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Biomass and carbon stock potential of forests around Sattal lake of Nainital district, Kumaun Himalaya

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Abstract
The forest biomass is now becoming the key parameter in dealing with current climate change issues as it able to mitigate the effect of global warming. The sampling plots were laid down in the forest around Sattal Lake (Nainital). Within each sampling plot tree CBH (Circumference at breast height) was measured and the species number was counted. However, for the estimation of shrub and herb biomass, proportional harvest method was used. The present study was carried with the aim to estimate biomass and carbon storage capacity of Sattal forest, Kumaun Himalaya and their role mitigating the effect of global warming. The study area was categorized into three stands as highly disturbed, moderately disturbed and undisturbed on the basis of regeneration status and anthropogenic pressure on forest resources. The forest biomass ranged from 328 t ha^{-1} to 431 t ha^{-1} across three forest stands around Sattal Lake. It was also observed that undisturbed stand had a good capacity to store carbon as compared to highly disturbed and moderately disturbed forest stand. The anthropogenic pressure in terms of lopping, grazing and wood cutting should be controlled by imparting knowledge about scientific and sustainable harvesting of forest resources. The anthropogenic pressure on forest resources could also be reduced by imparting climate change education to the local inhabitants.

Keywords: Forest biomass, climate change, Sattal Lake, carbon stock, Kumaun Himalaya

1. Introduction
According to IPCC [1], the Earth's average temperature has increased by 0.85 °C over the period 1880 to 2012 due to anthropogenic emission of greenhouse gases in the atmosphere and further increase is also expected if the situation continues. Among all the greenhouse gases i.e. carbon dioxide (CO_2), chlorofluorocarbons (CFCs), methane (CH_4) nitrous oxide (N_2O) and water vapor, the CO_2 emission contributes maximum and its one molecule can remain in the atmosphere for about more than hundred years. Therefore anthropogenic emission of CO_2 is considered one of the major causes for global warming. Increasing average global temperature due to anthropogenic emission of greenhouse gases and some natural causes such as volcanic eruptions, variation in Earth's orbit around the sun, etc. ultimately led to the global climate change. Climate change is one of the most important global environmental issues, which is likely to impact natural ecosystems as well as socio-economic systems [2].

The problem of anthropogenic CO_2 accumulation in the atmosphere could be addressed either by reducing emission or by developing some mitigating strategies. The forest biomass is now becoming the key parameter in dealing with current climate change issues as it able to mitigate the effect of global warming. Under Kyoto Protocol, forests are considered important for their unique role as carbon sinks because they are capable of capturing and storing carbon dioxide from the atmosphere [3]. Forests absorb CO_2 continuously from the atmosphere and release lifesaving gas oxygen (O_2) in the atmosphere by the process of photosynthesis. They store carbon as a necessary component for their growth and thus increase their biomass. The global forest cover is dwindling fast in view of great biotic pressure, industrialization, urbanization and land use changes for developmental activities [4]. Few studies have been reported that non-degraded forest contains much more biomass and carbon stock as compared to degraded forest [5, 6]. Knowing the spatial distribution of biomass is important for calculating the source and sink of the carbon and estimation of biomass flux [7]. In general, the biomass in Pine forest is found up to 200 t ha^{-1} and in oak forest ranged up to 400 t ha^{-1} in the Himalayan region [8].

Similarly in oak mixed forest of Central Himalaya has greater biomass (556-782 t ha^{-1}) than several oak and other broadleaf forests (102-450 t ha^{-1}) of temperate latitude [8]. The present study was carried out to estimate the biomass and carbon stock potential of three forest stands around Sattal Lake of Kumaun Himalaya.

2. Materials and method

2.1 Study area

The present study was carried out in three forest stands around Sattal Lake. Sattal is an interconnected group of seven freshwater lakes situated in the Nainital district of Kumaun Himalaya in Uttarakhand, India. The three stands were categorized as stand-I (highly disturbed), stand-II (moderately disturbed) and stand-III (undisturbed) on the basis of regeneration status and anthropogenic pressure in terms of lopping, grazing, wood cutting, etc. The stand-I was dominated with *Quercus leucotrichophora*, *Pinus roxburghii* and *Acer oblongum*; stand-II with *Q. leucotrichophora*, *Bauhinia variegata* and *A. oblongum* and stand-III was dominated with *Q. leucotrichophora*, and *Myrica esculenta*. The study area is located between 29° 20' − 29° 21' N latitude and 79° 31' − 79° 31' E longitude at an elevation of 1300 − 1450 m (Fig. 1).

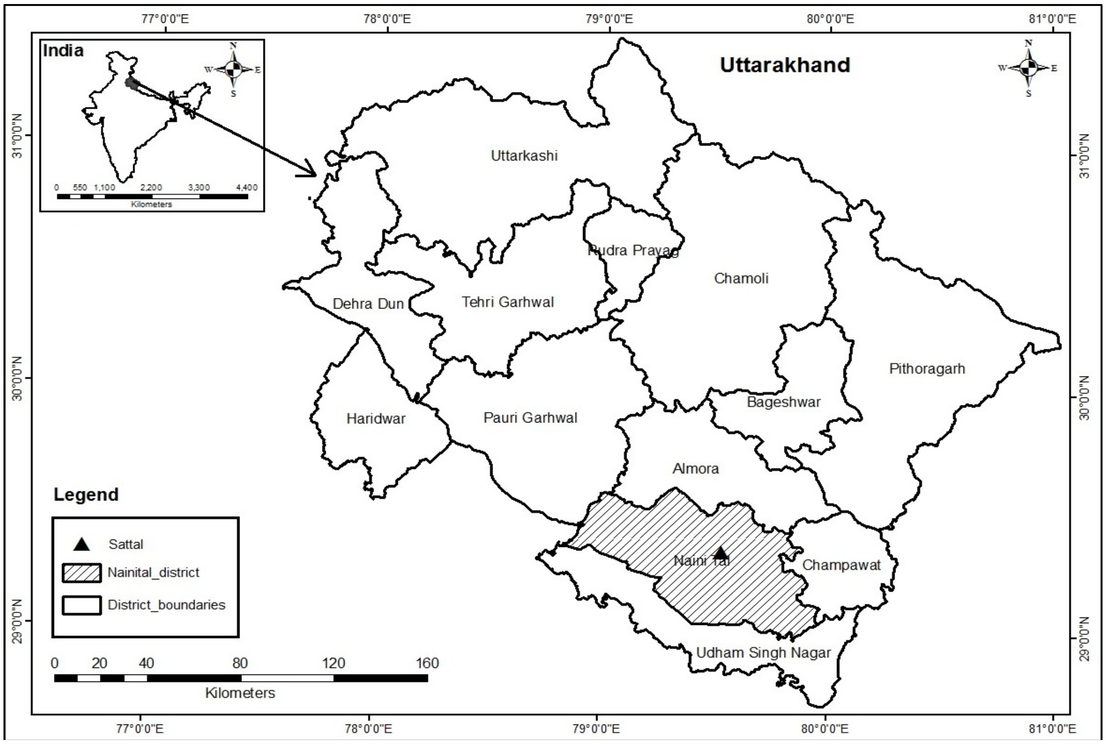

Fig 1: Location map of the study area

2.2 Sampling

Sampling plots of 10 m x 10 m, 5 m x 5 m and 1 m x 1 m sizes were laid down for trees, shrubs and herbs respectively [9]. A sum of 90 plots was laid down including shrubs and herb quadrates. Within each sampling plot (10 m x10 m) tree CBH (Circumference at breast height) was measured and the species number was counted.

2.3 Carbon-stock estimation in live biomass

Tree biomass was estimated using allometric equation in the form of Y= a + b Ln X, where Y= dry weight of component (kg); X= mean CBH (cm); a= intercept and b= slope. The value of a and b was taken from the literature [8] which is specific for each species. For the estimation of shrub and herb biomass, proportional harvest method was used. The C-stock was estimated as: C = 0.475 x B, where C= carbon content and B= biomass, by following [10].

3. Results and discussion

The forest biomass (t ha^{-1}) ranged from 328 to 431 across the three stands. The biomass of seedling and sapling stage was less at highly disturbed stand in comparison to moderately and undisturbed stand (Table 1). Density among different girth-classes such as seedling (<10 cm), sapling (10-30 cm), small trees (31-50 cm) and medium trees (51-70 cm) was estimated maximum for the stand-III followed by stand-II and minimum for stand-I (Fig. 2). It indicates that the stand-III was undisturbed in comparison to other two forest stands. However, there was also observed sign of anthropogenic pressure in terms of lopping, grazing and wood cutting at forest stand-I and II but there were no such signs at stand-III. Moreover, the stand-III was found to be planted patch of forest as the maximum density of tree species was found in sapling and small tree (31-50) stages. The sapling stage at stand-I and II was comparatively very less. Depending upon the above criteria, the three forest stands were categorized as highly disturbed (stand-I), moderately disturbed (stand-II) and undisturbed (stand-III).

The C-stock (t ha^{-1}) in live biomass was found to be ranging from 158 to 205 across the three forest stands around Sattal Lake. Maximum c-stock was estimated for undisturbed stand and minimum for highly disturbed stand (Fig.3). It reveals that the undisturbed stand had a good capacity to store atmospheric carbon as compared to highly disturbed and moderately disturbed forest stand.

Table 1: Biomass (t/ha) of different vegetation strata across three forest stands around Sattal Lake, Kumaun Himalaya

Vegetation strata	Highly disturbed	Moderately disturbed	Undisturbed
Seedling (<10)	3.6	6.6	12.8
Sapling (11 -30)	1.4	4.1	114.1
Small trees (31-50)	12.3	18.0	182.5
Medium trees (51-70)	16.5	22.6	51.4
Large trees (71-90)	54.0	33.6	10.6
Giant trees (>91)	237.7	251.0	56.0
Shrub layer	2.0	3.2	2.9
Herb layer	0.5	0.9	0.7
Total	328.0	340.0	431.0

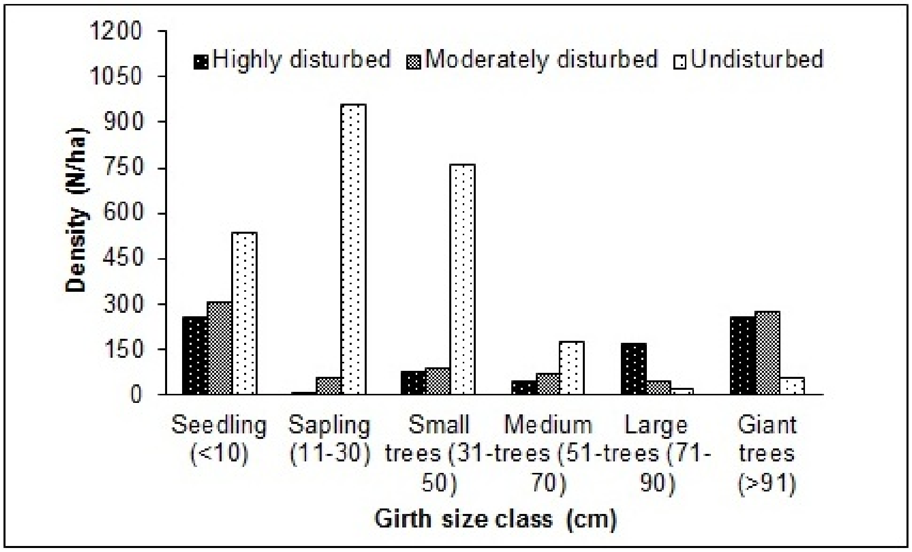

Fig 2: Girth size class wise density (N ha^{-1}) across three forest stands

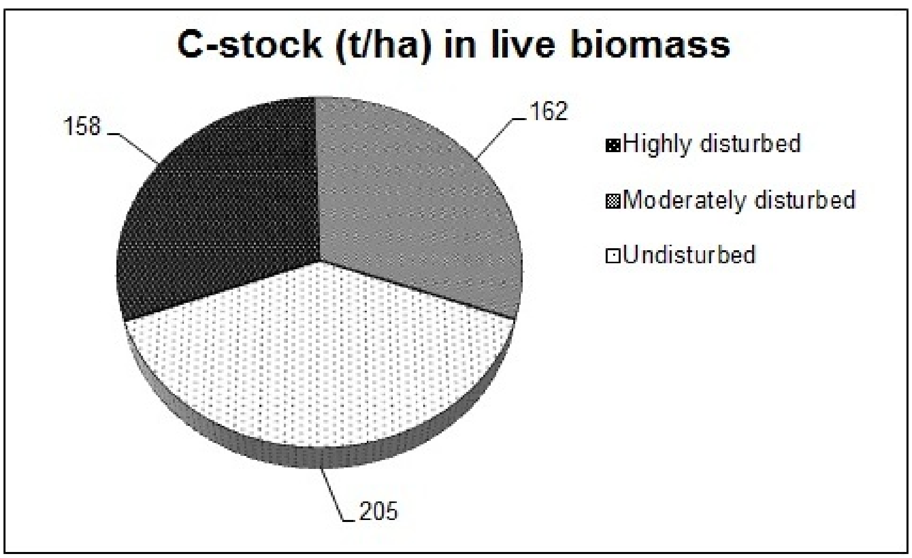

Fig 3: C-stock (t ha^{-1}) in live biomass of three forest stands around Sattal Lake

4. Conclusion

The better management of forest can be important in concerning the removal of atmospheric carbon; therefore anthropogenic pressure on forests should be controlled by imparting knowledge regarding scientific and sustainable harvesting of forest resources. The climate change education should also be imparted among local inhabitants to reduce the anthropogenic pressure on forests.

5. Acknowledgment

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