International Journal of Bio-resource and Stress Management https://pphouse.org/ijbsm.php

Crossref

IJBSM July 2022, 13(7):734-742 Print ISSN 0976-3988 Online ISSN 0976-4038 Article AR3092

Research Article Natural Resource Management

DOI: HTTPS://DOI.ORG/10.23910/1.2022.3092

Estimation of Carbon and Biomass Energy Loss Along Shoghi-Shimla-Dhali Bypass in Mashobra Range, Himachal Pradesh

Shelly Banyal[1], Rajeev Kumar Aggarwal[1], Satish Kumar Bhardwaj[1] and Anju Sharma[2]

[1]Dept. of Environmental Science, [2]Dept. of Basic Science, Dr. Y. S. Parmar University of Horticulture & Forestry, Nauni, Solan, Himachal Pradesh (173 230), India

Open Access

Corresponding shellybanyal24@gmail.com

0000-0002-3149-6497

ABSTRACT

The present study was conducted during 2018–2019 to estimate biomass, carbon storage, CO_2 sequestration rate, CO_2 mitigation potential and biomass energy of dominant tree species like *Pinus roxburghaii*, *Quercus oblongata*, *Cedrus deodara*, *Pinus wallichiana* grown along the National Highway-22 (Shoghi–Shimla–Dhali) bypass, Himachal Pradesh, India. Present investigation was carried out by non-destructive method. About 13,967 trees were cut down during road expansion along National Highway-22. The trees <20 cm dbh dominated the structure of stand density in the study area. The diameter class IV (10–19 cm dbh) showed highest stand density among all the species occurred in study area. Among species, the proportion of *Pinus roxburghaii* was 64.73%, 74.22% for *Quercus oblongata*, 73.27% for broad leaves, 53.64% for *Cedrus deodara* and 51.86% for *Pinus wallichiana* under class (10-20 cm dbh). The maximum biomass of 2205.3 t ha^{-1} was observed for *Quercus oblongata*. Total carbon ranged from 139.26 t ha^{-1} to 1102.61 for diameter class 10–19 cm dbh to IE>100 cm dbh. The total carbon sequestered rate was found to be 10,306.57 t ha^{-1}. The total CO_2 mitigated potential was estimated to be 7498.24 t ha^{-1} with average biomass energy of 4319.88 t oil equivalent. The study revealed that *Quercus oblongata* was the major contributor to the total carbon loss and has highest proportion of 39.36% among all species.

KEYWORDS: Biomass, carbon, diameter, dominant, energy, expansions, mitigation, sequestration

***Citation* (VANCOUVER):** Banyal et al., Estimation of Carbon and Biomass Energy Loss Along Shoghi-Shimla-Dhali Bypass in Mashobra Range, Himachal Pradesh. *International Journal of Bio-resource and Stress Management,* 2022; 13(7), 734-742. HTTPS://DOI.ORG/10.23910/1.2022.3092.

Data Availability Statement: Legal restrictions are imposed on the public sharing of raw data. However, authors have full right to transfer or share the data in raw form upon request subject to either meeting the conditions of the original consents and the original research study. Further, access of data needs to meet whether the user complies with the ethical and legal obligations as data controllers to allow for secondary use of the data outside of the original study.

Funding: The research was conducted with the kind and support from institute.

Conflict of interests: The authors have declared that no conflict of interest exists.

RECEIVED on 13th May 2022 RECEIVED in revised form on 10th July 2022 ACCEPTED in final form on 21st July 2022 PUBLISHED on 31st July 2022

1. INTRODUCTION

Carbon is an essential element found in various natural stocks like oceans, fossil fuels deposits, and terrestrial ecosystem and in the atmosphere. In terrestrial ecosystem, carbon is stored in trees for a long time, through carbon sequestration phenomenon in terms of live biomass (Cairns et al., 2014). 80% of above ground carbon (AGC) and 40% below ground carbon (BGC) stored in forest ecosystem through global carbon cycle (Dixon et al., 1994). Approximately 60% of carbon sequestered by the forest is released into forest via deforestation (Vicharnakorn et al., 2014). Sustainable management of forest carbon stock acts as a significant component globally (Read and Laurence, 2003). Forests act as a huge source and sink of CO_2 to regulate regional and global carbon cycle (Schlesinger, 1997). The most omnipresent developmental activity is road network. Road expansion in forest ecosystem leads primary and secondary impacts. The primary impacts like local deforestation for road construction, GHGs emission and local change in abiotic and biotic components, affects carbon stock of an existing ecosystem significantly (Alamgir et al., 2017, Barber et al., 2014, Clements et al., 2014, Laurance et al., 2009). During photosynthesis, atmospheric CO_2 actively absorbed and stored in terms of biomass of growing trees subsequently termed as carbon stock (Baes et al., 1977). Carbon sequestration is a cost-effective phenomenon, as it scavenge CO_2 from atmosphere into another long live pool like biotic, geologic and padeogenic strata to reduce the rate of GHGs emission (Lal, 2008), ultimately reduction in global warming. The climate has been changed due to anthropogenic activities in close proximity to mountainous areas, ultimately disturb the carbon sequestration potential (Sahoo et al., 2021), further cause negative impacts (Kumar et al., 2021), biodiversity loss (Deb et al., 2021) and continuous change in biomass density (Ahirwal, 2021). To limit the global temperature increases to 1.5°C, various mitigation and alternative routes has been adopted to generate more carbon (Gupta and Kumar, 2020, Kumar and Gupta, 2020). Tree carbon sequestration is often known as win – win or no regrets strategy as it provides various unlimited benefits (Lal et al., 2003). Therefore, growing trees (especially high carbon sequester) in proper land use pattern can be a potential contributor in reducing the concentration of CO_2 in atmosphere by its accumulation in the form of biomass. The biomass estimation at plot level, especially in hilly areas is labour intensive so, it is practically impossible to cover large area of land for carbon estimation without bias (Sileshi, 2014). Forest is the largest reservoir of storage of carbon for long tenure (Pragasan, 2022). To combat the climate change, policy makers have been prompted to be more conscious during designing any mitigation strategy (Bhat et al., 2020, Sheikh et al., 2021). In mountainous areas, plantation (Kurmi et al., 2020), agroforestry (Tamang et al., 2021), home gardening (Singh and Sahoo, 2021) and secondary forest (Gogoi, 2020, Thong et al., 2020) are the major management plans. The reduction in forest cover ultimately decreased the carbon stock due to the involvement of human activities (Meragiaw et al., 2021). This paper emphasis on trees of 4 dominant species acts as a sink for carbon along the national highway (NH-22) and stored it in the form of biomass during growth process. The objective of this research is to estimate the gross carbon loss derived from carbon stock and also to measure the sequestration potential of different tree species. Present study has been carried out to know about the carbon biomass energy loss during national highway construction. Hence, by using information about the gross carbon loss due to deforestation and degradation occurred during road expansion, we can adopt certain management practices as to develop a carbon neutral and healthy environment to sustain life in a better way.

2. MATERIALS AND METHODS

2.1. Study area

A 51 m wide and 27 km long stretch of NH-22 (Shoghi–Shimla–Dhali) by pass come across the Mashobra division of district Shimla, located in the land of snowy mountains, Himachal Pradesh, India and is extended from latitude 31°05'10" to 32°10'50" in North to longitude 76°57'05" to70 °07'45" in East in the Western Himalayas.

The study area was divided into 7 sites (Figure 1) whose elevation, latitude and longitude was measured by Global positioning system (GPS).

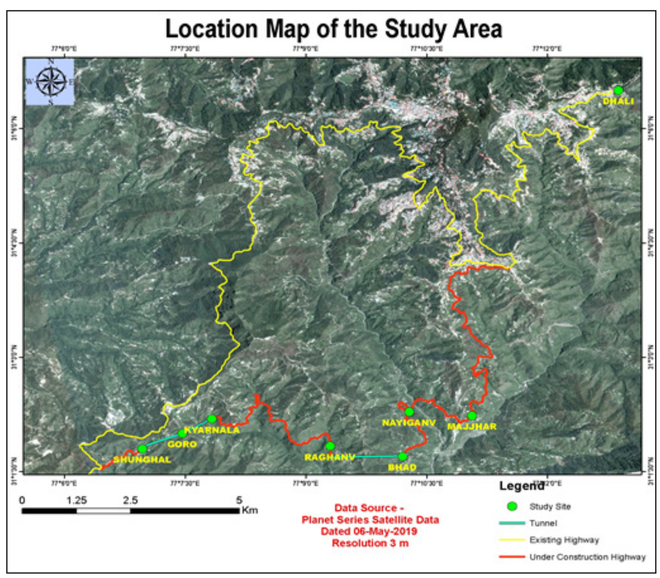

Figure 1: Location map showing different sites in the study area

2.2. Data collection

The study has been conducted in the year 2018–2019. During the national highway expansion, many trees were felled. To assess the total loss of tree biomass and carbon, secondary data were collected from HP State Forest Development Corporation Limited, Directorate Shimla. Accordingly, during the expansion and construction of NH-22 Shoghi to Dhali by pass, trees were enumerated and tabulated into standard diameter classes (Table 1).

Table 1: Distribution of trees in different classes

Diameter class	Diameter range(cm)	Diameter class	Diameter range(cm)
V	D1 (10–19)	IA	D6 (60–69)
IV	D2 (20–29)	IB	D7 (70–79)
III	D3 (30–39)	IC	D8 (80–89)
IIA	D4 (40–49)	ID	D9 (90–100)
IIB	D5 (50–59)	IE	D10 (>100)

The parameters were estimated during study as given in (Table 2). The Biomass expansion factor, specific gravity and R: S ratio of different forest trees species has been obtained from literature (Rajput et al., 1985, Rana and Singh, 1990, Kumar, 1998, Raturi et al., 2002, Anonymous, 2003).

Table 2: Parameters estimated

Sl. No.	Parameters
1.	Biomass=Specific gravity of stemm wood standing volume
2.	Branch biomass=Biomass × BEF
3.	AGTB = Stem biomass +branch biomass
4.	BGTB=AGTB ×Root:Shoot Ratio
5.	TB=AGTB+BGTB
6.	Carbon stock=Biomass×0.5
7.	CO_2 sequestered=Biomass carbon stock ×3.67
8.	CO_2 mitigated=CO_2 sequestrated-Carbon stock
9.	Energy content Energy fixed was calculated as follow: 1 t ha^{-1} biomass=4000 cal g^{-1}=4.0×109 cal t^{-1} (Kimmins, 1997) 1 kcal=4.184 KJ (Krebs, 1994) 1 KJ=2.3×10^{-8} t oil equivalent (toe) (Jackson and Jackson, 1997)

3. RESULTS AND DISCUSSION

The scrutiny of data revealed that the total 13,967 tree species were felled during national highway expansion. The tree species felled were *Pinus roxburghaii, Quercus oblongata, Cedrus deodara, Pinus wallichiana* with respective number of 6183, 4671, 1318 and 295.1500 broad leaves trees species were also included. In addition to these, some other miscellaneous species including sapling, seedlings, and poles were also felled during expansion of national highway. Along the NH-22, *Pinus roxburghaii* showed the maximum tree density 6183 trees ha^{-1} and the proportion of trees was 44.27%, whereas minimum tree density estimated for *Pinus wallichiana* was 295 trees ha^{-1} and the proportion of trees was 10.74%.

The data further indicated that Trees <20 cm dbh dominated the structure of stand density in the study area. Among diameter classes, class IV (10–19 cm dbh) showed highest stand density among all the species occurred in study area. Among species, *Pinus roxburghaii* showed maximum density (4002 trees ha^{-1}) and the proportion of *Pinus roxburghaii* was 64.73%,74.22% for *Quercus oblongata*, 73.27% for broad leaves, 53.64% for *Cedrus deodara* and 51.86% for *Pinus wallichiana* under class (10–20 cm dbh) as shown in (Figure 2). These results indicated that the forest has typical diameter frequency distribution of natural tree species with decreasing stem in the higher diameter classes. The results were in line with the findings of Bailey and Dell (1973). It was found in present study that density was increased as the diameter class increased but after 30 cm diameter class, the density of trees started decreases with increase in diameter class gradually due to the competition of tree in the study area. The results are in line with the findings of Pala et al. (2012) in Himalayan forest of India who also reported that stem density decrease with increase stem diameter. Similar results have also been observed by Nizami (2012).

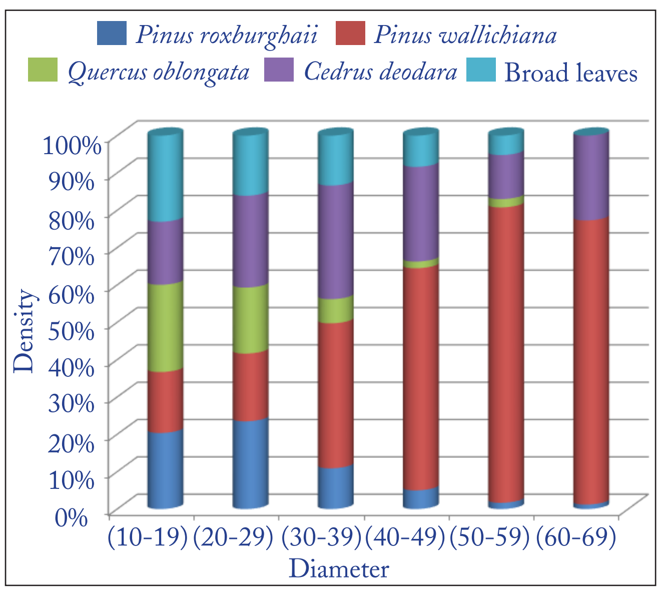

Figure 2: Density proportion among diameter classes for tree species

Overall, the maximum (593.52 m^3) volume was recorded under class IV (20–29 cm dbh) and minimum (2.92 m^3) volume was recorded for class IA having diameter 60–69 cm dbh for *Pinus roxburghaii*. The average maximum (1094.59 m^3) volume recorded for *Pinus roxburghaii* and minimum (292.67 m^3) for broad leaves. The increase in stem volume with increase in DBH is attributed natural and proportional growth of the tree. The results are in line with the findings of Negi (1997) who has reported that DBH increases with increase in diameter class by virtue of secondary or radial growth, which is responsible for increase in diameter of trees.

The maximum branch biomass (556.61 t ha^{-1}) was recorded for under diameter class IV (20–29 cm dbh) and minimum (2.74 t ha^{-1}) was recorded under class IC (60–69 cm dbh) for *Pinus roxburghaii*. The average maximum branch biomass (1041.35 t ha^{-1}) was recorded for *Quercus oblongata*, and minimum (102.65 t ha^{-1}) for *Pinus roxburghaii.* The branch biomass depends upon the average number of branches on the trees and also the branch biomass increased with an increasing in diameter class of trees. The results are in line with the findings of (Kumar et al., 2019) who reported that branch biomass depends upon the number of branches.

The maximum above ground biomass (848.02 t ha^{-1}) was recorded for *Pinus roxburghaii* under diameter class IV (20-29 cm dbh) and minimum (6.97 t ha^{-1}) was recorded for *Cedrus deodara* under class IC (80–89 cm dbh). The average maximum below ground biomass (618.76 t ha^{-1}) was recorded for *Quercus oblongata* and minimum (59.22 t ha^{-1}) for *Pinus wallichiana*.The result of present study showed that maximum average total above ground biomass (1586.56 t ha^{-1}) was observed for *Quercus oblongata* and diameter class of (IV 20–29 cm dbh) had proportion higher than other classes, which was 45.62% to the total, whereas *Pinus wallichiana* has minimum (219.31 t ha^{-1}) and diameter class of (IIA 40–49 cm dbh) had proportion higher than other classes, which was 21.32% (Table 3). It was found that higher above ground biomass recorded in higher diameter class but our values are higher as also studied by Rawat and Tanoon (1993) may be due to variation in climatic and edaphic factors from place to place even for the same species.

Table 3: Above ground biomass (t ha^{-1}) distribution in between diameter class

Class	Diameter	*Pinus roxburghaii*	*Quercus oblongata*	Broad leaves	*Cedrus deodara*	*Pinus wallichiana*
V	(10–19)	417.42	675.01	136.50	136.59	29.28
IV	(20–29)	848.02	723.80	106.44	223.13	38.38
III	(30–39)	215.37	143.17	46.61	142.66	44.37
IIA	(40–49)	-67.46	27.23	20.10	80.33	46.76
IIB	(50–59)	11.52	17.34	6.43	18.87	31.65
IA	(60–69)	4.17	-	-	18.07	15.19
IB	(70–79)	-	-	-	12.21	13.68
IC	(80–89)	-	-	-	6.97	-
ID	(90–100)	-	-	-	-	-
IE	(>100)	-	-	-	21.81	-
Total		1563.96	1586.56	316.08	660.63	219.31

The data further indicated that maximum below ground biomass (282.28 t ha^{-1}) were recorded for of diameter class IV (20-29 cm dbh) *Quercus oblongata* and minimum (1.74 t ha^{-1}) was recorded for broad leaves of class IIB (50–59 cm dbh). The average maximum below ground biomass (618.76 t ha^{-1}) was recorded for *Quercus oblongata,* and minimum (59.22 t ha^{-1}) for *Pinus wallichiana* (Table 4). Tree produces a larger root system that needed for the uptake of soil resources, thus resulting in higher values in higher diameter class as also studied by Hase and Foeister (1983). The results are in line with Shanmughavel and Ramarathinam, (1993) who reported that higher the diameter class, more will be below ground biomass.

It is evident from the data (Table 5) that maximum total ground biomass (1026.1 t ha^{-1}) and minimum (5.1 t ha^{-1}) biomass was recorded for *Pinus roxburghaii* of class IV (20–29 cm dbh), IA (60–69 cm dbh) respectively. The maximum average total ground biomass (2205.31 t ha^{-1}) was recorded for *Quercus oblongata*, and minimum (278.53 t ha^{-1}) for *Pinus wallichiana*. If we compare tree diameter classes with total ground biomass of all the species, it was found that tree species with low diameter class (10–19 cm) were more in density but accumulate less biomass whereas of range (20–29 cm) were lesser in number but accumulate more biomass. Thus, an inverse relation was seen between tree density and diameter class whereas direct relation was recorded in between diameter class and tree biomass, as similar studied carried out by Terakunpisut et al. (2007) in

Table 4: Below ground biomass (t ha^{-1}) distribution in between diameter class

Class	Diameter	*Pinus roxburghaii*	*Quercus oblongata*	Broad leaves	*Cedrus deodara*	*Pinus wallichiana*
V	(10–19)	87.66	263.25	36.85	36.88	7.90
IV	(20–29)	178.08	282.28	28.74	60.25	10.36
III	(30–39)	45.23	55.84	12.58	38.52	11.98
IIA	(40–49)	14.17	10.62	5.43	21.69	12.63
IIB	(50–59)	2.42	6.76	1.74	5.09	8.55
IA	(60–69)	0.88	-	-	4.88	4.10
IB	(70–79)	-	-	-	3.30	3.69
IC	(80–89)	-	-	-	1.88	-
ID	(90–100)	-	-	-	-	-
IE	(>100)	-	-	-	5.89	-
Total		328.43	618.76	85.34	178.37	59.22

Table 5: Total ground biomass (t ha^{-1}) distribution in between diameter class

Class	Diameter	*Pinus roxburghaii*	*Quercus oblongata*	Broad leaves	*Cedrus deodara*	*Pinus wallichiana*
V	(10–19)	505.1	938.27	173.35	173.46	37.18
IV	(20–29)	1026.1	1006.08	135.18	283.38	48.74
III	(30–39)	260.6	199.01	59.19	181.17	56.36
IIA	(40–49)	81.6	37.85	25.53	102.02	59.39
IIB	(50–59)	13.9	24.10	8.17	23.96	40.19
IA	(60–69)	5.1	-	-	22.94	19.30
IB	(70–79)	-	-	-	15.50	17.38
IC	(80–89)	-	-	-	8.86	-
ID	(90–100)	-	-	-	-	-
IE	(>100)	-	-	-	27.70	-
Total		1892.4	2205.31	401.43	839.00	278.53

different forest ecosystem of Thong Rha Phum National forest, Thailand.

The data further indicated that maximum carbon stock (513.05 C t ha^{-1}) of diameter class IV (20–29 cm dbh) and minimum (2.53 C t ha^{-1}) was recorded for *Pinus roxburghaii*. The average maximum carbon stock (1102.66 C t ha^{-1}) was recorded for *Quercus oblongata*, and minimum (139.26C t ha^{-1}) for *Pinus wallichiana* as shown in Table 6.

The data indicated that maximum carbon sequestration potential (1882.90 C t ha^{-1}) under diameter class IV (20–29 cm dbh) and minimum (9.97 C t ha^{-1}) under diameter class (IA 60–69 cm dbh) was recorded for *Pinus roxburghaii*. The average maximum carbon sequestration (4046.75 C t ha^{-1}) was recorded for *Quercus oblongata* and minimum (347.25C t ha^{-1}) for *Pinus roxburghaii* (Table 7). Tree density decreases with decrease in carbon storage capacity and carbon sequestration capacity. Since trees during their initial stages of growth i.e., when their DBH is lower will thus sequester less carbon but gradually as it increase in DBH would accumulate more carbon. Moreover, it has been observed younger trees grow much faster than older trees as also studied by Chisanga et al. (2018). This study was in conformity with the findings of Huston and Marland (2003), who showed that carbon sequestration depends not only on rates of productivity, but also on the size of tree. Total carbon storage and sequestration within tree species generally increases with increase girth at breast height as also studied by Mishra et al. (2012) for the estimation of standing carbon stock in different tree species grown in dry tropical forest of Vindhyan highland, Mirzapur India.

The data further indicated that maximum carbon mitigation potential (1369.85 t ha^{-1}) under diameter class IV (20–29 cm dbh) and minimum (6.74 t ha^{-1}) under diameter class (IA 60–69 cm dbh) was recorded for *Pinus roxburghaii*. Among all species, maximum carbon mitigation potential (3238.5) was shown by *Quercus oblongata*, and minimum

Table 6: Carbon stock (C t ha^{-1}) distribution in between diameter class

Class	Diameter	*Pinus roxburghaii*	*Quercus oblongata*	Broad leaves	*Cedrus deodara*	*Pinus wallichiana*
V	(10–19)	252.54	469.13	86.67	86.73	18.59
IV	(20–29)	513.05	503.04	67.59	141.69	24.37
III	(30–39)	130.30	99.51	29.60	90.59	28.18
IIA	(40–49)	40.81	18.93	12.77	51.01	29.69
IIB	(50–59)	6.97	12.05	4.08	11.98	20.10
IA	(60–69)	2.53	-	-	11.47	9.65
IB	(70–79)	-	-	-	7.75	8.69
IC	(80–89)	-	-	-	4.43	-
ID	(90–100)	-	-	-	-	-
IE	(>100)	-	-	-	13.85	-
Total		946.19	1102.66	200.71	419.50	139.26

Table 7: Carbon dioxide sequestration potential (C t ha^{-1}) in between diameter class

Class	Diameter	*Pinus roxburghaii*	*Quercus oblongata*	Broad leaves	*Cedrus deodara*	*Pinus wallichiana*
V	(10–19)	926.82	1721.72	391.36	1573.08	68.23
IV	(20–29)	1882.90	1846.17	305.20	1686.78	89.44
III	(30–39)	478.19	365.19	133.63	333.66	103.41
IIA	(40–49)	149.78	69.46	57.64	63.47	108.97
IIB	(50–59)	25.57	44.22	18.44	40.40	73.75
IA	(60–69)	9.27	0.00	0.00	0.00	35.41
IB	(70–79)	0.00	0.00	0.00	0.00	31.89
IC	(80–89)	0.00	0.00	0.00	0.00	0.00
ID	(90–100)	0.00	0.00	0.00	0.00	0.00
IE	(>100)	0.00	0.00	0.00	0.00	0.00
Total		347.25	4046.75	906.27	3697.39	511.10

Table 8: CO_2 mitigation potential (t ha^{-1}) in between diameter class

Class	Diameter	*Pinus roxburghaii*	*Quercus oblongata*	Broad leaves	*Cedrus deodara*	*Pinus wallichiana*
V	(10–19)	674.28	1252.59	284.72	1144.45	49.64
IV	(20–29)	1369.85	1343.12	222.04	1227.17	65.07
III	(30–39)	347.89	265.68	97.22	242.74	75.24
IIA	(40–49)	108.97	50.54	41.94	46.17	79.28
IIB	(50–59)	18.60	32.17	13.42	29.39	53.66
IA	(60–69)	6.74	0.00	0.00	0.00	25.76
IB	(70–79)	0.00	0.00	0.00	0.00	23.20
IC	(80–89)	0.00	0.00	0.00	0.00	0.00
ID	(90–100)	0.00	0.00	0.00	0.00	0.00
IE	(>100)	0.00	0.00	0.00	0.00	0.00
Total		2779.0	3238.5	725.3	2958.9	409.0

(725.3) for broad leaves (Table 8). The data reveals that CO_2 mitigation potential showed an increasing trend with increase in diameter class. As CO_2 mitigation by trees was directly related to biomass production of different tree component. The results are in line with the findings of (Lal and Singh, 2000, Abrecht and Kandji, 2003) who also reported that CO_2 mitigation potential is more in higher diameter class as compared to lower diameter class. Similar results have also been observed by Yadava (2010).

The total carbon was computed to be 2808.33 C t ha^{-1} and the total CO_2 sequestered by the above trees was 10,306.57 t and this sequestered CO_2 mitigated about 7498.24 t of CO_2. The % proportion of *Pinus roxburghaii*, *Quercus oblongata*, Broad leaves, *Cedrus deodara* and *Pinus wallichiana* were 33.69%, 39.36%, 7.15%, 14.94%, 4.96%, respectively. Therefore, during expansion of national highway, total 2808.33 t ha^{-1} carbon losses was recorded due to deforestation of these tree species (Table 9).

Table 9: Estimation of Total Carbon (C t ha^{-1}) loss due to felling of trees in the study area

Tree species	Number of trees	Vol (m^3)	AGB (t ha^{-1})	BGB (t ha^{-1})	TGB (t ha^{-1})	Total carbon (t ha^{-1})	Carbon (%)	CO_2 Sequestered (t ha^{-1})
Pinus roxburghaii	6183	1094.59	1563.96	328.43	1892.39	946.19	33.69	3472.53
Quercus oblongata	4671	660.059	1586.56	618.76	2205.31	1102.66	39.26	4046.75
Broad leaves	1500	292.67	316.08	85.34	401.43	200.71	7.15	736.62
Cedrus deodara	1318	588.168	660.63	178.37	839.00	419.50	14.94	1539.57
Pinus wallichiana	295	176.501	219.31	59.22	278.53	139.26	4.96	511.10
Total	13,967	2811.988	4346.54	1270.12	5616.66	2808.33	100	10,306.57

Total carbon stock: 2808.33 t ha^{-1}; CO_2 sequestered: Total carbon *3.67=10,306.57 (t ha^{-1}); CO_2 mitigated: CO_2 sequestered-total carbon stock = 7498.24 (t ha^{-1})

The biomass energy content of dominant tree species grown along NH-22 indicated that the *Quercus oblongata* have more biomass energy of 1696.15 t oil equivalent (toe) whereas *Pinus wallichiana* have lowest energy content of 214.92 toe as shown in (Table 10). The lowest and highest energy content depends upon biomass content of tree species. The average biomass energy of 4319.88 toe was diminished during expansion of national highway as similar study was carried by Jackson and Jackson (1997).

Table 10: Biomass energy content in the study area

Category	*Pinus roxburghaii*		*Quercus oblongata*		*Cedrus deodara*		Broad leaves		*Pinus wallichiana*		Mean
	Biomass (t ha^{-1})	Energy (Toe)	Biomass (t ha^{-1})	Energy (Toe)	Biomass (t ha^{-1})	Energy (Toe)	Biomass (t ha^{-1})	Energy (Toe)	Biomass (t ha^{-1})	Energy (Toe)	
AGB	1563.96	2405.74	1586.56	2440.51	660.63	1016.21	316.08	486.21	219.31	337.36	6686.03
BGB	328.43	505.21	618.76	951.80	178.37	274.38	85.34	131.28	59.22	91.09	1953.74
Total	946.19	1455.47	1102.66	1696.15	419.50	645.29	200.71	308.74	139.26	214.22	4319.88

4. CONCLUSION

The study quantified the current estimate of carbon stock and CO_2 sequestration rate among all the dominant tree species grown along the road. The total carbon loss was found to be 2808.33 t ha^{-1} and 10, 306.57 t ha^{-1} CO_2 would have sequestered by the dominant tree species. According to vegetation parameter, *Quercus oblongata* was found to be dominant and ecological significant tree species. The highest biomass energy was found to be 1696.15 toe in *Quercus oblongata*.

5. REFERENCES

Abrecht, A., Kandji, S.T., 2003. Carbon sequestration in tropical agroforestry systems. Agriculture Ecosystem and Environment 99(1–3), 15–27.

Ahirwal, J., Nath, A., Brahma, B., Deb, S., Sahoo, U.K., Nath, A.J., 2021. Patterns and driving factors of biomass carbon and soil organic carbon stock in the Indian Himalayan region. Science of the Total Environment 770, 145292. DOI 10.1016/j.scitotenv.2021.145292.

Alamgir, M., Campbell, M.J., Sloan, S., Goosem, M., Clements, G.R., Mahmoud, M.I., 2017. Economic, socio-political and environmental risks of road development in the tropics. Current Biology 27(20), R1130–R1140.

Anonymous, 2003. Good practice guidance for land use, land-use change and forestry. IPCC. National Greenhouse Gas Inventories Programme, Haryana, 295.

Baes, C.F., Goeller, H.E., Olson, J.S., Rotty, R.M., 1977. Carbon dioxide and climate: The uncontrolled experiment. American Scientists 65, 310–320.

Bailey, R.L., Dell, T.R., 1973. Quantifying diameter distribution with the Weibull function. Forest Science 19, 97–103.

Barber, C.P., Cochrane, M.A., Souza, C.M.R., Laurance, W.F., 2014. Roads, deforestation and the mitigating effect of protected areas in the Amazon. Biological Conservation 177, 203–209.

Bhat, J.A., Kumar, M., Negi, A.K., Todaria, N.P., Malik, Z.A., Pala, N.A., 2020. Species diversity of woody vegetation along altitudinal gradient of the Western Himalayas. Global Ecology and Conservation 24, e01302. DOI 10.1016/ j.gecco.2020.e01302.

Cairns, M.A., Olmsted, I., Granados, J, Argaes, J., 2003. Composition and aboveground tree biomass of a dry semi evergreen forest in Mexico's Yucatan peninsula. Forest Ecology and Management 186(1–3), 125–132.

Chisanga, K., Bhardwaj, D.R., Pala, N.A., Thakur, C.L., 2018. Biomass production and carbon stock inventory of high-altitude dry temperate land uses systems in North Western Himalaya. Ecological Processes 7, 22.

Clements, G.R., Lynam, A.J., Gaveau, D., Yap, W.L., Lhota, S., Goosem, M., Lurence, F., Laurence, W.F., 2014. Where and how are roads endangering mammals in Southeast Asia's forests. PLoS One 9(12), 1153–1176.

Deb, D., Jamatia, M., Debbarma, J., Ahirwal, J., Deb, S., Sahoo, U.K., 2021. Evaluating the role of community-managed forest in carbon sequestration and climate change mitigation of Tripura, India. Water Air Soil Pollution 232(5), 166. DOI 10.1007/s11270-021-05133-z.

Dixon, R.K., Brown, S., Houghton, R.A., Solomon, A.M., Trexler, M.C., Wisniewski, J., 1994. Carbon pools and fluxes of global forests. Science 263(5144), 185–190.

Gogoi, A., Sahoo, U.K., Saikia, H., 2020. Vegetation and ecosystem carbon recovery following shifting cultivation in Mizoram-Manipur-Kachin rainforest eco-region, Southern Asia. Ecological Processes 9, 21. DOI 10.1186/ s13717-020-00225-w.

Gupta, H., Kumar, R., 2020. Distribution of selected polycyclic aromatic hydrocarbons in urban soils of Delhi, India. Environmental Technology and Innovation 17, 100500. DOI 10.1016/j.eti.2019.100500.

Hase, H., Foeister, H., 1983. Impact of plantation forestry with teak (*Tectona grandis*) on the nutrient status of young alluvial soil of west Venezuela. Forest Ecology and Management 6(1), 33–57.

Huston, M.A., Marland, G., 2003. Carbon management and biodiversity. Journal of Environmental Management 67(1), 77–86.

Jackson, A.R.W., Jackson, J.M., 1997. Environmental science: the natural environment and human impact. Longman, Singapore, 361.

Kimmins, J.P., 1997. Forest ecology: a foundation for sustainable management (2nd Edn.). Macmillan Publishing Company, New York, 596.

Krebs, C.J., 1994. Ecology: The experimental analysis of distribution and abundance (4th Edn.). Harper Collins, New York, 801.

Kumar, A., Gupta, H., 2020. Activated carbon from sawdust for naphthalene removal from contaminated water. Environmental Technology and Innovation 20, 101080. DOI 10.1016/j.eti.2020.101080.

Kumar, A., Pinto, M.C., Candeias, C., Dinis, P.A., 2021. Baseline maps of potentially toxic elements in the soils of Garhwal Himalayas, India: Assessment of their eco-environmental and human health risks. Land Degradation and Development 32(14), 3856–3869. DOI 10.1002/ldr.3984.

Kumar, M., Kumar, R., Konsam, B., Sheikh M.A., Pandey, R., 2019. Above and below ground biomass production in *Pinus Roxburghii* forests along altitudes in Gharwal Himalaya, India. Current Science 116(9), 1506–1514.

Kurmi, B., Nath, A.J., Lal, R., Das, A.K., 2020. Water stable aggregates and the associated active and recalcitrant carbon in soil under rubber plantation. Science of the Total Environment 703, 135498. DOI 10.1016/j.scitotenv.2019.135498.

Lal, M., Singh, R., 2000. Carbon sequestration potential of Indian forests. Environmental Monitoring and Assessment 60, 315–327.

Lal, R., 2008. Carbon sequestration. Philosophical Transactions of the Royal Society B: Biological Sciences 363(1492), 815–830.

Lal, R., Follett, R.F., Kimble, J.M., 2003. Achieving soil carbon sequestration in the United States: A challenge to the policy makers. Soil Science 168(12), 827–845.

Laurance, W.F., Goosem, M., Laurance, S.G.W., 2009. Impacts of roads and linear clearings on tropical forests. Trends in Ecology and Evolution 24(12), 659–669.

Meragiaw, M., Woldu, Z., Martinsen, V., Singh, B.R.., 2021. Carbon stocks of above and below ground tree biomass in Kibate forest around Wonchi Crater Lake, Central Highland of Ethiopia. PLoS One 16(7), eo254231. DOI https://doi.org/10.1371/Journal. pone 0254231.

Mishra, A.K., Singh, J., Kumar, V., Srivastava, R., Srivastava, S., 2012. Standing carbon stock estimation in different tree species grown in dry tropical forest of Vindhyan highland, Mirzapur, India. Ecology, Environment and Conservation 19(2), 401–407.

Negi, S.S., 1997. Wood science and technology. International Book Distributors, Dehradun, India, 31.

Nizami, S.M., 2012. The inventory of the carbon stocks in subtropical forest of Pakistan for reporting order Kyto protocol. Journal of Forestry Research 23(3), 377–384.

Pala, N.A., Negi, A.K., Gokhale, Y., Aziem, S., Vikrant, K.K., Todaria, N.P., 2012. Carbon stock estimation for tree species of Sem Mukhem sacred forest in Gharwal Himalayas, India. Journal of Forestry Research 24(3), 457–460.

Pragasan, L.A., 2022. Tree carbon stock and its relationship to key factors from a tropical hill forest of Tamil Nadu, India. Geology, Ecology and Landscapes 6(1), 32–39. DOI https://doi.org/10.1080/24749508.2020.1742510.

Rajput, S.S., Shukla, N.K., Gupta, V.K., 1985. Specific gravity of Indian timbers. Journal of Timber Development Association of India 31, 12–41.

Rana, B.S., Singh, R.P., 1990. Plant biomass and productivity estimates for Central Himalayan mixed Banj oak (*Quercus leucotrichophora* A. Camus)-Chirpine (*Pinus roxburghii* Sarg.) forest. The Indian Forester 116(3), 220–226.

Raturi, R.D., Chauhan, L., Guptas, V.R.R., 2002. Indian woods, their identification, properties and uses. ICFRE Publication, Dehradun, India, 99.

Rawat, J.K., Tanoon, V.N., 1993. Biomass production and mineral cycling in young chir pine plantation in Himachal Pradesh. The Indian Forester 119(12), 977–985.

Read, L., Laurence, D., 2003. Recovery of biomass following shifting cultivation in dry tropical forests of the Yucatan. Ecological Applications 13(1), 85–97.

Sahoo, U.K., Tripathi, O.P., Nath, A.J., Deb, S., Das, D.J., Gupta, A., Devi, N.B., Charturvedi, S.S., Singh, S.L., Kumar, A., Tiwari, B.K., 2021. Quantifying tree diversity, carbon stocks and sequestration potential for diverse land uses in Northeast India. Frontiers in Environmental Sciences 9, 724–950.

Schlesinger, W.H., 1997. Biogeochemistry: An Analysis of Global Change (2nd Edn.). Academic Press, New York, 588.

Shanmughavel, P., Ramarathinam, D.R., 1993. Biomass and primary productivity of Tephrosia in semi-arid vegetation at Perungudi, district Madurai. The Indian Forester 119(4), 326–333.

Sileshi, G.W., 2014. A critical review of forest biomass estimation models, common mistakes and corrective measures. Forest Ecology and Management 329(1), 237–254.

Singh, S.L., Sahoo, U.K., 2021. Tree species composition, diversity and soil organic carbon stock in home-gardens and shifting cultivation fallows of Mizoram, Northeast India. Vegetos 34, 220–228. DOI 10.1007/s42535-021-00194-1.

Tamang, M., Chettri, R., Vineeta, S.G., Shukla, J.A., Kumar, A., Kumar, M., Bhatt, J.A., Suryawanshi, A., Pinto, M.M.S.C., Chakravarty, S., 2021. Stand structure, biomass and carbon storage in *Gmelina Arborea* plantation at agricultural landscape in foothills of Eastern Himalayas. Land 10(4), 387. DOI 10.3390/land10040387.

Terakunpisut, J., Gajaseni, N., Ruankawe, N., 2007. Carbon sequestration potential in aboveground biomass of Thong PhaPhum National Forest, Thailand. Applied Ecology and Environmental Research 5(2), 255–262.

Thong, P., Sahoo, U.K., Thangjam, U., Pebam, R., 2020. Pattern of forest recovery and carbon stock following shifting cultivation in Manipur, Northeast India. PLoS One 15(10), e0239906. DOI 10.1371/journal.pone.023990.

Vicharnakorn, P., Shrestha, R.P., Nagai, M., Salam, A.P., Kiratiprayoon, S., 2014. Carbon stock assessment using remote sensing and forest inventory data in Savannakhet, Lao PDR. Remote Sensing 6(6), 5452–5479.

Yadava, A.K., 2010. Carbon sequestration underexploited environmental benefits of Tarai agroforestry systems. Indian Journal of Soil Conservation 38(2), 125–131.