Quantification of Carbon Stocks in Pure Forests of *Pinus Roxburghii* Sarg. And *Quercus Leucotrichophora* A. Camus In Two Community Forests of Kumaun Central Himalaya

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Short Title: Quantification of carbon stocks in Community forests of Kumaun Himalaya

Abstract:
A major worldwide issue, climate change affects both natural ecosystems and socioeconomic systems. Because they sequester carbon, forests are essential for reducing the effects of climate change. This study evaluates the overall carbon stock in the Almora district of Uttarakhand, India which is home to two major forest types: Chir Pine and Banj Oak. According to the study, the carbon store of non-degraded areas is higher than that of degraded forests. The range of the average carbon stock levels was 219.86–490.33 Mg ha^{-1}. The findings also indicate that, in comparison to degraded locations, the carbon stock in forest biomass is substantially higher in non-degraded sites. The study emphasizes how crucial it is to preserve forests and use sustainable management techniques in order to improve carbon sequestration and slow down climate change. The study's conclusions aid in the creation of practical plans for lowering atmospheric carbon levels and encouraging sustainable forest management techniques. Findings are in line with other research that demonstrated the importance of forests as carbon sinks. Particularly with regard to reducing the consequences of climate change, the current findings have important implications for conservation and forest management plans. Furthermore,

the present study provides valuable insights into the carbon sequestration capability of Indian Himalayan forests and highlights the need for sustainable forest management practices to mitigate climate change.

Keywords:
Degraded and non-degraded sites, Van panchayat, Carbon stock, Carbon trading, Sequestration.

Introduction:
Reducing atmospheric carbon concentrations can be achieved in part through forest carbon sequestration. Significant amounts of atmospheric carbon can be captured and stored in this economical, safe, and environmentally friendly manner. The creation of tradable carbon credits at the same time offers financial incentives for taking carbon storage into account when making decisions about forest management. One of the most significant worldwide environmental concerns is climate change, which is expected to have an effect on both socioeconomic systems and natural ecosystems (1). Over the past century, the global climate has warmed by 0.7°C, and this century is expected to see a further 1.8–4.0°C increase [2]. Because of their capacity to absorb and retain carbon dioxide from the atmosphere, forests are valued under the Kyoto Protocol for their special function as carbon sinks [3]. Every time a forest grows two cubic meters of wood, about one ton of carbon dioxide from the air is collected, according to FAO [3]. By increasing above-ground biomass through increased forest cover and soil organic carbon content, forests serve as carbon sinks. "Mass of all organic matter per unit area at a specific time" (given in g/m2 or kg/ha) is the definition of biomass. All biomass of live plants, both woody and herbaceous, above the earth, including stems, branches, bark, foliage, and stumps, is referred to as above-ground biomass (AGB) in the IPCC Guidelines for National Gas Inventories (2006). As the largest terrestrial carbon sink, forest biomass makes up around 90% of all terrestrial biomass that is alive. A forest's biomass accumulation can be used to assess how much carbon it has sequestered (or lost), as carbon makes up around half of the dry biomass weight of a forest (3,4). Using fresh weight or dry weight, forest biomass can be quantified. The goal of this study is to assess the total amount of carbon stored in two VPs forests. Banj-Oak and Chir-Pine made up 12.29% and 16.36% of Uttarakhand's total land area, respectively.

Methods:
In Uttarakhand's Almora districts, the Van Panchayats of Dhaili and Toli are home to the two forest locations that were chosen. Between 29°45' and 30°15' latitude and 78°24' and 79°23' E longitude, the Almora district occupies a geographical area of 5440 square kilometers. Van Panchayats Toli and Dhaili are located between longitudes 30°08'10.52"-'30°07'05.4"N and latitudes -78°52'30.15"-78°45'29.02"E. These Van Panchayats range in elevation from 1750 m to 1825 m. Although the study region is situated in a temperate climate, it is latitudinally part of the subtropical belt. As shown in Figure 1, the minimum temperature ranged from 1.3°C to 2.5°C, while the highest temperature ranged from 25°C to 30°C [5].
Sorting degraded and non-degraded sites into different categories For this investigation, a single parameter (crown density) was employed. With the aid of degraded and non-degraded categories, crown density (crown cover) was assessed using a spherical densitometer in both sites; sites with less than 40% crown cover were classified as degraded, and those with 60% crown cover as non-degraded [6].

Sampling design
Two types of forests—the Chir pine and the Banj oak-dominated Van Panchayat forest—were chosen for the current study in order to estimate the biomass and carbon stock. Data was gathered using the transect sampling approach. A transect was created that was 500 meters long and 100 meters wide in each kind of forest. Each transect was 0.1 hectare (50 x 20 m) in size, with five sample plots created in Oak Forest Dhaili Van Panchayat and six sample plots created in Pine Forest Toli Van Panchayat. Ten quadrates (10 × 10 m) were created as a practical unit inside each sample plot. Five sample plots in Oak Forest Dhaili Van Panchayat and six sample plots in Pine Forest Toli Van Panchayat were sampled in total.

Sample Plot measurement

Measurements were taken of each tree's height and diameter at breast height (DBH) within the sample plot. The height was measured with a relay scope, and the CBH was measured with a meter tape at 1.37 meters above ground level. At 10-cm intervals, the enumerated diameter classes were split into five classes. The Shannon–Wiener diversity index [7] was used to calculate tree diversity, with the formula ¯H=−pi ln (pi), where ¯H is the Shannon–Wiener diversity index, pi is the percentage of individuals in species I, and ln is the natural log (i.e., base 2.718). Based on the publications of the Forest Research Institute (FRI) and Forest Survey of India (FSI) for the corresponding species, volume tables or volume equations were used to estimate the growing stock density [8–11]. FRI and FSI previously constructed these volume equations using multiple regression techniques, taking into account height or form factor in addition to basal area, girth, or dbh. Following that, the projected GSVD (m^3 ha-1) was multiplied by the appropriate Biomass Expansion Factor (BEF) to get the Above Ground Biomass Density (AGBD) of the forest's constituent tree parts (stem, branches, twigs, and leaves) [12]. When the diameter at breast height (DBH) of all living trees is ≥ 2.54 cm, the BEF (Mg m^{-3}) is the ratio of the above ground biomass density of all trees at DBH > 12.7 cm to the GSVD. The BEFs for pine and hardwood were determined using the following formulas:
Hardwood: BEF=exp {1.91−0.34×ln (GSVD)} (for GSVD ≤ 200 $m^3 ha^{-1}$).
BEF=1.0 (for GSVD>200 m^3 ha^{-1}).
Pine: BEF=1.68 Mg m^3 (for GSVD<10 m^3 ha^{-1}). BEF=0.95 (for GSVD=10- 100 m^3 ha^{-1}).
BEF=0.81 (for GSVD>100 m^3 ha^{-1}).
According to Cairns et al.'s regression equation [4], the below-ground biomass density, or BGBD (fine and coarse roots), was calculated for every species of forest as follows:
BGBD is equal to exp {−1.059 + 0.884×ln (AGBD) + 0.284}
The Total Biomass Density (TBD) was then calculated by adding AGBD and BGBD.
To calculate the Total Carbon Density (TCD), the following formula was used:
Carbon (C Mg ha^{-1})=Biomass (Mg ha^{-1})×Carbon%, where C=0.5[13]

Results and Discussion:

With varied degrees of disturbance, the current study aims to quantify the total carbon stock in two major forest types—Chir Pine and Banj Oak—that make approximately 7.30 and 10 hectares of land area, respectively, in two Van Panchayat forests in the Lamgara block of the Almora district of Uttarakhand. Carbon stock forest biomass ranged from 219.86 to 490.33 Mg ha^{-1} in the current investigation's non-degraded site, while carbon stock ranged from 193.36 to 294.38 Mg haa^{-1} in the degraded site. In the Indian Himalayan forests, the average carbon across all the forests evaluated (degraded and non-degraded) is in agreement with the current findings on oak and pine forests, which are consistent with the findings of Rana et al. [14], Malhi et al. (15]. The tree haa^{-1} densities in degraded and non-degraded oak forest areas were 650.0 and 750.0, respectively. The tree ha^{-1} in the pine forest is 346.66 and 406.66. The current analysis demonstrates that the highest tree density is found in non-degraded locations. Ross proposed that a larger number of young trees would have the highest carbon stock. Our findings demonstrated that, in comparison to degraded sites, non-degraded locations have the highest tree densities (Figure 2). For both degraded and non-degraded oak forest locations, the crown density was 29.17 and 70.33%, respectively. However, Jina et al. [6] found that in pine forests, 32.38 and 84.98% of the trees had lopped branches, which was 50% of the degraded areas, and less lopped branches were considered non-degraded. It shows that both degraded and non-degraded forest types have been documented in the oak and pine forests in the current study. Thus, in both types of forests, non-degraded areas had higher crown densities than degraded sites (Figure 2). In degraded and non-degraded oak forest locations, the average growing stock volume density was 186.3 and 439.7 m^3ha^{-1}, respectively. In contrast, degraded and non-degraded sites in the pine forest were found to be 276.1 and 531.5 m^3ha^{-1}, respectively. Twenty different forest types in the Garhwal Himalaya had their GSVD values compared to the current GSVD value [9]. The growth stage of each person determines the growing stock. Compared to the youthful stage, the mature stage has the largest growing stock. Thus, in oak and pine forests, both degraded and non-degraded locations have a rising supply (Figure 2). In the current study, the average AGBD values for degraded and non-degraded Oak forest sites were 304.8 and 350.89 Mg ha-1, respectively, whereas the average values for Pine forest sites were 463.86 and 790.47 Mg ha-1. These values are greater than those previously reported from 20 different forest types in the Garhwal Himalaya [16,17]. Due to the fact that both of the forest types in this study were completely stocked, mature old growth forests, their carbon stocks were higher than those of the adjoining Kumaun forest in the central Himalaya, indicating that they had more carbon stored in them (Figure 2). The total below-ground biomass density in deteriorated and non-degraded oak forest sites was 86.93 and 88.76 (Mg ha-1). Figure 2 shows that the pine forest is between 118.92 and 190.41 (Mg ha-1). The current study compares the total biomass density values with the sum of previous estimations of Indian forest biomass values. In sites that were not deteriorated, values for total biomass density were greater. These figures are greater than the total biomass reported from Kumaun Himalayas' twenty forest types [11] (Figure 2). The carbon store in forest biomass at the oak and pine forest sites of the current study was 219.86 and 490.33 Mg ha-1. in both damaged and undegraded forest sites (Figure 2). Rana et al. [14] and Malhi et al. [15] note that in the Indian Himalayan forest, the current findings on both forests are consistent with the findings of Bohra et al. [18] in Kumaon Central Himalaya, with reported values ranging between 18.37 and 296.09 Mt ha-1. 148 tons of carbon per hectare on average. where the average carbon store is 148 tons per hectare. the average carbon in both the degraded and non-degraded forest studies. Furthermore, Banj Oak and Chir Pine forests have considerably higher values. It was discovered that non-degraded sites have a higher carbon stock than degraded forests. Given the large percentage of carbon stock, the current study area is classified as a protected area. According to a study comparing degraded and non-degraded sites in the Kumaun Himalayan forest [6], non-degraded areas had higher carbon levels because they were better protected than degraded sites. This result was somewhat comparable to the current study.

Conclusions:

The current study revealed that, in contrast to oak forests, pine forests had a higher carbon stock. The highest c stored by the three categories is conifers > deciduous > evergreen > bamboos, according to Negi et al. [19]. Compared to broad-leafed forests, it was determined that the majority of conifer-dominated forests have a higher carrying capacity for c stock [11]. due to a lack of ground vegetation in Toli Van Panchayat's pine forest. For their fundamental needs (fuel, fodder, timber, etc.), the villagers had little reliance and no grazing; but, because of the close proximity to the forest, the people in the Oak forest of Dhaili Van Panchayat had a high level of dependency. For beding materialists, villagers gather fuel, fodder, and garbage, which disturbs the forest. As a result, human disturbance has an impact on the forest's carbon supply. Ross came to the conclusion that actions related to forestry and land use modify the amount and rates of carbon storage [20,21]. Some of the increase in forest carbon sequestration is due to leakage, which happens when output shifts.

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Figure 01. Map showing the geographical location of Almora district of Uttarakhand.