CHAPTER 6
Conclusions and Recommendations

A. Conclusion

The main objectives of this research were to (1) to investigate the growth rates and biomass productions of two different age series of para rubber plantations (RRIM600 clone) in areas of Phon Phisai and Chakkarat soil series, Nong Khai and Bueng Kan provinces, and (2) to assess the ecosystem carbon stock potentials of these two different aged series of para rubber plantations. The results could be summarized as followed:

6.1 Growths and Biological Productions of Two Series Rubber Plantations (RRIM600 Clone) and Adjacent Forests

(1) Rubber Growths and Productions

Phon Phisai Soil Series

The densities of rubber trees in different age rubber plantations varied between 456 and 537 trees per ha. The average stem girths of rubber trees in the 1, 5, 10, 15 and 20 years old plantations were increased with age: 8.23, 29.42, 36.76, 53.54 and 54.45 cm, respectively. The average tree heights were in the order: 6.49, 8.83, 11.98, 15.41 and 14.46 m, and the crown diameters were 2.60, 4.80, 5.30, 6.40, and 5.70 cm, respectively. The stem girth and number of harvesting trees for tapping were lower than in the South.

Amounts of average biomass of rubber trees in the 1, 5, 10, 15 and 20 years old plantations were estimated to 3.08, 39.79, 85.31, 243.95 and 231.74 kg/tree respectively. The average biomass amounts per area were 1.50, 17.66, 42.07, 122.64 and 123.07 Mg/ha, respectively. The biomass storages were rapid from the 1 to 15 years old, and became slow down from 15 to 20 years old. The allocation of biomass in different organs was also changed with age. The biomass allocation in stem, leaf and root was declined with age while the biomass in branch was adversely increased. The biomass storage in the 20 years old plantation was higher than the DDF.

Chakkarat Soil Series

The tree densities in different age rubber plantations varied about 468-500 trees/ha. The average stem girths of rubber trees in the 1, 5, 10, 15 and 20 years old plantations were increased with age: 15.61, 34.88, 51.67, 56.83 and 73.18 cm, respectively. The average tree heights were in the order: 5.56, 9.61, 11.98, 22.50 and 23.95 m, and the crown diameters were 2.46, 5.58, 6.19, 5.92 and 6.96 m, respectively. The growths and number of harvesting trees for tapping resin were lower than in the South.

The average amounts of biomass in these plantations were estimated to 7.50, 54.14, 192.14, 325.22 and 598.20 kg/tree, respectively. The average biomass amounts

per area were 3.75, 27.07, 100.46, 184.97 and 406.13 Mg/ha, respectively. The biomass storages in rubber plantations on Chakkarat soil series were higher than the Phon Phisai soil series.

(2) Plant Diversity and Productions in Adjacent Forests

Phon Phisai Soil Series

The dry dipterocarp forest (DDF) covered on Phon Phisai soil series. It was a secondary forest. The species richness was 76 species. Dominant trees in the forest included Teng (*Shorea obtusa*), Rung (*S. siamensis*) and Hiang (*Dipterocarpus obtusifolius*). The tree density in the forest was high, 1119 trees/rai. The dominant tree, Teng (*S. obtusa*), had the highest density and importance value index in the forest. They were followed by *S. siamensis*, *Canarium subulatum* , *Syzygium cumini*, *Terminalia alata*, *Dipterocarpus obtusifolius*, *Cratoxylum pruniflorum* , *Memecylon* sp., *Irvingia malayana*, etc. The species diversity index using Shannon-Wiener index (SWI) was high, 4.92. There were many tree species from the DEF exited in the forest, and resulted in the higher species diversity.

The biomass amount of all tree species in the forest was 14,796.51 kg/rai (92.48 Mg/ha), separated into stem, branch, leaf and root components to 60.21, 15.54, 2.84 and 13.89 Mg/ha, respectively. The biomass of 20 years plod rubber plantation on Phon Phisai soil series was 123.07 Mg/ha, and had 30.59 Mg/ha higher than the DDF. Therefore, the rubber plantations could store carbon and reduce CO_2 in atmosphere in the rapid rate.

Chakkarat Soil Series

The dry evergreen forest (DEF) covered on Chakkarat soil series. It was also a secondary forest. Some dominant tree species of mesic dipterocarps might be disappeared from the forest. The remaining dominant trees were some oaks (*Quercus elegans, Lithocarpus* spp.) and *Schima wallichii*. The tree density was lower than the DDF, 528 trees/rai. *Diospyros* sp. had the highest density. *Q. elegans* had the highest importance value index, 13.30% of all species. They were followed by *Diospyros* sp., *S. wallichii*, *Lithocarpus* sp., *Dalbergia* sp., *Garcinia cowa*, etc. The species diversity index using Shannon-Wiener index (SWI) was high, 4.63. It was a little lower than the DDF.

The biomass amount of all tree species in the forest was 40,235.10 kg/rai (251.47 Mg/ha), separated into stem, branch, leaf and root components to 161.98, 47.44, 5.18 and 36.87 Mg/ha, respectively.

6.2 Soil Properties in Two Series of Rubber Plantations (RRIM600 Clone) and Adjacent Forests

Phon Phisai Soil Series

Phon Phisai soil series were developed on the hill under by the dry dipterocarp forest where the forest site was very dry with frequently forest fire. Parent rocks were shale, siltstone and sandy stone. There were many gravel contents in the soil profile. The soil textural classes were sandy clay loam in surface soil and clay in the subsoil. The soil profile in the DDF was A, BA, Btcv1, Btcv2, BCv1/BCv2. A horizon was 5 cm and 5-15 cm for the BA. The bulk densities were relatively high. It was a shallow soil with low fertility. Soil reaction was very strongly acid, pH = 4.6-5.0. Organic matter contents were moderately high at surface soil and medium to very low in deeper soil. There were low nitrogen and available P, very low extractable Ca moderate extractable Mg, but high extractable K, moderate CEC, and low Base saturation. After land use change to rubber plantations for about 20 years, there were little changes in the physico-chemical soil properties.

Chakkarat Soil Series

Chakkarat soil series were developed on the lower areas of the hill under the dry evergreen forest where the forest site was very moist in rainy season. Parent rocks were also shale, siltstone and sandy stone. There were few gravel contents in the soil profile. The soil textural classes were sandy clay loam or sandy loam in surface soil and sandy clay loam in the subsoil. Therefore, water infiltration into the deeper soil was better than the Phon Phisal soil series. The soil profile in the DEF was A/Bt1/ Bt2/Bt3/Btc1/Btc2/Btc3/Btc4/Bt4. A horizon was 11 cm. The bulk densities were moderately low in surface soil and medium to high in the deeper soil. It was a deep soil with low fertility. Soil reaction was extremely acid (pH = 4.2-4.4) in surface soil and very strongly acid (pH =4.5-5.0) in the subsoil. Organic matter contents were moderately high at surface soil and very low in the deeper soil. There were very low nitrogen, P, extractable K, Ca and Mg, CEC, and Base saturation. After land use change to rubber plantations for about 20 years, there were also little changes in the physico-chemical soil properties.

6.3 Ecosystem Carbon Stocks in Two Series Rubber Plantations (RRIM600 Clone) and Adjacent Forests

(1) Carbon Stocks in Tree Biomass

Phon Phisai Soil Series:

In DDF, the amount of stored carbon in forest biomass was estimated to 45.68 Mg/ha. The amounts of biomass carbon in the 1, 5, 10, 15 and 20 years old rubber plantations were calculated to 0.85, 10.11, 24.01, 70.12 and 70.13 Mg/ha, respectively. The amounts were increased with the plantation age. The rates of carbon accumulation were very rapid from the 1 to 15 years old plantations and slow down

for the older plantations. The 20 years old plantation had the higher biomass carbon than the DDF.

Chakkarat Soil Series:

In DEF, the amount of stored carbon in forest biomass was estimated to 124.20 Mg/ha. The biomass carbon in the 1, 5, 10, 15 and 20 years old plantations were calculated to 2.13, 15.52, 57.38, 105.78 and 231.52 Mg/ha, respectively. The amounts were increased with the plantation age. The rates of carbon accumulation were also very rapid from the 1 to 15 years old plantations and slow down for the older plantations. The amounts of carbon storages in rubber plantations on Chakkrarat soils were more rapid than the Phon Phisai soils because of the more rapid growth. The 20 years old plantation had the higher biomass carbon than the DEF.

(2) Carbon Stocks in Soils

Phon Phisai Soil Series:

The soil under DDF could store the carbon amount of 33.53 Mg/ha in the one-meter profile. The amounts of carbon accumulated in one-meter soil profiles of the 1, 5, 10, 15 and 20 years old plantations were 21.67, 37.36, 28.64, 31.23 and 12.03 Mg/ha, respectively. They were not increased with the plantation age.

Chakkarat Soil Series:

The soil under DEF could store the carbon amount of only 10.42 Mg/ha in the one-meter profile. The amounts of carbon accumulated in one-meter soil profiles of the 1, 5, 10, 15 and 20 years old plantations were 14.26, 16.83, 18.52, 16.05 and 13.37 Mg/ha, respectively. They were not increased with the plantation age. The amounts of carbon accumulated in the Chakkarat soils were lower than the Phon Phisai soils.

(3) Carbon Stocks in Ecosystems

Phon Phisai Soil Series:

In the DDF, the ecosystem carbon amount was estimated to 134.62 Mg/ha, 57% in biomass and 7.77% in soil. The total amounts of the ecosystem carbon in the 1, 5, 10, 15 and 20 years old plantations were 22.52, 47.47, 52.65, 101.35 and 82.16 Mg/ha, respectively.

Chakkarat Soil Series:

In the DEF, the ecosystem carbon amount was estimated to 134.62 Mg/ha, 92.23% in biomass and 43% in soil. The total amounts of the ecosystem carbon in the 1, 5, 10, 15 and 20 years old plantations were 18.52, 65.89, 128.27, 202.03 and 354.39 Mg/ha, respectively.

The growths of rubber trees in plantations on Chakkarat soils were more rapid than those on Phon Phisai soils, and had influenced on the ecosystem carbon stocks.

Although the accumulated carbon amounts in soils under Chakkarat soils were lower than Phon Phisai soils, the total amounts of carbon stocks in ecosystems of rubber plantations were higher for Chakkarat soils. It is assumed that some soil physical properties were not allowed the carbon accumulation in Chakkarat soils. The better moisture condition in areas of Chakkarat soil series may be beneficial to the rubber growths as well as the carbon storage.

B. Recommendations

The results of this study indicated that the growths of rubber trees (RRIM600 clone) in the North were lower than those in the South and the East due to four factors. First, most of rubber growing areas in the northeast region were in the area with moderate potential level (L2) which took seven years to open tapping. There were some rubber holdings planted in the area with low potential level (L3), as the Rubber Research Institute, Department of Agriculture was not recommended. For the southern region, most of rubber growing areas were in the area with high potential level (L1) which took less than 6 years to open tapping. Second, most of the rubber holders in the northeastern region had less knowledge and inexperience in growing and maintaining rubber plantations than those from the southern region. This involved uses of unqualified planting materials and narrow planting space. Third, the rubber holders in the northeastern region were unable to fully implement in accordance with RRIT's recommendations due to their own economic situations. Finally, the rubber holders in the northeastern region urged to open tapping even if the tree size was small. This might be affect the growths of rubber trees after tapping, and might have shorter period of the yield. Likewise, the biological production and the carbon stock potential of rubber plantations in the northeastern region were lower than the eastern region due to the slower growth rates.

This research focused on the rubber (RRIM 600 clone) with ages of 1, 5, 10, 15 and 20 years old and two natural forests of the dry depterocarp and dry evergreen forests which were grown on Phon Phisai and Chakkarat soil series in Nong Khai and Bueng Karn provinces. The study on biological production of rubber trees was separated into stem, branch, leaf and root. Latex was excluded. Therefore, the further study on production potential of carbon storage by rubber trees should be covered other aspects for all rubber clones, various soil series and majority of rubber plantations in the country. The result of the research will be utilized for rubber development of the country. It would lead Thailand to be "Rubber Research of Carbon Stock Potential" in the rubber growing countries, and it would also push Thailand forward to be "Central Rubber's Carbon Credit Market" of the world accordingly.

The recommendations may be given as follow:

(1) For rubber smallholders:

It should be avoided to grow rubber in plantations in the potential rubber areas Level 3 (L3), and strictly followed the RRIT's recommendations on both immaturity period and maturity (harvesting) period.

(2) For Government:

(a) The government should provide fully supports, good quality of materials with reasonable prices directly to rubber smallholders throughout the country.

(b) The government should provide fully supports on all research projects regarding the carbon stock potential of rubber plantation in various issues and locations throughout the country. This includes the research with foreign institutions.

(c) The government should promote Thailand as a center of "Rubber Plantation Research of Carbon Stock Potential" of the natural rubber producing countries, and also the "Central Rubber's Carbon Credit Market" of the world.