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Soil Respiration in Subtropical Disturbed Mixed Pine Forest and Undisturbed Mixed Oak Forest of Manipur, North-Eastern India

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Abstract: ***Seasonal changes in soil respiration and its relationship with abiotic variables was studied in subtropical disturbed mixed pine forest and undisturbed mixed oak forest of Motbung and Saparmeina hill, Senapati Distirct, Manipur located at a distance of 23.6km and 30km respectively from the Imphal city. Forest site I at Motbung falls at 24.99 N^0 latitude and 93.90^0E longitude at an altitude of 970m and forest site II falls at Saparmeina falls at 25.04^0N and 93.94^0E at an altitude of 933m from the mean sea level by using alkali absorption method. The rate of soil respiration was highest during rainy season (472.98mg$CO_2m^{-2}hr^{-1}$ in disturbed pine forest site I and 534.72mg$CO_2m^{-2}hr^{-1}$ in undisturbed mixed oak forest site II) and minimum during winter season (85.72mg$CO_2m^{-2}hr^{-1}$ in disturbed pine forest and 105.35mg$CO_2m^{-2}hr^{-1}$ in undisturbed mixed oak forest). Aboitic variables (i.e. soil temperature, soil moisture, soil pH and soil organic carbon) also exhibited a positive significant relationship with the rate of soil respiration.***

Keywords: Soil respiration; disturbed mixed pine (forest site I) and undisturbed mixed oak forest (forest site II), abiotic variables

1. Introduction

Soil respiration is defined as the total CO_2 production in intact soils resulting from the respiration of soil microorganisms, roots and mycorrhizae. It is a useful parameter for studying soil biological activity, carbon cycling and energy flow in an ecosystem and is also considered as an important index of the decomposition system (Singh and Gupta, 1977) Hashimoto et al (2004) studied soil respiration in tropical forest of northern Thailand and reported that soil respiration was relatively high during the rainy season and low during dry season, although inter-annual fluctuation were large. Laishram et al, 2002; Bijayalaxmi and Yadava 2008) studied soil respiration and its relationship with abiotic factor in different forest but limited information is available on soil respiration in subtropical disturbed pine and undisturbed mixed oak forests. Therefore, the present study was carried out to investigate the seasonal change of soil respiration and its relationship to abiotic variables in subtropical disturbed mixed pine and undisturbed mixed oak forests of Manipur.

2. Study Area

The forest site is located at Motbung that lies ay 24.99^0N and 93.90^0E at an altitude of 970 m from the mean sea level and the forest site II is located at Saparmeina that lies at 25.04^0N and 93.94^0N at an altitude of 933m from the mean sea level. The average annual rainfall of the study sites is 1131.8 mm. the mean monthly maximum ranges from 4.9^0C (December) to 28.8^0C (July) during the study period as shown in figure 1.

The disturbed mixed pine forest site I is dominated by *Pinus Khesiya* Royle, *Bauhinia variegate*, *Emblica officinalis*, *Cedrellatoona* and other shrubs and herbs species. The disturbance occurs due to collecting of timber, grazing and other biotic disturbances. The undisturbed mixed oak forest site II is dominated by *Quercus serrate*, *Schimawallichii*, *Quercuspolystachya* and other herbs and shrubs.

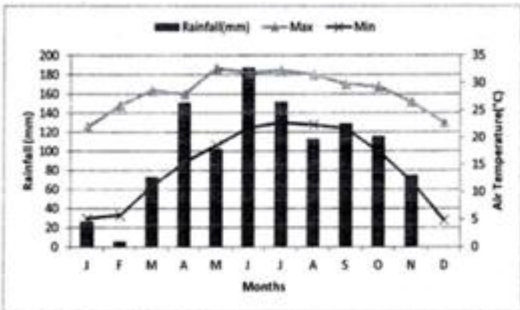

Figure 1: Clinical data of the study period

3. Materials and methods

The soil samples were collected from the upper layer of 0-10 cm in depth at monthly interval and brought to the laboratory for further analysis. The soil samples were sieved (<2mm) to remove stones, roots etc. Soil texture were analysed by pipette method. A soil thermometer was used to determine soil temperature. The soil moisture was measured by gravimetric method (oven dry at 105^0C till constant weight). Soil pH was determined by Walkley Black method, total nitrogen by Kjeldahl method, Phosphorous by molybdenum blue method (Anderson and Ingram, 1993) Potassium was estimated by Flame photometer (Jackson, 1958).

Soil respiration rate was measured by alkali absorption method using open-ended aluminium cylinder (13cm diameter and 25cm tall) inserted 10cm depth into the soil. Ten identical were used in each forest. Fifty ml of 0.25N NaOH solution in each cylinder was maintained for 24hr and all green vegetation inside the cylinder was removed. After 24 hr the alkali was titrated with 0.25N HCl solution using phenolphthalein as an indicator. CO_2 absorbed from the soil was calculated using the formula proposed by Anderson and Ingram (1993): VXN=CO_2 mg, where v=volume of HCl, N=Normality of HCL.

Correlation and regression coefficient analysis were done to assess the relationship between soil respiration and abiotic variables. ANOVA was also used to analyse the data.

4. Result

The soil of forest site I is sandy loam in texture (sand 42%, silt 25% and clayed 33%). The soil temperature ranges 8^0C to 30^0C, soil pH ranged from 4.63 to 6.67, soil moisture ranged from 21.15 to 26.13% soil organic carbon ranged from 0.727 to 4.8%, soil total nitrogen ranged from 0.092% to 0.587%, soil available phosphorous 0.021 to 0.096% and soil potassium ranged from 0.115 to 0.482% as shown in Table 1 and 2.

The soil of forest site II is clayed loam in texture (sand 32%, silt 25% and clayed 42%). The soil temperature ranged from 9^0C to 30^0C, soil pH ranged from 4.69 to 6.66, soil moisture ranged from 20.15 to 26.13%, soil organic carbon ranged from 0.728 to 4.90%, soil total nitrogen ranged from 0.125 to 0.692%, soil available phosphorous ranged from 0.023 to 0.96% and soil potassium ranged from 0.115 to 0.482% as shown in Table 1 and 2.

The rate of soil respiration ranged from 85.72 to 472.98mg$CO_2m^{-2}hr^{-1}$ in forest site I and 105.35 to 475.18 mg$CO_2m^{-2}hr^{-1}$ in forest site II respectively in different months throughout the year in both the study sites. It was highest in the rainy season followed by summer and winter seasons as shown in fig 2. The analysis of variance (ANOVA) indicated a significant differences ($P<0.01$) in the rate of soil respiration among different seasons in both the study sites as shown in Table 3. The rate of soil respiration was significantly positively correlated with soil temperature ($r=0.86$, $P<0.01$), soil moisture ($r=0.69$, $P<0.01$), soil organic carbon ($r=0.48$, $P<0.01$) and insignificant statistically in pH ($r=0.04$, $P<0.05$) in forest site I. Similar pattern of linear relation is observed in forest site II for soil respiration with soil temperature ($r=0.77$, $P<0.01$), soil moisture ($r=0.55$, $P<0.01$), soil organic carbon ($r=0.55$, $P<0.01$) insignificant with soil pH ($r=0.285$, $P>0.05$) as shown in table 4. The F-value of the regression, models for forest site I is 34.10($P<0.01$) and 13.15 ($P<0.01$) for forest site II. In forest site I, the total variation in the soil respiration is explained as 82% ($R^2=0.817$) by the abiotic and that of forest site II explained as 63% by the same abiotic variables as shown in table 5.

The fitted regression model for forest site I and forest site II are given by

Soil Respiration (forest site I)=-0.92+16.62(Soil temperature)+21.79(soil moisture)-87.17(soil pH)-10.55(soil organic carbon).

Soil Respiration (forest site II) = 165.30 + 21.39 (Soil Temperature) – 21.79 (Soil moisture) + 1.94 (Soil pH) + 42.05 (Soil Organic Carbon).

5. Discussion

The rate of soil respiration was found to be maximum in rainy season and minimum in winter season in both the study sites. Minimum rate of soil respiration in winter season in both the study sites may be due to low moisture content, temperature and as a result of decreased microbial population. In rainy season, due to high soil moisture and soil temperature, the soil microorganisms become more active causing enhancement in the decomposition of litter materials and finally contributing to more CO_2 emission from the soil. Table 6 compares the ranges of soil respiration values estimated in the present study with that of different Pine and Oak forest ecosystem of the world. The variation in soil respiration rate reported by different workers could be influenced by used methods, volume of alkali solution, different strength, exposure time and time intervals (Gupta and Singh, 1977).

Soil respiration is highly related with soil temperature and soil moisture. This is due to the fact that the biological activities in soil are strongly affected by the abiotic variables. Several workers have also shown that there is a significant positive correlation of soil respiration rate with soil moisture and temperature in different forest ecosystem (Laishram et al 2002, Y Launet et al, 2012, Lamnangbi et al, 2017). In the present study, the correlation matrix and regression coefficient of soil respiration rate with abiotic variables such as soil temperature, soil moisture, soil organic carbon and soil pH indicate a significant positive effect of abiotic variables. However, soil moisture, soil temperature and soil organic carbon have strong influence on soil respiration rate in comparison to soil pH in forest site I and site II. Hence, the present study concludes that soil respiration rate is highly influenced by seasons and positively correlated with abiotic variables.

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Table 1: Abiotic variables and physicochemical characteristics of soil

Abiotic variables	Forest site I	Forest site II
Soil temperature (^{0}C)	20.33	21.32
Soil moisture (%)	24.60	24.75
Rainfall (mm)	94.31	94.31
Air temperature(^{0}C)	23.65	23.65

Table 2: Soil physicochemical characteristics

Texture	Forest site I	Forest site II
Sand (%)	42	32
Silt (%)	25	25
Clay (%)	33	42
Soil organic carbon (%)	0.73-4.8	0.73-4.9
Soil total N (%)	0.09-0.58	0.125-0.692
Soil available P (%)	0.021-0.096	0.023-0.096
Soil Potassium K (%)	0.115-0.482	0.115-0.482

Table 3: Variation in soil respiration in forest Site I and forest Site II

Site	Season	N	Mean	S. D	95% CI for mean		Test value
					Lower	Upper	
I	Summer	9	193.17	30.61	169.64	216.70	F=62.23 P<0.01
	Rainy	15	377.80	82.85	331.92	423.68	
	Winter	12	122.50	43.38	94.94	150.07	
	Total	**36**	**246.54**	**130.16**	**202.50**	**290.59**	
II	Summer	9	180.28	35.71	152.83	207.73	F=28.55 P<0.01
	Rainy	15	358.64	128.19	287.65	429.63	
	Winter	12	117.97	16.05	107.77	128.17	
	Total	**36**	**233.83**	**137.70**	**187.24**	**280.42**	

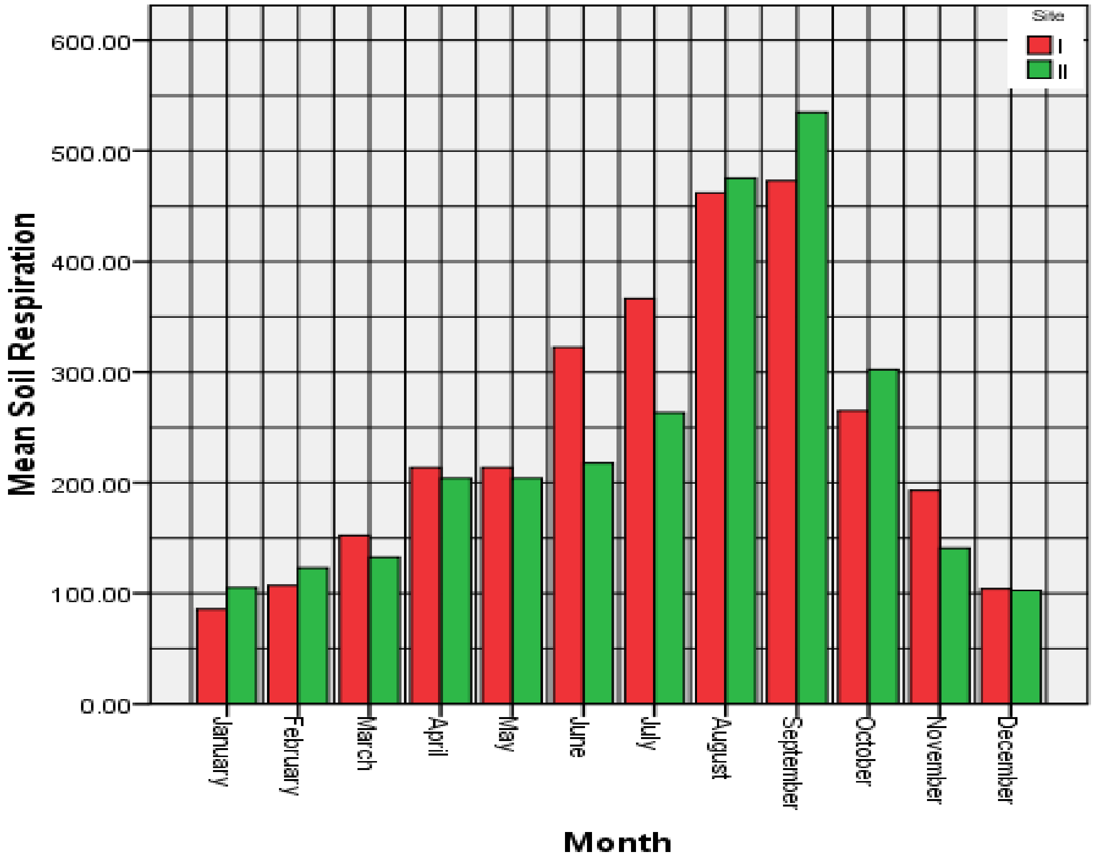


Figure 2: Monthly variation in soil respiration rate at two sites

Table 4: Correlation Matrix between soil repiration and temperature, moisture, pH and organic carbon

Site	Soil Parameters	Respiration	Temperature (^{0}C)	Moisture (%)	pH	Organic Carbon (%)
I	Respiration	1				
	temperature (^{0}C)	0.86** P<0.01	1			
	Moisture (%)	0.69** P<0.01	0.40** P<0.01	1		
	pH	0.04 P>0.05	0.42** P<0.01	-0.33** P<0.01	1	
	Organic Carbon (%)	0.48** P<0.01	0.64** P<0.01	-0.08 P>0.05	0.87** P<0.01	1
II	Respiration	1				
	temperature (^{0}C)	0.77** P<0.01	1			
	Moisture (%)	0.55** P<0.01	0.50** P<0.01	1		
	pH	0.284 P>0.05	0.49** P<0.01	-0.06 P>0.05	1	
	Organic Carbon (%)	0.55** P<0.01	0.56** P<0.01	-0.07 P>0.05	0.77** P<0.01	1

**significant at 0.01 probability level

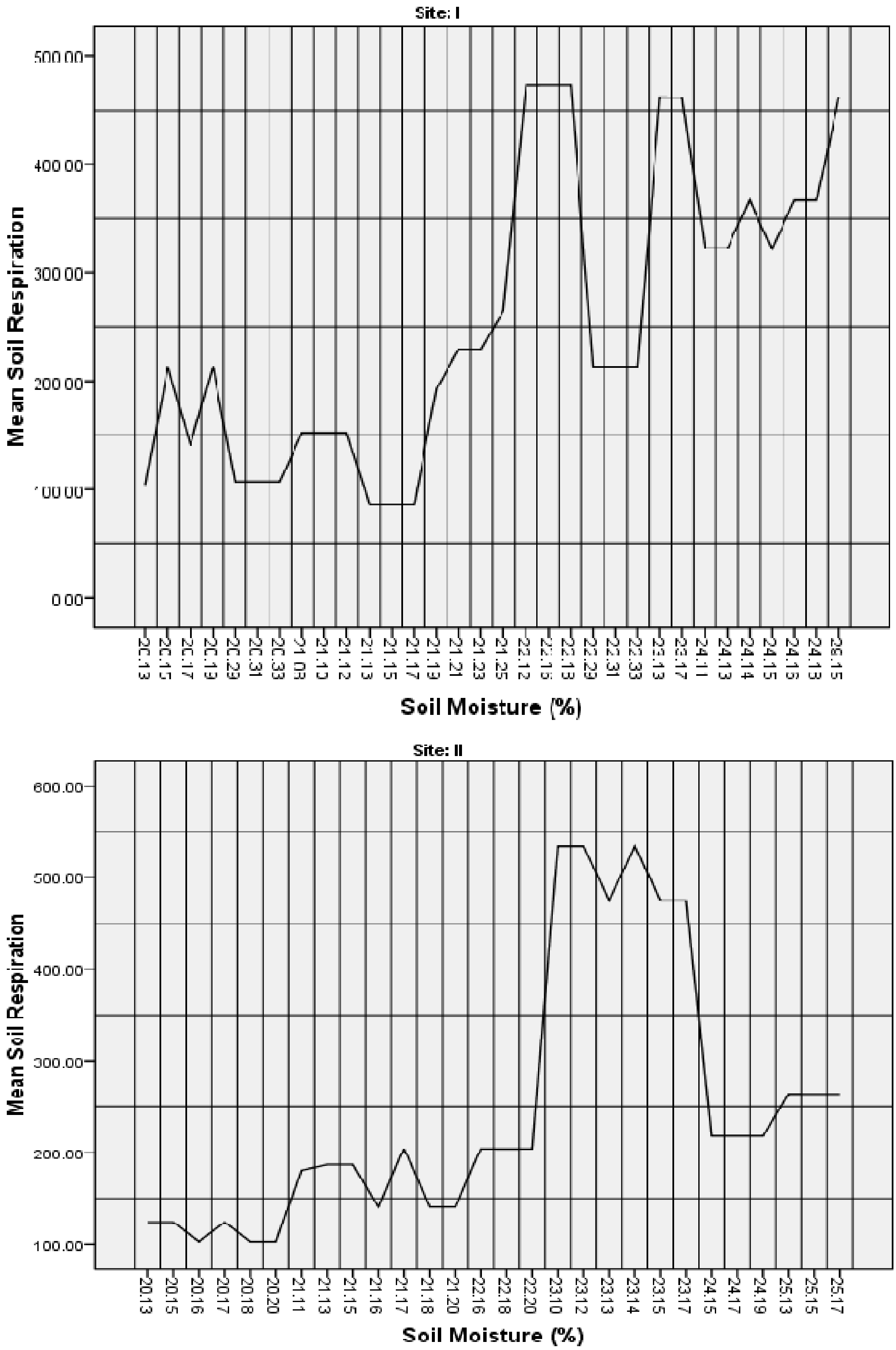
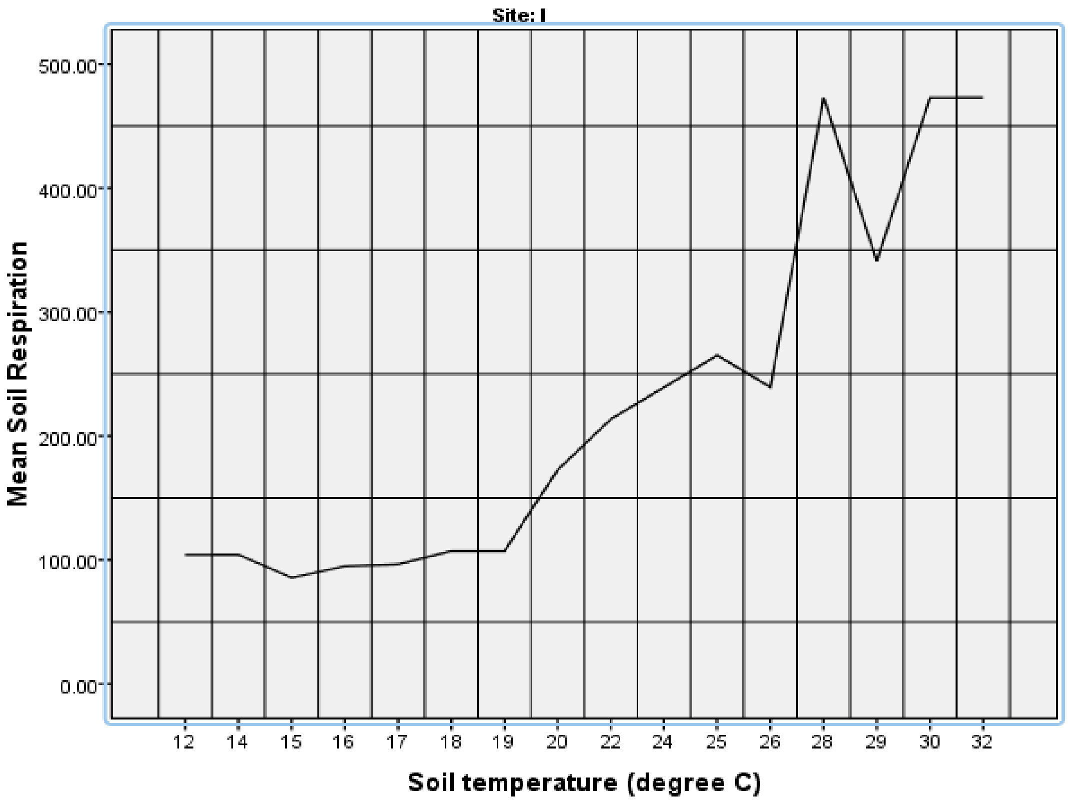


Figure 3: Variation in soil respiration rate with respect to soil moisture (%)



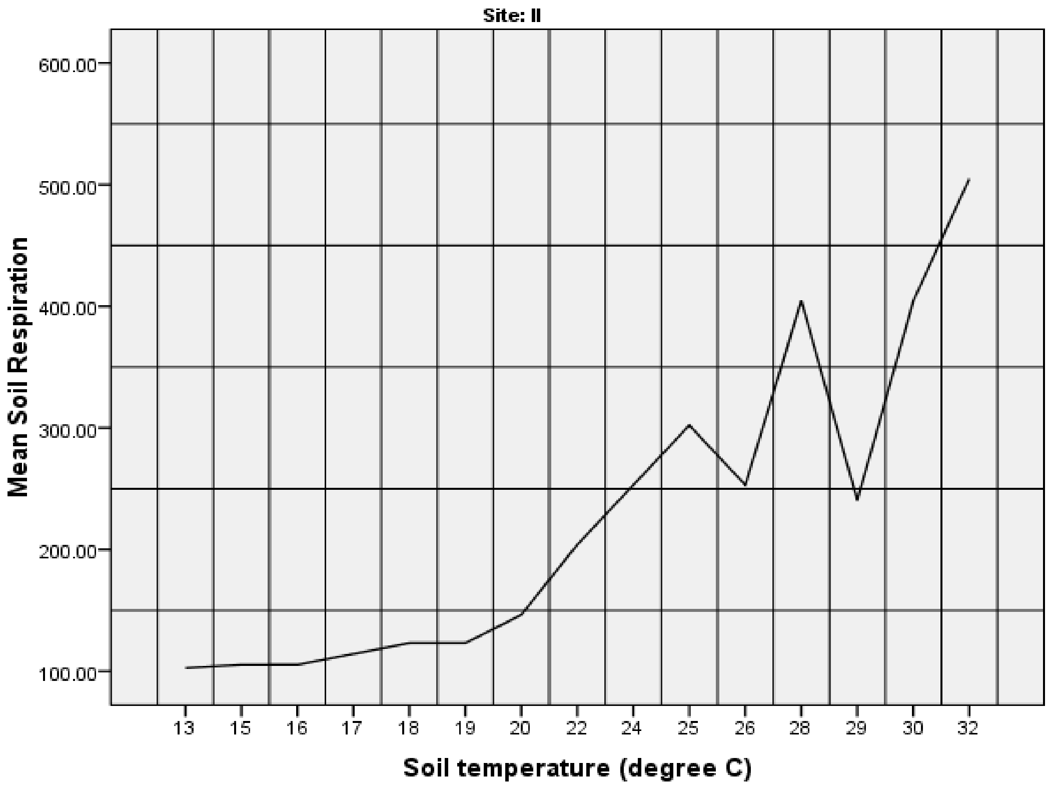


Figure 4: Variation in soil respiration rate with respect to soil temperature (^{0}C)

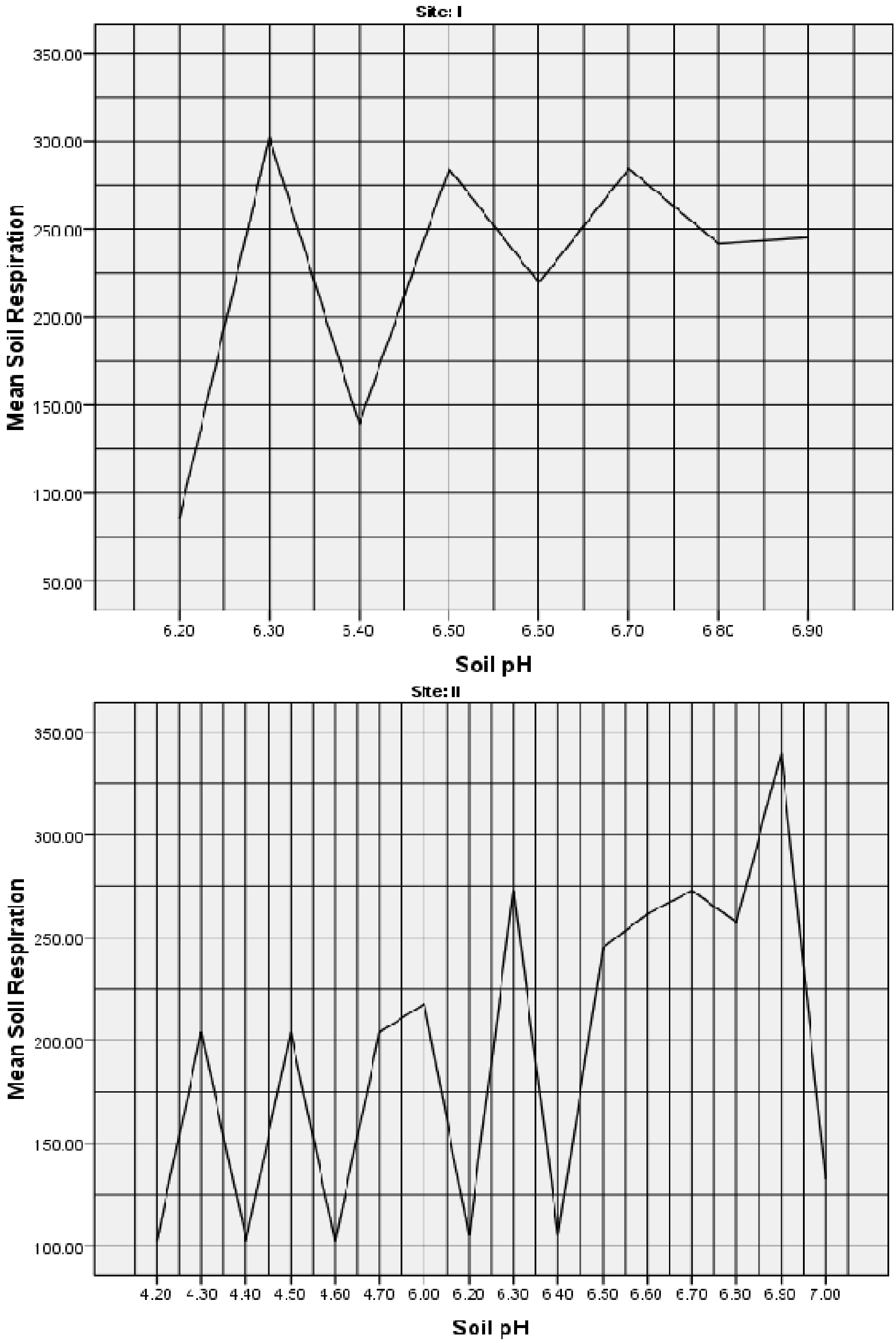


Figure 5: Variation in soil respiration rate with respect to soil pH

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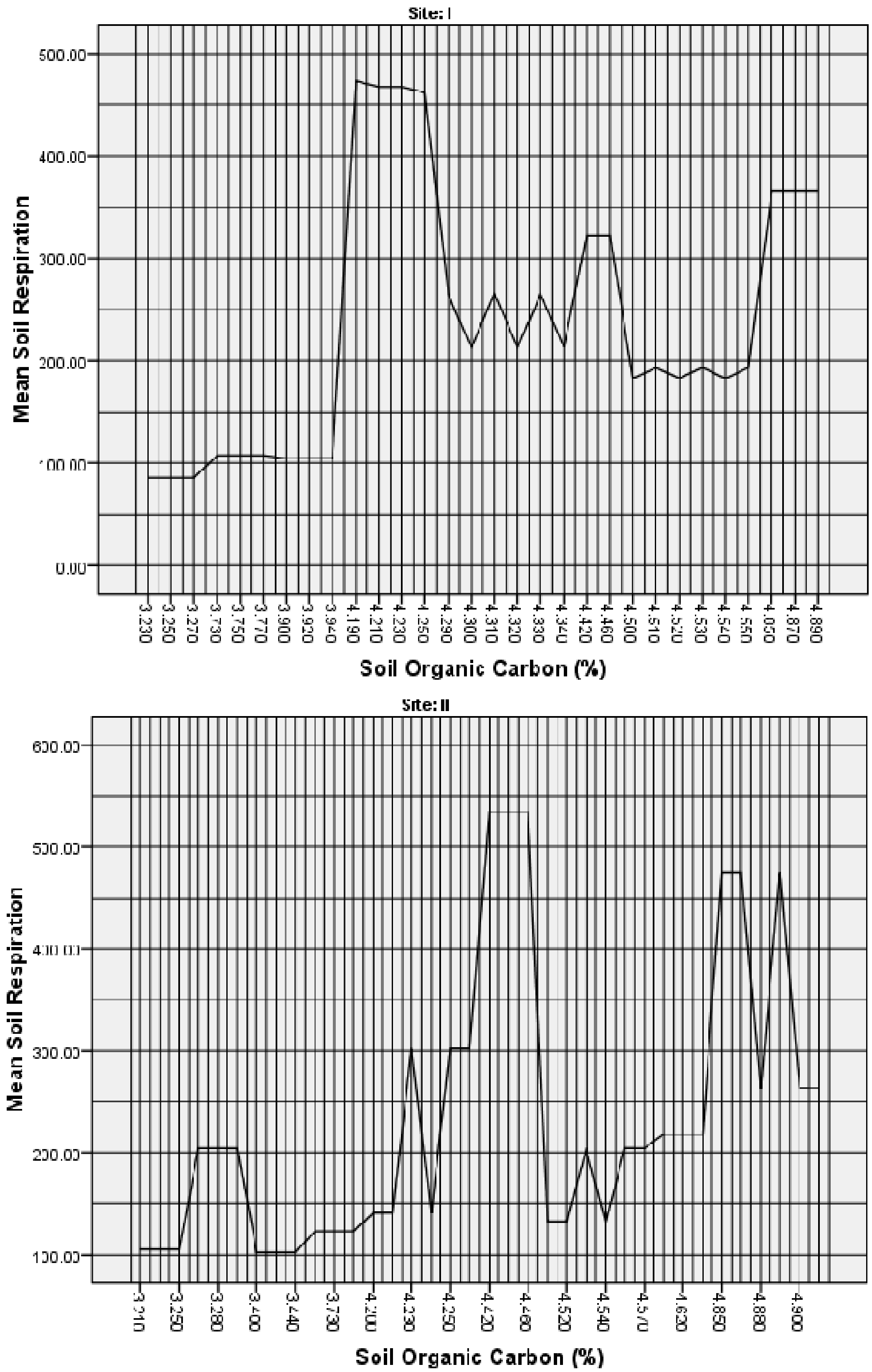

Figure 6: Variation in soil respiration rate with respect to organic carbon

Table 5: Regression Coefficients on Soil respiration rate according to abiotic variables

Site	Abiotic variable	b	S.E	t	P-value	95%CI for b		Diagnostic
						Lower	Upper	
I	(Constant)	-0.92	345.55	-0.01	>0.05	-705.67	703.84	F=34.10; P<0.01 R^2=82%
	Temperature (^{0}C)	16.62	2.48	6.71	<0.01	11.57	21.67	
	Moisture (%)	21.79	6.69	3.26	<0.01	8.14	35.44	
	pH	-87.17	50.73	-1.72	>0.05	-190.64	16.30	
	Organic carbon (%)	-10.55	30.18	-0.35	>0.05	-72.11	51.00	
II	(Constant)	165.30	318.35	0.52	>0.05	-483.98	814.59	F=13.15; P<0.01 R^2=63%
	Temperature (^{0}C)	21.39	4.59	4.66	<0.01	12.03	30.75	
	Moisture (%)	-28.11	18.10	-1.55	>0.05	-65.03	8.81	
	pH	1.94	25.96	0.08	>0.05	-51.00	54.88	
	Organic carbon (%)	42.05	46.36	0.91	>0.05	-52.50	136.59	

Table 6: Comparison of soil respiration rate ($mgCO_2m^{-2}hr^{-1}$) in different Pine and Oak forest ecosystem of the world

Sl. No.	Forest Type	Country	Soil respiration Rate	Authors
1	Mixed Oak	Belgium	20-15	Froment (1972)
2	Pine forest	South Carolina, USA	58-10	Reinke et al (1981)
3	Oak forest	India	75.83	Rout and Gupta (1989)
4	Oak forest	India	410.8-604	Laishram et al (2002)
5	Pine forest	Australia	92.2	Ralf and Klaus (2002)
6	Mixed oak	India	168.68-193.74	Bijayalaxmi (2005)
7	Tropical forest and oil palm plantation	Malaysia	707-966	Adachi et al (2006)
8	Deciduous forest	Indiana, USA	115.52	Wayson et al (2006)
9	Mixed oak forest	India	102-320	Pandey et al (2010)
10	Subtropical Montane	India	91.53-366.67	Arila 2017
11	Subtropical forest Site I. Disturbed mixed pine forest Site II. Undisturbed mixed oak forest	Manipur, India	 85.72-472.92 105.35-475.18	 Present Study Present Study