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Community Forest Carbon Assessment in Eastern Thailand from Forest Conservation Management by Local People

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One measure of increasing carbon sequestration areas is community forest conservation, which is the way to maintain common forest areas linking with human livelihoods. The first step towards implementing incentive mechanism of Reducing Emissions from Deforestation and Degradation (REDD) at the national level is to assess the amount of forest carbon. This is important for REDD inspections and subsequent funding from public funds or carbon markets. The objective is to find the carbon stock in soil, aboveground and belowground biomass for estimated carbon price in the community forest. The study site was carried out at Ban Phrao community forest, Sa Kaeo Province, East of Thailand. Field data were collected from temporary 16 plots the diversity of plant species, to assess forest biomass carbon storage based on the allometric equation, and to estimate the proportion of carbon contents in plant and soil by using CHN analyzer. Results showed that species diversity by Shanon-Wiener Index was 2.75, which the tree species range identified 29 families and 33 species. *Xylia xylocarpa* (Roxb.) Taub. was the dominant specie. Carbon stock in biomass for 2017 and 2019 were 19.04 and 44.86 t C ha^{-1}. The increasing rate of carbon stock in biomass was 12.90 t C ha^{-1} y^{-1}. The carbon stock in soil at 0-15 and 15-30 cm soil depth were 21.02 and 18.05 t C ha^{-1}. Estimated carbon price from biomass increasing rate at Ban Phrao community forest were 216.72 USD ha^{-1} y^{-1} or 35,576.75 USD y^{-1}. Then, Ban Phrao community forest was the potential to increase income for the surrounding community by maintaining and conserving the forest area to store carbon, preserve biodiversity and in return for conservation.

1. Introduction

The threat of climate change has urged increased global awareness and apprehension concerning interactions between society, the economy and the environment (Boonpanya and Masui, 2020). Forests play an essential role in maintaining the carbon cycle balance on earth. They storages and releases carbon to the atmosphere. With regards to carbon exchange between the earth and atmosphere, Forest tree has been mainly charged (Promjittiphong et al., 2018). Normally, carbon cycle in the forest is initiated when carbon is fixed via photosynthesis. Organic compounds are immobilized in tissue formation and transformed into carbon stored in the form of biomass and they were degraded through the respiration process by microbe plant, and animal. Carbon sequestration can be classified in each forest ecosystem as follows: aboveground biomass, belowground biomass, scrap biomass, ground cover plants and soil carbon storage. The carbon cycle has crucial role in regulating the Earth’s climate through stabilizing the CO_2 concentration in the atmosphere. The forests are the largest carbon reservoir in the world ecosystem. They have the potential to store CO_2 from various activities which released into the atmosphere, resulting in an excessive global warming effectively. Over the last few decades, the carbon sequestration value of forest ecosystems has attracted considerable attention as a result of global warming and climate change. As a requirement of the agreements, carbon sequestration has been focused to stabilize forest ecosystems and its regulations by implementing appropriate policies to reduce carbon emissions. According to information on community forest carbon issue as worldwide, there is required to understand the global carbon cycle for controlling and supporting their regulatory. REDD

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and REDD+ programs of the United Nations Framework Convention on Climate Change (UNFCC) are aimed at reducing emissions and sequestering carbon through preventing deforestation and promoting conservation of existing forests. While the REDD program exclusively focuses on preventing carbon emissions from deforestation and degradation, the REDD+ contains an additional objective of carbon removal through conservation and sustainable management of forests. REDD policy supports developing countries to reduce greenhouse gas from deforestation and forest degradation, sustainable management of forests and enhancement of forest. The national application is to assess the carbon content of forests, beginning with conservation forest area as community forests where humans have depended on the forests for ways of life. Community forests are considered as a green conservation area where variety of ecosystems play an important role in the carbon cycle for the nature and play its role on life support system to human community beings and uses. Thus, to make a survey of carbon sequestration of the community forests is supposed to be a priority issue to estimate the carbon stock baseline for initiating incentive projects and contributing to sustainable forest development planning to increase carbon stock in the next stage.

From the Community Forest Performance Summary Report in 2019. Currently, Thailand has more than 17,442 villages participating in the community forest project and 15,337 participating community forest. From Summary report Community Forest Management Office (RFD, 2020) conducted a study of carbon storage in community forest, found that 1,600 m^2 of community forest can store an average of 7 t carbon, which includes 100,000 ha of community forest can store carbon up to 40 Mt carbon throughout the country. There are marked differences among sites. For example, Nong Mek Community Forest, Sa Kaeo Province, Sang Khom District, Nong Khai Province, and Mancha Khiri Forest Park. Khon Kaen Province were 25.64, 78.19, and 64.70 t C ha^{-1}. Previous research has focused on the carbon stock of community forests based on physical factors like the terrain and type of forests, where the nature of each forest management approach and community livelihoods were lacked issuing. The differences in carbon storage among community forests reflect variation in a number of factors, including tree community composition, disturbance history, successional stage, age, climate, soil fertility, and conservation and management policies. The objective of this research is to find the amount of carbon sequestration in biomass, and to assess the carbon price in Ban Phrao community forest, Sa Kaeo Province, Eastern Thailand. To conduct the research, carbon stock in the community forest areas was measured and estimated carbon in aboveground biomass, belowground biomass, litter fall, cover plant and soil carbon. The outcome of this project is to provide knowledgeable information for community forest development as a sustainable forest resource management and this can support regulating of ecosystem services. Although the community forest was recorded as a secondary forest where carbon storage has been relatively low potential stage. Nowadays, the forest is on the process of conserving to prevent forest-fire damages that occur regularly during the summer by joining the community forest conservation project with the helps from Thai's government.

2. Methods

2.1 Study site

The study carried out in the community forest at Ban Phrao village, Sa Kaeo Province Thailand, lied between 13°43'44.3"N and 102°17'00.9"E. The total site of study area covers 164.16 ha. and the altitude is 86 m. from the sea level. The landscape of the Ban Phrao community forest has not been zoned into a conservation forest or use the forest. Ban Phrao forest was jointed to a program of community establishment under the national reserved community forest act since 2012. The forest was still disturbed by intensive human activities, for example: the illegal logging and removing trees, encroaching forests for farming, and burning of straw in rice fields near the forest which led to forest fires spreading. The culture of forest ordination ceremony is regarded to be a mechanism to preserve cutting down trees locating in the forest, and to prevent natural disasters. Impacts of forest fire were mostly caused forest damages in dry season during January-March. There were directly affecting saplings which suppressed them to ingrowth of mature trees. The climate was warm and sub-humid in tropical region. Mean annual air temperature during a year was 27.9 °C. The maximum and minimum air temperatures on April were 23.6 and 42.2 °C, and total precipitation was 1,200 mm y^{-1}, most of which falls between rainy season during May-October (TMD, 2020). The soil property was loamy sand, and soil pH was 5.5-7 on top soil layer but soil pH (4.5-5.5) was decreased in soil depth (LDD, 2015).

2.2 Data collection

Field data were collected basing on temporary samples of 16 plots within a total survey area of 1,600 m^2, collecting information of tree species, above ground biomass (AGB), below ground biomass (BGB), litterfall, cover plant and soil organic carbon (SOC), estimating of tree species and measure the height of tree larger than 4.5 cm diameter at breast height, (DBH) within plots 10 × 10 m and measure the height of the tree last than 4.5 cm diameter at breast height, (DBH) within plots 4 × 4 m, 1 × 1 m plot established was litterfall, cover plant, and soil organic carbon (SOC) (Figure 1). Totally, 64 plots were collected by using soil core method and measure soil organic carbon at 0-15 and 15-30 cm.

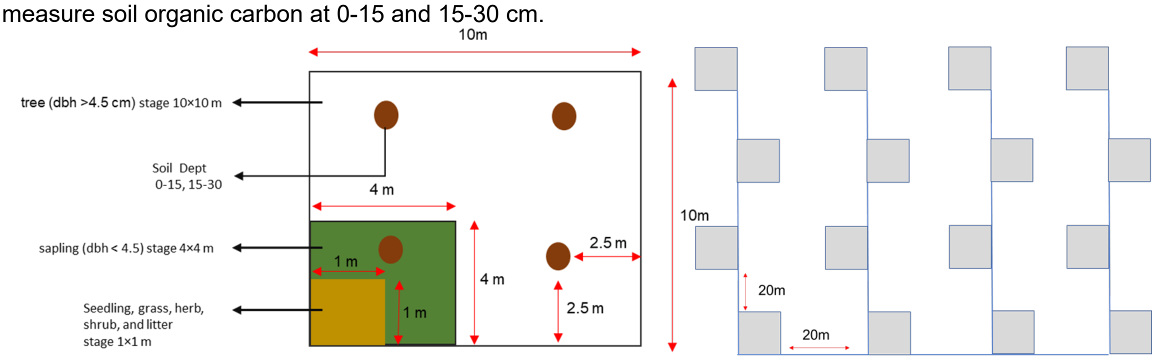

Figure 1: Plot set up for carbon stock estimation of biomass, litterfall and soil properties at Ban Phrao community forest

2.3 Data analysis

Observed forest tree species were identified according to taxonomy principles for the study of the characteristics of the plant society, and were analyzed the diversity of species where Important Value Index, IVI were estimated using Shannon' wiener Index. This study estimated carbon stock of Ban Phrao community forest, which is a secondary dry dipterocarp forest, from aboveground and belowground plant biomass. The aboveground and belowground biomass of the tree were estimated relationship among the range of tree diameters at breast high (130 cm.), aboveground level (D), and height (H) by using the allometric equations. Aboveground biomass consists of stems, branches, and leaves, while belowground biomass refers to roots. Carbon stock in all biomass were calculated following allometric equation for secondary dry dipterous forest in Thailand provided by (Hanpattanakit et al., 2016) Eqs(1)-(3)

$$\text{Log } W_{S+B} = 0.9608 \text{ Log } (D^2 H) - 1.1296 \quad (1)$$

$$\text{Log } W_L = 0.5225\text{Log } (D^2 H) - 0.8814 \quad (2)$$

$$\text{Log } W_R = 0.6066\text{Log } (D^2 H) - 0.0767 \quad (3)$$

Where, W_{S+B} = Stems and branches biomass (t dm/ha), W_L= leaves biomass (t dm/ha), W_R = root biomass (t dm/ha), D = Stem diameter (cm), H = tree height (m). Carbon ratio in biomass and soil were analysed by CHN Analyzer (PerkinElmer 2400 series II CHNS / O Elemental Analyzer). It was started measurement by oven dry method and crushes each plant and soil sample. Soil Organic Carbon (SOC) was analysed from two soil depth layers of 0-15 and 16-30 cm, using soil core to collect 128 samples for analysing bulk density and soil organic carbon in soil Eq(4)

$$SOC = BD \times \%C \times D \quad (4)$$

Where, SOC = soil organic carbon (t C/ha), BD = bulk density of soil (kg/m^3), %C = % carbon ratio (%) and D = soil depth (m). The BD was calculated density of soil in laboratory using the oven dry method and percent of C was estimated using CHN Analyzer. Estimated carbon stock in litterfall and cover plant were calculated following plant carbon stock (PCS) as shown in Eq(5)

$$PCS = B \times \%C \quad (5)$$

Where, PCS is plant carbon storage, B is biomass of plant in litterfall and cover plant (g/m^2), % C is carbon ratio (%). In addition, to estimate carbon price for the biomass increasing rate per year was normally estimated following carbon trading market in California carbon market which is based costly 16.48 USD/tC (TGO, 2020).

3. Result and discussion

3.1 Vegetation structure and species diversity

The tree species of 29 families and 33 species were found in Ban Phrao community forest where Shannon-Wiener Index indicated vary diversity of trees valued as 2.75. This estimated value was compared to primary dipterocarp forests, it shows lower species diversity than primary forest. This was because the forest had been previously disturbed by various factors related to human activities and natural phenomenon which misleading them to natural successional stage. Besides, the species diversity of sapling occurred at Ban Phrao community forest was found higher estimated level than it was occurred at Khok Yai Community Forest, Wapi Pathum District, Maha Sarakham Province where diversity of trees estimated as 2.42 (Bukaew et al., 2009). At the meantime, tree species diversity of this area showed lower estimate level than Tha Khoi community forest, Pachin Buri Province, because of forest fire problems that still occur annually. This can be the main factor that lower tree species diversity of Ban Phrao community. Although, forest fires are an important factor in determining the species of deciduous dipterocarp forest, it should be period managed to prevent frequency occurrences.

Xylia xylocarpa (Roxb.) Jaub. var. kerrii (Craib and Hutch.) Nielsen was the highest influenced this plant community, which is called as dominant species, followed by Important Value Index of tree species of *Shorea obtusa* Wall. ex Blume, *Canarium subulatum* Guillaumin, *Sindora siamensis* Teijsm. ex Miq and *Dipterocarpus tuberculatus* Roxb. which were showed in percentage of 43.08, 32.93, 29.93, 25.16, and 20.22. These tree species Importance index indicated that most of the trees, occurring at Ban Prao community forest, are frequently influence in dry dipterocarp forests. Considering on tree regeneration based on tree diameter class distribution, showed as L-shape model, the most diameter at breast height (DBH) was 4.5–13.77 cm, indicating stationary stage conditions of the forest as on developing stage of successional change in plant community (Jundang et al., 2010).

3.2 Carbon stock in aboveground and belowground biomass

The Eqs(1) to (3) were applied to evaluate biomass increment of forest trees from the forest. Diameter (D) and height (H) of 199 replication trees had been measures for 2 y during February 2017 to February 2019. The average of height and diameter in the beginning measured 8.72 ± 1.75 m and 11.85 ± 1.40 cm, and ending growth measured 11.42 ± 1.10 m and 15.44 ± 4.19 cm. The aboveground and belowground biomasses were calculated biomass increment by using the allometric equations of Eqs (1-3).

The rate of biomass increment of plant growth in leaf (WL), stem and branches (WS+B), and root (WR) in 2017 and in 2019 were 44.95, and 103.93 t dm ha^{-1}. The annual average of plant growth rate in WL, WS+B, and WR were 0.52, 11.73, and 7.41 t dm ha^{-1}. The assessment of carbon contents in leaves, stems, and roots was estimated 0.45, 0.43 and 0.42 %. The carbon storage in biomass was estimated by applying the carbon content multiply by each biomass, the result was found that the total carbon stock of the community forests in 2017 and 2019 was 19.05 and 44.86 t C ha^{-1} (Table 1).

Table 1: Biomass (t biomass dm ha^{-1}) and carbon stock (t C ha^{-1}) Ban Phrao community forest

Type of carbon stock	2017		2019		
	Biomass (T dm ha^{-1})	Carbon Stock (T C ha^{-1})	Biomass (T dm ha^{-1})	Carbon Stock (t C ha^{-1})	Ratio (%)
Stem and branch	16.87 ± 0.37	7.30	52.05 ± 2.92	22.52	26.83
Leave	2.72 ± 0.03	1.21	4.30 ± 0.09	1.92	2.29
Root	25.36 ± 0.53	10.53	47.58 ± 1.30	19.76	23.54
Cover Plant	-	-	-	0.05	0.06
Litterfall	-	-	-	0.61	0.73
Total C in biomass	44.95 ± 0.93	19.04	103.93 ± 4.31	44.86	
Soil Organic Carbon					
0-15 cm		-	-	21.02	25.04
16-30 cm				18.05	21.51
Total C stock				83.93	100

The annual average of carbon stock was estimated at 12.90 t C ha^{-1}. The carbon stock estimation in this study was resulted similar to carbon stock of biomass of dry dipterocarp forest in Nong Mek community forest (Kanhom et al., 2019). The community forest at Ban Phrao was lower than carbon stock in nature forest because the area adjacent to the foot of the hill, most of the low fertile soil, containing sandy soil with low water retention. The soil properties in the community forest of average C/N ratio and soil moisture were estimated as 37.54 and 6.37 vol%. Carbon content of the two depth soil layers at 0-15 and 15-30 cm were estimated as 1.83 and 1.50 %C. Carbon storage in biomass of dry dipterocarp around 34 – 80 t C ha^{-1} (Winterkorn and Diloksumpun, 2011).

The assessment of soil organic carbon at two depth soil layers of 0-15 and 16-30 cm were estimated as 21.02 and 18.05 t C ha^{-1}. The amount of carbon storage at top soil layer (0-15 cm) was estimated higher than at lower soil layer (15-30 cm). According to the study result of DDF at Mancha Khiri Forest Park in Khon Kaen Province, land use and accumulation of residue and all biomass can affect the amount of carbon stock in soil where cover plant and litter biomass were estimated at 0.61 and 0.05 t C ha^{-1} (Jundang et al., 2010)

3.3 Carbon market and its price of the community forest

The international carbon market had been developed under the Kyoto Protocol, while today's carbon pricing initiatives are continuously proposed at regional and national levels, especially in developing countries. This underlines the strong endorsement that carbon pricing still receives attention well compared to other policy instruments to reduce greenhouse gas emissions.

The carbon price fluctuates year by year, and as noted by many scholars, it is higher in Europe and developed countries such as Japan or Australia than many other parts of the world. Several national and regional emission trading schemes are already in place, such as the European Union Emission Trading Scheme (EUETS), the 2008 New Zealand Emissions Trading Scheme (ETS), and the Regional Greenhouse Gas Initiative. However, such schemes have not yet been established in many parts of the world (Davide, 2014). The carbon price is implemented in the form of carbon taxes to CO_2 emitters. On the other hand, CO_2 emitters can buy carbon certificates from CO_2 absorbers such as forest owners and/or protectors to ensure that they pay for the same amount of CO_2 and they emitted to the atmosphere. It is obvious that to gain carbon certificate, forest owners and/or protectors must approve how much carbon is now stored and will be accumulated in their own forests. This is not an easy work especially in developing countries where human resources, research equipment and scientific basics, estimating technology are still limited. Much remains unclear over those who are deemed to be responsible for issuing carbon certificates (Davide, 2014).

In the case of Thailand Greenhouse Gas Management Organization (Public Organization) or TGO develops a voluntary greenhouse gas reduction project in accordance with Thailand's standards (Thailand Voluntary Emission Reduction: T-VER) to support all sectors. This is especially for small project developers who can contribute to a voluntary domestic greenhouse gas reduction, while not having to go through complex and less costly procedures than the Clean Development Mechanism (CDM). The Clean Greenhouse Gas Reduction Program (CDM), and the T-VER project are offered as a co-benefit of reducing greenhouse gases mechanism. Carbon resource maintenance in the form of conservation of forest resources increasing green spaces helps reduce pollution, reduce energy and electricity consumption, support the local economy, and promote the development of new, more environmentally friendly careers. This community forest has possibly high potential for offering carbon stock sources, particularly its conservation zone where local people aimed at maintaining a variety of tree species in the forest.

The potential carbon stock in biomass of Ban Phrao community forest was estimated as 12.90 t C ha^{-1} y^{-1}, An annual carbon price was calculated as 216.72 USD ha^{-1} y^{-1} or 35,576.75 USD y^{-1}. This is reasonable price based on the result findings that illustrated an increasing encouragement of forest conservation and reforestation in the community forest areas. Community forests have the national reserved community forest act in use of forest resources by allowing communities to take advantage of forest resources for their livelihood only. From the forest plantations used in the forestry industry. The average amount of carbon sequestration each year was also due to the community cooperating in the conservation of forest resources. Reducing forest encroachment and strict forest fire prevention, can help the majority of plant species growing, and gradually form variety of mature trees that lead to enhance the carbon storage potential. Consequently, the value of carbon sequestration each year may be increased.

4. Conclusions

This study analyzes the carbon storage potential of community forest biomass in the year of 2017 and the year of 2019. The results of the carbon increment rate were estimated at 12.90 t C $ha^{-1}y^{-1}$. These can be seen that Ban Phrao community forest was still low carbon storage in biomass because of topographical factors, soil structure and climate which were regarded as important factors for plant growth. However, community's regulation was help to reduce forest encroachment, and to conserve forest areas and to prevent forest fires continually. In addition, government agencies and private sector have involved in forest management and they supported the community in the conservation of forest resources.

The community has formed strict measures to control forest land uses, prevent forest fire, and reduce illegal encroachment and destruction of forest resources. This can help sapling grow into mature trees, resulting in an estimation of higher biomass and carbon storage. Once the annual amount of carbon storage was assessed and traded in the carbon market, the Ban Phrao community forest will be earned 216.72 USD $ha^{-1}y^{-1}$ or 35,576.75 USD y^{-1}, which help to increase additional income for the community together with higher potential of people participate in the REDD project (reducing deforestation and forest degradation). This mechanism can enhance community encouragement and reduce CO_2 emissions from deforestation. To support the best practice for sustainable forest management, the Thai's government should initiate trade-off mechanism to increase carbon storage potential at the same time to increase compensation in form of carbon market trading. For future research, the emissions and carbon sequestration of community forests should be assessed. Carbon balance in forest between carbon sink and carbon source were explained by the term of Net Ecosystem Production (NEP). The NEP refers to differences of the amounts of organic carbon fixed by photosynthesis in forest ecosystem during respiration process. The NEP represents the organic carbon available for storage within the system or loss from it by export or non-biological oxidation.

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