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Original Research Article

Standing Tree Biomass and Carbon Stock of Natural Forests in Nainital District of Kumaun Himalaya

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Abstract: Present study deals with the standing tree biomass and carbon stock of natural forests in Nainital, district of Kumaun Himalaya. Uttarakhand the 27th state of the India is located between 28º43-31º27 N latitude and 77º34-81º02 E longitudes. Forests in the region of Uttarakhand are mainly composed of three dominated tree species such as Sal (*Shorea robusta* Gaertn.) in lower elevation (400-1200m), pine (*Pinus roxburghii* Sarg. in mid elevation(1200-1800m) and Oak (*Quercus* spp.) in higher elevation (1400-2700m), which indicates that the forest tree composition changes with the change in altitude and climate in the region. Vegetation analysis was carried out by using quadrat method in each selected forest sites. The tree species were analyzed by using quadrat size 10mx10m in each study forest site. In each tree species were measured at 1.37m. The ecological parameters like tree density, abundance, basal area and IVI of trees estimated in each study forest site. The ecological parameters like tree density, abundance, basal area and IVI of trees estimated in each forest site as followed by Misra (1968). The tree density range from 424-796 ind.ha^{-1}. The total basal areas of tree range between 40.41-49.42 m^2 ha^{-1}. The estimation of biomass was carried out using the allometric equation for each tree component. The biomass and carbon stock of the trees ranged from 135.43-513.20 t ha-^{1}yr-^{1} and 64.33-243.77 t ha-^{1}yr-^{1}. Based on the findings it can be concluded that vegetation structure, biomass and carbon stock of natural forest need the certain management inputs for their better conservation and development.

Keywords: Biomass, basal area, carbon stock, Kumaun Himalaya, tree density.

Introduction

The Indian Himalaya is a vast mountain system with a geographical area of about 591000sq.km responding 18% area of the country and is an important part of the global system. The Himalayan region is one of the most dynamic and complex mountain ranges in the world due to tectonic activity and is very vulnerable due to global climate changes. Global change whether generated by climate, land use change, biological invasion, global economic forces, will certainly affect the relationships that are present in the land and economics of the Himalayan region. Uncertainties and potential impacts of the rate and magnitude of climate change prevail, but there is no question that it is gradually and powerfully changing the ecological and socio economic landscape of the region. The fact is that India is one of the 17th mega biodiversity regions of the world are mainly due to the Himalaya region. The Indian Himalayan region is also called the 'water tower of the earth'.

Roughly 10-20% of the area is covered by glaciers, while 30-40% remains under seasonal snow cover (Bahadur, 2004). Despite the vast water resources movements such as retreating effects of glaciers, streams and rivers occurs regularly in the region. The Himalaya is a provider of variety of natural resources to the great Gangetic plains the heartland of the country including the life giving water. Researchers believe that there resources have largely being endangered by human activities due to over exploitation of forest products, uncontrolled grazing, encroachment and deforestation on the forest area. (Champion and Seth, 1968; Singh and Singh, 1991; Eckhlom, 1975).

Himalayan forest vegetation ranges from tropical dry deciduous forest in the foothills to alpine meadow above timberline (Singh and Singh, 1992). Composition of the forest is diverse and varies from place to place because of varying topography such as plains, foothills and upper mountains (Singh, 2006). Economically and environmentally, the natural resources are the main source for people in this region (Ram *et al.*, 2004). In addition, environmental problems are particularly noticeable in this region as a form of degradation and depletion of the forest resources (Sati, 2005).

The people of Indian Himalayan region resembling other mountain ecosystems, are greatly reliant for livelihood on their immediate natural resources and production from most important sectors i.e. agriculture, forestry and livestock, etc. The dependency of the ever increasing population no limited resources is getting higher. Lack of modern technology to reduce mountain specificities and enhanced production to meet the burden are exhausting the resources in conjunction with marginality of farmers in the end advancing poverty (Samant *et al.*, 2003). Despite its rich biological resources the region is underdeveloped. It won't be an understatement to call it a third world of a developing nation. Trends of environmental well being indicate that existing interventions are unsustainable. Economic indicators also do not show the desirable effects on monetary up liftmen, moreover, the natural delicateness of the mountains as well as the vulnerability of the Himalaya to human induced environmental impacts make people live in the gloom of uncertainties of natural calamities.

Biomass is defined as the total amount of AGB in trees expressed as oven-dry tons per unit area that reduces the concentration from atmospheric concentration of CO2. Biomass is an ecological material derived from living or recently living organism. As an energy source biomass can either be directly used via combustion to produce heat, or indirectly after converting it to various forms of bio-fuel. Biomass is the mass of originally bound carbon (C) that is present in forest area. Apart from bacteria, the total live biomass on earth is about 560 billion tones C and the total annual primary production of biomass is just over 100 billion tones t/yrs in the study forest area. However, the total live biomass of bacteria may exceed that of plants and animal.

Anderson (1970) opined that estimation of biomass is essential for determining the status and flux of biological materials in ecosystem and for understanding the dynamics of the ecosystem. The quantity of the tree biomass per unit area of land constitutes the primary inventory data needed to understand the flow of materials and water through forest ecosystem (Swank and Schedules 1974). The primary objectives of this study is to determine different vegetation parameters available in the sites and to calculate biomass and carbon stock in each selected forests.

Materials and methods

Site description:

The present study was conducted in three selected dominant forests viz., Oak (*Quercus leucotrichophora,* A. Camus) dominated forest; Pine (*Pinus roxburghii,* Sarg.) dominated forest and Sal (*Shorea robusta,* Gaertn. F.) dominated forest located in Kailakhan (29° 24' N; 79° 28' E), Sanitorium (29° 23.634' N; 79° 30.466' E) and the Ranibagh (29° 17.803' N; 79° 32.344' E) respectively at different elevation gradient, from the altitudinal range of 500m to 2100m above mean sea level in Nainital district.

Each forest study was carried out into three forest site i.e. hill top, hill mid and hill base in open, moderate and close canopy in the present study to assess the vegetation analysis and standing tree biomass. Each forest represents varied species composition and structure. There exists a varied topography, soil conditions, and forest quality from lower elevation to higher elevation representing Sal forest following subtropical pine forest and Oak forest moving toward the higher elevation in Nainital district of Kumaun Himalayas.

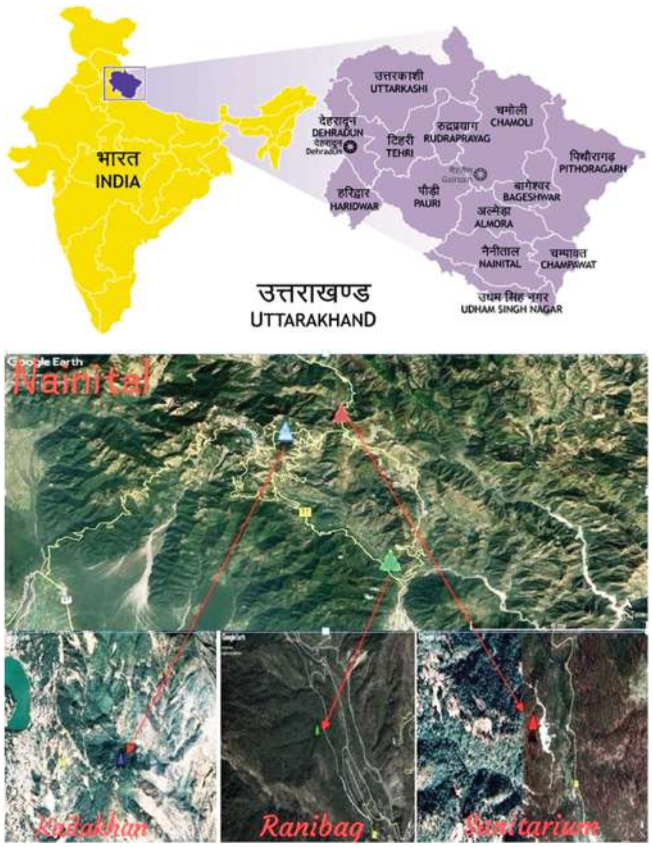

Fig. 1. Description of forest sites in Nainital district of Kumaun Himalaya. **Source:** www.mapofindia.com and Google earth.

Oak forest: Area falls under moist temperate forest type (Lesser Himalayan Zone: 1800- 2700 m) according to revised forest classification of India, (Champion and Seth, 1968). Oak dominated forest is mainly found associated with *Quercus floribunda, Cedrus deodara*, *Cupressus torulosa*, *Rhododendron arborium*, *Myrica esculanta, Alnus nepalensis, Acer oblungum, Lyonia ovalifolia*, Cornus oblonga, *Debrigesia longifolia* etc. in the higher regions Nainital district. Oak is well known temperate tree species for its quality fuel and fodder production in Kumaun Himalaya.

Pine forest: Pine was found associated with *Cupressus torulosa*, *Acer oblongum*, *Quercus spp, Myrica esculenta, Rhododendron arborium etc.* Pine forest was found extensively distributed in the subtropical regions of Nainital district. Pine, family; Pinaceae, is highly economic species which produce good timber, resin, bedding and packing material and several other non timber forest products.

Sal forest: Sal is a semi-evergreen large gregarious tree species and (Outer Himalayan Zone: 500-1250 m) was found generally associated with *Mallatos philipinsis*, *Toona ciliata*, *Holoptela intrifolia*, *Terminalia spp*. *Bauhinia spp*., *Syzygium cumini Schleichera oleosa*, *Melia azadirac, Murraya koenigii*, *Tectona grandis* etc. Sal forest is widely distributed along the foot hills of Kumaun Himalayan regions. Sal, family; Dipterocarpaceae, is an important species to produce valuable hardwood timber and non timber products like leaves and seed oils. The species reveals economic, social and cultural importance in India.

Vegetation analysis

For the phytosociological study, the quadrat method was used. The number and size of the quadrats were determined by the running mean method (Kershaw, 1973) and species area curve (Misra, 1968). 30 plots of 10 × 10 m at each site were randomly established for determination of species richness and other vegetation parameters. Circumference at breast height (CBH at 1.37 m from the ground) of individual tree and sapling was measured in each quadrat. Individual trees having ≥30 cm girth were considered as trees. Density, frequency, abundance, basal area and Importance value index (IVI) were calculated following Cottam and Curtis (1956).

Biomass and carbon stock estimation

The estimation of biomass was carried out using the allometric equation for each tree component as developed by Rawat and Singh (1988), Chaturvedi and Singh (1987), Lodhiyal *et al.* (1992) Rawat (1983); Rana et al. (1989) and Tewari *et al.* (1985)

$$\mathrm{Ln}\ Y = a + b\ \mathrm{Ln}\ X$$

Where,

Ln = natural log, Y= dry weight of component (kg tree^{-1}), X= CBH (cm), a = the y intercept and b = slope of regression.

Carbon stock was determined by using the biomass value of species multiplied by factor (C= Biomass x 0.475) as given by (Magnussen and Reed, 2004; Singh and Lodhiyal, 2009; Lodhiyal, 2014; Kapkoti, 2016, Bhakuni, 2016, Brown, 2002; Jhariya et al., 2014).

Results

Vegetation analysis:

Chir-pine forest Site-1 (Sanitorium)

Trees

The total six species were present i.e. *Pinus roxburghii*, *Quercus leucotrichophora, Myrica esculenta, Rhododendron arborium, Lyonia obifolia* and *Cupressus torulosa* in this forest site. The total tree density was 517 ind.ha^{-1}. Of which, *Pinus roxburghii* accounted for maximum 396 ind.ha^{-1} followed by *Quercus leucotrichophora 56* ind.ha^{-1} and *Myrica esculenta* 25 ind.ha^{-1} Total basal area of tree was 45.76 m^{2}ha^{-1}. Of which *Pinus roxburghii* shared 37.04 m^{2}ha^{-1} followed by *Quercus leucotrichophora* 4.53 m^{2}ha^{-1}. The IVI of forest was 299.95. Maximum IVI shared *Pinus roxburghii* 210.71 followed by *Quercus leucotrichophora* 37.75 (Table1).

Table 1. Vegetation analysis of trees in *Pinus roxburghii* forest in site-1.

Name of species	Density (ind.ha^{-1})	Frequency (%)	Abundance	A\F Ratio	TBA (m^2 ha^{-1})	IVI
Pinus roxburghii	396	100	3.96	0.039	37.04	210.71
Quercus leucotrichophora	56	32	1.75	0.054	4.53	37.75
Myrica esculenta	25	24	1	0.041	1.09	19.97
Rhododendron arborium	20	16	1.25	0.078	1.86	16.43
Lyonia obifolia	12	8	1.5	0.187	0.85	8.42
Cupressus torulosa	8	8	1	0.125	0.39	6.64
Total	**517**	**188**	**10.46**	**0.524**	**45.76**	**299.95**

Note: TBA= Total Basal Area, A/F= Abundance/Frequency and IVI=Important Value Index

Oak Forest Site -2 (Kailakhan)

Trees

The total five species were present i.e. *Quercus leucotrichophora, Myrica esculenta, Rhododendron arborium, Cedrus deodara* and *Acer oblungum* in this forest site. The total tree density was 424 ind.ha^{-1}. Of which, *Quercus leucotrichophora* accounted for maximum 356 ind.ha^{-1} folowed by Myrica esculenta 32m^2 ha^{-1} and Rhododendron arboretum 16m^2 ha^{-1} . Total basal area of tree was 49.42m^2 ha^{-1}. Of which *Quercus leucotrichophora* shared 45.3 m^2 ha^{-1} followed by *Acer oblungum* 1.28m^2 ha^{-1}. The IVI of forest was 299.93. Maximum IVI shared *Quercus leucotrichophora* 235.11 followed by *Myrica esculenta* 28.56 (Table 2).

Sal forest site 3 (Ranibag)

Trees

The total six species were present i.e, *Shorea robusta, Syzygium cumini, Mallatos Phillippensis, Toona ciliata, Emblica officinailis, Tectona grandis and Terminelia elliptica* in this forest site. The total tree density was 796ind.ha^{-1}. Of which, *Shorea robusta* accounted for maximum 620 ind.ha^{-1} followed by *Syzygium cumini* 68 ind.ha^{-1} and *Mallotos Phillippensis* 32 ind.ha^{-1} Total basal area of tree was 40.41m^{2}ha^{-1}. Of which *Shorea robustsi* shared 38.8m^{2}ha^{-1} followed by *Syzigium cumini* 0.72 m^{2}ha^{-1}. The IVI of forest was 299.8. Maximum IVI shared *Shorea robusta 216.15* followed by *Syzigyum cumini* 30.654 (Table 3).

Tree biomass

Pine forest (Sanitorium Site-1)

Total biomass of tree species was 135.43 tha^{-1}.The maximum biomass account for *Pinus roxburghii* 51.88 tha^{-1} followed by *Quercus leucotrichophora* 38.8 tha^{-1}. Among the various tree components, biomass of bole component shared 53.08 tha^{-1}while stump root contributed 53.08 tha^{-1} in Pine forest (Table 4).

Oak forest (Kailakhan site-2)

Total biomass of tree species was 337.3 tha^{-1}.The maximum biomass account for Quercus leucotrichophora 310.8 tha^{-1} followed by Myrica esculenta 11.94 tha^{-1}. Among the various

Table 2. Vegetation analysis of trees in *Quercus leucotrichophora* forest in site-2.

Name of Species	Density (ind.ha^{-1})	Frequency(%)	Abundance	A\F Ratio	TBA(m^2 ha^{-1})	IVI
Quercus leucotrichophora	356	100	3.56	0.03	45.3	235.11
Myrica esculenta	32	32	1	0.03	0.98	28.56
Rhododendron arborium	16	16	1	0.06	1.08	15.48
Cedrus deodara	8	8	1	0.12	0.78	8.22
Acer oblungum	12	12	1	0.08	1.28	12.56
Total	**424**	**168**	**7.56**	**0.32**	**49.42**	**299.93**

Note: TBA= Total Basal Area, A/F= Abundance/Frequency, IVI=Important Value Index

Table 3. Vegetation analysis of trees in *Shorea robusta* forest in site-3.

Name of Species	Density (ind.ha^{-1})	Frequency(%)	Abundance	A\F Ratio	TBA(m^2 ha^{-1})	IVI
Shorea robusta	620	100	6.2	0.062	38.80	216.15
Syzygium cumini	68	48	1.41	0.029	0.72	30.65
Mallotus phillippensis	32	32	1	0.031	0.21	18.09
Toona ciliata	16	16	1	0.062	0.06	8.93
Emblica officinalis	8	8	1	0.125	0.17	4.82
Tectona grandis	28	16	1.75	0.109	0.37	11.19
Terminelia elliptica	24	16	1.5	0.093	0.08	9.97
Total	**796**	**236**	**13.86**	**0.51**	**40.41**	**299.80**

Note: TBA= Total Basal Area, A/F= Abundance/Frequency, IVI=Important Value Index

Table 4. Component wise tree biomass (t ha^{-1}) of each tree species in forest site 1.

Name of the species	Bole	Branch	Foliage	Twig	Leaf	Stump root	Lateral root	Fine root	Total
Pinus roxburghii	25.13	18.8	0.06	-	-	6.12	1.58	0.19	51.88
Quercus leucotrichophora	16.94	10.28	-	3.87	2.26	4.89	0.53	0.03	38.8
Myrica esculenta	4.74	2.97	-	2.66	0.71	1.06	0.17	0.01	12.32
Rohodonderon arboreum	1.65	1.05	-	0.36	0.14	1.02	0.34	0.002	4.56
Lyonia ovalifolia	3.3	20.1	-	0.77	0.45	0.98	0.1	0.007	25.70
Cupressus	1.32	0.05	0.18	0.04		0.335	0.2	0.04	2.16
Total	**53.08**	**53.25**	**0.24**	**7.7**	**3.56**	**14.40**	**2.92**	**0.279**	**135.43**

Table 5. Component wise tree biomass (t ha^{-1}) of each tree species in forest site 2.

Name of the species	Bole	Branch	Twig	Leaf	Stump root	Lateral root	Fine root	Total
Quercus leucotrichophora	157.68	94.72	25.38	8.36	10.59	13.07	1.08	310.88
Myrica esculenta	4.85	3.02	1.34	0.78	1.76	0.18	0.01	11.94
Rhododendron arborium	1.18	0.76	0.27	0.11	0.71	0.23	0.03	3.29
Cedrus deodara	0.48	-	-	-	0.80	-	-	1.28
Acer oblungum	4.43	2.65	0.95	0.56	1.19	0.13	0.008	9.92
Total	**168.62**	**101.15**	**27.94**	**9.81**	**15.05**	**13.61**	**1.12**	**337.32**

tree components, biomass of bole component shared 168 tha^{-1}while stump root contributed 15.05 tha^{-1} in oak forest (Table 5).

Sal forest (Ranibag site-3)

Total biomass of tree species was 513.20 tha^{-1}.The maximum biomass account for *Shorea robusta* 505.08 tha^{-1} followed by

Table 6. Component wise tree biomass (t ha^{-1}) of each tree species in forest site 3.

Name of the Species	Bole	Branch	Twig	Leaf	Root	Total
Shorea robusta	257.83	67.58	30.43	21.23	128	505.08
Syzigium cumini	1.96	0.66	0.30	0.20	0.34	3.46
Mallotus phillippensis	0.41	0.19	0.04	0.02	0.07	0.75
Toona ciliata	0.14	0.06	0.028	0.02	0.03	0.29
Emblica officinailis	0.55	0.16	0.62	0.04	0.07	1.45
Tectona grandis	1.04	0.34	0.139	0.09	0.16	1.79
Terminalia elliptica	0.18	0.07	0.037	0.02	0.04	0.36
Total	**262.11**	**69.08**	**31.60**	**21.65**	**128.74**	**513.20**

Table 7. Component wise carbon stock (t C ha^{-1}) of each tree species in forest site 1.

Name of the species	Bole	Branch	Foliage	Twig	Leaf	Stump root	Lateral root	Fine root	Total
Pinus roxburghii	11.936	8.93	0.028	-	-	2.907	0.750	0.09	24.64
Quercus leucotrichophora	8.046	4.883	-	1.838	1.073	2.322	0.251	0.01	18.43
Myrica esculenta	2.251	1.410	-	1.263	0.337	0.503	0.080	0.004	5.852
Rohodonderon arboreum	0.783	0.498	-	0.171	0.066	0.484	0.161	0.0009	2.16
Lyonia ovalifolia	1.567	9.547	-	0.365	0.213	0.465	0.047	0.0033	12.21
Cupressus	0.627	0.023	0.085	0.019	0	0.159	0.095	0.019	1.028
Total	**25.213**	**25.293**	**0.114**	**3.657**	**1.691**	**6.842**	**1.387**	**0.132**	**64.33**

Table 8. Component wise carbon stock (t C ha^{-1}) of each tree species in forest site 2.

Name of the species	Bole	Branch	Twig	Leaf	Stump root	Lateral root	Fine root	Total
Quercus leucotrichophora	74.89	44.99	12.05	3.971	5.030	6.208	0.513	147.66
Myrica esculenta	2.303	1.435	0.636	0.370	0.836	0.085	0.004	5.67
Rhododendron arborium	0.560	0.361	0.128	0.052	0.337	0.109	0.014	1.56
Cedrus deodara	0.231	-	-	-	0.380	-	-	0.61
Acer oblungum	2.104	1.259	0.451	0.266	0.565	0.061	0.003	4.71
Total	**80.098**	**48.048**	**13.271**	**4.659**	**7.149**	**6.464**	**0.535**	**160.22**

Table 9. Component wise carbon stock (t C ha^{-1}) of each tree species in forest site 3.

Name of the species	Bole	Branch	Twig	Leaf	Root	Total
Shorea robusta	122.469	32.100	14.45	10.088	60.8	239.91
Syzigium cumini	0.931	0.314	0.142	0.095	0.161	1.64
Mallotus phillippensis	0.194	0.091	0.022	0.011	0.037	0.35
Toona ciliata	0.066	0.030	0.013	0.009	0.017	0.13
Emblica officinailis	0.261	0.080	0.294	0.020	0.034	0.69
Tectona grandis	0.497	0.162	0.066	0.047	0.080	0.85
Terminalia elliptica	0.085	0.033	0.017	0.012	0.023	0.17
Total	**124.50**	**32.814**	**15.011**	**10.284**	**61.153**	**243.77**

Syzigium cumini 3.46 tha^{-1}. Among the various tree components, biomass of bole component shared 262.11 tha^{-1} while root contributed 128.74 tha^{-1} in Pine forest (Table 6).

Carbon stock

Pine forest (Sanitorium-site 1)

The total carbon in forest site-1 was 64.33 t C ha^{-1}. Of this, *Pinus roxburghii* accounted maximum for 24.64 t C ha^{-1}. Of the total carbon, bole wood component accounted for 25.213 t ha^{1} followed by branch in above ground biomass 25.293 t C ha^{-1} while stump root accounted 6.842 t C ha^{-1} in belowground part at forest site 1 (Table 7).

Oak forest (Kailakhan-site 2)

The total carbon in forest site-2 was 160.22 t C ha^{-1}. Of this, *Quercus leucotrichophora* accounted maximum for 24.64 t C ha^{-1}. Of the total carbon, bole wood component accounted for 25.213 t ha^{1} followed by branch in aboveground biomass 25.293 t C ha^{-1} while stump root accounted 6.842 t C ha^{-1} in belowground part at forest site 1 (Table 8).

Sal forest (Ranibag-site 3)

The total carbon in forest site-3 was 243.77 t C ha^{-1}. Of this, *Shorea robusta* accounted maximum for 239.91 t C ha^{-1}. Of the total carbon, bole wood component accounted for 124.50 t ha^{1} followed by branch in above ground biomass 32.814 t C ha^{-1} while root accounted 61.153 t C ha^{-1} in belowground part at forest site 3 (Table 9).

Discussion

Forest plays a significance role in the development, livelihood and climate they provide timber, non-timber products agricultural implements to hill people and also improve fertility of the agriculture soil and control erosion and forests composition in the hill region, vary from place to place because of altitude, climate, slope, aspect and soil characteristics. Forests of Himalaya play vital role in the sustainable development of forests and mitigation of the climate change. This study provides a glimpse to view insight about, vegetation structure, biomass and carbon stock present in the sites and its contribution in forests of Kumaun Himalayan region. The objectives of study were to assess the vegetation structure (density, frequency, abundance, basal area and IVI), biomass and carbon content in Pine, Oak and Sal forest.

Oak forest

The density of oak forest site was 424 $ind.ha^{1}$ Of this, present values fall within range 420-1640 ind.ha-1 (Saxena and Singh, 1982) reported for temperate forests of western Himalayan and was higher than 570-760 $ind.ha^{1}$ $ind.ha^{1}$ reported for for oak forest (Rawat and Singh, 1988) and lower than 550-1250 $ind.ha^{1}$ in oak dominated forests in Kumaun Himalaya (Singh, Tamta Tewari and Ram, 2014). The shrub density was observed 668 $ind.ha^{1}$. However , Basal area was 40.41 m^{2} ha^{-1} which was higher than 33.89-36.83 m^{2} ha^{-1} reported for (Rawat and Singh, 1988) and lower side than 58.66 – 93.00 $m^{2}ha^{-1}$ reported for natural forest (Lodhiyal *et al.*, 2014).

The total biomass was reported 337.32 t ha^{-1} which falls within the range 285-458 t ha^{-1} reported for oak dominated forest (Rawat and Singh, 1988) and 236-400 t ha^{-1} for oak dominated forest at higher altitude (Adhakari, Rawat and Singh 1995) but lower than 651-718 t ha^{-1} of natural forest of Kumaun Himalayans. (Lodhiyal and Lodhiyal, 2014) and (Bhakuni, 2014). The carbon stock was 160.22 t ha^{-1} is higher than 229-270 t ha^{-1} reported in oak forest (Lal and Lodhiyal, 2016), 229 -341 t ha^{-1} of natural forest of Kumaun Central Himalaya (Lodhiyal *et. al* 2014).

Pine forest

Tree density of pine forest was 517 $ind.ha^{1}$. Of this, present values fall within range 420-1640 $ind.ha^{-1}$ reported for temperate forests of western Himalaya (Saxena and Singh 1982) and was lower than 720 $ind.ha^{1}$ reported for *Pinus roxburghii* forest by (Lodhiyal *et al.*, 2013) and lower than 540-1630 $ind.ha^{1}$ for pine forest in Kumaun region (Chaturvedi and Singh, 1987). Shrub density was 486 $ind.ha^{1}$. Total basal area 45.77 $m^{2}ha^{-1}$ was lower than 58.66-93.00 $m^{2}ha^{-1}$ reported for natural forests (Lodhiyal *et al.*, 2014) on the other side higher side than 25-47 $m^{2}ha^{-1}$ reported for pine forests in Kumaun region (Chaturvedi and Singh, 1987).

The total biomass estimates was 135 t ha^{-1} which falls lower than 154-301 tha^{-1} in pine forests of Kumaun Himalaya (Lal and Lodhiyal, 2015). However Present values fall within the range 112-283 t ha^{-1} reported for pine forests of central Himalaya (Chaturvedi and Singh, 1987). The carbon stock of the study site was 64.33 t ha^{-1} on lower side than 341-228 t ha^{-1} reported for natural forests (Lodhiyal *et al.*, 2014), and it falls on higher than 97-207 tha^{-1} reported for pine and mix Banj-oak forests (Rana *et al.,* 1989) and 122-86 t ha^{-1} for chir-pine van Panchayat forest (Jeena *et al.,* 2008). But present values are on higher side than 59.41 tha^{-1} oak and pine mixed forest of Lohaghat in Kumaun Himalaya (Lodhiyal and Lodhiyal, 2012) 16.73-18.54 t ha^{-1} of oak and pine forests in degraded forests (Jeena, Sah, Bhatt and Rawat, 2008).

Sal forest

Tree density of the forest site was 796 $ind.ha^{-1}$ the value of density is greater than the value obtained by (Bandhu, 1969) reported density 200 $ind.ha^{-1}$ of northon tropical dry deciduous forest near Baranasi. The plant density in the present study is also higher than the value 183 $ind.ha^{-1}$ by (Kumar *et al.*, in 1994) in dry peninsular sal forest similarly value was also higher than 194 $ind.ha^{-1}$ reported for sal forest by (Rana *et al.*, 1988). Shrub density was 2056 $ind.ha^{-1}$ Total basal area was 40.41 $m^2 ha^{-1}$ which is on higher side than 26.7 $m^2 ha^{-1}$ as reported by (Rana *et al.,* 1988). However the value of basal area falls lower than 76 $m^2 ha^{-1}$ as estimated in the sal forest of Royal Chitwan National Park, Nepal (Sejuwal, 1994).

The total bomass estimates was 513.20 t ha^{-1} which falls lower than 330.87 t ha^{-1} by (Giril, Aryal, Bhattaraiz, Ghimire, Shrestha and Jha, 1999) sal forests in the Royal Bardia National Park, Nepal. The Carbon stock of tree was 243.77 tha^{-1}, the value of the carbon falls in the range of 123.15 t ha^{-1} and 384.20 t ha^{-1} by (Pandey and M. Bhusal) in Sal (*Shorea robusta*) forest in two different ecological regions of Nepal.

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