CHAPTER 1
INTRODUCTION

1.1 Background

Global warming is an important environmental problem caused by the enhanced greenhouse effect that results from increased emissions of greenhouse gases (GHG) such as carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), chlorofluoro carbons (CFC_s), and sulfur hexafluoride (SF_6) into the atmosphere. Among these, CO_2 is the main greenhouse gas affecting to the global warming.

There has been a rapid increase in the atmospheric concentration CO_2 and other greenhouse gases since the industrial revolution. For example, the atmosphere concentration of CO_2 has increased from 280 ppmv in 1750 to 371 ppmv in 2001, increasing at the rate of 1.5 ppmv/year or 3.3 Pg C/year (1 Pg = petagram = 10^{15} g, IPCC, 2001b) and is currently increasing to 381 ppmv in 2005 (Kirstin and Thomas, 2007). This rapid increase of atmospheric CO_2 has been expedited by changes in land use and combustion of fossil fuels. This means that natural exchanges of carbon (C) between the atmosphere, the oceans and terrestrial ecosystems are currently being modified by human activities.

The concern over rising levels of CO_2 and other GHG in the atmosphere was addressed at the United Nations Conference on Environment and Development in 1992 in Rio de Janeiro, Brazil. At this meeting the United Nations Framework Convention on Climate Change (UNFCCC) was adopted. The Convention sets an ultimate objective of stabilizing greenhouse gas emissions at a level that would prevent dangerous anthropogenic interference with the climate system. Subsequently, at the Third Conference of the Parties held in Kyoto, a Protocol to the UNFCCC was adopted in 1997 (known as Kyoto protocol or KP). To achieve the GHG emission reduction goal, the KP specifically assigns time frames, which are legally binded and the responsibility for the UNFCCC member countries to achieve their greenhouse gas emission reduction are identified (Dunn, 2002).

Thailand is one of the participant countries that have ratified the Kyoto protocol. Various alternatives are available for Thailand to achieve greenhouse gas emission reduction. One promising option is using renewable energy from farm waste (biogas), residues from agriculture (biomass), wind energy and bioenergy. This strategy is alternative to fossil fuel use and thus could help lead to the stabilizing atmospheric CO_2 concentration. This is based on the assumption that CO_2 emissions from bioenergy consumption can be re-absorbed when plants are re-grown and thus, no net emission of CO_2 to the atmosphere.

How much greenhouse gas emissions could be mitigated by such renewable energy system in Thailand is poorly known. This is one example of mitigation potential questions which are relevant to policy implications. Scientific basis needs to be established in order to answer such questions. This study was focused on carbon flow and budgets in sugarcane production and utilization, specifically referring to the balance between sources and sinks of carbon. The results from this study may help provide data and information for the management of bioenergy production and utilization, and carbon emission from sugarcane plantation in Thailand.

1.2 Rationales

Concerns with global warming have led to a surge of interest in evaluating the effect of management practices on carbon sequestration in the agro-industry. This interest is justified, for example, because agricultural soils play a key role in the global carbon budget, containing 3.5 % of the carbon reserves of the earth, compared with 1.7 % in the atmosphere, 8.9 % in fossil fuels, 1.0 % in biota and 84.9 % in the oceans (Lal, 1995). In addition, some crops such as cassava and sugarcane can be used as an energy source to substitute for fossil fuel. Utilization of such materials, therefore, could reduce fossil fuel consumption and result in reduced emission of CO_2 to the atmosphere. An ecosystem could also contribute to CO_2 reduction by carbon sequestration in soil system. There is general agreement that many agriculture ecosystems have the potential to support enhanced carbon sequestration in the soil (Watson *et al.*, 2000).

Sugarcane is one of the important economic crops in Thailand and by-product or waste from sugarcane production and the utilization process could be used to support bioenergy production. A sugarcane bioenergy system still contributes to the atmospheric CO_2 in various ways and can be summarized as follows. First, it increases atmospheric CO_2 due to fossil fuel and energy inputs in the agriculture activities and industrial production of sugar. Secondly, it could reduce CO_2 release to the atmosphere by substituting bioethanol source such as: molasses for producing ethanol that can be used to replace fuel oil import and also by substituting sugarcane bagasse for surplus electricity in sugar production and other industrial production. Finally, carbon can be sequestered in the soil by incorporation of plant residue; organic fertilizer (i.e. filter cake) incorporation into soil can help preserve some portion of carbon in the soil.

As mentioned above, agricultural management provides one of the potential alternatives to mitigate greenhouse gas emissions. At the global scale, agriculture contributes to around 14 % of total anthropogenic greenhouse gas emissions (IPCC, 2007a). It is estimated that agriculture sector could potentially reduce greenhouse gas emissions by approximately 5.5-6.0 × 10^3 Mt CO_2-equivalent/yr by 2030 (IPCC, 2007). Regionally, the mitigation potential differs according to agricultural practices, and thus different measures exist which provide the mitigation opportunities.

Thailand is agricultural-based country and agriculture contributes about 21% of national total in 2000 (51 Mt CO_2-eq, JGSEE 2009). Emissions are subject to cultivation practices and processes throughout the agricultural production practices and the product utilization. Regarding to this context, our understanding of carbon processes and emission mitigation potentials in sugarcane agriculture system and sugar mill process in Thailand is limited. To achieve the goal of finding appropriate options to reduce GHG emission in sugarcane bioenergy system, thorough understanding of carbon flow in various components need to be established. Consequently, in this study, CO_2-C flux between the soil and the atmosphere and carbon mass balance in sugarcane production were emphasized and analyzed. In this study, sugarcane system is separated into two parts. The first part is in the sugarcane plantation which is managed by the farmer. The second part occurs in the sugar mill factory that is managed by industries. Thus, the study on sugarcane plantation; CO_2-C flux and CH_4-C flux, decomposition of sugarcane biomass and sugarcane farm management and activities for carbon flow in sugarcane agriculture system and study on sugar mill process base bioenergy utilization were performed in this study.

1.3 Objectives

The main objectives of this project study are:

1.3.1 To determine the flows and budgets of carbon in a sugarcane crop production system.

1.3.2 To evaluate the greenhouse gas emission reduction potential by using sugarcane by-products for bioenergy production.

1.4 Scope of study

The methodological framework of this study is based on the full carbon accounting concept. The study area is limited to Eastern Thailand where sugarcane is one of the main crops. This study is divided into two main parts. The first part determines CO_2 fluxes by using the chamber method. This part consists of two experiments: field and laboratory studied. In the field, chamber method was used to determine daily CO_2 flux in one sugarcane cropping (1 year). Soil samples were taken to analyze the amount of carbon storage in the soil. In the laboratory, an analysis of soil physical and chemical properties was performed. Determination of decomposition rate of sugarcane components during sugarcane growing season was also performed by using the litterbag technique. In addition, this part were characterized the carbon flow in sugarcane cultivation by using the data from our filed experiments and the questionnaire.

In the second part, determination of carbon flow in a sugar factory and bioenergy systems was carried out. Then, full carbon cycle assessment concepts were applied to determine potential carbon emission reductions from a sugarcane plantation and bioenergy systems.

In addition a geographic information system (GIS) and remote sensing technique were applied for soil carbon mapping of a sugarcane production system. The purpose from this part was to estimate soil carbon map in the study area. This was based on soil types, soil depth, soil bulk density and sugarcane area.