CHAPTER 1
INTRODUCTION

1.1 Rationale/Problem Statement

Global warming can be referred to as an increase in average global surface temperature and is an important indicator of global climate change. Scientific evidence, global shows that warming is caused by enhanced greenhouse gas concentrations in the atmosphere, such as carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), sulfur hexafluoride (SF_6) and Chlorofluorocarbons (CFC_s). For example, the global average atmospheric CO_2 concentration has increased from about 285 ppmv (parts per million on a volume basis) in 1850 to 379 ppmv in 2005, and the average global temperature increasing at the rate of $0.74 \pm 0.18°C\ yr^{-1}$ (IPCC, 2007). This can have certain adverse effects on global environments such as changes in precipitation patterns, sea levels rise, and increased frequency and intensity of extreme weather events.

The increases in atmospheric CO_2 concentrations and other greenhouse gases are largely attributed to human activities, mostly fossil fuel combustion, conversion of forest to other land uses, and the expansion of agricultural lands (Houghton, *et al.*, 2001). Natural and planted forests are the most important sinks of atmospheric CO_2. Annually, carbon used by land plants during the photosynthesis process takes up approximately 120 PgC yr^{-1} (1 PgC = 10^{15} g carbon) from the atmosphere. About 119 PgC yr^{-1} of carbon is released back to the atmosphere through ecosystem respiration. The net flux of the terrestrial ecosystem results in a carbon sink of about 1.4 PgC yr^{-1} (Luo and Zhou, 2006).

Forest ecosystems are also important and influence the carbon cycle in terrestrial ecosystems because large amounts of carbon are stored in biomass and soil. Houghton, (2003) reported that almost all of the global carbon flux occurs in the tropical regions (2.2 PgC yr^{-1} in the 1990s). Outside the tropics, the net flux is a small sink (0.2 PgC yr^{-1} during the 1990s). The tropical forests also contain higher carbon storage than other regions, approximately 60 percent of total carbon in biomass stock on the Earth (Dixon, *et al.*, 1994) and the annual net primary production is about 32% of global terrestrial photosynthesis (Field, *et al., 1998*). Diloksumpun, *et al.* (2008) studied the net primary production (NPP) in the Sakaerat Dry Evergreen (DEF) and the Maeklong Mixed Deciduous Forests (MDF) in Thailand. They found that NPP in DEF (15.3 tC $ha^{-1}\ yr^{-1}$) was higher than MDF (6.2 tC $ha^{-1}\ yr^{-1}$). However, the litter biomass product in MDF was higher than DEF by about 7% because the plant in MDF is to shed leaves. The results of investigation suggest that tropical forests act as both carbon sources and sinks, depending on the balance between photosynthesis and respiration, and their temporal responses to environmental variables.

Generally, carbon enters terrestrial ecosystems through a single process, photosynthesis, but is returned through a variety of processes, collectively referred to as respiration. Functionally, respiration is divided into CO_2 released by living plant leaves, stems and roots (autotrophic respiration), and CO_2 released during the decomposition of nonliving organic matter (heterotrophic respiration). Soil respiration (R_s) is an important pathway of carbon dioxide (CO_2) exchanges between the forest and the atmosphere, accounting for 40-90% of total ecosystem respiration (Schesinger, 2000). It is a combination of autotrophic root respiration (R_b) and heterotrophic microbial respiration (R_m) from the rhizosphere and bulk soil (Fang and Moncrieff, 1999) which can be expressed as Eq. 1.1:

$$R_s = R_b + R_m \qquad \textbf{(Eq. 1.1)}$$

It is estimated that the magnitude of soil respiration is about 10 times that of fossil fuel burning and cement manufacturing combined (7.8 Pg C y^{-1} in 2005) (Forster, *et al.*, 2007). This implies that about 10% of atmospheric CO_2 is cycled through the soil annually (Reichetein and Beer, 2008). Thus, even a small change in soil respiration may greatly influence the atmospheric carbon budget (Veenendaal, *et al.*, 2004; Kane, *et al.*, 2005). In recent years, soil respiration has been studied in various forest ecosystems and different regions. However, our knowledge on the soil respiration in tropical regions is still limited (Bond-Lamberty and Thomson, 2010), despite the fact that this region plays a key role in the global C cycle (Phillips, *et al.*, 1998; Malhi and Grace, 2000; Grace, *et al.*, 2001; Luyssaert, *et al.*, 2008).

Chamber, *et al.* (2004) studied the partitioning of ecosystem respiration near the city of Manaus, Brazil in the Central Amazon. They reported that out of the total respiration of 108.23 $tCO_2ha^{-1}yr^{-1}$, foliage, wood, and soil respiration contribute 36.08, 15.26, and 44.40 tCO_2 $ha^{-1}yr^{-1}$, respectively. This is equal to 33.34%, 14.10%, and 41.03% of total respiration, respectively. In other studies, the contributions of root and microbial respiration in the monsoon evergreen broad-leaf forest (BF), the pine forest (PF), and the pine, broad-leaf forest (MF) in China and dry dipterocarp forest (DDF) in Thailand are usually within the ranges of about 20 – 40% for root and 60 – 80% for microbial respiration, respectively (Yi, *et al.*, 2007 and Hanpattanakit, 2008).

In many ecosystems, soil temperature and soil moisture are the main controlling factors influencing the temporal dynamics of soil respiration (Borken, *et al.*, 2006). In many cases, differences in soil temperature and water content may explain most of the temporal variation in soil respiration (Davidson *et al.*, 1998; Qi and Xu, 2001; Reichstein *et al.*, 2002; Rey, *et al.*, 2002). In tropical Amazonian forests, Davidson, *et al.* (2000) reported that the soil respiration rate was highest during the rainy period and the lowest during the dry period. Hashimoto, *et al.* (2004) and Hanpattanakit, (2008) reported that soil respiration rates increased following increases of soil moisture in a tropical monsoon forest in Thailand. Tang, *et al.* (2006) studied effects of soil temperature and moisture on soil respiration in a broadleaf forest, a mixed forest, and a pine forest at Southern of China. The results showed that soil respiration was positively correlated with both soil temperature and soil moisture. However, the relationship between soil respiration and soil temperature in some locations such as the tropical forests in Brazil and China were found to be negative (Chamber, *et al.*, 2004; Shi, *et al.*, 2011). The soil temperature and moisture values of each experiment were not very different but the soil respiration rate of both experiments differed greatly. Therefore, there are some things that we could not explain when analyzing the relationships between respiration and temperature. Understanding how soil respiration responds to such factors is fundamental to accurate prediction of climate impacts on carbon cycling.

Increased global temperature and moisture may stimulate root activity and microbial-mediated organic carbon decomposition, and thus, CO_2 emissions from soil. Yi, *et al.* (2007) reported that high R_s was related to root biomass and soil microbial biomass in China. In addition, the higher root biomass caused higher root respiration and soil respiration during the rainy season. This suggests that soil microorganisms contributed to soil respiration and that this was stimulated by increased moisture. Adachi, *et al.* (2006) also found that soil respiration increased with fine root biomass and microbial biomass in the tropical forests. These results suggested that the temporal change in soil respiration was affected not only by the seasonal change of soil temperature and soil water content but also by the biotic factors. However there is little data on partitions of microbe and root respiration related with biotic factors, especially root biomass and microbial biomass in tropical forest. Thus, the understanding of soil respiration and their relationship with biotic factors could better explain the variation of soil respiration, and thus, improve the prediction of climate impacts on carbon cycling.

This study is attempting to improve our understanding in variations and the controlling factors of soil respiration in tropical forests. Dry dipterocarp forest is one of the important ecosystems in the tropics, especially in Thailand. It makes up about 21 percent of total natural forest area or 3,363,199 ha in 2005 (Royal Forest Department, 2007). So far no study on the partitioning of soil CO_2 efflux has been performed in the dry dipterocarp forests. It is expected that the results from this study on carbon flux from soil respiration components and their responses to environmental variables will be useful for improving our understanding carbon cycle processes in tropical ecosystem.

1.2 Objectives

1. To quantify CO_2 emissions through soil respiration and its components in a dry dipterocarp forest.
2. To understand the temporal variations of soil respiration and the controlling factors in a dry dipterocarp forest.

1.3 Scope of study

This study on soil respiration was carried out at King Mongkut's University of Technology Thonburi, Rachaburi Campus in Ratchaburi Province. There, the dipterocarp forest has an area of about 187.2 ha. This study will quantify and differentiate CO_2 emission between root and microbial respiration. The CO_2 fluxes will be determined by using the automated-chamber method. This part consists of two experiments; field and laboratory. In the field, the chamber method will be used to determine hourly CO_2 flux in a dry dipterocarp forest (4 years between February, 2008 – December, 2011). Along with a soil profile the CO_2 concentration was measured. Factors influencing soil respiration such as plant and microbial biomass, root biomass, and other abiotic factor (soil property, precipitation, soil temperature and moisture) were also investigated. In the laboratory, soil microbial biomass and soil properties were determined.