# The Estimation of Carbon Storages in Various Growth Stages of Sugarcane in Si Sat Chanalai District, Sukhothai Province, Thailand

การประเมินการสะสมคาร์บอนตามระยะการเจริญเติบโตของอ้อยในพื้นที่ อำเภอศรีสัชนาลัย จังหวัดสุโขทัย

**Wachirawan Watcharapirak, Sura Pattanakiat**

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

**Charlie Navanugraha**

*Faculty of Environment and Resource Studies, Mahasarakharm University, Mahasarakham, 44000*

## Abstract

The objectives of this research was to estimate carbon storage in sugarcane plantation in Si satchanalai district, Sukhothai province in one crop yield. The various growth stages of sugarcane were studied at aboveground and belowground. In addition, carbon storage in soil was studied in upper soil horizon. The carbon storage of the sugarcane plantation was analyzed both in plant and soil. The carbon storage in plant was estimated from biomass and organic carbon percentage in each part of the plant (leaves, stems roots and ground cover). The estimation of carbon content in each part of the plant was done by oven drying at 85°C until it was at constant weight. The percentage of organic carbon in plants was estimated by Titration method. Soil carbon contents were estimated at the upper soil horizon by Walkley and Black method.The results showed that the carbon storage in the tillering stage was 4,214.09 kg/rai, the carbon contents of sugarcane trees was 357.56 kg/rai, ground surface was 40.43 kg/rai and in upper soil horizon was 3,816.10 kg/rai. In the stalk elongation stage the results showed that the carbon storage in one crop yield was 7,648.37 kg/rai, the carbon contents in sugarcane trees was 702.38 kg/rai, ground surface was 50.43 kg/rai and in upper soil horizon was 6,895.55 kg/rai. In the maturity & ripening stage, the results showed that the carbon storage in one crop yield was 8,653.46 kg/rai, the carbon contents in sugarcane trees was 1,737.92 kg/rai, ground surface was 86.30 kg/rai and in upper soil horizon was 7,193.24 kg/rai. However, it was found that the carbon storage content of a sugarcane plantation in one crop yield consists of the carbon storage in sugarcanes and the organic carbon deposit in the soil was increased when the sugarcane trees grew.

**Key words**: carbon storage / sugarcane / carbon content / Biomass / Sukhothai

## บทคัดย่อ

การวิจัยนี้มีวัตถุประสงค์เพื่อศึกษาการประเมินการสะสมคาร์บอนตามระยะการเติบโตของอ้อย ใน อ.ศรีสัชนาลัย จ.สุโขทัย ในหนึ่งรอบการเพาะปลูก โดยศึกษา ทั้งส่วนที่อยู่เหนือพื้นดิน , ส่วนที่อยู่ใต้พื้นดิน และการสะสมคาร์บอนในดิน สำหรับพืชประเมินจากมวลชีวภาพและเปอร์เซนต์อินทรีย์คาร์บอน , สิ่งปกคลุมดินประเมินจากมวลชีวภาพโดยนำ พืชไปอบที่อุณหภูมิ 85 °ซ จนน้ำหนักคงที่ , การประเมินเปอร์เซนต์อินทรีย์คาร์บอนในพืช

โดยใช้วิธีการไตรเตรท สำหรับในดินประเมินการสะสมคาร์บอนที่ดินชั้นบนของหน่วยดินตัวแทนที่ใช้ปลูกอ้อย โดยประเมินอินทรีย์คาร์บอนในดิน จากวิธี Walkley and Black method ผลการศึกษาพบว่าปริมาณการสะสมคาร์บอนในพื้นที่ปลูกอ้อยในหนึ่งรอบการเพาะปลูก ซึ่งประกอบด้วย ในระยะแตกกอพบว่ามีปริมาณการสะสมคาร์บอนทั้งหมด 4,214.09 กก./ไร่ประกอบด้วย ปริมาณการสะสมคาร์บอนในพืช 357.56 กก./ไร่ สิ่งปกคลุมดิน 40.43 กก./ไร่ และในดิน 3,816.10 กก./ไร่ สำหรับในระยะย่างปล้องพบว่ามีปริมาณการสะสมคาร์บอนทั้งหมด 7,648.37 กก./ไร่ ประกอบด้วย ปริมาณการสะสมคาร์บอนในพืช 702.38 กก./ไร่ สิ่งปกคลุมดิน 50.43 กก./ไร่ และในดิน 6,895.55 กก./ไร่ และในระยะแก่และสุกพบว่ามีปริมาณการสะสมคาร์บอนทั้งหมด 8,653.46 กก./ไร่ ประกอบด้วยปริมาณการสะสมคาร์บอนในพืช 1,373.92 กก./ไร่ สิ่งปกคลุมดิน 86.30 กก./ไร่ และในดิน 6,216.43 กก./ไร่ ดังนั้นปริมาณการสะสมคาร์บอนในพื้นที่ปลูกอ้อยเพิ่มขึ้นตามระยะการเจริญเติบโตของพืช

**คำสำคัญ :** การสะสมคาร์บอน / อ้อย / ปริมาณคาร์บอน / มวลชีวภาพ / จังหวัดสุโขทัย

## 1. Introduction

Currently, the global climate is being affected by increasing greenhouse gases in the atmosphere and resulted to the global temperature rising continuously. This phenomenon would eventually cause the critical stage as we all known as “global warming” or “the green house effect” (Diloksumpun, 2007). However, after the industrial revolution period, the greenhouse gases emitted to the atmosphere has been started risen. Carbon dioxide levels increased rapidly and have been created the greenhouse effect. Carbon dioxide was increased approximately from 280 ppmv in 1950 to 358 ppmv in 1994 at the annual increasing rate of 0.6 percentages (IPCC, 1995). Carbon dioxide levels in the atmosphere have increased faster than the rate of absorption naturally and caused the carbon level imbalanced.Carbon is one of the most essential elements of living organisms. It is the main component of living organism tissues (IPCC, 1996). Generally carbon is accumulated mainly in the water, atmosphere, fuels, terrestrial living organisms and soil. (Taweesab, 2001). Each year the carbon circulation in the ecological system called the carbon cycle can absorb carbon dioxide from the atmosphere through photosynthesis and store carbon as biomass in different parts of aboveground, for example, stalks, branches and leaves. For belowground, it is stored in roots and soil itself. At the same time, carbon dioxide is released to the atmosphere through the respiration process and decomposed by microorganisms.

This research focused on the study of carbon storage in sugarcane plantation areas as a way for carbon absorption in the form of carbon dioxide within the agricultural land. This area could accumulate at a superior rate by applying suitable technology and well management such as selecting of plants that use more carbon dioxide for their photosynthesis process than others, and having products with high productivity and high lignin or crude fiber contents. Besides, plants should have long tab-root and well embedded in soil, and then it could store organic matters deep in the soil as well as having high biomass. Sugarcane should be a suitable alternative plant because of its naturally superb growth

characteristic, high yields and ability to endure unsuitable surroundings. Sugarcane is in the same family as grass with a group root system that penetrates deeply into the soil. (Jintrawet, 2004)

## 2. Methodology

### 2.1 The selection of sample plot

The data of Office of the Cane and Sugar Board about sugarcane plantation areas at district level was analyzed as database and then overlay with soil series data cover the area of all sugarcane plantation to prepare a map showing the area of sugarcane plantations within Si satchanalai district. Then sample sites selection of sugarcane plantation area base on all soil series was selected as the study area.

### 2.2 Sample collection

#### 2.2.1 Plant sample collection

Plant samples were collected for 3 times at the different stages of sugarcane (tillering stage, stalk elongation stage and maturity & ripening stage). Each sample plots was at the size of 40 x 40 $m^2$. The samples were collected from 5 sub plots and 3 replications of each sample plots. The total weight of each sample plots, which consisted of stems, leaves and roots, were collected and converted into total biomass of each sample plots.

#### 2.2.2 Ground surface sample

The samples of ground surface in sugarcane plantations were collected from 3 sub plots and 3 replications of each sample plots. Each sample plots was at the size of 1x 1 $m^2$.

#### 2.2.3 Soil sample

The soil sample plots were at the size of 40 x 40 $m^2$. Soil samples were collected at top soil horizon (0-30 cm.) from the surface for physical and chemical analysis. The soil sample plots were collected for 3 sub sample plots and 3 replications in each sample plots by simple random sampling method and composite sampling method. Then collected soil sample was packed in the plastic bag with approximately 1 kg.

### 2.3 Sample analysis

#### 2.3.1 Percentage of carbon content analysis

Plant samples both aboveground (stems and leaves) and belowground (roots) were analyzed to estimate percentage of carbon content in each part of plant by modified of titration method of Walk & Black method. (Wild. 1993)

### 2.3.2 Plant biomass analysis

Plant samples (stems, leaves and roots) of sugarcane were dried in the oven at 85 °C for 24 hours or until the weight is constant then weighted and estimated of biomass in term of gram/$m^2$.

### 2.3.3 Ground surface sample analysis

The sample of plant on soil surface within sugarcane plantations were analyzed for biomass analysis. They were dried at 85 °C for 24 hours or until the weight was constant, then weighted and estimated for biomass in term of gram/$m^2$ by the following equation:

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

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

### 2.3.4 Soil Analysis

#### 2.3.4.1 Soil Organic Carbon Analysis

Soil Carbon Content Analysis was analyzed from Soil Organic Carbon (SOM) by Walkley and Black method**.**

#### 2.3.4.2 Soil Properties Analysis

1. Physical property analysis was soil texture and Collected soil core for soil bulk density analysis and soil moisture analysis.
2. Chemical properties analysis were Soil Reaction (pH), Electrical Conductivity (EC), Organic Carbon (OC), Cation Exchange Capacity (CEC), Total Nitrogen (TKN), Available Phosphorus (Avai-P), Available Potassium (Avai-K)

### 2.4 Estimation of carbon content

### 2.4.1 Carbon content in plants

The estimation of total carbon content in plant was derived from summation of carbon content in each part of sugarcane trees (stems, leaves and roots). Carbon content of each parts were calculated by multiplication of biomass in each part of plants (kg/rai) and percentage of carbon content in each part of plants (%) as the following equations:

$$C_T = C_S + C_L + C_R$$

$$C_S = \% \text{ Carbon of Stem x } M_S$$

$$C_L = \% \text{ Carbon of leave x } M_L$$

$$C_R = \% \text{ Carbon of root x } M_R$$

Whereas; $C_T$ Total carbon of tree (kg/rai)
$C_S$ Total carbon of stems (kg/rai)
$C_L$ Total carbon of leaves (kg/rai)
$C_R$ Total carbon of roots (kg/rai)
$M_S$ Biomass of stems (kg/rai)
$M_L$ Biomass of leaves (kg/rai)
$M_R$ Biomass of roots (kg/rai)

**2.4.2 Carbon content in ground surface**

The estimation of carbon content in ground surface was analyzed from land cover and dead plants. The carbon content was calculated from the multiplication of total biomass of ground surface with 0.5 as following equations:

$$C_{GS} = 0.5M_{GS}$$

Whereas; $C_{GS}$ Total carbon of ground surface (kg/rai)
$M_{GS}$ Total biomass of ground surface (kg/rai)

**2.4.3 Carbon content in soil**

The estimation of carbon content in upper soil was analyzed from soil sample collected at soil depth 0-30 cm. The carbon content was calculated by multiplication of percentage of organic carbon (% OC) with soil bulk density of top soil (kg/$m^3$) and soil volume of top soil ($m^3$/rai) as following equations:

$$C_{Soil} = \%OC \text{ of top soil x } D_b \text{ x } V$$

Where as; $C_{Soil}$ Total soil carbon of top soil (kg/rai)
$D_b$ Soil bulk density of top soil (kg/$m^3$)
V Soil volume of top soil ($m^3$/rai)

**2.4.4 Total carbon content in the sugarcane plantations**

The total carbon content in the sugarcane plantations were calculated from summation of total carbon of tree (kg/rai), total carbon of ground surface (kg/rai) and total soil carbon of topsoil (kg/rai) as following equations:

$$C_{Total} = C_T + C_{GS} + C_{Soil}$$

Whereas; $C_{Total}$ Total carbon of sugarcane plantations (kg/rai)

$C_T$ Total carbon of tree (kg/rai)

$C_{GS}$ Total carbon of ground surface (kg/rai)

$C_{Soil}$ Total soil carbon of topsoil (kg/rai)

## 3. Results and Discussion

### 3.1 Biomass of Plant

Sugarcane biomass was studied in 3 parts : aboveground biomass (stems and leaves), ground surface biomass (ground cover and litter) and belowground biomass (roots). Data were collected at 3 different growth stages. The results as following Table 1

Table 1 Average biomass of sugarcane (kg/rai)

| | Average biomass of sugarcane (Kg/Rai) | | | |
|---|---|---|---|---|
| **Growth Stages** | **Stem** | **Leaves** | **Root** | **Total** |
| Tillering | 664.63 | 122.20 | 86.24 | 873.07 |
| Stalk Elongation | 1,660.60 | 392.43 | 291.11 | 2,344.14 |
| Maturity & Ripening | 2,121.14 | 572.30 | 583.73 | 3,277.17 |

### 3.2 Biomass of Ground Surface

Biomass of ground surface at sugarcane plantations in all 3 stages of collections are presented in Table 2 as follows:

Table 2 Average biomass of Ground Surface (kg/rai)

| Growth Stages | Average biomass of Ground Surface Stages (Kg/Rai) |
|---|---|
| Tillering | 80.87 |
| Stalk Elongation | 100.87 |
| Maturity & Ripening | 172.60 |

### 3.3 Soil Properties of sugarcane Plantation areas

Soil samples in the studied area were collected from 3 sub-plots in the main plots of 40 x 40 $m^2$ by random sampling method to collect top soil at the depth of 0-30 cm. Results of the analysis indicated that soil in the studied area was classified based on the following soil taxonomy.

Table 3 Soil Properties of sugarcane Plantation in the areas

| Soil Series Groups | Growth Stages | Soil Properties | | | | | |
|---|---|---|---|---|---|---|---|
| | | Moisture | Db | pH | EC | %OC | CEC |
| | | (%) | ($g/cm^3$) | (dS/m) | (%) | (cmol/kg) | (%) |
| Kamphaeng Saen (Silty Clay) | Tillering | 3.80 | 1.43 | 6.52 | 0.08 | 0.96 | 12.93 |
| | Stalk elongation | 8.65 | 1.37 | 5.76 | 0.14 | 1.38 | 19.50 |
| | Maturity and ripening | 7.77 | 1.32 | 6.33 | 0.11 | 1.28 | 17.90 |
| Si Satchanalai (Clay Loam) | Tillering | 2.94 | 1.59 | 6.03 | 0.04 | 1.16 | 16.93 |
| | Stalk elongation | 12.29 | 1.46 | 6.15 | 0.06 | 1.39 | 13.90 |
| | Maturity and ripening | 9.12 | 1.48 | 5.51 | 0.06 | 1.35 | 14.50 |
| San Pa Tong, mottled variant (Clay Loam) | Tillering | 6.06 | 1.24 | 5.84 | 0.04 | 0.74 | 6.20 |
| | Stalk elongation | 14.98 | 1.19 | 5.47 | 0.08 | 1.01 | 8.90 |
| | Maturity and ripening | 11.74 | 1.10 | 6.22 | 0.06 | 0.51 | 14.30 |
| Phon Pisai (Clay Loam) | Tillering | 3.17 | 1.56 | 6.33 | 0.04 | 0.96 | 13.00 |
| | Stalk elongation | 12.47 | 1.41 | 6.06 | 0.07 | 1.17 | 10.90 |
| | Maturity and ripening | 11.98 | 1.29 | 6.34 | 0.07 | 1.08 | 17.00 |
| Mae Sai (Sandy Clay Loam) | Tillering | 5.31 | 1.36 | 5.92 | 0.06 | 0.51 | 6.67 |
| | Stalk elongation | 15.74 | 1.19 | 5.08 | 0.11 | 0.81 | 13.80 |
| | Maturity and ripening | 13.91 | 1.02 | 6.09 | 0.06 | 0.60 | 12.30 |
| Chai Nat (Silty Clay Loam) | Tillering | 2.08 | 1.41 | 6.19 | 0.04 | 0.95 | 8.80 |
| | Stalk elongation | 4.99 | 1.31 | 5.69 | 0.08 | 1.33 | 13.80 |
| | Maturity and ripening | 12.21 | 1.28 | 6.31 | 0.07 | 1.23 | 21.73 |
| Muak Lek (Sandy Clay Loam) | Tillering | 1.23 | 1.31 | 6.12 | 0.01 | 0.88 | 2.93 |
| | Stalk elongation | 10.54 | 1.30 | 5.98 | 0.08 | 1.20 | 6.50 |
| | Maturity and ripening | 9.40 | 1.24 | 6.10 | 0.05 | 0.64 | 8.80 |
| Lad Ya/Tha Yan association (Clay Loam) | Tillering | 1.83 | 1.26 | 6.12 | 0.03 | 0.28 | 2.73 |
| | Stalk elongation | 16.11 | 1.17 | 6.02 | 0.09 | 0.57 | 7.20 |
| | Maturity and ripening | 11.06 | 1.07 | 6.11 | 0.08 | 0.49 | 13.70 |

**3.4 Carbon Contents in Plants and Soils**

Carbon contents in plant samples were analyzed in 2 parts: aboveground biomass (stems leaves and ground surface), and belowground biomass (roots).

Carbon contents in soil samples were analyzed from topsoil organic at the depth of 0-30 cm. Results of carbon content in plant and soil in sugarcane plantations are presented in Table 4 as follows

Table 4 Average Carbon Content in plant Ground Surface and Soil (kg/rai)

| | Carbon Content (kg/rai) | | | |
|---|---|---|---|---|
| Growth Stages | Plant Carbon | Ground Surface | Soil | Total |
| Tillering | 357.56 | 40.43 | 3,816.10 | 4,214.09 |
| Stalk Elongation | 702.38 | 50.43 | 6,895.55 | 7,648.37 |
| Maturity & Ripening | 1,373.92 | 86.30 | 6,216.43 | 7,676.65 |

### 3.5 Total Carbon Storage in the sugarcane Plantations at Srisatchanalai district, Sukhothai province

Total carbon storage in sugarcane Plantations were considered from carbon content in plants and soils. Results of total carbon storage in sugarcane Plantations in one crop yield are presented in Table 5 as follows:

Table 5 Total Carbon Storage in sugarcane Plantations from one crop yield

| | Carbon Content (tC) | | | |
|---|---|---|---|---|
| Growth Stages | Carbon of tree | Ground Surface | Soil | Total |
| Tillering | 10,086.75 | 1,140.62 | 107,652.23 | 18,879.61 |
| Stalk Elongation | 19,814.27 | 1,422.72 | 194,523.58 | 215,760.57 |
| Maturity & Ripening | 38,758.34 | 2,434.52 | 175,365.35 | 216,558.21 |

## 4. Conclusions

### 4.1 Carbon Storage in sugarcane Plantation

In summary, carbon storage in the plant and soil increased in accordance with growth stages of plant by storing carbon in the soil, plant and ground cover, respectively. For carbon storage in each part of the plant, it was found that carbon mostly stored in stem for all 3 stages of growth were 273.15, 413.56 and 823.77 kg/rai, respectively as compared with other parts of sugarcane.

For the analysis of each soil series, it was revealed that carbon storage increased in accordance with the growth stages of plant. However, carbon accumulation rates were different according to the properties of soil series and soil management (fertilizer application and weeds control). It was also found that in the area less attending, the amount of carbon in soil seemed to be less than the area with well management.

### 4.2 Relationship between Biomass and Carbon Content

This study shows the correlations between biomass stored in different parts of plant and volume of carbon store in different parts of plants in each growth stage that is when the plant absorbed $CO_2$ in the atmosphere to be used in the photosynthesis for plant's growth, plant biomass would be increased which in turn increasing carbon volume also since biomass content comprised of 50 percent of carbon. It has been founded through this study that storing biomass happened most at the stem, leaves and root, respectively. Because sugarcane is the annual crop with its stem capable of reaching the height of 2-3 meters, biomass and carbon can be more stored in the stem than other parts of sugarcane.

### 4.3 Relationship between Soil Properties and Carbon Content

From this study the results showed that at the tillering stage to stalk elongation stage, carbon accumulation rate in soil was increased while at the stalk elongation stage to maturity and ripening stage the accumulation rate in soil was decreased. For sugarcane plantation studied areas, the Sisatchanalai and Kamphang San soil series were to be more absorbed carbon than others since such soil series were more suitable for growing sugarcane and these soil series distributed throughout the Study areas. The sugarcane plantation in soil series of San Pa Tong, Phon Pisai, Mae Sai, Chai Nat and Muak Lek series, the carbon accumulation rates were nearly at the same rates. Because such soil series were well suitable for growing sugarcane. Area planted sugarcane with soil series of Lad Ya/Tha Yang, carbon accumulation rates was the lowest since this soil series was classified as low suitable for growing sugarcane.

Correlations between carbon volume in soil and percentage of organic carbon in soil showed that Results of the study indicated that when organic matters in the studied area contained high value, percentages of organic matters was also increased higher along with the growth stage, but when it was at the maturity and ripening stage, carbon and organic carbon percentages in soil would decrease. It could be explained that at this stage there were high volume of crop residual and ground cover resulted to high accumulated decomposition process by the microorganisms where as carbon dioxide created by this process was released into the atmosphere In addition, the results of all soil series analysis found that more organic matter resulted directly to soil bulk density as microorganisms in soil decomposed and turned soil into loose soil. Moreover, activity of microorganisms also resulted in increasing of pH and the Cation Exchange Capacity, CEC values affected to nitrogen values increased.

In summary, physical and chemical properties of soil were positively correlated with carbon storage in the study area. Results of the study showed that the different values in carbon storage according to seasons changing, soil structures and properties, soil nutrients and plantation management (fertilizer

application and weeds control) etc. Furthermore, carbon storage in soil was also correlated with soil structure of each soil series due to its chemical and physical properties significantly.

## 5. Acknowledgement

This research supported by the MAG-Climate Change, The Thailand Research Fund (TRF), 2007 and the opinion of report belong to the scholarship recipient. The Thailand Research Fund is not necessary agreement with this research all time.

## 6. References

Diloksumpun, S. 2007. The Carbon Storage in Forest with Global Warming. **Journal of Soil and Water Conservation**. Vol. 22(3): 15-21.

IPCC. 1995. **Technical Summary**. Intergovernmental Panel on Climate Change. WOM. Geneva. Switzerland IPCC. Revised 2007 Guidelines for National Greenhouse Gas Inventory, Vol. 5. OECD, 2007.

IPCC. 1996. **Greenhouse Gas Inventory Reference Manual**. Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge.

Jintrawet, A. 2004. **Carbon Storage**. Department of Soil Science and Conservation at Chiang Mai University. Chiang Mai.

Taweesab, P. 2001 **Carbon in Soil of Thailand**. Soil Analysis Division, Land Development Department. Bangkok.

Wild, A. 1993. **Soil and the Environment**. An Introduction. Cambridge University Press, Cambridge.