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ชื่อโครงการ Estimating soil respiration rates between wet and dry seasons in an urban park of Thailand

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Estimating soil respiration rates between wet and dry seasons in an urban park of Thailand

การประเมินอัตราการหายใจของดินระหว่างฤดูฝนและฤดูแล้งในพื้นที่สวนสาธารณะในเมืองในประเทศไทย

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บทคัดย่อ

กระบวนการหายใจของดิน (Rs) เป็นองค์ประกอบที่ใหญ่ที่สุดในระบบการแลกเปลี่ยนคาร์บอนของระบบนิเวศบนบกระหว่างดินกับชั้นบรรยากาศ ในขณะที่ดินเป็นแหล่งกักเก็บสารอินทรีย์คาร์บอนจากชั้นบรรยากาศ กระบวนการหายใจของดินสามารถเป็นแหล่งปลดปล่อยก๊าซคาร์บอนไดออกไซด์ได้อย่างมีนัยสำคัญ ในปัจจุบันยังไม่มีข้อสรุปที่ชัดเจนเกี่ยวกับสมดุลคาร์บอนในพื้นที่ในเขตเมืองว่ามีการกักเก็บคาร์บอนหรือปลดปล่อยมากกว่ากัน โดยเฉพาะพื้นที่สีเขียวในเมืองการทำความเข้าใจถึงสมดุลของปริมาณคาร์บอนในเมืองจึงเป็นสิ่งที่สำคัญ ที่สามารถเชื่อมโยงไปสู่ปัญหาเกี่ยวกับการเปลี่ยนแปลงทางสภาพอากาศได้ งานวิจัยนี้ได้ทำการสำรวจอัตราการหายใจของดินระหว่างฤดูฝนและฤดูแล้ง และวิเคราะห์เกี่ยวกับความสัมพันธ์ระหว่างอัตราการหายใจของดินกับปัจจัยทางสิ่งแวดล้อมได้แก่ อุณหภูมิของดิน ค่าความชื้นของดิน คาร์บอนอินทรียในดิน และประเภทของพืชที่ปกคลุมดิน การตรวจวัดอัตราการหายใจของดินดำเนินการบนดินตัวอย่าง 27 จุด ที่ปกคลุมไปด้วยต้นไม้ หญ้า และพุ่มไม้ในบริเวณอุทยาน 100 ปี จุฬา ฯ ด้วยเทคนิคแบบ close chamber ผลจากการศึกษาชี้ให้เห็นถึงความแตกต่างกันระหว่างค่าเฉลี่ยอัตราการหายใจของดิน โดยในฤดูฝน (1.70±0.41 g CO_2 m^{-2} hr^{-1}) และในฤดูแล้ง (1.29±0.34 g CO_2 m^{-2} hr^{-1}) อย่างมีนัยสำคัญเชิงสถิติ (p-value <0.0001) การวิเคราะห์สมการเส้นถดถอยแบบเส้นตรงพบว่า ความสัมพันธ์ระหว่างอัตราการหายใจของดินและปัจจัยทางสิ่งแวดล้อมในทั้งสองฤดูไม่ได้สัมพันธ์กันอย่างมีนัยสำคัญ อย่างไรก็ตาม ค่าเฉลี่ยอัตราการหายใจของดินที่ถูกปกคลุมด้วยหญ้านั้น มีค่าเฉลี่ยที่สูงกว่าเมื่อเทียบกับกับค่าเฉลี่ยอัตราการหายใจของดินที่ถูกปกคลุมด้วยต้นไม้แสดงให้เห็นว่าปริมาณอินทรีย์วัตถุที่สะสมในดินจากการจัดการสวน อย่างเช่น การจัดเก็บใบไม้ที่ร่วงหล่น ประกอบกับอุณหภูมิของดินใต้ต้นไม้ใหญ่ที่ต่ำกว่าบริเวณอื่น สามารถส่งผลกระทบต่อกระบวนการย่อยสลายและกิจกรรมของจุลินทรีย์ในดินได้

คำสำคัญ: การหายใจของดิน สารอินทรีย์วัตถุในดิน ประเภทของพืชปกคลุมดิน สวนสาธารณะในเมือง ปัจจัยทางสิ่งแวดล้อม

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Abstract

Soil respiration (Rs) is considered the largest component in the terrestrial-atmospheric carbon exchange system. While soils offset organic carbon from the atmosphere, Rs can be a significant source of CO_2 emission. In urban areas where the balance of carbon sink and source is still under debate whether which one is dominant. To understand the dynamics of the amount of urban carbon, in particular a green space, is the key linking to climate change issue. This research investigated Rs rates between the wet and dry seasons, and further analyzed the relationships between Rs rates and environmental covariates i.e. (soil temperature, soil moisture content, soil organic carbon and vegetation cover types). The measurement of Rs rates were conducted in twenty-seven soil samples around trees, grass and shrubs in the CU Centenary Park using a close chamber technique. The difference between average Rs rates in the wet season (1.70±0.41 g CO_2 m^{-2} hr^{-1}) and dry season (1.29±0.34 g CO_2 m^{-2} hr^{-1}) was found to be statistically significant (p-value < 0.0001). The linear regression model showed no statistically significance of relationship between Rs rates and environmental covariates in both seasons. However, higher mean Rs rate in the area covered by grass was determined when compared to the Rs rates covered by trees. The results indicated that low organic matter input from litterfall management and soil temperature around trees could affect the decomposition process and microorganism activity in the soil.

Keywords: soil respiration; soil organic carbon; vegetation cover types; urban park; environmental factors

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Jittiwas Phalodom

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CHAPTER 1

INTRODUCTION

Global carbon emission in the atmosphere was set to increase by 2.7 percent in 2018 and estimated to reach the highest on record in 2019 (Mulvaney, 2019). Atmospheric carbon dioxide rose to the peak at 414.7 ppm in May 2019 which is the highest level in history (Stein, 2019). The rise of carbon dioxide in the atmosphere is the main cause of global climate change. Terrestrial ecosystem around the world are the most important green landscape for nutrients and ecosystem cycle because of having tree and soil in large areas which can significantly act like carbon sink and carbon source to motivate the activities of the carbon life cycle. Soil respiration is the ecosystem process that can show the rates of carbon dioxide releasing from the soil to the atmosphere.

Soil respiration is sensitive to environmental factors of soil (Bain et al., 2005). Soil temperature, soil moisture, C:N ratio and vegetation types affect soil respiration (Luo and Zhou, 2006). Thailand is the country in tropical zone which has the important role in ecosystem to control carbon dioxide cycle. In an urban area such as in Bangkok, parks are important green spaces which play a key role in controlling carbon balance of terrestrial ecosystem in the city. Nowadays, Thailand has many urban parks in Bangkok which seem to be large areas for having soil respiration that affect the balance of carbon in the city. However, there are lack of information about seasonal variation on soil respiration in an urban park of Thailand.

Chulalongkorn University Centenary Park is one of the most important parks in Bangkok which established for the 100th anniversary of Chulalongkorn University. With 29 rais of park area, the CU Centenary Park is constructed to contribute both physical environment and mental well-being of people living in or around the urban area. Several parks are designed to mitigate the urban heat and absorb carbon from the atmosphere. However, Naka (2018) showed the contradicting results pointing that the CU Centenary Park released more carbon to the atmosphere through soil respiration process than it stored.

This research is aimed to continue and develop soil respiration study in the same park to obtain better understanding of the seasonal variations and related environmental factors affecting soil respiration.

Objectives

1. To compare soil respiration rates between wet and dry seasons in an urban park of Thailand.
2. To investigate relationships between soil respiration rates and environmental covariates i.e. (soil temperature, moisture content, organic carbon, and vegetation types.)

Outcomes of research

1. This research could provide CU Centenary Park and public with beneficial database and information on soil respiration rates in wet and dry seasons.
2. This research could show the important order of environmental covariates to soil respiration rates and further manage CU Centenary Park in offsetting carbon emissions.

CHAPTER 2

LITERATURE REVIEW

2.1 Carbon cycle

Carbon is an important component of biotic and abiotic in the earth which is a dynamic place to enhance the cycle of matter in atmosphere, hydrosphere, lithosphere, and biosphere.

Carbon cycles occur when carbon dioxide (CO_2) is fixed by plants in the atmosphere and turned into gross primary production (GPP) from photosynthesis. GPP in form of organic carbon is used to be the energy to grow the plant issue by photorespiration, the rest production from this process is called net primary production (NPP). After plant live, biomass such as stems, leaves and roots are decomposed as soil organic carbon substrate supply by microorganism in soil for microbial biomass growth which they release CO_2 back to the atmosphere during the process (Luo and Zhou, 2006).

2.2 Ecosystem respiration

In the carbon cycle, soil respiration (Rs) is a key process that release carbon from the soil out to the atmosphere in form of carbon dioxide (CO_2) which can be measured as CO_2 rates. Ecosystem respiration (Re) is come from above ground plant respiration (lawn grass, shrub, tree respiration) and Rs (root respiration and microbial respiration) which most of Re comes from Rs. Rs is the one important components of Re. Generally, 30-80% of Re is from Rs in forest. Rs is produced from both autotrophic respiration (root respiration) and heterotrophic respiration (microbial respiration). Microbes decompose soil organic matter (SOM) and release CO_2 out from the soil surface. Rs is respond to abiotic and biotic factor such as soil temperature, soil moisture and vegetation types. In tropical zone, soil temperature and soil moisture are sensitive to Rs rates (Bain et al., 2005). Releasing CO_2 from Rs is related to greenhouse gases (GHG) problem that led to climate change. CO_2 is the most important component of GHG substrate chemical compounds which form to be a layer to trap heat inside the earth atmosphere that cause a global warming. Human activities such as deforestation and changing land management put about 7.2 Pg (10^{15}g) C yr^{-1} to the atmosphere. Plant lands use about 120 Pg C yr^{-1} in photosynthesis and released back by ecosystem respiration. Amounts of CO_2 emission by natural processes are more than human activities but terrestrial carbon sink is dramatically decreased cause of anthropogenic carbon emission (Luo and Zhou, 2006).

2.3 Related research reviews

Estimated soil respiration and CO_2 concentration in northern tropical evergreen forest of Thailand that was dominated by oak trees. Rs rate was 2560 g C m^{-2} yr^{-1}. Result showed that Rs was highest in wet season (August to September) and lowest in dry season (December to February). During the year, soil moisture was different between seasons, but soil temperature was not changed much. Rs was depend on soil moisture, not on soil temperature (Hashimoto et al., 2004).

Investigated soil carbon (SC), soil organic carbon (SOC) to Rs rates at two sites of urban forests in India. First area was Banobitan that had slightly alkaline sandy loam soil with soil moisture content 7.26-9.74 %, TC 24.2-36.5 g kg^{-1}, SOC 2.8-8.3 g kg^{-1} and Rs rates 2.07 t C ha^{-1} yr^{-1}. Second area was Indian Botanic Garden that had slightly acidic clayey loam soil with soil moisture content 16.2-21.7 %, TC 50-80.1 g kg^{-1}, SOC 8.3-12.6 g kg^{-1} and Rs rates 3.34 t C ha^{-1} yr^{-1}. Annual Rs rates at Bonobitan was lower than Rs rates at Indian Botanic Garden (Bipal et al., 2009).

Rs rates were analyzed by closed chamber technique showed that amount of soil moisture at 5 cm depth and soil respiration in wet season were correlated with r^2 values of 0.53 and 0.51 for teak plantation and mixed deciduous forest in Thailand, respectively. Amount of soil moisture at 5 cm depth and soil respiration in dry were correlated with r^2 values of 0.68 and 0.51 for teak plantation and mixed deciduous forest, respectively. There was a poor correlation between soil temperature and Rs in seasonal variation. In teak plantation, average Rs rates in wet season was 150.7 and 117.2 mg CO_2 m^{-2} hr^{-1} in dry season. In the mixed deciduous forest, average Rs rates in wet season was 148.5 and 106.4 mg CO_2 m^{-2} hr^{-1} in dry season. At both sites showed was higher in wet season that had more moisture content than that in dry season. For diurnal variation, highest soil temperature around 12-2 pm. showed the peak of Rs rates at both sites (Wangluk et al., 2013).

Investigated soil respiration between wet (2013) and dry (2014) years in six land cover types; the mixed forest, deciduous broadleaf forest, evergreen needleleaf forest, lawn, wetland, and bare land in an Korean urban park which had annual Rs rates for 1.45 ± 0.11, 1.13 ± 0.09, 1.22 ± 0.08, 1.05 ± 0.09, 1.22 ± 0.09, and 0.48 ± 0.10 kg C m^{-2} y^{-1} respectively. Rs rates in mixed forest was highest while Rs rates in bare land was lowest. Difference in the annual Rs showed no significant through deciduous broadleaf forest, evergreen needleleaf forest, lawn, and wetland (ANOVA, $P > 0.05$). Rs rates increased in higher soil organic carbon (SOC) input which in the mixed forest area had a significantly higher NDVI and LAI to influent more SOC put into the soil that affected Rs rates. All types of land cover showed the positive correlation between soil respiration (μmol CO_2 m^{-2} s^{-1}) and soil temperature (°C) at a 20 cm depth (Bae and Ryu, 2017).

The result indicated that tree and shrub in non-domestic greenspace area could help to decrease soil surface temperature that affect urban heat island. In summer, soil temperature below trees and shrubs were lower than soil temperature below herbaceous vegetation 5.7 °C in maximum. On the other hand, grassland had maximum soil temperature in many days more than 30 °C (Edmondson et al., 2016). In brief, trees and shrubs showed the capability in controlling soil temperature that affect to reduce the urban heat island effect and air pollution from releasing CO_2 to atmosphere.

Investigated soil respiration to soil properties in China four urban green lands; park green-land, campus green-land, residential green-land, and factory green-land from April 2011- April 2013 in every two months. The result showed that Rs rate in the residential green-land was significantly lower than Rs in the campus and park green-lands due to the less carbon output by plants. Soil moisture at 18–25% had a positive significant on Rs. Soil temperature of 2.01–31.26 °C positively increased Rs. Rs was positively correlated with soil organic carbon in 0-10 cm soil layer (Xiao et al., 2016).

CHAPTER 3

METHODOLOGY

3.1 Study site

The study site was carried out in September and October in the wet season and in November and December in the dry season 2019 in the CU Centenary Park, Pathumwan district, located in the center of Bangkok in Thailand (13.7392 N, 100.5249 E) which had the large green space areas. Bangkok is characterized by a tropical climate with wet (May to October) and dry (November to April) seasons. The areas of the park are 29 rai that was surrounded by resident and building and opened from public utilization.

Figure 3.1 Chulalongkorn University Centenary Park (CU Centenary Park)

3.2 Sampling Design

There were twenty-seven sampling points in the CU Centenary Park and were recorded for each plot by GPS in a WGS84 system. CU01 to CU09 represented the area of soils covered by tree, CU10 to CU18 represented the area of soils covered by grass, and CU19 to CU27 represented the area of soils covered by shrub.

Figure 3.2 Soil sampling within the study site among different land cover types

3.3 Soil sampling collection

Twenty-seven soil samples were collected: nine samples around trees, nine around shrubs and nine inside lawns. Soil cylinder (diameter, 5 cm diameter; high, 5 cm height) was used for collected soil samples in September for wet season and in December 2019 for dry season to analyze for soil moisture, soil bulk density. Thermometer was used to investigate soil temperature while pH universal indicator paper was used to find soil pH. Soil samples were dried indoor by natural air drying for a week before being pounded and then strained by a 0.5 mm size grid and put all soil samples into zipped bags.

3.4 Laboratory analysis

3.4.1 Analysis of soil texture

Hydrometer method was used to analyze soil texture that used 50 g for each soil sample. All samples were soaked with sodium hexametaphosphate for 24 hours. After that, spin soil samples in the blender machine for 5 minutes then put mixed soil into 1000 ml hydrometer jar and adjusted the volume to 1000 ml by distilled water. Mix the soil solution for 1 minute by stirring rod and used thermometer and hydrometer to measure values at 40 seconds and 2 hours for calculate particulate matter size.

3.4.2 Analysis of organic carbon

The organic carbon analyzer (aj-Analyzer multi N/C 3100) was used for analyzing organic carbon of the soil samples which measured with three replicates in each soil sample. First, we tested strained 0.5 mm dried soil with a drop of the 10% HCL to make sure that soil samples have no inorganic carbon then put samples into oven for 2 hours to remove all inorganic carbon and moisture. Next, delivered about 250 mg soil sample into the organic carbon analyzer for 1199 °C to analyze total organic carbon showed as %OC.

3.4.3 Analysis of soil respiration

A closed-chamber technique was used for measurement soil respiration rates by TARGAS-1 pp system that measured soil respiration rates (g CO_2 m^{-2} hr^{-1}) with three replicates in each experimental plot which took for 60 seconds in measurement CO_2 concentration. The measurement was carried out monthly for 4 months. Samples obtained in September and October 2019 (represented wet season soil respiration.) November and December 2019 (represented dry season soil respiration). Experimental plots located the exact points of twenty-seven soil samples.

3.5 Statistical Analyses

A paired T-test was used to compare the average data of soil respiration rates between wet and dry seasons .Linear regression analysis was used to determine the relationships between soil respiration rates and soil temperature, soil moisture content, total organic carbon. Analysis of variance (ANOVA) and Tukey's post hoc tests were carried out to detect the significant differences between Rs rates and vegetation cover types.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Environmental conditions

For the weather, air temperature was around 31°C in the wet season 30°C in the dry season. The humidity was 74.6% in the wet season and 67.8% in the dry season. The major soil types in the tree and grass area represented sand texture while shrub area represented sandy loam to sand texture. Soil varied from slightly acidic to neutral (pH: 5-7). Table 4.1 illustrates the parameter of soil properties. In the wet season, soil temperature ranged between 27.94-33.28°C, soil moisture content ranged between 5.13-55.05%. SOC and Rs ranged from 0.11-3.22% and 1.11-2.58 (g CO_2 m^{-2} hr^{-1}). In the dry season, soil temperature ranged between 27.38-31.57°C, soil moisture content ranged between 2.25-35.15%. SOC and Rs ranged from 0.19-3.62% and 0.66-2.18 (g CO_2 m^{-2} hr^{-1}).

Table 4.1 Descriptive statistics of soil properties

Land covers and soil properties	Max	Min	Mean	SD	Max	Min	Mean	SD
Tree	Wet season				Dry season			
Rs rates (g CO_2 m^{-2} hr^{-1})	1.93	1.11	1.39	0.27	2.18	0.85	1.26	0.39
Soil temperature (°C)	29.78	28.34	29.06	0.52	30.36	27.64	28.94	1.01
Soil moisture (%)	14.13	5.13	9.13	2.98	8.94	3.94	6.81	1.60
SOC (%)	1.35	0.02	0.49	0.42	1.10	0.19	0.67	0.34
Grass	Wet season				Dry season			
Rs rates (g CO_2 m^{-2} hr^{-1})	2.57	1.31	1.89	0.37	1.87	1.10	1.50	0.23
Soil temperature (°C)	30.20	27.94	29.24	0.68	31.57	27.38	29.06	1.59
Soil moisture (%)	22.47	7.88	15.01	4.50	11.47	2.25	6.26	3.37
SOC (%)	1.73	0.02	0.45	0.53	1.68	0.20	0.63	0.48
Shrub	Wet season				Dry season			
Rs rates (g CO_2 m^{-2} hr^{-1})	2.58	1.17	1.82	0.41	1.45	0.66	1.09	0.26
Soil temperature (°C)	33.28	29.34	30.42	1.26	29.64	27.38	28.72	0.71
Soil moisture (%)	55.05	18.55	30.34	11.41	35.15	3.99	15.98	9.29
SOC (%)	3.22	0.83	2.03	0.95	3.62	0.71	1.86	1.17

4.2 Comparison of Rs rates between wet and dry seasons.

Average soil respiration rates in the CU Centenary Park during the wet and dry seasons were 1.70±0.41 and 1.29±0.34 g CO_2 m^{-2} hr^{-1}, respectively. This result showed that Rs rates in wet season was higher than that in dry season. Rs rates was significantly different between both seasons (p-value < 0.0001). Soil moisture content that significantly different (p-value < 0.0001) between both seasons which in wet season have higher average value than that in dry season may contribute to the Rs rates between both seasons. For this study, the average soil moisture content in the wet and dry season were 18.16±11.50 and 9.68±7.18%, respectively which in the wet season had more soil moisture content than that in the dry season that influent to have more Rs rates. The optimum soil moisture affects Rs rates by input more oxygen from water through the soil surface that motivate microorganism to have more microbial activities which use oxygen and nutrient for metabolism for their growth. Conversely, oxygen diffusion rates can limit respiration at high soil moisture level (Wangluk et al., 2013). The microbial activities release CO_2 for their product throughout the soil surface to the atmosphere. Similar result in teak plantation and mixed deciduous forest in Thailand, the Rs rates in wet season was higher than that in dry season and had the peak of Rs rates when soil moisture content reached around 28% in the wet season (Wangluk et al., 2013). Rs rates was higher in the warm-wet seasons and lower in the cool-dry seasons in three subtropical forests in China

(Fang et al., 2015).

4.3 Relationship between Rs rates, soil temperature, moisture content and organic carbon

The relationship between Rs rates and environmental covariates i.e., soil temperature, soil moisture content and soil organic carbon were investigated. From the scatter plots between Rs rates and environmental covariates showed that the data seem spread in the form of linear model (see Appendix). They were not significant with linear regression relationship between Rs rates and environmental covariates in both seasons except for relationship between Rs rates and soil organic carbon in the dry season that showed the weak significance.

Table 4.2 Regression statistics between Rs rates and soil temperature in wet season

Regression Statistics	
Multiple R	0.188452
R Square	0.035514
Adjusted R Square	-0.00307
Standard Error	0.411219
Observations	27

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.155666	0.155666	0.920551	0.346518
Residual	25	4.227531	0.169101		
Total	26	4.383198			

Table 4.3 Regression statistics between Rs rates and soil temperature in dry season

Regression Statistics	
Multiple R	0.100265
R Square	0.010053
Adjusted R Square	-0.02954
Standard Error	0.342972
Observations	27

ANOVA

	df	SS	MS	F	Significance F
Regression	1	0.029864	0.029864	0.253877	0.618769
Residual	25	2.940752	0.11763		
Total	26	2.970616			

Table 4.2 and 4.3 demonstrate the regression results between Rs rates and soil temperature in wet and dry season, respectively. The results show no significance between factors in either seasons (p >= 0.346). Similar results have been reported for role of soil temperature on soil respiration in the wet season which had no significant between Rs rates and soil temperature (p-value >=0.49) and had a weak significant (p<=0.048) in the dry season in mixed deciduous forest and teak plantation in Thailand (Wangluk et al, 2013). In their study, in the wet and dry seasons, their soil temperature ranged from 24.17-28.18 ˚C and 19.08-27.14 ˚C, respectively (Wangluk et al., 2013). Conversely, another research for the temporal variations in Rs in urban Seoul Forest Park under wet and dry years. In the condition which soil temperature ranged about 0-30 ˚C, the result showed significance

between soil temperature and Rs rates (p-value < 0.05) (Bae and Ryu, 2017). From the two research above explained that the ranged of soil temperature influents microbial activities to releasing CO_2 which affect the significance between Rs rates and soil temperature. This study had a small ranged of soil temperature in both wet and dry seasons which may result in no significance between Rs rates and soil temperature.

Table 4.4 Regression statistics between Rs rates and soil moisture content in wet season

Regression Statistics	
Multiple R	0.255367
R Square	0.065212
Adjusted R Square	0.027821
Standard Error	11.34577
Observations	27

ANOVA

	df	SS	MS	F	Significance F
Regression	1	224.5043	224.5043	1.74404	0.19859
Residual	25	3218.165	128.7266		
Total	26	3442.669			

Table 4.5 Regression statistics between Rs rates and soil moisture content in dry season

Regression Statistics	
Multiple R	0.29176
R Square	0.085124
Adjusted R Square	0.048529
Standard Error	0.329712
Observations	27

ANOVA

	df	SS	MS	F	Significance F
Regression	1	0.252871	0.252871	2.326111	0.139772
Residual	25	2.717745	0.10871		
Total	26	2.970616			

Table 4.4 and 4.5 demonstrate the relationship between Rs rates and soil moisture content in wet and dry seasons, respectively. The results show no significance between factors in either seasons ($p >= 0.139$). Different results have been reported for role of soil moisture content on Rs between wet and dry seasons which had significant between Rs rates and soil moisture content (p-value < 0.05) for both seasons in mixed deciduous forest and teak plantation in Thailand. In the wet and dry seasons, their soil moisture content ranged about 15-40 % and 12-23 % respectively which the peak of Rs rates occurred when soil moisture content was around 28% in the wet season (Wangluk et al., 2013). From the report, experiment was measured twice monthly for one year during wet and dry seasons that investigated more data to find the significant between Rs rates and soil moisture

content. This study was measured once monthly for two months per season could lead to has not enough data of the samples to find the significant of the relationship between Rs rates and soil moisture content in the study area.

Table 4.6 Regression statistics between Rs rates and soil organic carbon in wet season

Regression Statistics	
Multiple R	0.039273
R Square	0.001542
Adjusted R Square	-0.0384
Standard Error	0.418399
Observations	27

ANOVA

	df	SS	MS	F	Significance F
Regression	1	0.00676	0.00676	0.038618	0.845796
Residual	25	4.376437	0.175057		
Total	26	4.383198			

Table 4.7 Regression statistics between Rs rates and soil organic carbon in dry season

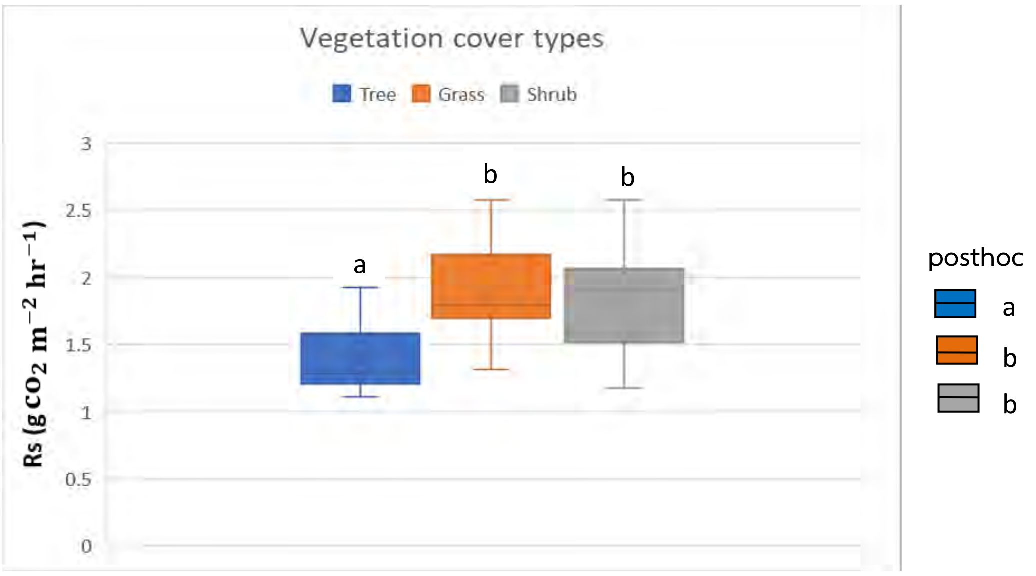
Regression Statistics	
Multiple R	0.380989
R Square	0.145153
Adjusted R Square	0.110959
Standard Error	0.318711
Observations	27

ANOVA

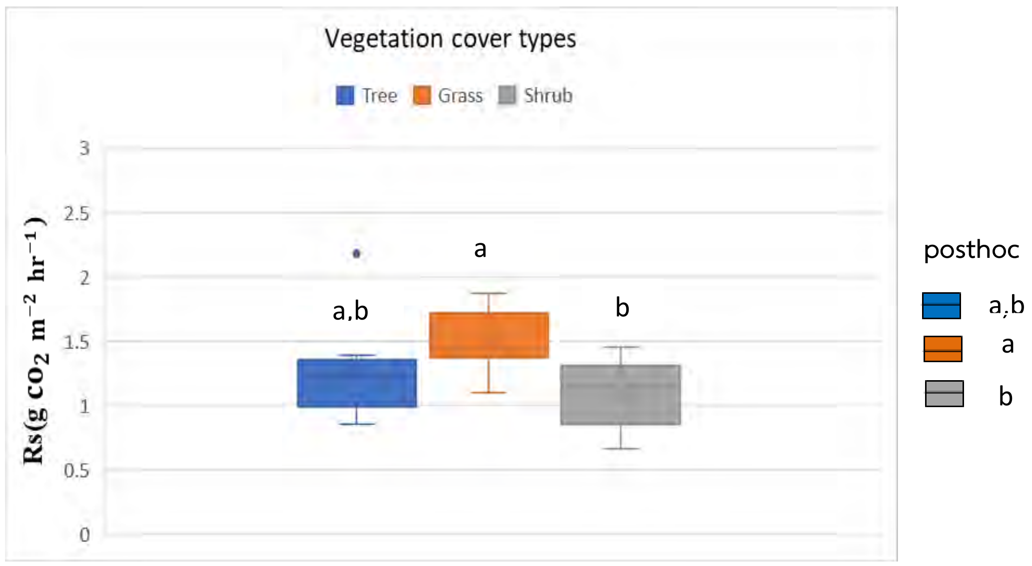
	df	SS	MS	F	Significance F
Regression	1	0.431194	0.431194	4.244997	0.049918
Residual	25	2.539422	0.101577		
Total	26	2.970616			

From the table 4.6 and 4.7 demonstrate the relationship between Rs rates and soil organic carbon in wet and dry season, respectively. The results show no significance between factors with p-value > 0.05 in the wet season but show the weak significance in the dry season (p = 0.0499) probably due to the other factors that were not investigated in the environment in the dry season that affect the relationship between Rs rates and soil organic carbon. Increasing in litter input into soil surface increased litter carbon loss by litter decomposition and increased Rs but did not motivate SOC content after two and a half years (Fang et al., 2015). From the information above showed that SOC took a long time to change in carbon cycle. The CU Centenary Park is the new urban park which still had a rebirth soil type and litterfall was removed by park managers everyday which affected to percent of SOC to make no different as much to motivate the changing in Rs rates.

4.4 Comparison of Rs among vegetation cover types



(a)



(b)

Figure 4.1 Boxplots display variations of Rs rates in the wet season (a) and Rs rates in the dry season (b) in three different vegetation land cover types: tree, grass, and shrub.

Vegetation cover types were classified into three types: tree, grass, and shrub. According to ANOVA and Tukey's post hoc test from the table 4.8 and 4.9, soil covered by tree had a significant lowest average Rs rates as compared to shrub and grass (p-value < 0.05) in the wet season. In the dry season, soil covered by grass had a significant high average Rs rates as compared to shrub (p-value <0.05). This probably due to the more density of the soil covered by shrub from water dehydrated in the dry season allowed less CO_2 to pass to the soil surface. These results suggested that vegetation cover influences the Rs rates. From the report about vegetation and Rs, vegetation probably affects Rs by soil microclimate, soil structure and the quantity of dead biomass in the soil. At the global scale, Rs rates correlate positively with litterfall rates (Raich and Tufekcioglu, 2000). Grasslands had about 20% average higher Rs rates than coniferous forests and broad-leaved forests (Raich and Tufekcioglu, 2000). In the urban area, Soil temperature below trees and shrubs were lower than soil temperature below grassland which found the maximum of soil temperature (Edmondson et al., 2016). From the information above can support that high level of soil temperature and dead biomass around the grassland could be the major factor for motivating microbial activities to release more CO_2 which resulted in average Rs rates around grass had high rates in both seasons. In the other hand, average Rs rates around trees had low rates in both seasons which properly due to litterfall from trees that was removed by park managers every day and the shade of leaves decrease soil temperature covered by trees. This activity led to has less input carbon source form litter into the soil covered by trees that affected to have low Rs rates in both seasons.

Table 4.8 Tukey's post hoc tests between Rs rates and vegetation cover types in the wet season

(I) LCtype	(J) LCtype	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Tree	Grass	-.504500866222*	.168018406952	.016	-.92409106981	-.08491066264
	Shrub	-.429729301111*	.168018406952	.044	-.84931950470	-.01013909753
Grass	Tree	.504500866222*	.168018406952	.016	.08491066264	.92409106981
	Shrub	.074771565111	.168018406952	.897	-.34481863847	.49436176870
Shrub	Tree	.429729301111*	.168018406952	.044	.01013909753	.84931950470
	Grass	-.074771565111	.168018406952	.897	-.49436176870	.34481863847

Table 4.9 Tukey's post hoc tests between Rs rates and vegetation cover types in the dry season

(I) LCtype	(J) LCtype	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Tree	Grass	-.242656281556	.142205582919	.223	-.59778445215	.11247188904
	Shrub	.173523377778	.142205582919	.453	-.18160479282	.52865154838
Grass	Tree	.242656281556	.142205582919	.223	-.11247188904	.59778445215
	Shrub	.416179659333*	.142205582919	.019	.06105148873	.77130782993
Shrub	Tree	-.173523377778	.142205582919	.453	-.52865154838	.18160479282
	Grass	-.416179659333*	.142205582919	.019	-.77130782993	-.06105148873

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Our study investigated on Rs rates between wet and dry seasons within the CU Centenary Park, Bangkok, Thailand. The park had Rs rates in the wet season (1.70±0.41 g CO_2 m^{-2} hr^{-1}) more than Rs rates in the dry season (1.29±0.34 g CO_2 m^{-2} hr^{-1}). The result occurred due to the soil moisture content in the wet season that had more percent to motivate Rs rates by microorganisms. Investigating relationships between Rs rates and environmental covariates, we found no statistically significant difference between Rs rates and soil temperature, soil moisture content and SOC in either seasons. Only the relationship between Rs rates and SOC in the dry season that showed the weak significance (p-value = 0.049). This result was presumably due to the short time of experiment that led to has less data and ranges for each environmental covariate to find out the significance in the study area. Nevertheless, we found significant difference of soil respiration rates among vegetation cover types. In the wet season, the soil under trees showed significant lower Rs rates than that under grass and shrub because of low SOC input from litterfall management and soil temperature. In the dry season, the soil under grass showed average Rs rates higher than that under trees and shrub because of high SOC input from biomass under the soil and soil temperature. This study provided an important information for the CU Centenary Park to minimize the carbon output for conservation the ecosystem in the future.

5.2 Recommendations

To achieve a better investigating and understanding of Rs rates and environmental covariates between the wet and dry seasons, the future study should expand the time of data collection and investigation in a long-term temporal variation. This could provide more possibility and opportunity to find the relationship between the factors and show the important order of environmental covariates to soil respiration rates for both seasons. Nitrogen is the source of microorganisms supply that is used to apply in form of fertilizer in the soil, so it is interesting to find the relationship between Rs rates and the quantity of nitrogen supply in the soil as well.

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Appendix

t-Test: Paired Two Sample for Means

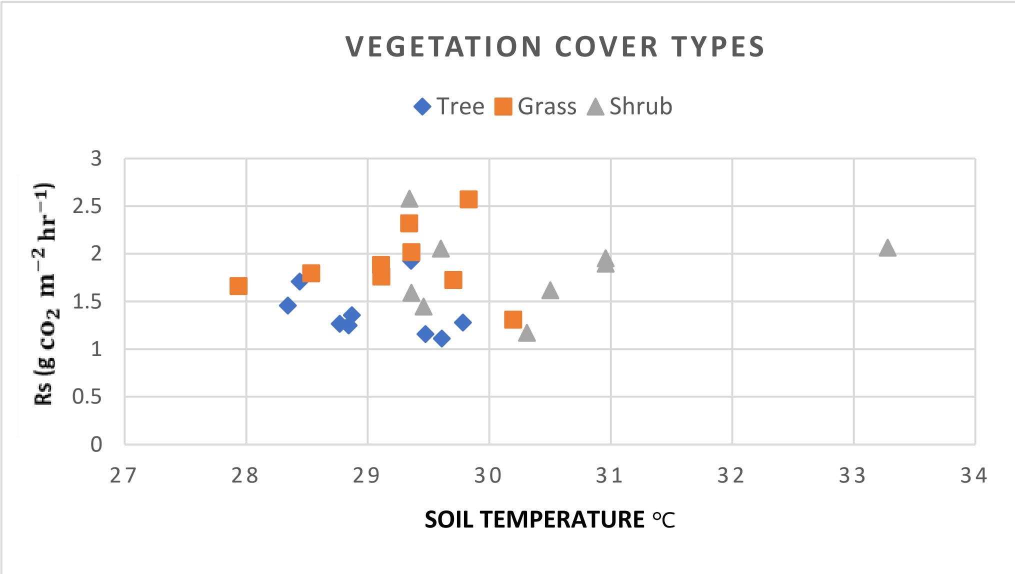
	Wet	Dry
Mean	1.701418	1.285363
Variance	0.168585	0.114254
Observations	27	27
Pearson Correlation	0.232535	
Hypothesized Mean Difference	0	
df	26	
t Stat	4.627129	
P(T<=t) one-tail	4.5E-05	
t Critical one-tail	1.705618	
P(T<=t) two-tail	8.99E-05	
t Critical two-tail	2.055529	

Significant difference of Rs rates between both seasons (p-value < 0.0001)

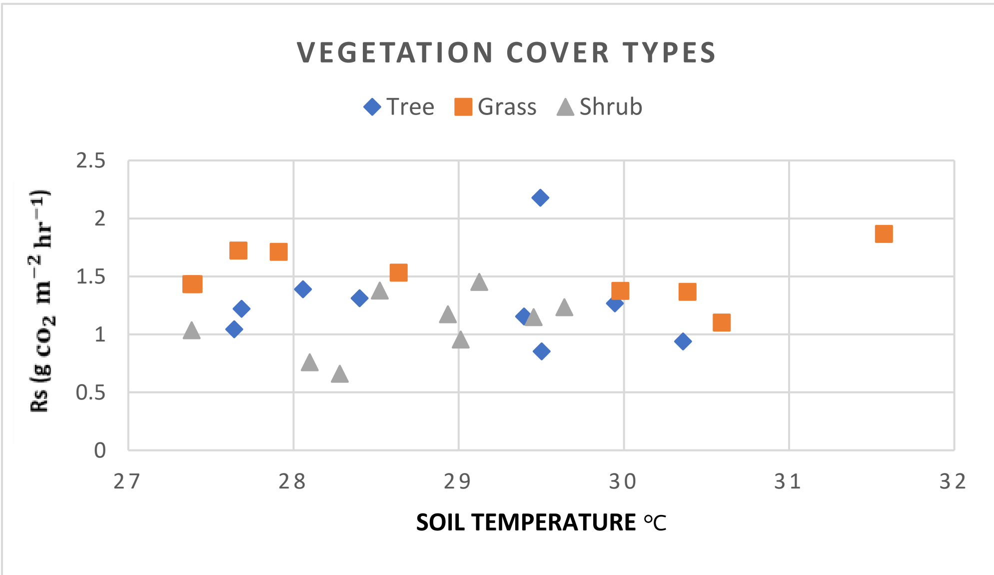
t-Test: Paired Two Sample for Means

	Wet	Dry
Mean	18.16111	9.682222
Variance	132.4103	51.50159
Observations	27	27
Pearson Correlation	0.789506	
Hypothesized Mean Difference	0	
df	26	
t Stat	6.022407	
P(T<=t) one-tail	1.16E-06	
t Critical one-tail	1.705618	
P(T<=t) two-tail	2.32E-06	
t Critical two-tail	2.055529	

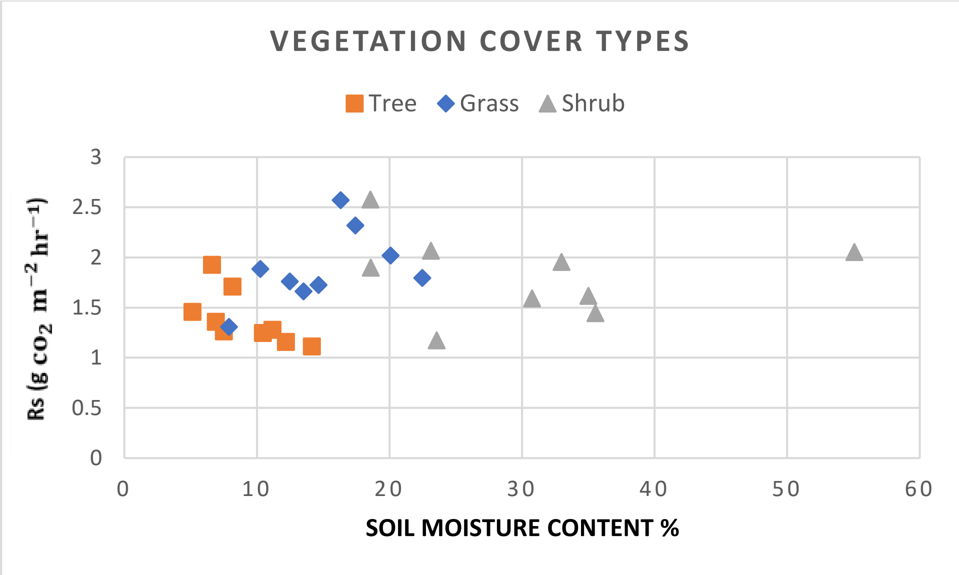
Significant difference of soil moisture content between both seasons (p-value < 0.0001)



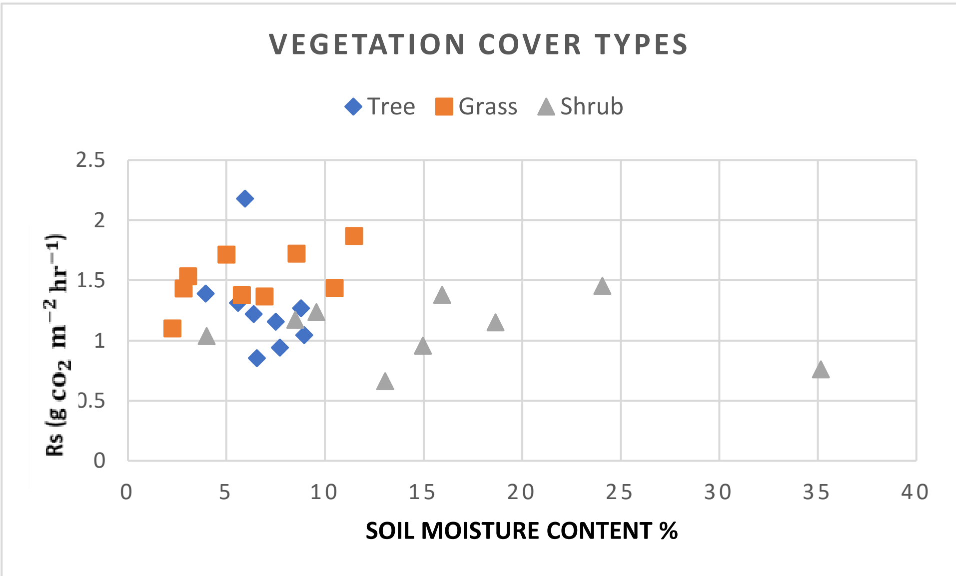
Scatter plot between Rs rates and soil temperature among vegetation cover types in the wet season



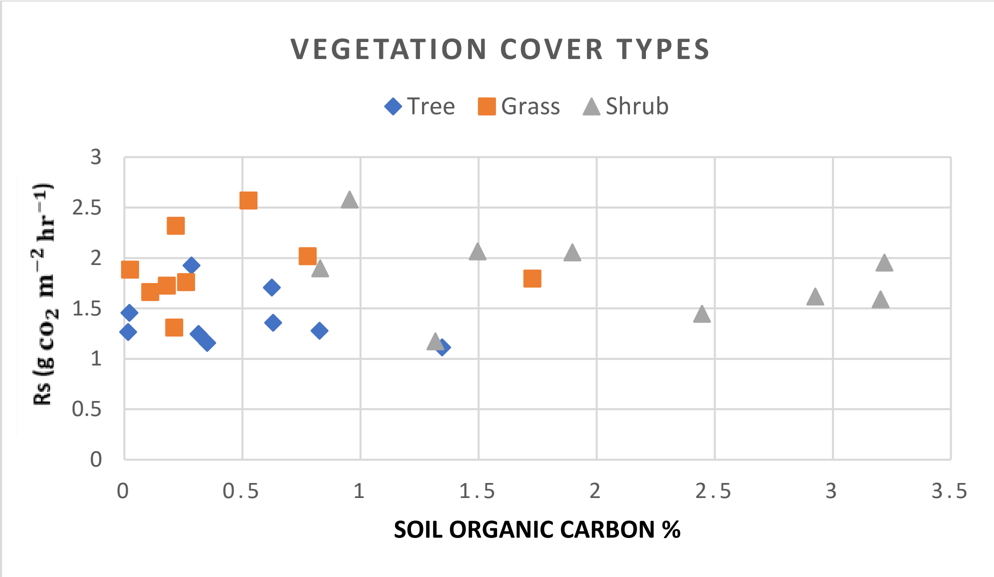
Scatter plot between Rs rates and soil temperature among vegetation cover types in the dry season



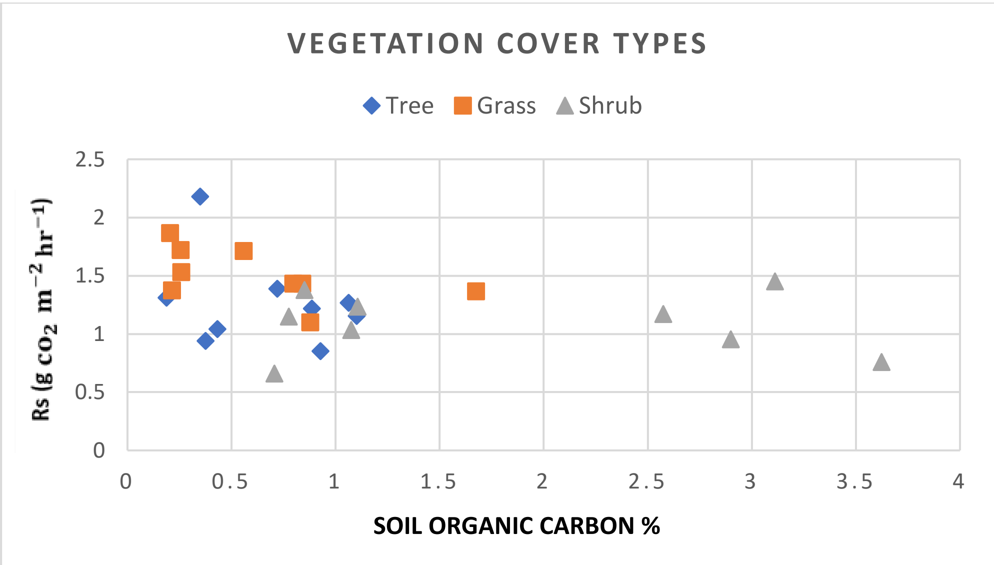
Scatter plot between Rs rates and soil moisture content among vegetation cover types in the wet season



Scatter plot between Rs rates and soil moisture content among vegetation cover types in the dry season



Scatter plot between Rs rates and soil organic carbon among vegetation cover types in the wet season



Scatter plot between Rs rates and soil organic carbon among vegetation cover types in the dry season

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