The Estimation of Carbon Storage in Dry Evergreen and Dry Dipterocarp Forests in Sang Khom District, Nong Khai Province, Thailand

การประเมินปริมาณการสะสมคาร์บอนของป่าดิบแล้ง และป่าเต็งรัง อ.สังคม จ.หนองคาย

Phouveth Senpaseuth, Charlie Navanugraha and Sura Pattanakiat

Faculty of Environment and Resource Studies, Mahidol University, Nakhon Pathom, Thailand 73170

Abstract

The objectives of this study were to identify the plant community characteristics and estimate and compare the carbon storage in dry evergreen and dry dipterocarp forests, including with soil (physical and chemical) properties, in Sang Khom district, Nong Khai province. Six temporary sample plots (20×50 m^2) were designed to collect data as the study area. The biomass of plant species was estimated from each of the tree components, both aboveground (stem, branch and leave) and belowground (root) portions, by using allometric equation. The biomass of the groundcover was also collected and evaporated by oven drying at 80^{o}C for 3-5 hours or until it was at a constant weight. Then the dried weight was used to estimate the biomass content. The carbon in the biomass of the aboveground, belowground portions of the trees and the biomass of the ground cover on the soil surface were calculated by multiplying with a conversion factor at 0.5. In additions, the soil properties and soil organic carbon were analyzed.

The results of this study showed that the plant community characteristic of dry evergreen and dry dipterocarp forests looked like a sparse forest, while the total carbon contents of both forest types were mostly different, especially, the aboveground carbon contents which were identified as the greatest amount of carbon contents. However, the total carbon content of dry evergreen forest was more than dry dipterocarp forest: they were 31,442.01 and 15,096.17 kg/rai, respectively. The aboveground (stem, branch and leave), belowground (root and soil) and ground cover carbon content of the dry evergreen forest was about 23,737.05, 7,682.26 and 22.71 Kg/rai, respectively. The aboveground (stem, branch and leave), belowground (root and soil) and ground cover carbon content of the dry dipterocarp forest was about 9,505.00, 5,578.57 and 12.61 kg/rai, respectively.

Key words: Nong khai province / Carbon storage / Soil organic carbon / Dry evergreen forest / Dry dipterocarp forest

บทคัดย่อ

การวิจัยครั้งนี้มีวัตถุประสงค์เพื่อจำแนกลักษณะโครงสร้างทางสังคมของพรรณพืช ประเมิน และเปรียบเทียบปริมาณการสะสมคาร์บอนของป่าดิบแล้ง และ ป่าเต็งรัง พร้อมทั้งคุณสมบัติต่าง ๆ ทั้งทางกายภาพ และเคมีของดินในบริเวณพื้นที่ อ.สังคม จ.หนองคาย ทำการเก็บรวบรวมข้อมูล โดยใช้แปลงเก็บตัวอย่างขนาด 20×50 m^2

ปริมาณมวลชีวภาพนั้นจะทำการประเมินจากส่วนประกอบต่างของต้นไม้ยืนต้น ซึ่งประกอบด้วยมวลชีวภาพเหนือพื้นดิน (ลำต้น, กิ่ง และใบ) และมวลชีวภาพใต้ดิน (ราก) โดยใช้สมาการ Allometric ส่วนพืชพื้นล่างจะทำการรวบรวม และอบด้วยอุณหภูมิ 80°C เป็นเวลา 3-5 ชั่วโมง หรือจนกว่าน้ำหนักจะคงที่ เพื่อนำน้ำหนักแห้งไปประเมินปริมาณมวลชีวภาพ ปริมาณคาร์บอนในมวลชีวภาพเหนือพื้นดิน ใต้ดิน และพืชพื้นล่าง โดยนำค่ามวลชีวภาพคูณด้วย Conversion Factor ซึ่งมีค่าเท่ากับ 0.5 นอกจากนี้ยังทำการประเมินคุณสมบัติต่างๆ พร้อมทั้งอินทรีย์คาร์บอนในดินด้วย

ผลการศึกษาพบว่าโครงสร้างทางสังคมพืชของป่าดิบแล้ง และป่าเต็งรังมีลักษณะเป็นป่าโปร่ง ในขณะที่ปริมาณการสะสมคาร์บอนทั้งหมดของป่าทั้งสองประเภทมีความแตกต่างกันอย่างมาก โดยเฉพาะปริมาณคาร์บอนเหนือพื้นดิน ซึ่งเป็นส่วนที่มีปริมาณการสะสมมากที่สุด โดยปริมาณการสะสมคาร์บอนทั้งหมดของป่าดิบแล้งมีปริมาณมากกว่าป่าเต็งรัง ซึ่งมีค่าเท่ากับ 31, 442.01 และ 15,096.18 กก/ไร่ ตามลำดับ ซึ่งปริมาณคาร์บอนเหนือพื้นดิน ใต้ดิน และพืชพื้นล่างของป่าดิบแล้งเท่ากับ 23,737.05, 7,682.26 และ 22.71 กก/ไร่ ตามลำดับ โดยป่าเต็งรังมีค่าเท่ากับ 9,505.00, 5,578.56 และ 12.61 กก/ไร่ ตามลำดับ

คำสำคัญ : จ.หนองคาย / การสะสมคาร์บอน / อินทรีย์คาร์บอนในดิน / ป่าดิบแล้ง / ป่าเต็งรัง

1. Introduction

The climate change is resulted from the greenhouse effect phenomena which is a global environmental problem. These phenomena was effectively impact to the ecosystems, natural resources, socio-economics and political through out the world. The majority cause of the greenhouse effect phenomena is mainly from the arising of human activities such as burning of fossil fuels, agricultural activities and deforestations. The major greenhouse gases are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and chlorofluorocarbon (CFCs). During 1980-1990, the concentration of greenhouse gases rapidly increased and caused emission to the atmosphere at the average of 26,000, 300, 6 and 0.9 million ton, respectively. These gases naturally are capable to adsorb solar radiation and storage in the atmosphere, so the percentage temperature of the earth has been warmed up to an average of 55, 15, 6 and 24 (%), respectively. The carbon dioxide has been considered to be the most important of greenhouse gases since the releasing and absorption has been more than other gases in the atmosphere. In the last decade, the carbon dioxide in the global was about 345 ppm. The results from various measurement prediction showed that the carbon dioxide would be trended to rise up about 440 to 660 ppm in 2050.

The forest ecosystem plays an important role as the source and sinks for the carbon dioxide. The appropriation of forest management could reduce the raising of greenhouse gases; especially, the carbon dioxide gas by reducing the affective of releasing to be accumulating sources instead. The carbon circulations in the forest ecosystems are the most important alter factors to reduce the concentration of greenhouse gases in the atmosphere. Since, the forest ecosystems are functioned as absorption and releasing the carbon dioxide (CO_2) through photosynthesis and respiration processes. The carbon accumulation in the forest ecosystems have been stored in form of biomass, including of aboveground and belowground biomass, and released much more than 60% or two fold of CO_2 that the plant species used in photosynthesis process to the atmospheric by respiration process. Otherwise, soil carbon contents are also the alter factor to reduce and increase the concentration of the greenhouse gases by soil reactions. The carbon circulation of the forest ecosystems were depended on types of plant species, soil and also involved with the environment that it's affected to the balance of the absorption and emission of CO_2 gas. The various nations were thus gathering into a group to solve and protect the global climate change. Afterwards, the coordinated committees were spaciously established and proceeded to protect the global climate system. In 1997, the Kyoto protocol was established to protect the greenhouse gases by appointing the goal and time period to reduce the concentration of the emission. In Thailand, there are many forest types, but it can be classified into 2 main types of forest, they were evergreen and deciduous forests. The evergreen forest is green through out the year and being classified into 14 types: tropical rain forest, lower mountain rain forest, dry evergreen forest, etc. The deciduous forest is seasonal forest which can be found in all regions with long dry season for 4-7 months. This type of forest would shed its leave and ready to produce young leaves at the rainy season or when the forest retains heavy moisture and also being classified as 3 types: mixed deciduous forest, dry dipterocarp forest and pine-deciduous forest.

2. Objectives

1. To identify plant community characteristics and soil properties of dry evergreen and dry dipterocarp forests in Sang Khom district, Nong Khai province.
2. To estimate and compare carbon storage in dry evergreen and dry diterocarp forests including soil composition.

3. Methodology

3.1. Plant community characteristics analysis

The community characteristics of dry evergreen and dry dipterocarp forests were considered of its frequency (F), density (D), dominance (D_o), relative frequency (RF), relative density (RD), relative dominance (RD_o) and important value index (IVI) for individual temporary sample plot (6 plots of both forest types).

$$\text{Frequency (F)} = \frac{\text{No. of sample plot with plant species presented}}{\text{Total sample plots of the study area}}$$

$$\text{Density (D)} = \frac{\text{Total number of such plant species}}{\text{Total sample plot area unit of the study}}$$

$$\text{Dominance-cover (D)} = \frac{\text{Plants occupied area}}{\text{Total area under observation}}$$

$$(RF_A) = \frac{\text{Frequency of A species}}{\text{Total frequency of all plant specie}} \times 100$$

$$(RD_A) = \frac{\text{Density of A species}}{\text{Total density of all plant species}} \times 100$$

$$(RD_{OA}) = \frac{\text{Total basal area of all plant species}}{\text{Survey area}} \times 100$$

$$\text{Important Value Index (IVI)} = RF_A + RD_A + RD_{OA}$$

3.2. Biomass estimation

3.2.1 Above ground and below ground biomass estimation

The biomass of each forest type was consisted of above ground (stems, branches, leaves and bamboos) and below ground (roots) was done with allometric equation.

The above-belowground and bamboo biomass of dry evergreen forest was estimated by using allometric equation proposed by Tsutsumi et al. (1983). The bamboo biomass was estimated by using allometric equation proposed by Kutintara et al. (1995). The allometric equation is related to the diameter at breath height (DBH, in cm) and tree height (H, in m).The allometric equation uses were

$$Ws = 0.0509(D^2H)^{0.919}$$

$$Wb = 0.00893(D^2H)^{0.977}$$

$$Wl = 0.0140(D^2H)^{0.669}$$

$$Wr = 0.0313(D^2H)^{0.805}$$

$$W_B = 0.17446\ (D^2)^{1.0437}$$

The above-belowground and bamboo biomass of dry dipterocarp forest was estimated by using allometric equation proposed by Ogino et al. (1967). The bamboo biomass was estimated by using allometric equation proposed by Kutintara et al. (1995). The allometric equation uses were

$$Ws = 189(D^2H)^{0.902}$$

$$Wb = 0.125W_s^{1.204}$$

$$\frac{1}{W_L} = \frac{11.4}{W_s^{0.9}} + 0.172$$

$$Wr = 8.2 \times 10^{-2}(D^2)$$

$$W_B = 0.17446\ (D^2)^{1.0437}$$

Where W_s, W_b, W_l, W_r and W_B are the biomass of stems, branches, leaves, roots and bamboo (*Cephalostachyum pergracile*), respectively. The allometric equation for stem, branch and leave biomass is related to the diameter at breath height (DBH, in m), while the equation for root biomass is related to diameter at breath height (DBH, in cm), and tree height (H, in m).

3.2.2 Groundcover biomass estimation

Biomass of groundcover in dry evergreen and dry dipterocarp forests were estimated by oven drying at 80^{o}C for 3-5 hours or until constant weight before biomass estimation with the following equation:

$$\%\ \text{Moisture} = \frac{(\text{Weight of fresh mass} - \text{Weight of dry mass}) \times 100}{\text{Weight of dry mass}}$$

$$\text{Weight of mass (or biomass)} = \frac{100 \times \text{Weight of fresh mass}}{\%\text{Moisture} + 100}$$

3.2.3 Soil sample analysis

Soil sample were collected by soil core and hoe. Then, soil core sample collection was dried at between 95-105°C for 24 hours or until its constant weight and calculated bulk density (Db) and soil moisture (%Moisture). The hoe sample collection was air dried, grinded and sieved by 2 mm screen for soil texture and other chemical soil properties (Soil reaction (pH), Electric conductivity (EC), Soil organic matter (SOM), Soil organic carbon (%OC), Cation exchange capacity (CEC), Total nitrogen (N), Available phosphorus (avai. P) and Available potassium (avai. K).

3.3. Carbon content estimation

3.3.1 Aboveground and belowground carbon content estimation

The carbon content in aboveground and belowground was calculated by summarizing the total biomass accumulation in each part (above-below ground) of both forest types; then, multiplying with conversion factor at 0.5 for carbon content estimation (Potchanee, 2001). The carbon content was estimated by the equation as follows:

$$B_T = B_S + B_B + B_L + B_R$$

$$T_C = B_T \times 0.5$$

Whereas:
- B_T Total biomass of tree (kg/rai)
- B_S Total biomass of stem (kg/rai)
- B_B Total biomass of branch (kg/rai)
- B_L Total biomass of leave (kg/rai)
- B_R Total biomass of root (kg/rai)
- T_C Total carbon content of tree (kg/rai)

3.3.2 Groundcover carbon content estimation

The groundcover carbon content was estimated by multiplying the total biomass of groundcover with conversion factor at 0.5. The groundcover carbon content was estimated by the equation as follows:

$$G_T = G_{CT} \times 0.5$$

Whereas:
- G_T Total groundcover carbon content (kg/rai)
- G_{CT} Total biomass of groundcover (kg/rai)

3.3.3 Soil carbon content estimation

The soil carbon content was calculated by multiplying the volume percentage of soil organic carbon at top soil horizon (0-30 cm) with soil bulk density value (g/cm^3) and then multiplying with 30 cm depth volume. The carbon content of top soil horizon (kg/rai) was calculated by the equation as follows:

$$S_T = \%V_{SOC} \times D \times V$$

Whereas:

- S_T Total soil carbon content in top soil horizon (kg/rai)
- $\%V_{SOC}$ Volume percentage of soil organic carbon (cm^3)
- D Soil bulk density of top soil horizon (g/cm^3)
- V Soil volume of top soil horizon (cm^3)

3.3.4. Total carbon content estimation

The total carbon content of dry evergreen and dry dipterocarp forests were calculated by summarizing the total carbon content in each part (above-belowground, groundcover and soil) of both forest types. The total carbon content was estimated by the equation as follows:

$$C_T = T_C + G_T + S_T$$

Whereas:

- C_T Total carbon content (kg/rai)
- T_C Total carbon content of tree (kg/rai)
- G_T Total carbon content of groundcover (kg/rai)
- S_T Total carbon content of soil (kg/rai)

3.3.5. The comparison of carbon content in dry evergreen and dry dipterocarp forests

The comparison of this study was described by SPSS for windows by employing descriptive statistical of its frequencies.

4. Results and discussion

This study was focused on plant community characteristic and carbon content in each part of tree components (above-belowground), groundcover and soil in dry evergreen and dry dipterocarp forests at Sang Khom district, Nong Khai province by using 20 × 50 m^2 temporary sample plot for plants species and soil data collection. The results of this study were identified as the following:

4.1 The plant community characteristics

The dry evergreen forest was located at UTM zone 48 (020454E, 2000749N). The result of this study showed that the plant community of dry evergreen forest was rarely a sparse forest which consisted of height and poling tree. The height and poling tree was translucently and dispersedly found throughout the area. The amount of 27 plant species and 16 families were found in the study area. The important plant species in the study area were *dipterocarpus turbinatus* Gaertn. F., *colona flagrocarpa* Craibvar. Siamica Craib, *shorea floribundia* G. Don, *lagerstroenmia duperreana* Pierre and *irvingia malayana* Oliv. ex A. Benn., respectively. The density of dry evergreen forest was 49 tree/rai. The average of DBH (cm) and total height (m) of stand tree was about 23.39 cm and 10.66 m, respectively.

The dry dipterocarp forest was located at UTM zone 48 (0203924E, 20001517N). The result of this study showed that the plant community of dry dipterocarp forest was also rarely a sparse forest which consisted of height and poling tree. The average DBH are likely as the same level. The characteristics of crown cover were irregularly and spreadable clumping; since the size and its form of stand tree were quietly difference. The amount of 24 plant species and 13 families were found in the study area. The important plant species in the study area were *shorea siamensis* Miq., *wendlandia tinctoria* A. DC., *vitex penduncularis* Wall. Ex Schauer, *aporusa villosa* Baaill and *dalbergia dongnaiensis* Pierre, respectively. The density of dry dipterocarp forest was 187 tree/rai. The average of DBH (cm) and total height (m) of stand tree was about 15.94 cm and 10.10 (m), respectively.

4.2 The biomass accumulation

The biomass accumulation of dry evergreen forest (tree components) for individual temporary sample plot was considered in 2 parts; 1) Aboveground biomass (stems, branches and leaves) and 2) Belowground biomass (roots). The result of this study showed that the total average biomass of dry evergreen forest (stem, branch, root and leave) was about 35,047.99, 11,889.28, 5,606.64 and 536.82 kg/rai, respectively. The total average of aboveground biomass was about 53,080.73 Kg/rai.

The biomass accumulation of dry dipterocarp forest (tree components) biomass for individual temporary sample plots were considered in 2 parts; 1) Aboveground biomass (stems, branches and leaves) and 2) Belowground biomass (roots). The result of this study showed that the total average biomass of dry dipterocarp forest (stem, branch, root and leave) was about 12,541.74, 4,511.87, 3,861.73 and 1,956.39 Kg/rai, respectively. The average total biomass was about 22,871.73 Kg/rai.

4.3 The soil properties

The soil texture of top soil horizon in dry evergreen and dry dipterocarp forests were classified as clay loam. The percentage of soil moisture value was high; they were 12.63 and 12.62 (%), respectively. The soil bulk density value was 1.02 and 0.95 (g/cm^3). Otherwise, the soil reaction (pH) were strongly or extremely acid, they were 5.07 and 4.76, respectively. The electric conductivity (EC) value was likely the same value (0.038 and 0.039 us/cm), so it could be concluded that the soil of this area was not affected by salinity. The cation exchange capacity (CEC) value was at low level (5.49 and 2.33 cmol/kg). The average soil organic matter (SOM) values were at low moderate level (1.90 and 1.39 g/kg soil). The average of soil organic carbon (%OC) value was 1.10 and 0.81 (%). The total nitrogen (N) value was 1.06 and 0.91 (%). The average available phosphorus (avai. P) value was 0.23 and 0.20 ppm. The average available potassium (avai. K) value was 138.37 and 97.09 ppm. The statistical analysis found that the soil properties of top soil horizon in both forest types were mostly not statistical significant at the level of 0.05.

4.4 The carbon content in dry evergreen and dry dipterocarp forests

The carbon content in each part of tree in both forest types were calculated by multiplying total biomass accumulation with conversion factor at 0.5. The soil carbon content was also calculated. The result of the study showed that the total carbon content in dry evergreen and dry dipterocarp forests were 31,442.01 and 15,096.17 kg/rai, respectively. The aboveground (stem, branch and leave), belowground (root and soil) and groundcover carbon content in dry evergreen forest was 23,737.04, 7,682.26 and 22.71 kg/rai, respectively. The aboveground (stem, branch and leave), belowground (root and soil) and groundcover carbon content in dry dipterocarp forest was 9,505, 5,578.56 and 12.61 kg/rai, respectively.

5. Conclusion and recommendation

5.1 Conclusion

The plant community characteristic of dry evergreen and dry dipterocarp forests were similarly as a sparse forest. The characteristic (DBH and total height) of stand tree in dry evergreen forest was higher than dry dipterocarp forest while the amount of stand tree was lesser. From the study, it could be concluded that dry evergreen forest was dominantly in crown cover for such a stand tree, but dry dipterocarp forest was dominantly in crown cover the area. The dominant plant species (Basal area) of dry dipterocarp and dry evergreen forests were 0.03 and 0.01 (m^2/m^2), respectively. However, the status of plant community of both forest types were still abundance, since the rigorously conservation of the state authorities.

The soil properties in both forest types were plentifully since the forestry is conserved by state authorities. The soil properties are directly affected to the growing of plants and the increasing of soil organic matter (SOM) or carbon content in the soil. In this study, the SOM of dry evergreen forest was more than dry dipterocarp forest, so it could be concluded that the carbon entering to the soil of dry evergreen forest was more than dry dipterocarp forest. The soil carbon content in dry evergreen and dry dipterocarp forests were 4,878.94 and 3,647.70 kg/rai, respectively.

The increasing of each stand tree biomass accumulation was related to the diameter at breath height (DBH) and total height (m), which the size of each stand tree in the forest type was also difference, so it could be concluded that the increasing amount of biomass accumulation was depended on forest type. From this study, the amount of biomass accumulation in dry evergreen forest was more than dry dipterocarp forest; especially, the aboveground are the most important part of biomass accumulation. Besides, the increasing of carbon content was also depended on forest type since the carbon content was estimated from each part (aboveground, belowground, groundcover and soil) of forest accumulation. The total average carbon content of dry evergreen and dry dipterocarp forests were 31,442.01 and 15,096.17 kg/rai, or the average percentage of 67.56 and 32.44 (%), respectively.

5.2 Recommendation

5.2.1 The dry dipterocarp forest is capable to accumulate carbon at good level, but its potential to accumulate might be less if comparing with the dry evergreen forest. The dry dipterocarp forest is therefore considered as an important source of carbon accumulation, since it could absorb and decrease the greenhouse gas (carbon dioxide) which causes an emission of global warming, so we should be participated to preserve it for solving this crisis.

5.2.2 This study focused on the estimation of carbon storage in plants based on 50% or conversion factor at 0.5 by using allometric equations. It is an approach to apply for a regression equation that directly coverts related measurement values (i.e. stem and height) into the total tree biomass. The analyzed results might be less accuracy. As tree is a significant carbon sink it is suggested for further study that tree sample should be cut down for actual measure and weight in order to get the actual right value.

5.2.3 The rate of carbon dioxide absorption should be studied more on carbon dioxide exchange during the seasons, due to the fact that differences in seasons would certainly effect to the increasing and decreasing of carbon dioxide.

5.2.4 In this study, the carbon accumulation on soil surface was calculated just only for only one month (March) during the dry season, generally it should be studied for every month throughout the year. The frequency of random sampling might be showed the form of growing or increasing of carbon storage in groundcover.

5.2.5 For the carbon estimation of dry evergreen and dry dipterocarp forests, they were estimated only for the aboveground (stem, branch and leave), belowground (root and soil) and ground cover on soil surface; but not at all for the litter fall. It is suggested that the direct and indirect to covert carbon estimation should be done for all factors related to forest ecosystems.

5.2.6 In this study, the top soil horizon (30 cm depth) was selected to estimate the soil carbon content. From the reviewed literature it showed that the soil carbon content could be accumulated more than 1 m depth depending on soil textures and land uses in the study site.

5.2.7 The estimation of carbon storage in this study was used only 6 temporary sample plots for both forest types, so it might be caused incorrectness and less accuracy results. To increase more accuracy of the estimation of carbon accumulation in each forest type, it should have more plots (point of study) and sites for field observations in order to get more field data to analyze for more accuracy of carbon content in the study forest area.

6. Acknowledgement

The accomplishment of this thesis is possible with the assistance and support from many individuals who provided their guidelines and approvals throughout the research. I would like to express my profound gratitude, especially the major advisor, Assoc. Prof. Charlie Navanugraha, Ph.D. (Soil science) and co-advisor, Assoc. Prof. Sura Pattanakiat, Ph.D. (Forestry). Besides, I would to grateful thank to my parents and cousin for their kindness and supporting funds for my research.

7. References

พจนีย์ มอญเจริญ และชูจิตต์ สงวนทรัพยากร. (2544). **วิธีวิเคราะห์ดินทางเคมี**. เอกสารทางวิชาการกองวิเคราะห์ดิน ฉบับที่ 1/2544. กรุงเทพฯ: กรมพัฒนาที่ดิน.

Tsutsumi, T., Yoda. K., Sahunalu, P., Dhanmanonda, P., and Prachaiyo, B. 1983. Forest: felling, burning and regeneration. In K. Kyuma and C. Pairitra (eds.). **Shifting cultivation**. (pp. 13-26). Tokyo.

Kutintara, U., D. Marod, M. Takahashi, and T. Nakashizuka. 1995. Growth and dynamics of bamboo in tropical seasonal forest. In **The International Workshop on "The Change of Tropical Forest Ecosystems by EL Nio and Others"**. Proceedings of Bangkok, Japan Science & Technology Agency & National Research Council of Thailand & Japan International Science & Technology Exchange Center (pp. 125-139).

Ogino, K., D. Ratanawong, T. Tsutsumi and T. shidei. 1967. The primary production of tropical rain forest in Thailand. **The Southeast Asian Studies**. 5(1): 122-154.