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STUDY OF FOREST SOIL THROUGH LINEAR REGRESSION BETWEEN SOC AND SOIL PROPERTIES IN SHINKIARI-MANSEHRA, KHYBER PAKHTUNKHWA PAKISTAN

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ABSTRACT

The present study was design to know the role of forest soil which play an important role in balancing and storing of the earth 's carbon, which ultimately reduces the global warming consequences. Nonetheless, this balance of carbon stock storage is disturbed rapidly over the last several decades because of deforestation and change in landscape pattern. Chir Pine *(Pinus roxburghii)* forest of Shinkiari-Mansehra is under constant threat because of deforestation and change in land-use patterns. Therefore, the current study was designed to evaluate the impact of deforestation and land-use pattern on soil-carbon stock through developing an inventory at the national level on the soil of Chir Pine (*Pinus roxburghii*) forest, Shinkiari-Mansehra. Forest 's soil is one of the sources of carbon sequestration. It has been estimated that approximately 1500 (±20 %) Gt of carbon is sequestered in 1m soil and detritus whereas about 800 Gt of carbon is pooled in forest soils globally. Forest sequestered a major portion of the carbon in the soil. Thus, forest ecosystem plays an important function to balance the climate of the country. A slight imbalance in a forest ecosystem can cause a disturbance in the carbon cycle thus climate change may occur. The present study will be important to explore the carbon in the soil of Chir of the Chir Pine (*Pinus roxburghii)* forest. Our data showed that stepwise regression model is best suitable for precise and accurate predicting of soil carbon stocks in relation to soil properties (BD, texture, pH, EC, and SOC stocks) Chir pine (Pinus roxburghii) forest of Shinkirai-Khyber Pakhtunkhwa. The overall correlation of the SLR model was good with R2 value (0.81) which explained 81 % of the SOC data with elevation and forest density and only 19 % data left unexplained. There was a weak correlation with SOC and BD, pH, and EC.

KEY WORDS: Forest soil, Linear Regression, shinkiari, SOC, carbon Sequestration, chir pine.

INTRODUCTION:

Forest soil is one of the sources of carbon sequestration. It has been estimated that approximately 1500 (±20 %) Gt of carbon is sequestered in 1m soil and detritus whereas about 800 Gt of carbon is pooled in forest soils globally (Melvin,1996;). Indian forest soils sequestered nearly 4.1 Gt of carbon (Chhabra *et al*., 2003; Dewar, 1991). Pakistan occupies less than 5 % of the forest in the world. Therefore, forests soil carbon storage is extremely low in Pakistan than other forest soils around the world. It has been estimated that total soil carbon stock was 8.0 to 9.2 t/ha in the Murree+Lethrar forests, while 30.2 t/ha in the Tropical Thorn Forest (Riverine Forests) of the Jhelum district (Kimble *et al*., 1990; Nizami, 2010; Saeed *et al*., 2016; Ali *et al*., 2019).

An accurate estimate of soil carbon stocks primarily depends on the equilibrium between carbon addition and release to the atmosphere. Soil carbon stock distribution along an altitudinal gradient is directly related to climatic factors such as precipitation and temperature (Hengl et al., 2015; Khan et al., 2019). Soil physical characteristics such as soil moisture and texture may affect the SOC distribution later or horizontally (Gomes et al., 2019; Mayer, 1994). Gomes et al (2019) found that around 57 % of soil carbon stocks were sequestered in Ferralsols and Acrisols than Luvisols and Histosols.

Forest soil sequestered more carbon and managed the balance of carbon and nitrogen cycles between earth and atmosphere. Forest soil carbon stocks mitigate the climate change and can sequester enough carbon than barren soils (Jandl et al., 2019; Ontl et al., 2013). Forest soil carbon stocks conservation need to be addressed because of deforestation and change in land-use pattern cause depletion in soil carbon stocks.

The present study will be important to explore the carbon in the soil of Chir of the Chir Pine (*Pinus roxburghii)* forest.

The bulk density of the soil is improved when organic matter is present. The bulk densities are determined in large part by factors such as the soil quality, the soil health, and the level of soil compaction (Gopinath et al., 2019). Tropical forest soils are acidic therefore organic matter mineralization occurs rapidly under acidic conditions (Binkley and Richter, 1987; Fujii, 2014; Dilawar et al., 2019). This acidification induces essential macronutrient loss such as potassium, magnesium, phosphorus thus promotes leaching. These soils are deficient in potassium, magnesium, phosphorus, and anions (Fujii et al., 2010). Aluminum toxicity is observed in plants when grown over-acidic soils (Kochian et al., 2004; Zaidey et al., 2010). However, there is contradictory evidence on the relationship between pH and organic matter mineralization. Some reported that soil pH less than 5 may not promote organic carbon mineralization (Zelles et al., 1987; Persson et al., 1989; Spain, 1990).

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Study Area:

The study was carried out in 9 forest compartments of the Chir-Pine (*Pinus roxburghii)* of Shinkiari-Mansehra. The study site is situated between 34º280N latitude and 73º170E longitude with an altitudinal gradient from 600-2260 m asl and elevation of 1100-1750 m covered an area of 140.4 ha in Shinkiari-Mansehra-Khyber Pakhtunkhwa (http://www.maplandia.com/pakistan/n-w-f-p/mansehra/shinkiari-34-28- 0-n-73-17-0-e/).

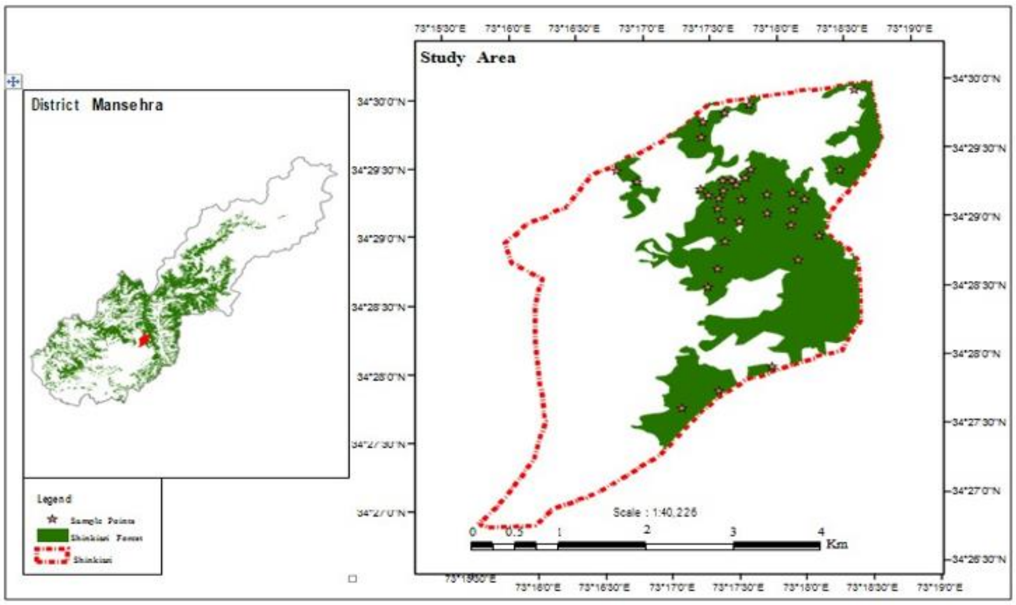

Figure 1 Location map of Chir-Pine (Pinus roxburghii) of Shinkiari- Mansehra (Nizami, 2010). Shows elevation on a map.

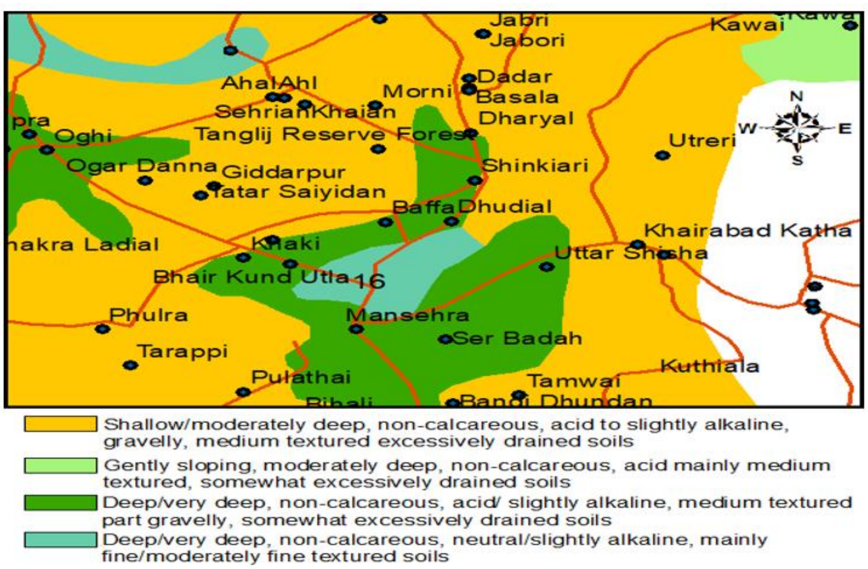

Figure 2 Soils of Shinkiari (adopted from Soil Survey of Pakistan, 2008).

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Material and Methods:

Sub-tropical forests (*Pinus roxburghii*)

In Pakistan, the forest is classified as high even-aged forests i.e., Chir Pine (*Pinus roxburghii*) participates in a major part of the top story (i.e. 36 m and 2 m in girth). In the May- June, Chir pine release leaf due to climate change variations and catching fire in Chir pine forests is common if proper precautionary measures are not adapted to minimize the risk.

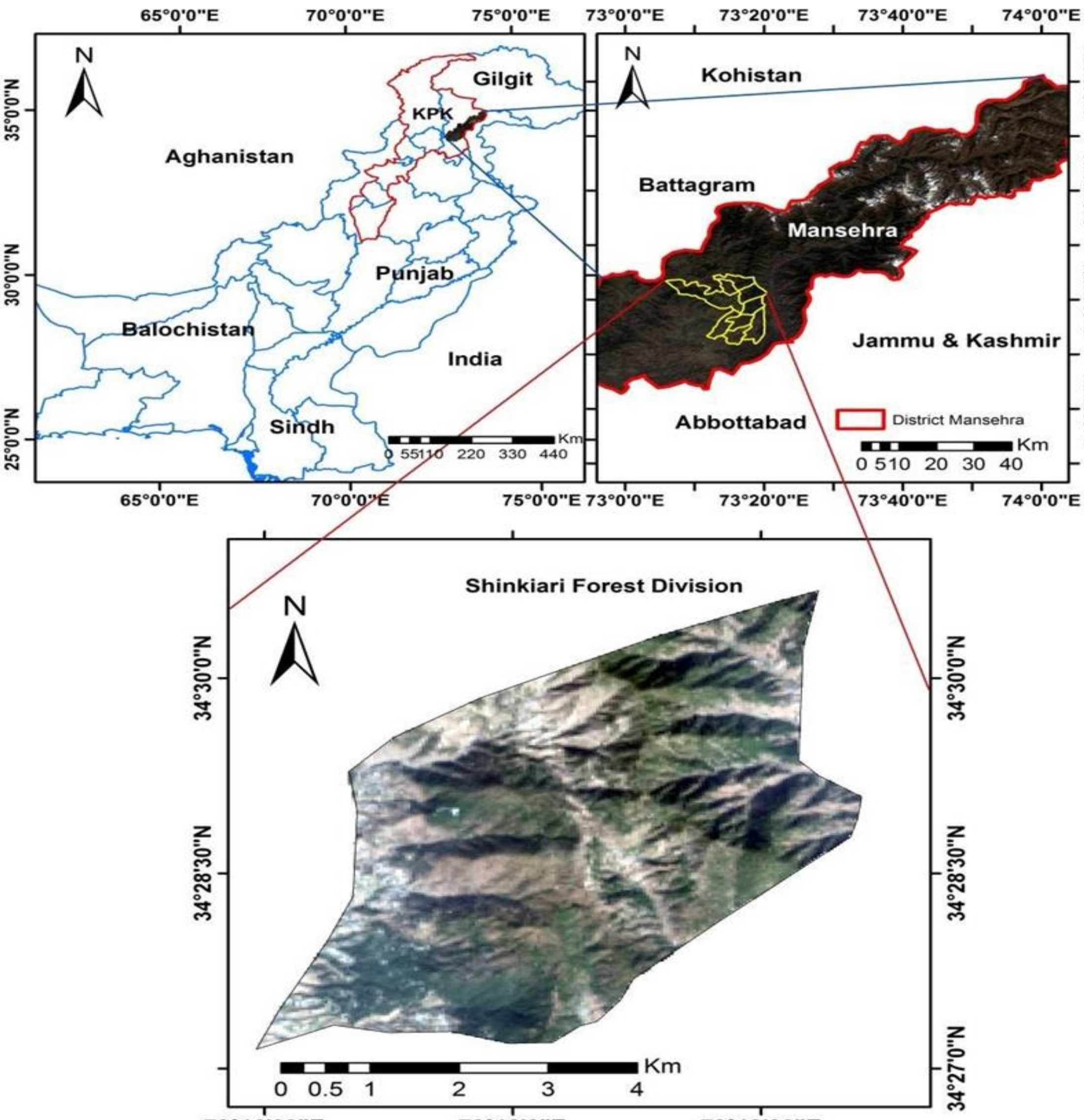

Figure 1 Map of the Research area

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Table 1 Vegetation and Soil Radiometric Derived from Sentinel-2 Image

Indices	Bands Used
Normalized Vegetation Index (NDVI)	(B8- B4) ÷ (B8A + B4)
Soil Adjusted Vegetation Index (SAVI)	((B8 - B4) ÷ (B8A + B4 + 0.5)) × (1+0.5)
Bare Soil Index (BSI)	[(B11-B4)-(B8-B2)]÷ [(B11+B4)-(B8+B2)]
Brightness Index (BI)	$[(B4^2+B3^2+B2^2)/3)]^{0.5}$
Colour Index (CI)	(B4-B2)/(B4+B2)

RESULTS AND DISCUSSION:

The study entitled, ―Carbon Stocks Assessments in the soils of Chir Pine (*Pinus roxburghii*) forest of Shinkiari-Mansehra‖ included the general survey for the site selection, periodical analyses of forest and soil and calculation of nutrient balancing. The results of these basic components of the study are presented and briefly discussed in the following sections.

The Mansehra Granitic Complex (MGC) is exposed in the northwest (NW) in Pakistan and is contained of Mansehra Granite (MG), Hakale Granite (HG), Karkale & Sukal Granites along with pegmatites, aplites, microgravity (MIG) and leucogranitic (LG) bodies. Paleozoic Cambrian Mansehra Granite Cm Augen and flaser granite and granodiorite gneiss, megacrystic granite, intruded by tourmaline granite, metagabbro, amphibolite, and pegmatite. Precambrian Proterozoic Tanawal Formation PCt Predominantly composed of arenaceous sequence comprising quartzite, fine- grained quartzose schist, biotite quartz schist, with subordinate argillaceous and carbonaceous rocks. Cenozoic Holocene Surficial Deposit Qa Loose clay, silt, sand, and gravel (Blatt *et al*., 2005).

Table 2 Plot-wise Geographic Locations and Topographic factors

Plot No	X	Y	Elevation (m)	Slope (Degree)	Aspect (degree)
1.	73.2816	34.452	1024	3.77	225.00
2.	73.2928	34.4636	1123	28.20	269.50
3.	73.2839	34.4645	1027	8.55	262.88
4.	73.2829	34.4556	1006	5.25	246.04
5.	73.2872	34.4552	1028	6.08	336.80
6.	73.2882	34.4633	1016	21.07	321.88
7.	73.2869	34.4875	1200	18.72	277.91
8.	73.287	34.4767	1024	7.60	282.10
9.	73.2891	34.4839	1154	18.61	291.95
10.	73.2921	34.4643	1054	15.50	297.00
11.	73.2986	34.4746	1148	26.95	211.50
12.	73.2892	34.484	1157	18.61	291.95
13.	73.2844	34.4671	1019	3.25	189.46
14.	73.2883	34.4869	1145	18.40	275.63
15.	73.2886	34.4619	1026	6.78	191.31
16.	73.2969	34.4631	1160	26.50	245.11

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17.	73.2846	34.4658	1039	9.06	232.13
18.	73.288	34.468	1045	17.57	283.63
19.	73.2981	34.4636	1145	19.40	263.16
20.	73.2887	34.4675	1063	13.91	250.20
21.	73.2826	34.4688	1016	10.47	280.18
22.	73.2891	34.4852	1175	29.92	220.40
23.	73.2887	34.463	1049	13.18	305.27
24.	73.2834	34.4956	1202	42.56	189.94
25.	73.2848	34.4675	1037	6.08	156.80

Shinkiari soils are placed in Missa and Zaramiana soil series. It is moderately extended. The **s**oil is usually dark yellowish to brown and dark brown (10YR, 4/3, 3/3, 4/4), silty loam to silty clay in texture, massive to moderate granular, common fine interstitial pores. Subsurface soil is yellowish-brown to dark yellowish-brown (0YR, 5/4, 4/4, 34), moist, silty clay loam to silty clay, moderate coarse and medium blocky to sub angular blocky, non-calcareous with a thickness of 150-200 cm in depth. Soil profile depth reaches to 200 cm in level to nearly level plains. The physicochemical characteristics of the Shinkiari soil series are given in Table 1.1 (Soil Survey Report of Abbottabad, 1979).

Table 3 Physicochemical characteristics of the soil of Shinkiari-Mansehra- Khyber Pakhtunkhwa (Soil Survey of Pakistan, 2008).

Horizon	Depth (cm)	Present					EC*10^{-3} (dS/m)	pH sat paste
		Sand	Silty	Clay	$CaCO_3$ Mg/kg	OM (%)		
Ap	0-13	10	61	29	0	30.23	0.36	7.5
Bt1	13-25	11	59	30		30.23	0.47	7.2
Bt2	25-137	11	47	42	0.5	1.85	0.30	7.2
Bt3	137-150	11	46	43	0.5	1.44	0.2	7.1
Bw	150-165	12	46	42	0.5	0.62	0.31	7.7

Table 4: the elevation and area covered by each compartment of the Chir Pine (Pinus roxburghii) forest of Shinkirari-Mansehra-KHYBER PAKHTUNKHWA

Sampling points	Compartments	Location of sampling		Elevation (mslu)	Soil type	Soil depth (cm)
		X-axis	Y-axis			
3	Tambah Massar 05	73.28721	34.45516	1028	loamy gravelly	0-15
1	Tambah Massar 05	73.28156	34.45198	1024	sandy stratified	15-30
2	Tambah Massar 05	73.28289	34.45561	1006	limestone origin	15-30
4	Tambah Massar 05	73.28863	34.46189	1026	silty partly sandy	15-30
2	Tambah Massar 06	73.29276	34.46356	1123	loamy gravelly	0-15

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10	Tambah Massar 06	73.29207	34.46427	1054	loamy gravelly	0-15
19	Tambah Massar 06	73.29811	34.46362	1145	sandstone	0-15
6	Tambah Massar 06	73.28818	34.46328	1016	sandy and loamy	15-30
16	Tambah Massar 06	73.29692	34.46315	1160	sandy stratified	15-30
23	Tambah Massar 06	73.28865	34.46302	1049	limestone origin	15-30
3	Shinkiari Massar 07	73.28391	34.46448	1027	loamy gravelly	0-15
13	Shinkiari Massar 07	73.28436	34.46711	1019	limestone origin	15-30
17	Shinkiari Massar 07	73.28465	34.46576	1039	sandy stratified	15-30
18	Shinkiari Massar 07	73.28802	34.46797	1045	sandy and loamy	15-30
20	Shinkiari Massar 07	73.28871	34.46752	1063	limestone origin	15-30
25	Shinkiari Massar 07	73.28478	34.46749	1037	sandy stratified	15-30
7	Shinkiari Massar 08	73.28693	34.48747	1200	sandy stratified	15-30
12	Shinkiari Massar 08	73.28918	34.48397	1157	silty partly sandy	15-30
9	Shinkiari Massar 08	73.28911	34.48392	1154	silty partly sandy	15-30
22	Shinkiari Massar 08	73.28914	34.48521	1175	silty partly sandy	15-30
24	Shinkiari Massar 08	73.28343	34.49562	1202	silty partly sandy	15-30
14	Shinkiari Massar 08	73.28832	34.48692	1145	sandy stratified	15-30
8	Bedadi Massar 09	73.28695	34.47673	1024	Sandstone	0-15
21	Bedadi Massar 09	73.28264	34.46882	1016	Sandstone	0-15
11	Bedadi Massar 09	73.29858	34.47459	1148	silty partly sandy	15-30

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Table 5 The difference in the BD (g/cm3) between the surface (0-15cm) and subsurface soil (15-30 cm) at Tambah Massar 5 and 6 and Shinkiari Massar 7 and 8 and Bedadi Massar 9 along an elevation gradient of (1006-1202 m) of Chir Pine (Pinus roxburghii) forest.

Sampling points	Compartments	Location of sampling		Elevation (mslu)	BD (g /cm^3)	BD g/cm^3	Soil type	Soil depth (cm)
		X-axis	Y-axis					
5	Tambah Massar 05	73.28721	34.45516	1028	1.05	1.05	loamy gravelly	0-15
1	Tambah Massar 05	73.28156	34.45198	1024	1.07	1.34	sandy stratified	15-30
4	Tambah Massar 05	73.28289	34.45561	1006	1.07		limestone origin	15-30
15	Tambah Massar 05	73.28863	34.46189	1026	0.76		silty partly sandy	15-30
2	Tambah Massar 06	73.29276	34.46356	1123	0.99	0.9	loamy gravelly	0-15
10	Tambah Massar 06	73.29207	34.46427	1054	1.02		loamy gravelly	0-15
19	Tambah Massar 06	73.29811	34.46362	1145	0.71		sandstone	0-15
6	Tambah Massar 06	73.28818	34.46328	1016	0.65	0.95	sandy and loamy	15-30
16	Tambah Massar 06	73.29692	34.46315	1160	0.76		sandy stratified	15-30
23	Tambah Massar 06	73.28865	34.46302	1049	1.45		limestone origin	15-30
3	Shinkiari Massar 07	73.28391	34.46448	1027	0.96	0.96	loamy gravelly	0-15
13	Shinkiari Massar 07	73.28436	34.46711	1019	1.04	0.90	limestone origin	15-30
17	Shinkiari Massar 07	73.28465	34.46576	1039	0.95		sandy stratified	15-30
18	Shinkiari Massar 07	73.28802	34.46797	1045	0.83		sandy and loamy	15-30
20	Shinkiari Massar 07	73.28871	34.46752	1063	0.72		limestone origin	15-30
25	Shinkiari Massar 07	73.28478	34.46749	1037	0.99		sandy stratified	15-30

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7	Shinkiari Massar 08	73.28693	34.48747	1200	1.05		sandy stratified	15-30
12	Shinkiari Massar 08	73.28918	34.48397	1157	1.06	1.01	silty partly sandy	15-30
9	Shinkiari Massar 08	73.28911	34.48392	1154	0.98		silty partly sandy	15-30
22	Shinkiari Massar 08	73.28914	34.48521	1175	0.82		silty partly sandy	15-30
24	Shinkiari Massar 08	73.28343	34.49562	1202	1.25		silty partly sandy	15-30
14	Shinkiari Massar 08	73.28832	34.48692	1145	1.21		sandy stratified	15-30
8	Bedadi Massar 09	73.28695	34.47673	1024	1.05	0.91	sandstone	0-15
21	Bedadi Massar 09	73.28264	34.46882	1016	0.78		sandstone	0-15
11	Bedadi Massar 09	73.29858	34.47459	1148	1.23	1.23	silty partly sandy	15-30

Table 6 Soil organic carbon (g/cm) in humus, the soil at 0-15, and 15-30 cm recorded at different sample location points along an elevation gradient of (1006-1202 meters) of Chir Pine (Pinus roxburghii) forest of Shinkiari- Mansehra-Khyber Pakhtunkhwa.

Sampling points	Compartments	Location of sampling		Elevation (mslu)	Forest (density (%)	Soil organic carbon (g/cm)			Mean SOC in Humus
						Humus	Surface Soil (0-15 cm)	Subsurface soil (15-30 cm)	
		X-axis	Y-axis						
1	Tambah Massar 05	73.28156	34.45198	1123	55	11.28	2.35	2.12	3.41
4	Tambah Massar 05	73.28289	34.45561	1028	45	11.25	2.3	2.1	3.35
5	Tambah Massar 05	73.28721	34.45516	1016	50	11.11	2.22	1.88	3.16
15	Tambah Massar 05	73.28863	34.46189	1160	60	10.53	1.19	1.33	1.855
6	Tambah Massar 06	73.28818	34.46328	1200	75	10.86	1.3	1.09	1.845
10	Tambah Massar 06	73.29207	34.46427	1148	75	11	2.23	1.14	2.8

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16	Tambah Massar 06	73.29692	34.46315	1039	50	10.56	2.13	2.17	3.215
19	Tambah Massar 06	73.29811	34.46362	1063	50	10.98	2.12	2.26	3.25
23	Tambah Massar 06	73.28865	34.46302	1202	75	11.17	1.33	1.21	1.935
2	Tambah Massar 06	73.29276	34.46356	1027	55	11.1	2.24	1.77	3.125
3	Shinkiari Massar 07	73.28391	34.46448	1006	70	11.37	2.47	2.18	3.56
13	Shinkiari Massar 07	73.28436	34.46711	1145	50	10.22	2.2	1.16	2.78
17	Shinkiari Massar 07	73.28465	34.46576	1039	50	10.88	1.39	2.11	2.445
18	Shinkiari Massar 07	73.28802	34.46797	1045	80	10.09	2.07	2.18	3.16
20	Shinkiari Massar 07	73.28871	34.46752	1016	50	11.21	1.77	2.36	2.95
25	Shinkiari Massar 07	73.28478	34.46749	1123	55	11.28	2.35	2.12	3.41
12	Shinkiari Massar 08	73.28918	34.48397	1019	60	10.43	2.32	1.08	2.86
7	Shinkiari Massar 08	73.28693	34.48747	1024	45	11.24	2.28	1.98	3.27
9	Shinkiari Massar 08	73.28911	34.48392	1054	60	11.19	2.26	1.88	3.2
14	Shinkiari Massar 08	73.28832	34.48692	1026	50	10.95	2.05	1.23	2.665
22	Shinkiari Massar 08	73.28914	34.48521	1049	45	10.33	2.1	2.34	3.27
24	Shinkiari Massar 08	73.28343	34.49562	1037	40	10.31	1.17	1.84	2.09
11	Bedadi Massar 09	73.29858	34.47459	1157	50	11.11	2.01	1.21	2.615
8	Bedadi Massar 9	73.28695	34.47673	1154	45	10.87	1.58	1.21	2.185
21	Bedadi Massar 09	73.28264	34.46882	1175	55	10.88	2.18	2.19	3.275

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Table 7 Stepwise Linear Regression between SOC and Soil Properties

Variables Entered/Removed			**Model Summary**				
Variables Included	**Variables Excluded**	**Significance**	**R**	**R Square**	**Adjusted R Square**	**Std. error of the Estimate**	
Elevation		0.000	0.902	0.814	0.797	3.471	
Forest Density		0.000	**ANOVA**				
	pH	0.477		Sum of Squares	df	Mean Square	F
	EC	0.974	Regression	1157.31	2	578.655	48.031
	Humus	0.925	Residual	265.044	22	12.047	
			Total	1422.35	24		
Coefficients							
	Unstandardized		Standardized	T	Sig.	Model Equation	
	B	Std. Error	Beta			**SOC= 104.111-0.72*Elevation +0.292*Forest Density**	
(Constant)	104.111	14.928	-.634	6.974	.000		
Elevation	-.072	.012	.419	-6.177	.000		
Forest Density	.292	.072	-.634	4.081	.000		
Dependent Variable: SOC Predictors in the Model: (Constant), Elevation and Forest Density							

Table 8 Stepwise Linear Regression between SOC and Soil Properties

	SOC	**pH**	**EC**	**Hums**	**Elevation**	**Forest Density**
SOC	1	-.711**	-.087	.206	-.820**	.700**
pH	-.711**	1	.097	-.104	.889**	-.280
EC	-.087	.097	1	.057	.057	-.128
Humus	.206	-.104	.057	1	-.187	.187
Elevation	-.820**	.889**	.057	-.187	1	-.443*
Forest Density	.700**	-.280	-.128	.187	-.443*	1

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Table 9 Summary of Regression Models between Elevation (m) and Soil Chemical Properties

S. No	Independent Variable	Regression Model	Equation	R2
1	pH	Power	$y = 0.0132x^{0.8626}$	0.79
	BD	Polynomial	$y = 5E\text{-}09x^4 - 2E\text{-}05x^3 + 0.0341x^2 - 24.95x + 6828.3$	0.11
2	Electric Conductivity	Polynomial	$y = 2E\text{-}09x^4 - 9E\text{-}06x^3 + 0.0155x^2 - 11.464x + 3180.7$	0.13
3	Humus	Polynomial	$y = 2E\text{-}08x^4 - 8E\text{-}05x^3 + 0.138x^2 - 101.18x + 27787$	0.15
4	Humus SOC (0-15 cm)	Polynomial	$y = -8E\text{-}07x^3 + 0.0025x^2 - 2.7744x + 1013.7$	0.13

Stepwise Linear Regression between SOC and soil Properties

O check the relationship between soil properties (independent variables) which include elevation, forest density, pH, electric conductivity, and humus, and SOC (dependent variable) stepwise linear regression (SLR) was developed. SLR model followed stepwise criteria to enter variables having a significance value less than or equal to 0.50 and the probability of variables to remove was equal or greater than 0.10 as shown in Table 4.8. Results of the SLR model showed that among five explanatory variables, there was a significant relationship between two variables (elevation and forest density) with SOC (p-value is less than 0.001) whereas other soil parameters (pH, electrical conductivity, humus) were insignificant. These insignificant values were removed from the final model because their p-values were greater than 0.10 i.e., 0.477, 0.974, and 0.925 for pH, electrical conductivity, and humus respectively. The overall correlation of the SLR model was good with R^2 value (0.81) which explained 81% of the SOC data and only 19% data left unexplained. Adjusted R^2 was 0.79 with a standard error of 3.47 (t/ha) in SOC estimation. Moreover, the model has good prediction power and scatterplot between standardized predicted and residuals values depicted that the SLR model meets variance homogeneity and normal distribution of the residuals.

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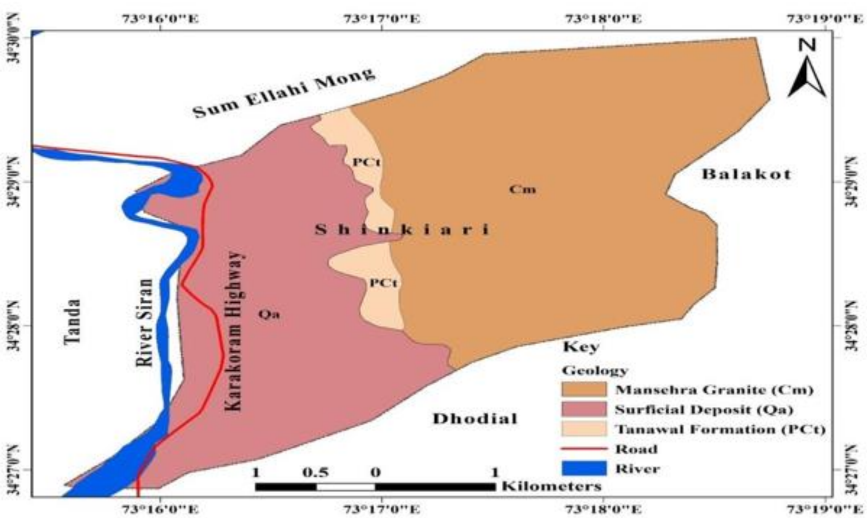
Figure 2 Taking Soil Samples



CONCLUSION

Forest sequestered a major portion of the carbon in the soil. Thus, forest ecosystem plays an important function to balance the climate of the country. A slight imbalance in a forest ecosystem can cause a disturbance in the carbon cycle thus climate change may occur. The present study will be important to explore the carbon in the soil of Chir of the Chir Pine (*Pinus roxburghii)* forest.

The study has determined the carbon stock determine the carbon stocks in the soil at 0-15 cm, 15-30 cm depth and assessed the geochemical composition of the soil at the

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various altitudinal gradient of the study area and developed the map of soil carbon stocks using the GIS tool.

The stepwise regression model is best suitable for precise and accurate predicting of soil carbon stocks in relation to soil properties (BD, texture, pH, EC, and SOC stocks) Chir pine (*Pinus roxburghii)* forest of Shinkirai-Khyber Pakhtunkhwa. The overall correlation of the SLR model was good with R^2 value (0.81) which explained 81 % of the SOC data with elevation and forest density and only 19 % data left unexplained. There was a weak correlation with SOC and BD, pH, and EC.

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