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Studies on Carbon Dynamics in Fire Affected Pine Dominated Forests in Western Himalyas

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ABSTRACT

Conifer (pine) or mixed conifer forests covers approximately 40 per cent of the total forest areain subtropical area of Himachal Pradesh and are most susceptible to frequent forest fires.However, there is no clear cut data regarding the forest fires and their impact on the carbon sequestration rate in Himachal Pradesh.The present study was conducted with the objective toascertain the loss of carbon by the fire in pine dominated forest.Shrubs numberdecreased just after fire and increased thereafter till the fire erupted next time. The carbon stock in the shrub biomass also varied with the time after fire. It ranged from.0.53 Mg /ha to 0.87 Mg/ha in the first year of fire incidence and the fifth year of fire incidence. The CO_2 mitigation varied from 4.22 Mg/ha to 6.93 Mg/ha. The grass diversity is adversely affected by the fire. Grass species number increased with the time after fire incidence. Soil carbon varied from 20.76 Mg/ha to 41.29 Mg/ha. Overall carbon in the forest (tree+shrubs+ grasses+ soil) clearly depict the affect of fire on carbon dynamics.

Keywords:

Forest fire, CO_2 mitigation, soil carbon, conifer forest

INTRODUCTION

Pinus roxburghii along with broad leaved tree species dominate from low to mid elevation in Western Himalayas. These forests confront challenges of occurrence in varying intensities Fire has become an unwarranted feature during the dry spells despite of utmost precautionary measures (Kumar and Thakur, 2008), and is posing a great threat in the sustainability of this type of ecology in the Central Himalaya. Forest ecosystems can act as sources as well as sinks of CO_2, the most abundant greenhouse gas (Haripriya 2002).The chir pine forests emit carbon through burning and sink through floral growth. Pine forests play an important role carbon (C) cycles because they store large quantities of C in vegetation and soil, exchange C with the atmosphere through photosynthesis and respiration, are sources of atmospheric CO_2release.

They are disturbed by accidental or intentional fires and become atmospheric C sinks during re-growth after fire.The average atmospheric CO_2 concentration has increased to 364 μmol mol^{-1} in 1994, and is currently increasing at a rate of about 1.5 μmol mol^{-1} year^{-1} (Kelling and Whorf 1998). The International Panel on Climate Change (IPCC) in its fourth assessment report has strongly recommended to limit the increase in global temperature below 2°C as compared with pre-industrial level (i.e. measured from 1750) to avoid serious ecological and economic threats. A rise in global mean temperature by 0.74°C has already been recorded, and hence climate scientists are focusing on an urgent action to curb global warming (IPCC 2007; Kerr 2007). Fire has long been integral part of the forest environment and has played an important role in shaping the flora and fauna.

An annual average of some 1.14 million ha. inventories conducted by the Forest Survey of India show that on average 55% of forest area in India is affected by fire and 78 percent by grazing. Subsequently, little regeneration occurs in 72 percent of forested areas (Ministry of Environment and Forest, 1997). The annual losses from forest fires in India for the entire country have been moderately estimated at Rs 440 crores (US$ 107 million). The study area is characterized by hilly and mountainous terrain supporting mostly Chir Pine (*Pinus roxbughii*), ranging from about 493m to 1600 m above mean sea level. The area under forest cover represents one third of the total geographical area of the State Himachal.The main objective of the investigation is to understand the role of fire in carbon dynamics in the flora and soil over the time.

MATERIALS AND METHODS

To estimate biomass of different kinds of flora such as tree shrubs and grasses quadrates were laid in sites between 32° 16′-32°18′N latitude and 75°54′-75°54′E longitude in the Nurpur Forest Range of Himachal Pradesh, which had history of forest fire of different intensities, and in sites with similar condition i.e. natural forests where sites escaped fire. The 50x50 cm quadrates were laid out in the study sitesto estimate the grass diversity and biomass.Three sample plots of 5mx5m each was systematically laid out on each stand to take the shrubs data. Three sample plots of 0.1 ha each were systematically laid out on each stand to take the tree data representing a particular forest type. The height and dbh (diameter at breast height) of all the trees falling within the sample plot were measured. The tree height was measured using a Ravi multimeter and the tree diameter was measure with the vernier calliper. The growing stock volume density (GSVD) was estimated using volume tables or volume equations based on the Forest Research Institute (FRI) and Forest Survey of India (FSI) publications for the respective species (FSI 1996). The estimated GSVD ($m^3 ha^{-1}$) was then converted into aboveground biomass density (AGBD) of tree components (stem, branches, twigs and leaves) (Uniayal et al 2002), In each forest stand four soil samples were collected from 0–10 cm depth from each sample. The needle biomass was calculated by putting the polythene sheet all around the tree covering the whole crown width. The needle biomass was calculated on month basis and added up in the end of the year.It was correlated with tree canopy size in each plot and extrapolation was done on per ha basis to calculate the needle biomass per ha per year. The pine tree biomass and carbon stock is given in table 1.

Soil samples were packed in bags and brought to the laboratory for organic C estimation. For organic C determination, the soil samples were sieved through a 2 mm sieve and then thoroughly mixed. The total carbon in the soilwas measured by the TOC Analyser model TOCH-SSM-5000A.The bulk density of soil was measured by taking two aggregatedisturbed blocks of soil by metal cylinder of 30 cm length and 3 cm internal diameter. When taking cores for measurements of bulk density, extra care was taken to avoid any loss of soil from the samples. The exact volume of the soil taken by a metal cylinder was determined by measuring the volume of the cylinder. The soil samples were dried in an oven at 70°C for 72 h and then weighed until two subsequent values were constant. In the soils containing coarse rocky fragments, the coarse fragments were retained and weighed. The bulk density of the mineral soil core was calculated with the help of following formula described by Wilde et al. (1964). The Soil organic carbon was calculated by IPCC (2003) in good practices for LULUCF.

RESULTS AND DISCUSSION

The Perusal of data in the table 1 reveals that tree biomass is more or less constant and did not depict any significant variation due to fire in the study period. However, the inspection of annual growth rings depicts the unevenness in the annual ring after some intervals at the early stage. This can be correlated with the sudden fluctuations in the

Table 1: Total carbon stock and CO_2 mitigation by *Pinus roxburghii* (Chirpine) in fire affected pine forests

Years after fire	Total tree biomass (Mg /ha)	Total carbon stock in Chir pine (Mg /ha)	CO_2 mitigation by chir pine trees (Mg /ha)	CO_2 mitigation potential of chirpine forests (Mg /ha)
4th year after fire	86.96	39.13	143.50	1.65
3th year after fire	71.31	32.09	117.66	1.96
2th year after fire	79.47	35.76	131.13	2.62
1th year after fire	83.26	39.04	143.15	1.46
0th year after fire	61.18	27.53	100.93	1.44

temperature around the tree but needs further investigation. However, table 2 clearly depicts that pine needle accumulation on ground varied with the time after fire. It was lowest at the site affected by fire in current year i.e. 2.16 Mg/ha and maximum in the site received fire five year back i.e. 7.20 Mg/ha. The CO_2 mitigation was also affected significantly by the fire (Table 2). The variation in carbon as a result of fire had also been reported by Ryan (2002) who reported that spatial and temporal variation in severity within a fire can have long-lasting impacts on the structure and species composition of post-fire communities and the potential for future disturbances. Data in table 3 reveals that the numbers of shrubs were also affected by the fire. The number of individuals of shrubs increased with the time after fire and decreased just after the fire. Pure chir pines as are affected by the fire climate change and dry spell in the central Himalaya (Singha and Yadava, 2013). Carbon stock in shrubs ranged from 0.53 Mg/ha to 0.87 Mg/ha in the first year of fire incidence and the fifth year of fire incidence. The CO_2 mitigation varied from 4.22 mega gramm per ha to 6.93 Mg/ha. Table 4 revealed that grass diversity was adversely affected by the fire. Grass species number increased with the time after fire incidence. The carbon stock by the grasses varied greatly with the time after fire incidence at a particular site. The carbon stock in the grasses varied from 0.51 Mg/ha to 2.64 Mg/ha. Similar was the trend of CO_2 in all the sites (Table 4). Although there was no trend in the soil organic carbon however, there was significant affect of fire on the soil carbon. It ranged from 0.94% to 1.91 % in the soil strata upto 10 cm depth. Pal et al 2013 had reported about 3% organic carbon in 0-15 cm soil in chir pine forest of Himachal Pradesh. The inorganic carbon was negligible and range from 0.03 % to 0.07 per cent. The carbon varied from 20.76 Mg/ha to 41.29 Mg/ha (Table 5). Negi and Gupta (2012) reported the similar level of carbon in chir-pine forest of Uttrakhand, while comparing the different forests.

Over all carbon in the forest (tree+shrubs+ grasses+ soil) clearly depict the affect of fire on carbon dynamics (Fig 1). The CO_2 mitigation in the

Table 2. Fallen Pine needle biomass and Carbon stock and CO_2 mitigation by pine forests as affected by fire.

Fire affected Sites	Pine needles (Mg /ha)	Carbon in pine needles Mg /ha	Co2 mitigation by pine needles (Mg /ha)
4th year after fire	7.20	3.24	11.88
3th year after fire	6.44	2.90	10.63
2th year after fire	4.66	2.10	7.70
1th year after fire	3.50	1.57	5.76
0th year after fire	2.16	0.97	3.56
SE	0.70	0.32	1.34
$CD_{0.05}$	1.40	0.65	2.69

Table 3: Carbon stock and CO_2 mitigation by the under story shrubs in fire affected pine forests.

Total Carbon Sequestration by the shrubs after the different intervals of Fire	Number of stems per ha	Total shrub Biomass (Mg /ha)	Carbon stock (Mg /ha)	CO2 mitigation in shrubs (Mg /ha)
4th year after fire	11600	1.89	0.87	6.93
3th year after fire	10800	1.88	0.86	6.89
2th year after fire	6000	1.85	0.85	6.78
1th year after fire	8400	1.72	0.79	6.31
0th year after fire	6800	1.15	0.53	4.22
SE	2000.12	0.23	0.11	1.03
$CD_{0.05}$	4002.25	0.47	0.22	2.07

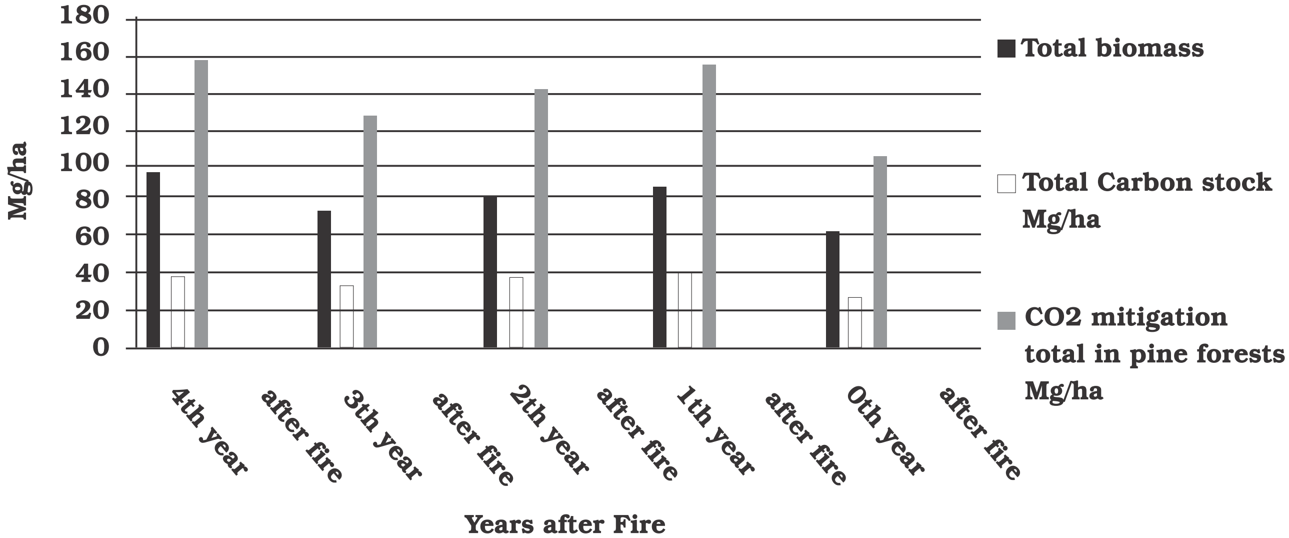
Table 4: Above and below ground carbon stock and CO_2 mitigation by grasses in fireaffected pine forests.

Years After Fire	Grass Species	Above ground Biomass of grass (Mg /ha)	Below ground biomass (Mg /ha)	Carbon stock in Herbace ous stock (Mg /ha)	CO 2 mitigation per ha (Mg /ha)
4 th year after fire	1.Dholu (Chrysopogon montanus Trin) 2.Lamba (Heteropogon contortus) 3. Thermedia anathera	4.16	1.64	2.64	9.69
3 th year after fire	1.Dholu (Chrysopogon montanus Trin) 2.Lamba (Heteropogon contortus) 3. Thermedia anathera	2.42	0.95	1.52	5.58
2 th year after fire	1.Dholu (Chrysopogon montanus Trin) 2.Lamba (Heteropogon contortus) 3. Thermedia anathera	2.18	0.93	1.89	6.95
1 th year after fire	1.Dholu (Chrysopogon montanus Trin) 2.Lamba (Heteropogon contortus) 3. Thermedia anathera	3.16	1.16	1.94	7.12
0 th year after fire	1. Lamb grass (Heteropogoncontortus	0.8 0	0.95	0.51	1.87
	SE	0.21	0.13	0.22	1.33
	CD 0.05	0.43	0.27	0.45	2.68

Table 5 : Carbon sequestration level in the forest soils of *Pinus roxburghii* dominated forests affected by fires

Years After Fire	Total carbon (%)	In - organic carbon (%)	Total Organic Carbon per ha (Mg /ha)
4 th year after fire	1.91	0.07	41.29
3 th year after fire	1.06	0.02	22.92
2 th year after fire	1.84	0.03	40.84
1 th year after fire	1.24	0.03	30.16
0 th year after fire	0.94	0.03	20.76
SE	0.17	0.009	8.34
CD 0.05	0.35	0.019	16.69

Fig 1. Carbon stock and CO_2 mitigation by fire affected Pine forests forests.



pine forest increase with the time after fire and again come down the fire erupts next time. So this phenomenon of fire results in release of carbon stored by the pine forest and ready to be transferred to ground for further storage and use by the system. Fire may also play a role in recycling nutrients from the ground-layer vegetation and litter to the overstorey trees, thereby counteracting the infertile substrates and arrested decay (Vogl 1974). Areas under larger burned patches have higher cover of tree seedlings and shrubs, greater densities of opportunistic species, and lower species richness than smaller patches (Turner et al. 1997).

REFRENCES

Anonymous 2007 State of forest report, 2007. Forest survey of India.112pp

Haripriya GS 2002 Biomass carbon of truncated diameter classes in Indian forests. *For. Ecol. Manage*. **168** 1–13

IPCC 2003 IPCC good practice guidance for LULUCF.3.3:290-300pp

IPCC 2007 Climate change 2007: Synthesis report: Contribution of working groups I, II and III to the fourth assessment report (Intergovernmental Panel on Climate Change):566 pp

Kelling CD and Whorf TP 1998 Atmospheric CO_2 records from sites in the SIO air sampling network, in trends: A compendium of data of global change Carbon dioxide (Oak Ridge,T N: Information Analysis Center, Oak Ridge National Laboratory)

Kerr AR 2007 How urgent is climate change? *Science* **318** 1230–1231

Kumar R and Thakur V 2008 Effect of forest fire on trees, shrubs and regeneration behaviour in chir pine forest in northern aspects under Solan forest division, Himachal Pradesh. *Indian J For*. **31(1)**: 19-27.

Negi SS and Gupta MK 2012. Carbon sequestration through soil organic carbon pool under different forest covers in Chamoli district of Uttrakhand. *Indian Forester* **140(2)**: 207-211.

Pal S, Panwar P and Bhardwaj DR, 2013. Soil quality under forest compared to other land-uses in acid soil of North Western Himalaya, India *Ann. For. Res.* **56(1):** 187-198.

Ryan KC 2002 Dynamic interactions between forest structure and fire behavior in boreal ecosystems. *Silva Fennica* **36(1)**: 13-39.

Singh P and Yadava AK 2013. Plant biodiversity distribution pattern under pure and mixed chir-pine (Pinus roxburghii Sarg.) forests of central Himalaya, India. *New York Science Journal* **6(9)**: 66-73.

Turner Monica G, William H, Romme, Robert H. Gardner, William W, Hargrove 1997. Effects Of Fire Size And Pattern On Early Succession In Yellowstone National Park. *Ecological Monographs* **67(4)**: 411-433

Uniyal DP, Verma SK, Sharma SK and Sharma VK 2002, Provenance variation in the specific gravity. *Indian Forester*. **128(12)**: 1295-1301.

Vogl J. Richard. 1974 'Effects of fire on Grasslands' in T. T, Kozlowski, C. E. Ahlgren (Eds.), *Fire and Ecosystem.* Academic Press.: 173.

Wilde SK, Voigt GK and Iyer JG 1964 Plant and soil analysis for tree culture. Oxford Publishing House, Calcutta, India.