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Evaluation of carbon dioxide absorbed in para rubber biomass to the valuation of the contracts on carbon credits in voluntary markets.

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Abstract

Prospective imbalances between supply and demand have been indicated in the rubber market resulting in a continuous plunge in rubber prices. The highest average price in 2011 to lowest average price in 2014, has dropped 54.84 percent due to direct impact on the costs of rubber planters especially new area of para rubber plantation such as Huai Thalaeng District in Nakhon Ratchasima Province. There is the possibility of the offset prices in rubber plantations by evaluation of carbon dioxide absorbed in para rubber to the valuation of the contract on carbon credits in voluntary markets. Carbon Storage in Para Rubber Biomass was assessed in the equations of biomass allometric to determine the carbon dioxide was absorbed from the atmosphere.
The results of the study found that rubber plantations through seven years before latex tapping with biomass accumulation in the average of 0.027, 0.200, 0.641, 1.454, 3.343, 8.078 and 15.213 Mg ha^{-1}respectively. While, average carbon storage in biomass at 0.014, 0.099, 0.321, 0.727, 1.671, 4.039 and 7.607 Mg ha^{-1}, respectively. Furthermore, the carbon dioxide was absorbed from the atmosphere in the average of 0.051, 0.363, 1.177, 2.666, 6.127, 14.810 and 27.892 Mg ha^{-1}, respectively. Subsequently, the net income from contracts equal to 578.637 US$ ha^{-1} from the carbon dioxide was absorbed from the atmosphere in case of trading of carbon credit sin the voluntary market. In addition, rubber tree is an essential tree species that absorbed carbon dioxide in the atmosphere and stored in its biomass. With this, rubber plantation can act as carbon sink. Therefore, Thailand, especially Huai Thalaeng has potential for rubber plantation and mitigated greenhouse gases in the atmosphere through carbon trapping of rubber plantations.

Keywords: Carbon dioxide absorption, rubber plantations, Carbon stock

1. Introduction

From past to present, rubber plant is an important economic plant in the world since it is a key raw material for the manufacture of products such as tires. Major rubber producing countries in top 5 of the world are Indonesia, Thailand, Malaysia, China and India account for the proportion of 30.36, 24.55, 8.99, 8.86 and 6.28, respectively [1]. In the field of export, ASEAN countries are the largest rubber exporter representing a market share of 80 percent and Thailand is one of the world's top exporters with a market share of 33.1 percent followed by Indonesia with a market share of 30.7 percent [2]. The rubber export market is divided into five categories: natural latex, smoked sheets, natural rubber and so on, while the imbalance of supply and demand for rubber in the global market. As shown in Figure 1, resulting in a state of decline in global rubber prices, the highest average price in 2011 was 4,078.67 US$ ton^{-1} to the lowest in the average price, 1,842.00 US$ ton^{-1} in 2014, as shown in Figure 2, a decrease of 54.84 percent from the average price in 2011

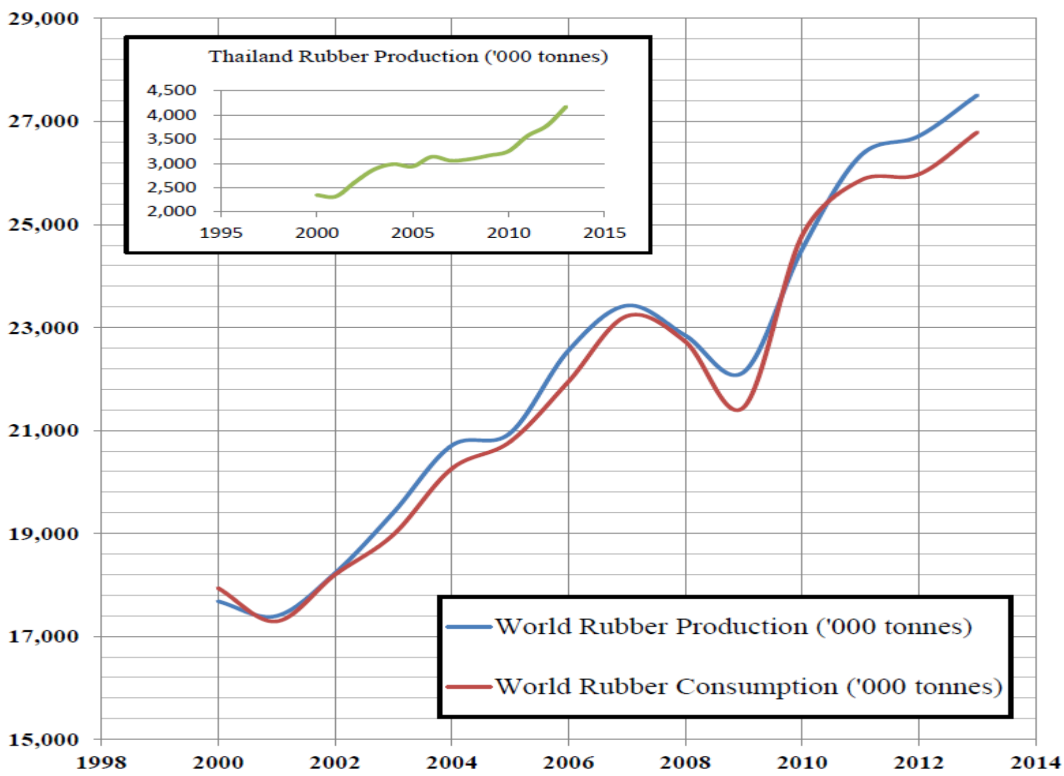

Figure 1 the demand and supply of rubber in the world market

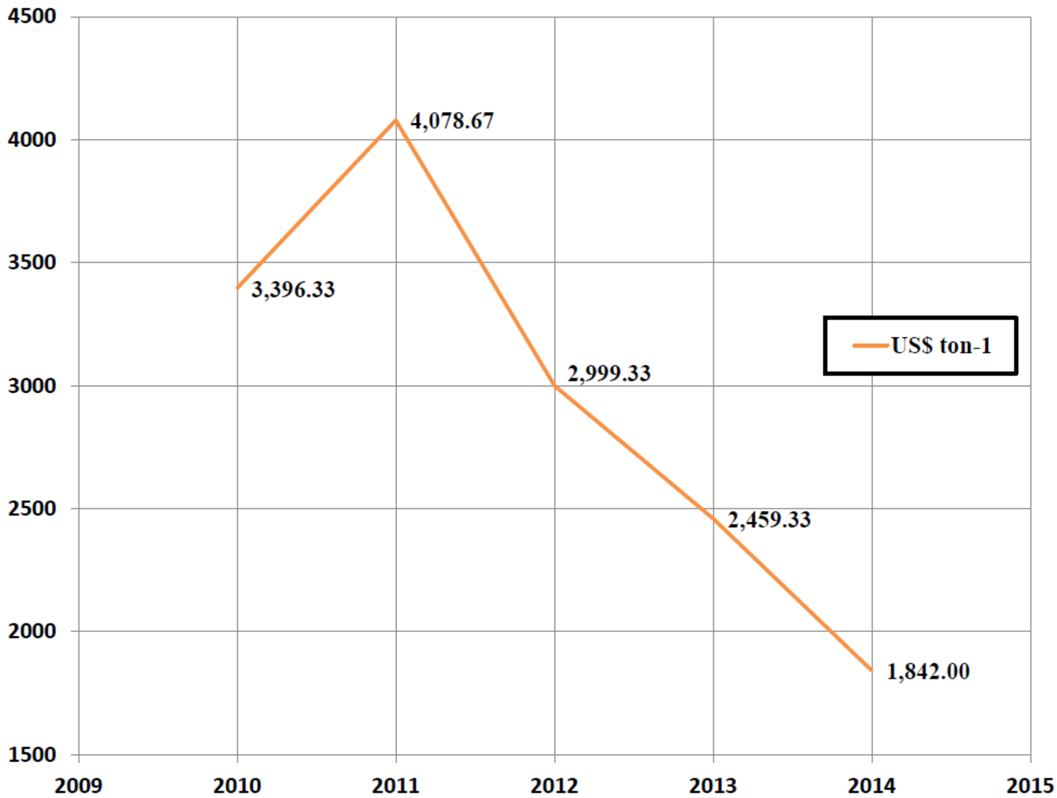

Figure 2 the trend in the decline of rubber prices in the world market

According to the situation, an impact is on rubber planters, especially in 1-7 years of rubber plantations deprived of latex tapping (Girth at Breast Height: GBH of less than 50 cm. and the height of 1.30 m. from the ground) as latex tapping is attained from rubber trees. In the above result, productivity decreased throughout the life cycle by 25-29 percent and rubber growth rate by 28-60 percent. In the meantime, planters receive the expense of rubber plantations aged 1-7 years for 5,459.66 US\$ ha^{-1} (10,000 m^2 = 1 hectare) included the cost on cleaning, terracing, investment in digging of pits and planting, cost on sprayer, planting material etc [3]. Therefore, the evaluation of carbon storage in para rubber biomass to the valuation of the contract on carbon credits is derived from the carbon credit contracts in the voluntary rubber market. This concept reduces the effects of global warming through the plant mechanism to absorb carbon dioxide for photosynthesis. By this means, the amount of reduced carbon dioxide in the atmosphere is through the plant life by carbon stocks in biomass [4]. According to COP21 Agreement creates a new carbon trading mechanism. It manages to do so with mentioning the words “carbon” or “trading” or “markets”. Instead these words are replaced by the term “voluntary cooperation”. Carbon offsets are “internationally transferred mitigation outcomes”. And the new carbon trading mechanism is a “mechanism to contribute to the mitigation of greenhouse gas emissions and support sustainable development” [5].

2. Literature Review

Generally, ecosystem is defined as a functional unit of the environment which consists of physical and biological components. The cycling of carbon in forest ecosystems is a topic of considerable importance with rising atmospheric CO_2 concentrations, global climate change, and the poorly defined role that terrestrial ecosystems play in mitigating or exacerbating these phenomena [6].

In addition, increasing value is being placed on ecosystem services in forests and carbon cycling. It is among the most important of these services. Also, aboveground biomass (the amount of organic matter in living and dead plant material) is a critical component of the cycle of carbon in forest ecosystems, providing both short and long-term carbon sequestration. For tropical forests, in particular, they are major components of the terrestrial carbon cycle, accounting for 26 percent of global carbon storage in biomass and soils [7-9].

Furthermore, climate change, increasing atmospheric CO_2 concentrations, and increasing reactive nitrogen deposition have a strong potential to influence carbon-cycling processes in terrestrial and aquatic environments [10-12]. The fourth assessment report (AR4) by the IPCC (2007) [13] stated that the best estimates of likely increases in the mean global surface-air temperature by the end of the 21st century are between 1.1°C and 2.9°C for the “low scenario” and 2.4°C and 6.4°C for the “high scenario,”. Therefore, the major cause of global warming is the human-induced increase of GHG in the atmosphere.

Besides, the climate change may influence the frequency of extreme events, such as droughts, fires, heat waves, flooding, and hurricanes, thereby releasing additional carbon into the atmosphere by photosynthesis can be used to convert the CO_2 into organics and storage by plants, and if the forest area is large enough, the biological fixation may also become and effective way to reduce atmospheric CO_2 concentration. Therefore, the biological CO_2 fixation method is feasible, the total global forest area is limited and the forest resources distribution which is uneven and most important is the world forest area which stills on the decline [14]. And, allometric equations allow aboveground tree biomass and carbon stock to be estimated from tree size. These allometric equations form have been used to estimate forest biomass and carbon worldwide [15].

However, determine biomass and carbon storage in trees and soil of dry dipterocarp forest and eucalypt plantation at Mancha Khiri Plantation, Khon Kaen Province, by allometric equations of Ogawa et al (1965) [16]. The result showed that carbon storage in trees was highest in 3 year old eucalypt plantation with the amount of 66.85 Mg ha^{-1}. The amount of carbon was equivalent to CO_2 uptake of 8.50, 33.35, 51.61 and 30.73 Mg ha^{-1} per year in dry dipterocarp forest and 2-4 year old eucalypt plantation, respectively [17].

Therefore, estimated carbon storage in biomass of trees planted in Santiphap Park, Bankok by dry evergreen forest allometric equations of Tsutsumi et al (1983) [18] and dry dipterocarp forest allometric equation of Ogawa et al (1965) [16]. The result also indicated a similar trend of aboveground and belowground tree biomass and the carbon stored in the tree biomass. Peltophorum pterocarpum (DC.) Backer ex K. Heyne had the greatest tree biomass and the carbon storage of 31.03 and 14.58 Mg, respectively due to their large size and greater density. And, evaluated biomass carbon stocks of Pinus kesiya and other tree species of pine plantations [19] which were studied at the Boa Kaew watershed management station, Chiang Mai province. In total, 63 sample plots, 40 x 40 m^2 in size (3 plots/age classes) were established. Stem diameter at 1.30 m above ground and the height of all trees were measured to calculate the aboveground biomass. Likewise, the biomass of P. kesiya was calculated from an allometric equation constructed using a stratified-clip technique. It was found that the aboveground biomass varied among plantations (78.06 - 232.83 Mg ha^{-1}) including 18.77 - 171.82 Mg ha^{-1} for P. kesiya and 9.88 - 120.24 Mg ha^{-1} for other tree species. The carbon stocks varied between 38.93 and 116.93 Mg ha^{-1}, of which 9.52 - 86.77 Mg ha^{-1} was for pine and 4.91 - 59.62 Mg ha^{-1} was for the other species.

Moreover, PuParn Royal Development Study Centre quoted in Watershed Conservation and Management Office [20] has been developed allometric equation of carbon storage in biomass of Para rubber and other species planted. The result indicated that the highest growth and biomass was observed in Para rubber (*H. brasiliensis*), followed by Eucalyptus (*E. camaldulensis*) and Teak (*T. grandis*) with the total biomass of 150.98, 118.32 and 27.46 Mg ha^{-1}, and the below ground biomass of 33, 44 and 43% of the above-ground biomass, respectively. It is consistent with the total of biomass and carbon contents were higher in tissues of Para rubber (*H. brasiliensis*) than in those of Eucalyptus (*E. camaldulensis*) and Teak (*T. grandis*) with the mean values of 49.90, 48.95, and 46.60% of dry weight, respectively.

3. Materials and Methods

The research site is located in Huai Thalaeng District, Nakhon Ratchasima Province, Thailand. The site is located between latitude 15 degrees 12 minutes north and longitude 101 degrees 66 minutes east. The land elevation from normal sea level sits between 168-210 meters with incline of 1-7%. In addition, Huai Thalaeng District is new para rubber plantation areas in Northeast of Thailand. The soil in the area is high in acrisols, alisols, plinthosols (ac), acid soil with clay-enriched lower horizon and low saturation of bases. However, that is different with suitable soil series recommendation for Para-rubber planting in East of Thailand [21].

Growth Studies

Tree samples are selected from seven different age groups of plantations including 1, 2, 3, 4, 5, 6, and 7 years old that are 40x40 square meters in size for each year of sample. Growth studies measurement including girth at breast height or GBH (130 cm from the ground), diameter at breast height or DBH (DBH = GBH/π) and the total height or TH were measured directly on each tree.

Assessment of carbon storage in rubber plantation

Assessment of carbon storage in rubber plantation by which the ratio's between different aspects of tree size change when small and large trees of the same species are compared are generally known as "allometric" relations. The allometric of carbon stock in rubber plantation, the correlation between carbon storage in biomass and independent variables as parabolic volume was in the variables from growth studies included Diameter at Breast Height: DBH, and Total Height: TH. The rubber growth measurements are shown in Table 1.

Table 1 the plot samples and rubber growth measurements

Age (Year)	Duration (m^2)	Density Trees per 1,600 m^2	GBH (cm)	DBH (cm)	TH (m)
1	3x6	104	5.60±1.26	1.78±0.40	1.80±0.24
2	3x6	104	11.13±2.61	3.54±0.83	2.60±0.46
3	3x6	104	15.81±1.95	5.03±0.62	4.28±0.46
4	3x6	104	20.69±2.31	6.59±0.74	5.66±0.41
5	3x6	104	27.68±3.16	8.82±1.01	6.62±0.55
6	3x6	104	36.66±2.88	11.67±0.92	7.96±0.51
7	3x6	104	44.84±2.93	14.28±0.93	9.93±0.66

* **GBH**: Girth at Breast Height, **DBH**: Diameter at Breast Height, **TH**: Total Height of Tree
* 10,000 m^2 = 1 ha and 1,600 m^2 = 1 rai

Allometric equation for biomass accumulation and carbon stocks in rubber was developed by PuParn Royal Development Study Centre quoted in Watershed Conservation and Management Office [20] as the equation shown in Table 2.and 3

Table 2 allometric equation for biomass accumulation of rubber tree

Biomass Accumulation (kg biomass per tree)	Equations	R^2
Stems (W_S)	$WS = 0.0804\ (DBH^2H)^{0.8341}$	0.97
Branch (W_B)	$WB = W_T - W_S - W_L$	-
Leaf (W_L)	$WL\ 0.000008\ (DBH^2H)^{1.4986}$	0.91
Root (W_R)	$WR = 0.0005\ (DBH^2H)^{1.269}$	0.95
Rootlet (W_r)	$Wr = 0.0022\ (DBH^2H)^{1.0296}$	0.92
Above the ground (W_T)	$WT = 0.0046\ (DBH^2H)^{1.2046}$	0.95

Source: Watershed Conservation and Management Office, 2013 [6].

Table 3 allometric equation for carbon storage in rubber biomass (carbon stock)

Carbon Stocks (kg carbon per tree)	Equations	R^2
Stems (C_S)	$C_S = 0.03860\ (DBH^2H)^{0.8341}$	0.97
Branch (C_B)	$C_B = W_T - W_S - W_L$	-
Leaf (C_L)	$C_L = 0.000004\ (DBH^2H)^{1.4986}$	0.91
Root (C_R)	$C_R = 0.00023\ (DBH^2H)^{1.269}$	0.95
Rootlet (C_r)	$C_r = 0.00109\ (DBH^2H)^{1.0296}$	0.92
Above the ground (C_T)	$C_T = 0.00230\ (DBH^2H)^{1.2046}$	0.95

Source: Watershed Conservation and Management Office, 2013 [6].

Assessment of carbon dioxide absorbed in rubber plantation

Assessment of carbon dioxide (CO_2-e) absorbed in rubber plantation by calculate the mean carbon stock in biomass for each year, converted to carbon dioxide equivalents [22] as shown in the equation.

$$CO_2\text{-e} = \text{Carbon stock} \times 44/12$$

As CO_2-e = carbon dioxide absorbed in rubber tree per hectare (Mg ha^{-1})
Carbon stock = carbon storage in biomass per hectare (Mg ha^{-1})
44 = molecular weight of carbon dioxide (g/mol)
12 = molecular weight of carbon (g/mol)

Assessment revenues from contracts in the voluntary rubber market

Assessment revenues from contracts in the voluntary rubber market as stated by implementation of U.S. California Carbon Market [23] of 1-7 year-old rubber trees before latex tapping in order to estimate annual value and total revenue (US$) over the 7 years as shown in the equation.

$$\therefore T_c = [(CO_2\text{-e}) \times (CTP)] - F_T$$

As CO_2-e = the amount of CO_2 absorbed in Para rubber tree (Mg)
CTP = average trading prices of carbon credits
(12.5 US$ per Mg (CO_2-e)) [23]
(Carbon market weekly: March 28- April 1, 2016) [23]
F_T = total cost of contract fees of carbon credits and offset of reserved carbon credits (US$)

$$F_T = F_a + F_v + F_c$$

As F_a = total cost of contract fees with the agent (US$).
= 10% of [(CO_2-e) x (CTP)]
F_v = total costs of fees to validate the contract (US$).
= 0.15 US$ per Mg (CO_2-e)
F_c = total cost of fees for the trading market, CTP (US$).
= 0.20 US$ per Mg (CO_2-e)

4. Results and Discussion

At 1-7 year-old rubber trees before latex tapping, the value of the biomass accumulation, carbon stocks in biomass, and carbon dioxide absorbed in the maximum equal to 15.213±5.066, 7.607±2.533, and 27.892±9.288 Mg ha^{-1} respectively, at the age of 7 years, as shown in Table 4.

The results showed that the carbon stock in biomass is 50 percent of the accumulated biomass consistent with the findings by Sapit Diloksumpan, 2550, IPCC, 1996 and the IPCC, 2006 [24-26] in the variation of carbon storage in biomass. Accordingly, the carbon storage in the biomass of forest depends on carbon accumulation in different parts in each type of tree as an important element and the total biomass of the forest land. Similarly, carbon storage in plant biomass plantations, areas with plants, component plants depend on the amount of carbon and biomass production of the plants. In general, the amount of carbon was accumulated variation in a smaller amount by IPCC, (1996). It set the default value of carbon stock in biomass is 50 percent of the dry weight and the IPCC, (2006) was later changed the default value as 47 percent of the dry weight. On the other hand, the study by Sapit Diloksumpan, 2550 [24] found that plants in the natural forest types of Thailand in the average of carbon content in the biomass accumulation between 48-55 percent of dry weight. Accordingly, the amount of carbon was stored in the maximum biomass accumulation in mangrove forest, followed by the evergreen, mixed deciduous forest and pine forests, respectively. While the plantation species, such as teak and eucalyptus, found carbon accumulation in different parts of the plants on the average of 44-52 percent depending on types and ages of planting trees as part of the trunk, branches or leaves. Nevertheless, the variability of carbon storage in biomass accumulation found of the natural forest or in the forest areas depending on a difference of biomass carbon unrelated in the biomass accumulation, due to increasing biomass loads in an area, there was more carbon accumulation over there.

The value of the carbon dioxide (CO_2-e) was absorbed from the atmosphere through 7 years as 53.086 Mg ha^{-1}, representing a net income due to contracts for the offset of carbon credits over seven years as 578.637 US$ ha^{-1} as shown in Table 5

Table 4 biomass accumulation, carbon stocks and Carbon dioxide absorbed in rubber trees

Age (years)	Biomass accumulation Mg ha^{-1}	Carbon stocks in biomass Mg ha^{-1}	Carbon dioxide absorbed CO_2-e Mg ha^{-1}
1	0.027±0.016	0.014±0.008	0.051±0.029
2	0.200±0.134	0.099±0.067	0.363±0.246
3	0.641±0.265	0.321±0.133	1.177±0.488
4	1.454±0.647	0.727±0.324	2.666±1.188
5	3.343±1.717	1.671±0.859	6.127±3.150
6	8.078±2.945	4.039±1.472	14.810±5.397
7	15.213±5.066	7.607±2.533	27.892±9.288

Table 5 estimation of potential income through seven years of the contract.

Contract(years)	Carbon dioxide absorbedCO_2-e, Mg ha^{-1}	Estimated annual value, (C_s)x(CTP), US$ ha^{-1}
1	0.051	0.638
2	0.363	4.538
3	1.177	14.713
4	2.666	33.325
5	6.127	76.588
6	14.810	185.125
7	27.892	348.650
Estimated subtotal	53.086	663.575
Fees and deductions, F_T		(84.938)
Net income (US$ ha^{-1})		578.637

However, the carbon stocks and carbon dioxide absorbed in rubber garden are different in each plantation area. The climate and soil regions particularly are affected by drought. Subsequently, the rubber gardens are potential for carbon stores. In comparison with other perennials in similar ages in forestry plantations such as teak and eucalyptus [27] as the rubber trees can grow before and after latex tapping. The garden management principles, it contributes carbon stocks in trees and soil such as intercropping or multiple cropping with no-tillage after latex tapping [28].

5. Conclusion

The results of the study found that the value of girth at breast height, GBH (1.30 m from the ground) of Para rubber plantations aged 1-7 year-old equal to 44.84±2.93 cm, less than 50 cm consistent with the findings by Chantuma, P., 2010 [29] found the GBH of Para rubber in 1-7 year-old less than 50 cm. If latex tapping attained from rubber tree when GBH less than 50 cm, productivity decreased throughout the life cycle by 25-29 percent and rubber growth rate by 28-60 percent.

The rubber plantations aged 1-7 year-old rubber trees before latex tapping with average carbon storage in biomass at 0.014, 0.099, 0.321, 0.727, 1.671, 4.039 and 7.607 Mgha^{-1}, respectively. While, the carbon stock in biomass is 50 percent of the accumulated biomass consistent with the findings by Sapit Diloksumpan, 2550 [24] found that plants in the natural forest types of Thailand in the average of carbon content in the biomass accumulation between 48-55 percent of dry weight. Also, the carbon dioxide equivalent (CO_2-e) was absorbed from the atmosphere in the average of 0.051, 0.363, 1.177, 2.666, 6.127, 14.810 and 27.892 Mg ha^{-1}, respectively.

Estimate the net income from contracts through seven years equal to 578.637 US$ ha^{-1} from the carbon dioxide was absorbed from the atmosphere in case of trading of carbon credit sin the voluntary market.

In addition, rubber tree is an essential tree species that absorbed carbon dioxide in the atmosphere and stored in its biomass. With this, rubber plantation can act as carbon sink. Therefore, Thailand, especially Huai Thalaeng District has potential for rubber plantation and mitigated greenhouse gases in the atmosphere through carbon trapping of rubber plantations.

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