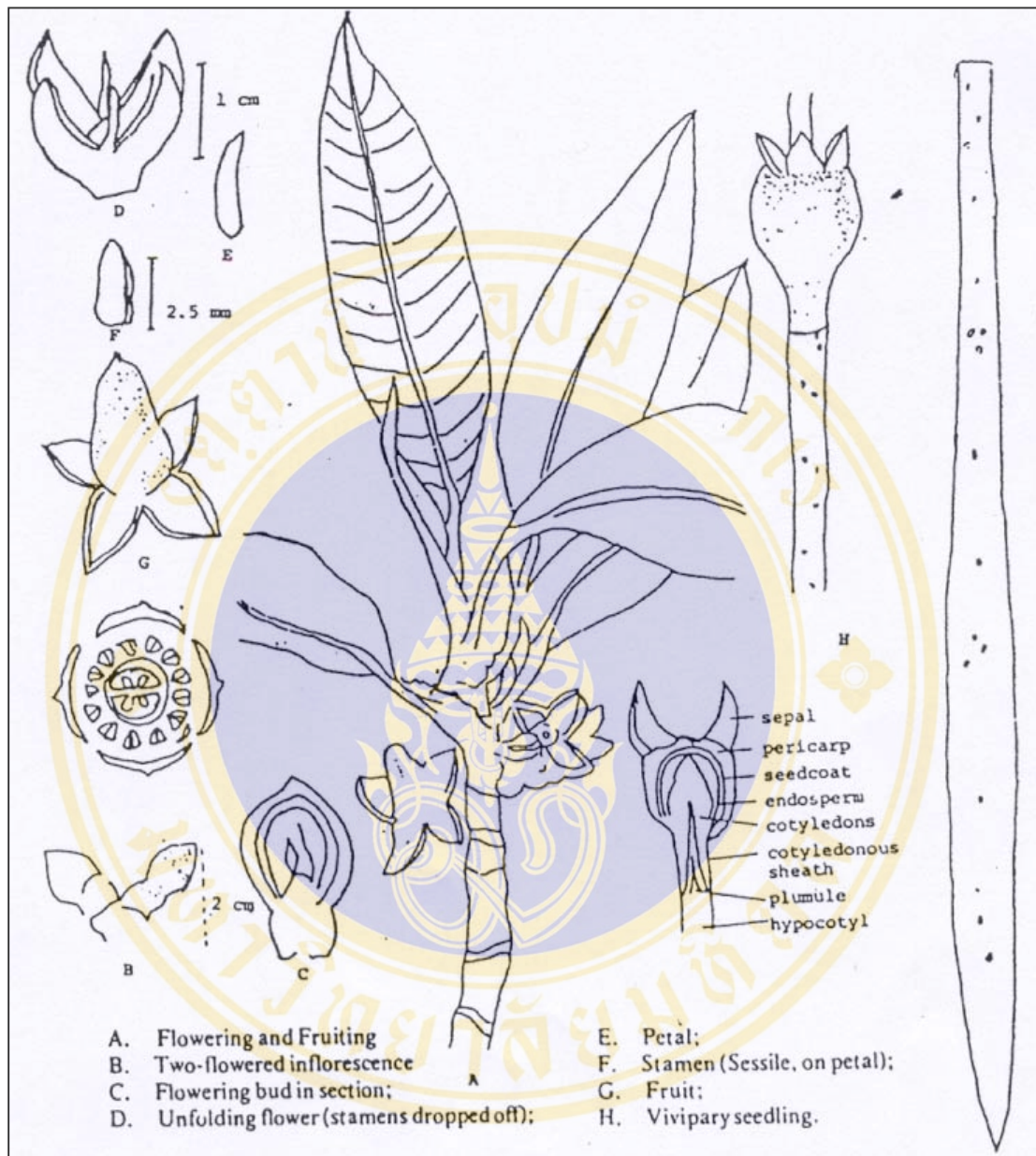


Figure 2-1 Picture of *Rhizophora apiculata*

2.6.2 Plantation of *Rhizophora apiculata* Forest

1. Land preparation

Mangroves grow well in muddy soil with sufficient seawater, close to the shore, river and canal. Hence, proper land for *Rhizophora apiculata* plantation depends on the soil properties and seawater sufficiency. Highland and insufficient

seawater are obstacles of the growth of *Rhizophora apiculata* plantation. Furthermore, *Rhizophora apiculata* needs more light, so proper land should be widely opened to the light. Wooden waste should be brought out from the land because seawater may take them to damage seedlings. Land preparation is a significant stage for *Rhizophora apiculata* plantation. Time is an important factor. In order to prepare land, mowing and wood clearing will take about 5 months. Keeping wooden waste in small heaps with fence will avoid them to damage the seedlings while flooding. Re-mowing should be done prior to plantation. Woods from the first mowing will be decayed at that time (13).

2. Seedlings preparation

To prepare pods of *Rhizophora apiculata*, small bag size 3x6 inches and mixed muddy soil with burned rice hull (1:1) are used for convenience of transfer. Seedling preparation can be summarized as follows:

Table 2-5 Seedlings preparation for *Rhizophora apiculata*

Plant Variety	Seedlings collection	Seedlings Preparation	Cultivation
<i>Rhizophora apiculata</i>	Collect fallen or attached mature pods. <i>Rhizophora mucronata</i> pods have green and yellow calyx but <i>Rhizophora apiculata</i> have red violet calyx.	Keep seedlings in vertical line with regular water and no strong sun	Plant pods into each bag at around 1.5-3 inches deep.

Source: (14)

To cultivate pods in bags, brackish water is used or the nursery should be in the land with regular seawater submersion. In the initial phase, net should be set for barring 50-70% of light to prevent dried pods.

3. Methods for *Rhizophora apiculata* plantation

Sophon Hawanont suggested that *Rhizophora apiculata* should be planted in rainy season, using the distance 1.5 x 1.5.meter. Two planting methods may be used as follows (13):

3.1 Direct pod plantation: pods should be held at one-third from the bottom while planting under the ground. Sharp wooden stick may be used to make a hole before planting. Compressing soil around the pod will keep the pod under the ground.

3.2 Seedling plantation: this method is good for second plantation. Planters must be careful when planting the seeds because the roots of mature seedlings may be damaged and survival rate of mature seedlings may be lowered.

4. The survival rate of *Rhizophora apiculata*

Dusit Wechakit conducted the research on the growth and survival rate of *Rhizophora apiculata* plantation at Umphawa District, Samutsongkram Province (15), and provided the findings as follows:

4.1 After plantation with the density of seeds around 25,000 seeds/hectare (distance between seeds about 0.63 x 0.63 meter), there was high survival rate of plants at the age of 1-2 years at 92-95%.

4.2 Causes of death were crabs, uprooting by macaques and imperfect seeds.

4.3 Trend of survivor was decreased when age of plantation was higher as of high density of seedlings that generated competition, particularly treetops. *Rhizophora apiculata* significantly needed light for growth, so weak seedlings would die if they were not strong enough.

4.4 At the age of 3-4 years, treetops were fairly closed, survival rate was still as high as 87%. At the aged of 5-8 years, the survival rate was 81-84%. Plantation with older ages had lower survival rate. There was less than a half of total plants (41 - 46%) when plantation was aged 13-15 years.

4.5 Average survival rate would decrease about 4% per year or 1,000 trees/hectare.

5. Energy of Charcoal from *Rhizophora apiculata*

A significant benefit of mangrove forest is fuel, especially charcoal. Woods in *Rhizophora apiculata* plantation are good quality charcoal that are popular in the market. Heat value of most kinds of dry woods in mangrove forest was about 4,500-5,000 calorie/gram. Charcoal from mangrove forest has heat value of 6,400-7,600 calorie/gram, which is sufficient for household cooking (16).

Dry stems of *Rhizophora apiculata* have the highest average energy value. Other parts such as roots and branches also have heat value. The amount of energy and percent of ash from *R.apiculata* combustion are presented in Table 2-6 and 2-7.

Table 2-6 Quantity of energy from dry stems, branches and prop roots of *Rhizophora apiculata*

Age (year)	Energy, calories/gram											Average
	8	9	10	11	12	13	14	15	16	17	18	
Dry stems	3,653	3,716	3,508	3,877	3,722	3,846	4,121	3,770	3,895	3,990	4,013	3,832.8
Branches	3,652	3,711	3,580	3,608	3,738	3,818	3,940	3,678	3,678	3,764	3,728	3,717.5
Prop roots	3,683	3,724	3,795	3,847	3,732	3,890	3,974	3,780	3,780	3,876	3,844	3,819.6

Source: (16)

Table 2-7 Percent of wood ash from *Rhizophora apiculata* combustion

Age (year)	Quantity of wood ash, %											Average
	8	9	10	11	12	13	14	15	16	17	18	
Dry stems	1.0	0.8	0.9	0.8	1.0	0.9	1.0	1.1	1.1	1.1	1.1	0.97
Branches	1.7	1.4	1.5	1.7	1.4	1.5	1.4	2.1	2.4	2.8	2.0	0.82
Prop roots	0.8	0.6	0.8	0.7	0.9	1.0	1.8	1.8	1.7	1.2	1.5	1.10

Source: (16)

6. Relevant Researches

Phaisan Thanapermpul conducted the research on *Rhizophora apiculata* plantation in Yaring District, Pattani Province, measuring the growth in height, diameter, biomass and volume at different ages between 5-20 years. The findings were as follows (11):

(1) Average height of *Rhizophora apiculata* during 5-20 years plantation was between 3.56-14.23 meter. The highest growth of plantation was in the age of 17 and the lowest growth was at the age of 19. Height of 17 years and 19 years were increased 1.76 meter/year and 0.06 meter/year respectively. Average growth rate of plantation was 0.71 meter/year.

(2) Average diameter of *Rhizophora apiculata* during 5-20 years plantation was between 2.64-9.70 centimeter. The highest diameter growth was at the plantation age of 17 years and the lowest diameter growth was at the age of 13. The incremental rate of diameter at 17-year and 13-year were 1.30 cm/year and 0.01 cm/year respectively. Average diameter growth rate was 0.47 cm/year.

(3) Total biomass of *Rhizophora apiculata* during 5-20 years plantation was between 22.81-234.30 ton/hectare. The highest biomass growth was when the plantation aged 14 with the increased biomass 20.92 ton/hectare/year.

(4) Total volume of *Rhizophora apiculata* during 5-20 years plantation was between 14.33-197.16 cubic-meter/hectare. Plantation aged 14 years showed the highest volume growth. The total volume and volume of goods were increased as 24.87 and 22.61 cubic-meter/hectare/year respectively.

Chawalit Urapephanpong stated that woods from mangrove forest were mostly popular for charcoal e.g. *Rhizophora spp.* *Rhizophora spp.* consisted of 2 types as *Rhizophora apiculata*. Bi and *R. mucronata* Poir. Mangrove in Thailand offered higher volume and better quality of *Rhizophora spp.* However, less popular species for charcoal production belonged to *Bruguiera spp.*, *Ceriop spp.*, *Xylocarpus spp.*, *Avicennia spp.*, and *Lumnitzera spp.* Volumes of these woods were lesser than of *Rhizophora spp.*, and will be lesser in the future because of the elimination of those woods and substitute plantation of *Rhizophora spp.* (17).

Arun chomchan studied humidity in mangrove forest and reported that *Rhizophora apiculata* had normal humidity as 6,354 and *R.mucronata* had normal humidity as 6,530 (18).

2.7 Theories, Analysis Principles and Feasibility of the Project

2.7.1 Project Analysis Theory

Basic economic problems of all countries are the limitation of resources such as labor, land, cost and natural sources. Natural resources should be effectively utilized to be products and services for the highest net return on investment. However, social demands are varied, uncertain and endless so it is necessary to effectively utilize and economize existing natural resources. In the meantime, it should be mostly consistent with demands or holistic purpose. Hence, prior to make decision of using natural resources for any purpose, it is essential to estimate existing resources for the highest benefit. One way to analyze economic effectiveness of natural resource utilization is feasibility study of the project.

Project analysis is one method to present effectiveness of natural resource utilization and economization under specific purpose or social demand in convenient and proper pattern because there is the estimation on the whole benefits and costs of the project.

Financial analysis is to determine the project in term of private investment. The return on investment should be good as well as profit. Project analysis is not only good for investors but also necessary for financial institutes, cooperatives and organizations that offer loan (19).

In addition, financial analysis includes proper financial planning for the project and project analysis of return on investment for each investor such as farmers, private sector, government enterprise and relevant ones. It assures the project will yield incentive return for investors (20).

2.7.2 Relevant Costs of Mangrove Plantation Project

1. Fixed cost consists of depreciation of assets that are necessary for plantation and opportunity cost e.g. land, construction, accessories- machines, vehicles and office supplies (21).

2. Variable costs are expenses for the first year of plantation and annual maintenance that can be classified by the following characteristic (21):

(1) Operative costs

- Labor e.g. salary and wages
- Materials, office supplies, stationaries, fuel and oil

(2) Expenses of land and forest preparation

- Labor e.g. survey boundary, mowing and burning
- Accessories e.g. fuel
- Pods and seedlings preparation

(3) Plantation

- Labor e.g. transportation from seedlings nursery to field, planting and lining, pitching and transporting piles
- Accessories e.g. fuel for vehicle to transport seedlings

(4) Maintenance

- Labor e.g. insect and animal detection
- Accessories e.g. fuel for vehicle to transport labor to field
- Seedlings repair within 5 years since the beginning of plantation

(5) Fees (22)

- Land preparation
- Concession fee
- Royalty fee
- Maintenance fee

(6) Charcoal making and selling (22)

- Labor
- Fuel
- Hemp bags

2.7.3 Relevant Researches with Project Analysis

Jirasak researched about the benefits from *Rhizophora apiculata* plantation at Samutsakorn Province, in cases of participation and non-participation in government economic plantation project. The study results showed that the ratio of benefit to cost (B/C) of *Rhizophora apiculata* plantation in case of participation in government project was over 1 in each age cycle at the interest rate 6%-14%. Ratio of B/C in case of non-participation in government project would be more than 1 when plantation age was 10-15 years at the interest rate less than 10% (23).

For the Net Present Value (NPV) of *Rhizophora apiculata* plantation, farmers would have profit (B/C over 1) from the same ages and interest rate (23).

B/C of participation in government project was higher than B/C of non-participation. In case of participation, plantation aged 10-15 years yielded B/C as 21.17%, 20.33%, 19.53%, 18.78%, 18.18% and 17.44% respectively. In case of non-participation, plantation aged 10-15 years offered B/C as 10.85%, 10.90%, 10.83%, 10.70%, 10.53% and 10.34% respectively. It emphasized that the participation in government project would provide higher B/C than non-participation (23).

Piya studied about expenses and profit of carbon dioxide reduction in both conservation and commercial *Rhizophora apiculata* plantations. In 1994, expense was 932.67 baht/rai/year with land of 11.13 million rai. Expense for reducing carbon dioxide was 0.149 baht/k Wh and 232.22 baht/CO₂ without any profit except carbon dioxide reduction. If there were 60% of plantation, 1.05 million rai for commercial charcoal, use of LPG would be decreased 47.7% in 1996 (24).

Kasem carried out a complete evaluation on forest work of Forest Industrial Organization at Khao Laem Dam, in all Deciduous Forest, Deciduous Dipterocarp Forest, Evergreen Forest, Tropical Green Forest, and Montane Forest. Using the interests of 9%, 12% and 15%, the B/C over 1 were 1.22, 1.20 and 1.17 respectively. That meant the project was worth for investment (25).

Santi researched on economy and marketing of Eucalyptus plantation, Khon kaen Province, emphasizing on the cost of Eucalyptus plantation for paper production. Distance of plantation was 2 x 2 meter per rai. There were 3 types of selling prices: selling per overage weight at 706 baht/ton, selling per rai at 3,479 baht/rai, and selling per tree at 35 baht/tree. Economic cost-profit analysis was employed with the discount rates 6%, 9%, 12%, 15% and 18%. B/Cs were 1.81, 1.77, 1.73, 1.69 and 1.65 respectively. IRR equaled 85.73%. NPV were 3,188.01, 2,847.40, 2,275.28 and 2,034.58 baht/rai respectively. That expressed the worth of investment (26).

Koraphat studied the financial analysis of *Tectona grandis* Forest in 25 cycles, in Maelee Plantation, Lumpoon Province. Characteristics of teak were 1) having identifying marks, 2) perfect logs, 3) square wood with identifying marks, 5) sheet wood with identifying marks and 6) perfect sheet woods. Perfect woods showed more NPV than woods with identifying marks. IRR in normal case were 12%, 19%, 12.54%, 16.88%, 17.48%, 23.71% and 25.21% respectively. NPV with 6% discount in the first case was decreased as 7.55% when compared with the second case. NPV of the 3rd case was reduced from the 4th case as 12.27%. NPV of the 5th case was less than the 6th case as 23.48%. Sensitivity of the project showed that the 3rd case had the highest risk if compared with the 1st and 2nd case respectively. Consequently, higher discount influenced higher risk of project (27).

Waraporn presented the economic analysis of plantation of Forest Industrial Organization by employing 3 types of analysis: B/C ratio, NPV and IRR. The samples were 3 fields with different interests and prices of goods sold. The analysis results stated that wooden price in some level such as 450-500 baht/cubic meter influenced the investment of plantation with the interest of 11%-15%. Those showed poor return on investment. If selling price was 550 baht/cubic meter and over, return on investment would be interesting (28).

2.8 Study Area

2.8.1 Location

Mangrove of the Mangrove Development Office-39 and the Yaring Natural Mangrove Study Center is located at the Pattani Bay (the Yaring National Conservation Forest) yamu, Talokapro Sub-district, Yaring District, Pattani Prvince (6).

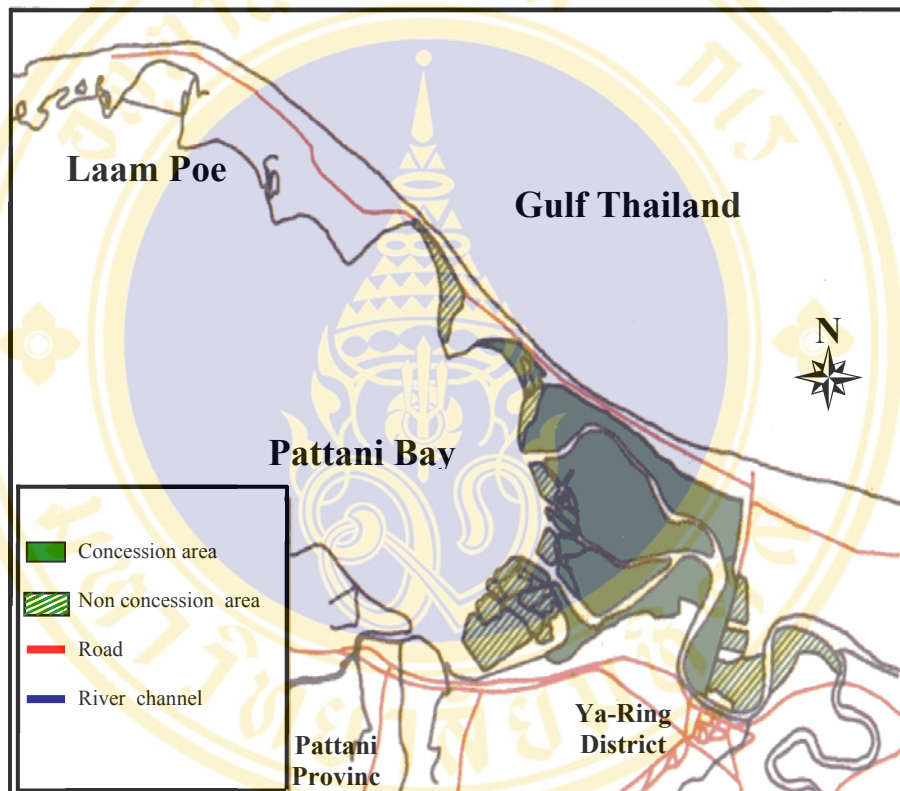


Figure 2-2 Study site

2.8.2 Characteristics of the Area

The Yaring mangrove area is flooding plain of the mouth of the river. The sediment is deposited at both sides of the river. It is clay and becomes shallow. The stream has changed the direction, and then becomes canal. The main canals are Kolae canal, Bang Pu canal, Ya Mu canal and Klang canal (6).

2.8.3 Climate

Pattani province is under affected by the Southwest monsoons, Northeast monsoons and Southeast monsoons. It is divided into 2 seasons. Rainy season starts in

May to January. Southwest monsoons will come from the Indian Ocean during the rainy season, between May to September. The amount of rainfall water is average at 100-150 millimeter in each month. The Northeast monsoons passing through the Gulf of Thailand cause heavy rain; especially in November and December. The amount of rainfall is average at 200-4000 millimeter. Summer starts in February to April. Southeast monsoons come from the high-density area in South China Sea. The average temperature is 26.9 degree. April is the hottest month; the average temperature is 28.1 degree. The average relative humidity is 81 % all years (6).

2.8.4 Geology

The mangrove of Yaring and vicinity area is unconsolidated sediment of Quaternary period. The coastal plains in Yaring and vicinity area are divided in four parts as follows (6):

1. Old and recent beach ridges are continuing form to the sea. The age of the ridges are graded from the oldest to the youngest. The youngest ridge is beach nearby the recent shoreline. There are varieties of soil texture, between medium sand and very fine sandy clay.
2. Old and recent lagoon is not drown by the seawater and is deposited by fine sandy clay.
3. Former and recent tidal flat is wide area, from the oldest beach ridge to the alluvium sediment.
4. Old and recent beach ridges associated with old and recent lagoon.

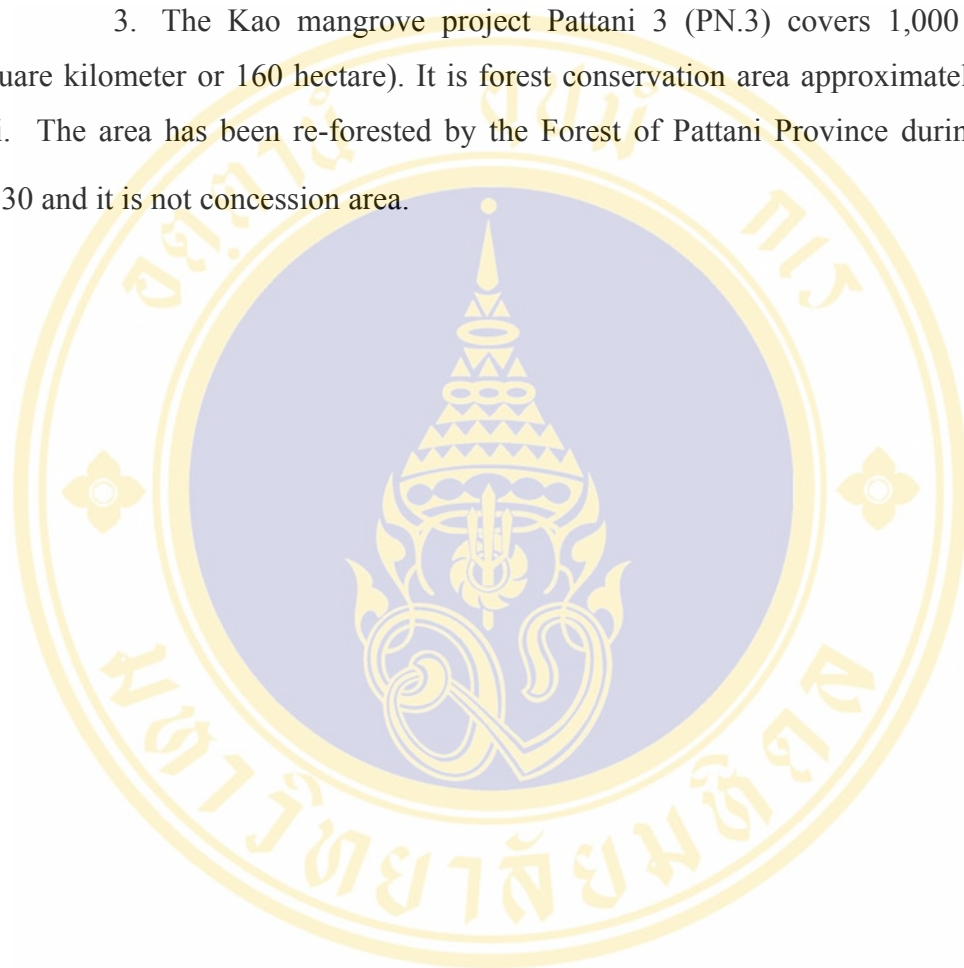
2.8.5 Land Use.

Yaring area is covered by of natural forest and forest plantation. The Forest Department plans the mangrove project in this area, divided into 3 phases as follow (6):

1. The Yaring mangrove project Pattani 1 (PN.1) covers 4,700 rai (2,937.5 square kilometer or 752 hectare). It is natural forest and used to be the forestry concession area, but the concession is stopped now.

2. The Bang Pu mangrove project Pattani 2 (PN.2) covers 1,200 rai (750 square kilometer or 192 hectare). It is forest conservation area approximately 1,021.50 rai. The area has been re-forested by the Forest of Pattani Province during 2509 – 2530 and it is not concession area.

3. The Kao mangrove project Pattani 3 (PN.3) covers 1,000 rai (625 square kilometer or 160 hectare). It is forest conservation area approximately 712.75 rai. The area has been re-forested by the Forest of Pattani Province during 2509 – 2530 and it is not concession area.



CHAPTER 3

METHODOLOGY

3.1 Planning of Research

This research was a survey research that gathered secondary data from relevant organizations and primary data from samples in field data collection. Mathematics and economic formulas were used as well as research instrument to analyze and compile findings.

3.2 Study Site

Data collection from *R.apiculata* plantations for conservation and commercial purpose was done in Yaring (Pattani Project 1 – PN.1) within the area of 4,700 rai. The area was under care of Mangrove Development Office 39 and the Yaring Natural Mangrove Study Center, Yaring District, Pattani Province. The Yaring mangrove was conservation mangrove that was in the second round of concession but now the forest activities were prohibited.

3.3 Equipment

Research instruments were as follows:

3.3.1 Data on cost of *R.apiculata* plantation for conservation purpose since the 1st – 30th year and *R.apiculata* plantation for commercial purpose since the first year until the harvest year.

3.3.2 Equations and formulas for calculations were as follows: (11)

Biomass of the dry stems:

$$\log W_s = \log A + h \log D^2H \dots\dots\dots(1)$$

when W_s = dry weight or biomass of the dry stems

D = Diameter

H = Height

Biomass of the prop roots:

$$\log W_p = \log A + h \log D^2H \dots\dots\dots(2)$$

when W_p = dry weight or biomass of the prop roots

D = Diameter

H = Height

Biomass of the branches of trees:

$$\log W_B = \log A + h \log D^2H \dots\dots\dots(3)$$

when W_B = dry weight or biomass of branches

D = Diameter

H = Height

Biomass of the leaves:

$$\log W_L = \log A + h \log D^2H \dots\dots\dots(4)$$

when W_L = dry weight or biomass of leaves

D = Diameter

H = Height

Volume of wood products:

$$\log V_M = 1.2830 + 1.0947 \log D^2H \dots\dots\dots(5)$$

when V_M = Volume of wood product

D = Diameter

H = Height

Logistic growth model: (23)(6)

$$W_T = \frac{W_{max}}{1+me^{-rt}}$$

When, W_T = mean total aboveground carbon content per ha ($t\ ha^{-1}$)

W_{max} = maximum mean total aboveground carbon content per ha ($t\ ha^{-1}$)

t = age (year)

m, r = constants

Carbon storage = Total biomass x 0.5 (9)(7)

Present value : (29)

$$PV = m / (1+r)^t \dots\dots\dots(8)$$

When PV = present value

m = benefit or total cost value

r = discount rate

t = year

3.3.3 Topographic Map of the Royal Thai Survey Department at sheet 5222 I, series L7017, scale 1: 50,000, year 1987. Pattani Province

3.3.4 Global Position System (GPS)

3.3.5 Equipments for plotation and wooden volume measurement

- a) Rope
- b) Diameter Tape
- c) Measuring pole
- d) Data Sheet

3.3.6 Personal Computer

3.3.7 Program Curve-Expert 1.3, Microsoft Excel

3.4 Data Collection

3.4.1 Primary data

(a) Plotation of *R.apiculata* plantation was done and wooden volume was measured as follows.

1. The sampled plots of *R.apiculata* plantation for conservation purpose were at the age of 22, 24, 27, 28 and 30 years, 3 plots of each age, and plot size was 10 x 10 meter. Total sampled plots were 15. Data collected were height and diameter, see Figure 3-1.

2. The sampled plots of *R.apiculata* plantation for commercial purpose were within the concession area, at the age of 7, 9, 11, 13 and 15 years, 6 plots of each age and plot size was 10 x 10 meter. Total sampled plots were 30, 15 plots of the first cycle and 15 plots of the second cycle. Data collected were height and diameter, see Figure 3-1.

(b) Data on cost and benefit of *R.apiculata* plantation for commercial purpose (concession) were acquired by in depth interview with the licensee of the concession (Mr.Surin and family, see Appendix A).

3.4.2 Secondary data

Height, diameter, biomass and volume of wood product and cost of *R.apiculata* plantation for conservation purpose were collected from the Mangrove Development Office-39th.

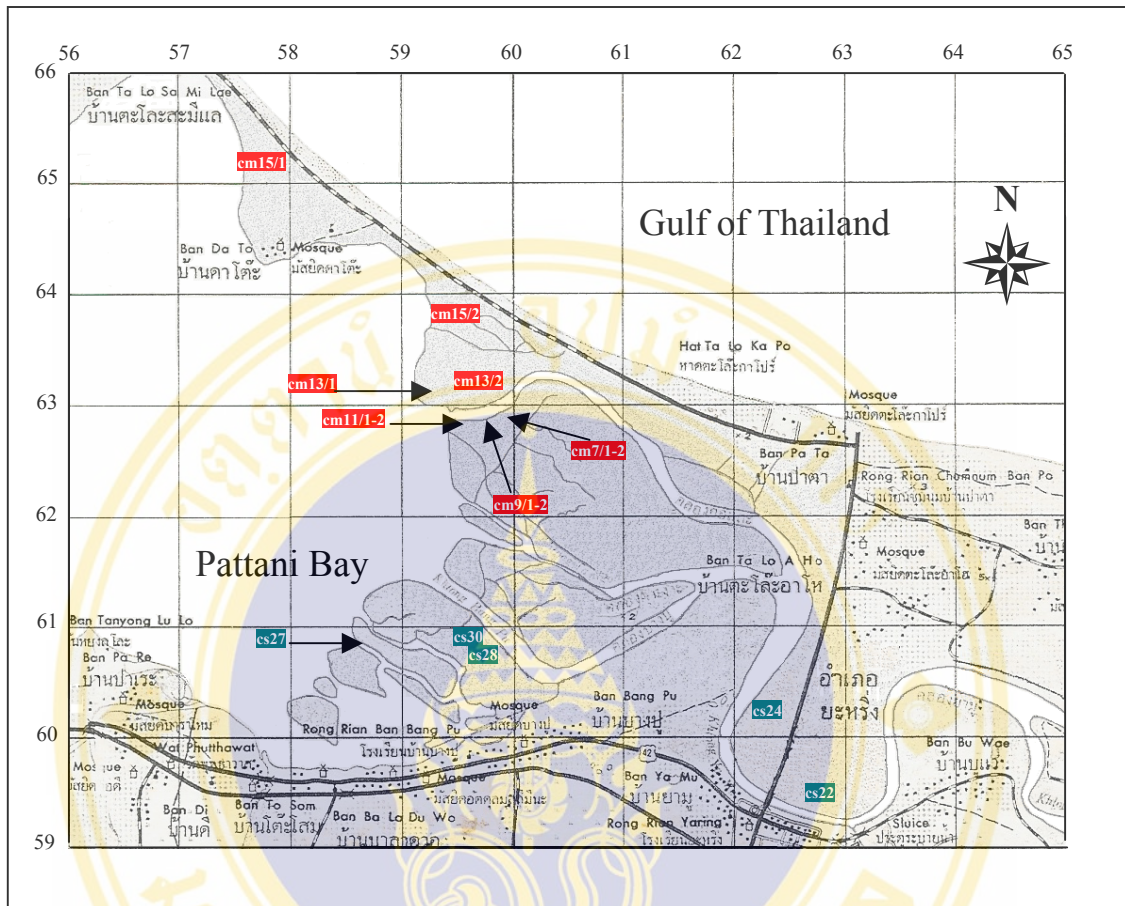


Figure 3-1 Sampled plots in the study area

- cs22 = Sampling plot of *R.apiculata* plantation for conservation purpose (age 22 year)
- cs24 = Sampling plot of *R.apiculata* plantation for conservation purpose (age 24 year)
- cs27 = Sampling plot of *R.apiculata* plantation for conservation purpose (age 27 year)
- cs28 = Sampling plot of *R.apiculata* plantation for conservation purpose (age 28 year)
- cs30 = Sampling plot of *R.apiculata* plantation for conservation purpose (age 30 year)
- cm7/1 = Sampling plot of *R.apiculata* plantation for commercial purpose (age 7 year) : cycle 1
- cm7/2 = Sampling plot of *R.apiculata* plantation for commercial purpose (age 7 year) : cycle 2
- cm9/1 = Sampling plot of *R.apiculata* plantation for commercial purpose (age 9 year) : cycle 1
- cm9/2 = Sampling plot of *R.apiculata* plantation for commercial purpose (age 9 year) : cycle 2
- cm11/1 = Sampling plot of *R.apiculata* plantation for commercial purpose (age 11 year) : cycle 1
- cm11/2 = Sampling plot of *R.apiculata* plantation for commercial purpose (age 11 year) : cycle 2
- cm13/1 = Sampling plot of *R.apiculata* plantation for commercial purpose (age 13 year) : cycle 1
- cm13/2 = Sampling plot of *R.apiculata* plantation for commercial purpose (age 13 year) : cycle 2
- cm15/1 = Sampling plot of *R.apiculata* plantation for commercial purpose (age 15 year) : cycle 1
- cm15/2 = Sampling plot of *R.apiculata* plantation for commercial purpose (age 15 year) : cycle 2

3.5 Data Analysis

3.5.1 *R.apiculata* plantation for conservation purpose

(a) Biomass, carbon storage and volume of wood product were calculated using Logistic Growth Model...(6), (22) and mathematics equation and formula algometric method (11) as follows

Biomass of the dry stems.....	(1)
Biomass of the prop roots.....	(2)
Biomass of the branches of trees.....	(3)
Biomass of the leaves.....	(4)
Volume of wood product.....	(5)
Carbon storage = Total biomass x 0.5.....	(7)

(b) Analysis of economic return

1. The total cost of *R.apiculata* plantation for conservation purpose was total fixed costs plus total variable costs. The details of total cost were as follows:

1.1 Fixed costs included depreciation of assets and opportunity cost from plantation.

1.2 Variable costs comprised expenses of plantation in the first year and annual maintenance cost as follows:

- 1.2.1 Surveying
- 1.2.2 Land clearing
- 1.2.3 Boundary setting
- 1.2.4 Stakes sitting
- 1.2.5 Seedlings for replanting
- 1.2.6 Planting
- 1.2.7 Pods for planting

1.2.8 Counting survival rate and replanting

1.2.9 Maintenance

1.2.10 Miscellaneous

1.2.11 Materials

2. The benefit of *R.apiculata* plantation for conservation purpose was derived from carbon storage value (quantity of carbon storage x minimum and maximum price of carbon storage).

3. The net economic return of *R.apiculata* plantation for conservation purpose was derived from the present value of benefit minus the present value of total costs. The present value of benefit and total cost was calculated as follows:

$$PV = m / (1+r)^t \dots \dots \dots (8)$$

Remark: Discount rates 6%, 8%, 10%, 12% and 14%.

3.5.2 *R.apiculata* plantation for commercial purpose

(a) Biomass, carbon storage and volume of wood product were calculated using Logistic Growth Model and calculation methods as described in 3.5.1..

(b) Analysis of economic return

1. The total cost of *R.apiculata* plantation for commercial purpose was total fixed costs plus total variable costs. The details of total cost were as follows:

1.1 Fixed costs included depreciation of assets and opportunity cost from plantation such as: structure cost, charcoal kiln cost, a motor boat cost, a tug boat cost and water pump cost.

1.2 Variable costs comprised expenses of plantation in the first year and annual maintenance cost as follows:

- 1.2.1 Operating
- 1.2.2 Cutting
- 1.2.3 Land preparation
- 1.2.4 Seedlings for replanting
- 1.2.5 Planting
- 1.2.6 Pods for planting
- 1.2.7 Counting survival rate and replanting
- 1.2.8 Opening forest fee
- 1.2.9 Royalty fee
- 1.2.10 Maintenance
- 1.2.11 Making a charcoal

Remark: If the wood was used for construction material, charcoal kiln cost and cost of making were not included.

2. The benefit of *R.apiculata* plantation for commercial purpose was derived wood use patterns as follows:

2.1 100% charcoal production (quantity of charcoal product x price of charcoal).

2.2 99% charcoal production 1% and construction material:

2.2.1 Benefit from charcoal (quantity of charcoal product x price of charcoal).

2.2.2 Benefit from construction material (quantity of construction material x price), plus carbon storage value in construction material (quantity of carbon storage in construction material x price).

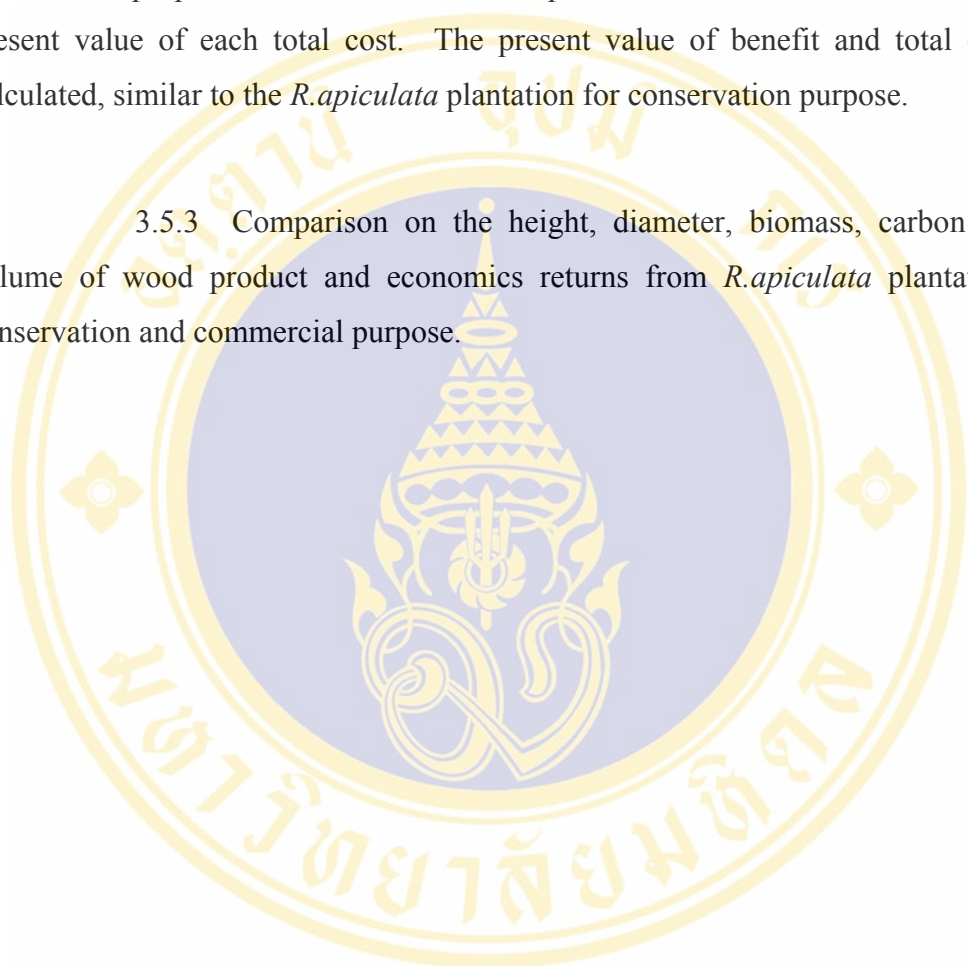
2.3 100% construction material

2.3.1 Benefit from construction material (quantity of construction material x price).

2.3.2 Carbon storage value in construction material (quantity of carbon storage in construction material x price).

3. The net economic return of *R.apiculata* plantation for commercial purpose was derived from the present value of each benefit minus the present value of each total cost. The present value of benefit and total cost was calculated, similar to the *R.apiculata* plantation for conservation purpose.

3.5.3 Comparison on the height, diameter, biomass, carbon storage, volume of wood product and economics returns from *R.apiculata* plantations for conservation and commercial purpose.



CHAPTER 4

RESULTS AND DISCUSSION

4.1 *Rhizophora apiculata* plantation for conservation purpose

4.1.1 Analysis on height, diameter, biomass, carbon storage and volume of wood product provided.

(1) Height

R. apiculata at the age of 1-5 years had little increase of height, from 0.96 to 2.8 m. (Table 4-1). Increase of height was in the range of 0.3-0.6 m., or 0.36 m./year on average (Table 4-2).

R. apiculata at the age of 6-10 years had rapid increase of height from 3.53 to 7.27 m. (Table 4-1). The average increase of height was 0.89 m./year (Table 4-2). During the age of 11-15 years, the height increased from 8.21 to 11.03 m. (Table 4-1) with the average increase of height 0.75 m./year (Table 4-2).

During the age of 16-30 years, the height increased from 11.46 to 12.82 m. (Table 4-1) with the average increase of height 0.11 m./year (Table 4-2). Figure 4-1, indicated that *R. apiculata* had the highest growth during the age of 6-15 years and had the trend to stop growing during the age of 16-30 years.

(2) Diameter

R. apiculata age 1-5 years had the growth of diameter from 2.12 to 3.28 cm. (Table 4-1). The average increase of diameter was 0.23 cm./year (Table 4-2). During the age of 6-10 years and 11-15 years, the growth of diameter was 3.63-5.28 cm. and 5.74 - 7.70 cm. respectively (Table 4-1). The average increase of diameter was 0.4 and

0.48 cm./year (Table 4-2). During the age of 16-30 years, diameter was between 8.19-13.27 cm. (Table 4-1). The average increase of diameter was 0.36 cm./year (Table 4-2). Figure 4-1 showed the steadily increase of diameter during the age of 1-15 years and the diameter growth tended to be slower during the age of 16-30 years.

(3) Biomass and carbon storage

R. apiculata plantation age 1-5 years had the same trend of increase of biomass and carbon storage as of height and diameter. During the age of 6-10 and 11-15 years, biomass and carbon were more rapidly increased. Biomass increased from 2.55 to 19.14 tc./ha. during the age of 6-10 years and rapidly increased from 43.80 - 208.70 tc./ha. during the age of 11-15 years (Table 4-1). The average increase of biomass was 3.43 and 37.91 tc./ha. (Table 4-2). During the age of 6-10 and 11-15 years, carbon storage was 1.28-9.57 and 21.90-104.35 tc./ha. (Table 4-1) and the average increase of carbon storage was 1.71-18.95 tc./ha. (Table 4-2).

R. apiculata age 16-30 years had the slower biomass growth and carbon storage. Biomass was 209.49-209.56 t./ha. (Table 4-1). The average increase of biomass was 0.05 t./ha./year (Table 4-2). Carbon storage was 104.75-104.78 tc./ha (Table 4-1) and the average increase of carbon storage was 0.02 tc./ha/year (Table 4-2).

Figure 4-1 showed that *R. apiculata* had the highest increase of biomass and carbon storage, during the age of 6-15 years and tended to have steady biomass and carbon storage during the age of 16-30 years.

(4) Volume of wood product

During the age of 1-5 years, volume of wood product increased from 2.26 to 14.56 m³/ha. (Table 4-1). The average increase of volume of wood product was 2.46 m³/ha./year (Table 4-2). The volume at the age of 6-10 years and 11-15 years increased from 22.54 to 92.25 and from 115.51 to 117.16 m³/ha respectively (Table 4-1). The average increase of volume of wood product was 15.53 and 16.98 m³/ha./year

respectively (Table 4-2).

During the age of 16-30 years, volume of wood product slightly increased from 183.54 to 194.85 m³/ha. (Table 4-1). The average increase of volume of wood product was 1.17 m³/ha./year. (Table 4-2). Figure 4-1 showed that *R. apiculata* had the highest increase in wood volume during the age of 6-15 years and tended to have steady wood volume after 16 year old.

According to Figure 4-1, *R. apiculata* had rather slight increase of height, biomass, carbon storage and volume of wood product. Rapid growth occurred during the age of 6-15 years. More steady growth occurred during the age of 16-30 years.

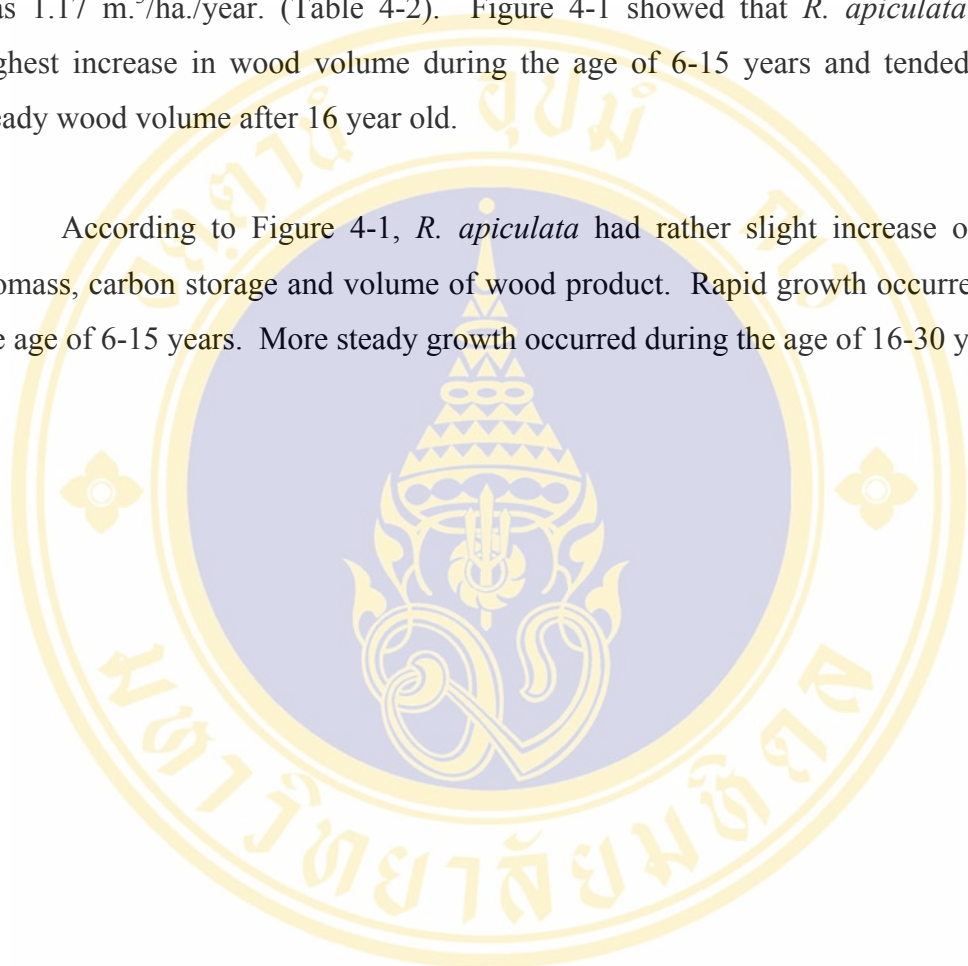


Table 4-1 Average height, diameter, biomass, carbon storage and volume of wood product of *R.apiculata* plantation for conservation purpose: by calculation

Age (year)	Height (m.)	Diameter (cm.)	Biomass (t. / ha.)	Carbon storage (tc. / ha.)	Volume of wood product (m. ³ / ha.)
1	0.96	2.12	1.20	0.60	2.26
2	1.28	2.37	1.30	0.65	3.64
3	1.68	2.65	1.44	0.72	5.82
4	2.18	2.95	1.65	0.83	9.26
5	2.80	3.28	1.99	1.00	14.56
6	3.53	3.63	2.55	1.28	22.54
7	4.37	4.01	3.54	1.77	34.05
8	5.30	4.41	5.44	2.72	49.75
9	6.28	4.83	9.49	4.75	69.56
10	7.27	5.28	19.14	9.57	92.25
11	8.21	5.74	43.80	21.90	115.51
12	9.08	6.22	99.31	49.65	136.81
13	9.85	6.70	168.89	84.44	154.40
14	10.50	7.20	202.00	101.00	167.72
15	11.03	7.70	208.70	104.35	177.16
16	11.46	8.19	209.49	104.75	183.54
17	11.80	8.68	209.55	104.78	187.71
18	12.05	9.15	209.56	104.78	190.38
19	12.25	9.62	209.56	104.78	192.07
20	12.40	10.06	209.56	104.78	193.13
21	12.52	10.49	209.56	104.78	193.79
22	12.60	10.89	209.56	104.78	194.20
23	12.66	11.27	209.56	104.78	194.45
24	12.71	11.62	209.56	104.78	194.61
25	12.74	11.95	209.56	104.78	194.71
26	12.77	12.26	209.56	104.78	194.77
27	12.79	12.53	209.56	104.78	194.80
28	12.80	12.79	209.56	104.78	194.83
29	12.81	13.02	209.56	104.78	194.84
30	12.82	13.23	209.56	104.78	194.85

Table 4-2 Increase of height, diameter, biomass, carbon storage and volume of wood of *R.apiculata* plantation for conservation purpose

Age (year)	Increase of height (m.)	Increase of diameter (cm.)	Increase of biomass (t. / ha.)	Increase of carbon storage (tc. / ha.)	Increase of volume of wood product (m. ³ / ha.)
1	-	-	-	-	-
2	0.32	0.25	0.10	0.05	1.38
3	0.40	0.28	0.14	0.07	2.18
4	0.50	0.30	0.21	0.11	3.44
5	0.62	0.33	0.34	0.17	5.30
6	0.73	0.35	0.56	0.28	7.98
7	0.84	0.38	0.99	0.49	11.51
8	0.93	0.40	1.90	0.95	15.70
9	0.98	0.42	4.05	2.03	19.81
10	0.99	0.45	9.65	4.82	22.69
11	0.94	0.46	24.66	12.33	23.26
12	0.87	0.48	55.51	27.75	21.30
13	0.77	0.48	69.58	34.79	17.59
14	0.65	0.50	33.11	16.56	13.32
15	0.53	0.50	6.70	3.35	9.44
16	0.43	0.49	0.79	0.40	6.38
17	0.34	0.49	0.06	0.03	4.17
18	0.25	0.47	0.01	0	2.67
19	0.20	0.47	0	0	1.69
20	0.15	0.44	0	0	1.06
21	0.12	0.43	0	0	0.66
22	0.08	0.40	0	0	0.41
23	0.06	0.38	0	0	0.25
24	0.05	0.35	0	0	0.16
25	0.03	0.33	0	0	0.1
26	0.03	0.31	0	0	0.06
27	0.02	0.27	0	0	0.03
28	0.01	0.26	0	0	0.03
29	0.01	0.23	0	0	0.01
30	0.01	0.21	0	0	0.01

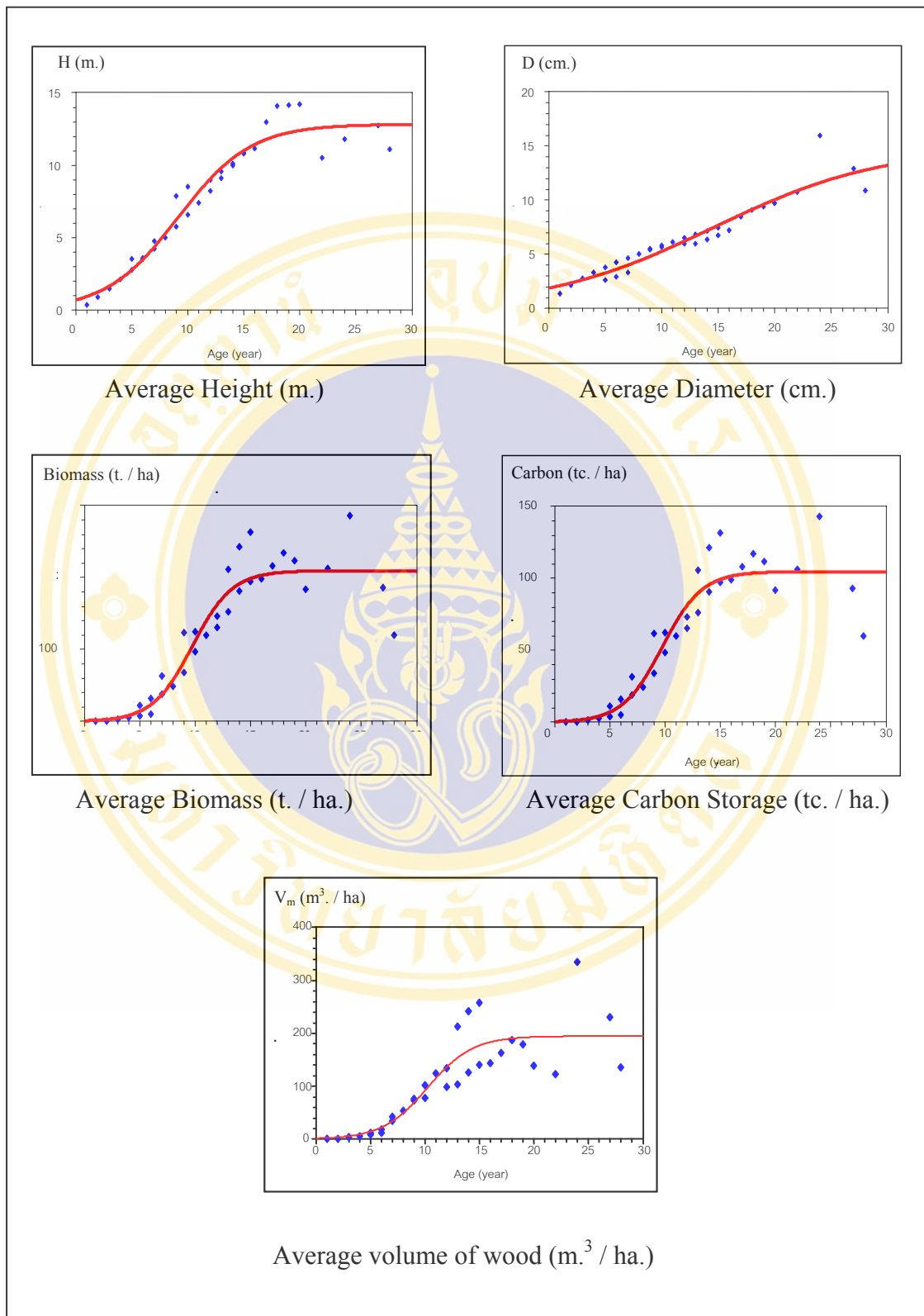


Figure 4-1 Average height, diameter, biomass, carbon storage and volume of wood of *R. apiculata* plantation for conservation purpose

4.1.2 Analysis on cost, benefit and net economic return

(1) Cost of *R.apiculata* plantation for conservation purpose

The cost of planting *R.apiculata* for conservation purpose provided by the Mangrove Development Office-39th Pattani was categorized as follows: (See Appendix A)

a) Total cost in the first year was 26,250 baht/hectare, illustrated in Table 4-3.

b) Total cost in the second year was 4,687.50 baht/hectare (Table 4-4). In the 3rd-6th year, the cost of each year was equal to the cost in the 2nd year. There was no cost after the 6th year.

Table 4-3 Cost of planting *R.apiculata* for conservation purpose: 1st year

	Cost	baht / hectare
	Variable cost	
1	Surveying	312.50
2	Land clearing	7,500.00
3	Boundary setting	2,812.50
4	Stakes setting	2,062.50
5	Seedling for replanting	2,150.00
6	Planting	3,500.00
7	Pods for planting	1,734.38
8	Counting survival rate and replanting	2,812.50
9	Maintenance	2,437.50
10	Miscellaneous	625.00
11	Materials	303.13
	Total	26,250.00

Source: see Appendix B-1

Table 4-4 Cost of planting *R.apiculata* for conservation purpose: 2nd year

	Cost	baht / hectare
	Variable cost	
1	Counting survival rate and replanting	1,606.25
2	Maintenance	2,875.00
3	Miscellaneous	96.88
4	Materials	109.38
	Total	4,687.500

Source: see Appendix B-2

According to the data of the Mangrove Development Office-39th Pattani, the fixed cost was not clearly stated in the budget of plantation. Considering the existing activities, motor boat was the only fixed cost which was used for all activities, not only for the mangrove plantation. Therefore, the motor boat cost could not be counted as the fixed cost.

(2) Benefit of *R.apiculata* plantation for conservation purpose

For conservation purpose, the only benefit from *R.apiculata* plantation would be the carbon storage value. The maximum and minimum carbon storage values per hectare varied according to the trading price of developing countries as follows:

1. Minimum value: 50\$ per ton or approximately 2,000 baht/ton
2. Maximum value: 100\$ per ton or approximately 4,000 baht/ton

Hence, one hectare would provide benefit from selling carbon storage in the year 30th (carbon storage in the year 30th was 104.78 tc./ha., See Table 4-1) at the minimum of 209,560 baht/hectare and at the maximum of 419,120 baht/hectare, see Table 4-5.

Table 4-5 Cost and benefit of *R.apiculata* plantation for conservation purpose

Year	Cost (baht / ha.)	Minimum benefit: (baht / ha.)	Maximum benefit (baht / ha.)
1	26,250.00 ⁽¹⁾	-	-
2	4,687.50 ⁽²⁾	-	-
3	4,687.50 ⁽³⁾	-	-
4	4,687.50 ⁽⁴⁾	-	-
5	4,687.50 ⁽⁵⁾	-	-
6	4,687.50 ⁽⁶⁾	-	-
7-29	-	-	-
30	-	209,560*	419,120.00**
Total	49,687.50	209,560	419,120.00

Remark: - (1) See Table 4-3, (2) – (6) See Table 4-4

- * and ** See Appendix E

In the 1st-6th years, there was the cost of plantation but there was no benefit because the plantation would provide benefit in the 30th year only. During the 7th-29th years, there was no cost and benefit. In the 30th year, the carbon storage could be traded at the minimum of 209,560 baht/ha. and at the maximum of 419,120 baht/ha..

During the project operation, there was no benefit until the end of the 30th year which might be very long period and very risky for investment.

(3) Net economic return

The net economic return of *R.apiculata* plantation for conservation purpose was in the range of -33,030 to 29,581 baht/ha. according to discount rates, see Table 4-6.

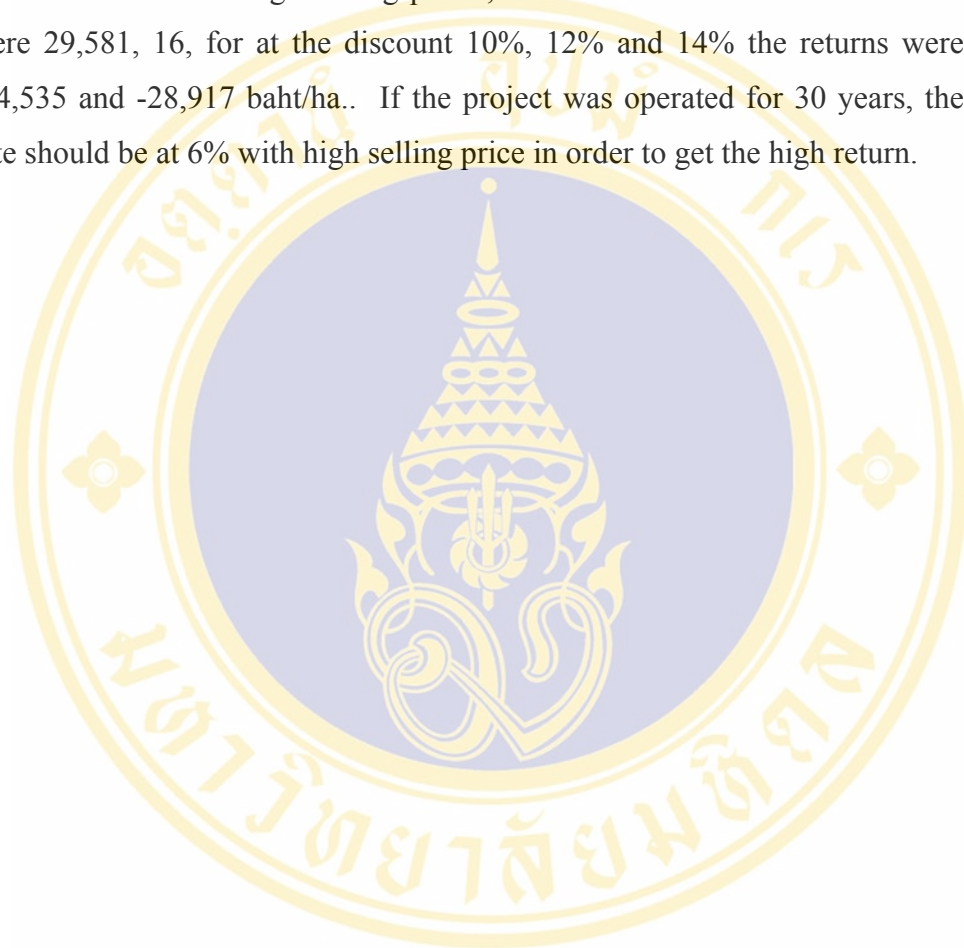
The present value of cost, benefit and net economic return of *R.apiculata* plantation for conservation purpose were illustrated in Table 4-6.

Table 4-6. Present value of cost, benefit and net economic return of *Rhizophora apiculata* plantation for conservation purpose

Year	Present Value (baht / ha.)																					
	6%			8%			10%			12%			14%									
	Cost	Benefit	Net economic return	Cost	Benefit	Net economic return	Cost	Benefit	Net economic return	Cost	Benefit	Net economic return	Cost	Benefit	Net economic return							
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.						
1	24,764	-	-24,764	24,764	24,306	-24,306	-24,306	-	-24,306	23,864	-	-23,864	23,418	-	-23,418	23,072						
2	4,172	-	-4,172	4,019	4,019	-4,019	-4,019	-	-4,019	3,874	-	-3,874	3,737	-	-3,737	3,607						
3	3,936	-	-3,936	3,721	3,721	-3,721	-3,721	-	-3,721	3,522	-	-3,522	3,336	-	-3,336	3,164						
4	3,713	-	-3,713	3,445	3,445	-3,445	-3,445	-	-3,445	3,202	-	-3,202	2,979	-	-2,979	2,775						
5	3,503	-	-3,503	3,190	3,190	-3,190	-3,190	-	-3,190	2,911	-	-2,911	2,660	-	-2,660	2,435						
6	3,305	-	-3,305	2,954	2,954	-2,954	-2,954	-	-2,954	2,646	-	-2,646	2,375	-	-2,375	2,136						
7-29	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-						
30	-	36,487	36,487	72,973	20,826	41,651	20,826	41,651	12,010	24,019	12,010	24,019	6,995	13,989	6,995	13,989						
Total	43,392	36,487	72,973	41,635	20,826	41,651	20,809	41,635	40,018	12,010	24,019	-28,008	38,524	6,995	13,989	31,530	-24,535	37,143	4,113	8,226	-33,010	-28,917

From Table 4-6, at the discount rate: 6%, 8%, 10%, 12% and 14%, the minimum selling price would provide the return -6,905, -20,809, -28,008, -31,530 and -33,030 baht/ha., respectively. The higher the discount rate, the less the return.

For the high selling prices, at the discount rate: 6% and 8% the returns were 29,581, 16, for at the discount 10%, 12% and 14% the returns were -15,998, -24,535 and -28,917 baht/ha.. If the project was operated for 30 years, the discount rate should be at 6% with high selling price in order to get the high return.



4.2 *R.apiculata* plantation for commercial purpose

4.2.1 Analysis on height, diameter, biomass, carbon storage and volume of wood product

The analysis on height, diameter, biomass, carbon storage and volume of wood product from filed data collection (see Appendix D) done by Growth Model provided the results as follows:

(1) Height

In the 1st cycle, *R. apiculata* age 1-5 years had the increase of height from 1.14 to 3.08 m. (Table 4-7) and the average increase of height 0.38 m./year (Table 4-8). During the age of 6-10 years, the height increased from 3.78 to 6.89 m. (Table 4-7) and the average increase of height was 0.76 m./year (Table 4-8). The highest growth of *R. apiculata* was in this age range. The height between the age of 11-15 years was 7.58-9.43 m. (Table 4-7). The average increase of height reduced to 0.5 m./year (Table 4-8). Figure 4-2 showed rapid increase of height during the age of 6-10 years.

In the 2nd cycle, *R. apiculata* age 1-5 years had the increase of height from 0.99 to 2.95 m. (Table 4-7) with the average increase of height 0.39 m./year (Table 4-8). During the age of 6-10 years, the height was in the range of 3.69-6.99 m. with the average increase of height was 0.8 m./year (Table 4-8). The *R. apiculata* had a rapid growth during the age of 6-10 years. During the age of 11-15 years, the height was 7.69-9.44 m., having the average increase of height 0.49 m./year (Table 4-8). Figure 4-2 rapid increased of height during the age of 6-10 years.

(2) Diameter

In the 1st cycle, *R. apiculata* age 1-5 years had the growth of diameter 2.15-3.06 cm. (Table 4-7) and the average increase of diameter 0.18 cm./year (Table 4-8). During the age of 6-10 years, the diameter was 3.37-5.26 cm. (Table 4-7) and the average increase of diameter 0.44 cm./year (Table 4-8). *R. apiculata* had the highest growth of diameter during the age of 6-10 years and during the age of 11-15 years

with the diameter of 6.00-12.00 cm. (Table 4-7). The average increase of diameter was 1.35 cm./year (Table 4-8).

From Figure 4-2 showed that during the age of 1-5 years, *R. apiculata* had slow growth of diameter. The increase of diameter was more during the age of 6-10 years was highest during the age of 11-15 years.

In the 2nd cycle, *R. apiculata* age 1-5 years had the growth of diameter 1.24-2.66 cm. (Table 4-7) and the average increase of diameter 0.28 cm./year (Table 4-8). During the age of 6-10 years, the diameter was 3.17-5.86 cm. (Table 4-7) and the average increase of diameter 0.64 cm./year (Table 4-8). *R. apiculata* had high growth of diameter during the age of 6-10 years. During the age of 11-15 years, the increase of diameter was highest from 6.65 to 9.83 cm. (Table 4-7) with the average increase of diameter 0.79 cm./year (Table 4-8).

Figure 4-2 showed that the increase of diameter during the age of 1-10 years in both cycles was similar. During the age of 11-15 years, especially in the 15th year, diameter of *R. apiculata* in the 2nd cycle was less than in the 1st cycle and the average increase of diameter was lower.

(3) Biomass and Carbon Storage

In the 1st cycle, *R. apiculata* age 1-5 years had the increase of biomass from 2.65 to 10.86 t./ha. (Table 4-7) and the average increase of biomass 1.64 t./ha./year (Table 4-8). Carbon storage was 1.32-5.43 tc./ha. (Table 4-7). The average increase of carbon storage was 0.82 tc./ha./year (Table 4-8). During the age of 6-10 years, biomass increase from 15.30 to 53.52 t./ha. (Table 4-7) with the average increase of 8.61 t./ha./year (Table 4-8). Carbon storage during the age of 6-10 years was 7.65-26.96 tc./ha. (Table 4-7) with the average increase of 4.3 tc./ha./year (Table 4-8). During age of 11-15 years, the biomass was 70.55-153.77 t./ha. (Table 4-7) and the average increase was 19.97 t./ha./year (Table 4-8). Carbon storage was 35.28-76.89 tc./ha. (Table 4-7) with the average increase of 9.9 tc./ha./year (Table 4-8).

Figure 4-2 showed that during the age of 1-5 years, both biomass and carbon storage were low and would rapidly increase during the age of 6-10 years and would more rapidly increase during the age of 11-15 years.

For the 2nd cycle, *R. apiculata* age 1-5 years had the increase of biomass from 0.03 to 1.28 t./ha. (Table 4-7). The average increase of biomass was 0.25 t./ha./year (Table 4-8). Carbon storage was 0.02-0.64 tc./ha. (Table 4-7) with the average increase of 0.12 tc./ha./year (Table 4-8). During the age 6-10 years, the growth of biomass was 3.22-61.27 t./ha. (Table 4-7) and the average increase of 12.99 t./ha./year (Table 4-8). Carbon storage was 1.61-33.17 tc./ha. (Table 4-7) with the average increased 6.5 tc./ha./year (Table 4-8). During the age of 11-15 years, the growth of biomass was 92.76-123.78 t./ha. (Table 4-7) with the average increase of 11.50 tc./ha./year (Table 4-8). Carbon storage was 46.38-61.89 tc./ha. (Table 4-7). The average increase of carbon storage was 5.75 tc./ha./year (Table 4-8).

(4) Volume of Wood Product

In the 1st cycle, *R. apiculata* age 1-5 years had the increase of volume of wood product from 3.15 to 18.65 m.³/ha. (Table 4-7) with the average increase of 3.10 m.³/ha./year (Table 4-8). During the age of 6-10 years, the volume of wood product increased from 28.19 to 102.81 m.³/ha. (Table 4-7) with the average increase of 16.83 m.³/ha./year (Table 4-8). During the age of 11-15 years, the growth of volume was 125.39-182.15 m.³/ha. (Table 4-7) with the increase of 15.86 m.³/ha./year (Table 4-8).

During the age of 1-5 years, *R. apiculata* had less volume of wood product due to its age and size. The volume of wood product would rise during the age of 6-10 years. During the age of 11-15 years, *R. apiculata* less increase of wood product. See Figure 4-2.

In the 1st cycle, *R. apiculata* age 1-5 years had the growth of volume of wood product 0.22-5.65 m³/ha (Table 4-7). The average increase of volume of wood product was 1.08 m³/ha./year (Table 4-8). During the age of 6-10 years, the growth of volume of wood product was 12.36-117.37 m³/ha. (Table 4-7) with the average increase of 22.34 m³/ha./year (Table 4-8). During the age of 11-15 years, the growth of volume of wood product was 143.71-172.89 m³/ha. (Table 4-7). The average increase of volume of wood product was 11.10 m³/ha./year (Table 4-8).

Figure 4-2 showed that during the age of 1-5 years, volume of wood product was less because of age and size of trees. The volume of wood product would increase much during the age of 6-10 years. *R. apiculata* had the increase of volume of wood product in the 2nd cycle more than in the 1st cycle. During the age of 11-15 years, the increase of volume of wood product was less than during the age of 6-10 years.

(5) Comparison on height, diameter, biomass, carbon storage and volume of wood product in both cycles

For both cycles, growth characters were likely the same but in the 2nd cycle, there was the trend of steady growth during the age of 11-15 years. The increase of diameters of both cycles were similar. The 1st cycle showed the trend of extensive diameter while the 2nd cycle was stable.

Figure 4-2 showed that in the 1st cycle, biomass, carbon storage and volume of wood product increased slower than in the 2nd cycle during the age of 1-5 years. Rapid increase occurred during the age of 6-10 years and there was the trend to continue growing through 15 years. The 2nd cycle had similar growth pattern.

R. apiculata plantation for commercial purpose had less increase in height, diameter, biomass, carbon storage and volume of wood product. There was slight difference in growth pattern between both cycles the age of 1-15 years.

From the 2 cycles, the mean height was 9.43 m., the mean diameter was 10.93 cm., average biomass and carbon storage were 138.77 t./ha. and 69.39 tc./ha. respectively. The average volume of wood product was 177.52 m.³/ha.



Table 4-7 Average height, diameter, biomass, carbon storage and volume of wood product of *R.apiculata* plantation for commercial purpose (the 1st and 2nd cutting cycle): by calculation

Age (year)	Cutting cycle	Height (m.)	Diameter (cm.)	Biomass (t. / ha.)	Carbon storage (tc. / ha.)	Volume of wood product (m3/ ha.)
1	1 st	1.14	2.15	2.65	1.32	3.12
2		1.49	2.34	3.78	1.89	4.94
3		1.93	2.55	5.39	2.70	7.76
4		2.45	2.79	7.67	3.84	12.11
5		3.08	3.06	10.86	5.43	18.65
6		3.78	3.37	15.30	7.65	28.19
7		4.54	3.73	21.38	10.69	41.48
8		5.34	4.15	29.55	14.78	58.88
9		6.14	4.65	40.28	20.14	79.86
10		6.89	5.26	53.92	26.96	102.81
11		7.58	6.00	70.55	35.28	125.39
12		8.18	6.94	89.85	44.93	145.39
13		8.68	8.14	111.01	55.50	161.54
14		9.10	9.76	132.77	66.39	173.62
15		9.43	12.03	153.77	76.89	182.15
1	2 nd	0.99	1.24	0.03	0.02	0.22
2		1.33	1.51	0.07	0.04	0.49
3		1.76	1.84	0.20	0.10	1.12
4		2.30	2.22	0.50	0.25	2.52
5		2.95	2.66	1.28	0.64	5.65
6		3.69	3.17	3.22	1.61	12.36
7		4.51	3.75	7.91	3.96	25.84
8		5.36	4.39	18.42	9.21	49.51
9		6.20	5.10	38.30	19.15	82.78
10		6.99	5.86	66.27	33.14	117.37
11		7.69	6.65	92.76	46.38	143.71
12		8.28	7.46	109.94	54.97	159.39
13		8.76	8.28	118.52	59.26	167.41
14		9.15	9.07	122.26	61.13	171.18
15		9.44	9.83	123.78	61.89	172.89

Table 4-8. Increase of height, diameter, biomass, carbon storage and volume of wood product of *R.apiculata* plantation for commercial purpose (the 1st and 2nd cutting cycle)

Age (year)	Cutting cycle	Height (m.)	Diameter (cm.)	Biomass (t. / ha.)	Carbon (tc. / ha.)	Volume of wood product (m3/ ha.)
1	1 st	-	-	-	-	-
2		0.35	0.19	1.13	0.57	1.82
3		0.44	0.21	1.61	0.81	2.82
4		0.52	0.24	2.28	1.14	4.35
5		0.63	0.27	3.19	1.59	6.54
6		0.70	0.31	4.44	2.22	9.54
7		0.76	0.36	6.08	3.04	13.29
8		0.80	0.42	8.17	4.09	17.40
9		0.80	0.50	10.73	5.36	20.98
10		0.75	0.61	13.64	6.82	22.95
11		0.69	0.74	16.63	8.32	22.58
12		0.60	0.94	19.30	9.65	20.00
13		0.50	1.20	21.16	10.57	16.15
14		0.42	1.62	21.76	10.89	12.08
15	0.33	2.27	21.00	10.50	8.53	
1	2 nd	-	-	-	-	-
2		0.34	0.27	0.04	0.02	0.27
3		0.43	0.33	0.13	0.06	0.63
4		0.54	0.38	0.30	0.15	1.40
5		0.65	0.44	0.78	0.39	3.13
6		0.74	0.51	1.94	0.97	6.71
7		0.82	0.58	4.69	2.35	13.48
8		0.85	0.64	10.51	5.25	23.67
9		0.84	0.71	19.88	9.94	33.27
10		0.79	0.76	27.97	13.99	34.59
11		0.70	0.79	26.49	13.24	26.34
12		0.59	0.81	17.18	8.59	15.68
13		0.48	0.82	8.58	4.29	8.02
14		0.39	0.79	3.74	1.87	3.77
15	0.29	0.76	1.52	0.76	1.71	

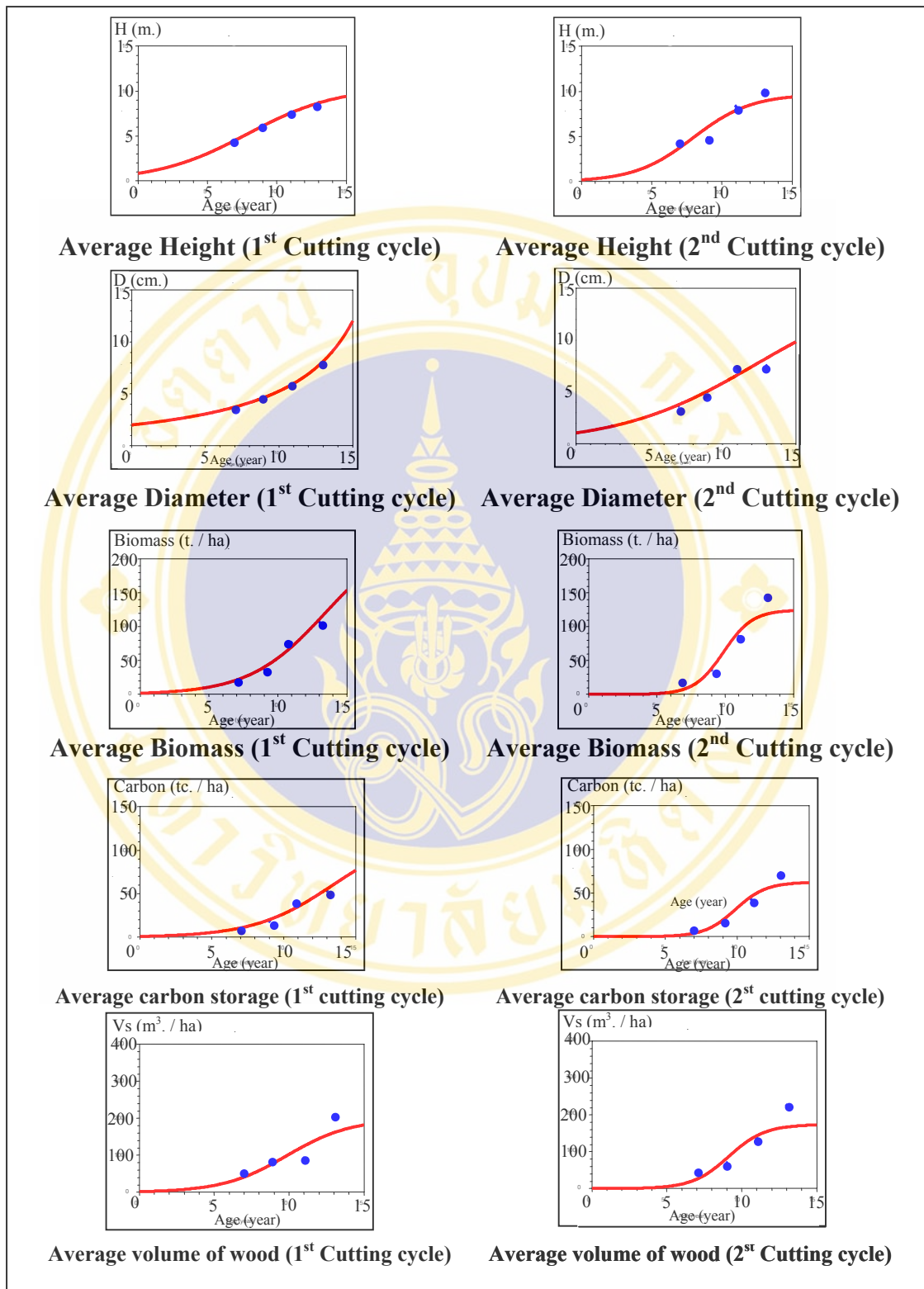


Figure 4-2 Average height, diameter, biomass, carbon storage and volume of wood product of *R.apiculata* plantation for commercial purpose: 1st and 2nd cutting cycle

4.2.2 Analysis on cost, benefit and economic return

The analysis on cost, benefit and economic return of the *R. apiculata* plantation for commercial purpose was based on 3 beneficial patterns as follows:

- (1) 100% Charcoal production
- (2) 99% Charcoal production and 1% construction wood product
- (3) 100% Construction wood product

Different wood use patterns had different costs. For example, the royalty fee was 5 baht/m.³ for charcoal production and was 20 baht/m.³ for construction materials (30).

Consequently, the calculation of cost, benefit and economic return for each wood use pattern was carried out and resulted as follows:

- (1) Cost, benefit and economic return from 100% charcoal production
 - (1.1) Cost
 - (a) Total cost in the first was year 23,460.91 baht/ha., illustrated in Table 4-9.
 - (b) Total cost in the second year was 25,070.62 baht/ ha., by including the maintenance cost in the 1st year (see Table 4-10).
 - (c) Total cost in the third year was 27,129.13 baht/ ha., by including the maintenance cost in the 1st and 2nd years (see Table 4-1).

Table 4-9 Cost of *R.apiculata* plantation for commercial purpose (1st year)
(Wood used pattern: 100% charcoal production)

	Cost	baht / hectare
	Fixed costs	
1	Building	89.10
2	Charcoal kiln	132.98
3	A motor boat	159.57
4	A tug boat	59.84
5	Water pump	7.31
	Variable costs	
6	Operating	82.45
7	Cutting	9,727.50
8	Land preparation	708.51
9	Seedlings for replanting	1,344.00
10	Planting	1,053.19
11	Pods for planting	1,260.00
12	Counting survival rate and replanting	1,041.22
13	Concession fee	79.79
14	Royalty fee	389.10
15	Maintenance	2,058.51
16	Making charcoal	5,267.84
	Total	23,460.91

Source: see Appendix A-1

Table 4-10 Cost of *R.apiculata* plantation for commercial purpose (2nd year)
(Wood used pattern: 100% charcoal production)

	Cost	baht / hectare
	Variable costs	
1	Operating	82.45
2	Cutting	9,727.50
3	Land preparation	708.51
4	Seedlings for replanting	1,344.00
5	Planting	1,053.19
6	Pods for planting	1,260.00
7	Counting survival rate and replanting	1,041.22
8	Concession fee	79.79
9	Royalty fee	389.10
10	Maintenance	4,117.02
11	Making charcoal	5,267.84
	Total	25,070.62

Source: see Appendix A-1

**Table 4-11 Cost of *R.apiculata* plantation for commercial purpose (3rd year)
(Wood used pattern: 100% charcoal production)**

	Cost	baht / hectare
	Variable costs	
1	Operating	82.45
2	Cutting	9,727.50
3	Land preparation	708.51
4	Seedlings for replanting	1,344.00
5	Planting	1,053.19
6	Pods for planting	1,260.00
7	Counting survival rate and replanting	1,041.22
8	Concession fee	79.79
9	Royalty fee	389.10
10	Maintenance	6,175.53
11	Making charcoal	5,267.84
	Total	27,129.13

Source: see Appendix A-1

The cost in the 4th to the 30th year was equaled to one in the 3rd year, see Table 4-12.

From the 1st to 3rd year, the cost of the 1st year was less than the 2nd and 3rd year because the cost in the 2nd year included the maintenance cost of the 1st and 2nd year and the cost of the 3rd year included the maintenance cost of the 1st, 2nd and 3rd year. The *R.apiculata* plantation for commercial purpose or concession would involve cutting and replanting in all years, so the cost of the 4th to 30th year was equaled to the 3rd year.

Cost during the 1st to 30th year and the total cost of 30 years are illustrated in Table 4-12.

(1.2) Benefit

For 100% charcoal production, the benefit from charcoal product was 40,275.94 baht/ha./year, see Table 4-12. Annual benefit and the total benefit from 30 years are illustrated in Table 4-12.

**Table 4-12 Cost and benefit of *R.apiculata* plantation for commercial purpose
(Wood used pattern: 100% charcoal production)**

Year	Cost (baht / ha.)	Benefit (baht / ha.)
1	23,460.91 ⁽¹⁾	40,275.94*
2	25,070.62 ⁽²⁾	40,275.94
3	27,129.13 ⁽³⁾	40,275.94
4-29	27,129.13 ⁽⁴⁻²⁹⁾	40,275.94
30	27,129.13 ⁽³⁰⁾	40,275.94
Total	808,147.17	1,208,278.20

Remark: - (1) see Table 4-9

- (2) see Table 4-10

- (3-30) see Table 4-11

- * see Appendix F-1

Table 4-12 illustrates the cost and benefit of the 1st year and following years. For 100% charcoal production, there was no carbon storage because the charcoal was used for cooking and lost all carbon.

(1.3) Net economic return

The 100% charcoal production provided showed the net economic return from 96,864 to 186,256 baht/ha. Depending on the to discount rate, see Table 4-13.

The net economic returns based on all discount rates are illustrated in Table 4-13

Table 4-13 Cost, benefit and net economic return of *Rhizophora apiculata* plantation for commercial purpose:
(Wood used pattern: 100% charcoal production)

Year	Present Value (baht / ha.)														
	6%			8%			10%			12%			14%		
	Cost	Benefit	Net economic return	Cost	Benefit	Net economic return	Cost	Benefit	Net economic return	Cost	Benefit	Net economic return	Cost	Benefit	Net economic return
1	22,133	37,996	15,863	21,723	37,293	15,569	21,328	36,614	15,286	20,947	35,961	15,013	20,580	35,330	14,750
2	22,313	35,845	13,533	21,494	34,530	13,036	20,720	33,286	12,566	19,986	32,108	12,122	19,291	30,991	11,700
3	22,778	33,816	11,038	21,536	31,972	10,436	20,383	30,260	9,877	19,310	28,668	9,358	18,311	27,185	8,874
4	21,489	31,902	10,414	19,941	29,604	9,663	18,530	27,509	8,979	17,241	25,596	8,355	16,063	23,847	7,784
5	20,272	30,097	9,824	18,464	27,411	8,947	16,845	25,008	8,163	15,394	22,854	7,460	14,090	20,918	6,828
6	19,125	28,393	9,268	17,096	25,381	8,285	15,314	22,735	7,421	13,744	20,405	6,661	12,360	18,349	5,990
7	18,042	26,786	8,743	15,830	23,501	7,671	13,922	20,668	6,746	12,272	18,219	5,947	10,842	16,096	5,254
8	17,021	25,270	8,248	14,657	21,760	7,103	12,656	18,789	6,133	10,957	16,267	5,310	9,510	14,119	4,609
9	16,058	23,839	7,782	13,571	20,148	6,577	11,505	17,081	5,576	9,783	14,524	4,741	8,342	12,385	4,043
10	15,149	22,490	7,341	12,566	18,656	6,090	10,459	15,528	5,069	8,735	12,968	4,233	7,318	10,864	3,546
11	14,291	21,217	6,926	11,635	17,274	5,638	9,509	14,116	4,608	7,799	11,578	3,779	6,419	9,530	3,111
12	13,482	20,016	6,534	10,773	15,994	5,221	8,644	12,833	4,189	6,963	10,338	3,374	5,631	8,360	2,729
13	12,719	18,883	6,164	9,975	14,809	4,834	7,858	11,667	3,808	6,217	9,230	3,013	4,939	7,333	2,394
14	11,999	17,814	5,815	9,236	13,712	4,476	7,144	10,606	3,462	5,551	8,241	2,690	4,333	6,432	2,100
15	11,320	16,806	5,486	8,552	12,697	4,144	6,494	9,642	3,147	4,956	7,358	2,402	3,801	5,643	1,842
16	10,679	15,854	5,175	7,919	11,756	3,837	5,904	8,765	2,861	4,425	6,570	2,145	3,334	4,950	1,616
17	10,075	14,957	4,882	7,332	10,885	3,553	5,367	7,968	2,601	3,951	5,866	1,915	2,925	4,342	1,417
18	9,505	14,110	4,606	6,789	10,079	3,290	4,879	7,244	2,365	3,528	5,237	1,710	2,565	3,809	1,243
19	8,967	13,312	4,345	6,286	9,332	3,046	4,436	6,585	2,150	3,150	4,676	1,526	2,250	3,341	1,091
20	8,459	12,558	4,099	5,821	8,641	2,821	4,033	5,987	1,954	2,812	4,175	1,363	1,974	2,931	957
21	7,980	11,847	3,867	5,389	8,001	2,612	3,666	5,443	1,777	2,511	3,728	1,217	1,732	2,571	839
22	7,528	11,177	3,648	4,990	7,408	2,418	3,333	4,948	1,615	2,242	3,329	1,086	1,519	2,255	736
23	7,102	10,544	3,442	4,621	6,860	2,239	3,030	4,498	1,468	2,002	2,972	970	1,332	1,978	646
24	6,700	9,947	3,247	4,278	6,351	2,073	2,754	4,089	1,335	1,787	2,653	866	1,169	1,735	566
25	6,321	9,384	3,063	3,961	5,881	1,920	2,504	3,717	1,213	1,596	2,369	773	1,025	1,522	497
26	5,963	8,853	2,890	3,668	5,445	1,777	2,276	3,379	1,103	1,425	2,115	690	899	1,335	436
27	5,626	8,352	2,726	3,396	5,042	1,646	2,069	3,072	1,003	1,272	1,889	617	789	1,171	382
28	5,307	7,879	2,572	3,145	4,669	1,524	1,881	2,793	912	1,136	1,686	550	692	1,027	335
29	5,007	7,433	2,426	2,912	4,323	1,411	1,710	2,539	829	1,014	1,506	491	607	901	294
30	4,723	7,012	2,289	2,696	4,003	1,306	1,555	2,308	753	906	1,344	439	532	790	258
Total	368,135	554,392	186,256	300,253	453,418	153,165	250,708	379,678	128,970	213,614	324,430	110,816	185,174	282,039	96,864

Table 4-13 showed that there was the return from investment at each discount rate. Even for the 30 years period, the longer the duration, the higher the discount rate the fewer return. Appropriate discount rate was 10% and would provide a total return from 30 years at 128,970 baht/ha..

(2) Cost, benefit and economic return from 99% charcoal production and 1% construction material

(2.1) Cost

(a) Total cost in the first year was 23,458.96 baht/ha., see Table 4-14.

(b) Total cost in the second year was 25,068.66 baht/ ha., including the maintenance cost in the 1st year (see Table 4-15).

(c) Total cost in the third year was 27,127.17 baht/ ha., including the maintenance cost in the 1st and 2nd years (see Table 4-16).

**Table 4-14 Cost of *R.apiculata* plantation for commercial purpose (1st year)
(Wood used pattern: 99% charcoal production and
1% construct material)**

	Cost	baht / hectare
	Fixed costs	
1	Building	89.10
2	Charcoal kiln	132.98
3	A motor boat	159.57
4	A tug boat	59.84
5	Water pump	7.31
	Variable costs	
6	Operating	82.45
7	Cutting	9,727.50
8	Land preparation	708.51
9	Seedlings for replanting	1,344.00
10	Planting	1,053.19
11	Pods for planting	1,260.00
12	Counting survival rate and replanting	1,041.22
13	Concession fee	79.79
14	Royalty fee	392.02
15	Maintenance	2,058.51
16	Making charcoal	5,262.96
	Total	23,458.96

Source: see Appendix A-2

**Table 4-15 Cost of *R.apiculata* plantation for commercial purpose (2nd year)
(Wood used pattern: 99% charcoal production and
1% construct material)**

	Cost	baht / hectare
	Variable costs	
1	Operating	82.45
2	Cutting	9,727.50
3	Land preparation	708.51
4	Seedlings for replanting	1,344.00
5	Planting	1,053.19
6	Pods for planting	1,260.00
7	Counting survival rate and replanting	1,041.22
8	Concession fee	79.79
9	Royalty fee	392.02
10	Maintenance	4,117.02
11	Making charcoal	5,262.96
	Total	25,068.66

Source: see Appendix A-2

**Table 4-16 Cost of *R.apiculata* plantation for commercial purpose (3rd year)
(Wood used pattern: 99% charcoal production and
1% construct material)**

	Cost	baht / hectare
	Variable costs	
1	Operating	82.45
2	Cutting	9,727.50
3	Land preparation	708.51
4	Seedlings for replanting	1,344.00
5	Planting	1,053.19
6	Pods for planting	1,260.00
7	Counting survival rate and replanting	1,041.22
8	Concession fee	79.79
9	Royalty fee	392.02
10	Maintenance	6,175.53
11	Making charcoal	5,262.96
	Total	27,127.17

Source: see Appendix A-2

The cost in the 4th to the 30th year was equaled to one in the 3rd year, see Table 4-17.

The cost of the 1st year of this pattern was slightly less than the cost of the 1st year of the 100% charcoal production.

From the 1st to 3rd year, the cost of the 1st year was less than the 2nd and 3rd year because the cost in the 2nd year included the maintenance cost of the 1st and 2nd year and the cost of the 3rd years included the maintenance costs of the 1st, 2nd and 3rd year. The plantation for commercial purpose or concession would involve cutting and replanting in all years, so the cost of the 4th to 30th year was equaled in the 3rd year.

Cost during the 1st to 30th year and the total cost of 30 years are illustrated in Table 4-17.

(2.2) Benefit

For 99% charcoal production and 1% construct material, the benefit from charcoal product was 40,177.90 baht/hectare and from construct material 3,215.64 baht/hectare. The total benefit was 43,393.54 baht/hectare. Besides, there was also benefit from carbon storage value, at the minimum of 2,451.63 baht/hectare and at the maximum of 4,903.27 baht/hectare. The total minimum benefit was 45,845.17 baht/hectare and the total maximum benefit was 48,296.81 baht/hectare, see Table4-17. Annual benefit and the total benefit from 30 years are illustrated in Table 4-17.

**Table 4-17 Cost and benefit of *R.apiculata* plantation for commercial purpose
(Wood used pattern: 99% charcoal production and 1% construct
material)**

Year	Cost (baht / ha.)	Minimum benefit: (baht / ha.)	Maximum benefit (baht / ha.)
1	23,458.96 ⁽¹⁾	45,845.17*	48,296.81**
2	25,068.66 ⁽²⁾	45,845.17	48,296.81
3	27,127.17 ⁽³⁾	45,845.17	48,296.81
4-29	27,127.17 ⁽⁴⁻²⁹⁾	45,845.17	48,296.81
30	27,127.17 ⁽³⁰⁾	45,845.17	48,296.81
Total	808,088.38	1,375,355.10	1,448,904.30

Remark: - (1) see Table 4-14

- (2) see Table 4-15

- (3-30) see Table 4-16

- * and ** see Appendix F-2

Benefit from this wood use pattern was slightly higher than of the 100% charcoal production, because there was additional benefit from construction material and value of carbon storage of construction material.

(2.3) Net economic returns

The 99% charcoal production and 1% construction material provided the minimum net economic return from 135,878 to 262,943 baht/ha. and the maximum net economic return from 153,046 to 296,689 baht/ha., depending on discount rates., see Table 4-18.

The net economic returns based on all discount rates are illustrated in Table 4-18.

Table 4-18 Cost, benefit and net economic return of *Rhizophora apiculata* plantation for commercial purpose: (Wood used pattern: 99%charcoal production and 1%construct material)

Year	Present Value (baht / ha.)																								
	6%				8%				10%				12%				14%								
	Cost	Benefit	Net economic return		Cost	Benefit	Net economic return		Cost	Benefit	Net economic return		Cost	Benefit	Net economic return		Cost	Benefit	Net economic return						
Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.				
1	22,131	43,250	21,119	23,432	21,721	42,449	44,719	20,728	22,998	21,326	41,677	43,906	20,351	22,580	20,946	40,933	43,122	19,988	22,177	20,578	40,215	42,366	19,637	21,788	
2	22,311	40,802	42,984	18,491	20,673	21,492	39,305	41,407	17,813	19,914	37,889	39,915	17,171	19,197	19,985	36,547	38,502	16,563	18,517	19,290	35,276	37,163	15,987	17,873	
3	22,776	38,492	40,251	15,716	17,774	21,534	36,393	38,340	14,859	16,805	20,381	34,444	36,286	14,063	15,905	19,309	32,632	34,377	13,323	15,068	18,310	30,944	32,599	12,634	14,289
4	21,487	36,314	38,256	14,826	16,768	19,939	33,698	35,500	13,758	15,560	18,328	31,313	32,987	12,785	14,459	17,240	29,135	30,693	11,896	13,454	16,061	27,144	28,596	11,083	12,534
5	20,271	34,258	36,090	13,987	15,819	18,462	31,201	32,870	12,759	14,408	16,844	28,466	29,989	11,622	13,145	15,393	26,014	27,405	10,621	12,012	14,089	23,811	25,084	9,722	10,995
6	19,124	32,319	34,047	13,195	14,924	17,095	28,890	30,435	11,796	13,340	15,313	25,878	27,262	10,566	11,950	13,743	23,227	24,469	9,483	10,725	12,359	20,886	22,003	8,528	9,645
7	18,041	30,490	32,120	12,449	14,079	15,828	26,750	28,181	10,922	12,352	13,921	23,326	24,784	9,605	10,863	12,271	20,738	21,847	8,467	9,576	10,841	18,321	19,301	7,480	8,460
8	17,020	28,764	30,302	11,744	13,282	14,656	24,769	26,093	10,113	11,437	12,655	21,387	22,531	8,732	9,876	10,956	18,516	19,506	7,560	8,550	9,510	16,071	16,931	6,562	7,421
9	16,057	27,136	28,587	11,079	12,530	13,570	22,934	24,160	9,364	10,590	11,505	19,443	20,483	7,938	8,978	9,782	16,532	17,416	6,750	7,634	8,342	14,098	14,852	5,756	6,510
10	15,148	25,600	26,969	10,452	11,821	12,565	21,235	22,371	8,670	9,806	10,459	17,675	18,621	7,217	8,162	8,734	14,761	15,550	6,027	6,816	7,317	12,366	13,028	5,049	5,710
11	14,290	24,151	25,442	9,860	11,152	11,634	19,662	20,714	8,028	9,079	9,508	16,068	16,928	6,561	7,420	7,798	13,179	13,884	5,381	6,086	6,419	10,848	11,428	4,429	5,009
12	13,481	22,784	24,002	9,302	10,521	10,773	18,206	19,179	7,433	8,407	8,644	14,608	15,389	5,964	6,745	6,963	11,767	12,397	4,804	5,434	5,630	9,516	10,024	3,885	4,394
13	12,718	21,494	22,643	8,776	9,925	9,975	16,857	17,759	6,883	7,784	7,858	13,280	13,990	5,422	6,132	6,217	10,507	11,068	4,290	4,852	4,939	8,347	8,793	3,408	3,854
14	11,998	20,277	21,362	8,279	9,363	9,236	15,608	16,443	6,373	7,207	7,143	12,072	12,718	4,929	5,575	5,551	9,381	9,882	3,830	4,332	4,332	7,322	7,713	2,989	3,381
15	11,319	19,130	20,153	7,810	8,833	8,552	14,452	15,225	5,901	6,674	6,494	10,975	11,562	4,481	5,068	4,956	8,376	8,824	3,420	3,868	3,800	6,423	6,766	2,622	2,966
16	10,679	18,047	19,012	7,368	8,333	7,918	13,382	14,097	5,464	6,179	5,904	9,977	10,511	4,074	4,607	4,425	7,478	7,878	3,053	3,453	3,334	5,634	5,935	2,300	2,602
17	10,074	17,025	17,936	6,951	7,862	7,332	12,391	13,053	5,059	5,721	5,367	9,070	9,555	3,703	4,188	3,951	6,677	7,034	2,726	3,083	2,924	4,942	5,206	2,018	2,282
18	9,504	16,062	16,920	6,558	7,417	6,789	11,473	12,086	4,684	5,298	4,879	8,246	8,687	3,367	3,808	3,528	5,962	6,280	2,434	2,753	2,565	4,335	4,567	1,770	2,002
19	8,966	15,152	15,963	6,187	6,997	6,286	10,623	11,191	4,337	4,905	4,436	7,496	7,897	3,061	3,461	3,150	5,323	5,608	2,173	2,458	2,250	3,803	4,006	1,553	1,756
20	8,458	14,295	15,059	5,836	6,601	5,820	9,836	10,362	4,016	4,542	4,032	6,815	7,199	2,782	3,147	2,812	4,753	5,007	1,940	2,195	1,974	3,336	3,514	1,362	1,540
21	7,980	13,486	14,207	5,506	6,227	5,389	9,107	9,594	3,718	4,205	3,666	6,195	6,526	2,529	2,861	2,511	4,243	4,470	1,733	1,959	1,731	2,926	3,083	1,195	1,351
22	7,528	12,722	13,403	5,194	5,875	4,990	8,433	8,884	3,443	3,894	3,332	5,632	5,933	2,299	2,601	2,242	3,789	3,991	1,547	1,750	1,519	2,567	2,704	1,048	1,185
23	7,102	12,002	12,644	4,900	5,542	4,620	7,808	8,226	3,188	3,606	3,030	5,120	5,394	2,090	2,364	2,002	3,383	3,564	1,381	1,562	1,332	2,252	2,372	919	1,040
24	6,700	11,323	11,928	4,623	5,228	4,278	7,230	7,616	2,952	3,338	2,754	4,654	4,903	1,900	2,149	1,787	3,020	3,182	1,233	1,395	1,169	1,975	2,081	806	912
25	6,321	10,682	11,233	4,361	4,932	3,961	6,694	7,052	2,733	3,091	2,504	4,231	4,458	1,728	1,954	1,596	2,697	2,841	1,101	1,245	1,025	1,732	1,825	707	800
26	5,963	10,077	10,616	4,114	4,653	3,666	6,198	6,530	2,531	2,862	2,276	3,847	4,052	1,571	1,776	1,425	2,408	2,537	983	1,112	899	1,520	1,601	620	702
27	5,625	9,507	10,015	3,882	4,390	3,396	5,739	6,046	2,343	2,650	2,069	3,497	3,684	1,428	1,615	1,272	2,150	2,265	878	993	789	1,333	1,404	544	616
28	5,307	8,969	9,448	3,662	4,141	3,144	5,314	5,598	2,170	2,454	1,881	3,179	3,349	1,298	1,468	1,136	1,920	2,022	784	886	692	1,169	1,232	477	540
29	5,007	8,461	8,914	3,455	3,907	2,911	4,920	5,184	2,009	2,272	1,710	2,890	3,045	1,180	1,335	1,014	1,714	1,805	700	791	607	1,026	1,081	419	474
30	4,723	7,982	8,409	3,259	3,686	2,696	4,556	4,800	1,860	2,104	1,555	2,627	2,768	1,073	1,213	905	1,530	1,612	625	707	532	900	948	367	415
Total	368,108	631,051	664,797	262,943	296,689	300,230	516,115	543,715	215,885	243,485	250,690	432,178	455,290	181,489	204,600	213,598	369,291	389,040	155,693	175,442	185,161	321,038	338,206	135,878	153,046

Table 4-18 showed that the discount rate 10% was the appropriate rate for project operation providing the minimum total benefit of 30 years at 181,489 baht/ha./year and the maximum at 204,600 baht/ha./year.

(3) Cost, benefit and economic return from 100% construction material

(3.1) Cost

(a) Total cost in the first year was 19,277.38 baht/ha., illustrated in Table 4-19.

(b) Total cost in the second year was 20,970.07 baht/ ha., including the maintenance cost in the 1st year (see Table 4-20).

(c) Total cost in the third year was 23,028.58 baht/ ha., including the maintenance cost in the 1st and 2nd years (see Table 4-21).

**Table 4-19 Cost of *R.apiculata* plantation for commercial purpose (1st year)
(Wood used pattern: 100% construct material)**

	Cost	baht / hectare
	Fixed costs	
1	Building	89.10
2	A motor boat	159.57
3	A tug boat	59.84
4	Water pump	7.31
	Variable costs	
5	Operating	82.45
6	Cutting	9,727.50
7	Land preparation	708.51
8	Seedlings for replanting	1,344.00
9	Planting	1,053.19
10	Pods for planting	1,260.00
11	Counting survival rate and replanting	1,041.22
12	Concession fee	79.79
13	Royalty fee	1,556.39
14	Maintenance	2,058.51
	Total	19,277.38

Source: see Appendix A-3

**Table 4-20 Cost of *R.apiculata* plantation for commercial purpose (2nd year)
(Wood used pattern: 100% construct material)**

	Cost	baht / hectare
	Variable costs	
1	Operating	82.45
2	Cutting	9,727.50
3	Land preparation	708.51
4	Seedlings for replanting	1,344.00
5	Planting	1,053.19
6	Pods for planting	1,260.00
7	Counting survival rate and replanting	1,041.22
8	Concession fee	79.79
9	Royalty fee	1,556.39
10	Maintenance	4,117.02
	Total	20,970.07

Source: see Appendix A-3

**Table 4-21 Cost of *R.apiculata* plantation for commercial purpose (3rd year)
(Wood used pattern: 100% construct material)**

	Cost	baht / hectare
	Variable costs	
1	Operating	82.45
2	Cutting	9,727.50
3	Land preparation	708.51
4	Seedlings for replanting	1,344.00
5	Planting	1,053.19
6	Pods for planting	1,260.00
7	Counting survival rate and replanting	1,041.22
8	Concession fee	79.79
9	Royalty fee	1,556.39
10	Maintenance	6,175.53
	Total	23,028.58

Source: see Appendix A-3

The cost in the 4th to the 30th year was equaled to one in the 3rd year, see Table 4-22.

The cost of the 1st year was less than of the 2nd and 3rd year because the cost in the 2nd year included the maintenance cost of the 1st and 2nd year and the cost of the 3rd year included the the maintenance cost of the 1st, 2nd and 3rd year. The total cost

plantation for 100% construction material was less than the other 2 previous wood uses because there was no fixed cost of charcoal kiln and no variable cost of charcoal production, although the royalty fee was higher. However, the total cost was still lower and thus provided higher economic return. The cost during the 1st to 30th year and the total cost of 30 years are illustrated in Table 4-22.

(3.2) Benefit

For 100% construct material the benefit from construct material was 85,528.03 baht/hectare. The benefit from carbon storage value was 65,372.83 baht/hectare and at the minimum 130,745.66 baht/hectare at the maximum. The total minimum benefit was 150,900.86 baht/hectare/year and the total maximum was 216,273.69 baht/hectare/year. The annual benefit for 30 years and the total benefit of 30 years are presented in Table 4-22.

**Table 4-22 Cost, benefit of *R.apiculata*. plantation for commercial purpose
(Wood used pattern: 100% construct material)**

Year	Cost (baht / ha.)	Benefit : Min. (baht / ha.)	Benefit : Max. (baht / ha.)
1	19,277.38 ⁽¹⁾	150,900.86*	216,273.69**
2	20,970.07 ⁽²⁾	150,900.86	216,273.69
3	23,028.58 ⁽³⁾	150,900.86	216,273.69
4-29	23,028.58 ⁽⁴⁻²⁹⁾	150,900.86	216,273.69
30	23,028.58 ⁽³⁰⁾	150,900.86	216,273.69
Total	685,130.67	4,527,025.80	6,488,210.70

Remark: - (1) see Table 4-14, (2) see Table 4-15, (3-30) see Table 4-16

- * and ** see Appendix F-3

Benefit from this wood use pattern was higher than ones from other wood use, because there were benefits from construction material and carbon storage value.

(3.3) Net economic returns

The 100% construction material provided the minimum net economic return from 900,321 to 1,765,511 baht/ha. and the maximum net economic return from 1,358,105 to 2,665,357 baht/ha., depending on discount rates., see Table 4-23. The net economic returns based on all discount rates are illustrated in Table 4-23.

Table 4-23 Cost, benefit and net economic return of *Rhizophora apiculata* plantation for commercial purpose: (Wood used pattern: 100% construct material)

Year	Percent Value (baht / ha.)																								
	6%				8%				10%				12%				14%								
	Cost	Benefit		Net economic returns		Cost	Benefit		Net economic returns		Cost	Benefit		Net economic returns		Cost	Benefit		Net economic returns						
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.					
1	18,186	142,359	204,032	124,173	183,846	17,849	139,723	200,253	121,874	182,404	17,525	137,183	196,612	119,658	179,088	17,212	134,733	193,102	117,521	175,890	16,910	132,369	189,714	115,459	172,804
2	18,663	134,301	192,483	115,638	173,820	17,978	129,373	185,420	111,395	167,441	17,331	124,711	178,739	107,381	161,408	16,717	120,397	172,412	108,580	155,695	16,136	116,113	166,416	99,978	150,280
3	19,335	126,699	181,588	107,364	162,232	18,281	119,790	171,685	101,509	153,404	17,302	113,374	162,490	96,072	145,188	16,391	107,408	153,939	91,017	137,548	15,544	101,854	145,979	86,310	130,435
4	18,241	119,528	171,309	107,287	153,068	16,927	110,917	158,968	93,900	142,041	15,729	103,067	147,718	87,338	131,989	14,635	95,900	137,446	81,265	122,811	13,635	89,345	128,051	75,711	114,417
5	17,208	112,762	161,612	95,554	144,404	15,673	102,701	147,192	87,028	131,519	14,290	93,698	134,289	79,399	119,990	13,697	85,625	122,720	72,558	109,652	11,980	78,373	112,326	66,413	100,365
6	16,234	106,379	152,464	90,145	136,230	14,512	95,093	136,209	80,581	121,777	12,990	85,180	122,081	72,181	109,082	11,667	76,451	109,571	64,784	97,904	10,492	68,748	98,531	58,257	88,080
7	15,215	100,258	143,834	85,042	128,519	13,437	88,049	126,194	74,612	112,757	11,817	77,436	110,983	65,619	99,163	10,417	68,260	97,831	57,843	87,414	9,203	60,306	86,431	51,103	77,228
8	14,448	94,677	135,693	80,229	121,244	12,442	81,237	116,846	69,085	104,404	10,743	70,396	100,893	59,653	90,130	9,301	60,946	87,349	51,645	78,048	8,073	52,900	75,817	44,827	67,744
9	13,631	89,318	128,012	75,687	114,381	11,520	75,488	108,191	63,368	96,671	9,766	63,997	91,721	54,230	81,955	8,304	54,416	77,990	46,112	69,686	7,081	46,403	66,506	39,322	59,424
10	12,839	84,262	120,766	71,403	107,907	10,667	69,896	100,177	59,230	89,510	8,879	58,179	83,383	49,300	74,504	7,415	48,386	69,634	41,171	62,220	6,312	40,705	58,338	34,493	52,127
11	12,131	79,493	113,930	67,362	101,799	9,877	64,719	92,756	54,842	82,880	8,071	52,890	75,803	44,818	67,731	6,620	43,380	62,174	36,760	55,553	5,449	35,706	51,174	30,257	45,725
12	11,444	74,993	107,481	63,549	96,037	9,145	59,925	85,885	50,780	76,740	7,338	48,082	68,911	40,744	61,574	5,911	38,732	55,512	32,822	49,601	4,780	31,323	44,890	26,541	40,110
13	10,797	70,748	101,398	59,952	90,601	8,468	55,486	79,523	47,018	71,056	6,671	43,211	62,647	37,040	55,976	5,278	34,383	49,564	29,305	44,287	4,193	27,474	39,377	23,282	35,184
14	10,186	66,744	95,658	56,558	85,472	7,840	51,376	73,633	43,536	65,792	6,064	39,737	56,952	33,673	50,887	4,712	30,877	44,254	26,165	39,542	3,678	24,100	34,541	20,422	30,863
15	9,609	62,866	90,243	53,337	80,634	7,260	47,570	68,178	40,311	60,919	5,513	36,124	51,774	30,612	46,261	4,207	27,569	39,512	23,362	35,305	3,226	21,141	30,299	17,914	27,073
16	9,065	59,402	85,135	50,336	76,070	6,722	44,047	63,128	37,325	56,406	5,012	32,840	47,067	27,829	42,056	3,756	24,615	35,279	20,859	31,522	2,830	18,544	26,578	15,714	23,748
17	8,552	56,039	80,316	47,487	71,764	6,224	40,784	58,452	34,560	52,228	4,536	29,855	42,789	25,299	38,233	3,354	21,978	31,499	18,624	28,145	2,482	16,267	23,314	13,785	20,832
18	8,068	52,867	75,770	44,799	67,702	5,763	37,763	54,122	32,000	48,359	4,142	27,141	38,899	22,999	34,757	2,995	19,623	28,124	16,628	25,130	2,178	14,269	20,451	12,092	18,273
19	7,611	49,875	71,481	42,263	63,870	5,336	34,966	50,113	29,630	44,777	3,765	24,673	35,362	20,908	31,597	2,674	17,531	25,111	14,847	22,437	1,910	12,517	17,940	10,607	16,029
20	7,180	47,052	67,435	39,871	60,235	4,941	32,376	46,401	27,435	41,460	3,423	22,430	32,148	19,007	28,725	2,387	15,643	22,420	13,256	20,033	1,676	10,980	15,736	9,304	14,061
21	6,774	44,388	63,618	37,614	56,844	4,575	29,977	42,964	25,403	38,389	3,112	20,391	32,225	17,279	26,113	2,132	13,967	20,018	11,836	17,887	1,470	9,631	13,804	8,162	12,334
22	6,391	41,876	60,017	35,485	53,627	4,236	27,357	39,781	23,521	35,546	2,809	18,538	26,568	15,709	23,739	1,903	12,471	17,873	10,568	15,970	1,286	8,449	12,109	7,159	10,819
23	6,029	39,305	56,620	33,477	50,591	3,922	25,701	36,835	21,779	32,913	2,572	16,852	24,153	14,281	21,581	1,699	11,135	15,958	9,435	14,259	1,131	7,411	10,622	6,280	9,491
24	5,688	37,269	53,415	31,582	47,727	3,632	23,797	34,106	20,165	30,475	2,338	15,330	21,957	12,982	19,619	1,517	9,942	14,249	8,424	12,731	992	6,501	9,317	5,509	8,325
25	5,366	35,160	50,391	29,794	45,026	3,363	22,034	31,380	18,672	28,217	2,125	13,928	19,961	11,802	17,836	1,355	8,876	12,722	7,522	11,367	870	5,703	8,173	4,832	7,303
26	5,062	33,170	47,539	28,108	42,477	3,114	20,802	29,241	17,289	26,127	1,932	12,661	18,147	10,729	16,214	1,209	7,925	11,359	6,716	10,149	763	5,002	7,169	4,239	6,406
27	4,775	31,292	44,848	26,517	40,073	2,883	18,891	27,075	16,008	24,192	1,757	11,510	16,497	9,754	14,740	1,080	7,076	10,142	5,986	9,682	670	4,388	6,289	3,718	5,619
28	4,505	29,521	42,310	25,016	37,805	2,669	17,491	25,069	14,822	22,400	1,597	10,464	14,997	8,867	13,400	964	6,318	9,055	5,354	8,091	587	3,849	5,377	3,262	4,929
29	4,250	27,850	39,915	23,600	35,665	2,472	16,196	23,212	13,724	20,741	1,452	9,513	13,634	8,061	12,182	861	5,641	8,085	4,780	7,224	515	3,376	4,839	2,861	4,324
30	4,010	26,273	37,655	22,264	33,646	2,289	14,996	21,493	12,708	19,204	1,300	8,648	12,394	7,338	11,075	769	5,037	7,219	4,268	6,450	452	2,982	4,245	2,510	3,793
Total	311,614	2,677,123	2,976,971	1,765,511	2,665,337	254,013	1,698,809	2,434,762	1,444,797	2,180,730	211,977	1,422,530	2,038,794	1,210,552	1,836,817	180,509	1,215,534	1,742,124	1,035,025	1,561,615	156,387	1,056,708	1,514,692	900,321	1,358,105

Table 4-23 showed that the discount rate 10% was the appropriate rate for project operation, providing the minimum total benefit of 30 years at 1,210,552 baht/ha./year and the maximum at 1,826,817 baht/ha./year.

4.3 Comparison between *R.apiculata* plantation for conservation and commercial purposes

4.3.1 Height: *R. apiculata* planted for conservation purpose had little increase of height during the age of 1-5 years and had rapid growth during the age of 6-10 years. During the age of 11-15 years, the increase of height was reduced and tended to be steady during the age of 16-30 years.

R. apiculata planted for commercial purpose had the increase of height similar to those planted for conservation purpose, having rapid growth during the age of 6-10 years. During the age of 11-15 years, the increase of height tended to be more steady.

The result was conformable with the study on *R. apiculata* plantation in Samutsongkram province (15), Trang province (32) and Chonburi province (33).

In comparison, *R. apiculata* planted for conservation purpose had more average height than *R. apiculata* planted for commercial purpose for concession, 11.03 and 9.43 m., respectively.

4.3.2 Diameter: *R. apiculata* planted for conservation purpose had the average increase of diameter during in the age of 1-5 years, 6-10 years, 11-15 years and 16-30 years at 0.23, 0.44, 0.48 and 0.36 cm./year (Table 4-2). The average diameter rapidly increased during the ages of 6-10 years and 11-15 years. The increase of diameter during the 16-30 years was steady.

R. apiculata planted for commercial purpose had a similar increase of diameter as those planted for conservation purpose. In the 2nd cycle, it had less growth than the 1st cycle.

The result was conformable with the study on *R. apiculata* plantation in Samutsongkram province (15), Trang province (32) and Chaburi province (33).

In comparison, *R. apiculata* planted for conservation purpose had less increase of diameter than those planted for commercial purpose. Average diameter of *R. apiculata* in the conservation plots was 7.7 cm. (Table 4-1), of the commercial plots in the 1st cycle was 12.03 cm. and in the 2nd cycle was 9.83 cm. (Table 4-7).

4.3.3 Biomass: *R. apiculata* planted for conservation purpose had average increase of biomass during the age of 1-5 years, 6-10 years, and 11-15 years at 0.15, 3.43 and 37.91 t./ha./year, respectively (Table 4-2). During the age of 16-30 years, the biomass increased as slowly as 0.05 t./ha./year (Table 4-2). Total biomass of 30 years was 209.56 t./ha. (Table 4-1).

R. apiculata planted for commercial purpose had the biomass in the 1st cycle and in the 2nd cycle, 153.77 t./ha. and 123.78 t./ha. respectively (Table 4-7).

Comparing both types of plantations in 30 years, *R. apiculata* plantation for commercial purpose had more biomass than for conservation purpose

4.3.4 Carbon storage: *R. apiculata* planted for conservation purpose had the average total carbon storage of 104.78 tc./ha. within 30 years (Table 4-1).

R. apiculata planted for commercial purpose had the carbon storage of 76.89 tc./ha. and 61.89 tc./ha. in the 1st and 2nd cycle, respectively (Table 4-7).

Comparing both types of plantations in 30 years, *R. apiculata* planted for the commercial purpose had more carbon storage than for conservation.

4.3.5 Volume of wood product: *R. apiculata* planted for conservation purpose had the volume of wood product 194.85 m³/ha. within 30 years. (Table 4-1).

R. apiculata planted for the commercial purpose had 182.50 and 177.89 m³/ha. of wood volume in the 1st and 2nd cycle, respectively.

Comparing both types of plantations in 30 years, *R. apiculata* planted for commercial purpose had more volume of wood product than for conservation purpose.

4.3.6 Cost, benefit and return

(1) The total cost of conservation plantation was less than the total cost of commercial plantation. The cost of conservation plantation was 37,143 to 43,392 Baht/ha.. For commercial plantation, the cost of plantation for 100% charcoal production was 185,174 to 368,135 baht/ha. depending on the discount rates, for 99% charcoal production and 1% construction material was 185,161 to 368,108 baht/ha., and for 100% construction material was 156,387 to 311,614 baht/ha. (Table 4-24).

(2) Benefit from conservation plantation was only from carbon storage. The minimum benefit was 4,113 to 36,487 baht/ha. and the maximum benefit was 8,226 to 72,973 baht/ha. depending on the discount rates. For commercial purpose, plantation for 100% construction material gave the minimum benefit 1,056,708 to 2,077,125 baht/ha. and maximum benefit 1,514,492 to 2,976,970 baht/ha.. Plantation for 99% charcoal production and 1% construction material gave the minimum benefit 321,038 to 631,051 baht/ha. and the maximum benefit 338,206 to 664,797 baht/ha.. Plantation for 100% charcoal production gave the benefit between 282,039 to 554,392 baht/ha., depending on the discount rates (Table 4-24).

(3) The net economic return of the conservation plantation was less than the commercial plantation. The conservation plantation provided the net economic return -33,030 to -6,905 baht/ha. at the minimum and -28,917 to 29,581 baht/ha. at the maximum. The commercial plantation for 100% construction material

had the highest net economic return, 900,321 to 1,765,511 baht/ha. at the minimum and 1,358,105 to 2,665,357 baht/ha. at the maximum respectively, depending on the discount rates. Plantation for 99% charcoal production and 1% construction material provided the net economic return 135,878 to 262,943 baht/ha. and 153,046 to 296,689 baht/ha. at the maximum, depending on the discount rates. Plantation for 100% charcoal production provided the net economic return 96,864 to 186,256 baht/ha. depending on the discount rates, see Table 4-24.



Table 4-24 Cost, benefit and net economic return of *R.apiculata* plantation for conservation and commercial purpose

Plantation purpose	Present Value (bath / ha.)																									
	6%				8%				12%				14%													
	Cost	Benefit		Net economic return	Cost	Benefit		Net economic return	Cost	Benefit		Net economic return	Cost	Benefit		Net economic return										
	Min.	Max.	Min.	Max.		Min.	Max.	Min.	Max.		Min.	Max.	Min.	Max.	Min.	Max.										
Conservation	43,392	38,487	72,973	-4,895	29,581	41,635	28,826	41,631	-20,809	16	40,618	12,010	24,019	-28,004	-15,996	38,224	6,995	13,889	-31,330	-24,535	37,143	4,113	8,226	-33,030	-28,917	
Commercial: 100% charcoal production	364,135		344,392	186,236	308,253	453,418		376,678	124,678	211,614	324,430	110,816		103,174	282,839		96,864									
Commercial: 100% charcoal production and 1% contract material	358,108	431,631	644,797	262,943	286,689	514,115	443,715	243,485	213,883	249,698	472,179	455,238	181,489	204,660	346,291	389,840	153,695	175,442	185,161	311,039	334,204	155,878	155,846			
Commercial: 100% charcoal production and 1% contract material	311,614	2,077,125	2,496,971	1,765,311	2,665,337	254,013	1,698,889	2,424,262	1,444,797	2,188,730	311,977	1,422,353	2,038,794	1,428,972	1,828,817	186,509	1,215,534	1,702,136	1,833,625	1,561,815	156,387	1,494,798	1,514,492	968,321	1,394,185	

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion on the Economic Returns of Conservation and Commercial Plantations

5.1.1 Conservation plantation: the total cost was 37,143 to 43,392 baht/ha.. Minimum benefit was 4,113 to 36,487 baht/ha. and maximum benefit was 8,226 to 72,973 baht/ha.. Minimum net economic return was -33,030 to -6,905 baht/ha. and maximum was -28,917 to 29,581 baht/ha. (Table 4-25).

5.1.2 Commercial plantation for 100% charcoal production: the total cost was 185,174 to 368,135 baht/ha.. The benefit was 282,039 to 554,392 baht/ha.. The net economic return was 96,864 to 186,256 baht/ha. (Table 4-25).

5.1.3 Commercial plantation for 99% charcoal production plus 1% construction material: the total cost was 185,161 to 368,108 baht/ha.. Minimum benefit was 321,038 to 631,051 baht/ha. and maximum benefit was 338,206 to 664,797 baht/ha.. Minimum net economic return was 135,878 to 262,943 baht/ha. and maximum was 153,046 to 296,689 baht/ha. (Table 4-25).

5.1.4 Commercial plantation for 100% construction material: the total cost was 156,387 to 311,614 baht/ha.. Minimum benefit was 1,056,708 to 2,077,125 baht/ha. and maximum benefit was 1,514,492 to 2,976,971 baht/ha.. Minimum net economic return was 900,321 to 1,765,511 baht/ha. and maximum was 1,358,105 to 2,665,357 baht/ha. (Table 4-25).

5.1.5 Carbon storage of the *R.apiculata* plantation for conservation purpose in a total of 30 years was 104.78 tc./ha., less than 138.78 tc./ha. of the *R.apiculata* plantation for 100% construction material. For 99% charcoal production and 1% construction material, the carbon storage in 30 years was only 1.23 tc./ha., and for 100% charcoal production, there was no carbon storage in 30 years (Table 4-25).



Table 4-25 Cost, benefit, net economic return and carbon storage of *R.apiculata* plantation for conservation and commercial purpose

Plantation purpose	Present Value (baht / ha.)												Carbon storage (t/ha)									
	6%			8%			10%			12%				14%								
	Cost	Benefit	Net economic return	Cost	Benefit	Net economic return	Cost	Benefit	Net economic return	Cost	Benefit	Net economic return		Cost	Benefit	Net economic return						
Conservation	43,392	36,487	75,973	-4,995	29,581	41,635	26,826	41,651	-19,192	1,633	36,326	26,826	41,651	-17,699	3,127	37,143	26,826	41,651	-16,317	4,508	188,78	
Commercial: 100% charcoal production	348,135	564,392	186,256	306,253	453,418	256,708	379,678	128,976	213,614	183,174	262,039	96,864										
Commercial: 99% charcoal production and 1% commercial material	348,186	631,891	283,705	306,226	541,715	256,690	432,179	181,449	213,598	185,161	369,640	158,693	348,206	175,442	338,206	135,678	153,046	1,314,692	986,321	1,314,692	138,78	
Commercial: 100% commercial material	311,614	2,077,123	1,765,509	254,913	1,696,809	211,977	1,422,336	1,268,352	188,509	1,742,334	1,605,825	1,561,615	1,514,992	1,514,992	1,514,992	1,514,992	1,514,992	1,514,992	1,514,992	1,514,992	1,514,992	138,78

Table 4-25 indicated that although the commercial plantation provided the higher economic return than the plantation for conservation, but if carbon storage was preferred for the highest return on investment, decision should be made on *R. apiculata* plantation for 100% construction material. This pattern provided carbon storage of 138.78 tc./ha.. Charcoal production (100%) had no carbon storage. Charcoal production (99%) and construction material (1%) had little carbon storage. The conservation plantation had carbon storage of 104.78 tc./ha..

5.2 Recommendations

5.2.1 This research considered the economic return of *R. apiculata* plantation from wooden products and carbon storage value only. Other indirect benefits of both conservation and commercial plantations such as value of travel attractions, value of medicinal plant resources and value of nutritional resources should also be considered in calculation of the net economic return.

5.2.2 This research applied the sets of secondary data on biomass and carbon storage from previous researches in the analysis by the Growth Model. For further study on biomass and carbon storage, each data should be analyzed and compared in order to see which method would provide better accuracy.

5.2.3 There might be the change in future demand on wood use. Other options should be explored, besides 99% charcoal production plus 1% construction material.

5.2.4 The growth rate of plantation for conservation purpose stopped the increase of carbon storage. Cutting some trees for construction material and allowing new trees to grow, the carbon storage may be increased and the plantation can still be used for conservation purpose.

5.2.5 Cutting cycle affected the tree growth, biomass and carbon storage. Appropriate cutting cycle should therefore be re-considered.

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APPENDIX A-1

**Table A-1 Calculation for cost of *R.apiculata* plantation for commercial purpose
(Wood used pattern: 100% charcoal production)**

	Cost	(1) baht	(2) Area (rai)	(3) baht / rai (1) / (2)	(4) baht / ha. (3) * 6.25
	Fixed costs				
1	Building	67,000.00	4700	14.26	89.10
2	Charcoal kiln	100,000.00	4700	21.28	132.98
3	A motor boat	120,000.00	4700	25.53	159.57
4	A tug boat	45,000.00	4700	9.57	59.84
5	Water pump	5,500.00	4700	1.17	7.31
	Variable costs				
6	Operating	62,000.00	4700	13.19	82.45
7	Cutting	7,315,080.00	4700	1,556.40	9,727.50
8	Land preparation	532,800.00	4700	113.36	708.51
9	Seedlings for replanting	1,010,688.00	4700	215.04	1,344.00
10	Planting	792,000.00	4700	168.51	1,053.19
11	Pods for planting	947,520.00	4700	201.60	1,260.00
12	Counting survival rate and replanting	783,000.00	4700	166.60	1,041.22
13	Concession fee	60,000.00	4700	12.77	79.79
14	Royalty fee	292,603.20	4700	62.26	389.10
15	Maintenance	1,548,000.00	4700	329.36	2,058.51
16	Making charcoal	3,961,416.00	4700	842.85	5,267.84

Remark: From 2nd – 30th years, the cost will have only variable cost. And from the 1st to 3rd years, the cost of the 1st year was less than the 2nd and 3rd years because the cost in the 2nd year including maintenance cost of the 1st and 2nd years and the cost of the 3rd years came from maintenance costs of the 1st, 2nd and 3rd years. Hence, the costs of the 2nd and 3rd years were more than the 1st year.

APPENDIX A-2

**Table A-2 Calculation for cost of *R.apiculata* plantation for commercial purpose
(Wood used pattern: 99% charcoal production and 1% construction material)**

	Cost	(1) baht	(2) Area (rai)	(3) baht / rai (1) / (2)	(4) baht / ha. (3) * 6.25
	Fixed costs				
1	Building	67,000.00	4700	14.26	89.10
2	Charcoal kiln	100,000.00	4700	21.28	132.98
3	A motor boat	120,000.00	4700	25.53	159.57
4	A tug boat	45,000.00	4700	9.57	59.84
5	Water pump	5,500.00	4700	1.17	7.31
	Variable costs				
6	Operating	62,000.00	4700	13.19	82.45
7	Cutting	7,315,080.00	4700	1,556.40	9,727.50
8	Land preparation	532,800.00	4700	113.36	708.51
9	Seedlings for replanting	1,010,688.00	4700	215.04	1,344.00
10	Planting	792,000.00	4700	168.51	1,053.19
11	Pods for planting	947,520.00	4700	201.60	1,260.00
12	Counting survival rate and replanting	783,000.00	4700	166.60	1,041.22
13	Concession fee	60,000.00	4700	12.77	79.79
14	Royalty fee	294,795.75	4700	62.72	392.02
15	Maintenance	1,548,000.00	4700	329.36	2,058.51
16	Making charcoal	3,957,748.13	4700	842.07	5,262.96

Remark: From 2nd – 30th years, the cost will have only variable cost. And from the 1st to 3rd years, the cost of the 1st year was less than the 2nd and 3rd years because the cost in the 2nd year including maintenance cost of the 1st and 2nd years and the cost of the 3rd years came from maintenance costs of the 1st, 2nd and 3rd years. Hence, the costs of the 2nd and 3rd years were more than the 1st year.

APPENDIX A-3

**Table A-3 Calculation for cost of *R.apiculata* plantation for commercial purpose
(Wood used pattern: 100% construction material)**

	Cost	(1) baht	(2) Area (rai)	(3) baht / rai (1) / (2)	(4) baht / ha. (3) * 6.25
	Fixed costs				
1	Building	67,000.00	4700	14.26	89.10
2	A motor boat	120,000.00	4700	25.53	159.57
3	A tug boat	45,000.00	4700	9.57	59.84
4	Water pump	5,500.00	4700	1.17	7.31
	Variable costs				
5	Operating	62,000.00	4700	13.19	82.45
6	Cutting	7,315,080.00	4700	1,556.40	9,727.50
7	Land preparation	532,800.00	4700	113.36	708.51
8	Seedlings for replanting	1,010,688.00	4700	215.04	1,344.00
9	Planting	792,000.00	4700	168.51	1,053.19
10	Pods for planting	947,520.00	4700	201.60	1,260.00
11	Counting survival rate and replanting	783,000.00	4700	166.60	1,041.22
12	Concession fee	60,000.00	4700	12.77	79.79
13	Royalty fee	1,170,405.00	4700	249.02	1,556.39
14	Maintenance	1,548,000.00	4700	329.36	2,058.51

Remark: From the 1st to 3rd years, the cost of the 1st year was less than the 2nd and 3rd years because the cost in the 2nd year including maintenance cost of the 1st and 2nd years and the cost of the 3rd years came from maintenance costs of the 1st, 2nd and 3rd years. Hence, the costs of the 2nd and 3rd years were more than the 1st year. Cost of construction material 100% would be less than those previous wood uses because there was no fixed cost of charcoal kiln and variable cost of charcoal production but royalty fee was more.

APPENDIX B-2

แผนการปฏิบัติงานและการใช้จ่ายงบประมาณประจำปีงบประมาณ 2547 แผนงานอนุรักษ์และพัฒนาทรัพยากรธรรมชาติ ขงงานจัดการทรัพยากรทางทะเลและชายฝั่ง กิจกรรมฟื้นฟูสภาพป่าชายเลน งานบำรุงพื้นที่ป่าชายเลน อนุ 2-6 ปี รหัสบัญชี 0101 หมวดรายจ่าย ค่าครุภัณฑ์ที่ดินและสิ่งก่อสร้าง หมวดอุดหนุนป่าชายเลนที่ 1 จังหวัดปัตตานี ฝ่ายอนุรักษ์และฟื้นฟูทรัพยากรป่าชายเลน ส่วนบริหารจัดการทรัพยากรป่าชายเลนที่ 3

งานที่ปฏิบัติ	ปริมาณงาน	หน่วยนับ	อัตราค่าจ้าง (บาท)	งบผูกพัน / งบประมาณค่าจ้าง (บาท)								หมายเหตุ				
				งบผูกพัน 1		งบผูกพัน 2		งบผูกพัน 3		งบผูกพัน 4						
				พ.ศ. 45	พ.ศ. 46	พ.ศ. 45	พ.ศ. 46	พ.ศ. 46	พ.ศ. 46	พ.ศ. 46	พ.ศ. 46					
ค่าจ้างช่างเทคนิค	400	ปี	12,000	400	400	400	400									
ค่าจ้างช่างเทคนิค	400	ปี	13,600	4,000	4,000	100	100	100	100							
ช่างเทคนิค	400	ปี	78,000													
ช่างเทคนิค	400	ปี	34,000													
ช่างเทคนิค	400	ปี	8,000													
ค่าจ้างช่างเทคนิค	56,000	ปี	6,300													
ค่าจ้างช่างเทคนิค		ปี	16,800													
ค่าจ้างช่างเทคนิค		ปี	7,000													
รวมค่าจ้าง			300,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000

APPENDIX C

Table C Height, diameter, biomass, carbon storage and volume of wood
of *R.apiculata* plantation for conservation purpose

Age (year)	Height (m.)	Diameter (cm.)	Biomass (t. / ha.)	Carbon (tc. / ha.)	Volume of wood product (m3. / ha.)	Reference
1	0.38	1.39	0.06	0.03	0.06	(31)
2	0.91	2.14	0.40	0.20	0.47	(31)
3	1.49	2.75	3.14	1.57	3.76	(31)
4	2.13	3.29	5.27	2.63	6.22	(31)
5	2.81	3.78	7.45	3.73	8.67	(31)
6	3.52	4.23	10.68	5.34	12.18	(31)
7	4.25	4.65	37.89	18.94	42.40	(31)
5	3.56	2.64	22.81	11.41	12.56	(11)
6	3.63	2.92	31.77	15.89	18.45	(11)
7	4.77	3.32	62.83	31.42	35.28	(11)
8	5.00	5.05	48.32	24.16	53.04	(31)
9	5.79	5.44	68.12	34.06	73.44	(31)
10	6.60	5.80	96.78	48.39	102.49	(31)
9	7.90	5.47	124.03	62.02	76.99	(11)
10	8.50	5.63	124.82	62.41	77.44	(11)
11	7.42	6.16	119.68	59.84	124.62	(31)
12	8.26	6.50	130.49	65.24	133.71	(31)
13	9.12	6.83	211.22	105.61	213.12	(31)
14	9.99	7.15	242.99	121.50	241.56	(31)
15	10.88	7.46	263.53	131.76	258.38	(31)
12	9.02	5.99	146.15	73.08	98.53	(11)
13	9.60	6.00	152.57	76.29	104.29	(11)
14	10.08	6.34	181.43	90.72	126.90	(11)
15	10.82	6.78	194.86	97.43	140.88	(11)
16	11.19	7.20	198.22	99.11	143.84	(11)
17	12.95	8.50	215.75	107.88	163.82	(11)
18	14.09	9.11	234.30	117.15	187.87	(11)
19	14.15	9.40	223.10	111.55	179.07	(11)
20	14.23	9.70	184.17	92.09	139.29	(11)
22	10.54	10.71	213.20	106.60	123.40	*
24	11.82	15.96	286.50	143.25	335.05	*
27	12.75	12.95	185.89	92.95	230.36	*
28	11.10	10.88	120.20	60.10	135.18	*
30	13.17	12.58	164.88	82.44	224.00	*

Remark: * = Field check

APPENDIX D

Table D Height, diameter, biomass, carbon and volume of product of
R.apiculata plantation for commercial purpose (cutting cycle 1st and 2nd)

Year	Cutting cycle	Height (m.)	Diameter (cm.)	Biomass (t. / ha.)	Carbon Storage (tc. / ha.)	Volume of wood product (m3/ ha.)	Reference
7	1 st	4.54	3.73	20.90	10.45	50.13	*
9		6.14	4.65	37.47	18.74	83.84	*
11		7.58	6.00	76.04	38.02	91.36	*
13		8.68	8.14	107.22	53.61	209.37	*
15		9.43	12.03	154.80	77.40	159.45	*
7	2 nd	4.42	3.63	19.60	9.8.0	45.41	*
9		4.86	5.04	36.26	18.13	68.88	*
11		8.36	7.36	85.54	42.77	137.77	*
13		10.13	7.56	145.38	72.69	226.44	*
15		8.36	10.08	103.36	51.68	124.40	*

Remark: * = Field check

APPENDIX E

Calculate benefit from selling carbon storage of *R.apiculata* plantation for conservation purpose

When; Minimum value: 50\$ per ton or approximately 2,000 baht/ton
Maximum value: 100\$ per ton or approximately 4,000 baht/ton

* Where; benefit = carbon storage content (tons carbon / hectare) x
minimum value (baht/tons.)
= 104.78 x 2000
= 209,560 baht / hectare

** Where; benefit = carbon storage content (tons carbon / hectare) x
maximum value (baht/tons.)
= 104.78 x 4000
= 419,120 baht / hectare

APPENDIX F-2

Calculate benefit from selling carbon storage of *R.apiculata* plantation for commercial purpose: wood use pattern for charcoal production 99% and construction material 1%

* Where; Minimum benefit= [charcoal product quantity (kg./ha.) x price of charcoal product (baht/kg.)] + [construction material quantity (m.³/ha.) x price of construction material (baht/ m.³)] + [carbon storage quantity of construction material (tc./ha.) x minimum value of carbon storage (baht/tons.)]

When	Charcoal product quantity	=	5,357.05	kg./ha.
	Price of charcoal product	=	7.50	baht/kg.
	Construction material quantity	=	160.78	piece/ha.
	Price of construction material	=	20.00	baht/ m. ³
	Carbon storage quantity of construction material	=	1.23	tc./ha.
	Minimum value of carbon storage	=	2,000	baht/tons.

$$\begin{aligned}
 \text{Minimum benefit} &= [5,357.05 \times 7.50] + [160.78 \times 20] + [1.23 \times 2,000] \\
 &= 40,177.90 + 3,215.64 + 2,451.63 \\
 &= 45,845.17 \text{ baht / hectare}
 \end{aligned}$$

** Where; Maximum benefit = [charcoal product quantity (kg./ha.) x price of charcoal product (baht/kg.)] + [construction material quantity (m.³/ha.) x price of construction material (baht/ m.³)] + [carbon storage quantity of construction material (tc./ha.) x minimum value of carbon storage (baht/tons.)]

When	Charcoal product quantity	=	5,357.05	kg./ha.
	Price of charcoal product	=	7.50	baht/kg.
	Construction material quantity	=	160.78	piece/ha.
	Price of construction material	=	20.00	baht/ m. ³
	Carbon storage quantity of construction material	=	1.23	tc./ha.
	Minimum value of carbon storage	=	4,000	baht/tons.

$$\begin{aligned}
 \text{Maximum benefit} &= [5,357.05 \times 7.50] + [160.78 \times 20] + [1.23 \times 4,000] \\
 &= 40,177.90 + 3,215.64 + 4,903.27 \\
 &= 48,296.81 \text{ baht / hectare}
 \end{aligned}$$

APPENDIX F-3

Calculate benefit from selling carbon storage of *R.apiculata* plantation for commercial purpose: wood use pattern for construction material 100%

* Where; Minimum benefit= [construction material quantity (m.³/ha.) x price of construction material (baht/ m.³)] + [carbon storage quantity of construction material (tc./ha.) x minimum value of carbon storage (baht/tons.)]

When Construction material quantity = 4,276.40 piece/ha.
 Price of construction material = 20.00 baht/ m.³
 Carbon storage quantity of construction material = 32.69 tc./ha.
 Minimum value of carbon storage = 2,000 baht/tons.

$$\begin{aligned} \text{Minimum benefit} &= [4,276.40 \times 20] + [32.69 \times 2,000] \\ &= 85,528.03 + 65,372.83 \\ &= 150,900.86 \text{ baht / hectare} \end{aligned}$$

** Where; Maximum benefit = [construction material quantity (m.³/ha.) x price of construction material (baht/ m.³)] + [carbon storage quantity of construction material (tc./ha.) x minimum value of carbon storage (baht/tons.)]

When Construction material quantity = 4,276.40 piece/ha.

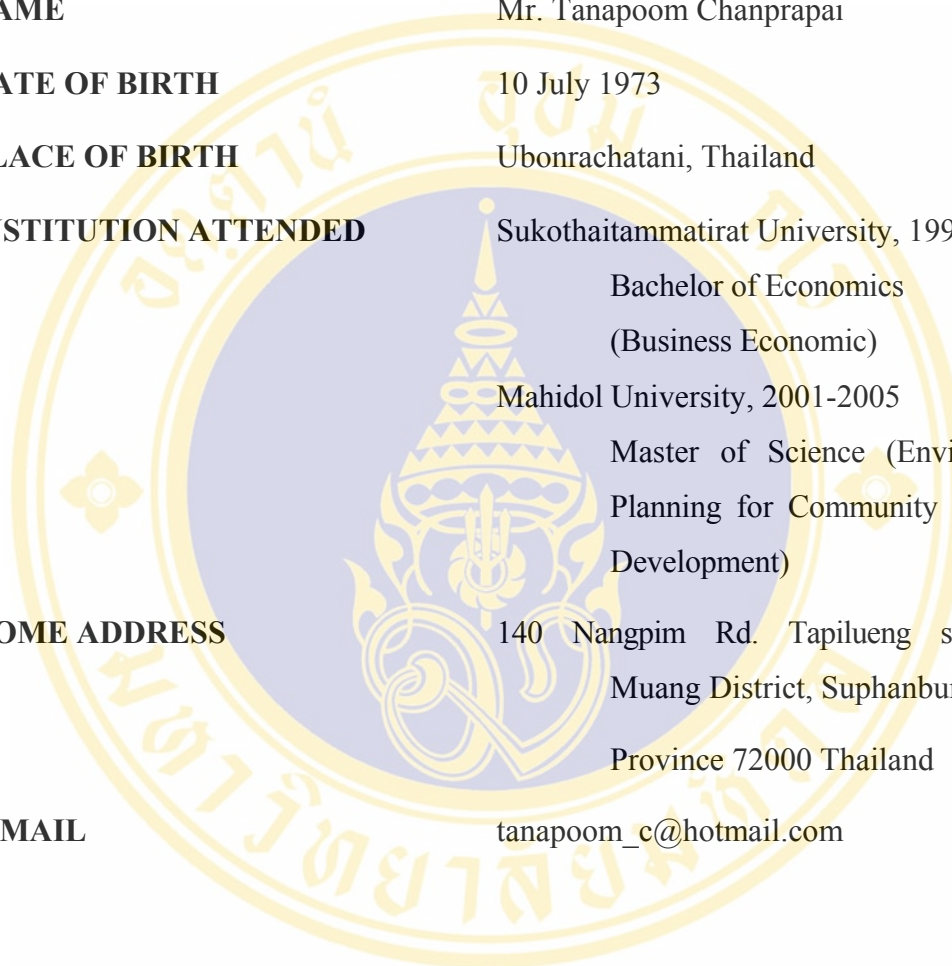
Price of construction material = 20.00 baht/ m.³

Carbon storage quantity of construction material = 32.69 tc./ha.

construction material

Minimum value of carbon storage = 4,000 baht/tons.

$$\begin{aligned} \text{Maximum benefit} &= [4,276.40 \times 20] + [32.69 \times 4,000] \\ &= 85,528.03 + 130,745.66 \\ &= 216,273.69 \text{ baht / hectare} \end{aligned}$$

BIOGRAPHY

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