RESEARCH ARTICLE

PRODUCTIVITY AND CARBON SEQUESTRATION POTENTIAL OF VAN PANCHAYAT FOREST IN KUMAUN HIMALAYA

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Abstract: Present study deals with biomass and carbon sequestration potential in Letibunga van panchayat forest in Nainital district of Kumaun Himalaya. The van panchayat was dominated by banj oak (*Q. leucotrichophora*) species and associated with some other tree species. The whole van panchayat forest was divided into three sub-sites viz., hill top, hill slope and hill base site. In van panchayat, total 7, 14 and 34 species of tree, shrub and herb were reported. *Quercus leucotrichophora* was the dominant tree species in each site with maximum density. The biomass and productivity of forest was 523 t ha^{-1} and 21 t ha^{-1} yr^{-1}, of which tree layer accounted for 99 and 86 per cent, respectively. The carbon stock and carbon sequestration was 249 t ha^{-1} and 10 t ha^{-1} yr^{-1}, of this tree layer contributed 99 and 86 per cent, respectively. This study concluded that van panchayat forest having oak tree species not only provide the wood demands of the local people in the area but also play a vital role in the conservation of carbon, therefore mitigates the climate change problem and also supports the sustainability of the region. In this context, such community forests must be protected and managed in such a way so that the sustainable development could not be hampered in near future.

Key words: Van panchayat forest, Biomass, Productivity, Carbon stock, Carbon sequestration

INTRODUCTION

Forests are the important natural resources that fulfill various needs of the country. They provide numbers of products like timber, fuel-wood, fodder etc as well as ameliorate the sites and improve the microclimate of an area. The forest resources provide indirect services like water availability, fresh air, flood-drought control, run off and soil erosion control etc. Apart from these, they also play significant role in the mitigation of climate change. All these forests are either being managed and/or conserved by the government organization and/or by the village organization. In hills, more than 20% forest have been conserved and managed by the community people known as van panchayat. Recently the van panchayat forests are under heavy pressure caused by the villagers due to their domestic needs. Therefore it is very imperative to assess the actual condition of a forest particularly in selected site. The objective of present study was to assess the biomass, productivity, carbon stock and carbon sequestration in van panchayat forest.

MATERIAL AND METHOD

Description of study site: The study site was located in the Letibunga-Sesbani village of Dhari block in Nainital district in between 29^0 25' 42.9" N latitude and 79^0 39' 45.2" E longitudes. The altitude of hill base, hill slope and hill top site was 1865, 2082 and 2153m respectively. This van panchayat was formed in the year1932 having an area of 58 hectares. For the collection of data, 30 quadrats of 10x10m size were placed randomly in each forest site for tree. The size of quadrat used for shrub and herb was, 5x5m and 1x1m respectively. The circumference of tree species was measured at breast height (1.37m). For estimation of biomass (B_1) of tree and shrub components, already developed allometric linear equations were used while the biomass of herbs was estimated by harvest method (Rawat and Singh, 1988). The biomass of trees, shrubs and herbs was summed up to obtain the total vegetation biomass in the each site. Finally the average biomass value was determined. For productivity, 100 trees and 25 shrubs of different species were marked in each site and re-measured after one year interval for increments. On the basis of increments of tree and shrub, the biomass B_2 was estimated. The net change in biomass (ΔB) for each site was estimated. Similarly the carbon was estimated on the basis of biomass by using the factor 0.475 as used by Magnussen and Reed (2004). The carbon (stock/sequestration) of forest site was determined by multiplying the biomass value with factor.

RESULT AND DISCUSSION

The density of tree species in studied oak mixed forests was 1000-1400 ind ha^{-1}. Oak (*Quercus leucotrichophora*) was the dominant tree species in all the forest sites (Table 1). The present tree species density was somewhat similar to 1330 ind ha^{-1} (Lodhiyal and Lodhiyal, 2012), 960-1170 ind ha^{-1} (Pandey and Lodhiyal, 2015), 920-1345 ind ha^{-1} (Lodhiyal *et al.*, 2013), 550-1250 ind ha^{-1} (Singh *et al.*, 2014) and 980-1010 ind ha^{-1} (Lal and Lodhiyal, 2016) reported for oak forests in the central Himalayan region. The density of tree species was

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higher side than 570-760 ind ha^{-1} (Rawat and Singh, 1988) reported for oak forest in Kumaun Himalaya but falls within the range 420-1640 ind ha^{-1} reported for temperate forests of Western Himalaya (Saxena and Singh, 1982). The shrubs density was 5680-9360 ind ha^{-1} (Table 2). The present shrub density was on higher side than 1060 ind ha^{-1} (Rawat and Singh, 1988), 310-1540 ind ha^{-1} (Lodhiyal *et al.,* 2015) reported for oak mixed forest. The herbs density was 102.5-122 ind m^{-2} (Table 3). The density of herbs in the studied forest sites was on higher side than 20.3-34.7 ind m^{-2} (Kharkwal and Rawat, 2010) and 14-49.1 ind m^{-2} (Lodhiyal *et al.,* 2015) reported for oak forest of Kumaun Himalaya. The basal area of tree species ranged from 49.3 to 77.3 m^2 ha^{-1}.in the studied forest sites. The total mean basal area was 60.3 m^2 ha^{-1} (Table 1). These values are somewhat similar to 58.7- 93.0 m^2 ha^{-1} (Lodhiyal *et al.,* 2014) and 31.8-63.9 m^2 ha^{-1} (Lal and Lodhiyal, 2016) reported for oak dominated forests in the Kumaun Himalayan region. The tree biomass ranged from 461 to 614 t ha^{-1} (Table 4). The shrub biomass was 1.56-3.2 t ha^{-1} (Table 5). The total mean biomass of studied forest sites was 523.46 t ha^{-1}, of this tree layer contributed 99% of the total biomass (Table 6**)**. The present biomass was higher than 285.3-387.3 t ha^{-1} (Rawat and Singh, 1988) and 101.45 t ha^{-1} (Lodhiyal and Lodhiyal, 2012) for oak forest. The biomass was somewhat similar to 481-569 t ha^{-1} (Lal and Lodhiyal, 2016) and 495-718 t ha^{-1} (Lodhiyal *et al.,* 2014) reported for different oak forests. The productivity ranged from 16.3-20.8 t ha^{-1} yr^{-1} (Table 4) and was found to be somewhat similar to 16.9-20.9 t ha^{-1} yr^{-1} (Lal and Lodhiyal, 2016) and 16.6 t ha^{-1} yr^{-1} (Rawat and Singh, 1988) reported for oak forests. The shrub productivity was 0.83-1.53 t ha^{-1} yr^{-1} (Table 5). The total mean productivity in studied forest sites was 21.2 t ha^{-1} yr^{-1}, of this 86 % accounted for tree layer (Table 6). The tree carbon stock was 219- 292 t ha^{-1} (Table 7). The shrub carbon stock was 0.74-1.53 t ha^{-1} (Table 8). The total mean carbon stock in the studied forest sites was 248.6 t ha^{-1} (Table 9) which was higher than the values 25.02, 59.94 t ha^{-1},155.41 and 168.08 t ha^{-1} reported for various van panchayat forests (Tewari and Karky, 2007; Raikwal, 2009; Rawat, 2012). The carbon stock was somewhat similar to values 228.5-270.3 t ha^{-1} (Lal and Lodhiyal, 2016) and 242.6-290.6 t ha^{-1} (Jina *et al.,* 2008) reported for oak dominated forest in Kumaun Himalaya but lower than 341.0 t ha^{-1} (Lodhiyal *et al.,* 2014). The carbon sequestration of tree and shrub species ranged from 7.78 to 9.89 and 0.42 to 0.82 t ha^{-1} yr^{-1} respectively (Table 7 and 8). The total mean carbon sequestration in the studied forest sites was 10.14 t C ha^{-1} yr^{-1}. Of this, tree layer shared 86 per cent (Table 9). The present values of carbon sequestration was higher side than the values 5.5-6.2 t C ha^{-1} yr^{-1} in non-degraded oak forests (Jina *et al.,* 2008) and 0.82-5.71 t C ha^{-1} yr^{-1} in different van panchayat forests (Tewari and Karky, 2007, Raikwal, 2009, Rawat, 2012). But falls within range 7.99- 9.96 t C ha^{-1} yr^{-1} for oak dominated forests of Kumaun Himalaya (Lal and Lodhiyal, 2016). The hill top forest site of studied van panchayat contained maximum biomass and carbon stock while the hill base forest site accounted for maximum productivity and carbon sequestration. The high productivity at hill base forest site was due to the presence of younger age classes of tree species and their higher density. While the hill slope forest site showed low productivity because of more pressure of forest resources extraction by the villagers as site was in close vicinity of forest.

Table 1. Density (ind ha^{-1}) and basal area (m^2 ha^{-1}) of tree layer in Letibunga Van Panchayat at three forest sites

Species	Density (ind ha^{-1})				Basal area (m^2 ha^{-1})			
	Hill Top	Hill Slope	Hill Base	Mean	Hill Top	Hill Slope	Hill Base	Mean
Quercus leucotrichophora A. Camus	710 (59.2)	630 (63.0)	610 (43.5)	650.0	63.92	45.55	23.26	44.24
Myrica esculenta Buch.-Ham. Ex D. Don	200 (16.6)	40 (4.0)	110 (7.9)	116.6	3.31	0.80	5.37	3.16
Rhododendron arboreum Sm.	290 (24.2)	250 (25.0)	480 (34.3)	340.0	10.04	5.16	14.41	9.87
Lyonia ovalifolia (Wall.) Drude	-	60 (6.0)	130 (9.3)	63.3	-	2.42	4.25	3.34
Pyrus pashia Buch.-Ham. Ex D. Don	-	20 (2.0)	-	6.7	-	0.29	-	0.29
Quercus semecarpifolia Sm.	-	-	50 (3.6)	16.7	-	-	0.96	0.96
Pinus roxburghii Sarg.	-	-	20 (1.4)	6.7	-	-	1.08	1.08
Total	1200	1000	1400	1200	77.27	54.22	49.33	60.27

Note- value given in parentheses are per cent value

Table 2. Density (ind ha^{-1}) and total basal area (m^2 ha^{-1}) of shrubs in Letibunga Van Panchayat at three forest sites

Species	Density (ind ha^{-1})				TBA (m^2 ha^{-1})			
	Hill Top	Hill Slope	Hill Base	Mean	Hill Top	Hill Slope	Hill Base	Mean
Asparagus racemosus Wild.	600	560	600	586.7	0.004	0.007	0.005	0.005
Berberis aristata D.C	760	600	520	626.7	0.002	0.003	0.006	0.004

Daphne papyracea Wall. ex G. Don	600	-	760	680.0	0.025	-	0.003	0.014
Desmodium elegans DC.	480	760	840	693.3	0.015	0.004	0.003	0.007
Deutzia campacta Craile	920	-	760	840.0	0.004	-	0.005	0.005
Indigofera heterantha Brandis	640	600	520	586.7	0.002	0.004	0.004	0.003
Prinsepia utilis Royle	680	480	720	626.7	0.004	0.001	0.003	0.003
Pyracantha crenulata D.Dun	680	840	560	693.3	0.003	0.002	0.001	0.002
Reinwardtia indica Dum.	840	-	680	760.0	0.018	-	0.002	0.010
Rhamnus virgatus Roxb.	520	640	480	546.7	0.004	0.005	0.005	0.005
Rhus parviflora Roxb.	760	-	640	700.0	0.002	-	0.009	0.006
Rubus ellipticus Smith.	560	680	760	666.7	0.010	0.003	0.002	0.005
Rubus lensiocarpus Thunb.	600	520	680	600.0	0.008	0.004	0.003	0.005
Viburnum coriaceum Blume	720	-	600	660.0	0.006	-	0.005	0.006
TOTAL	9360	5680	9120	8053.3	0.107	0.032	0.056	0.065

Table 3. Density (ind m^{-2}) of herbs in Letibunga Van Panchayat at three forest sites

Species name	Hill top	Hill slope	Hill base	Mean
Achyranthes bidentata L.	4.7	7.6	5.7	6.0
Ageratum conyzoides L.	4.1	4.4	6.2	4.9
Apluda mutica L.	2.4	2.6	5.4	3.5
Anaphalis busua (buch.-Ham.) DC.	2.4	3.8	6.2	4.1
Anthroxon lanceolatus (Roxb.) Hpchst.	6.1	6.1	1.6	4.6
Artemisia vulgare L.	3.1	2.6	3.3	3.0
Bidens pilosa L.	7.4	5.4	3.6	5.5
Bidens biternata L.	2.6	9.8	0.8	4.4
Blumia balsamifera D. Don	4.1	3.5	3.6	3.7
Commelina benghalensis L.	3.9	4.2	1.7	3.3
Cyperus rotundus L.	4.7	3.5	4	4.1
Cyperus triceps Endl.	3.2	2.6	0.9	2.2
Desmodium parviflorum Dalz.	-	-	3.8	3.8
Desmodium triflorum (L.) DC.	6.1	4.2	4.7	5.0
Drocera peltata Thunb.	0.4	4.4	4.7	3.2
Erigeron bonarionsis L.	6.1	3.1	2.6	3.9
Eupatorium adenophorum Spreng.	-	-	3.3	3.3
Gallium rotundifolium L.	3.4	4.9	4.5	4.3
Geranium nepalensis Sweet	2.2	4.2	4.5	3.6
Justicia simplex D. Don	3.2	4.3	4.8	4.1
Leucas lanata Benth.	2.6	6.4	5.6	4.9
Micromeria biflora (Buch.-Ham. Ex D. Don)	3.2	3.3	5.4	4.0
Nepeta longiflora Vent.	2.7	2.1	1.8	2.2
Oxalis corniculata L.	6.4	5.6	3.6	5.2
Polygonum nepalense Meisn.	3.2	2.3	2.2	2.6
Prunella vulgaris (L.)	2.8	2.2	2.1	2.4
Rubia cordifolia L.	-	-	4.5	4.5
Scutellaria laterifolia (L.)	4.5	9.6	4.2	6.1
Setaria glauca (L.) P. Beauv	2.5	8.1	6.2	5.6
Smilax glabra L.	-	-	0.5	0.5
Taraxacum officinelis (L.) Weber ex F.H. Wigg	2.3	-	4.4	3.4
Thymus vulgaris L.	2.2	-	2.5	2.4
Viola canescens Wall.	-	-	1.2	1.2
Vitis himalayana (Royal) Brandis	-	-	1.9	1.9
Total	102.5	120.8	122	115.1

Table 4. Tree layer biomass (t ha^{-1}) and productivity (t ha^{-1} yr^{-1}) of Letibunga Van Panchayat at three forest sites

Sites/tree species	Biomass (t ha^{-1})						Productivity (t $ha^{-1}yr^{-1}$)					
Hill top site	Bole	Branch	Twig	Foliage	Root	Total	Bole	Branch	Twig	Foliage	Root	Total
Q. leucotrichophora	257.68	155.35	43.03	14.24	42.24	512.54	6.34	3.69	0.81	0.26	0.77	11.87
M. esculenta	21.00	13.66	6.37	3.70	9.54	54.27	2.04	1.24	0.45	0.26	0.62	4.61
R. arboreum	16.69	11.11	4.31	1.93	13.30	47.34	0.45	0.26	0.06	0.01	0.43	1.21
Total	295.37	180.12	53.71	19.87	65.08	614.15	8.83	5.19	1.32	0.53	1.82	17.69
Hill slope site												
Q. leucotrichophora	197.54	119.77	34.58	11.51	34.20	397.60	6.44	3.78	0.81	0.26	0.77	12.06
M. esculenta	4.52	2.92	1.34	0.78	1.99	11.55	0.55	0.33	0.12	0.07	0.15	1.22
L. ovalifolia	11.43	7.11	2.91	1.69	10.83	33.97	0.63	0.37	0.11	0.07	0.15	1.33
Pyrus pashia	1.80	1.19	0.58	0.32	0.86	4.75	0.15	0.09	0.03	0.02	0.06	0.35
R. arboreum	12.08	8.24	3.40	1.61	9.18	34.51	0.46	0.28	0.15	0.02	0.46	1.37
Total	227.37	139.23	42.81	15.90	57.06	482.38	8.23	4.85	1.22	0.44	1.59	16.33
Hill base site												
Q. leucotrichophora	123.35	76.39	25.18	8.49	25.40	258.81	6.99	4.17	0.99	0.32	0.94	13.41

M. esculenta	24.75	15.13	5.88	3.44	8.40	57.60	1.00	0.59	0.19	0.12	0.26	2.16
L. ovalifolia	22.08	13.75	5.66	3.30	8.21	53.00	1.06	0.62	0.21	0.13	0.29	2.31
Q. semecarpifolia	4.65	3.02	1.39	0.81	2.06	11.93	0.28	0.17	0.06	0.04	0.08	0.63
R. arboreum	26.36	17.67	6.98	3.16	20.72	74.89	0.66	0.39	0.09	0.02	0.64	1.80
P. roxburghii	3.17	0.76	0	0.19	0.95	5.07	0.32	0.08	0.001	0.01	0.09	0.50
Total	204.36	126.72	45.09	19.39	65.74	461.30	10.31	6.02	1.54	0.64	2.30	20.81

Table 5. Shrub layer biomass (t ha^{-1}) and productivity (t ha^{-1} yr^{-1}) of Letibunga Van Panchayat at three forest sites

Sites/tree species	Biomass (t ha^{-1})				Productivity (t ha^{-1} yr^{-1})			
Hill top site	Stem	Foliage	Root	Total	Stem	Foliage	Root	Total
Asparagus racemosus	0.07	0.03	0.08	0.18	0.01	0.01	0.01	0.03
Berberis aristata	0.08	0.03	0.09	0.20	0.02	0.03	0.01	0.05
Daphne papyracea	0.10	0.05	0.10	0.25	0.04	0.03	0.02	0.08
Desmodium elegans	0.08	0.34	0.07	0.50	0.03	0.07	0.02	0.11
Deutzia campacta	0.10	0.04	0.11	0.25	0.08	0.08	0.05	0.22
Indigofera heterantha	0.06	0.02	0.08	0.17	0.01	0.04	0.01	0.06
Prinsepia utilis	0.08	0.03	0.09	0.20	0.04	0.02	0.04	0.09
Pyracantha crenulata	0.07	0.03	0.08	0.18	0.05	0.05	0.02	0.12
Reinwardtia indica	0.13	0.05	0.13	0.31	0.06	0.06	0.02	0.13
Rhamnus virgatus	0.06	0.02	0.07	0.15	0.01	0.01	0.003	0.02
Rhus parviflora	0.08	0.03	0.09	0.20	0.02	0.01	0.02	0.05
Rubus ellipticus	0.08	0.03	0.08	0.20	0.03	0.09	0.04	0.16
Rubus lensiocarpus	0.08	0.04	0.09	0.20	0.03	0.04	0.02	0.08
Viburnum coriaceum	0.08	0.03	0.09	0.21	0.01	0.02	0.004	0.03
TOTAL	1.15	0.78	1.26	3.20	0.44	0.54	0.28	1.26
Hill slope site								
Asparagus racemosus	0.07	0.03	0.08	0.18	0.03	0.01	0.03	0.07
Berberis aristata	0.07	0.03	0.08	0.17	0.08	0.07	0.04	0.19
Desmodium elegans	0.08	0.03	0.10	0.21	0.02	0.004	0.01	0.03
Indigofera heterantha	0.05	0.02	0.07	0.14	0.03	0.07	0.02	0.12
Prinsepia utilis	0.04	0.02	0.06	0.11	0.05	0.04	0.03	0.11
Pyracantha crenulata	0.00	0.03	0.10	0.21	0.01	0.02	0.01	0.03
Rhamnus virgata	0.07	0.03	0.08	0.19	0.04	0.04	0.02	0.10
Rubus ellipticus	0.07	0.03	0.09	0.19	0.01	0.01	0.01	0.04
Rubus lensiocarpus	0.06	0.02	0.07	0.15	0.09	0.01	0.03	0.14
TOTAL	0.61	0.24	0.72	1.56	0.35	0.28	0.20	0.83
Hill base site								
Asparagus racemosus	0.07	0.03	0.07	0.17	0.04	0.03	0.01	0.09
Berberis aristata	0.10	0.03	0.10	0.24	0.02	0.03	0.02	0.07
Daphne papyracea	0.08	0.03	0.08	0.19	0.03	0.03	0.02	0.09
Desmodium elegans	0.06	0.03	0.07	0.16	0.02	0.07	0.02	0.11
Deutzia campacta	0.06	0.02	0.07	0.15	0.02	0.01	0.02	0.05
Indigofera heterantha	0.09	0.04	0.09	0.22	0.02	0.02	0.01	0.06
Prinsepia utilis	0.07	0.03	0.08	0.18	0.04	0.03	0.01	0.09
Pyracantha crenulata	0.07	0.03	0.08	0.18	0.04	0.05	0.02	0.11
Reinwardtia indica	0.09	0.04	0.10	0.23	0.06	0.04	0.03	0.14
Rhamnus virgata	0.07	0.03	0.09	0.18	0.03	0.09	0.04	0.16
Rhus parviflora	0.08	0.03	0.09	0.20	0.11	0.13	0.07	0.32
Rubus ellipticus	0.05	0.02	0.07	0.14	0.03	0.04	0.02	0.10
Rubus lensiocarpus	0.07	0.03	0.08	0.18	0.01	0.01	0.01	0.03
Viburnum coriaceum	0.07	0.03	0.09	0.19	0.06	0.08	0.04	0.19
TOTAL	1.03	0.40	1.16	2. 60	0.56	0.67	0.36	1.59

Table 6. Total vegetation biomass (t ha^{-1}) and productivity (t ha^{-1} yr^{-1}) in Letibunga Van Panchayat forests.

Vegetation layer	Biomass (t ha^{-1})				Productivity (t ha^{-1} yr^{-1})			
	HT site	HS site	HB site	Mean	HT site	HS site	HB site	Mean
Tree layer	614.15	482.38	461.30	519.28 (99.2)	17.69	16.33	20.81	18.28 (86.1)
Shrub layer	3.20	1.56	2.60	2.45 (0.5)	1.28	0.83	1.53	1.21 (5.7)
Herb layer	1.76	2.18	1.24	1.73 (0.3)	1.76	2.18	1.24	1.73 (8.2)
Total vegetation	619.11	486.12	465.14	523.46(100)	20.73	19.34	23.58	21.22(100)

Note- HT= Hill top forest site, HS= Hill slope forest site and HB= Hill base forest site

Table 7. Tree layer carbon stock (t ha^{-1}) and carbon sequestration (t ha^{-1} yr^{-1}) of Van Panchayat at three forest sites

Sites/tree species	Carbon stock (t ha^{-1})						Carbon sequestration (t ha^{-1} yr^{-1})					
Hill top site	Bole	Branch	Twig	Foliage	Root	Total	Bole	Branch	Twig	Foliage	Root	Total
Q.	122.40	73.79	20.43	6.77	20.06	243.45	3.01	1.75	0.38	0.12	0.37	5.63

leucotrichophora												
M. esculenta	9.97	6.49	3.03	1.76	4.53	25.78	0.97	0.59	0.21	0.13	0.29	2.19
R. arboreum	7.93	5.28	2.05	0.92	6.32	22.50	0.21	0.13	0.03	0.01	0.21	0.59
Total	140.30	85.56	25.51	9.45	30.91	291.73	4.19	2.47	0.62	0.26	0.87	8.41
Hill slope site												
Q. leucotrichophora	93.83	56.89	16.43	5.46	16.25	188.86	3.06	1.80	0.39	0.13	0.37	5.75
Myrica esculenta	2.15	1.39	0.64	0.37	0.95	5.50	0.26	0.16	0.06	0.03	0.07	0.58
Lyonia ovalifolia	5.43	3.38	1.38	0.81	5.14	16.14	0.30	0.18	0.05	0.03	0.07	0.63
Pyrus pashia	0.85	0.56	0.27	0.16	0.41	2.25	0.07	0.04	0.02	0.01	0.03	0.17
R. arboreum	5.74	3.92	1.62	0.76	4.36	16.40	0.22	0.13	0.07	0.01	0.22	0.65
Total	108.00	66.14	20.34	7.56	27.11	229.15	3.91	2.31	0.59	0.21	0.76	7.78
Hill base site												
Q. leucotrichophora	58.59	36.29	11.96	4.03	12.07	122.94	3.33	1.98	0.47	0.15	0.45	6.38
Myrica esculenta	11.76	7.19	2.79	1.63	3.99	27.36	0.48	0.28	0.09	0.06	0.12	1.03
Lyonia ovalifolia	10.49	6.53	2.69	1.57	3.90	25.18	0.50	0.29	0.10	0.06	0.14	1.09
Q. semecarpifolia	2.21	1.43	0.66	0.38	0.98	5.66	0.13	0.08	0.03	0.02	0.04	0.30
R. arboreum	12.52	8.39	3.31	1.50	9.84	35.56	0.31	0.18	0.05	0.01	0.30	0.85
Pinus roxburghii	1.51	0.36	0.001	0.09	0.45	2.41	0.15	0.04	0.001	0.01	0.04	0.24
Total	97.08	60.19	21.41	9.20	31.23	219.11	4.90	2.85	0.74	0.31	1.09	9.89

Table 8. Shrub layer carbon stock (t ha^{-1}) and carbon sequestration (t ha^{-1} yr^{-1}) of Van Panchayat at three forest sites

Sites/tree species	Carbon stock (t ha^{-1})				Carbon sequestration (t ha^{-1} yr^{-1})			
Hill top site	Stem	Foliage	Root	Total	Stem	Foliage	Root	Total
Asparagus racemosus	0.03	0.01	0.04	0.09	0.01	0.01	0.004	0.02
Berberis aristata	0.04	0.01	0.04	0.09	0.01	0.01	0.004	0.03
Daphne papyracea	0.05	0.02	0.05	0.12	0.02	0.01	0.01	0.04
Desmodium elegans	0.04	0.16	0.04	0.24	0.02	0.03	0.01	0.05
Deutzia campacta	0.05	0.02	0.05	0.12	0.04	0.04	0.03	0.10
Indigofera heterantha	0.03	0.01	0.04	0.08	0.01	0.02	0.003	0.03
Prinsepia utilis	0.04	0.02	0.04	0.09	0.02	0.01	0.02	0.05
Pyracantha crenulata	0.03	0.01	0.04	0.09	0.02	0.02	0.01	0.06
Reinwardtia indica	0.06	0.03	0.06	0.15	0.03	0.03	0.01	0.06
Rhamnus virgatus	0.03	0.01	0.03	0.07	0.004	0.01	0.001	0.01
Rhus parviflora	0.04	0.01	0.04	0.09	0.01	0.01	0.01	0.03
Rubus ellipticus	0.04	0.02	0.04	0.09	0.02	0.04	0.02	0.08
Rubus lensiocarpus	0.04	0.02	0.04	0.10	0.01	0.02	0.01	0.04
Viburnum coriaceum	0.00	0.02	0.05	0.10	0.01	0.01	0.002	0.02
TOTAL	0.54	0.37	0.60	1.51	0.21	0.26	0.13	0.60
Hill slope site								
Asparagus racemosus	0.04	0.02	0.04	0.09	0.01	0.01	0.02	0.04
Berberis aristata	0.03	0.01	0.04	0.08	0.04	0.04	0.02	0.09
Desmodium elegans	0.04	0.02	0.05	0.10	0.01	0.002	0.003	0.01
Indigofera heterantha	0.03	0.01	0.03	0.07	0.01	0.03	0.01	0.06
Prinsepia utilis	0.02	0.01	0.03	0.05	0.02	0.02	0.01	0.05
Pyracantha crenulata	0.04	0.02	0.05	0.10	0.004	0.01	0.003	0.01
Rhamnus virgata	0.04	0.01	0.04	0.09	0.02	0.02	0.01	0.05
Rubus ellipticus	0.04	0.01	0.04	0.09	0.01	0.01	0.01	0.02
Rubus lensiocarpus	0.03	0.01	0.03	0.07	0.04	0.01	0.02	0.07
TOTAL	0.29	0.11	0.34	0.74	0.16	0.14	0.10	0.40
Hill base site								
Asparagus racemosus	0.03	0.01	0.04	0.08	0.02	0.02	0.01	0.04
Berberis aristata	0.05	0.02	0.05	0.11	0.01	0.02	0.01	0.03
Daphne papyracea	0.04	0.02	0.04	0.09	0.02	0.02	0.01	0.04
Desmodium elegans	0.03	0.01	0.03	0.07	0.01	0.03	0.01	0.05
Deutzia campacta	0.03	0.01	0.03	0.07	0.01	0.01	0.01	0.03
Indigofera heterantha	0.04	0.02	0.04	0.10	0.01	0.01	0.01	0.03
Prinsepia utilis	0.03	0.01	0.04	0.08	0.02	0.02	0.01	0.04
Pyracantha crenulata	0.03	0.01	0.04	0.09	0.02	0.02	0.01	0.05
Reinwardtia indica	0.04	0.02	0.05	0.11	0.03	0.02	0.02	0.07
Rhamnus virgata	0.03	0.01	0.04	0.09	0.02	0.04	0.02	0.08
Rhus parviflora	0.04	0.01	0.04	0.10	0.05	0.06	0.04	0.15
Rubus ellipticus	0.03	0.01	0.03	0.07	0.02	0.02	0.01	0.05
Rubus lensiocarpus	0.03	0.01	0.04	0.08	0.01	0.01	0.01	0.02
Viburnum coriaceum	0.04	0.01	0.04	0.09	0.03	0.04	0.02	0.09
TOTAL	0.49	0.19	0.55	1.23	0.27	0.32	0.17	0.76

Table 9. Total carbon stock (t ha^{-1}) and carbon sequestration (t ha^{-1} yr^{-1}) in Letibunga Van Panchayat forests

Vegetation	Carbon Stock (t ha^{-1})				Carbon Sequestration (t ha^{-1} yr^{-1})			
	HT site	HS site	HB site	Mean	HT site	HS site	HB site	Mean
Tree layer	291.73	229.15	219.12	246.67 (99.2)	8.41	7.78	9.89	8.69 (85.7)
Shrub layer	1.53	0.74	1.22	1.16 (0.5)	0.64	0.42	0.82	0.63(6.2)
Herb layer	0.84	1.04	0.59	0.82 (0.3)	0.84	1.04	0.59	0.82(8.1)
Total vegetation	294.10	230.93	220.93	248.65(100)	9.89	9.24	11.30	10.14(100)

Note- HT= Hill top forest site, HS= Hill slope forest site and HB= Hill base forest site

CONCLUSION

It is evident from the results of van panchayat forest and comparison of findings with other forests of the region that the studied van panchayat forest was in good condition with respect to dry matter storage, productivity and carbon sequestration apart from fulfilling the basic needs of community people. Thus it is concluded that the van panchayat forests played the vital role not only to meet out the livelihood needs of the villagers but also mitigated the growing problems of climate change in the region.

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