Volume 3, Number 1, 2026 Pages 532-572

Bioscience Insights

ISSN: 3080-3489 (Print)
ISSN: 3080-3497 (Online)

BiosciInsights.com

CARBON SEQUESTRATION POTENTIAL OF JUNIPER FOREST IN ZIARAT, BALOCHISTAN:ASSESSMENT OF ABOVEGROUND AND BELOWGROUND CARBON STOCKS

Akhtar Bibi[1], Tahira Bibi[*2], Hidayatullah Kakar[3], Nelofer Jamil[4], Nazima Yousaf Khan[5], Shaista Ajum[6], Rabail Urooj[7]

*[1,*2]Department of Botany, Sardar Bahadur Khan Women's University, Quetta*
[3]Directorate of Agriculture Research, Soil and Water Testing, ARI, Saryab Quetta, Pakistan
[4]Department of Environmental Sciences, Sardar Bahadur Khan Women's University, Quetta
[5]Institute of Biochemistry, University of Balochistan, Quetta
[6]Department of Botany, University of Balochistan, Quetta
[7]Department of Environmental Sciences, Sardar Bahadur Khan Women's University, Quetta.

[1]bibiakhtar23@gmail.com, [*2]tahira_botany@yahoo.com, [3]kaintkk@gmail.com, [4]nelofer.sbkwu@gmail.com, [5]nazimakhan_chem@yahoo.com, [6]shaista.alizai@yahoo.com, [7]rabail.urooj@sbkwu.edu.com

Article Information

Article History

Received:	April 15, 2026
Revised:	May 27, 2026
Accepted:	June 12, 2026
Available Online:	June 30, 2026

Keywords:
Juniper forest, Carbon stock, Biomass, Ziarat, Kotal Tanra and Carbon sequestration.

Abstract

In juniper forest Ziarat, no detailed inventories have been carried out so far to determine the carbon stock estimation of juniper forest. Therefore, the proposed study was conducted to investigate the status of carbon stock in various pool of juniper forest across different locations in tehsil Ziarat and to develop inventories of plant species influencing the extent of carbon stock. Five different locations such as Lori top (location 1), jangla (location 2), Kotal Tanra (location 3), Prospect point (location 4) and Sundamen Tangi (location 5) were selected across tehsil Ziarat. In this way, above ground and below ground biomass of herb, shrubs and trees as well as in forest litters and soil organic carbon were determined using standard procedureThe data based on the average of 10 quadrates revealed higher stocking rate of 450 trees ha-1 and stand basal area of 63.72 m2 ha-1 in location 3 and lower values of 290 trees ha-1 and 11.02 m2 ha-1 were recorded in location 1. As regard to total carbon stock (TCS) in various components of juniper forest Ziarat, higher carbon stock in soil and forest litters of 9.93 and 6.96 t ha-1 was observed in location 4. But lower carbon stock in litters was 2.22 t ha-1 which present in Sundamen

Tangi area. The TCS across five locations revealed 247.83,518.43, 1040.47, 345.58, 392.58 t ha-1 in Lori Top, Jangla, Kotal Tanra, Prospect Point and Sundamen Tangi respectively. From this study it was inferred that total carbon stock (TCS) per unit area of juniper forest fluctuated across different locations. TCS in various components for forest such as above and below ground biomass carbon stock (AGBCS & BGBCS) in herbs, shrubs and junipers trees, forest litters and soil organic matter also found different. Higher TCS in juniper trees was existed in Kotal Tanra area, TCS in herbs was found in Sundamen Tangi, TCS in shrubs was greater in Prospect point while TCS in tillers and soil was more in Prospect point area. Such fluctuation in TCS was due to anthropogenic activities and areas with less population pressure manifested higher plant biodiversity with higher carbon storage. So, it is suggested that protective measures need be adopted to preserve this unique forest and its biodiversity which have now been declared as world forest heritage.

Introduction

The Juniper forests and the associated diversity of plants and animals constitute a unique ecosystem, in arid mountains with harsh climatic conditions in Balochistan Province, Pakistan. These forests are considered to be one of the worlds' largest, oldest and extremely slow growing and long lived (>3000 years). They are often termed "Living Forest Fossils". Balochistan has approximately 141,000 hectors of *Juniperus excelsa* forests, out of which approximately 86,000 hectors of these are found in Ziarat and Loralai districts. J. excelsa typically grows as pure stands, and are characteristically open and multi-storied forests between elevations 2000 to 3000 meters (Sheikh, 1985). These forests are an important source of fuel wood for local residents and offer protection from soil erosion to the district's watersheds. These forests also provide grazing pastures, summer recreation, bark for roofing, essential oils, "berries" for flavoring and are used as remedy for kidney and many other diseases.

The valley of Ziarat is situated in northern Balochistan, which possess one of the largest natural, and rare forest type i.e., dry temperate Juniper forest (Ahmed *et al*., 2006). Ziarat Juniper forest is the second largest Juniper forest in the world the first being the Juniper forest California. It is the only forest area of Balochistan, and one of the oldest juniper trees of the world having trees as old as 2500 to 3500 years are found here (Marcoux, 2000).

The dramatic increase in global surface temperature is mainly due to the increase in carbon dioxide (CO_2) concentration in the atmosphere which is largely attributed to human activities (Petit *et al*., 1999). Thus, the global climate change is a widespread and growing concern that has led to extensive international discussions and negotiations. Responses to these concerns have focused on reducing emissions of greenhouse gases (GHGs), especially CO_2, and on measuring carbon absorbed by and stored in forests, soils, and oceans. One option for slowing the rise of GHG concentrations in the atmosphere, and thus possible climate change, is to increase the amount of carbon removed by and stored in forests (Broadmeadow and Robert, 2003; IPCC, 2000; IPCC, 2007b).

Forests play a critical role in the natural global carbon cycle. It sequesters and stores more carbon than any terrestrial ecosystem i.e. they store more than 80% of all terrestrial above ground carbon and more than 70% of all soil organic carbon (Jandl *et al*., 2006; Sundquist *et al.,*2008). As a result, forest ecosystems are regarded as the largest terrestrial carbon pool. According to the intergovernmental panel on climate change (IPCC, 2007a) report, forests have an average biophysical mitigation potential of 5,380 Mt CO_2/year until 2050.

Pakistan ratified the Kyoto Protocol and the United Nations Framework Convention on climate Change (UNFCC) in the year 2005. After its acceptance it has to come into force for maintaining its net greenhouse gas emission over the Kyoto Protocol's first commitment period (CPI, the 5 years from 1 January 2008 to December 2012).

Good Practice Guidance for LULUCF activities requires carbon stock changes to be estimated in an unbiased, transparent, and consistent manner, where uncertainties are determined and recorded over

time (IPCC, 2003). Net carbon stocks in each forest type of Pakistan will be evaluated for reporting under Kyoto Protocol. Keeping in view the importance of carbon stock estimation of forest in global perspective of climate change, the proposed study will be carried out to estimate carbon stocks in Juniper forest Ziarat.

1.1. Materials and Mathods

1.2. Study area

District Ziarat is comprised of 1487 km^2 area and one of the smallest districts of the province located at 30°22′51 North and 67°43′37 East (Figure 3.1) at an altitude of 2453 meters (8050 feet). The world's largest Juniper Forest makes Ziarat famous for the second largest juniper forest in the world. Administratively the district has two tehsils with seven union councils and situated in east of Quetta at a distance of 70 km (GoB, 2011). It is mountain locked district distributed into several valleys with altitude of 1,800 to 3,488 meters. The prominent vallys are Kach, Kawas, Ziarat, Zandra, Mangi, Mana and Gogi Ahmadoon. Five different locations were selected across tehsil Ziarat and plant biodiversity were identified in each location. In this way, above ground and below ground biomass of trees, shrubs and herb were determined using standard procedure. Then, the carbon contents of trees were measured as 50% of biomass is carbon. In each location, 10 quadrates were laid down with the size of each quadrate being 10 × 10 m for tree strata, 5 × 5 m for shrubs, and 1 × 1 m for herbs. This is the standard scientific method that is followed by various workers (Nayak *et al.* 2000; Lu *et al.* 2004; Nautiyal, 2008).

1.3. Plant species composition, abundance, frequency and density

Plant species composition, abundance, frequency and density in each location were calculated according to the following formula:

$$\text{Frequency} = \frac{\text{Number of sampling units (quadrates) in which a species occurs}}{\text{Total number of sampled units studied}} \times 100$$

$$\text{Density} = \frac{\text{Total number of individual in all sampling units}}{\text{Total number of sampled units studied}} \times 100$$

$$\text{Abundance} = \frac{\text{Total number of individuals in all sampling units}}{\text{Total number of sampling units of occurence}}$$

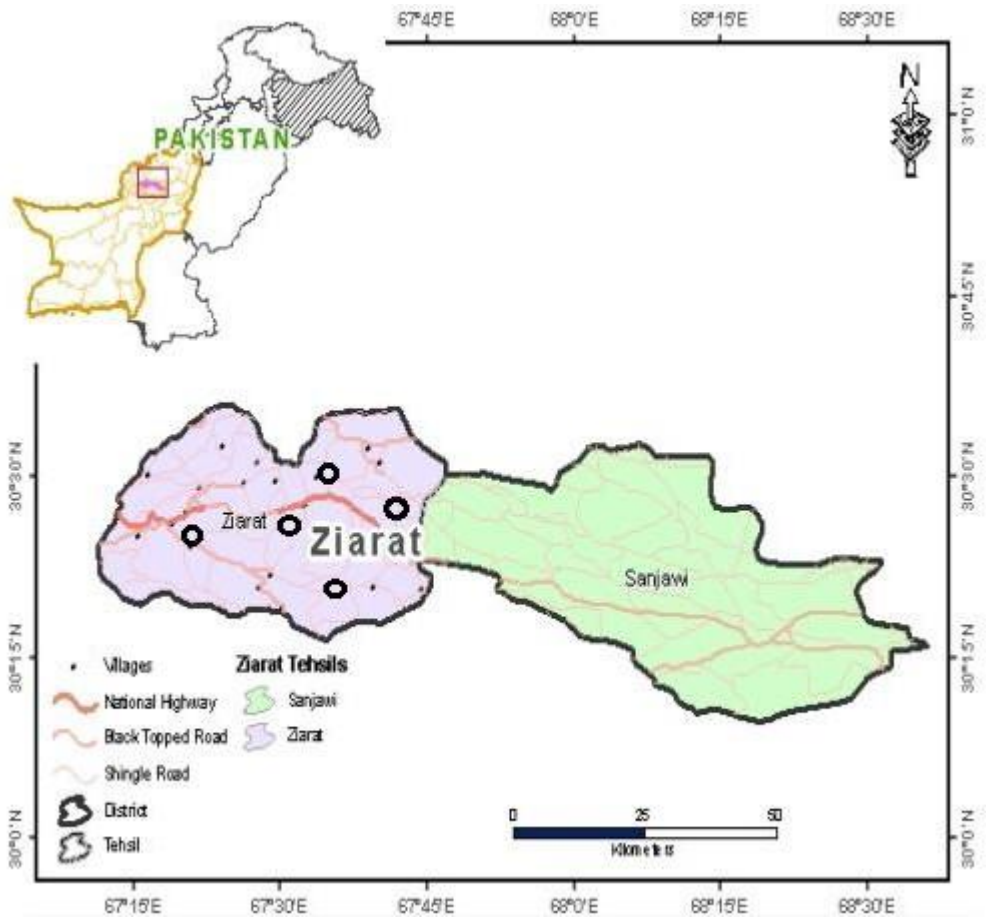


Figure 3.1 Map of sampling across five locations in juniper forest Ziarat

1.4. Stocking rate of juniper forest

The density or stocking rate of a forest is described as the number of trees per hectare. This can be easily calculated for each plot as follows:

Stocking Rate (stems/ha) = Trees in plot / Plot area (ha)

1.5. Stand height (foot) of juniper forest

The heights of the tallest trees in a plantation or native forest are usually quite uniform and therefore rather than measure the height of each and every tree in the plot it is common to select a sub-sample. In most cases a number of the fattest trees of good

form were measured for height - this is called the "Mean Dominant Height". Tree height was calculated with help of Clinometer (Robert, 2010).

1.6. Stand basal area of juniper forest

Stand Basal Area (SBA) is simply the basal area of all the trees at breast height per hectare of forest or plantation (m^2 /ha). Stand Basal Area can be used to estimate stand volume or as a useful measure of the degree of competition in the stand.

The most accurate method of assessing the Basal Area of a stand of trees is to measure all tree diameters in a plot, calculate individual tree Basal Areas and add these up (Glover and Barlow, 2009):

1.7. Above and below ground biomass of herbs and shrubs

The above ground biomass of individual shrub or herb was measured by cutting shrub or herb at collar and its fresh weight was found by direct weighing on balance. While, part of the shrub or herb was separately weighed and then taken to the laboratory for oven drying and grinding. Then the carbon contents of it were determined by ignition method. In this way, the total number shrubs and/or herbs were determined by multiplying the respective numbers. Whereas, below ground biomass of each shrub and herb were determined as 15% of above ground biomass.

1.8. Leaf Litter

Litter samples were collected in a 1 x 1 m rectangular sub-plot within the larger plot. A total of five sub-plots (four at corners and one in the center) were used for litter collection. The leaf litter within each 1 m^2 sub plot were collected and weighed. A composite sample of 100g was submitted for laboratory analysis placing in a plastic bag. The total dry weight was determined in the laboratory using dry ashing method as per Allen *et al.* (1986). Finally, carbon in leaf litter t ha^{-1} for each site was determined.

1.9. Soil Organic Carbon (SOC)

Soil samples were collected from the five sub-plots used for litter collection. A 30 cm soil probe was used to collect the soil samples. Samples were collected using a 30 cm depth core sampler with a diameter of 5 cm. The volume of the soil sample was determined from the height and radius of core sampler. All samples were placed in paper bags with appropriate label. Five equal weights of each sample from each sub-plot was taken and mixed homogenously while a composite sub sample of 100 gm from each plot was submitted for laboratory analysis. Finally, the bulk density, soil organic matter and soil organic carbon were calculated.

1.10. Carbon stock estimation

In this study, Carbon stock of individual tree, shrub, herb, litter in l m^2 and soil organic carbon were determined according to the standard method and spatial variability of Carbon stock in juniper forest across tehsil Ziarat were measured and causes of fluctuation were estimated.

1.11. Statistical analysis

The data obtained from DBH, diameter, height of each species, fresh weight and dry weight of litter and soil were analyzed using Statistical software Statistix 8.1. Descriptive statistics were used to determine statistically significant differences of carbon stocks for each carbon pools.

RESULTS4

4.1 Data Analysis

This study was undertaken in Juniper forest Ziarat, Balochistan where five locations in Tehsil Ziarat were selected according to the forest covered area. These were included Lori Top, Jangla, Kotal Tanra, Prospect Point and Sundamen Tangi. Carbon stock estimation in various components of Juniper forest

across five locations were carried out along with plant flora biodiversity, composition and some forest trees characteristics. The data regarding plant species composition, abundance, frequency, relative density and density in each location were recorded and depicted in (Table 1-5). Juniper trees stocking rate (no. of trees ha^{-1}) and diameter at breast height (DBH) (foot) are presented in Figure 1 and 2 while, the linear relationship between tree biomass and DBH noted across five locations are expressed in (Figure 3-7). Whereas, carbon stock estimation in soil and forest litters are given in (Figure 8 & 9). The estimation of carbon stock in above and below ground biomass in various components of juniper forest Ziarat are shown in (Table 6-10). The results of these studied parameters are described below under different headings.

4.1 Plant species composition, abundance, frequency and density

4.1.1 Herb and shrubs at location 1 (Lori Top)

The most prevailing and dominant species of herbs and shrubs found in Lori Top region of juniper forest Ziarat are shown in (Table 1) and Annexure-1 reflecting plant species, frequency, abundance, relative density and density along with botanical name and vernacular name. Five species of herbs were recorded included *salvia bucharica, Thymus vulgaris* L. *Solanum nigrum* L. *Eremurus persicus* (Jaub.& Spach) Boiss and *Eremurus stenophyllus* (Boiss.& Bushe) Baker. Among them, *Salvia bucharica, Thymus vulgaris* L. manifested the highest frequency (70%), abundance (2.9 and 3.0), relative density (32.3) and (33.9) and density (2.0, 2.1) respectively. While, *Solanum nigrum* Linn recorded lowest frequency (40%), abundance (1.0), relative density (6.5) and density (0.4). The comparison of two species of genus *Eremurus* showed same frequency but *Eremurus persicus* (Jaub.& Spach) Boiss. indicated greater relative density of (16.1) over Eremurus
stenophyllus (Boiss.& Bushe) Baker. So, the composition of herbs reveled that there were 4 genera and 5 species (Table 1).

Forest floor flourished with diversified plant biodiversity of herb and shrubs. Shrubs are economically important plants that can be used for fodder, fuel and medicinal purpose. In Lori Top region of juniper forest Ziarat, six genera and species were found as most dominantly originate in the area. These were included *Peroviskia abrotanoides* Karel, *Peganum hermala* L. *Artemisia stricta* Edgew, *Berberis baluchistanica* Ahrendt., *Saphora molis,* and *Caragna ambigua* (Table 1). The composition of shrubs varies across locations, latitude and type of mountains structure and position. In this study, *Artemisia stricta* Edgew revealed higher frequency (50%), abundance (6.0), relative density (85.7) and density (3.0) followed by *Peganum hermala* Linn. Reflecting frequency of (30%), relative density of (28.6) and density of (1.0) respectively. While, the lowest frequency (10%), relative density (2.9) and density (0.1) were recorded for *Caragna ambigua* but the two species *Berberis baluchistanica* Ahrendt., *Caragna ambigua* manifested similar level of abundance of (1.0).

4.1.2 Herb and shrubs at location 2 (Jangla)

Juniper forest Ziarat is the hub of medicinal plants which are locally used for the treatment of common

diseases like dysentery, cough, allergy and indigestion. These plants are also used for preserving perishable food particularly meet. So, Jangla is another significant area of juniper forest that flourished with various herbs and shrubs (Annexure-II). Their frequency, abundance, relative density and density is given in (Table 1). The species composition of herbs in Jangla is similar to that of Lori Top area reflecting 4 genera and five species included *Salvia bucharica*, *Thymus vulgaris* L. *Solanum nigrum* L. *Eremurus persicus* (Jaub.& Spach) Boiss, and *Eremurus stenophyllus* (Boiss.& Bushe) Baker. Except the species *Eremurus stenophyllus* (Boiss. & Bushe) Baker, all the four species revealed higher but similar frequency levels i.e. (60%). However, their abundance, relative density and density varied from one another. Among them, the higher abundance (3.0), relative density (32.1) and density (1.8) were noted for *Salvia Eremurus persicus* (Jaub.& Spach) Boiss (Table 1).

Table 4.1. The frequency, abundance, relative density and density of herbs and shrubs in location 1 (Lori Top) district Ziarat

Botanical name	**Vernacular name**	**Frequency (%)**	**Abundance**	**Relative density**	**Density**
Herbs					
Salvia bucharica	Sarsandi	70	2.9	32.3	2.0
Thymus vulgaris L.	Shin Moray	70	3.0	33.9	2.1
Solanum nigrum L.	Karezgi (Mako)	40	1.0	6.5	0.4
Eremurus persicus (Jaub.& Spach) Boiss	Shezgi (white flower)	60	1.7	16.1	1.0
Eremurus stenophyllus (Boiss.& Bushe) Baker	Shezgi (yellow flower)	40	1.8	11.3	0.7
Shrubs					
Peroviskia abrotanoides Karel	shanshobai	20	4.5	25.7	0.9
Peganum hermala L.	Ispanda	30	3.3	28.6	1.0
Artemisia stricta Edgew	Zhusane Turkha	50	6.0	85.7	3.0
Berberis baluchistanica Ahrendt.	Tor zaralg	20	1.0	5.7	0.2

Saphora molis	Guzeraan	20	1.5	8.6	0.3
Caragna ambigua	Maakhai	10	1.0	2.9	0.1

The Jungla region of juniper forest Ziarat was enriched with shrubs reflecting 7 genera and 9 species as shown in (Table 2). These species were included *Peroviskia abrotanoides* Karel, *Artemisia stricta* L. *Artemisia stricta* Edgew, *Berberis baluchistanica* Ahrendt., *Berberis calliobotrys* Aitch. & Koehne, *Saphora molis*, *Caragna ambigua*, *Hertia intermedia* (Boiss) O.Ktze., and *Peganum hermala* Linn. respectively. The genera *Artemisia* and *Berberis* representing two species each while other genera representing single species. The data collected in 10 quadrates showed higher frequency of 100% for *Artemisia stricta* L. followed by (70%) for *Hertia intermedia* (Boiss) O.Ktze. and *Artemisia stricta* L. while, the lowest frequency of 10% was recorded for *Artemisia stricta* Edgew and *Berberis calliobotrys* Aitch. & Koehne. Among them, *Artemisia stricta* Linn. was found the dominant species manifesting higher abundance (3.7), relative density (25.5) and density (2.6). Whereas, two species such as *Artemisia stricta* Edgew and *Berberis calliobotrys* Aitch.& Koehne recorded lower level abundance (1.0), relative density (1.0) and density (0.1). The second dominant species was *Peganum hermala* L. that showed relative density of (19.6) and density of (2.0). In addition to that other species like *Caragna ambigua* and *Hertia intermedia* (Boiss) O.Ktze. were also found in sufficient ranges indicating relative density of (10.8) and (12.7) which was comparatively higher over other low dominating species.

4.1.3 Herb and shrubs at location 3 (Kotal Tanra)

The frequency, abundance, relative density and density of herbs and shrubs in juniper forest Ziarat at location 3 (Kotal Tanra) are given in (Table 3) and (Annexure-III). The common herbs as existed in location 1 and 2 were also existed in this location 3 with two more species such as *Ixiolirion tataricum* and *Plantago lanceolate*. The most dominant species was *Thymus vulgaris* L. and recorded higher frequency (90%), abundance (4.3), relative density (47.0) and density (3.9) while the lower frequency of (20%) was noted for *Salvia bucharica* reflecting abundance of (1.5), relative density of (3.6) and density of (0.30) respectively. The two species viz. *Eremurus persicus* and *Ixiolirion tataricum* manifested lower frequency of (30.0%) with minimum abundance of (1.3) was observed for *Ixiolirion*

Table 4.2. The frequency, abundance, relative density and density of herbs and shrubs in juniper forest Ziarat at location 2 (Jangla)

Botanical name	**Vernacular name**	**Frequency (%)**	**Abundance**	**Relative density**	**Density**
Herbs					
Salvia bucharica	Sarsandi	60	3.0	32.1	1.8
Thymus vulgaris L.	Shin Moray	60	2.2	23.2	1.3

Solanum nigrum L.	Karezgi (Mako)	60	1.5	16.1	0.9
Eremurus persicus (Jaub.& Spach) Boiss	Shezgi (white flower)	60	1.2	12.5	0.7
Eremurus stenophyllus (Boiss.& Bushe) Baker	Shezgi (yellow flower)	50	1.8	16.1	0.9
Shrubs					
Peroviskia abrotanoides Karel	Shanshobai	30	2.7	7.8	0.8
Artemisia stricta L.	Tarkha sperah (Zeher)	70	3.7	25.5	2.6
Artemisia stricta Edgew	Zhusane Turkha	10	1.0	1.0	0.1
Berberis baluchistanica Ahrendt.	Tor zaralga	40	1.3	4.9	0.5
Berberis calliobotrys Aitch.& Koehne	Shin zaralga	10	1.0	1.0	0.1
Saphora molis	Guzeraan	40	1.3	4.9	0.5
Caragna ambigua	Sasi	50	2.2	10.8	1.1
Hertia intermedia (Boiss) O.Ktze.	Gungan	70	1.9	12.7	1.3
Peganum hermala L.	Ispanda	100	2.0	19.6	2.0

tataricum. So, this location (Kotal Tanra) exhibited 6 genera and 7 species of herbs. Among them, *Salvia bucharica* presented the lowest density (0.3) along with other two species viz. *Ixiolirion tataricum* and *Plantago lanceolata* that presented similar but comparatively lower density of (0.5) (Table 3).

This region of juniper forest Ziarat was rich with biodiversity of shrubs that showed 9 genera and 10 species. These species were included *Onobrychis cornuta*, *Peroviskia abrotanoides* Karel, *Hertia intermedia* (Boiss) O. Ktze., *Artemisia maritima* L. *Artemisia stricta* Edgew, *Berberis calliobotrys* Aitch. & Koehne, *Peganum hermala* L. *Ephedra intermedia* Schrenk., and *Saphora molis*. Out of 10 species, *Onobrychis cornuta* was the most dominant species recorded higher frequency of (70%) with abundance of (3.7), relative density of (30.6) and density of (2.6) (Table 3). While, the *Peroviskia abrotanoides* Karel was ranked second in term of abundance (3.0) but expressed lowest frequency (10%). In addition, the *Berberis calliobotrys* Aitch.& Koehne and *Ephedra intermedia*

Schrenk exhibited the lowest abundance (1.0), relative density (2.4) and density (0.2).

4.1.4 Herb and shrubs at location 4 (Prospect Point)

The frequency, abundance, relative density and density of herbs and shrubs in juniper forest Ziarat at location 4 (Prospect point) are given in (Table 4) and (Annexure-IV). The herbs existed in location 3 were also existed in this location 4. The most dominant species was *Solanum nigrum* L. that recorded higher frequency (80%), abundance (2.4), relative density (29.2) and density (1.9) while the two species such as *Salvia bucharica* and *Astragalus sp.* Showed lower and similar values of frequency (20%), abundance (1.0), relative density (3.1) and density (0.2) respectively. So, this location (Prospect point) exhibited 6 genera and 7 species of herbs. While, the genera *Thymus* representing two species and other genera representing one species each. Among them, *Salvia bucharica* presented the lowest density (0.2) along with other two species viz. *Ixiolirion tataricum* and *Plantago lanceolata* that presented lower density of (0.3) and (0.2) (Table 4).

Prospect point is the most important area of juniper forest Ziarat where majority of forest components flourished and less affected by the dwellers. The data regarding shrubs species distribution, frequency, abundance, relative intensity and intensity is shown in

Table 4 that revealed 9 genera and 10 species included *Onobrychis cornuta, Peroviskia abrotanoides* Karel, *Hertia intermedia* (Boiss) O.Ktze., *Artemisia maritima* L. *Artemisia stricta* Edgew, *Berberis baluchistanica* Ahrendt., *Peganum hermala* L. *Saphora molis*, and *Amygdalus spinosissima* respectively. The most dominant species was *Onobrychis cornuta* that manifested higher frequency (100%), abundance (7.7), relative density (42.8) and density (7.7) followed by *Artemisia maritima* L. with frequency of 70% and relative density of (11.1) and density of 2.0 (Table 4). The two species such as *Saphora molis* and *Amygdalus spinosissima* recorded lower but similar frequency (40%) while, lowest value of abundance (1.3), relative density (2.8) and density (0.5) was recorded for *Amygdalus spinosissima*.

4.1.5 Herbs and shrubs at location 5 (Sundamen Tangi)

The components of juniper forest Ziarat varied across locations within the large portion of forest included its composition and richness (Annexure-V). In location 5 (Sundamen Tangi), there was 5 genera and 6 species of herbs such as *Nepeta juncea* Benth., *Thymus vulgaris* L. *Solanum nigrum* L. *Eremurus persicus* (Jaub.& Spach) Boiss, *Eremurus stenophyllus* (Boiss.& Bushe) Baker, and *Plantago lanceolate* (Table 5). Except the two species i.e. *Nepeta juncea* Benth. and *Plantago lanceolate,* 4 species were found same as that existed in other locations in juniper forest Ziarat. The genera *Eremurus* represented two species while other genera represented single species each. The most dominated species was *Thymus vulgaris* L. that recorded higher frequency (60%), abundance (3.5), relative density (28.8) and density (2.1) followed by *Nepeta juncea* Benth. manifested frequency of (60%) abundance of (2.5) relative density of (20.5) and density of (1.5) respectively. While, the *Plantago lanceolata*

occurred with minimum frequency (30%), relative density (8.2) and density (0.6). Except two species (*Solanum nigrum* L.. & *Plantago lanceolata*), all the four species expressed similar frequency (i.e. 60%).

The dominant shrubs found in the area of Sundamen Tangi (location 5) were comprised of 7 genera and 9 species included *Onobrychis cornuta*, *Artemisia persokia*, *Hertia intermedia* (Boiss) O.Ktze., *Artemisia maritima* L. *Artemisia stricta* Edgew, *Berberis baluchistanica* Ahrendt., *Berberis calliobotrys* Aitch. & Koehne, *Peganum hermala* L. and *Saphora molis* respectively (Table 5). Two genera i.e. *Artemisia* & *Berberis* represented two species each while other genera represented single species each. Among them, *Hertia intermedia* (Boiss) O.Ktze. was the dominant species that showed 90% frequency followed by *Peganum hermala* L. reflecting 70% frequency. Whereas, the lower frequency of (10%) was manifested by *Berberis baluchistanica* Ahrendt. with abundance of (1.0) relative density of (1.3) and density of (0.1) (Table 5). Furthermore, the higher abundance of (2.5) was noted for *Artemisia stricta* Edgew, and higher relative density of (22.7) was observed for *Peganum hermala* L.. with density of (1.7).

Table 4.3. The frequency, abundance, relative density and density of herbs and shrubs in juniper forest Ziarat at location 3 (Kotal Tanra)

Botanical name	**Vernacular name**	**Frequency (%)**	**Abundance**	**Relative density**	**Density**
Herbs					
Salvia bucharica	Sarsandi	20	1.5	3.6	0.3
Thymus vulgaris L.	Shin Moray	90	4.3	47.0	3.9
Solanum nigrum L.	Karezgi (Mako)	40	3.3	15.7	1.3
Eremurus persicus (Jaub.& Spach) Boiss	Shezgi (white flower)	30	2.0	7.2	0.6
Eremurus stenophyllus (Boiss.& Bushe) Baker	Shezgi (yellow flower)	50	2.4	14.5	1.2
Ixiolirion tataricum	-	30	1.7	6.0	0.5
Plantago lanceolate	-	40	1.3	6.0	0.5
Shrubs					
Onobrychis cornuta	Sasi	70	3.7	30.6	2.6
Peroviskia abrotanoides Karel	shanshobai	10	3.0	3.5	0.3

Hertia intermedia (Boiss) O.Ktze.	Gungan	40	1.5	7.1	0.6
Artemisia maritima L.	Tarkha sperah (Zeher)	60	1.5	10.6	0.9
Artemisia stricta Edgew	Zhusane Turkha	50	2.0	11.8	1
Berberis calliobotrys Aitch.& Koehne	Shin zaralga	20	1.0	2.4	0.2
Peganum hermala L.	Ispanda	50	3.6	21.2	1.8
Ephedra intermedia Schrenk.	Uman	20	1.0	2.4	0.2
Saphora molis	Guzeraan	40	2.3	10.6	0.9

Table 4.4. The frequency, abundance, relative density and density of herbs and shrubs in juniper forest Ziarat at location 4 (Prospect point)

Botanical name	**Vernacular name**	**Frequency (%)**	**Abundance**	**Relative density**	**Density**
Herbs					
Salvia bucharica	Sarsandi	20	1.0	3.1	0.2
Thymus vulgaris L.	Shin Moray	70	1.9	20.0	1.3
Solanum nigrum L.	Karezgi (Mako)	80	2.4	29.2	1.9
Eremurus persicus (Jaub.& Spach) Boiss	Shezgi (white flower)	40	2.3	13.8	0.9
Eremurus stenophyllus (Boiss.& Bushe) Baker	Shezgi (yellow flower)	60	3.2	29.2	1.9
Ixiolirion tataricum	-	30	1.0	3.9	0.3
Astragalus sp.	-	20	1.0	3.1	0.2
Shrubs					
Onobrychis cornuta	Sasi	100	7.7	42.8	7.7

Peroviskia abrotanoides Karel	Shanshobai	50	2.4	6.7	1.2
Hertia intermedia (Boiss) O.Ktze.	Gungan	50	2.4	6.7	1.2

Artemisia maritima L.	Tarkha sperah (Zeher)	70	2.9	11.1	2
Artemisia stricta Edgew	Zhusane Turkha	40	4.5	10.0	1.8
Berberis baluchistanica Ahrendt.	Tor zaralga	60	2.0	6.7	1.2
Peganum hermala L.	Ispanda	60	2.3	7.8	1.4
Saphora molis	Guzeraan	40	2.5	5.6	1
Amygdalus spinosissima	-	40	1.3	2.8	0.5

Table 4.5. The frequency, abundance, relative density and density of herbs and shrubs in juniper forest Ziarat at location 5 (Sundamen Tangi)

Botanical name	**Vernacular name**	**Frequency (%)**	**Abundance**	**Relative density**	**Density**
Herbs					
Nepeta juncea Benth.	Chenjenbooti	60	2.5	20.5	1.5
Thymus vulgaris L.	Shin Moray	60	3.5	28.8	2.1
Solanum nigrum L.	Karezgi (Mako)	40	2.0	11.0	0.8
Eremurus persicus (Jaub.& Spach) Boiss	Shezgi (white flower)	60	1.7	13.7	1
Eremurus stenophyllus (Boiss.& Bushe) Baker	Shezgi (yellow flower)	60	2.2	17.8	1.3
Plantago lanceolate	-	30	2.0	8.2	0.6
Shrubs					
Onobrychis cornuta	Sasi	30	2.0	8.0	0.6
Peroviskia abrotanoides Karel	Shanshobai	40	1.5	8.0	0.6
Hertia intermedia (Boiss) O.Ktze.	Gungan	90	1.7	20.0	1.5

Artemisia maritima L.	Tarkha sperah (Zeher)	40	1.5	8.0	0.6
Artemisia stricta Edgew	Zhusane Turkha	40	2.5	13.3	1
Berberis baluchistanica Ahrendt.	Tor zaralg	10	1.0	1.3	0.1
Berberis calliobotrys Aitch. & Koehne	Shin Zaralga	30	1.0	4.0	0.3
Peganum hermala L.	Ispanda	70	2.4	22.7	1.7
Saphora molis	Guzeraan	60	1.8	14.7	1.1

4.2 Stocking rate (trees ha^{-1}) and stand basal area (m^2 ha^{-1})

Deforestation is one of the main causes of global warming. Stroking rate is used for the judgement of forest value that describe the sufficiency of a forest stand density in consultation with management objectives. The data regarding socking rate across five locations in juniper forest Ziarat as shown in Figure (1.0) revealed significant fluctuation that manifested higher stocking rate of 430 in location 3 (Kotal Tanra) and 450 in location

4 (Prospect point) and lower stocking rate of 290 in location 2 (Jangla) and 300 in location

5 (Sundamen Tangi). It means that the area of Kotal Tanra showed (33.46) and (48.26%) higher stocking rate over the area of Lori top and Jangla while, the area of Prospect point exhibited (39.66) and (49.65%) increase in stocking rate over Lori Top and Jangla respectively.

Stand basal area (SBA) is a relative term and a very useful parameter for computing forest stand based on diameter of trees at breast height per unit area. The SBA of juniper forest measured across 5 locations are shown in Figure 2 that revealed significant variations and higher SBA (63.72 m^2 ha^{-1}) was recorded in the area of Kotal Tanra followed by (49.38 m^2 ha^{-1}) in Sundamen Tangi of juniper forest Ziarat. While, minimum SBA (11.02 m^2 ha^{-1}) was found at Lori Top region of juniper forest. The 4th location (Prospect point) also exhibited comparatively lower SBA of (36.25 m^2 ha$^{-1)}$.

4.3 Diameter at breast height (DBH)

The circumference of individual tree in each of 10 quadrates at breast height was measured and then converted into diameter (Annexure-XI to XV). So, the data of DBH across five locations in juniper forest Ziarat as shown in Figure 3 was the average of 10 quadrates that manifested higher DBH of 1.5 foot in Jangla region followed by (1.42) foot in Kotal Tanra area of juniper forest. But the lowest DBH of (0.72) foot was noted in Lori Top area (location 1). The trees measured at Prospect point for DBH also expressed lower value of (1.05) foot as averaged of 10 quadrates. However, three locations such as Jangla, Kotal Tanra and Sundamen Tangi revealed statistically at par DBH values which were significant over Lori Top area.

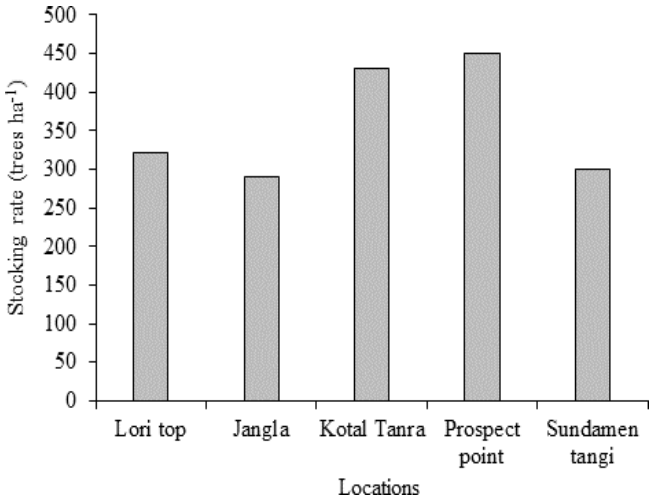


Figure 4.1 Stocking rate of juniper trees across five different locations in Juniper forest Ziarat

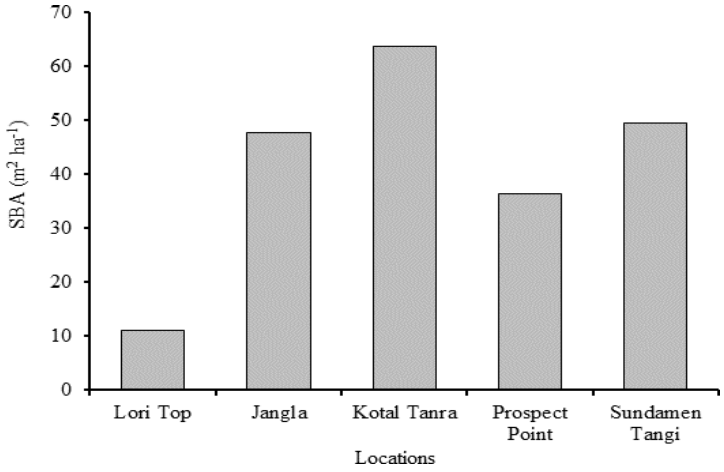


Figure 4.2. Stand Basal Area (m^2 ha^{-1}) of juniper trees based on 10 Quadrates across various locations in juniper forest Ziarat

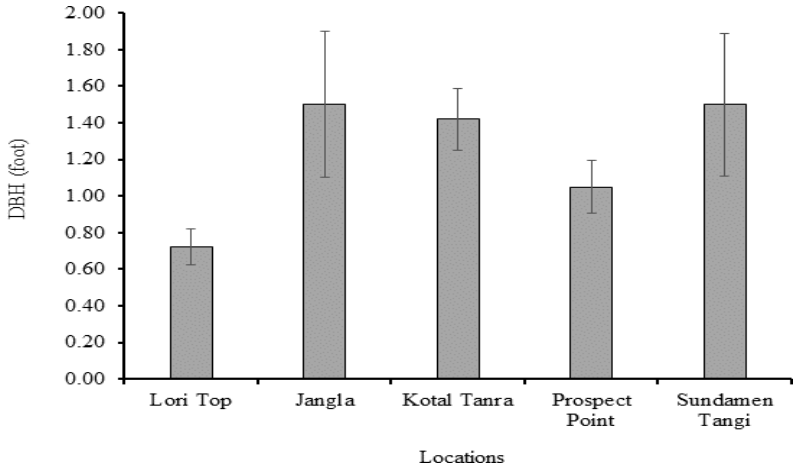


Figure 4.3 Diameter at breast height (DBH) of juniper tree as averaged of 10 Quadrates across various locations in Juniper forest Ziarat

4.4 Linear relationship between tree biomass and DBH

Tree biomass (Annexure-VI to X) and its diameter at breast height have shown positive and highly significant linear relationship with each other across various locations in juniper forest Ziarat as depicted in (Figure 4-8). In the area of Lori Top, tree biomass was positively and significantly correlated with DBH reflecting coefficient of determination (r^2) of (96%) with coefficient of variance (r) of (0.96) (Figure 4). It means that a unit increase in DBH correspondingly increase tree biomass. In other location 2 (Jangla), the tree biomass was correlated with DBH significantly and positively showing R^2 value of (42%) and r value of (0.62) as mentioned in (Figure 5). While, the location 3 (Kotal Tanra) expressed that tree biomass was positively and significantly correlated with DBH indicating R^2 value of (78%) and r value of (0.88) (Figure 6). Likewise, trees in Prospect point manifested the association between tree biomass and DBH positively and significantly recorded R^2 of (83%) with r value of (0.85) (Figure 7). Linear regression between tree biomass and tree diameter at breast height (DBH) under Juniper forest Ziarat at location 5 (Sundamen Tangi) was also positive and statistically significant as depicted in (Figure 8) and noted coefficient of determination of (78%) and coefficient of variance of (0.89). These results demonstrate that higher DBH tree possesses higher tree biomass and reduction in DBH also results in reduction in tree biomass.

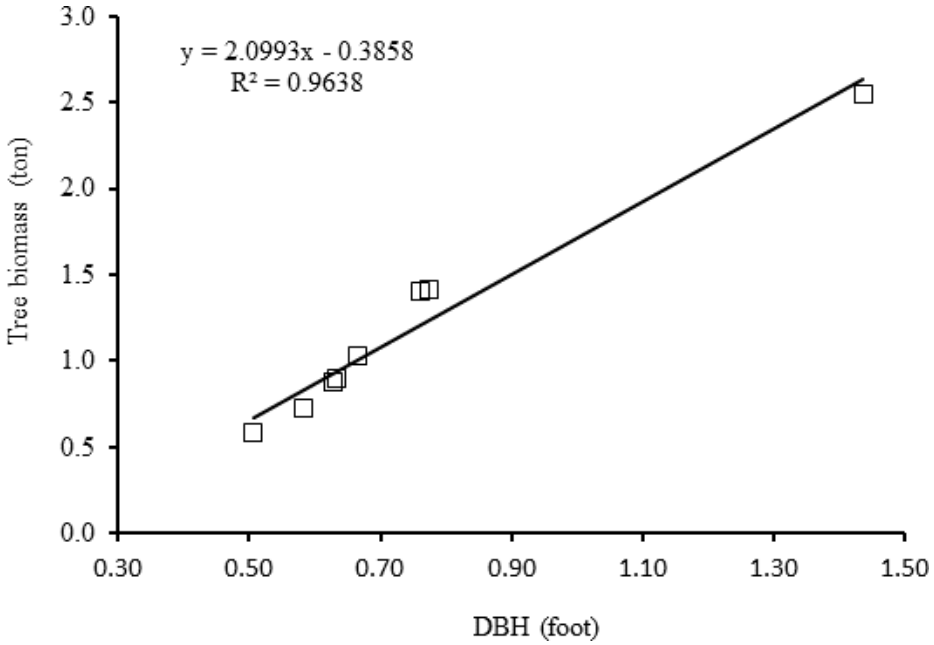


Figure4. 4 Linear regression between tree biomass and tree diameter at breast height under Juniper forest Ziarat at location 1 (Tori Top)

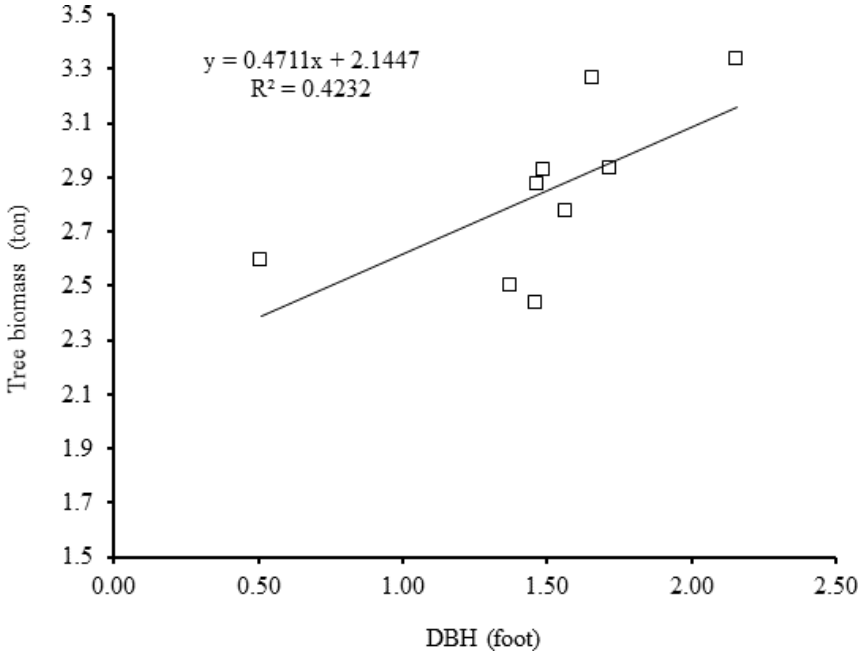


Figure 4.5. Linear regression between tree biomass and tree diameter at breast height (DBH) under Juniper forest Ziarat at location 2 (Jangla)

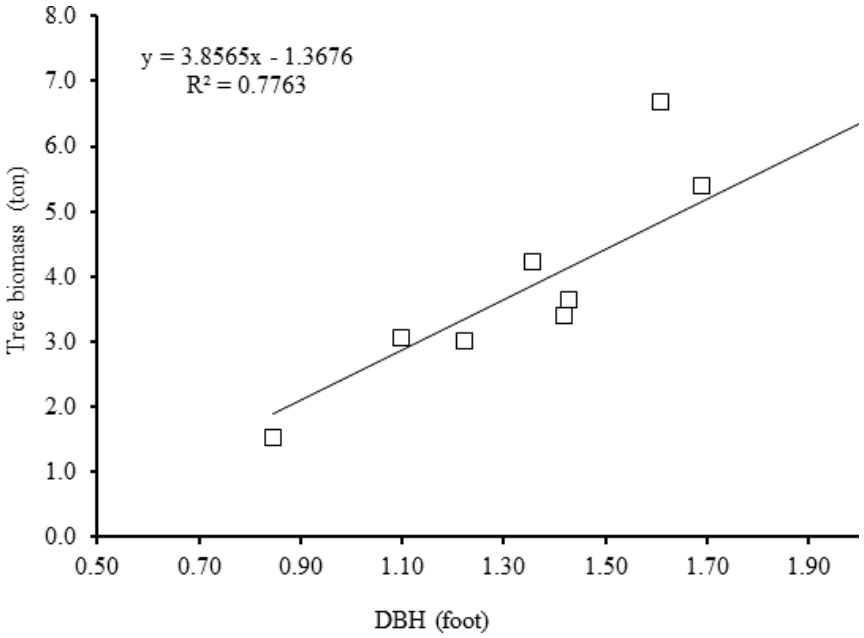


Figure 4.6. Linear regression between tree biomass and tree diameter at breast height (DBH) under Juniper forest Ziarat at location 3 (Kotal tanra)

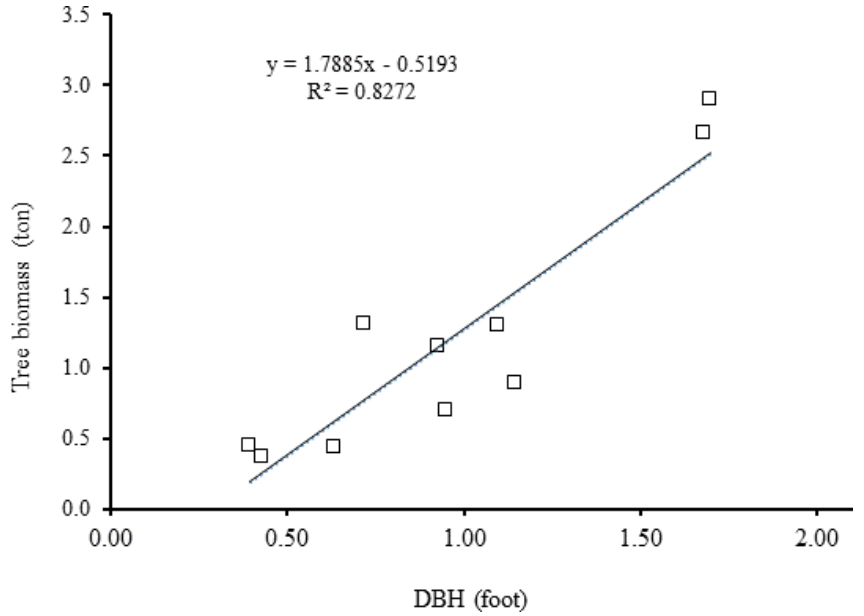


Figure 4.7. Linear regression between tree biomass and tree diameter at breast height (DBH) under Juniper forest Ziarat at location 4 (Prospect point)

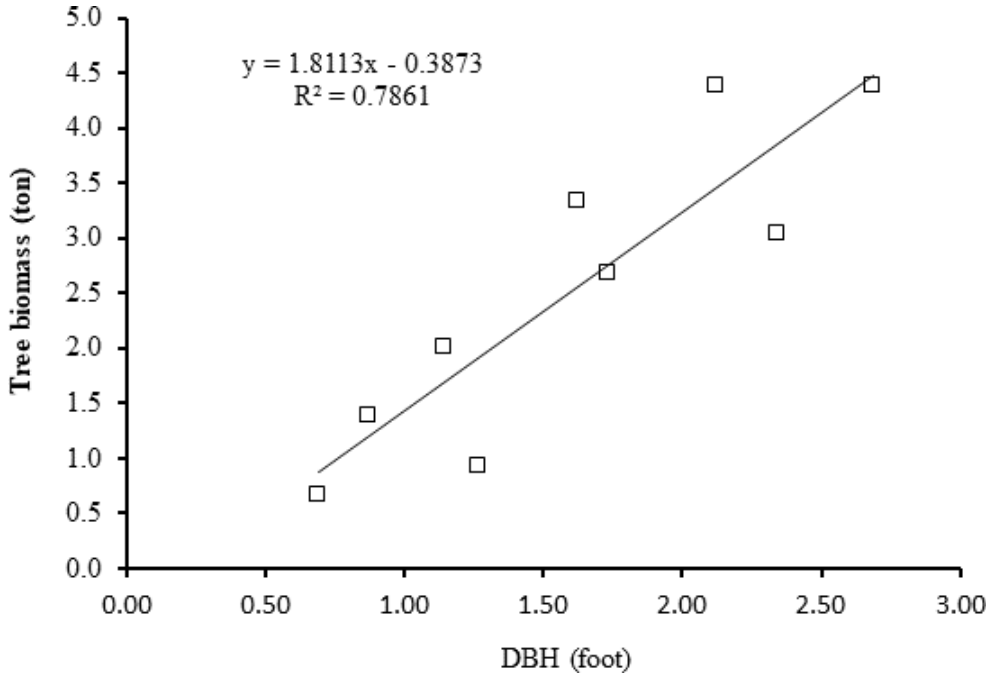


Figure 4.8. Linear regression between tree biomass and tree diameter at breast height (DBH) under Juniper forest Ziarat at location 5 (Sundamen Tangi)

4.5 Carbon stock (t ha^{-1}) estimation in soil and litters of juniper forest

Carbon stock in soil and letters varied across locations in juniper forest Ziarat as shown in (Figure 9). Statistically higher carbon stock of (9.93 t ha^{-1}) was found in the area of Prospect point and lower carbon stock of (7.46 t ha$^{-1)}$ was noted in Jungla region of the forest. While other locations expressed statistically at par differences in soil carbon stock that indicated (8.85), (8.46) and (8.40 t ha$^{-1)}$. Carbon stock in soil was estimated by measuring soil bulk density (Bd), soil organic matter and then converting SOM into SOC and finally made calculations based on multiplication of Bd x SOC x depth of soil (15 cm) (Annexure-XVI). In case of carbon stock in soil of Sundamen Tangi was (8.40 t ha$^{-1)}$ indicating mean soil bulk density of (1.32 g cm$^{-3)}$, SOC of (0.42%) and soil depth of 15 cm. It means that soil of sundamen Tangi contains low organic matter when compared to the critical values of organic matter based on oxidation method. The comparison of CS revealed that Prospect point area of juniper forest Ziarat contain (33.11%) higher carbon over the area of Jangla.

The litters under the canopy of juniper trees across various locations juniper forest Ziarat were evaluated for carbon stock estimation as expressed in Figure 10 revealed higher carbon stock of (6.96 t ha^{-1}) in Prospect point area followed by (5.35 t ha^{-1}) in the Lori Top regions which were statistically at par from one another. But lower carbon stock in letters was (2.22 t ha$^{-1)}$ which present in Sundamen Tangi area of the forest followed by (3.07 t ha$^{-1)}$ in Jangla region reflection non-significant variations. In addition

to that the Kotal Tanra area also showed (35.18%) higher carbon stock in litters over Jangla and (86.94%) over that of Sundamen Tangi area. These results demonstrate that biomass of litters deposited under the canopy of forest trees varies with respect to locations even in the same region of the forest which can be observed in variations in its carbon stock. Further, it can be seen that these litters deposition and decomposition might results in buildup soil organic carbon in forest ecosystem. Because soil is the largest sink of carbon globally.

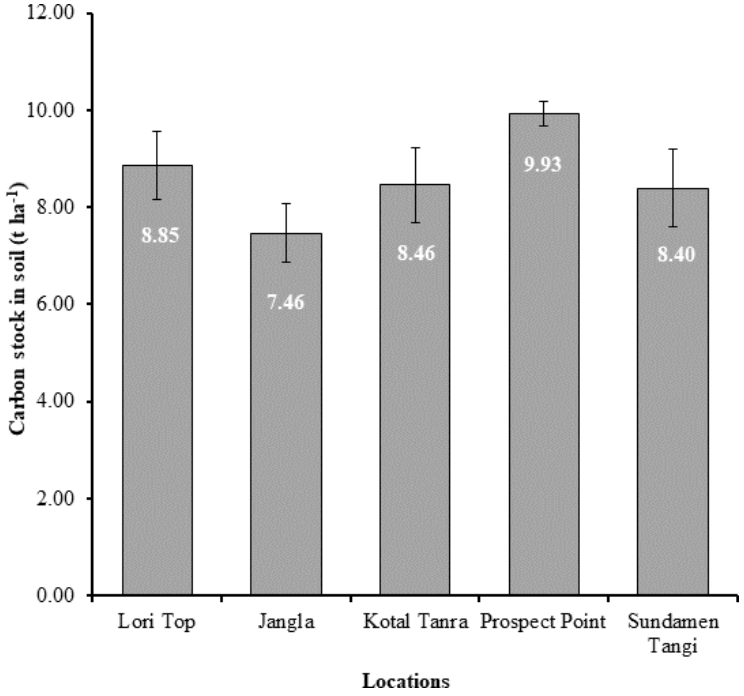


Figure 4.9. Carbon stock in soil across different locations in Juniper forest Ziarat

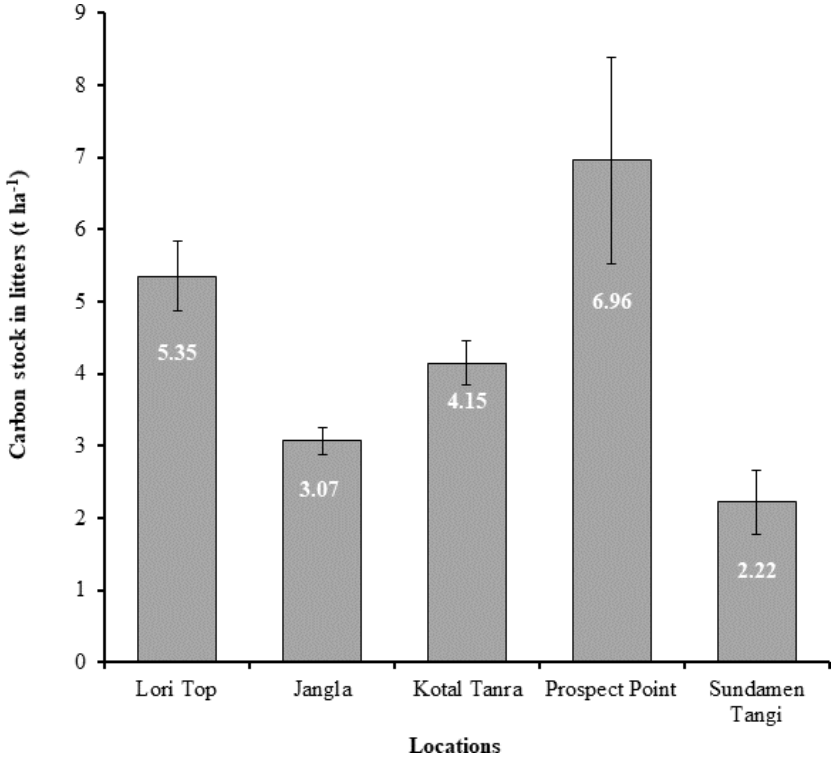


Figure 4.10. Carbon stock in litters across different locations in Juniper forest Ziarat

4.6 Carbon stock (t ha^{-1}) estimation in various components of forest at location 1 (Lori Top)

Biomass carbon stock in various components of juniper forest Ziarat at Lori Top Region was explored which were comprised of herbs, shrubs, juniper trees, forest litters and soil organic carbon as shown in (Table 6). The herbs above ground biomass (AGB) and below ground biomass (BGB) were (1.86) and (0.28 t ha$^{-1)}$ with total biomass of (2.13 t ha$^{-1)}$ that stocked above ground biomass carbon (AGBC) of (0.947 t ha$^{-1)}$ and below ground biomass carbon (BGBC) of (0.28 t ha$^{-1)}$ reflecting total carbon stock (TCS) of (1.22 t ha$^{-1)}$ respectively (Table 6). Among the herbs species, *Eremurus persicus* (Jaub.& Spach) Boiss manifested higher total biomass (0.56 t ha^{-1}) that stored total carbon stock of (0.32 t ha$^{-)1}$. But *Solanum nigrum* Linn recorded the the lower total biomass of (0.06 t ha$^{-1)}$ with total carbon stock of (0.03 t ha^{-1}).

The shrubs species evaluated for above ground biomass (AGB), below ground biomass (BGB), total biomass (TB), total above ground biomass carbon (TAGBC), total below ground biomass (TBGB) and total carbon stock (TCS) at location 1 (Lori Top) in juniper forest Ziarat and presented in Table 6 based on the average of 10 quadrates. The results revealed that the shrubs AGB and BGB were (17.58) and (2.63 t ha^{-1})with TB of (20.21 t ha^{-1}) that stocked AGBC of (8.965 t ha^{-1}) and BGBC of (2.63 t ha^{-1})reflecting total carbon stock (TCS) of (11.59 t ha^{-1}) respectively (Table 6). Among the shrub's species, *Berberis baluchistanica* Ahrendt. and *Saphora molis* exhibited higher TB of (5.26) and (5.69 t ha^{-1}) that stored TCS of (3.02) and (3.26 t ha^{-1}.) But *Peganum hermala* Linn. recorded lower TB of (1.29 t ha^{-1}) with TCS of (0.74 t ha^{-1}).

Juniper trees are main components of juniper forest along with forest litters and soil organic matter where maximum TB of tees were (451 t ha^{-1}) that gained TCS of (220.82 t ha^{-1}) and TCS of litters and soil organic carbon were (5.35) and (8.85 t ha^{-1}) So, in this region of juniper forest the TAGB, TBGB and TB were 412.34, 51.76 and (464.1 t ha^{-1}) that reflected TAGBC of (206.312 t ha^{-1}) TBGBC of (27.33 t ha^{-1}) with TCS of (247.83 t ha^{-1}) respectively (Table 6). Component wise TCS of herb was (1.22 t ha^{-1}), shrubs was (11.59 t ha^{-1}) , juniper trees was (220.82 t ha^{-1}), forest litters was (5.35 t ha^{-1}) and soil organic carbon was(8.85 t ha^{-1}) with overall TCS of (247.83 t ha^{-1}).

Table 4.6. Biomass carbon stock (t ha^{-1}) in various components of juniper forest Ziarat at location 1 (Lori Top)

Carbon source	$^{+}$TAGB	TBGB	TB	TAGBC	TBGB	TCS
Herbs						
Salvia bucharica	$^{++}$0.46	0.07	0.53	0.237	0.07	0.31
Thymus vulgaris L.	0.41	0.06	0.47	0.209	0.06	0.27

Solanum nigrum L.	0.05	0.01	0.06	0.025	0.01	0.03
Eremurus persicus (Jaub.& Spach) Boiss	0.49	0.07	0.56	0.249	0.07	0.32
Eremurus stenophyllus (Boiss.& Bushe) Baker	0.45	0.07	0.51	0.227	0.07	0.29

Shrubs						
Peroviskia abrotanoides Karel	2.50	0.37	2.87	1.273	0.37	1.65
Peganum hermala L.	1.12	0.17	1.29	0.573	0.17	0.74
Artemisia stricta Edgew	2.29	0.34	2.64	1.170	0.34	1.51
Berberis baluchistanica Ahrendt.	4.58	0.69	5.26	2.334	0.69	3.02
Saphora molis	4.95	0.74	5.69	2.522	0.74	3.26
Caragna ambigua	2.14	0.32	2.46	1.093	0.32	1.41
Juniper trees	392.9	48.85	451.8	196.4	24.42	220.82
Forest Litters	-	-	-	-	-	5.35
Soil organic carbon	-	-	-	-	-	8.85
Total carbon stock	412.34	51.76	464.1	206.312	27.33	247.83

[+]TAGB-Total above ground biomass, TBGB-Total below ground biomass, TB-Total biomass, TAGBC-Total above ground biomass carbon, TBGBC-Total below ground biomass carbon, TCS-Total carbon stock

[++] Values of 10 quadrates converted into t ha^{-1}.

4.7 Carbon stock (t ha^{-1}) estimation in various components of forest at location 2 (Jangla)

Biomass carbon stock in various components of juniper forest Ziarat at Jangla region was explored which were comprised of herbs, shrubs, juniper trees, forest litters and soil organic carbon as shown in (Table 7). The herbs above ground biomass (AGB) and below ground biomass (BGB) were (5.59) and (0.84 t ha^{-1}) with total biomass of (6.42 t ha^{-1}) that stocked above ground biomass carbon (AGBC) of (3.38 t ha^{-1}) and below ground biomass carbon (BGBC) of (0.46 t ha^{-1}) reflecting total carbon stock (TCS) of (3.84 t ha^{-1}) respectively (Table 7). Among the herbs species, *Salvia bucharica* manifested higher total biomass (1.64 t ha^{-1}) that stored total carbon stock of (0.872 t ha^{-1}). But *Eremurus persicus* (Jaub.& Spach) Boiss recorded the lower total biomass of (1.03 t ha^{-1})with total carbon stock of (0.680 t ha^{-1}).

The shrubs species evaluated for above ground biomass (AGB), below ground biomass (BGB), total biomass (TB), total above ground biomass carbon (TAGBC), total below ground biomass (TBGB) and total carbon stock (TCS) at location 2 (Jangla) in juniper forest Ziarat and presented in (Table 7) based on the average of 10 quadrates. The results revealed that the shrubs AGB and BGB were (3.67) and (0.549 t ha^{-1}) with TB of (4.20 t ha^{-1}) that stocked AGBC of (1.99 t ha^{-1})and BGBC of (0.303 t ha^{-1}) reflecting total carbon stock (TCS) of (2.3 t ha^{-1})respectively (Table 7). Among the shrub's species, *Artemisia stricta* L. and *Hertia intermedia* (Boiss) O.Ktze.exhibited higher TB of (0.74) and (0.77 t ha^{-}

[1])that stored TCS of (0.30) and (0.47 t ha^{-1}). But *Artemisia stricta* Edgew recorded lower TB of (0.04 t ha^{-1})with TCS of (0..2 t ha^{-1}).

Juniper trees are the main components of juniper forest along with forest litters and soil organic matter where maximum TB of tees were (1003.5 t ha^{-1}) that gained TCS of (501.76 t ha^{-1}) and TCS of litters and soil organic carbon were (3.07) and (7.46 t ha^{-1}) . So, in this region of juniper forest the TAGB, TBGB and TB were 881.445, 132.277 and (441.684 t ha^{-1}) that reflected TAGBC of (441.684 t ha^{-1}), TBGBC of (66.2137 t ha^{-1}) with TCS of (518.432 t ha^{-1})respectively (Table 7). Component wise TCS of herb was (3.84 t ha^{-1}), shrubs was (2.30 t ha^{-1}), juniper trees was (501.76 t ha^{-1}), forest litters was (3.07 t ha^{-1})and soil organic carbon was (7.46 t ha^{-1})with overall TCS of (518.43 t ha^{-1}).

Table 4.7. Biomass carbon stock (t ha^{-1}) in various components of juniper forest Ziarat at location 2 (Jangla)

Carbon source	**[+]TAGB**	**TBGB**	**TB**	**TAGBC**	**TBGB**	**TCS**
Herbs						
Salvia bucharica	[++]1.423	0.21347	1.64	0.7549	0.1174	0.872
Thymus vulgaris L.	0.999	0.14978	1.15	0.7598	0.0824	0.842
Solanum nigrum L.	0.987	0.14808	1.14	0.5871	0.0814	0.668
Eremurus persicus (Jaub.& Spach) Boiss	0.896	0.13439	1.03	0.6062	0.0739	0.680

Eremurus stenophyllus (Boiss.& Bushe) Baker	1.28	0.19208	1.47	0.6762	0.1056	0.782
Shrubs						
Peroviskia abrotanoides Karel	0.48	0.072	0.55	0.32	0.040	0.36
Artemisia stricta L.	0.65	0.097	0.74	0.25	0.053	0.30
Artemisia stricta Edgew	0.03	0.005	0.04	0.02	0.003	0.02
Berberis baluchistanica Ahrendt.	0.57	0.085	0.65	0.25	0.047	0.30
Berberis calliobotrys Aitch.& Koehne	0.09	0.014	0.11	0.06	0.008	0.07
Saphora molis	0.41	0.062	0.47	0.28	0.034	0.31
Caragna ambigua	0.39	0.058	0.44	0.20	0.032	0.23
Hertia intermedia (Boiss) O.Ktze.	0.67	0.100	0.77	0.41	0.055	0.47
Peganum hermala L.	0.38	0.056	0.43	0.20	0.031	0.24
Juniper trees	872.6	130.89	1003.50	436.31	65.45	501.76
Forest Litters	-	-	-	-	-	3.07
Soil organic carbon	-	-	-	-	-	7.46
Total carbon stock	881.445	132.277	1014.13	441.684	66.2137	518.434

[+]TAGB-Total above ground biomass, TBGB-Total below ground biomass, TB-Total biomass, TAGBC-Total above ground biomass carbon, TBGBC-Total below ground biomass carbon, TCS-Total carbon stock

[++] Values of 10 quadrates converted into t ha^{-1}.

4.8 Carbon stock (t ha^{-1}) estimation in various components of forest at location 3 (Kotal Tanra)

Biomass carbon stock in various components of juniper forest Ziarat at Jangla region was explored which were comprised of herbs, shrubs, juniper trees, forest litters and soil organic carbon as shown in (Table 8). The herbs above ground biomass (AGB) and below ground biomass (BGB) were (6.09) and (0.91 t ha^{-1})with total biomass of (7.01 t ha^{-1})that stocked above ground biomass carbon (AGBC) of (3.077 t ha^{-1})and below ground biomass carbon (BGBC) of (0.502 t ha^{-1}) reflecting total carbon stock (TCS) of (3.58 t ha^{-1}) respectively (Table 8). Among the herbs species, *Thymus vulgaris* L. manifested higher total biomass (2.15 t ha^{-1}) that stored total carbon stock of (0.98 t ha^{-1}) But *Plantago lanceolata* recorded the lower total biomass of (0.24 t ha^{-1})with total carbon stock of (0.095 t ha^{-1})

The shrubs species evaluated for above ground biomass (AGB), below ground biomass (BGB), total biomass (TB), total above ground biomass carbon (TAGBC), total below ground biomass (TBGB) and total carbon stock (TCS) at location 3 (Kotal Tanra) in juniper forest Ziarat and presented in (Table 8) based on the average of 10 quadrates. The results exposed that the shrubs AGB and BGB were (4.09) and (0.613 t ha^{-1})with TB of (4.71 t ha^{-1})that stocked AGBC of (1.98 t ha^{-1})and BGBC of(0.338 t ha^{-1})reflecting total carbon stock (TCS) of (2.33 t ha^{-1})respectively (Table 8). Among the shrub's species, *Onobrychis cornuta* and *Artemisia stricta* Edgew exhibited higher TB of (1.79) and (1.31 t ha^{-1})that stored TCS of (0.92) and (0.59 t ha^{-1}.) But *Peroviskia abrotanoides* Karel recorded lower TB of(0.07 t ha^{-1})with TCS of (0.04 t ha^{-1}).

Juniper trees are the main components of juniper forest along with forest litters and soil organic matter where maximum TB of tees were (2043.89 t ha^{-1}) that gained TCS of (1021.95 t ha^{-1})and TCS of litters and soil organic carbon were (4.15) and (8.46 t ha^{-1}).So, in this region of juniper forest the TAGB, TBGB and TB were (1787.48), (268.113) and (2055.61 t ha^{-1})that reflected TAGBC of (893.71 t ha^{-1}), TBGBC of (134.14 t ha^{-1}) with TCS of (1040.47 t ha^{-1})respectively (Table 8). Component wise TCS of herb was (3.58 t ha^{-1}), shrubs was (2.33 t ha^{-1}), juniper trees was (1021.95 t ha^{-1}), forest litters was (4.15 t ha^{-1})and soil organic carbon was 8.46 t ha^{-1} with overall TCS of (1040.47 t ha^{-1}).

Table 4.8. Biomass carbon stock (t ha^{-1}) in various components of juniper forest Ziarat at location 3 (Kotal Tanra)

Carbon source	**+TAGB**	**TBGB**	**TB**	**TAGBC**	**TBGB**	**TCS**
Herbs						
Salvia bucharica	++0.22	0.03	0.25	0.102	0.018	0.120
Thymus vulgaris L	1.87	0.28	2.15	0.823	0.154	0.977
Solanum nigrum L	1.29	0.19	1.49	0.650	0.107	0.756
Eremurus persicus (Jaub.& Spach) Boiss	0.70	0.11	0.81	0.322	0.058	0.380
Eremurus stenophyllus (Boiss.& Bushe) Baker	1.53	0.23	1.76	0.923	0.126	1.049

Ixiolirion tataricum	0.27	0.04	0.31	0.179	0.022	0.202
Plantago lanceolate	0.21	0.03	0.24	0.078	0.017	0.095
Shrubs						
Onobrychis cornuta	1.56	0.234	1.79	0.79	0.129	0.92
Peroviskia abrotanoides Karel	0.06	0.010	0.07	0.03	0.005	0.04
Hertia intermedia (Boiss) O. Ktze.	0.15	0.022	0.17	0.06	0.012	0.07
Artemisia maritima L.	0.30	0.045	0.35	0.14	0.025	0.17
Artemisia stricta Edgew	1.14	0.170	1.31	0.50	0.094	0.59
Berberis calliobotrys Aitch. & Koehne	0.19	0.028	0.22	0.12	0.016	0.14
Peganum hermala L.	0.64	0.096	0.74	0.30	0.053	0.36
Saphora molis	0.05	0.008	0.06	0.04	0.004	0.04
Juniper trees	1777.3	266.59	2043.89	888.65	133.30	1021.95
Forest Litters	-	-	-	-	-	4.15
Soil organic carbon	-	-	-	-	-	8.46
Total carbon stock	1787.48	268.113	2055.61	893.707	134.14	1040.469

[+]TAGB-Total above ground biomass, TBGB-Total below ground biomass, TB-Total biomass, TAGBC-Total above ground biomass carbon, TBGBC-Total below ground biomass carbon, TCS-Total carbon stock

[++] Values of 10 quadrates converted into t ha^{-1}.

4.9 Carbon stock (t ha^{-1}) estimation in various components of forest at location 4 (Prospect point)

Biomass carbon stock in various components of juniper forest Ziarat at Prospect poiont region was explored which were comprised of herbs, shrubs, juniper trees, forest litters and soil organic carbon as shown in (Table 9). The herbs above ground biomass (AGB) and below ground biomass (BGB) were (8.31) and (1.24 t ha^{-1})with total biomass of (9.56 t ha^{-1}) that stocked above ground biomass carbon (AGBC) of (3.088 t ha^{-1})and below ground biomass carbon (BGBC) of 0.687 t ha^{-1} reflecting total carbon stock (TCS) of (3.77 t ha^{-1})respectively (Table 9). Among the herb's species, *Eremurus persicus* (Jaub.& Spach) Boiss manifested higher total biomass (4.10 t ha^{-1}) that stored total carbon stock of (1.26 t ha^{-1}). But *Salvia bucharica* recorded the lower total biomass of (0.22 t ha^{-1}) with total carbon stock of (0.119 t ha^{-1}).

The shrubs species evaluated for above ground biomass (AGB), below ground biomass (BGB), total biomass (TB), total above ground biomass carbon (TAGBC), total below ground biomass (TBGB) and total carbon stock (TCS) at location 4 (Prospect Point) in juniper forest Ziarat and presented in (Table 9) based on the average of 10 quadrates. The results revealed that the shrubs AGB and BGB were (14.45) and (2.166 t ha^{-1})with TB of (16.61 t ha^{-1})that stocked AGBC of (7.85 t ha^{-1})and BGBC of (1.19 t ha^{-1})reflecting total carbon stock (TCS) of (9.04 t ha^{-1})respectively (Table 9). Among the shrub's species, *Onobrychis cornuta* and *Amygdalus spinosissima* recorded higher TB of (5.88) and (3.18 t ha^{-1})with TCS of (3.18) and (2.24 t ha^{-1}). But the lower TB of(0.52 t ha^{-1})was observed for *Hertia intermedia* (Boiss) O.Ktze. that expressed TCS of (0.17 t ha^{-1}).

Juniper trees are the main components of juniper forest along with forest litters and soil organic matter where maximum TB of tees were (630.1 t ha^{-1})that gained TCS of (315.88 t ha^{-1})and TCS of litters and soil organic carbon were (6.96)and(9.93 t ha^{-1}) So, in this region of juniper forest the TAGB, TBGB and TB were (570.586), (85.586) and (656.27 t ha^{-1})that reflected TAGBC of (284.87 t ha^{-1}), TBGBC of (42.98 t ha^{-1})with TCS of (345.58 t ha^{-1})respectively (Table 9). Component wise TCS of herb was (3.77 t ha^{-1})

.shrubs was (9.04 t ha^{-1}) juniper trees was (315.88 t ha^{-1}) , forest litters was(6.96 t ha^{-1}) and soil organic carbon was(9.93 t ha^{-1})with overall TCS of (345.58 t ha^{-1}).

Table4.9 Biomass carbon stock (t ha^{-1}) in various components of juniper forest Ziarat at location 4 (Prospect Point)

Carbon source	**+TAGB**	**TBGB**	**TB**	**TAGBC**	**TBGB**	**TCS**
Herbs						
Salvia bucharica	++0.19	0.03	0.22	0.103	0.016	0.119
Thymus vulgaris L.	0.78	0.12	0.90	0.341	0.065	0.405
Eremurus persicus (Jaub.& Spach) Boiss	3.56	0.53	4.10	0.967	0.294	1.261
Eremurus stenophyllus (Boiss.& Bushe) Baker	1.77	0.26	2.03	0.807	0.146	0.952

Ixiolirion tataricum	1.78	0.27	2.05	0.728	0.147	0.874
Astragalus sp.	0.23	0.03	0.26	0.142	0.019	0.160
Shrubs						
Onobrychis cornuta	5.12	0.767	5.88	2.76	0.422	3.18
Peroviskia abrotanoides Karel	1.01	0.152	1.17	0.73	0.084	0.81
Hertia intermedia (Boiss) O.Ktze.	0.45	0.068	0.52	0.14	0.037	0.17
Artemisia maritima L.	0.55	0.082	0.63	0.20	0.045	0.25
Artemisia stricta Edgew	1.72	0.259	1.98	0.77	0.142	0.92
Berberis baluchistanica Ahrendt.	1.05	0.158	1.21	0.39	0.087	0.47
Peganum hermala L.	0.62	0.092	0.71	0.02	0.051	0.07
Saphora molis	1.16	0.173	1.33	0.83	0.095	0.93
Amygdalus spinosissima	2.77	0.415	3.18	2.01	0.228	2.24
Juniper trees	547.88	82.18	630.10	273.94	41.10	315.88
Forest Litters	-	-	-	-	-	6.96
Soil organic carbon	-	-	-	-	-	9.93
Total carbon stock	570.64	85.586	656.27	284.878	42.978	345.58

[+]TAGB-Total above ground biomass, TBGB-Total below ground biomass, TB-Total biomass, TAGBC-Total above ground biomass carbon, TBGBC-Total below ground biomass carbon, TCS-Total carbon stock

[++] Values of 10 quadrates converted into t ha^{-1}.

4.10 Carbon stock (t ha^{-1}) estimation in various components of forest at location 5 (Sundamen Tangi)

Biomass carbon stock in various components of juniper forest Ziarat at Prospect point region was explored which were comprised of herbs, shrubs, juniper trees, forest litters and soil organic carbon as shown in (Table 10). The herbs above ground biomass (AGB) and below ground biomass (BGB) were (21.14)and (3.16 t ha^{-1})with total biomass of (24.3 t ha^{-1})that stocked above ground biomass carbon (AGBC) of (10.608 t ha^{-1})and below ground biomass carbon (BGBC) of (1.745 t ha^{-1})reflecting total carbon stock (TCS) of (12.35 t ha^{-1})respectively (Table 10). Among the herb's species, *Nepeta juncea*

Benth.manifested higher total biomass (16.94 t ha^{-1}) that stored total carbon stock of (8.10 t ha^{-1}). But

Solanum nigrum L.. recorded the lower total biomass of (1.11 t ha^{-1})with total carbon stock of (0.546 t ha^{-1}).

The shrubs species evaluated for above ground biomass (AGB), below ground biomass (BGB), total biomass (TB), total above ground biomass carbon (TAGBC), total below ground biomass (TBGB) and total carbon stock (TCS) at location 5 (Sundamen Tangi) in juniper forest Ziarat and presented in (Table 10) based on the average of 10 quadrates. The results showed that the shrubs AGB and BGB were (5.21) and(0.78 t ha^{-1}

)with TB of (5.99 t ha^{-1})that stocked AGBC of (2.75 t ha^{-1})and BGBC of (0.43 t ha^{-1}) reflecting total carbon stock (TCS) of (3.18 t ha^{-1}) respectively (Table 10). Among the shrub's species, *Saphora molis* and *Peganum hermala* L. recorded higher TB of (1.71) and (1.07 t ha^{-1}) with TCS of (0.92) and (0.57 t ha^{-1}). But the lower TB of (0.14 t ha^{-1})was observed for *Berberis baluchistanica* Ahrendt. that expressed TCS of 0.07 t ha^{-1}.

Juniper trees are the main components of juniper forest along with forest litters and soil organic matter where maximum TB of tees were (637.28 t ha^{-1})that gained TCS of (366.43 t ha^{-1})and TCS of litters and soil organic carbon were (2.22) and (8.4 t ha^{-1}). So, in this region of juniper forest the TAGB, TBGB and TB were (663.63, 99.54) and 7(63.17 t ha^{-1}) that reflected TAGBC of (331.98 t ha^{-1}), TBGBC of (49.74 t ha^{-1})with TCS of (392.58 t ha^{-1})respectively (Table 10). Component wise TCS of herb was (12.35 t ha^{-1}),shrubs was (3.18 t ha^{-1}), juniper trees was (366.43 t ha^{-1}), forest litters was (2.22 t ha^{-1})and soil organic carbon was (8.4 t ha^{-1})with overall TCS of (392.58 t ha^{-1}).

Table 4.10. Biomass carbon stock (t ha^{-1}) in various components of juniper forest Ziarat at location 5 (Sundamen Tangi)

Carbon source	+TAGB	TBGB	TB	TAGBC	TBGB	TCS
Herbs						
Nepeta juncea Benth.	13.93	2.09	16.02	6.944	1.149	8.093
Thymus vulgaris L.	1.62	0.24	1.86	0.657	0.134	0.791
Solanum nigrum L.	0.97	0.14	1.11	0.466	0.080	0.546

Eremurus persicus (Jaub.& Spach) Boiss	2.02	0.30	2.32	0.976	0.167	1.143
Eremurus stenophyllus (Boiss.& Bushe) Baker	2.60	0.39	2.99	1.565	0.215	1.779
Shrubs						
Onobrychis cornuta	0.29	0.044	0.34	0.13	0.024	0.16
Artemisia peroskia	0.64	0.095	0.73	0.35	0.053	0.41
Hertia intermedia (Boiss) O.Ktze.	0.91	0.137	1.05	0.50	0.075	0.57
Artemisia maritima L.	0.15	0.023	0.17	0.08	0.012	0.09
Artemisia stricta Edgew	0.37	0.055	0.43	0.16	0.030	0.19
Berberis baluchistanica Ahrendt.	0.12	0.018	0.14	0.06	0.010	0.07
Berberis calliobotrys Aitch.& Koehne	0.31	0.046	0.35	0.18	0.025	0.20
Peganum hermala L.	0.93	0.140	1.07	0.50	0.077	0.57
Saphora molis	1.49	0.223	1.71	0.79	0.123	0.92
Juniper trees	637.28	95.60	732.88	318.63	47.80	366.43
Forest Litters	-	-	-	-	-	2.22
Soil organic carbon	-	-	-	-	-	8.40
Total carbon stock	663.63	99.541	763.17	331.988	49.974	392.582

[+]TAGB-Total above ground biomass, TBGB-Total below ground biomass, TB-Total biomass, TAGBC-Total above ground biomass carbon, TBGBC-Total below ground biomass carbon, TCS-Total carbon stock

[++] Values of 10 quadrates converted into t ha^{-1}.

4.11 Carbon stock (t ha^{-1}) evaluation across five locations in juniper forest Ziarat

Total above ground biomass carbon stock (TAGBCS), Total below ground biomass carbon stock (TBGBCS) and total carbon stock (TCS) as shown in (Figure 11)and 12 revealed significant differences across five locations in juniper forest Ziarat. The results exhibited greater TAGBCS (893.71 t ha^{-1}) and TBGBCS (134.14 t ha^{-1}) in location 3 (Kotal Tanra) followed by (441.68) and (66.21 t ha^{-1})carbon stock in above and below ground biomass of juniper forest (Figure 11). While, the lower TAGBCS (206.31 t ha^{-1}) and TBGBCS (27.33 t ha^{-1}) were found in Lori Top region (location 1) of juniper forest.

Other two locations such as Prospect point and Sundamen Tangi expressed TCS as (284.88) and

(331.99 t ha^{-1})which were comparatively lower as compared to Kotal Tanra and Jangla but higher over Lori Top (Figure 11).

Total carbon stock (TCS) of a location in juniper forest is the sum of carbon stock in herbs, shrubs, juniper trees, forest litters and soil organic matter. So, the TCS in juniper forest Ziarat varied significantly across five locations as depicted in (Figure 12) that revealed higher TCS (1040.47 t ha^{-1}) in the region of Kotal Tanra (location 3) followed by (518.43 t ha^{-1})TCS in region of Jangla as location 2. But the lower TCS of (247.83 t ha^{-1}) was recorded in location 1 (Lori Top) (Figure 12). In addition to that the two locations such as Prospect point and Sundamen Tangi manifested TCS of (345.6) and (392.58 t ha^{-1}) which were higher over TCS of Lori Top area but comparatively lower when compared to TCS of location 3 and 2 (Figure 12).

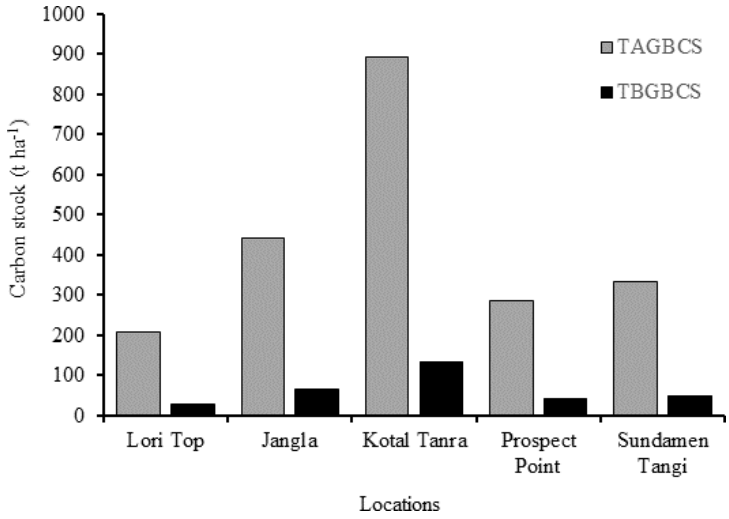


Figure 4.11 Above and below ground carbon stock (t ha^{-1}) of juniper forest Ziarat across five locations

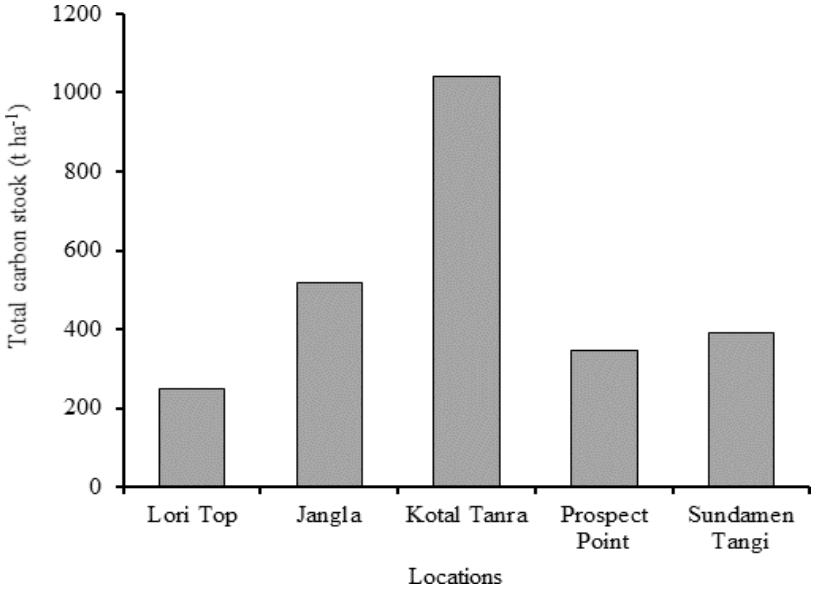


Figure 4.12 Total carbon stock (t ha^{-1}) estimation in juniper forest Ziarat across five locations

DISCUSSION

The selected five locations for assessment of above and below carbon stock in juniper forest Ziarat possesses a significant position in juniper ecosystem in terms of species composition, their frequency, abundance, relative density and density. The herbs and shrubs found in these locations revealed varying level fluctuation where four herb species such as *Salvia bucharica, Thymus vulgaris* L. *Solanum nigrum* L.., *Eremurus persicus* (Jaub.& Spach) Boiss, and *Eremurus stenophyllus* (Boiss.& Bushe) Baker prevailed in all locations with different frequencies, abundance and density. *Ixiolirion tataricum* and *Plantago lanceolata* occurred in location 3 (Kotal Tanra) while *Astragalus sp.* was existed in location 4 (Prospect point). Whereas, herb species *Nepeta juncea* Benth. was only present in location 5 (Sundamen Tangi) and not in any other locations. However, *Plantago lanceolata* as existed in location 3 was also in present in location 5. These demonstrate that herb species with respect to location in a juniper ecosystem varied that might be due to alternate utilization of herbs by the native people and also due to livestock open grazing pattern. Because some herbs like *Thymus vulgaris* Linn. is used for medicinal purpose by the native people particularly in the treatment of cough and dysentery problems. In addition to that other two species of herbs like *Solanum nigrum* L. and *Eremurus stenophyllus* (Boiss.& Bushe) Baker are utilized as vegetables. *Salvia bucharica* was dominant in location 1showing 70% frequency with relative density of (32.3). The region of Kotal tanra *Thymus vulgaris* L. was the dominant species with frequency of 90% and in area of Prospect point *Solanum nigrum* L. was found as dominant species with frequency of 80%. In location 5 (Sundamen Tangi) all species expect *Solanum nigrum* L. and *Plantago lanceolata* exhibited similar level frequency of 60%. Importance of herbs flora for medicinal purpose has been reported by many researchers (Karki, 2002; Chaudhary *et al*., 2006; Shinwari, 2009; Srithi *et al.*, 2009). According to some estimates in Pakistan that approximately 300 species are being utilized in preparation of traditional medicines (Haq, 1998; Perveen and Hussain, 2007). As reported by Shinwari (2009) that Ziarat comes under the subregion of western Irano-Turanian having an estimated floral diversity of (45%).

The shrubs' species studied for frequency, abundance, relative density and density across five locations in juniper forest Ziarat and evaluated for above and below ground carbon stock estimations. The most commonly found species were *Amygdalus spinosissima*, *Artemisia stricta* Edgew, *Artemisia stricta* L.., *Berberis baluchistanica* Ahrendt, *Berberis calliobotrys* Aitch.& Koehne, *Caragna ambigua*, *Ephedra intermedia* Schrenk, *Hertia intermedia* (Boiss) O.Ktze., *Peganum hermala* L.., *Peroviskia abrotanoides* Karel, and *Saphora molis* respectively. In the area of Lori top (location 1), *Artemisia stricta* Edgew was the dominant species with frequency of (50%)and *Caragna ambigua* was leas dominated with frequency of 10%. While, in the Jangla region (location 2) *Peganum hermala* L. was

the dominant species manifested 100% frequency with relative density of 19.6 followed by *Hertia intermedia* (Boiss) O.Ktze. and *Artemisia stricta* L. that expressed frequency of 70%. But the two species such as *Artemisia stricta* Edgew and *Berberis calliobotrys* Aitch.& Koehne showed lower frequency of 10% in this area of juniper forest. In 3rd 4th locations (Kotal Tanra and Prospect point) the most dominant species was *Onobrychis cornuta* that revealed 70 and 100% frequency while *Peroviskia abrotanoides* Karel was found with lowest frequency of 10% in location 3. According to IUCN report entitled "Flora of Ziarat: Ethnobotanic and Medicinal Importance" that juniper forest Ziarat create a unique ecosystem comprising of *Juniperus excelsa* flourishing in the ecological condition having calcareous, shallow and stony soil with low precipitation along with shrubs covering ground area of the forest that were mostly dominated by *Artemisia* sp., *Perviskia abrotanoides*, *Sophora mollis* and *Thymus linearis*. The survival of land plants in such areas relies on the availability of water and their adaptation to stress (Kramer, 1984). The presence of such arid communities depends upon soil moisture condition which strongly correlates with plant cover (Branson *et al*., 1976). Plants grow sparsely leaving a wide area of bare soil (Hussain, 1989) that is the characteristic feature of arid environments (Burke & Mennheimer, 2003).

As regard to the stocking rate of juniper forest across various locations in Tehsil Ziarat revealed significant fluctuation. The results manifested higher stocking rate of 430 trees ha^{-1} in region of Kotal Tanra and 450 trees ha^{-1} in prospect point but the lower

stocking rate of 290 trees ha^{-1} recorded in location 2 (Jangla). It means that the area of Kotal Tanra showed (33.46) and (48.26%) higher stocking rate over the area of Lori top and Jangla while, the area of Prospect point exhibited (39.66) and (49.65%) increase in stocking rate over Lori Top and Jangla respectively. It demonstrates that these two locations have very limited level of permanent residents over other areas because permanent settlers indiscriminately utilize forest resources for their livelihood, use timbers in construction of their homes and clearing forest land for the establishment of deciduous fruit orchards and that can be seen in the area of Lori top, Jangla and Sundamen Tangi as well. Similar results were reported by Hosonuma *et al.* (2012) that the menace of deforestation and degradation of juniper forest has augmented seriously. It is further mentoned that expansion in urbanization and agricultural practices have now resulted in decline of forest cover (Forest and Ministry of Environment, 2009). Many research groups have found expansion in agricultural land with corresponding decrease in forest area (Sarangzai *et al.*, 2012; Achakzai *et al.*, 2013).

Carbon stock in various components of juniper forest Ziarat was estimated that revealed significant fluctuation across locations. These components were comprised of herbs, shrubs, juniper trees, forest litters and soil organic carbon that were assessed for total carbon stock (TCS) in five different area in juniper ecosystem. The results regarding TCS in soil and forest litters exhibited significant differences where higher carbon stock of (9.93) and (6.96 t ha^{-1})in soil and litters were found in the area of Prospect point and lower carbon stock of (7.46 t ha^{-1})was noted in Jungla region of the forest. But lower TCS

in litters was observed in Sundamen Tangi area (location 5). The higher TCS in soil and litters in Prospect point area were due to greater frequency of *Onobrychis cornuta* and *Artemisia maritima* L. as forest ground cover that helped in retention of litters on soil surface during runoff of rain water and further its decomposition helped in buildup of soil organic carbon. It means that the conservation of plants biodiversity as ground cover in juniper forest ecosystem is pivotal for ensuring sustainability of ecosystems services and functions. In addition to that the low population pressure and minimum open livestock grazing pattern have resulted in greater frequency of *Onobrychis cornuta* leading to augmented level TCS in soil and litters. This scenario depicts that how land use changes affect the carbon stock within areas of juniper forest. As reported by Lal *et al.* (2005) that expansion in agricultural land by clearing forest and range areas have now resulted in reduction in soil organic carbon or in another words such practices accelerated the loss of carbon from soil. It is imperative to note that in juniper forest soil is an important carbon sink (Charro *et al.*, 2017). According to Davidson and Janssens (2006) that soil across the world stock greater carbon as compared to carbon store in the atmosphere. Another group of researchers have reported that loss of carbon stock from the soil have been occurred severely (Jackson *et al.*, 2017). Nonetheless, if best management practices are adopted for enhancement of soil organic carbon, then it can correspondingly increase the quality of soil essential for sustaining soil biodiversity to cater proper functioning of ecosystem services (Lal *et al.*, 2015). Our results are in line with those reported by Jallat *et al.* (2021) who observed carbon stock in forest's soil of (24.35 t ha^{-1}) and (1.52 t ha^{-1})carbon stock in litters.

Total carbon stock (TCS) estimated in various locations in juniper forest Ziarat revealed significant differences and the area of Kotal Tanra (location 3) expressed higher TCS of (1040.47 t ha^{-1})in which total above ground biomass carbon stock (TAGBCS) was (893.71 t ha^{-1})and total below ground biomass carbon (TBGBCS) was (134.14 t ha^{-1}). However, the lower TCS (247.83 t ha^{-1}) was recorded in Lori top area (location 1) in which TAGBCS was (206.31 t ha^{-1})and TBGBCS was (27.33 t ha^{-1}). The higher TCS values in Kotal Tanra area was might be due to higher stand basal area (63.72 m^2 ha^{-1}) and stocking rate (430 trees ha^{-1}). These results are in accordance with estimates of Sarmiento *et al.* (2005) who reported that stand basal area of a forest is a good indicator for manifesting biomass and carbon stock as many other researchers have observed that SBA and biomass of trees are correlated with DBH (diameter at breast height) of trees (Burrows *et al.*, 2000). In total carbon stock (TCS) estimation the contribution of herbs, shrubs ad litters can't be ignored. Because herb and shrubs are the main ground cover in a forest. Among the five locations, higher TCS (12.35 t ha^{-1}) in herbs was recorded in location 5 (Sundamen Tangi) because of negligible level open livestock grazing in the area. Whereas, higher TCS of (11.59 t ha^{-1})in shrubs were noted in Lori top area that might be due to low population pressure where shrubs have less subjected to alternate utilization. Our results are in line with estimation of Jallat *et al.* (2021) who noted TCS of (24.35, 1.52) and (4.66 t ha^{-1})in soil, litters and shrubs in juniper forest Ziarat. Consequently, the overall TCS scenario across five locations in

juniper forest revealed that TCS in various components of forest were affected by anthropogenic activities and higher TCS was manifested in the areas where the population pressure by native people was low because most of the people fell juniper trees and use its timbers in theirs houses, making fences around orchards and for fuel purpose. Iron of fate is that many of the native people sale out timbers to the neighboring districts where juniper wood demand as timber is higher. According to Jallat *et al.* (2021) that forest resources were inversely proportional to population due to clearing of forest land for agriculture activities (Hosonuma *et al.*, 212). Another group of researchers reported that increasing in population correspondingly accelerated the loss of forest in terms of firewood and timber uses leading to augmentation in non-forest area in district Ziarat (Gul *et al.*, 216; BBC, 2016).

References

Achakzai, A.K.K., H. Batool, T. Aqeel, Z.A. Bazai. 2013. A comparative study of the deforestation and regeneration status of Ziarat Juniper forest. Pak. J. Bot. 45: 1169–1172.

Ahmed, M., T. Husain., A.H. Sheikh., S.S. Hussain and M.F. Siddiqui. 2006. Phytosociology and structure of Himalayan forests from different climatic zones of Pakistan. Pak. J. Bot., 38(2):361-383.

Alamgri, M. and M. Al-Amin. 2008. Allometric models to estimate biomass organic carbon stock in forest vegetation. Journal of Forestry Research, 19:101. https://doi.org/10.1007/s11676-008-0017-4

Baishya, R. and K.B. Saroj. 2011. Estimation of tree biomass, carbon pool and net primary production of an old-growth *Pinus kesiya* Royle ex. Gordon forest in north-eastern India. Annals of Forest Science, 68:727-736.

BBC—British Broadcasting Corporation. 2018. Pakistan's Ziarat: An Ancient Juniper Forest and Its Living Fossils. Available online: https://www.bbc.com/news/world-asia-43660466 (accessed on 21 September 2018).

Branson, F.A., R.F. Miller and I.S. Mcqueen. 1976. Moisture relationships in twelve northern desert shrub communities near Grand Junction, Colorado. Ecology, 57: 1104-1124.

Broadmeadow, M. and M. Robert. 2003. Forests, Carbon and Climate Change: The UK Contribution. Forestry Commission Bulletin 125. Forestry Commission, Edinburgh.

Burke, A. and C. Mannheimer. 2003. Towards a density measure for assessments of arid plant populations- examples from the Southern Namib desert. African. J. Ecol., 41: 254- 256.

Burrows, W.H., M.B. Hoffmann, J.F. Compton, P.V. Back, L.I. Tait. 2000. Allometric relationships and community biomass estimates for some dominant eucalypts in Central Queensland woodlands. Aust. J. Bot. 48: 707–714.

Charro, E., A. Moyano, R. Cabezón. 2017. The potential of Juniperus thurifera to sequester carbon in semi-arid forest soil in Spain. Forests, 8: 330.

Chaudhary, N.I., A. Schnapp, J.E. Park. 2006. Pharmacologic Differentiation of Inflammation and Fibrosis in the Rat Bleomycin Model. Am. J. Respir. Crit. Care Med. 173:769-776.

Davidson, E.A., I.A. Janssens. 2006. Temperature sensitivity of soil carbon decomposition and feedbacks to climate change. Nature, 440:165.

Forests & Ministry of Environment. 2009. Pakistan Forestry Outlook Study; Food and Agriculture Organization: Bangkok, Thailand.

Fredeen, A.L., C.H. Bois, D.T. Janzen, P.T. Sanborn. 2005. Comparison of coniferous forest carbon stocks between old-growth and young second-growth forests on two soil types in central British Columbia, Canada. Can. J. For. Res. 35: 1411–1421. http://cjfr.nrc.ca

GoB-Government of Balochistan. 2011. District Development Profile Ziarat. Planning and Development Department Government of Balochistan, Quetta.

Gul, S., M.A. Khan, S.M Khair. 2016. Population Increase: A Major Cause of Deforestation in District Ziarat. J. Appl. Emerg. Sci. 5: 124-132.

Hosonuma, N., M. Herold, V. De Sy, R.S. De Fries, M. Brockhaus, L. Verchot, A. Angelsen, E. Romijn. 2012. An assessment of deforestation and forest degradation drivers in developing countries. Environ. Res. Lett. 7: 044009.

Hosonuma, N., M. Herold, V. De Sy, R.S. De Fries, M. Brockhaus, L. Verchot, A. Angelsen, E. Romijn. 2012. An assessment of deforestation and forest degradation drivers in developing countries. Environ. Res. Lett. 7: 044009.

Hussain, S.S. 1989. Pakistan Manual of Plant Ecology. National Book Foundation, Islamabad.

Intergovernmental Panel on Climate Change (IPCC). (2003). Penman J. et al. (Eds.). Good Practice Guidance for Land Use, Land-Use Change and Forestry 2003: IPCC National Greenhouse Gas Inventories Programme Technical Support Unit. Institute for Global Environmental Strategies 2108-11, Kamiyamaguchi Hayama, Kanagawa Japan.

IPCC (International Panel on Climate Change). 2000. Land Use, Land-Use Change, and Forestry. Special Report, IPCC, Geneva, Switzerland.

IPCC 2007b. Facts on climatic change. A summary of the 2007 assessment report of IPCC. Cambridge University Press, Cambridge, UK.

IPCC. 2007a. Highlights from Climate Change 2007. The Physical Science Basis. Summary for Policy Makers. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Institute of Terrestrial Ecology, Edinburgh. pp. 545-552.

Jackson, R.B., K. Lajtha, S.E. Crow, G. Hugelius, M.G. Kramer, G. Piñeiro. 2017. The ecology of soil carbon: Pools, vulnerabilities, and biotic and abiotic controls. Annu. Rev. Ecol. Evol. Syst., 48: 419–445.

Jallat, H., M.F. Khokhar, K.A. Kudus, M. Nazre, N.U. Saqib, U. Tahir, W.R. Khan. 2021. Monitoring

Carbon Stock and Land-Use Change in 5000-Year-Old Juniper Forest Stand of Ziarat, Balochistan, through a Synergistic Approach. Forests, 12: 51. https://dx.doi.org/10.3390/f12010051

Jandl, R., K. Rasmussen, M. Tomé and D.W. Johnson. 2006. The role of Forests in carbon Cycles, Sequestration and Storage. Issue 4. Forest management and carbon sequestration. Federal Research and Training Centre for Forests, Natural Hazard and Landscape (BFW), Vienna, Austria.

Karki, M. (2002). Medicinal and aromatic Plants Programme in Asia. IDRC/SARO. New Agolla, J.E. 2009. Occupational Stress among Police Officers. The case of Botswana Police service, Res. J. Bus. Manage. 2 (1): 25-35.

Kramer, P.J. 1984. Problems in water relations of plants and cells. In: International Review of Cytology, (Ed.): P.J. Kramer. pp. 254-286.

Lal, R. 2005. Forest soils and carbon sequestration. For. Ecol. Manag., 220: 242-258.

Lal, R., W. Negassa, K. Lorenz. 2015. Carbon sequestration in soil. Curr. Opin. Environ.

Sustain. 15: 79-86.

Latte, N., G. Colinet, A. Fayolle, P. Lejeune, J. He´bert, H. Claessens, S. Bauwens. 2013. Description of a new procedure to estimate the carbon stocks of all forest pools and impact assessment of methodological choices on the estimates. Eur J Forest Res., 132:565–577 DOI 10.1007/s10342-013-0701-6

Marcoux, A. 2000. Population and Deforestation. SD Dimensions. Sustainable Development Department, Food and Agriculture Organization of the United Nations (FAO).

Nizami, S.M. 2012. The inventory of the carbon stocks in subtropical forests of Pakistan for reporting under Kyoto Protocol. Journal of Forestry Research, 23(3):377-384.

Palosuo, T., B. Foereid, M. Svensson, N. Shurpali, A. Lehtonen, M. Herbst, R. Jandl. 2012. A multi-model comparison of soil carbon assessment of a coniferous forest stand. Environmental Modelling & Software, 35:38-49.

Petit, J., J. Jouzel, D. Raynauud, N.I. Barkov, J.M. Barnola, I. Basile, M. Bender, J. Chappelaz, M. Davis, G. Delaygue, M. Delmote. 1999. Climate and atmospheric history of the past 420,000 years from the Vostok ice core in Antarctica. *Nature 339:* 429-436.

Salunkhe, O., P.K. Khare, Daulat Ram Gwalwanshi and Swati Uniyal. 2014. Biomass Estimation from Herb, Shrub and Litter component of Tropical Dry Deciduous

Forest of Madhya Pradesh State of India. The Journal of Ecology. Photon, 109:358-362.

Sarangzai, A.M., M. Ahmed, A. Ahmed, L. Tareen, S.U. Jan. 2012. The ecology and dynamics of Juniperus excelsa forest in BalochistanPakistan. Pak. J. Bot. 44: 1617–1625.

Sarmiento, G., M. Pinillos, I. Garay. 2005. Biomass variability in tropical American lowland rainforests. Ecotropicos 18: 1-20.

Sheikh, I.S. 1985. Afforestation in Juniper forests of Balochistan. Pakistan Forest Institute, Peshawar.

Shinwari, Z. K. 2009. Loss of Biodiversity in the Pakistani Hindukush Himalayas; In the Science advisory board.

Srithi, K., H. Balslev, P. Wangpakapattanawong, P. Srisanga, C. Trisonthi. 2009. Medicinal plant knowledge and its erosion among the Mien (Yao) in northern Thailand. J. Ethnopharmacol. 123:335-342.

Sundquist, E., B. Robert, F. Stephen, G. Robert, H. Jennifer, K. Yousif, T. Larry, W. Mark. 2008. Carbon Sequestration to Mitigate Climate Change. U.S. Geological Survey, science for a changing world, New York, USA. pp. 1-4.

Ullah, M.R. and M. Al-Amin. 2012. Above-and Below-ground carbon stock estimation in a natural forest of Bangladesh. Journal of Forest Science, 58(8):372-379.

Vayreda, J., G. Marc, G.C. Josep and R. Javier. 2012. Spatial Patterns and Predictors of Forest Carbon Stocks in Western Mediterranean. Ecosystems, 15:1258-1270.

Walle, I.V., N.V. Camp, D. Perrin, R. Lemeur, K. Verheyen, B. V. Wesemael, E.Laitat. 2005. Growing stock-based assessment of the carbon stock in the Belgian forest biomass. Ann. For. Sci. 62: 853-864

Yang, Y., P. Li, J. Ding, X. Zhao, W. Ma, C. Ji, J.I. Fang. 2014. Increased topsoil carbon stock across China's forests. Global Change Biology, 20:2687–2696.