Tentative Proposal

Title : **Effect of Temperature Changes and Drought on Soil Respiration and Fine Root Dynamics in Secondary Dry Dipterocarp Forest at Ratchaburi Province, Thailand**

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1. Background and Rationale

The impacts of climate change are increasing in severity. The main cause of climate change is an increase in greenhouse gas emissions by natural and man-made sources, such as burning fossil fuels, deforestation, and plant and soil respiration. Carbon dioxide (CO_2) remains the major anthropogenic greenhouse gases (GHG) accounting for 76% (38±3.8 Gt CO_2eq $year^{-1}$) of total anthropogenic GHG emissions in 2010 (IPCC, 2014). The average atmospheric CO_2 concentration increased from 285 ppmv in 1850 to 397 ppmv in 2005 and it is increasing rate of 1.5 ppmv yr^{-1} (Hanpattanakit, 2014). Scientific evidence shows that global temperature is rising, along with changes occurring in precipitation and sea level. During 1960 to 2000, the average global temperature increased by 0.6˚C (Lueangarphapong, 2010). The maximum temperature, average temperature, and minimum temperature in the past of Thailand (1955 to 2009) were increased by 0.57, 0.81, and 0.89˚C, resulting in Thailand getting hotter nationwide. The rate of Thailand's average temperature rose per decade (0.174˚C per decade) was higher than the global rate (0.126˚C per decade) (Limsakul and Limjirakan, 2011). Furthermore, average annual relative humidity and temperature were increasing, while the evaporation rate fell. Thailand's average annual precipitation over the past 55 years showed slight decreases, although the results were not statistical significance at the 95% confidence level. Effects of climate variability such as drought and flood conditions, the weather being extremely hot or cold, seasonal shift and change have impacted to human and environment. For example, increasing global surface temperature is the most symbolic parameter of climate change (IPCC, 2014) and ambient high temperature, especially prolonged extreme high temperature as heatwave (Ma and et al, 2015), has caused substantial health burden globally (Gasparrini and et al, 2015). According to study the effect of heatwave was associated with greater cumulative effects on cause-specific mortality in Thailand (Huanga et al., 2018). These regions vulnerable to heatwaves and proportion of elderly population was the major driver behind the spatial heterogeneity of heatwave vulnerability (Huanga et al., 2018).

In addition, climate change has an impact on carbon cycling in forest ecosystems. The carbon cycle in forest ecosystems is one of the most important elements influencing carbon dioxide in the atmosphere. Forests have important process for sink and emission of carbon dioxide through photosynthesis. Plants serve as carbon sinks by accumulating carbon through photosynthesis process. Some organic carbon compounds are used to develop biomass, while others are broken down during respiration to supply plants with energy. During this process, carbon dioxide is released into the atmosphere from ecosystem respiration, deforestation, and animal respiration. Soil respiration (R_s) is the second largest carbon emission in forest ecosystems, contributing 50 to 90% of the total ecosystem

respiration (Chambers et al., 2004; Hanpattanakit et al., 2015; Janssens et al., 2001). It is a key process in the global carbon cycle that supplies nutrients to forest ecosystems (Hanpattanakit, 2014). It is a combination of autotrophic root respiration (R_b) and heterotrophic microbial respiration (R_m) to environmental factors (Hanpattanakit et al., 2015). Previous studies found that A study in a temperate coniferous-deciduous forest in Belgium measured R_s rate of 2.24 kg CO_2 m^{-2} yr^{-1} (Yuste et al., 2004), and R_s rate was measured at 4.62 kg CO_2 m^{-2} yr^{-1} in dry evergreen forest (Wiriyatangsakul et al., 2006). The average soil CO_2 emission rate was 4.29 kg CO_2 m^{-2} yr^{-1} in the dry evergreen forest compared to 5.07 kg CO_2 m^{-2} yr^{-1} in the mixed deciduous forest (Panuthai et al., 2005). The variations in the sensitivity of soil respiration to soil temperature and moisture have been attributed to the relative proportion of the R_b and R_m components (Butler et al., 2012). Intanil et al. (2018) found the component of Rs was R_m (62%) and R_b (38%). Soil temperature alone was the main driver of diurnal variation, while the combination of soil moisture and soil temperature determined the seasonal variations (Hanpattanakit et al., 2015).

However, quantifying fine root phenology and mortality belowground will also impact the evaluation of belowground carbon stocks and emissions (Wauters et al., 2008), with increasing the accuracy and precision of estimating carbon uptake capacity in forest ecosystems. Fine root is small root size less than or equal to 2 mm in diameter. It has a pivotal role in resource acquisition, nutrients, water, elemental and carbon cycling in forest. Fine root dynamic changes in the rate of growth and death, and there are various environmental factors. Fine root growth or degradation is a very important part of soil nutrient cycling (Nadelhoffer and Raich, 1992) and soil carbon fixation in the form of organic matter (Shibata et al., 2005). Akamanuwat (2017) found the fine root biomass ranged from 0.76 to 1.12 kg m^{-3} at 4 levels soil depth (0-5, 5-10, 10-15, 15-20 cm), which fine root biomass decreased with increasing soil depth (Burke and Raynal, 1994). Previous studies have reported that fine root production and turnover vary with biome types and climate at global or regional scales while they vary with topography, soil properties, stand structure, species composition, stand age, and aboveground productivity at the local scale (Finér et al., 2011; Nadelhoffer and Raich, 1992; Pierick et al., 2021; Vogt et al., 1996).

Hence, estimating soil respiration and quantifying fine root dynamics are crucial to the understanding of carbon cycling in forest ecosystems and study how carbon cycling in forest ecosystems respond to climate change. Especially, rainfall and temperature change in the forest ecosystems of Thailand. Therefore, this study will be conducted in secondary dry dipterocarp forest (DFR) in Ratchaburi Province, Thailand, to study the influence of climate change especially effects of drought on soil respiration and fine root dynamics including to study the relationship between fine root dynamics with soil respiration and environmental factors

2. Objectives of the Study

2.1 To study the influence of climate change especially effects of drought on soil respiration and fine root dynamics in secondary dry dipterocarp forest at Ratchaburi Province, Thailand

2.2 To study the relationship between soil respiration with fine root dynamics and environmental factors in secondary dry dipterocarp forest at Ratchaburi Province, Thailand

3. Methodology

3.1 Scope and Conceptual framework of the Study

This study will carry out at secondary dry dipterocarp forest (DFR) in Ratchaburi Province, Thailand to study the influence of climate change especially effects of drought on soil respiration and fine root dynamics from reducing the amount of rainfall by half or 50 percent of normal rainfall. This study will estimate CO_2 emission from soil respiration (R_s), and will be separated root respiration (R_b) and microbial respiration (R_m). The CO_2 emission will be determined by using 4 CO_2 probes for each R_s and R_m with the soil gradient method and trenching method will use to separate R_b and R_m. Along with fine roots dynamics and environmental factors will be measured. The fine roots will collect by using the soil core 5 cm diameter in once per month and separate fine roots (size ⩽2 mm) both life and alife fine root. The fine roots elongation will be analyzed by using the Image J program, and fine root biomass will be oven dried and weight. Including, air and soil temperature, soil moisture, rainfall, and soil properties will measure continuously in both sites. Moreover, study and analyze the relationship between fine root dynamics with soil respiration variation and environmental factors.

3.2 Site description

The DFR locate within King Mongkut's University of Technology Thonburi, Ratchaburi campus, Ratchaburi province, Western Thailand (latitude: 13° 35′ 13.3" N, longitude: 99° 30' 3.9" E, elevation 110 m). The DFR has a total area of 187.2 ha, which has been preserved since 2005 after the forest was utilized by surrounding communities for energy (wood and charcoal), and building structures (menagerie and hut). As a result, most of the trees are in the recovery phase (Hanpattanakit et al., 2015). From 2011 to 2015, the average annual precipitation was 1,029 mm and the air temperature was 28.46°C. The average minimum and maximum air temperatures are 22.82°C and 34.18°C, respectively (Statistical Office of Ratchaburi Province, 2017). The soil texture for the top 100 cm depth at this site is loamy sand, with average sand, silt, and clay particle content of 75.79%, 20.86%, and 3.35%, respectively (Hanpattanakit, 2008). Soil pH, bulk density, and organic carbon ranged from 4.8 to 5.1, 1.3 to 1.4 g cm-3, and 0.3 to 0.5%, respectively (Hanpattanakit et al., 2015).

3.3 Preparation the study plot

Preparation the study plot in DFR for reducing the amount of rainfall by half or 50 percent of normal rainfall. Build a roof structure, which the roof is installed to prevent rainfall 50 percent of the area with install rain gutters to drain rainfall from the experimental area.

Moreover, this study measured both soil respiration (total soil respiration; R_s) and microbial respiration (R_m). Which, separated root respiration (R_b) from R_m by root extraction technique using trenching method (Hanpattanakit et al., 2015). One plot each for a trenched and untrenched plot was established with two CO_2 probes installed for each plot at different soil layers. For the trenched plot, dug trenches around the study area and backfilled after installing the gypsum board to prevent root ingrowth. The size of each trenched plot was 1 m wide × 1 m length × 0.3 m depth.

3.4 Instrumentation and CO_2 emission calculations

CO_2 emission from R_s will measure using CO_2 probes (GMP343: Vaisala Inc., Finland) with the soil gradient method. The trenching method will use to separate root respiration (R_b) and microbial respiration (R_m). This method has been widely used to partition soil respiration (Bond-Lamberty et al., 2011; Bowden et al., 1993; Jiang et al., 2005). It has the advantage that it has relatively less disturbance to remaining trees than other methods and the relative ease of the experimental implementation. There

are 4 CO_2 probes for each R_s and R_m in both sites. Two CO_2 probes will be buried vertically at depths of 5 and 20 cm to detect CO_2 concentration. CO_2 concentrations from R_s will record every minute by data loggers (CR1000: Campbell Scientific, Logan, Utah, USA) (Figure 1). Then, the CO_2 concentrations with environmental factors were used to calculate CO_2 fluxes using equations 1 to 5 (Bulsathaporn et al., 2018; Tang et al., 2003).

$$F = -D_s \frac{dC}{dZ} \quad (1)$$

where F is the soil CO_2 flux (mg CO_2 m^{-2} hr^{-1}), D_s is the CO_2 diffusion coefficient in the soil (m^2 s^{-1}), $\frac{dC}{dZ}$ is the vertical soil CO_2 gradient, C is the CO_2 concentration (µmol mol^{-1} or µmol m^{-3}), and Z is the soil depth (m).

$$Ds = \xi D_a \quad (2)$$

where D_a is the CO_2 diffusion coefficient in free air (m^2 s^{-1}) and ξ is the gas tortuosity factor.

$$D_a = D_{a0} \left(\frac{T}{293.15}\right)^{1.75} \left(\frac{P}{101.3}\right) \quad (3)$$

where D_{a0} is the reference value of D_a at 20°C (293.15 K) and 101.3 kPa, given as 14.7×10^{-3} m^2 s^{-1}, T is the air temperature (K), and P is the air pressure (kPa). There are several empirical models for computing ξ (Tang et al., 2003) as

$$\xi = \alpha^{10/3}/\varphi^2 \quad (4)$$

where α is the volumetric air content and φ is the porosity.

$$\varphi = \alpha+\theta = 1-\frac{\rho_b}{\rho_m} \quad (5)$$

where θ is the volumetric soil water content, ρ_b is the bulk density (g cm^{-3}) and ρ_m is the particle density of the mineral soil (g cm^{-3}).

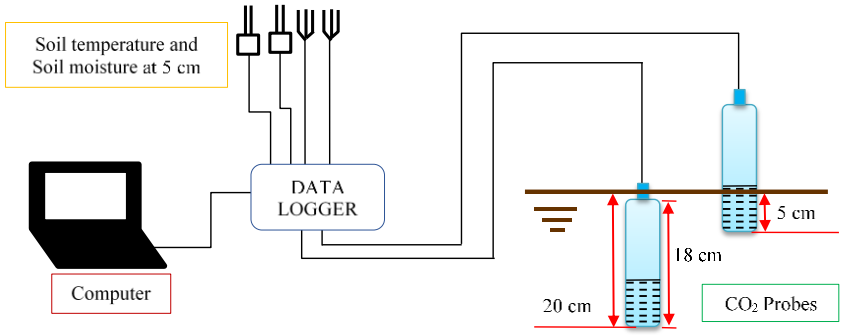

Figure 1. Placement and position of the GMP343 probes in the soil profile for soil CO_2 concentration and environmental variables measurements

3.5 Fine roots collection

The fine roots will collect from the soil core 5 cm diameter in once per month at soil depth 4 levels (0-5, 5-10, 10-15, and 15-20 cm) with 20 random samplings. Then, will separate fine roots (size ≤2 mm) from soil and washed through a 2 mm mesh screen both live and alive fine root. It will observe by eyes based on color and consistency. The live fine roots are usually light or brown-green color and

are succulent. While, the alive fine roots are black or dark color, dry texture, and brittle (Hanpattanakit, 2013). We will scan, resize and analyze the fine root elongation by using the Image J program with WinRHIZO (Regent Instruments INC, Canada) packaged program. Then these fine roots will be oven dried at 50˚C for 24 hrs. and weighed as biomass.

3.6 Climate factors measurement

Air temperature, soil temperature, soil moisture, and rainfall will measure continuously to analyze the relationship between soil respiration with fine root dynamics and environmental factor. Soil temperature and moisture were measured at a depth of 5 cm. Air and soil temperature will measure by two averaging thermocouple probes (TCAV, Campbell Scientific, Inc., USA) and soil moisture will measure by two averaging moisture reflectometers (CS615, Campbell Scientific, Inc), and rainfall will measure by Tipping bucket rain gauge (TE525, Campbell Scientific, Inc). These data were recorded in a data logger model CR1000 (Campbell Scientific, Logan, Utah, USA).

3.7 Analysis of soil properties

We will collect soil samples from four soil depth levels (0-5, 5-10, 10-15 and 15-20 cm) using a soil core with a 5 cm diameter to analyze pH, bulk density, carbon and nitrogen content, and organic carbon (SOC). Soil pH will analyze by using a pH meter (HI-3220, Hanna Instrument, Inc., USA) with a soil to water ratio of 1:1 (w w^{-1}) (Land Development Department, 2004). Soil samples will be oven-dried at 105°C for 48 hrs. and weighed to calculate the bulk density using equation 6 (Hanpattanakit, 2013). Soil carbon and nitrogen content will analyze by using a CHN analyzer (628 series, LECO Corporation, St Joseph, Michigan, USA) and SOC will calculate using equation 7 (Li et al., 2017).

$$\text{Bulk density} = \frac{\text{Dry weight of soil (g)}}{\text{Total volume of soil (cm}^3\text{)}} \quad (6)$$

$$\text{SOC} = \text{C x BD x D} \quad (7)$$

3.8 Data analysis

CO_2 emissions from R_s, R_b, R_m, fine root biomass, fine root elongation, and environmental factors in DFR will statistically compare using one-way ANOVA. The influence of climate change especially effects of drought on soil respiration and fine root dynamics, and the relationships between R_s, R_b, R_m and fine root biomass, fine root elongation, and environmental factors in both sites will use Pearson's correlation analysis. The correlation pattern will be further examined by principal component analysis (PCA), and will be used to determine which aggregates of variables best explained the variances of R_s. The statistical analyses were conducted using IBM SPSS for Windows, version 17.0 (IBM Crop., Armonk, N.Y. USA) at a 95% significance level.

4. Expected Result

11.1 Understand the temporal variation of soil respiration and fine root dynamic in secondary dry dipterocarp forest.

11.2 Understand the influence of climate change especially effects of drought on soil respiration and fine root dynamics.

11.3 Understand the affecting of environmental factors on the variation of soil respiration and its component and fine root dynamics in secondary dry dipterocarp forest.

11.3 This research can be used to link carbon stock and emissions data in forests to Asian data and can apply the knowledge to disseminate in the forum academic conference and publish research results in academic journals.

5. Reference

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