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Impact of Chronic Anthropogenic Disturbance on Soil Carbon and Macro-Nutrients (N,P,K) in Banj Oak (*Quercus leucotrichophora A. Camus*) Forests of Central Himalayas

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Abstract *Q. leucotrichophora* commonly known as Banj oak is a forest forming species between altitudes of 1400 to 2200 m in the Central Himalayan region this is also the most populous zone in terms of human settlements. The rural communities around these forests heavily depend on these forests to meet their and fuel wood demands which has resulted in degradation leading to losses in carbon stocks in biomass and soils of these forests. The study was carried out between 2013 and 2016 in Nainital district (29°23-29′N and 79°29-39′E) at elevations between 1400—2200 m with an aim to understand the impact of biomass extraction on soil carbon and macro nutrient (N,P,K) status due to human induced disturbances. Four disturbance categories on the basis of branch lopping, litter present of the ground and grazing were used for the study ; 360 composite soil samples across 3 different depths (0-10, 10-20 and 20 to 30 cm) were analyzed. As degradation levels increase, SOC was significantly lower at all soil depths measured. The degraded forest stands had only one-fourth to one eight as much SOC when compared to undisturbed sites. The degraded forests are subject to high level of litter removal which impacts the moisture levels and little decomposition rates eventually leading to reduced soil formation rates.

Keywords *Q. leucotrichophora*, Central Himalayas, Degradation, Soil nutrient.

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Introduction

Oak belongs to the family Fagaceae and to botanists it is known as Quercu. In Central Himalaya, there are total five species of Quercus namely ; *Quercus leucotrichophora, Quercus semecarpifolia, Quercus floribunda, Quercus lenuginosa and Quercus glauca*. Of the five species, *Quercus leucotrichophora*, commonly known as Banj oak is the most valuable species for the local people.

Banj oak is a large evergreen tree and is the dominant forest forming species between altitudes of

1400 m and 2200 m coinciding with human settlement of the region. Banj meets all the forest based requirements of the local people, as it is a good source of fuelwood, fodder and fertilizer. The hill economy depends on agriculture and animal husbandry and both these activities use this species heavily (Singh and Singh 1987).

Singh and Singh (1987) classify the Himalayan forests into 11 forests types based on temperature and rainfall. Forests dominated by Banj oak are termed as Low to mid-montane hemi-sclerophyllous broadleaf forests with concentrated summer leaf drop. Rainfall in these forests ranges from 100-250 cm and mean annual temperatures are from 13-16°C. The forests are found between 1500-3000 m (Thadani 1999).

In Central Himalayas human use of a forest landscape has resulted in major changes in ecosystem functioning. The removal of leaves, growing tips and young branches as a result of lopping for fuelwood and fodder results in a significant loss of productivity, lowered growth rates and greatly decreased carbon sequestration. Disturbance to the understory, directly through removal of leaf litter (to be used as compost fertilizer), low-intensity understory fires (encouraged by locals to promote grass growth), soil compaction by grazing cattle, and direct damage to tree seedlings through grazing, as well as indirect changes, such as through the opening of the forest canopy by lopping has occurred. This impacts species selection at the regeneration stage, and changes carbon stocks through lowered leaf biomass and through impacts on mycorrhizal growth, root productivity and carbon presence in the soil (Santer et al. 2003).

In a chronic form of disturbance, whole tree cutting is uncommon, mostly trees are lopped until they become severely denuded, with Vlittle crown left. In order to meet the everyday demands of fuel wood, and fodder, people in the Western Himalayan regions remove small and invisible fractions of biomass at a given time, generally as head loads of fire wood, or of fodder and leaf litter. Grazing is one of the common practices followed in this region, and each household has a number of livestock. This form of disturbance is chronic in nature (Singh 1998), unlike deforestation which comprises acute disturbance. In a chronic disturbance, the system does not get respite while in ecology, an event of disturbance is supposed to be followed by recovery time. While deforestation generally is associated with commerce, forest degradation has more of a poverty angle; it is rare in rich countries (Skutsch et al. 2008, Cadman 2008). Poor local people living in and around forests depend on forest biomass to sustain their subsistence living.

The problem with chronic form of disturbance is that ecosystems often do not get adequate time to recover, because human presence and interference never stops. This can cause adverse changes in the forest, even if rates of biomass removal are within the carrying capacity of the forest net primary production (Singh 1998). This form of disturbance occurs in much of the Himalayan east-to-west arc, and includes Indian states of Kashmir, Himachal Pradesh, Uttarakhand and much of Nepal (Singh et al. 2014, Singh 2014, Singh and Thadani 2015).

Forest degradation due to small scale chronic disturbances is a common problem in the Banj oak forest of Central Himalaya. A decline of Banj forests has been reported (Champion and Seth 1968, Singh and Singh 1992). This may be due to lack of Banj seedling establishment in the Central Himalayan stands (Saxena and Singh 1982, Upreti et al. 1985, Singh and Singh 1992). They have trouble establishing under intact oak canopies, where they are likely to be outcompeted by more shade tolerant species. Forest degradation is also a reason behind decline in seedling establishment (Singh 2017, Souza 2003, Tewari et al. 2008, Thadani 2008). Above ground studies to understand its impact exist but its impact on soils and below ground are lacking.

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Table 1. Criteria used to visually estimate the forest disturbance categories.

Disturbance category	Oak canopy	Understory	Litter removal	Grazing trails
Undisturbed	No apparent lopping	Undisturbed	No apparent litter removal	No grazing trails
Moderately disturbed (A)	Low levels of lopping but tree morphology intact	Unidisturbed	Moderate/High	Grazing trails visible
Moderately disturbed (B)	Considerable lopping, large branches intact	Grazed / bushy appearance	Ground swept bare, over 70% litter removed	Grazing trails visible
Degraded	Heavy lopping, pole like tree morphology, or cut down to stump height	Heavy grazing apparent	Low availability of litter	Ground covered with grazing trails

uted in this work in one way or the other, thank you once again for your useful insights).

Materials and Methods

In this present study, chronic disturbances in Banj oak forests was examined in four disturbance regimes in Mukteshwar region of Central Himalayas. Sites were selected between 1400 to 2200 m altitude in Banj oak dominated zone. In order to stratify sampling, each forest was assigned one of four disturbance categories viz.,Undisturbed (UD), Moderately disturbed-A (MA), Moderately disturbed-B (MB) and Degraded (D) forest.

Ten sites of each disturbance type were selected for the study. The sites were classified by ocular estimation based on criteria followed by Thadani (1999). The disturbance parameters were canopy cover, understorey growth, forest floor status and grazing trails (Table 1).

The soil samples were taken by digging 9 pits up to 30 cm depth on each forest site, thus a total of 360 samples for all four disturbance regimes. The soil samples were collected from three soil depths i. e. 0-10 cm, 10-20 cm, 20-30 cm for soil carbon analysis. For total nitrogen (N), available phosphorus (P) and avilable potassium (K), three composite samples at different depths (0—10 cm, 10-20 and 20-30 cm) from top were taken. The samples were then packed in moisture boxes and brought to the laboratory for physical and chemical analysis. Walkey's and Blacks titration method (Jackson 1967) was used to measure soil carbon concentration. Total nitrogen (N), was estimated by Kjeldhal method, available phosphorus was extracted by treating the soil with $N/_2$ $NaHCO_3$ and phosphorus content in the extract was determined by developing molybdate blue color and reading the color intensity through calibrated Spectrophotometer. Available content of potassium was extracted in normal neutral ammonium acetate and determined with the help of Flame Photometer.

Results and Discussion

Table 2 summarizes the total soil carbon, available nitrogen, available phosphorus and available potassium recorded at different depths from the four disturbance categories. In undisturbed sites, total carbon (t/ha) at different soil depths ranged between 18.93 ± 0.25 - 26.83 ± 0.28 (t/ha). In Moderately disturbed -A, it ranged from 16.86 ± 0.27 - 25.60 ±0.26 (t/ha), 7.01 ± 0.11 - 13.00 ± 0.16 (t/ha) in Moderately disturbed -B and 2.89 ± 0.04 - 7.01 ± 0.11 (t/ha) in Degraded category.

Available nitrogen (t/ha) in undisturbed category ranged from 1.33 ± 0.003 - 1.82 ± 0.004 (t/ha), in Moderately disturbed -A, it ranged from 1.72 ± 0.002 - 1.87 ± 0.002 (t/ha), 1.86 ±0.02 - 3.02 ± 0.02 (t/ha) in Moderately disturbed - B and 0.50 ± 0.005 - 1.68 ±0.004 (t/ha) in Degraded category.

Table 2. Impact of forest degradation on soil total carbon, available nitrogen, available phosphorus and available potassium. UD-Undisturbed forest, MA - Moderately disturbed-A, MB-Moderately disturbed-B and D- Degraded forest.

	Forest disturbance categories					
		UD			MA	
Parameters	0-10	11-20	21-30	0-10	11-20	21-31
Bulk density (g/cm^3)	0.79	0.79	0.8	0.81	0.82	0.82
Porosity (%)	69.77	69.54	69.19	68.85	68.62	68.42
pH	6.26 ± 0.08	5.91 ± 0.08	5.93 ± 0.08	5.87 ± 0.10	6.3 ±0.10	6.41 ± 0.07
Total carbon (t/ha)	26.83 ± 0.28	23.40 ± 0.25	18.93 ± 0.25	25.60 ± 0.26	20.52 ± 0.30	16.86 ± 0.27
Available nitrogen (t/ha)	1.82 ± 0.004	1.43 ± 0.003	1.33 ± 0.003	1.87 ± 0.002	1.52 ± 0.002	1.72 ± 0.002
Available phosphorus (t/ha)	0.053 ± 0.02	0.028 ± 0.0003	0.023 ± 0.004	0.15 ± 0.002	0.10 ± 0.001	0.08 ± 0.001
Available potassium (t/ha)	0.003 ±0.000	0.002 ± 0.000	0.002 ±0.000	0.003 ± 0.000	0.002 ±0.000	0.002 ± 0.000

Table 2. Continued.

	Forest disturbance categories					
			MB		D	
Parameters	0-10	11-20	21-30	0-10	11-20	21-30
Bulk density (g/cm^3)	0.82	0.82	0.84	0.84	0.85	0.85
Porosity (%)	68.46	68.31	67.81	67.85	67.46	67.27
pH	6.13 ± 0.12	5.98 ± 0.11	5.82 ± 0.14	5.11 ± 0.07	5.12 ± 0.06	4.91 ± 0.06
Total carbon (t/ha)	13.00 ± 0.16	11.21 ± 0.12	7.01 ± 0.11	6.81 ± 0.04	4.29 ± 0.06	2.89 ± 0.04
Available nitrogen (t/ha)	3.02 ± 0.02	2.17 ± 0.02	1.86 ± 0.02	1.68 ± 0.004	1.27 ± 0.004	0.50 ± 0.005
Available phosphorus (t/ha)	1.21 ± 0.01	0.98 ± 0.01	0.67 ± 0.01	0.39 ± 0.006	0.29 ± 0.005	0.14 ± 0.003
Available potassium (t/ha)	0.005 ± 0.000	0.004 ± 0.000	0.004 ±0.000	0.001 ± 0.002	0.001 ± 0.003	0.001 ± 0.002

Available phosphorus (t/ha) in undisturbed category ranged from 0.023 ± 0.0004 - 0.053 ± 0.002 (t/ha), in Moderately disturbed -A, it ranged from 0.08 ±0.001 - 0.15 ± 0.002 (t/ha), 0.98 ± 0.01 - 1.21 ±0.01 (t/ha) in Moderately disturbed-B and 0.14 ±0.003 - 0.39 ± 0.006 (t/ha) in Degraded category.

Available potassium (t/ha) in undisturbed cat-

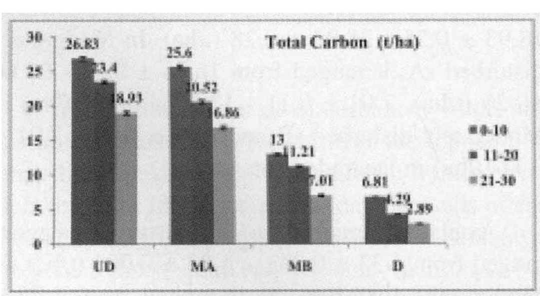

Fig. 1. Effect of forest degradation on soil total carbon. UD-Undisturbed forest, MA-Moderately disturbed -A, MB-Moderately disturbed-B and D-Degraded forest.

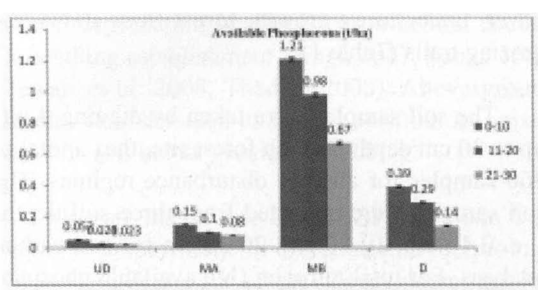

Fig. 2. Effect of forest degradation on soil available phosphorus . UD-Undisturbed forest, MA-Moderately disturbed-A, MB-Moderately disturbed -B and D- Degraded forest.

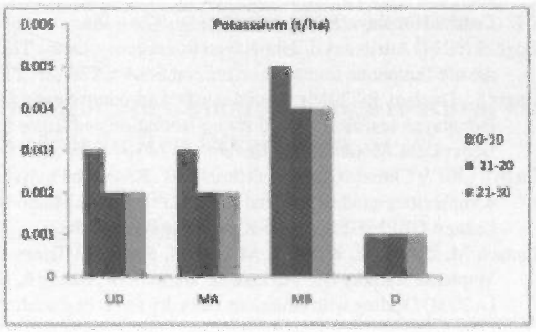

Fig. 3. Effect of forest degradation on soil available potassium. UD- Undisturbed forest, MA-Moderately disturbed-A, MB-Moderately disturbed -B and D-Degraded forest.

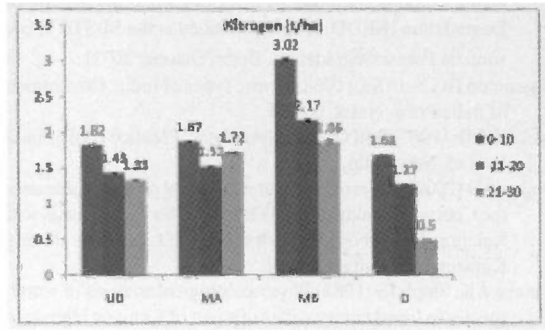

Fig. 4. Effect of forest degradation on soil available nitrogen. UD-Undisturbed forest, MA-Moderately disturbed-A, MB-Moderately disturbed -B and D-Degraded forest.

egory ranged from 0.002 ± 0.000 - 0.003 ± 0.000 (t/ha), in Moderately disturbed-A, it ranged from 0.002 ± 0.000 (t/ha), 0.004 ± 0.000 - 0.005 ± 0.000 (t/ha) in Moderately disturbed-B and 0.001 ± 0.002 - 0.001 ± 0.002 (t/ha) in Degraded category.

Results showed that carbon percents in undisturbed forests were marginally high than the other forests. In undisturbed forest highest carbon percent was observed at all the depths. Total soil carbon (t/ha) varied significantly ($p<0.001$) across all the depths and sites (Table 2). It is generally noticed that as the depth increases quantity of carbon in the soil reduces. It was observed that the high concentration of carbon exists on the upper layers of the soil and with increasing depth, soil carbon declined (Table 2).

Conclusion

The research focuses on a critical zone of the Himalaya. The 1400-2200 m belt is among the most extensive zones in the region given the patterns of Himalayan folding (i.e. a large proportion of the area of the Himalaya falls in this altitudinal belt). The forests of this zone are the most extensively used by rural populations. Despite extensive use of the oak pine forests by humans for biomass, there have been very little study of the impact of chronic anthropogenic disturbance. Changes in soil nutrients are studied and understanding soil carbon change is important for issue such as REDD and also to understand ecosystem services emanating from forests.

Soil organic carbon followed predicted pattern. The degradation of forest, and most importantly the removal of leaf litter, reduces soil organic content. Leaf litter is swept away for use in compost fertilizer. Our estimates indicate that as much as 40% of leaf litter is removed from disturbed forest stands. The lack of a litter covering also leads to higher erosion rates during rainfall which likely adversely impacts soil carbon.

As degradation levels increase, SOC was significantly lower at all soil depths measured, viz., 0-10 cm, 10-20 cm and 20-30 cm (Fig. 1). Typically the degraded forest stands had only about one-fourth to one eight as much SOC with compared to undisturbed sites.

Soil phosphorus shows greater varibility. In the Himalayan forests phosphorus is often limiting. In undisturbed forest, much of the available phosphorus gets locked up in biomass and this may lead to low phosphorus availability in soils (Figs. 2—4). Highly degraded sites again show low phosphorus as this nutrient is lost from the ecosystem due to high erosion and biomass removal. Similar results were observed by Singh (2009) and Raikwal (2009).

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