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Biomass and Carbon Stock in Kharsu Oak (*Quercus semecarpifolia*) Dominated Forest in Nainital District of Kumaun Himalaya

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Abstract—*Climate change is the most severe ecological hazard of this century. Climate change incidence over the past decades has raised concern in well-being of human and their society. The major cause of climate change is increase in greenhouse gases in the atmosphere as a result of anthropogenic activities. To combat and mitigate climate change, the cost effective method is carbon sequestration by forests. This study was conducted to analyze vegetation and estimate biomass and carbon stock in Kharsu Oak (Quercus semecarpifolia) dominated forest in Nainital district of Kumaun Himalaya. Biomass and carbon content was measured in two different aspects i.e., South west and South east. Biomass was determined using allometric equations of different tree species and carbon content by multiplying the biomass by 0.475. The density was found higher in the South east aspect (819 ind/ha) than the South west aspect (733 ind/ha), both having Kharsu Oak as dominant species. Total aboveground and belowground biomass was also found higher in South east aspect (487.13 t/ha and 143.43 t/ha) than the South west aspect (366.40 t/ha and 113.85 t/ha). The total carbon stock was found to be 228.10 t/ha and 299.46 t/ha in South west and South east aspect, respectively. Higher biomass and carbon content in South east aspect was found which is due to availability of sunlight and moisture in adequate quantity.*

Keywords*: Climate change, greenhouse gases, carbon sequestration, allometric equations.*

1. INTRODUCTION

Oak occupy a large amount of the area about 20,000 sq km from 1,000 to 3,000 m altitude in the Central and Western Nepal, Uttarakhand and Himanchal Pradesh [24]. In the Central Himalaya Oaks are widely distributed at an elevation between 1,800 to 3,000 m [1]. *Quercus semecarpifolia* forests dominate the high altitudes of Central Himalaya between 2,400 and 2,750 m and the timber line areas. The species is viviparous with short seed viability and germination takes place in monsoon rains (July-August).

Climate change is the most severe ecological hazard of this century impacting natural ecosystems and socio-economic systems [18]. Managing the forests in sustainable manner is key challenge for human kind. The main dimension of sustainability revolves around the climate change debate. From 1880 to 2012, the Earth's average temperature has amplified by 0.875 ^{0}C and is likely to further increase if the condition remains unchanged [7]. The major cause for climate change is attributed to GHG emission due to human activities. The major GHGs are carbon dioxide, chloroflurocarbons, methane, nitrous oxide and water vapour. CO_2 emission is the most significant contributor among all GHGs. To combat and mitigate climate change, the cost effective method is carbon sequestration by forest [8]. Carbon sequestration is the method of removing carbon from the atmosphere and storing it in reservoir other than atmosphere such as lithosphere, hydrosphere and biosphere [13]. Under Kyoto Protocol, forests are regarded essential for their carbon sinks role because they can capture and store CO_2 from the atmosphere for a long time [5]. Forests store carbon as an important element for their growth hence, increases their biomass. Forest ecosystems consist of (62-78) % of the total terrestrial carbon [6]. Globally, relationship of biodiversity with the carbon cycle has brought focus that mitigating climate change is possible by reducing the conversion of natural ecosystems [14]. Biomass of forests in Himalayan region is found in significant amount. In Himalayan region, Pine and Oak forest can have biomass up to 200 t/ha and 400 t/ha, respectively. The range of biomass in Oak mixed forest (556-782 t/ha) is higher than any other Oak and broadleaf forest (102-450 t/ha) of temperate region [23]. The study was conducted to analyze vegetation and estimate biomass and carbon stock in Kharsu Oak (*Quercus semecarpifolia*) dominated forest in Nainital district of Kumaun Himalaya.

2. MATERIALS AND METHOD

2.1 Study area

The study area was selected around the highest elevation which was hilly tract of the Nainital district in Uttarakhand (see Figure 1). The study was carried out in South east and South west aspect in China peak of Nainital district. The South east aspect of study area lies in 29°24.245'N latitude and 79°26.419'E longitude at an elevation of 2598 m. Similarly, South west aspect lies in 29°24.331'N latitude and 79°26.437'E longitude at an elevation of 2598 m. Natural vegetation of Nainital shows great variation in its composition and distribution. This might be largely attributed to the differences in topography, climatic conditions and altitudes. Both aspect of the study area was dominated by *Q. semecarpifolia.* The climate of entire study area was influenced by monsoon pattern of rainfall. Nainital district has temperate summers, with maximum temperature 27°C (81° F) and minimum temperature 7°C (45° F). Winters of Nainital receives snowfall between December and February with temperature varying between a maximum of 15°C (59° F) and a minimum of -3°C (27° F).

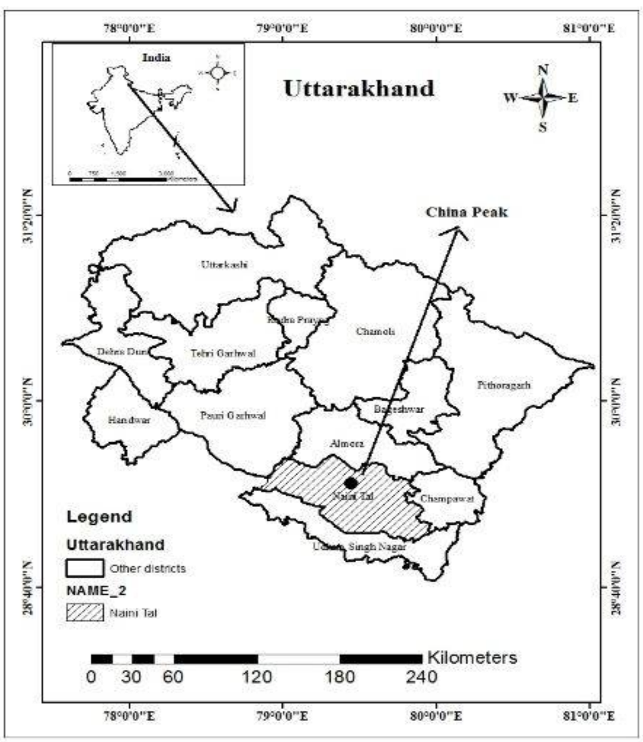

Figure 1: Map showing study site

2.2 Vegetation analysis

The tree analysis was done using quadrat method of 10 m × 10m size in South east and South west aspect. A total of 30 quadrats, 15 in each aspect were quantified. The circumference of each tree species were measured at breast height (1.37 m) using measuring tape from the ground level. The vegetational data were analyzed for density, frequency, abundance following [3], relative density (R.D), relative frequency (R.F) and relative dominance (R.Do) following [15] and Importance Value Index (IVI) of individual species following [4].

$$IVI = R.D + R.F + R.Do$$

2.3 Species diversity:

Tree diversity was calculated using Shannon-wiener theory (H) [21].

$$H = -\sum 3.322 \left(\frac{Ni}{N}\right) \log \left(\frac{Ni}{N}\right)$$

Where, Ni is the total number of individual of species, H is the species diversity and N is the total number of individual of all species.

2.4 Biomass and carbon estimation

The tree biomass was calculated using allometric equations of different tree species which is written below:

$$Y= a+b \text{ In } x$$

Where, Y=dry weight of different tree components (kg), X = mean CBH (cm), a= intercept, b = slope and In = log natural. The values of a and b are taken from the literature [23].

Similarly, biomass was multiplied by a constant 0.475 to estimate the value of carbon stock [11].

$$C = B \times 0.475$$

Where, C is the carbon stock and B is the biomass of tree component. The selected carbon stock of tree species was calculated by multiplying density of respective tree species.

3. RESULTS

3.1 Vegetation analysis

3.1.1 South west aspect

The total density of all species of the aspect was 733 trees ha^{-1} of which dominant species *Q. semecarpifolia* shows the 533 trees ha^{-1}. The total frequency of the species was 140. The maximum frequency was reported for *Quercus semecarpifolia* and minimum frequency was reported for *Acer oblongum.* The total abundance of the species was 17.76. Of this maximum abundance was recorded for *Quercus semecarpifolia* i.e. 8.89 and minimum abundance was recorded for both *Cedrus deodara* and *Litsea umbrosa* i.e 1. All tree species shows the contagious pattern of distribution. Total basal area varies from

0.090 m^2ha^{-1} to 31.09 m^2ha^{-1} with total basal area of 32.614 m^2ha^{-1}. IVI varied from species to species of which *Quercus semecarpifolia* and *Cedrus deodara* shows highest and lowest IVI, respectively (see Table 1).

Table 1: Vegetation parameters of SW aspect

Species	D	F	A	A/F	TBA	IVI
Q. semecarpifolia	533	60	8.89	0.15	31.09	210.92
Cedrus deodara	7	6.67	1	0.15	0.56	7.42
Cornus macrophylla	153	53.33	2.87	0.05	0.78	61.34
Acer oblongum	27	6.67	4	0.60	0.09	8.72
Litsea umbrosa	13	13.33	1	0.08	0.09	11.57
Total	733	140	17.76	-	32.61	299.97

(Note: D = Density (ind/ha), F = Frequency (%), A = Abundance, TBA = Total Basal Area (m^2/ha) and IVI = Importance Value Index)

3.1.2 South east aspect

Total density of all species was 819 trees ha^{-1}. *Q. semecarpifolia* was the dominant species showing density 473 trees ha^{-1}. The total frequency was 160.01% and frequency of all species varies from 6.67% to 60%. The total abundance of the species was 20.89 of which highest abundance was 7.89 and lowest abundance was 1. The distribution pattern of *R. arboreum* was random while all other species shows the contagious pattern of distribution. *Q. semecarpifolia* has the highest total basal area i.e. 45.38 m^2ha^{-1} while *A. oblongum* ha the lowest basal area i.e. 0.19 m^2ha^{-1}. IVI of the species varies from 6.96 to 178.59 (see Table 2).

Table 2: Vegetation parameters of SE aspect

Species	D	F	A	A/F	TBA	IVI
Quercus semecarpifolia	473	60	7.89	0.131	45.38	178.59
Litsea umbrosa	45	20	2.33	0.13	0.39	18.72
Acer oblongum	20	6.67	3	0.45	0.19	6.96
R. arboreum	67	40	1.67	0.04	3.12	38.90
Cornus macrophylla	80	20	4	0.2	0.74	23.64
Quercus floribunda	67	6.67	1	0.15	0.85	13.92
Cedrus deodara	67	6.67	1	0.15	3.76	19.26
Total	819	160.01	20.89		54.43	299.99

(Note: D = Density (ind/ha), F = Frequency (%), A = Abundance, TBA = Total Basal Area (m^2/ha) and IVI = Importance Value Index)

3.2 Species diversity

3.2.1 South west aspect

The total tree diversity was 1.24. Maximum diversity was for *Cornus macrophylla* and recorded as 0.46 where minimum diversity was for *Cedrus deodara* and recorded as 0.11 (see Figure 2).

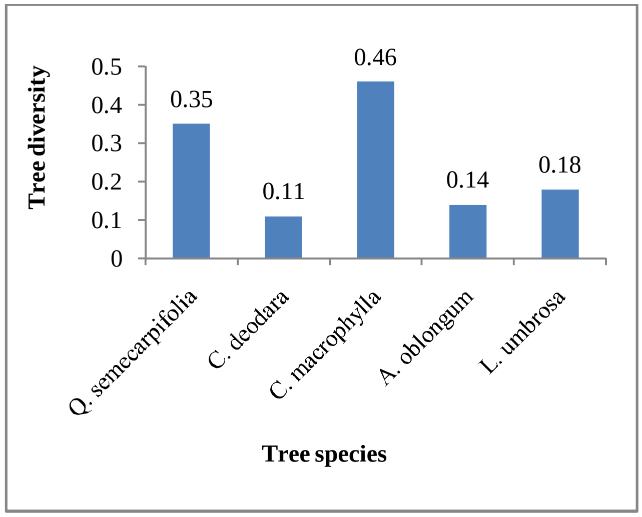

Figure 2: Tree diversity in SW aspect

3.2.2 South east aspect

Total tree diversity was 1.92. Maximum and minimum diversity was recorded for *Q. semecarpifolia* i.e. 0.45 *and A. oblongum* i.e. 0.11, respectively (see Figure 3).

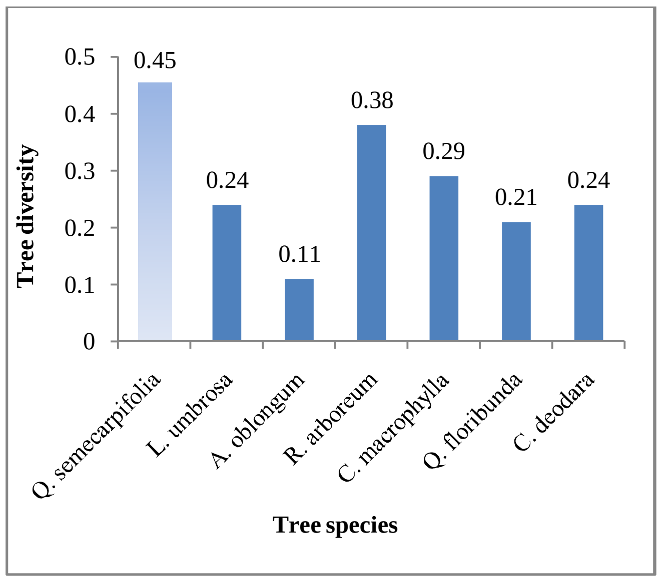

Figure 3: Tree diversity in SE aspect

3.3 Biomass content

3.3.1 South west aspect

The total above and belowground biomass of all tree species was 480.19 t ha^{-1} (see Table 3).

Table 3: Component wise biomass in SW aspect

Species	Components										
	Bole	**Bole bark**	**Branch**	**Twig**	**Foliage**	**TAG**	**Stump root**	**Lateral root**	**Fine root**	**TBG**	**Total**
Q. semecarpifolia	240.85	21.28	62.56	10.75	8.78	344.44	67.20	28.94	11.53	108.33	452.77
C. deodara	2.09	-	1.27	0.48	0.28	4.25	0.61	0.07	0.004	0.67	4.92
C. macrophylla	6.44	-	4.17	2.55	1.46	15.19	3.60	0.37	0.04	4.01	19.2
A. oblongum	0.86	-	0.60	0.37	0.21	2.06	0.52	0.05	0.007	0.58	2.64
L. umbrosa	0.23	0.01	0.08	0.03	0.017	0.44	0.14	0.006	0.01	0.23	0.67
Total	250.47	21.29	68.68	14.18	10.75	366.37	72.07	29.44	11.59	113.82	480.19

Table 4: Component wise biomass in SE aspect

Species	Components										
	Bole	**Bole bark**	**Branch**	**Twig**	**Foliage**	**TAG**	**Stump root**	**Lateral root**	**Fine root**	**TBG**	**Total**
Q. semecarpifolia	282.74	24.91	99.49	11.84	9.61	402.98	75.67	32.87	12.75	122.14	525.12
L. umbrosa	1.15	0.05	0.34	0.10	0.07	1.72	0.26		0.05	0.85	2.57
A. oblongum	1.32	-	0.89	0.46	0.27	3.10	0.63	0.06	0.007	0.71	3.81
R. arboreum	5.39	0.15	2.18	1.35	0.46	10.10	2.18	0.89	0.13	3.23	13.33
C. macrophylla	5.18	-	3.49	1.82	1.05	11.82	2.51	0.26	0.03	2.79	14.61
Q. floribunda	14.09	1.23	6.52	1.69	1.57	25.04	4.69	2.60	0.82	8.20	33.24
C. deodara	15.64	-	9.67	3.84	2.24	32.37	4.93	0.53	0.04	5.5	37.87
Total	325.51	26.34	122.58	21.1	15.27	487.13	90.87	37.21	13.83	143.42	630.55

Of this, total aboveground biomass was 366.37 t ha^{-1} and total belowground biomass was 113.82 t ha^{-1}. Maximum and minimum biomass was recorded for *Quercus semecarpifolia* and *Litsea umbrosa* i.e. 452.77 t ha^{-1} and 0.67 t ha^{-1}, respectively. In every tree species bole has the highest biomass and foliage consist of minimum biomass than the other aboveground component. Similarly, stump root has the highest and fine root has the lowest biomass than the other root component. The total bole biomass of all tree components was 250.47 t ha^{-1} while foliage biomass was 10.75 t ha^{-1} (see Table 3).

3.3.2 South east aspect

Total tree aboveground biomass was 487.13 t ha^{-1} and total belowground biomass was 143.42 t ha^{-1}. The total above and belowground biomass of all tree species was 630.55 t ha^{-1}. *Quercus semecarpifolia* has the highest biomass i.e. 525.12 t ha^{-1} and *Litsea umbrosa* has the lowest biomass i.e. 2.57 t ha^{-1} than other tree species. The total bole biomass and foliage biomass accounts for 325.51 t ha^{-1} and 15.27 t ha^{-1}, respectively. The total biomass of stump root was 90.87 t ha^{-1} and fine root has 13.83 t ha^{-1} (see Table 4).

3.4 Carbon stock

3.4.1 South west aspect

The total carbon stock was 228.1 t ha^{-1}. *Q. semecarpifolia* (215.05 t ha^{-1}) share the highest whereas, *L. umbrosa* (0.32 t ha^{-1}) share minimum carbon content. The total above and belowground carbon was 174.03 t ha^{-1} and 54.07 t ha^{-1}, respectively. Bole has the highest aboveground carbon (119.01 t ha^{-1}) whereas, foliage has the least carbon content (5.09 t ha^{-1}) (see Table 5). Similarly, stump root (34.24 t ha^{-1}) shares highest and fine root (5.49 t ha^{-1}) shares lowest carbon, respectively.

Table 5: Component wise carbon stock in SW aspect

Species	Components										
	Bole	**Bole bark**	**Branch**	**Twig**	**Foliage**	**TAG**	**S. root**	**L. root**	**Fine root**	**TBG**	**Total**
Q. semecarpifolia	114.41	10.11	29.72	5.10	4.17	163.59	31.92	13.74	5.47	51.46	215.05
C. deodara	0.99	-	0.60	0.23	0.13	2.02	0.29	0.03	0.001	0.32	2.34
C. macrophylla	3.06	-	1.98	1.21	0.69	7.23	1.71	0.17	0.02	1.90	9.13
A. oblongum	0.41	-	0.29	0.17	0.09	0.98	0.25	0.02	0.003	0.28	1.26
L. umbrosa	0.14	0.006	0.04	0.01	0.008	0.21	0.07	0.002	0.005	0.11	0.32

Total	119.01	10.12	32.63	6.72	5.09	174.03	34.24	13.96	5.49	54.07	228.1

Table 6: Component wise carbon stock (t ha^{-1}) in SE aspect

Species	Components										
	Bole	**Bole bark**	**Branch**	**Twig**	**Foliage**	**TAG**	**Stump root**	**Lateral root**	**Fine root**	**TBG**	**Total**
Q. semecarpifolia	134.30	11.83	47.26	5.62	4.56	191.41	35.94	15.61	6.05	58.02	249.43
L. umbrosa	0.54	0.03	0.16	0.05	0.03	0.82	0.26	0.12	0.02	0.41	1.23
A. oblongum	0.63	-	0.42	0.22	0.13	1.43	0.30	0.03	0.003	0.33	1.76
R. arboreum	2.55	0.07	1.03	0.64	0.22	4.79	1.04	0.43	0.06	1.53	6.32
C. macrophylla	2.46	-	1.66	0.86	0.49	5.61	1.19	0.12	0.01	1.33	6.94
Q. floribunda	2.69	0.58	3.09	0.80	0.74	11.89	2.23	1.23	0.39	3.89	15.78
C. deodara	7.43	-	4.59	1.82	1.06	15.37	2.34	0.25	0.02	2.61	17.98
Total	150.6	12.51	58.21	10.01	7.23	231.32	43.3	17.79	6.55	68.12	299.44

3.4.2 South east aspect

The total above and belowground carbon content was 299.44 t ha^{-1}. Among all tree species *Q. semecarpifolia* has the maximum carbon content i.e. 249.43 t ha^{-1} and *Litsea umbrosa* has the minimum carbon content i.e. 1.23 t ha^{-1}. The total aboveground carbon content of all tree species was 231.32 t ha^{-1} and total belowground carbon content of the species was 68.12 t ha^{-1}. Among the different tree components bole shares the maximum aboveground carbon content i.e. 150.6 t ha^{-1} and foliage shares the minimum belowground carbon content i.e. 7.23 t ha $^{-1}$. Similarly, in belowground stump root shares maximum carbon content i.e., 43.3 t ha^{-1} and fine root shares minimum carbon content i.e., 6.55 t ha^{-1}. Among all components bole is the dominant carbon content component (see Table 6).

4. DISCUSSION

4.1 Vegetation analysis

Total tree density in South west aspect was 733 tree ha^{-1} and 819 tree ha^{-1} in South east aspect. The density of South east aspect was on higher side and that of south west aspect falls within the range (570-760 trees ha^{-1}) reported for Oak forest in Himalayan forest [19].

4.2 Tree Diversity

Tree diversity ranged from 1.24 - 1.29. The diversity of both aspects falls within range (0.46 - 2.02) reported for Oak forest in Nainital district of Kumaun Himalaya [22]. Similarly, present findings also falls between the range (1.2 - 2.7) for Central Himalaya forest [10] and (0.78 - 3.45) for Garhwal Himalaya [17]. The mixed forest had the greatest tree diversity and diversity increases with increasing basal cover [20].

4.3 Biomass

The total biomass of tree species was 480.19 t ha^{-1} and 630.55 t ha^{-1} in South west and South east aspect, respectively. The maximum biomass of forest was shared by *Q. semecarpifolia* in which the biomass range was on higher side than (285-458 t ha^{-1}) in both aspects reported for Oak forest [19], 426 t ha^{-1} for Oak-Pine mixed forest [16] and (236-400 t ha^{-1}) for Oak mixed forests of higher elevation [2]. While biomass range of South west aspect was on lower side and biomass of South east aspect falls within the range of 556-782 t ha^{-1} reported for Riyanj and Tilonj dominated mixed Oak forest of Central Himalaya [16].

4.4 Carbon

Carbon content in South west and South east aspect was 228.1 t ha^{-1} and 299.44 t ha^{-1}, respectively. The South west aspect carbon content was slightly less and carbon content of South east aspect falls between the ranges of (271-380 t ha^{-1}) for Oak dominant forests of Central Himalaya [16]. Similarly, South west aspect present estimates of carbon content was on lower side and South east aspect present estimates of carbon content was on slightly higher side of (248 – 296 t ha^{-1}) reported for Oak Van Panchayat [9]. However, the values in both aspects were higher than (148 t ha^{-1}) in Oak forest [12]. The carbon content of South west aspect was on lower side and that of South east aspect lies within the range of (250-300 t ha^{-1}) for Central Himalayan forests [23]. Biomass and carbon stock varies in both the aspects where higher stock was found in South east aspect and lower stock was found in South west aspect.

5. CONCLUSION AND RECOMMENDATIONS

Forests have great potential to store and sequester carbon if managed suitably. The study revealed that Oak dominated forests of Kumaun Himalaya have huge ability to store carbon. It found out that the South east aspect have higher density, basal area and biomass content than South west aspect. Forests of temperate region can hold carbon for long duration of time if managed sustainably. It is concluded that the Himalayan forests can play a huge role in mitigating climate change as they are huge sequester of carbon. It is recommended to aware the public globally about the anthropogenic pressure on forests, its consequences and possible ways to combat them.

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REFERENCES

[1] Adhikari, B. S., "Biomass productivity and nutrient cycling of Kharsu oak and silver forest in Central Himalaya", Ph.D Thesis, Kumaun University, Nainital, 1992.

[2] Adhikari, B. S., Dhalia-Adhikari, S., and Rawat, Y. S., "Structure of Himalayan moist temperate cypress forest at and around Nainital, Kumaun Himalayas", *Oecologia* Montana, Prunella publishers, 7, 1988, pp. 21-31.

[3] Curtis, J. T. and Mclntosh, R. P., "The interrelations of certain analytic and systematic phytosociological characters", *Ecology*, 31, 1950, pp. 434-455.

[4] Curtis, J. T., "The Vegetation of Wisconsin", An ordination of plant communities, Univ. (Wisconsin press, Madison, Wisconsin), 1959, pp. 657.

[5] FAO, "Land covers classification system", classification concepts and user manual, *Environment and Natural Resource*, Rome, Italy, 2005, pp. 8.

[6] Hagedorn, F., Landolt, W. and Tarjan, D., "Elevated CO2 influences nutrient availability in young beech-spruce communities on two soil types, *Oecologia*, 132, 2002, pp. 109–117.

[7] IPCC, "Fifth Assessment Report: Synthesis report summary for policy maker", 2014.

[8] IPPC, "Radiative forcing of climate change and an evaluation of the IPPC IS92 emission scenarios", Cambridge University press, Cambridge, UK, 1995, pp. 339.

[9] Jina, B. S., Sah, P., Bhatt M. D. and Rawat, Y. S., "Estimating carbon sequestration rates and total carbon stock pile in degraded and non-degraded sites of Oak and Pine Forest of Kumaun Central Himalaya", *Ecoprint*, 15, 2008, pp. 75-81.

[10] Kumar, A. and Ram, J., "Anthropogenic disturbances and plant biodiversity in forests of Uttarakhand, Central Himalaya", Biodiversity and conservation, 14, 2005, pp. 300-331.

[11] Magnussen, S. and Reed, D., "Modeling for estimation and monitoring", FAO-IUFRO, 2004.

[12] Malhi, Y., Nobre, A. D. and Grace, J., "Carbon dioxide transfer over a central Amazonian rain forest", *Journal of geophysical Research*, 103, 1998, pp. 593-631.

[13] Mandal, R. A., and Laake, P., "Carbon sequestration in community forests", an eligible issue for CDM, (A case study of Nainital, India), *Banko Janakari*, 15, 2, 2005, pp. 64-72.

[14] Midgley, G. F., Bond, W. J., Kapos, V. K., Ravilious, C., Scharlemann, J. P. W., Woodward, F. I., "Terrestrial carbon stocks and biodiversity, key knowledge gaps and some policy implications", Current opinion of Environmental sustainability, 2, 2010, pp. 264–270.

[15] Phillips, E. A., "Methods of Vegetation Study", A Holt-dryden book, Henry Hoit and Co inc, 1959, pp. 107.

[16] Rana, B. S., Singh, R. P. and Singh, S. P., "Carbon and energy dynamics of seven Central Himalayan forests", *Tropical Ecology*, 30, 2, 1989, pp. 253–264.

[17] Raturi, G. P., "Forest community structure along an altitudinal gradient of district Rudraprayg of Garhwal Himalaya, India", *Ecology*, 2, 3, 2012, pp. 76-84.

[18] Ravindranath, N. H., Sathaye, J., "Climate change and developing countries, Kluwer Academic, Dordrecht, The Netherlands, 2002.

[19] Rawat, Y. S. and Singh, J. S., "Structure and function of Oak forests in Central Himalaya", I. Dry matter dynamics, *Annals of Botany*, 62, 1988, pp. 397-411.

[20] Saxena, A. K. and Singh, J. S., "Quantitative profile structure of certain forest in the Kumaun Himalayan", *Proceeding of the Indian Academy of Sciences*, 91, 1982, pp. 529-49.

[21] Shannon, C. E. and Wiener, W., "The mathematical theory of communication, Urbana univ. illinois press, 1963.

[22] Singh, J. S. and Singh, S. P., "Forest vegetation of the Himalaya", *Botanical Review*, 52, 1987, pp. 80-192.

[23] Singh, J. S., and Singh, S. P., "Forests of Himalaya, Structure, Functioning and impact of man", Gyanodaya Prakashan Nainital, India, 1992.

[24] Singh, S. K. and Rawat, G. S., Flora of Great Himalaya National Park, Dehradun, India, 2000.