SOIL ANALYSIS, SPECIES COMPOSITION AND CARBON DYNAMICS OF *ABIES PINDROW* FOREST OF DIR KOHISTAN, PAKISTAN

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Abstract. This study highlighted the structure, species composition and biomass carbon stock in the *Abies Pindrow* dominant community in Dir Kohistan, temperate region of Pakistan. The results showed that stem density varied between 3 ha^{-1} in *Acer ceasium* to 273 ha^{-1} in *Abies pindrow*, with a total stand density of 350 trees ha $^{-1}$. The importance value index (IVI) varied between 2.27 (*Acer ceasium)* and 62.22 (*Abies pindrow*). The mean basal area was recorded at 132.15 m^2 ha^{-1}. The average stem volume was measured at 120 m^3 $ha^{-1.}$ The mean stem and total tree biomass carbon was 639 and 967 t ha^{-1} respectively. Similarly, the understory vegetation and litter, dead wood and cone biomass carbon was found 1.43 t ha^{-1} and 12.02 t ha^{-1} respectively. Soil carbon (0-30 cm) was calculated by using Walkey-Black methods multiplied by mean soil bulk density measurements. The average soil organic carbon was calculated 70.75 t ha^{-1}. The Total average carbon stock of the community was calculated at 568.63 t ha^{-1}. These results provide the evidence that, *Abies Pindrow* dominant community has a greater potential of sequestering carbon. Upon proper carbon management the ecosystem might be included in the carbon trading of Kyoto protocol.
Keywords: *soil, temperate region, structural attributes, growing stock, biomass, carbon, Kumrat Valley*

Introduction

Forests sequester and accumulate more carbon than any other terrestrial ecosystem and are a significant natural ‘brake’ on climate change (Pan et al., 2011; Espírito-Santo et al., 2014; Manan et al., 2018). Forest biomass contained a significant amount of carbon and can accumulate continuous carbon through their life spin (IPCC, 2006; Ahmad et al., 2014, 2015). Various anthropogenic activities e.g. industrialization, deforestation, forest degradation and burning of fossil fuel, has caused an increase in the level of carbon in the atmosphere and disrupted the global carbon cycle (Sharma and Rai, 2007; Ahmad et al., 2014; Manan et al., 2018). However, nature has its own mechanism of sequestering and storing the carbon in its “reservoirs” or “sinks’’. The removal of carbon for decreasing the CO_2 level is need of the time (Wani et al., 2014, 2016). Forest plays an important role in

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the global carbon cycle as carbon sinks of the terrestrial ecosystem (Coulston et al., 2015; Calfapitera et al., 2015). Forest contained about 4 billion ha of the globe with 861 ± 66 Pg stock carbon (Wani et al., 2014; FAO, 2015).

The Intergovernmental Panel on Climate Change (IPCC) identified five carbon pools of the forest ecosystem, namely the above-ground biomass, below-ground biomass, litter, woody debris and soil organic matter (Nizami, 2012). Among all the carbon pools, the above-ground biomass constitutes the major portion of the carbon pool (Ahmad et al., 2014). Estimating the amount of forest biomass is very crucial for monitoring and estimating the amount of carbon that is lost or emitted, as well the forest's potential to sequester and store carbon (Ahmad et al., 2018; Manan et al., 2018; Saeed et al., 2019). The IPCC and the Kyoto protocol (KP) identified forest as one of the important tool for the mitigating climate change through managing forest carbon for climate change strategy (Hosonuma et al., 2012). Concerns regarding the climate change mitigation, the international community stresses on the national and regional monitoring of forest carbon under the IPCC proposed guidelines (Böttcher et al., 2008).

Pakistan, being a member, to the IPPC and KP, the measurement of periodic and annual budgeting of the stored carbon in their forest is their obligation. In Pakistan various researcher outline the carbon stock of different forest like in temperate region (Ahmad et al., 2014; Ahmad et al., 2015; Ahmad and Nizami, 2015; Manan et al., 2018; Ahmad et al., 2018), in subtropical region (Nizami, 2012; Manan et al., 2018; Amir et al., 2018) and in planted forest. However, the carbon stock potential as well the species composition of the dominant Abies Pindrow community is not worked out yet. Looking into consideration this study was designed with the objectives to figure out the soil analysis, forest structure, species composition and biomass carbon of the *Abies pindrow* forest of Dir Kohistan, Pakistan.

Materials and methods

Study area and research design

Dir Kohistan is located to the North West side of Khyber Pakhtunkhwa province Pakistan. Geographically Dir Kohistan is mountainous with elevation ranges from 2000 to 6000 m (Ahmad et al., 2018). The *Abies pindrow* community occurred with in elevation range of 2500 to 3000 m along with latitude 35° 34' to 35° 43' and longitude72° 10' to 72° 16'. The mean annual precipitation in area ranges from 1000 to 1500 mm, while the mean temperature ranges from 0.6 to 25 °C (Ahmad and Nizami, 2015). Geologically most of the rocks are diorites, nitrites, and schist is the principle types of rocks. The underground rocks are mostly quartzite, schist, shale, slate, and granites. Soil is rich in organic matters and acidic in nature (Ahmad and Nizami 2015; Ahmad et al., 2018). For the related data collection, 14 sample plots, each of size 0.1 ha were laid out randomly in the forest (*Table A1* in the *Appendix*). The species composition and their related attributes, the growing stock, and biomass carbon in the respective pools were assessed (*Fig. 1*).

Species composition and related attributes

The species composition and their related attributed like stem density, relative density, basal area, relative basal area, frequency, relative frequency and importance value index were measured using *Equations 1-6* given below.

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$$\textbf{Density (D)} = \frac{\text{Total number of individual of a species in all the sample plots}}{\text{Total number of sample plots taken}} \quad \text{(Eq.1)}$$

$$\textbf{Relativedensity (D3)} = \frac{\text{Total No,individual of a species in all quadrates}}{\text{Total No.of individuals of all species in all quadrates}} \times 100 \quad \text{(Eq.2)}$$

$$\textbf{Average cover per species, (C)} = \frac{\text{Total cover (square feet) of a species}}{\text{Number of plants of a species}} \quad \text{(Eq.3)}$$

$$\textbf{Relative Cover of Species (C3)} = \frac{\text{TotalCoverSqftofallPlantsofallSpp}}{\text{TotalCoverSqftofallPlantsOfallSpecies}} \quad \text{(Eq.4)}$$

$$\textbf{Frequency (F)} = \frac{\text{Number of quadrats of occurrence of a species}}{\text{Total number of quadrats used by sampling}} \times 100 \quad \text{(Eq.5)}$$

$$\textbf{RelativeFrequency (F3)} = \frac{\text{Frequency of a species}}{\text{Total frequency of all species}} \times 100 \quad \text{(Eq.6)}$$

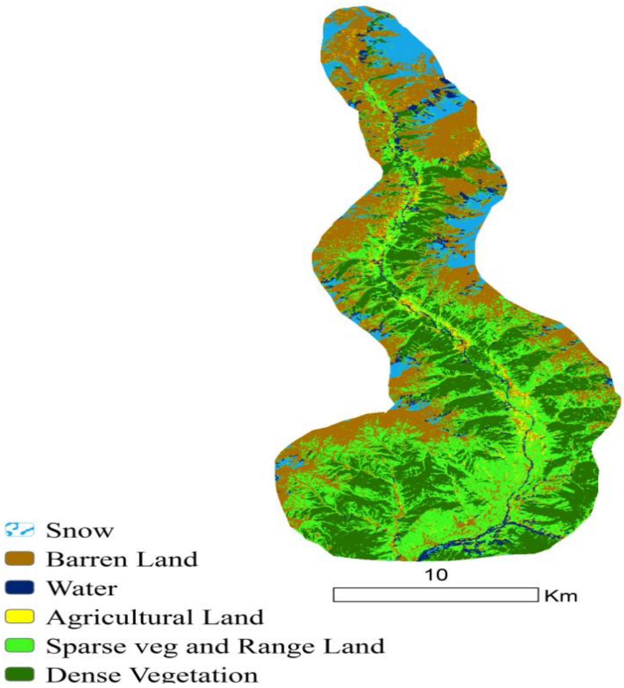

Figure 1. *Study area*

Importance value index (IVI)

In mixed forest, data of density, cover and frequency of a species do not give a clear data about the main species. It was estimated by adding the value of relative cover, relative density, and relative frequency and to dividing it by 3 given the importance value index (IVI) of the species. IVI for a forest stand were calculated as the total of the relative density, relative frequency and relative cover (Curtis, 1959).

$$\text{I.V.I} = \frac{\text{D3} + \text{C3} + \text{F3}}{3} \quad \text{(Eq.7)}$$

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Biomass carbon estimation

For upper storey vegetation biomass carbon, in each plot diameter and tree height was measured. The stem volume was measured from the relationship of diameter (cm) and height (m) following formula:

$$\text{Tree volume } (m^3) = \pi/4d^2 \times h \times FF \quad \text{(Eq.8)}$$

Stem biomass (kg) was calculated from the relationship of stem volume (m^3) and basic wood density (Kg/m^3). Basic wood density was sourced from available literature (Haripriya, 2000; Ahmad et al., 2014; Manan et al., 2018,). The following formula was used to estimate stem biomass:

$$\text{Stem biomass (kg)} = \text{Stem volume } (m^3) \times \text{Wood density } (Kg/m^3) \quad \text{(Eq.9)}$$

To estimate total biomass, biomass expansion factor was used. The BEF ratio of 1.51 for conifers and 1.55 for broad leaved was used to find out total biomass of a tree (Haripriya, 2000; Ahmad et al.,2018; Manan et al., 2018).

$$\text{Total biomass (Kg)} = \text{Stem biomass (Kg)} \times \text{BEF} \quad \text{(Eq.10)}$$

For the measurement of understory vegetation, dead wood, cone, and litter biomass carbon, sub plots each of 1 m^2 size were laid out. From the each sub plot, the understory vegetation was harvested destructively and dead wood, cone and litter were collected and their fresh weight was measured. The collected samples were oven dried for 48 h at 72 °C and their dry weight was taken as their biomass (Ahmad and Nizami, 2015; Ahmad et al., 2018; Manan et al., 2018).

The carbon values were assessed from the biomass of the respective pools. The conversion factor of 0.5 was used to convert biomass into carbon that has been used widely around the Globe (Brown and Lugo, 1982; Malhi et al., 2004; Nizami, 2012; Ahmad et al., 2014; Amir et al., 2018; Saeed et al., 2019). For soil carbon assessment, soil samples were collected from each plot at the depth of 30 cm. The soil organic carbon was measured following (Walkely, 1934). The soil carbon in t ha $^{-1}$ was assessed from the soil bulk density, depth increment and soil organic carbon following (Ahmad and Nizami, 2015; Saeed et al., 2018; Ahmad et al., 2018).

Results and discussion

Species composition and growing stock

The results regarding the species composition and related attributed are given in *Table 1*. The results clearly figure out that *Abies pindrow* is the dominant tree species with the maximum species compositional attributes while the minimum values for these attributes were recorded for *Acer cesium*. Over all the results showed that the stem density varied between 3 ha^{-1} (*Acer caesium*) and 276 ha^{-1} (*Abies pindrow*) with a total stem density of 350 trees ha^{-1}. The results of frequency in *Table 1* explained that along with *Abies pindrow*, *Taxus baccata* and *Picea smithiana* were found throughout the community. Regarding the growing stock (volume m^3 ha^{-1}) details are given in *Table 2*. The results in *Table 2* showed that the total growing stock in the community was

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recorded at 1720 m^3 ha^{-1}. Regarding the relationship between basal area (m^2 ha^{-1}) and growing stock (m^3 ha^{-1}), the results in *Figure 2* showed a strong positive linear correlation with R^2 value of 0.98. The highly positive correlation of basal area and growing stock indicated that growing stock is the function of basal area (Nizami, 2012; Ahmad et al., 2014; Ahmad and Nizami, 2015; Saeed et al., 2019; Amir et al., 2018).

Table 1. *Species composition and related attributes*

Species	D ha^{-1}	RD %	BA ha^{-1}	RB %	F %	RF %	IVI
Abies pindrow	276	77.23	112.39	85.12	100.00	27.31	63.22
Taxus baccata	35	10.64	3.61	2.78	100	27.14	13.52
Picea smithiana	25	7.56	11.02	8.08	100	27.14	14.26
Acer caesium	3	0.65	0.53	0.33	28.57	5.83	2.27
Juglans regia	8	2.17	2.09	1.34	42.85	8.69	4.06
Platanus orientalis	4	1.11	2.51	1.66	21.42	4.04	2.27
Total	350	100.00	132.15	100.00		100.00	100.00

D = Density, RD = Relative density, BA = Basal area, RB = Relative basal area, F = Frequency, RF = Relative frequency, IVI = Importance value index

Table 2*. Volume and biomass carbon of upper storey vegetation*

Species	Volume m^3 ha^{-1}	Stem biomass t ha^{-1}	Total tree biomass t ha^{-1}	Carbon stock t ha^{-1}	Percentage
Abies pindrow	1425	528	800	400	82.64
Taxus baccata	54	20	30	15	3.08
Picea smithiana	164	60	94	47	9.66
Acer caesium	8	3	5	2	0.46
Juglans regia	31	11	18	9	1.83
Platanus orientalis	37	14	21	11	2.20
Total	1720	636	967	484	100

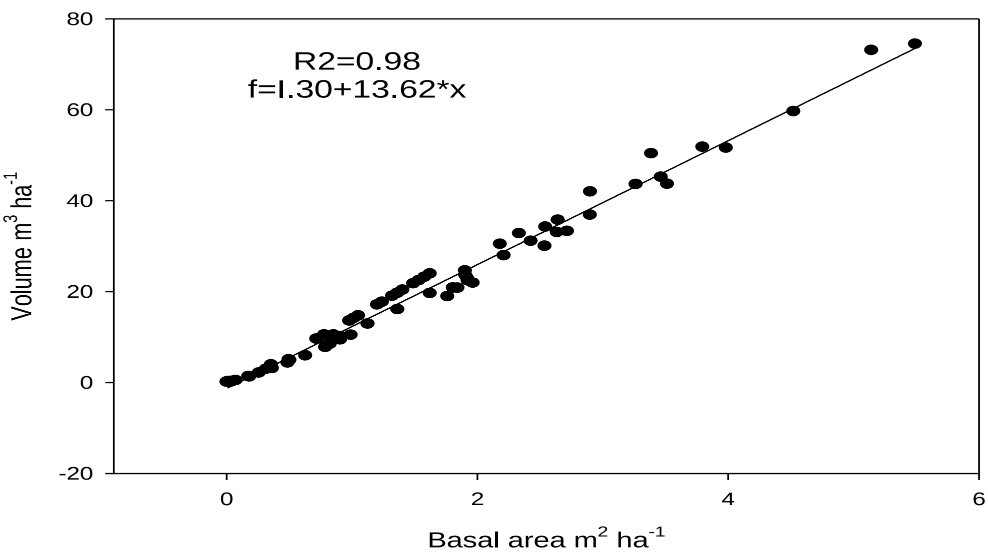

Figure 2. *Relationship between volume (m^3 ha^{-1}) and basal area m^2 ha^{-1}*

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Biomass carbon

The total tree biomass value varied between 5 and 800 t ha^{-1} (*Table 2*) with overall value of 967 t ha^{-1}. The relationship of basal area (m^2 ha^{-1}) and biomass is presented in *Figures 3* and *4*. The value of R^2 suggested a very strong correlation between basal area and biomass. The basal area and biomass have a functional relationship and with increase in the basal area the biomass also increases (Nizami, 2012; Saeed et al., 2018). Under storey vegetation were mostly consist of grasses, forbs and shrubs. The average biomass of under storey vegetation was 2.87 t ha^{-1}. The biomass carbon of the upper story vegetation was 484 t ha^{-1}. In the total tree biomass carbon, the contribution of *Abies pindrow* was 82.64%. In the under storey vegetation, the mean carbon stock was 1.43 t ha^{-1}. Similarly, the carbon stock in litter, dead wood and cones was recorded as 12.02 t ha^{-1}. The soil carbon varied from 52.13 to 81.78 t ha^{-1} (*Table 3*) with mean value of 70.74 t ha^{-1} (*Table 4*).

Table 3. *Soil bulk density and soil organic carbon stock tons* ha^{-1}

Plot	Bulk density (0-15 cm)	Bulk density (15-30 cm)	SOM %	SOM %	Total SOM%	T otal SOC%	SOC tons ha^{-1}
1	1.01	1.05	3.14	0.98	4.12	2.38	73.07
2	1.009	1.04	3.39	1.19	4.58	2.65	80.46
3	1.009	0.93	3.16	1.02	4.18	2.42	73.43
4	0.99	1.03	2.84	1.02	3.86	2.23	66.52
5	0.91	1	2.34	0.94	3.28	1.90	52.13
6	0.99	0.89	2.54	0.78	3.32	1.92	57.21
7	1	1.05	3.68	1.02	4.7	2.72	81.78
8	0.99	0.95	3.78	0.94	4.72	2.73	81.34
Total	7.908	7.94	24.87	7.89	32.76	18.95	565.94

Table 4. *Total carbon stock in forest ecosystem*

S. No	Carbon pools	Average carbon stock (tons ha^{-1})
1	Upper storey vegetation carbon stock	484
2	Under storey vegetation carbon stock	1.43
3	Litter, dead wood and cones carbon stock	12.02
4	Soil carbon stock	70.74
Total average carbon stock		568.63

Overall the results in *Table 4* showed that the *Abies pindrow* community stored 568.63 t ha^{-1} carbon. The upper storey vegetation hold maximum carbon followed by soil, whereas the understory vegetation hold the minimum carbon. In compression the current carbon values in the biomass gives higher estimates from the reported values from Himalayan temperate regions (Sharma et al., 2010, 2011; Wani et al., 2014). This higher value might be the results of the presences of larger tree particularly of *Abies pindrow*. We found trees up to 150 cm in diameter that resulted in the maximum carbon value in the community. However, the soil carbon was found low from the reported value of Sharma et al. (2011) and Wani et al. (2014). This may be due to the

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management practices. The forest are managed forest and during management operations the dead wood are removed from the forest floor and upon the removal of the deadwood the forest floor have little deadwood stuff, resulting low soil carbon (Barbati et al., 2007).

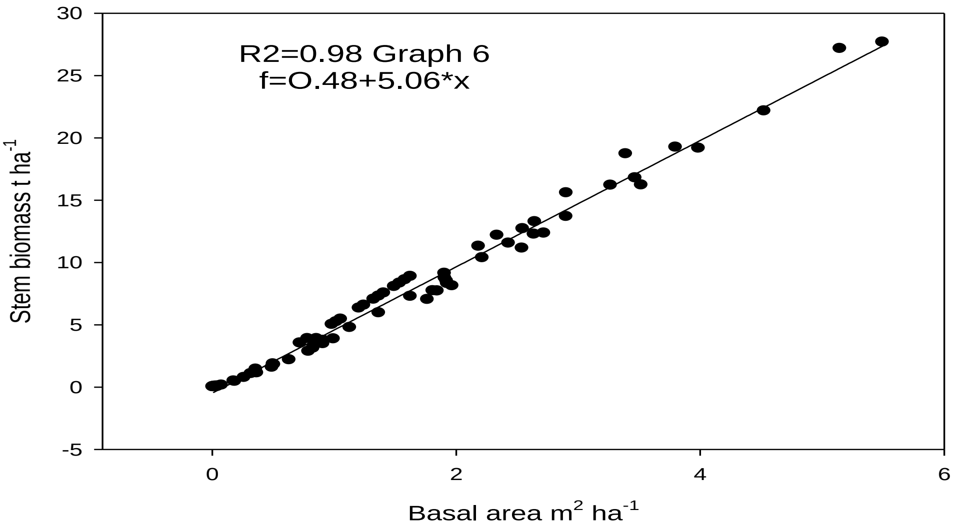

Figure 3. *Relationship between stem biomass (t ha^{-1}) and basal area m^2 ha^{-1}*

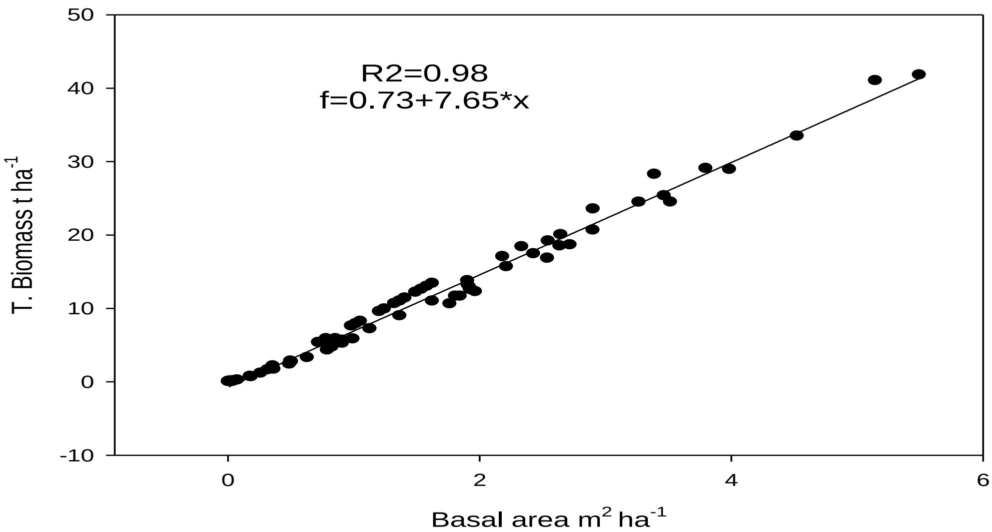

Figure 4. *Relationship between stem biomass (t ha^{-1}) and basal area m^2 ha^{-1}*

Soil carbon stock

Soil carbon in tons ha^{-1} was calculated from the relation of soil organic carbon (SOC %), Soil bulk density (gm/cm^3) and thickness of horizon (cm). Soil carbon was estimated by the use of different chemical solution like M K_2 Cr_2O_7 and H_2SO_4. Composite soil samples were collected at 0-15 and 15-30 cm depths from each inventory plot, using an auger. Soil carbon concentration (g C/g of soil) was established using the Walkey-Black titration method. Data collection for desired objectives was

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recorded using standard procedures (FAO, 2005). The result of study showed that soil organic carbon stock decrease with increasing soil depth. The high value of organic carbon content showed that there is fast decomposition rate in forest litter in suitable environment. The soil organic carbon is affected due to different environmental factors geographic location along with slope. The average soil organic carbon was 70.75 ± 11.26 t ha^{-1} with average soil bulk density 0.99 ± 0.032 was recorded.

Soil PH

Soil pH was measured by using soil pH meter (Mc Lean, 1982). The average pH was recorded 6.19 ± 0.12 the minimum soil pH was recorded 5.93 while maximum was 6.33 with coefficient variance. The result of the study shows that the soil was strongly acidic.

Conclusion

The presented finding in this study revealed that the *Abies pindrow* community having the greater carbon sequestration potential. However, the forest faces greater pressure in term of grazing, fuel wood collection and timber harvest. In this regard activities like Reduction in timber harvest, promotion of aforestation, reforestation, and the development of Hydropower should be imitated from the preservation and conservation of the forest.

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APPENDIX

***Table A1.** Geographic position and elevation of each plot*

Plot no	Elevation ft	Latitude	Longitude
1	8030	35° 34'.09"	72° 10'.28"
2	8050	35° 34'.15"	72° 10'.35"
3	8082	35° 34'.23"	72° 10'.38"
4	8098	35° 35'.33"	72° 11'.44"
5	8127	35° 35'.55"	72° 11'.58"
6	8160	35° 36'.45"	72° 12'.09"
7	8198	35° 37'.55"	72° 12'.58"
8	8221	35° 39'.38"	72° 13'.34"
9	8240	35° 39'.53"	72° 13'.51"
10	8267	35° 40'.09"	72° 14'. 04"
11	8289	35° 40'.50"	72° 14'.49"
12	8308	35° 41'.44"	72° 15'.22"
13	8345	35° 42.51"	72° 15'.51"
14	8431	35° 43'.15"	72° 16'.35"

***Table A2.** Soil bulk density and soil organic carbon stock tons ha^{-1}*

Plot	Bulk density (0-15 cm)	Bulk density (15-30 cm)	SOM%	SOM%	Total SOM%	T SOC%	SOC tons ha^{-1}
1	1.01923	1.05769	3.14	0.98	4.12	2.38	73.0724
2	1.009615	1.04808	3.39	1.19	4.58	2.65	80.4647
3	1.009615	0.93269	3.16	1.02	4.18	2.42	73.4372
4	0.99038	1.03846	2.84	1.02	3.86	2.23	66.5235
5	0.91346	1	2.34	0.94	3.28	1.90	52.1372
6	0.99038	0.89423	2.54	0.78	3.32	1.92	57.2171
7	1	1.05769	3.68	1.02	4.7	2.72	81.7865
8	0.99038	0.95192	3.78	0.94	4.72	2.73	81.3448
Mean	0.99038	0.99759	3.10	0.98	4.095	2.37	70.7479
SD	0.03291	0.06372	0.51	0.11	0.5757	0.33	11.2661
Std error	0.01163	0.02253	0.18	0.04	0.2035	0.11	3.98318
Variance	0.00108	0.00406	0.26	0.01	0.3314	0.11	126.925
CV %	3.32292	6.3883	16.5	11.6	14.057	14.05	15.9243

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