POLISH JOURNAL OF NATURAL SCIENCES
Abbrev.: Pol. J. Natur. Sc., Vol 37(4): 481–495, Y. 2022

DOI: 10.31648/pjns.8096

VALUATION OF CARBON STOCK IN TREE FOR SMALL COMMUNITY FOREST: CASE STUDY BAN KHUM COMMUNITY FOREST, UTTARADIT PROVINCE, THAILAND

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Key words: carbon offset, carbon stock, dry dipterocarp forest, voluntary market, community forest.

Abstract

This study aimed to assess the tree species and density, biomass, carbon stocks, and the value of carbon stocks in a small community forest in Thailand. The research estimated the biomass above and below ground, carbon stocks, carbon dioxide absorption, and the value of carbon stocks using the European Union Allowance (EUA) and US California Carbon Market exchange rates. The conserved forest zone had 14 different tree species and a density of 618 trees per ha, with a total biomass of 68.130 tonnes, 3.204 tonnes of carbon stored, and 91.74 tonnes of carbon dioxide absorbed. The carbon stock value was calculated at € 1,478.08 and $ 965.66, respectively. In contrast, the utilized forest zone had 7 tree species and a density of 46 trees per ha, with a total biomass of 1.584 tonnes, which was equivalent to 1.584 tonnes of carbon stored or 4.50 tonnes of carbon dioxide absorbed. The value of carbon stock in this zone was € 39.78 and $ 60.90, respectively. The total value of carbon stock at the Ban Khum community forest was $ 2,853.14, assuming a 6% annual interest rate and a carbon trading price of $ 50/tonne CO_2.

Introduction

The impact of population growth on natural resources and the environment, particularly forest resources, is immense. As the population increases, forest areas are being encroached upon for agriculture, and illegal logging is also rampant in Thailand and other places. The situation is exacerbated by the rising carbon dioxide emissions from the industrial and transportation sectors, which further deplete forest resources. According to data from the Royal Forest Department of Thailand, the forested area of the country was 31.58% in 2016, and it has remained close to 31% in

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recent years, despite the shrinking forest area, which is opposite to the trend of increasing population (OUNKERD et al. 2015). As the population grows, the demand for resources increases in many areas, such as housing and subsistence agriculture, leading to greater forest encroachment and the need for wood, paper, furniture, energy, and other products and services. This is particularly challenging in light of climate change.

The accumulation of greenhouse gases is the primary cause of global climate change, which results in increased global temperatures. Greenhouse gases are usually responsible for regulating temperatures since the world would be too cold without them, and living things would not be able to survive (SURIN 2008). However, greenhouse gases are increasing in the atmosphere, partially due to deforestation. Forests play a crucial role in moderating the amount of carbon dioxide in the atmosphere since trees use carbon dioxide to create oxygen. Carbon dioxide is taken out of the atmosphere through photosynthesis and stored in the form of biomass (TIMILSINA et al. 2014). However, when forest resources are depleted, the storage of carbon dioxide is also reduced, leading to an increase in severe natural disasters. According to predictions by the IPCC (2007), the average temperature of the earth's surface will rise by approximately 1.1–6.4°C between 1990 and 2100, resulting in a sea level rise of 1.5–95 centimeters (with moderate predictions of 50 centimeters) and an increase in severe storms. Trees contain 47% carbon by dry weight (IPCC 2006), making it necessary to reduce deforestation and conserve existing forested areas, especially through community-based forest management and other forms of forestry, to reduce the amount of carbon dioxide in the atmosphere.

The voluntary market in particular has had an important role in forestry sector that allows carbon to be voluntarily trades as carbon credits called Verified Emission Reduction (VER) or Carbon Offset in order to trade (ISSARAPAP and JARUNTORN, 2019) in key markets such as US California Carbon Market (CCA), European Union Allowance (EUA), Climate Registry (CR) and bilateral trading between buyers and development project (Over-the-Counter: OTC). Sales contracts can be made between carbon trading organizations and farmers or departments during any participating period by calculating the carbon in soil (soil offset projects) in agricultural lands (IGNOSH et al. 2009).

Community forestry in Thailand is not formally recognized by legislation, yet over 8,300 community forests covering an area of approximately 500,000 hectares have been registered with the Royal Forest Department (RFD) of the Ministry of Natural Resources and Environment (MONRE), with another 3,500 community forests in the process of registration. However, the issue of the illegality of community forestry in national parks, reserves, and sanctuaries is a matter of debate in Thailand and affects approximately 2 million people who rely on forest resources in those areas. Forests in Thailand have become an important source of carbon dioxide absorption and a potential carbon stock.

The report presented the advantages of selling carbon credits for agricultural operators and landowners. The public sector has already implemented credit programs in Thailand's community forests in 2019. To showcase the income potential through carbon trading using the US California Carbon Market (CCA) and European Union Allowance (EUA), the study evaluated the revenue generated from the carbon stock in community forests and soil organic carbon throughout the project's duration.

Materials and Methods

The study area

The study area is located at Uttaradit province, northern Thailand (Figure 1), covering approximately 300 hectares. The area is flat, hills, and the soil is sandy loam with laterite. The local climates were tropical and subtropical with three distinctive seasons – summer, rainy and winter, with an average annual rainfall of 1,400 mm. The different ecotypes surrounding the study area rage from mixed deciduous forest and dry dipterocarp forest. Geographic coordinates at 100.027 E, 17.641 N.

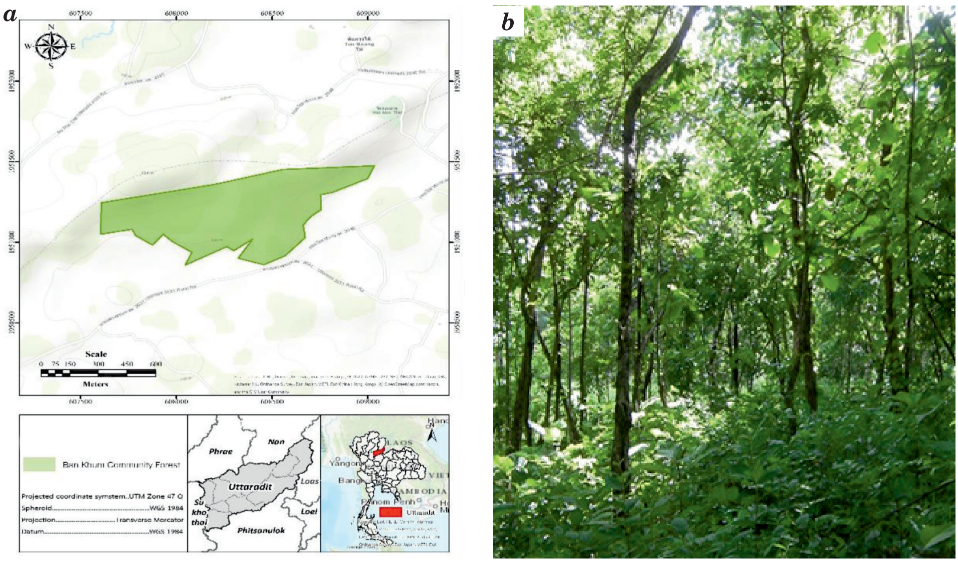

Fig. 1. Study area Ban khum community forest located at Chai Chumphon Subdistrict, Laplae district, Uttaradit province, Thailand: *a* – map of study area; *b* – characteristics of the community forest area used in the research

Study design and methods

Stratified random Sampling in two zone were conserved forest zone and utilized zone. The conserved forest zone mentioned in the previous text refers to an area of the forest that is strictly protected and where the use of forest products is prohibited. On the other hand, the utilized zone mentioned in the text is an area of the forest where some level of utilization of forest products is allowed, such as for subsistence agriculture or small-scale timber extraction. It is important to note that the degree of utilization allowed in the utilized zone may vary depending on the regulations and management practices in place in each specific community forest.

The data was collected from permanent plots in 40 × 40 m^2 quadrate that divided into 25 sub plots of 10 × 10 m^2. A vegetation census was used to collect data on forest structure and species composition. Trees in these plots were recorded all trees DBH > 4.5 cm in each plot of 10 × 10 m^2, with five random subplots of 4 × 4 m^2 within this plot selected for the recording of all tree DBH ≤ 4.5 cm (sapling). Finally, all tree heights ≥ 1.30 m was measured in five randomly located plots of 1 × 1 m, while all trees in five plots of 4 × 4 m was recorded for trees DBH ≤ 4.5 cm and height < 1.30 m (seedling). Analysis gives precise measures of the floristic composition, species density, basal area and ecological characteristics.

1. Each plot's tree stems, branches, and leaves were measured for their above-ground biomass. The aboveground biomass of dipterocarp forest was estimated by equations (1–4) (Ogino et al. 1964):

$$\mathrm{Logw_S} = 2.50913 \log D - 0.94402 \quad (1)$$

$$\mathrm{Logw_B} = 1.81022 \log D - 1.98034 \quad (2)$$

$$\mathrm{Logw_L} = 1.81022 \log D - 1.41128 \quad (3)$$

$$\text{and } W_T = W_S + W_B + W_L \quad (4)$$

where:

D – the diameter at breast height [cm]
W_S – the dry weight mass of stem [kg]
W_B – the dry weight mass of branch [kg]
W_L – the dry weight mass of leaf [kg]
W_T – the total dry weight mass of stem and branch [kg].

2. The below ground biomass was estimated by root/shoot ratio biomass, IPCC (2006) have determined the ratio between below ground biomass to above ground biomass equal to 0.28, can be found as in equation (5):

$$B_b = 0.28\ W_t \quad (5)$$

where:

B_b – below ground biomass [kg]
W_t – above ground biomass [kg].

3. C-stock in aboveground biomass was calculated based on IPCC 2006 by multiplying the 0.47 conversion factor to the biomass (McGroddy et al. 2004).

4. Equation (6) is used to determine the amount of carbon dioxide absorbed from the atmosphere by trees during photosynthesis. This is done by calculating the amount of carbon accumulated in the trees, as they absorb carbon dioxide from the atmosphere for photosynthesis. The carbon content of the trees is then multiplied by a factor of 3.667, as per the guidelines provided by the Intergovernmental Panel on Climate Change (IPCC 2006).

$$\text{Amount of carbon dioxide absorbed in tree} = \text{C-stock} \cdot 3.667 \qquad (6)$$

5. The carbon sequestration valuation is calculated from the annual incremental rate of carbon sequestration multiplied by the price of carbon in each market traded. The annual increment of carbon sequestration can be calculated from the annual increase of biomass of Ban Khum community forest by using the rate according to the study in the dipterocarp community forest (Sunthornhao et al. 2013, Ounkerd et al. 2015) at 4.52 percent per rai per year. This study, with a study duration of 5 years, assuming that Khao Wong community forests are growing at an accelerated rate, as can be seen in Equation (7):

$$B_t = 1.0452\ t\ B_0 \qquad (7)$$

where:

B_t = biomass carbon at t year [kg ha^{-1}]

B_0 – biomass carbon at current year [kg ha^{-1}]

t – time (year) is 1, 2, 3… 5.

Calculate carbon stock values over the next 5 years using multiple market prices from the Thailand Greenhouse Gas Management Organization Public Organization's weekly carbon trading report (2019), including voluntary carbon markets such as the US California Carbon Market; CCAs price. Buying and selling carbon as of 18 September 2019 is equal to 17.62 US dollars/ton of Carbon Dioxide or 538.12 baht/ton of Carbon dioxide. The average exchange rate used during Round 3 at the end of 2019, with an exchange rate of 1 US dollar at an average of 30.54 baht. Official EU market, European Union Allowance (EUA) market, as of September 18, 2019 equals 26.97. Euro/ton carbon dioxide or 911.05 baht/ton carbon dioxide using the average exchange rate during the 3rd quarter of the year 2019, which the exchange rate of 1 Euro is averaged 33.78 baht (Bank of Thailand 2019), as well as compared with the assumptions in order to study the sensitivity of the trading in 3 different levels, 500, 750 and 1,000 baht/ton of carbon dioxide, and compared at the interest rates of 4, 6, 8 and 10%, can be found as in Equation (8) Sunthornhao et al. (2013), Ounkerd et al. (2015):

$$V_t = V_0 \cdot (1.0r)\ t \quad (8)$$

where:

V_t – valuation of carbon stock at t year [baht/ha]
V_0 – valuation of carbon stock at current year [baht/ha]
r – interest rate equal to 4,6,8 and 10
t – times (year) is 1, 2, 3... 5.

Results and Discussion

Community composition and ecological status of Ban Khum community forest

The selected Ban Khum community forest showed variability in various forest structural attributes such as density, diversity, species riches, and total basal cover.

Table 1

Geographical coordination of the study area of Ban Khum community forest

Name	Location	Altitudes [m asl]	Forest types	Dominant species
Ban-Khum Lab-Lare district, Uttaradit province, Thailand	100.027 E 17.641 N	320	dry dipterocarp forest	Dipterocarpus obtusifolius

* MDF is mixed deciduous forest

The findings demonstrate that all research plots have approximately as many species as other forest areas (Table 2). The MEF and DEF's soils had more moisture than the other woods at the other site, most likely. Moisture levels are an important factor controlling the species composition of each forest (PONGUMPAI 1976, GLUMPHABUTR et al. 2006). The number of species depends on soil moisture in the forest, and it will increase as soil moisture content increases from dry dipterocarp forest to mixed deciduous forest, and the dry evergreen forest and hill evergreen forest to the moist evergreen forest, respectively (OGAWA et al. 1965). Compared to other forests in Thailand, for example Khao Kaset Forest area (KHOPAI 2006), Khun Korn Waterfall Forest Park, Thailand (NUKOOL 2002) and Thung Salaeng Luang National Park (CHATTANONG 2013).

Tree density

The community forest had a lower density of trees with DBH ≥ 4.5 cm compared to other forests such as the dry dipterocarp forest, mainly due to the presence of numerous small trees. Table 2 provides a comparison of the tree density in the study plots with that of other forest types located in different parts of Thailand. The tree density in all study plots was relatively high, particularly in the Ban Khum community forest, which had a comparable density to that of other mixed deciduous forests.

Table 2

Number of species, tree density and basal area of community forest and other mixed deciduous forests in Thailand, only trees with DBH ≥ 4.5 cm

Land use	Forest types	Area	Number of species [sp. ha^{-1}]	Tree density [tree ha^{-1}]	Basel area [%]	Source
Community forest	MDF	Ban-Khum Community Forest	21	664	1.351	present study
Natural forest	MDF	Thung Salaeng Luang National Park	35	2,205	–	PODONG et al. (2013)
Natural forest	MDF	Khao Kaset Forest area	33	959	–	KHOPHAI (2006)
Natural forest	MDF	Khun Korn Waterfall Forest park	62	358	0.358	NUKOOL (2002)

Tree biomass

The study conducted a biomass assessment of trees, which was divided into two categories: above ground biomass, comprising the stem, branches, and leaves, and below ground biomass, comprising the roots. The results revealed that the Ban Khum community forest area had an average biomass content of 1.577±0.498 tonne ha^{-1} divide into stem, branches leaves and root sections of 0.401±0.127 tonne ha^{-1}, 0.400±0.127 tonne ha^{-1}, 0.401±0.127 tonne ha^{-1} and 0.345±0.109 tonne ha^{-1}, respectively. Total biomass was 71.496 tonne, with conserved forest zone having the highest biomass content average 2.271±0.678 tonne ha^{-1} divide into stem, branches leaves and root sections of 0.430±0.134 tonne ha^{-1}, 0.400±0.127 tonne ha^{-1}, 0.401±0.127 tonne ha^{-1} and 0.345±0.109 tonne ha^{-1}.The forest utilized zone had the least amount of biomass average 0.187±0.077 tonne ha^{-1} divide into stem, branches leaves and root sections of 0.540±0.021 tonne ha^{-1}, 0.400±0.127 tonne ha^{-1}, 0.401±0.127 tonne ha^{-1} and 0.345±0.109 tonne ha^{-1}, respectively (Table 2). However, there is a difference in biomass between conserved forest zone and utilized forests zone statistically significant ($p \leq 0.05$). This tree biomass distribution was found in the study showed that the biomass distribution was in the 0.003–1.492 tonne ha^{-1} (Figure 2).

Table 2

Tree biomass of Ban Khum community forest, Uttaradit province, Thailand

Types of forest zone	Area [ha]	Biomass [tonne ha^{-1}]					Total Biomass [ton]
		stems	branches	leaves	roots	total	
Conserved forest zone	30	0.430±0.134	0.400±0.127	0.401±0.127	0.345±0.109	2.271±0.678	68.130
Utilized forest zone	18	0.540±0.021	0.047±0.019	0.046±0.019	0.041±0.017	0.187±0.077	3.366
Mean	–	0.401±0.127	0.400±0.127	0.401±0.127	0.345±0.109	1.577±0.498	–
Total	48	–	–	–	–	–	71.496

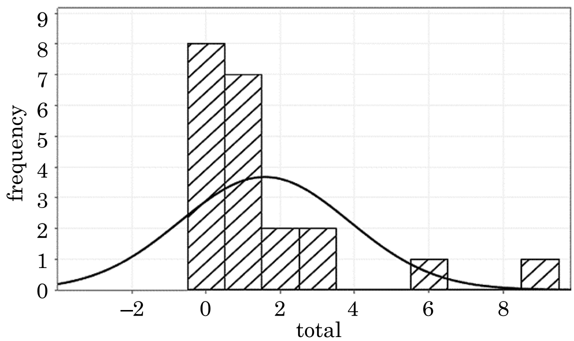

Fig. 2. Histogram with normal curve of total biomass Ban Khum community forest, Uttaradit province, Thailand

Carbon stock

Carbon stock in tree biomass showed that the Ban Khum community forest area had an average carbon stock of 0.741±0.234 tonne C ha^{-1}, divide into stem, branches leaves and root sections of 0.202±0.060 tonne C ha^{-1}, 0.198±0.060 tonne C ha^{-1}, 0.401±0.127 tonne C ha^{-1}, respectively. Total carbon stock was 4.788 tonne C ha^{-1}, with conserved forest zone having the highest biomass content average 1.068±0.319 tonne C ha^{-1} divide into stem, branches leaves and root sections of 0.291±0.086 tonne C ha^{-1}, 0.272±0.082 tonne C ha^{-1}, 0.174±0.649 tonne C ha^{-1} and 0.230±0.070 tonne C ha^{-1}, respectively. The forest utilized zone had the least amount of biomass average 0.088±0.036 tonne C ha^{-1}divide into stem, branches leaves and root sections of 0.025±0.009 tonne C ha^{-1}, 0.047±0.019 tons C ha^{-1}, 0.047±0.020 tonne C ha^{-1} and 0.019±0.010 tonne C ha^{-1}, respectively (Table 3). The Ban Khum community forest slightly higher biomass (1.577 tonne ha^{-1}) and carbon stock (0.741 tonne C ha^{-1}) than other deciduous forests in Thailand, such as Thong Pha Phum National Forest (TERAKUNPISUT et al. 2007), western Thailand (CHIYO et al. 2011) and lower northern Thailand (KAEWKROM et al. 2011). Net primary production in a tropical forest is ~11–21 tonne ha^{-1} with 25–65% contributed from leaf litter (BROWN and LUGO 1982). Though the turnover time of biomass is approximately 34 years, the turnover time of litter is much shorter, < 1 year (BROWN and LUGO 1982) – Table 4.

Table 3

Total carbon stock of Ban Khum community forest, Uttaradit province, Thailand

Types of forest zone	Area [ha]	Carbon stock [tonne C ha^{-1}]					Total biomass [tonne C]
		stems	branches	leaves	roots	total	
Conserved forest zone	30	0.291±0.086	0.272±0.082	0.174±0.649	0.230±0.070	1.068±0.319	3.204
Utilized forest zone	18	0.025±0.009	0.047±0.019	0.047±0.020	0.019±0.010	0.088±0.036	1.584
Mean	–	0.202±0.060	0.198±0.060	0.401±0.127	0.162±0.235	0.741±0.234	–
Total	48	–	–	–	–	–	4.788

Table 4

Summary of carbon stock and above-ground biomass in tropical forest

Locations	Aboveground biomass [tonne ha^{-1}]	Biomass carbon stock [tonne C ha^{-1}]	Source
South East Asia	–	0.078–0.18 (continental), 0.0096–0.225 (insular)	IPCC (2006)
Mixed deciduous forest, Lower Northern Thailand	0.0509 (secondary forest) 0.1045 (primary forest)	0.0307 (secondary forest) 0.0519 (primary forest)	KAEWKROM et al. (2011)
Ratchaburi province, West	0.0309 (dry dipterocarp forest) 0.054 (mixed deciduous forest)	0.0145 (dry dipterocarp forest) 0.0279 (mixed deciduous forest)	CHAIYO et al. (2011)
Kanchanuburi province, West	0.0962 (mixed deciduous forest)	0.0481 (mixed deciduous forest)	TERAKUNPISUT et al. (2007)

Figure 3 shows an obvious linear relationship between carbon stock and number of species (n = 21, R = 0.98, a = 0.1111) and carbon stock and tree density (n = 21, R = 0.98, a = 0.5247). The carbon stock with number of species and tree density in Ban Khum community forest showed a stronger positive correlation

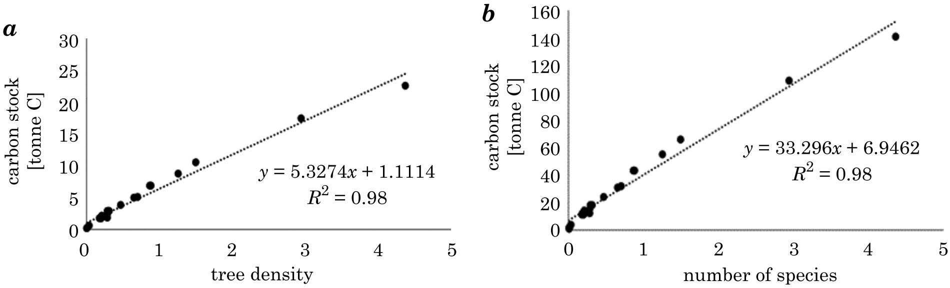

Fig. 3. Relation between carbon stock and number of species, carbon stock and tree density of Ban Khum community forest

Carbon dioxide absorption

When determining the carbon stock in tree biomass to assess the carbon dioxide absorption, it was found that Ban Khum community forest area had an average 0.594±0.188 tonne CO_2 ha^{-1}, divide into stem, branches leaves and root sections of 2.123±0.671 tonne CO_2 ha^{-1}, 0.742±0.231 tonne CO_2 ha^{-1}, 0.690±0.220 tonne CO_2 ha^{-1}and 0.594±0.188, respectively. Total carbon dioxide absorption was 91.74 tonne CO_2, with conserved forest zone having the highest carbon dioxide absorption average 3.058±0.913 tonne CO_2 ha^{-1} divide into stem, branches leaves and root sections of 1.066±0.315 tonne CO_2 ha^{-1}, 0.995±0.299 tonne CO_2 ha^{-1}, 0.997±0.299 tonne CO_2 ha^{-1} and 0.856±0.256 tonne CO_2 ha^{-1}, respectively. Total carbon dioxide absorption was 4.50 tonne CO_2, with utilized zone having the highest carbon dioxide absorption average 0.250±0.104 tonne CO_2 ha^{-1} divide into stem, branches leaves and root sections of 2.123±0.671 tonne CO_2 ha^{-1}, 0.742±0.231 tonne CO_2 ha^{-1}, 0.690±0.220 tonne CO_2 ha^{-1} and 0.070±0.029 tonne CO_2 ha^{-1}, respectively (Table 5). Conserved forests zone has higher amounts of carbon dioxide absorption than forests utilized zone for. Which tends in the direction of biomass and carbon stock.

Figure 4 shows an obvious linear relationship between CO_2 absorption and number of species (n = 21, R = 0.98, a = 0.3516) and CO_2 absorption and tree density (n = 21, R = 0.98, a = 0.9591). The CO_2 absorption with number of species and tree density in Ban Khum community forest showed a stronger positive correlation.

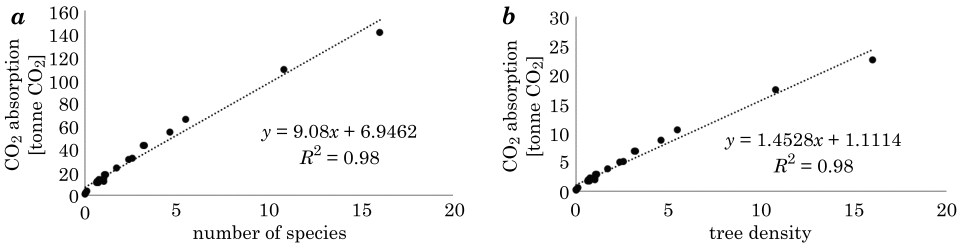

Fig. 4. Relation between CO_2 absorption and number of species, carbon stock and tree density of Ban Khum community forest

Table 5

Carbon dioxide absorption of Ban Khum community forest, Uttaradit province, Thailand

Types of forest zone	Area [ha]	Biomass [tonne CO_2 ha^{-1}]					Total Biomass [tonne CO_2]
		stems	branches	leaves	roots	total	
Conserved forest zone	30	1.066±0.315	0.995±0.299	0.997±0.299	0.856±0.256	3.058±0.913	91.74
Utilized forest zone	18	0.093±0.037	0.078±0.034	0.080±0.033	0.070±0.029	0.250±0.104	4.50
Mean	–	2.123±0.671	0.742±0.231	0.690±0.220	0.691±0.220	0.594±0.188	–
Total	48	–	–	–	–	–	96.24

Carbon stock value

Estimation of carbon stock in the last five years (2015–2019) in Ban Khum community forests was 120.05 tonne CO_2 ha^{-1}. Assessment of carbon stock at an interest rate of 6 percent per year at each level of carbon trading prices (as of 18 September 2019) revealed a total carbon stock value of € 1,538.98 at the price level of the EUA market, equal to € 26.97 per ton of carbon stock. For the CCA market, the purchase price of carbon was $ 17.62 per tonne of carbon stock, providing a total carbon stock value of $ 1,005.44. If the purchase price increased up to $ 20, $ 30 and $ 50 per tonne of carbon stock total value would be $ 1,141.26, $ 1,711.88 and $ 2,853.14. Forest ecosystems are quite variable in the determination of prices. Whether the forest in question is a community or natural forest, pricing depends on the potential and present ecological management of the area. A company's main area will depend on the number of trees if not handled properly by the major academic inevitably result in the environmental sustainability of the system easily, as shown in Table 6.

Table 6

Carbon stock value of Ban Khum community forest, Uttaradit province, Thailand year 2015. The given interest rate of 6 percent per year

Types of forest zone	Area [ha]	Carbon dioxide absorption [tonne CO_2]	Carbon stock value by given carbon price level [tonne CO_2]				
			EUA € 26.97	CCAR $ 17.62	Carbon price [$]		
					20	30	50
Conserved forest zone	30	91.74	1,478.08	965.66	1,096.10	1,644.14	2,740.24
Utilized forest zone	18	4.50	60.90	39.78	45.16	67.74	112.90
	48	96.24	1,538.98	1,005.44	1,141.26	1,711.88	2,853.14

In this study, we explicitly set a fixed volume of carbon from 2014–2020 to be utilized in income estimation for the initial five years. Exchanging and appraisal of carbon rely upon purchasers and vendors who may wish to continue to exchange after the period ends. In addition, carbon stock is to be checked at regular intervals, pretty much as settled upon. The agreement should be reasonable and dependent on academic standards. For example, if the amount of carbon stock is confirmed at regular intervals, and the agreement is made for 25 years, confirmation should be performed multiple times throughout the period. Incomes are, therefore, liable to change, depending on the carbon stock determination (IGNOSH et al. 2009). Carbon credit contracts for zones with forestation may fluctuate rapidly, and strategies are required to determine charges, obligations and income. All of these factors can produce a variety of results following an alternate check charge or expense exception on the 20% carbon stock (FARLEE and STELZER 2008). Some organizations may apply a higher compensation for the same stock (CURRENT et al. 2010) due to the market's diverse referential valuing or if the value is below USD 4 per weight, among other reasons. Therefore, the total income of carbon credits can be changed from the study of other trees such as rubber, it was found that the average income compared to land tenure for rubber plantation in Thailand was approximately 1.6 hectares per household (ISSARAPAP and JARUNTORN 2019). The results of this study indicate that forest community can be developed and placed in voluntary access programs, as well as other forest sectors. Stock or large numbers, both on the aboveground and belowground with good management to reduce train emissions (ISSARAPAP and JARUNTORN 2019) throughout the use of forest community will be able to stretch the deal in accordance with US California Carbon Market and European Union Allowance (EUA) market, however, contract or should not be carefully scrutinized to determine the appropriate value with an effective methodology program for forest community.

Conclusion

In conclusion, the study found that the conserved forest zone had a higher tree species diversity and density compared to the utilized forest zone. The conserved forest zone had a total biomass of 68.130 tonne and a carbon stock of 3.204 tonne C, which resulted in the absorption of 91.74 tonne CO_2. The value of carbon stock in the European Union Allowance (EUA) market was € 1,478.08 and in the US California Carbon Market was $ 965.66. On the other hand, the utilized forest zone had a lower tree species diversity and density with a total biomass of 1.584 tonne, which was converted to a carbon stock of 1.584 tonne C and absorbed 4.50 tonne CO_2. The value of carbon stock in the European Union Allowance (EUA) market was € 39.78 and in the US California Carbon Market was $ 60.90. These findings highlight the importance of conserving forests for carbon sequestration and the potential economic benefits of carbon trading in markets such as the EUA and US California Carbon Market. Previous studies have also shown the importance of forest conservation for carbon sequestration and the potential for carbon trading as a means of promoting conservation efforts. For example, a study by Houghton et al. (2000) found that tropical forests are responsible for absorbing approximately 1.4 billion tonnes of carbon per year, highlighting the potential impact of forest conservation on mitigating climate change. Another study by Börner et al. (2010) investigated the potential for carbon trading in the Brazilian Amazon and found that a system of payments for environmental services could be a viable mechanism for promoting forest conservation and mitigating greenhouse gas emissions. These findings support the importance of continued research and implementation of policies and practices that promote forest conservation and carbon sequestration.

Acknowledgements

This study was funded by research from the Office of the Higher Education Commission. This research can be accomplished as well. The researcher would like to thank the Department of Environmental Science for being able to help in the areas of materials, equipment and tools as well as facilitating research. Thank you to each community leader for providing information and facilitating the research area. Finally, I would like to thank the Office of the Office of the Higher Education Commission together with the Uttaradit Rajabhat University for providing support for research grants.

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