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Studies on CO_2 flux and carbon sequestration in natural Grass communities under natural Chir-pine forests of Indian North West Himalayas

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Abstract

Effect of fire on nature, biomass, CO_2 flux and carbon sequestration potential of under storey grasses in chir pine forests receiving fire after regular intervals along the altitude and aspect was studied. Species composition, biomass, and productivity patterns of perennial grass communities under Chir-pine dominated forests at different altitudes varied greatly with the level of exploitation and fire incidence. The carbon sequestration by the ground floor species also vary with altitude and fire level. The four types of grass species were found in the fire affected forests viz. *Chrysopogon montanus* Trin, *Apluda mutica*, *Heteropogon contortus* and *Themeda anathera.* Pure grass land recorded the maximum CO_2 mitigation 16.29 mega grams and the CO_2 mitigation increased with the altitude at same aspect. Similarly, CO_2 mitigation increased from 19.29 to 28.22 mega grams per ha in the soil at different altitude. *F*orest soils carbon increased from 0.94 % just after the fire and (Zero year after fire) and highest after four years of fire i.e. 1.91 %. The total organic carbon increased up to 41.29 mg ha^{-1}in forest after four years of fire.

Keywords: CO_2 flux, carbon sequestration, Grass communities, Chir-pine, Himalayas

Introduction

Lower Himalayas, between latitudes 26°N to 36°N and longitudes 71°E to 93°E (Ghildiyal et al 2009) is home of chir pine (*Pinus roxburghii* Sargent) which is one of the most divergent and economically important plant species, providing valuable timber, resin, fuel and protect watersheds to sustain the water supply to millions residing in the Himalayan basin. In Himachal Pradesh around 1346 km^2 area is under chir pine providing vast grazing area. People in this area have acquired a faith over the years that summerfires in chir pine forests enhance forage production. Thus, these forests are occasionally subjected to wild fires every year.

Chir forests occur scattered between 450 m –1680 m over the outer Siwalik Hills and lower Himalayas. *Pinus roxburghii* is commonly known as long-leaved pine or chir pine is one of the most important and widely spread conifers in the Western Himalayan region. The northern India is one of the best habitats of chir pine forests. In recent years, detailed ecological studies have been carried out on the chir pine forests *viz*, Gupta2000, Guleria, 1999,. Tivedi, 1994; Singh and Singh, 1992; Anita (2001).

As in continental and insular Southeast Asia, a large variety of bio geographic features and climatic conditions within the region have shaped a high diversity of forest ecosystems and other wooded land with different fire regimes and vulnerabilities. The deciduous, seasonally dry forests of the lowlands and the coniferous (pine) forests in the higher elevations are regularly burned. According to an assessment of the Forest Protection Division of the Ministry of Environment and Forests, Government of India, 3.73 million ha of forests are affected by fires annually in India. Conifer (pine) mixed conifer, broadleaf with conifer, plantations and degraded forests, which cover approximately 40 per cent of the total forest area, are most susceptible to frequent forest fires. The natural grasses are the fodder banks of the nomadic communities which keep on moving from high altitude to low in winter and low altitude to high altitude in summer. But periodic natural fire in chir pine dominated forests alters the relationship of nomadic and grasses by affecting the species types and productivity. So in the recent past site degradation in chir pine forest has increased, alarmingly. The effect of fire on grass communities underneath and carbon dynamics as affected by wild fire and altitudinal variations in western Himalaya has not been studied seriously. Its relation to carbon dynamics has also not been studied so far. There is need to estimate the carbon stocks and losses by the natural incidences to site specific and species interaction. Keeping in view, the present study was undertaken in chir pine forests of Shivalik ranges of Himachal Pradesh to investigate the effect of fire on grass productivity and carbon sequestration potential of grasses and affect of wild fire on it.

Materials and Methods

The Shivalik hills having Chir-pine upto 1400 above msl. and there is great variation of temperature and soil types. However, the soil organic matter and nutrient mineralization varies with altitudinal range and density of Chirpine. The soil organic matter also varies with the altitude, and aspect. The studies were conducted in the Shivalik ranges of western Himalayas between 400-1400 m above mean sea level. The annual rainfall varied from 1100 mm to1500 mm, mean maximum temperature from 32^{O}C37°C and the mean minimum temperature from 6°C to 10°C. The Chir pine dominated forest floor were studied for grass types, biomass and carbon estimation. The studies were conducted in the chir pine forests having chir pine tree density >80%, 60% and <40 pine density per ha) and pure grass land. After survey of the area four sites each of approx. 0.3 to 0.4 ha. were studied to assess the carbon sequestration by grass community at different altitudinal ranges from. <400m, 400-900 and >900m above mean sea level. The chir pine forest of same age and density were selected for the studies.

Chir pine forest experience fire after every four to five years. So five years interval period was taken in to consideration for estimating the fire impact on grass communities. One year after fire was name as zero years, two year after fire was named as 1st year after fire, third year after fire was named as 2nd year after fire, fourth year after fire was named as 3rd year after fire and fifth year after year was named as 4th year after firer. The area receives 1000-1500mm annual rainfall. The relative humidity varies from 35 to 80 per cent with yearly average of 50 per cent. May- June are the hottest months and Dec-Feb are the coldest months. Area receives fire in April- June and heavy rainfall July- September every year. Early monsoon curtail the fire hazard period whereas, late arrival of monsoon increase fire incidence in the chir pine dominated forests. The soil of the area comprise of carbonaceous shales, calcareous shales, dolomite limestone with bands of intermittent shales. The grass communities were estimated by putting quadrates of 50 cm x 50 cm size at each site and replicating it in three for each treatment. The above and below ground carbon was estimated by highly sophisticated TOC analyzer as per IPCC Guidelines. The data was analysed by using statistical methods by Gomez and Gomez (1984).

Results and Discussion

The natural vegetation cover (forest, scrub and grassland) is around 29.36% of the total geographical area of India (Reddy et al. 2015). The total forest area facing disturbances due to fire is estimated as 57,127.75 km^2 in natural vegetation types. Area of 46.63% in dry deciduous forest types and 32.77% in moist deciduous forest types is burnt by fire every year (Reddy et al. 2015). CO_2emissions from natural grass lands have been identified as an environmental issue in the context of global warming. In the present study we have estimated the impact of fire on the CO^2 flux and carbon sequestration in natural grass lands in chir-pine dominated forest types of Lower Western Himalayas. *Chrysopogon montanus, Heteropogon contortus and Themeda anathera* were the three main grass species recorded in the forests dominated by the chirpine and facing regular fire after some intervals (table-1).

However, dominant grass species were different at different altitudes *viz*, *hrysopogon montanus* was dominant at lower altitude and *Apluda mutica* and *Themeda anathera* was at higher altitude (Table-1). *C. montanus*, *H. contortus*, *T. anathera* and *P. maximum* were invariably recorded under chir pine forest by Gupta et al(2009), Guleria et al (1999). Gupta et al(2009) reported that grass community behavior changes due to imposed fire-treatments , reduced pine-needle litter deposition and curtailed release of allelochemicals besides enhancing nutrient release from fuel load.

Table 1: Carbon stock and CO2 mitigation potential of grasses under chir-pine forests

Altitude	Name of Grass spp	Above ground Biomass of herbaceous components t/ha	Root : Shoot Ratio	Below ground biomass (Mega gram/ha)	Carbon stock in perennial herbs (Mega gram/ha)	CO_2 mitigation (Mega gram/ha)
<400m above msl	1. Dhaolu (*Chrysopogonmontanus* Trin) 2.Lamba (*Heteropogon contortus*) (Lamba)	2.03	0.33	0.53	1.10	4.05
(400-900 m above msl	1. *Apluda mutica* 2.Lamba (*Heteropogon contortus*) (Lamba) *3.Themeda Anathera*	2.24	0.43	0.96	1.44	5.27
(<900 m above msl	1. *Apluda mutica* 2. *Thimeda Arundinacea*. 3.Lamba (*Heteropogon contortus*) (Lamba)	3.92	0.53	1.76	2.56	9.32
Pure Grass land	--	8.00	0.23	1.88	4.44	16.29

The changes in nature and biomass production of perennial grasses has also been recorded in the present studies along the altitude at same aspect in fire affected pine forests. The above ground biomass was higher than the below ground biomass at all the altitudes. The root: shoot ration also changed with the altitude (table-2). It increased with altitude and was maximum in the grass species growing at the altitude >900 m above msl. Carbon stock ranged from 1.10 mega gram/ha to 2.56 mega gram per ha in perennial grasses under chir pine however, the pure grass land sequestered higher carbon to the tune of 4.44 mega gram per ha Similarly, CO_2 dynamics was also affected with altitude. Lennka (2012) reported SOC sequestration upto 1.35 mg $ha^{-1}yr^{-1}$ in erosion prone areas by putting the grass barriers. Similarly Khaki and Wani(2011) reported the CO_2 2.0115 mg ha^{-1} under natural grass lands in Himachal Pradesh. Over all forest carbon sequestration varied from 25.48 mg ha^{-1} to28.22 mg ha^{-1} in the forests under study.

Table 2: Carbon sequestration level forest forest soils of *Pinus roxburghii* dominated forest as affected by altitude

Altitude Range	Total carbon (%)	In-organic carbon (%)	Total Organic Carbon per ha (mega Gramm Per Ha)
(<400m above MSL (Aond Nurpur)	1.29	0.17	25.48
(400-900 m above MSL (Koti range chamba)	0.97	0.10	19.39
(>900 m above MSL (Dalhausie, Chamba)	1.26	0.05	28.22

It was quite evident that only one species i.e *Heteropogon contortus* was recorded in the sites affected by the fire in first year after fire took place. Forest fire is the major cause of CO_2 release in the air as it burns the under storey in pine forests (table-3). The studies revealed that perennial grasses sequestered higher level of carbon over time after last fire in the underground biomass and also the soil SOC increased in the soil as the time elapsed after occurrence of last fire. Around 7.82 mg per ha was added to the forest by perennial grass community in pine forest after four years of last fire incidence

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Table 3: Above ground below ground biomass, carbon stock and CO_2 mitigation by the under grasses in fire affected pine forest

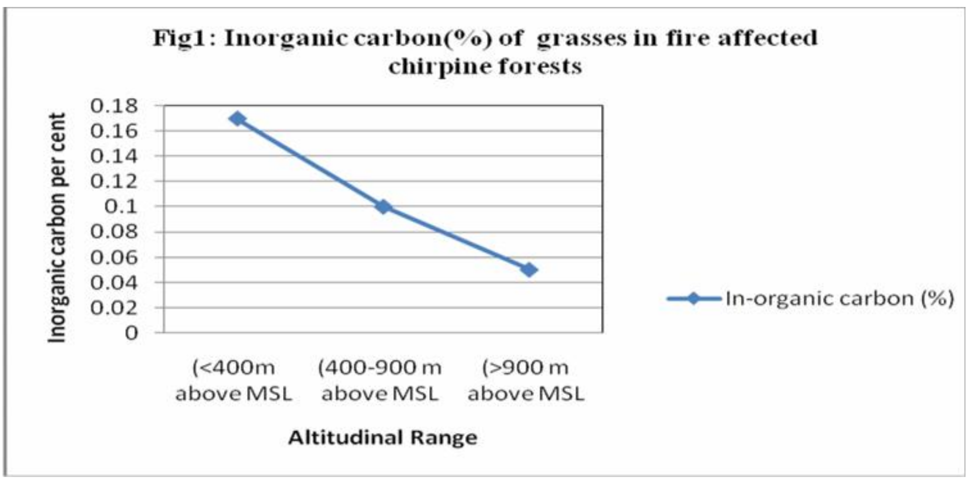
Fire affected Sites	Grass Species	Above ground Biomass of grass (Mega gramm/ha)	Below ground biomass (Megagram/ ha)	Carbon stock in Herbaceous stock (Megagram/ha)	CO_2 mitigation per ha (Megagram/ ha)
4th year after fire	1.Dholu (*Chrysopogon montanus* Trin) 2. Lamba (*Heteropogon contortus*) (Lamba) 3.*Thermedia anathera*	4.16	1.64	2.64	9.69
3th year after fire	1. *Chrysopogon montanus* Trin. 2.Dholu (*Heteropogon contortus*) (Lamba) 3 .*Thermedia anathera*	3.16	1.16	1.94	7.12
2th year after fire	1.*Chrysopogon montanus* Trin. 2. (*Heteropogon contortus*) 3. Thermedia anathera	2.18	0.93	1.89	6.95
1th year after fire	1.Dholu *Chrysopogon montanus* Trin 2.Lamb Grass (*Heteropogon contortus*) 3. Thermedia anathera	2.42	0.95	1.52	5.58
0th year after fire	1. Lamb grass *(Heteropogon contortus)*	0.80	0.95	0.51	1.87

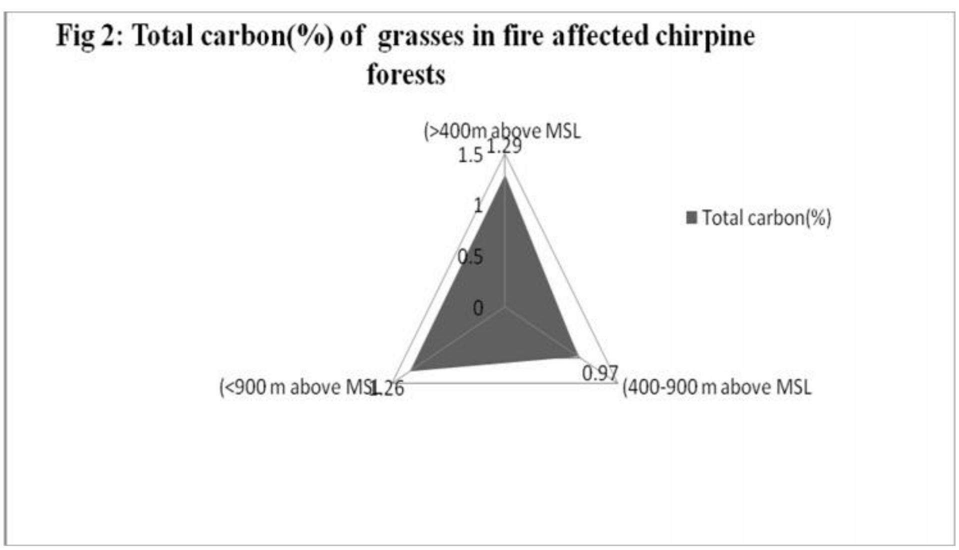
Over all forest soils showed increase in soil carbon (table-4) with interval after fire took place last time. The total carbon in the soil was lowest to the tune of 0.94 % just after the fire and (Zero year after fire) and highest after four years of fire i.e. 1.91 %. The total organic carbon varied after the fire and increased up to 41.29 mg ha^{-1}in forest after four years of fire. Reddy et al (2017)observed that tropical dry deciduous forests are contributing high emissions of about 33.88 Tg yr−1 followed by the tropical moist deciduous forests (26.65 Tg yr−1), tropical semi-evergreen forests (4.19 Tg yr−1) and tropical wet evergreen forests (1.73 Tg yr−1). Among the non-forest types, tropical dry scrub and grassland were estimated with high emissions of 20.49 and 22.33 Tg yr−1, respectively. Similar results were also reported by Chan and McCoy(2008) who proved that the management have effect on the variation in SOC amongst different pastures. Even in savannah, it has been shown that C lost through combustion can be replaced during the following growing season (Ansley *et al*., 2002). Regarding the soil, the intensity and speed of the fire will govern the depth to which it is affected. In one study where burning was used to clear forests, 4 tonnes C/ha was lost in the top 3 cm of soil, but this was replaced within one year under a pasture system (Chone *et al*., 1991).

Table 4: Carbon sequestration level in forest soils of *Pinus roxburghii* Sarg. Dominated forest affected by fire

Fire affected Sites in different years	Total carbon (%)	In-organic carbon (%)	Total Organic Carbon per ha(mega Gramm Per Ha)
4th year after fire	1.91	0.07	41.29
3th year after fire	1.06	0.02	22.92
2th year after fire	1.84	0.03	40.84
1th year after fire	1.24	0.03	30.16
0th year after fire	0.94	0.03	20.76

Not all soil C is associated with organic material; there is also an inorganic carbon component in soils. In-organic soil carbon also showed changes along altitude under Chir pine forests. It decreased along the altitude at same aspect under same density of pine trees having same age. It was recorded to be maximum of 0.17% in pine forests growing at elevation below than <400 m msl and lowest in the soils to the tune of 0.05% in pine forests growing at the altitude of >900 m above msl (Fig-1). The dynamics of the inorganic carbon pool are poorly understood although it is normally quite stable. Sequestration of inorganic C occurs via the movement of HCO^-_3 into groundwater and closed systems Schlesinger (1997). Lal, Hassan and Dumanski (1999) believe that the sequestration of secondary carbonates can contribute 0.0069 - 0.2659 Pg C/year in arid and semi-arid lands and also opined that release CO_2 will be there from inorganic carbon if the carbonates become exposed through erosion.





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