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Fire environment and community based forest fire management in Central Siwalik region of Nepal

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Abstract

Forest fire is a result of complex interactions among vegetation, weather and forest users in Nepal. A study was carried out in 20 community forest of central Siwalik of Nepal. Forest fire data of about a decade from Fire Information for Resource Management System (FIRMS) and meteorological data of 30 years were also analyzed in the study. In the last decade, March, followed by April and February witnessed largest number of fire in study area. The environment on those months is very conducive for the fire to occur on forest due to phenological character of vegetation and weather in the area. Month of March and April receive highest amount of leaf fall. Similarly, temperature in the area reaches as high as 40 ^{0}C in that period and those months receive less than 20 mm of rainfall in total, often receiving no precipitation for entire five months period in worst cases the result of which is the severe drought. With growing human population, the forest is under pressure to cater diversified needs of people. Fire is intentionally set by herders to promote sprouting of grasses and by hunters to catch prey. Accidental fire is also common where the interaction between people and forest is acute. The fire hazard is increasing indicated by increasing number of dry days and rising temperatures. Forest users haven't realized ecological effect of change in fire regime though. Even though some community forest user groups have intensified their activity to manage fire in their forest, most of them are not technically capable in managing fire in their forest effectively; they are practicing some labor intensive methods for exclusion and suppression of fire. Even though they haven't been able to totally exclude fire from their forest, they have largely been successful in minimizing the area consumed by fire in recent years, however. The study revealed that forest users are unaware about ecological and cultural aspects of fire. The effort of fire management is limited to exclusion of fire from forest through sensitizing and mobilizing users, improving communication channel for firefighting operations, institutional strengthening for sanctioning the non-cooperating users and constructing fire lines to exclude fire. The study therefore suggests concerned authority to formulate policy and programs to aware forest users on community based integrated forest fire management and assist them to plan and implement fire management in their forests.

Introduction

Fire is a common phenomenon in every continent except Antarctica. Ignition sources and flammable materials interact to cause fire in temperate ecosystems, boreal and tropical forests, and savannas and grasslands (Omi, 2005). Nepal, a small country with area of 147,181 sq. km and human population of 23 million in South Asia has 29 percent of forest cover (DFRS, 1999). The country witnesses the diversity of forest due to high altitudinal variation that ranges from 60 m to 8,848 m from mean sea level. Fire is common on forests of all physiographic regions in the country, particularly in dry deciduous forest.

Fire is one of the major drivers of deforestation and forest degradation. About 90% of the forest area in the tropical region of the country is affected from fire annually, most of which is surface fire which results in the reduced regenerative capacity of forest (ITTO, 2009). Forests in tropical region are under high risk due to fire prone fuel and management system. Every year, fire burns the large area consuming lives and property so it is considered most important human induced disasters (FAO, 2006b).

358 forest fires were detected in Nepal only on April, 25, 2009 (PSPL & FECOFUN, 2010). The damage by forest fire in year 2009 is burning of 146,742 ha, 43 people killed; estimated total loss by fire excluding cost of environmental damage and flora and fauna is NRs[1] 134,415,000 (GoN, 2010). This large number of fire on a single day indicates the gravity of forest fire issue in the country.

Community Forests and Forest Fire

Community forest is the part of national forest which, according to Forest Act, 1993, is "forest handed over to users group for the development, protection and utilization of forest in the interest of the community." Under this management regime, formally registered Community Forest User Group (CFUG) is handed over the use and management right of the forest of its vicinity for the indefinite period. CFUG prepare periodic operational plan in participatory way for guiding forest management by themselves (GoN, 1995).

Community forest occupies more than one fifth area i.e. 21.34 % of total forest in the country. Forest area handed over to the community is just 34. 92% of potential area that can be handed over to the communities as community forest (DoF, 2010). The forest handed over to the communities are commonly fragmented and surrounded by villages. The communities are responsible for all the activities in their forest. However, neither do they have appropriate plan for systematic prevention of forest fire given to their limited technical capacity nor do they possess sophisticated technologies and modern equipments tools to manage forest and fight forest fire. Although the community forests in Siwalik region are fire prone, fire management activities by communities is limited to appointment of fire watchers and mobilization of forest

[1] Approximately 100 NRs (Nepalese Rupees)= 1 USD (United States Dollar)

guard in dry period and communicating to users for help in any incidences in active CFUGs (FAO, 2006b).

Forest fire in Community Forests in Central Siwalik

There are three main factors which, according to Heikkila, 2007, influence fire behavior are fuel, weather and topography. Fuel for forest fire is the organic material- live or dead- that will ignite and burn in, on or above the ground. It comprises dry leaves, twigs, stump and so on. Fuel availability is primarily affected by fuel moisture content, wind, and topography (Omi, 2005).

A study in Siwalik region of Makwanpur district revealed various characteristics of fuels in the forest. The fuel was continuous in most instances and leaves were present in one to four layers. Leaves comprised 95 % of volume of total fuel where leaves of Sal (*Shorea robusta*) were 90 % in volume of the total volume of leaves. The dry volume of fuel was as much as 10.7 tones per hectares (DFO/Makwanpur, 2008).

Sal (*Shorea robusta*) forest along with smaller proportion of some patches of moist evergreen forest, dry deciduous forest and Khair (*Acacia catechu*) forest is found on the area with tropical climate on the country. Forest covers 475,000 ha, in the region. Similarly, shrubland and grassland covers 111,000 ha in the region. Glabrous Sal leaf litter in the forest catches fire every year and other naturally regenerated herbs and shrubs also got burnt in the process. The fire is not so severe that it neither damages large trees nor does to the root system. Only plants exposed on the ground level are burnt (FAO, 2002).

Weather alone is not sufficient to determine fire behavior, yet it is one of the most important factors. It interacts with other factors and results in the actual fire behavior. The magnitude and seasonal distribution of weather factors have tremendous impact on fire (Omi, 2005). Temperature, another basic weather factor, influences the drying of forest fuel (Heikkila et al., 2007). Forest fire weather mainly explains drought in the environment. Amount of fuel and its moisture content determines the fuel availability; availability of fuel for fire is dependent not only on biomass in the forest but also the dryness of the biomass in the forest (Wagner, 1987).

From June to September, 80 % of the precipitation in the country occurs in the form of summer monsoon. The average annual rainfall in the country is about 1600 mm but it shows spatial variation. Temperature also varies across the climatic regions. Winter temperate in tropical region ranged between 22 and 27^0C which exceeds 37^0C in summer. As a thumb rule, the temperature decreases by 6^0C with gain in altitude of every 1000m in the country (ICIMOD, 2007).

Forest Fire Management

Fire is regarded as one of the components of social ecological system-“an integrated system of ecosystems and human systems with reciprocal feedbacks and interdependence” (Resilience

Alliance, 2010). Fire management, according to Myers, 2006, is "range of possible technical decisions and actions directed toward preventing, detecting, controlling, containing, manipulating or using fire in a given landscape to meet specific goals and objectives". Based on the definition, the fire management triangle, which explains the balance of fire use, prevention and suppression to achieve the desired goals as depicted in Figure 1.

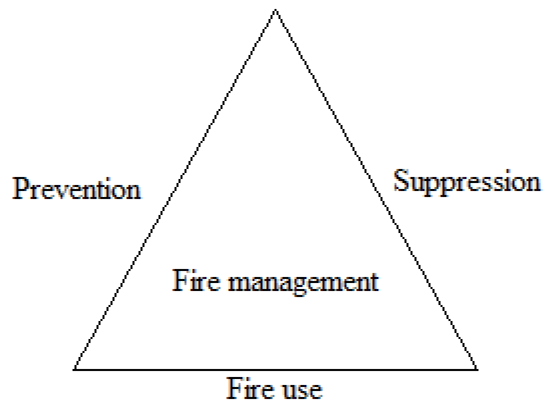


Figure 1 Fire Management Triangle Adapted from Myers, 2006

The fire management practice by community has been given the name community-based fire management (CBFiM) which is increasing in developing countries. Communities, under this practice, manage fire in participatory manner according to their self-interest which emerges over time in a landscape. CBFiM is being practiced in India, China, Nepal and Turkey where handling fire by community in forest has been improved credit of which goes to changed attitude due public awareness program and new community regulation (FAO, 2007).

Fire is not always hazardous; livelihood of many groups of people depends on regular occurrence of fire on forest. Also, fire is seen as a reliable means of reducing fire hazard through controlled burning. Acknowledging this benefit, people in the community sometimes set fire on forest. However, most of the community put effort to exclude fire from forest. Community involvement in forest management is considered successful for rehabilitating forest condition in Nepal (Chapagain and Banjade, 2009).

Forest users can bring positive change in their lives and bring sustenance in resource system engaging in collective action. Inclusive institution have empowering role in protecting and improving livelihood of forest users (Bruns and Bruns, 2004). This opens up the way for participatory management of fire (FAO, 2006a). Government of Nepal and other agencies working in the field have emphasized the community based fire management the result of which is encouraging. Fire management by community forest in the country is publicized as largely successful approach. The communities share the responsibility of preventing and suppressing fire in their forest. There is increasing community involvement and interest in participatory integrated management of fire (FAO, 2007).

Integrated Forest Fire Management in Nepal

Integration of three technical components of fire management, key ecological attributes of fire and socio economic and cultural necessities of fire use and its negative impact involves in integrated fire management. People in Nepal have been using the fire as means of land clearing, stimulating the growth of forage, etc. (FAO, 2006a) many of which are undocumented. Though, fire has cultural link with people, fire is seen as only problem on almost all policy and legal document (GoN, 1993; GoN, 1995).

Government has discouraged the introduction of fire in forest irrespective of its purpose and effect. In legal documents of Nepal, there is provision of punishment for the people or agency that set fire in forest (GoN, 1993). Based on this law, management plans of forest focus on excluding fire from the forest. Fire management practice mostly involves the exclusion of fire from forest; they focus on prevention and suppression of fire among three technical component of fire management (FAO, 2003). Based on available and collected data, this article briefly analyses the fire environment of community forests and management effort by Community Forest User Groups in Central Siwalik of Nepal.

Materials and Methods

Study area

The study was carried out in Siwalik area of Makwanpur and Chitwan districts in Central Development region in Nepal (Fig 2). The area selected for the study is located between 27^{0}21’ and 27^{0}46’ N latitude and 83^{0}55’ and 84^{0}35’E longitude and possesses tropical climate. Forest, mostly of mixed Shorea robusta, is the dominant land cover in the area (56.7% in Makwanpur and 62.92% in Chitwan) (DDC/Chitwan 2005; DDC/Makwanpur 2010). The study was carried out in 20 Community Forests of Central Siwalik Region of Nepal. The study represents tropical area between Churiya range in the South and Mahabharat range in the North in Makwanpur and Chitwan districts. Similarly, the eastern and western boundaries of the study area are Bagmati River and Narayani River respectively. The area was selected for the study because of the following key characteristics of the area (DFO/Makwanpur, 2011; DFO/Chitwan, 2011):

- High fire susceptibility
- Forest as dominant land cover
- Pioneer districts in community forestry in the physiographic region

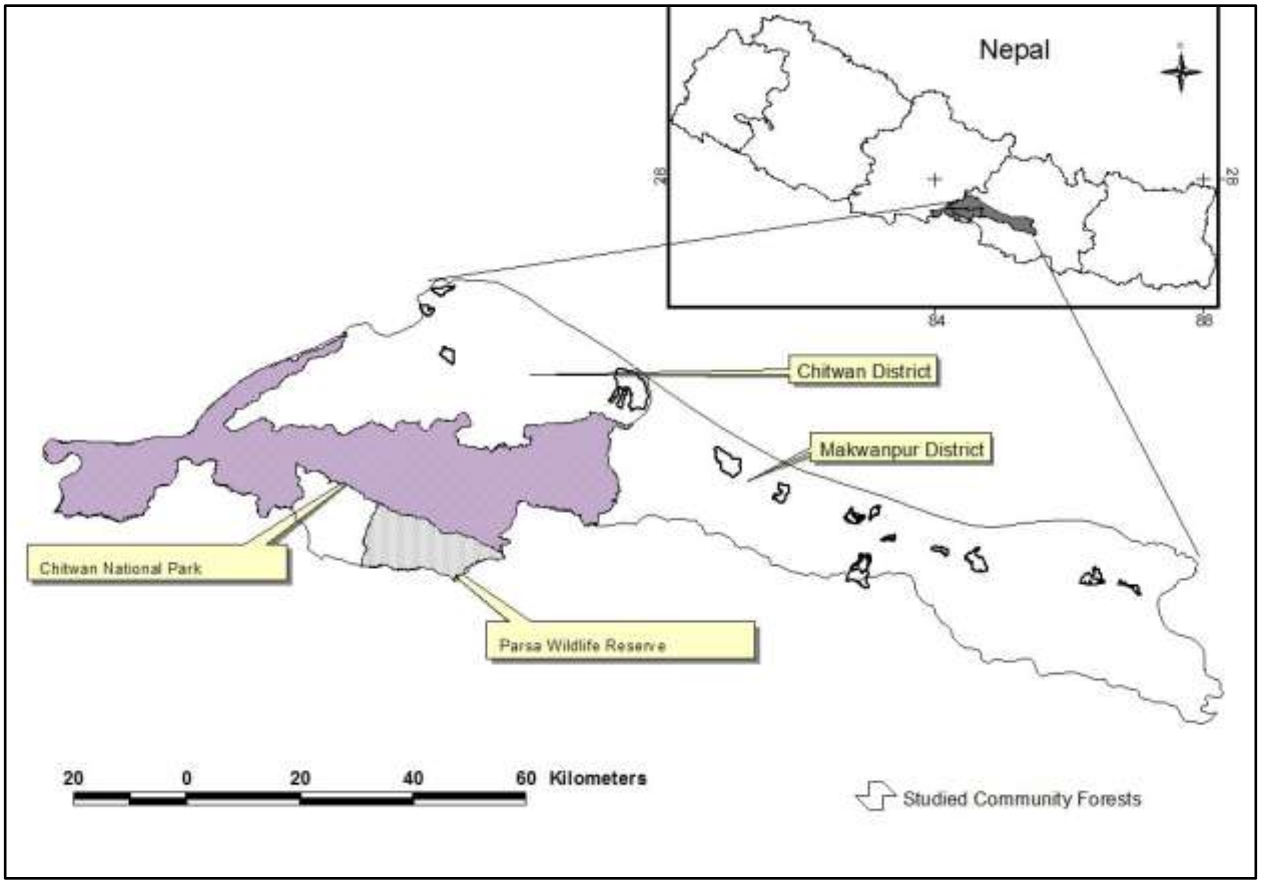


Fig 2 Map showing Study area and studied community forests

Data collection and analysis

Different types of data were collected for the study purpose. Meteorological data were collected from meteorological stations of Department of Hydrology and Meteorology of Government of Nepal for 30 years. Daily precipitation and temperature (maximum and minimum) data collected from eight stations from the year 1981 to 2010 were obtained. However, due to irregularity, data from two stations only viz. Hetauda and Rampur were considered worthy of analysis. Hetauda station lies in Siwalik region of Makawanpur district while Rampur station lies on Siwalik region of Chitwan district. The temperature data was analyzed to get monthly maximum temperatures, yearly maximum and its trend. Similarly, precipitation data was analyzed to get monthly average precipitation, total annual precipitation, annual maximum number of consecutive dry days i.e. days receiving less than 1 mm precipitation, and their trends.

The data on fire occurrence in Nepal for 2001 to 2012 was obtained from FIRMS which generated data on fire spots from satellite images captured by MODIS and processed and supplied by University of Maryland. The data was supplied in the .shp file for all the possible points for the whole country which was clipped for the Siwalik region of Makwanpur and Chitwan districts excluding other forest regimes. The data were classified into 3 groups as guided by FIRMS. The data points having confidence level equal to or more than 80 percent were grouped into high group for their high probability of being forest fire occurred site. Likewise, the spot having confidence interval between more than 30 and less than 80 were grouped under medium and those below 30 were under low confident points. To ensure certainty, only the points falling in the high group were only counted as the fire spots.

Table 1 Description of studied CFUGs

S.N.	Name of CFUG	Address	Area (ha)	Number of HHs	Year of CFUG registration
1	Jyamire Kalika	Manahari-7, Makawanpur	410	477	1993
2	Chanauta	Basamadi-1, Makawanpur	316.92	229	1998
3	Dangdunge	Hetauda-11, Makwanpur	196.4	400	1995
4	Neureni Chisapani	Hetauda-7, Makwanpur	71.13	248	1990
5	Ashok	Hatiya-2, Makawanpur	137.5	193	1993
6	Mahankal	Phaparbari-7, Makwanpur	155	71	1997
7	Sundar	Hetauda-1,2, Makawanpur	109	206	1995
8	Parebashwori	Piple-6, Mahadevtar Chitwan	1311.9	601	1996
9	Shivapuri	Piple-7, Chitwan	127	261	1995
10	Pashupati Kailashpuri	Piple-7, Chitwan	127	226	1996
11	Thakal dada	Basamadi-8, Makawanpur	99.47	130	1996
12	Ektare	Hetauda-11, Makwanpur	58.8	170	1994
13	Kalika Chandika	Bhaise-2.3, Makawanpur	896.75	212	1998
14	Panchakanya	Harnamadi-4, Makawanpur	516.61	211	1995
15	Namobuddha	Phaparbari-7, Makawanpur	115	170	2000
16	Pari Pakha Harda dada	Phaparbari-3,4,5, Makawanpur	163.88	222	2001

17	Ratmate	Churiyamai-3, Makwanpur	457.28	312	1997
18	Satanchuli	Bharatpur-1, Chitwan	198.1	560	1999
19	Jaldevi	Bharatpur-2, Chitwan	189.87	982	2001
20	Rambel	Bharatpur-12, Chitwan	197	1306	2001

Source: Operational plans of studied CFUGs, 2011

Similarly, socio-ecological data were collected from 20 CFUGs of Siwalik area of Makwanpur and Chitwan district (Table 1) in 5 months i.e. from September 2011 to January 2012. The CFUGs were selected so as to represent variability brought about by different location of CFUGs and activeness of communities in responding to forest fire. District Forest Offices (DFOs) and Federation of Community Forest User Group at local level helped to select the CFUGs considering objective of the study. Focus group discussion was carried out in each CFUG for collecting data on source, timing, location and trend of fire in their forest. Similarly, 60 users from six different CFUGs were interviewed for their understanding on different aspects of forest fire.

Results and discussion

Fuel in Community Forest in Central Siwalik

Shorea robusta constitutes more than two third biomass of the community forest in the Siwalik region. The species is dominant in all the community forests considered in this study. Users reported that most of leaf shedding of *Shorea* takes place in short period of less than a month in March. Monthly data collected by Bhatta & Shrestha in 2006 and 2007 from Rani Community Forest, a community in Siwalik area of Makwanpur district, supports the claim of users. In their study on amount of leaf shedding in community forest having pole strata of 18 years in Siwalik, leaf of *Shorea robusta* constituted 66% of total leaf fall in a year i.e. 8.35 tons/hactre (Fig 3). Their study showed leaf fall of *Shorea* took place within a short period of less than a month in peak dry season. Also, leaf fall in forest of Siwalik followed unimodal pattern with majority of leaf shedding in short period from February to end of May demonstrating peak in March. Left in the forest floor in peak dry season, the dried leaf is the main fuel load in the forest (Bhatta & Shrestha, 2010).

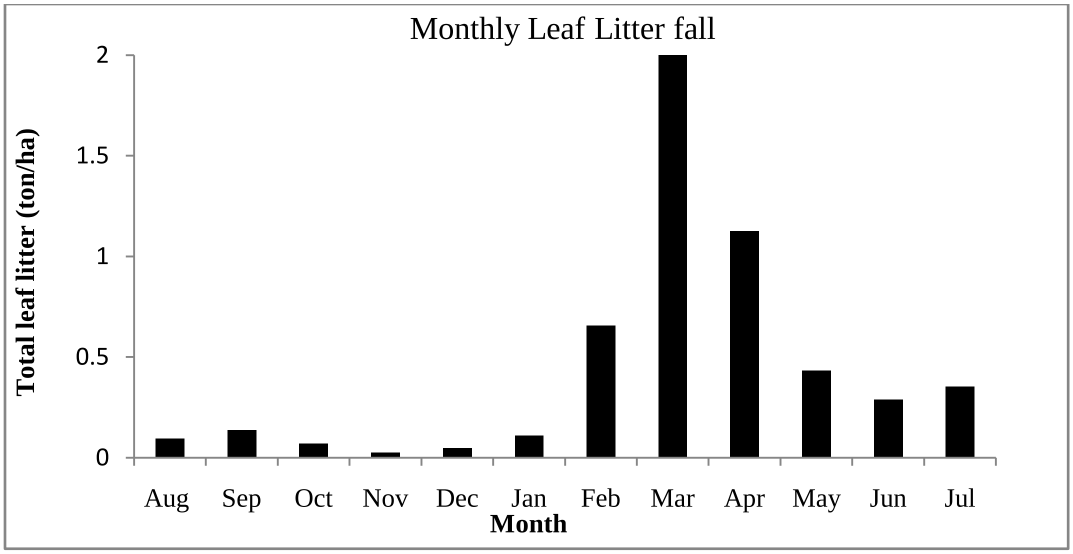


Fig 3 Monthly leaf litter fall of *Shorea robust* community forest adapted from Bhatta & Shrestha, 2010

All the CFUGs reported that growing stock in their community forest is increasing. They reported that, with increase in conservation effort by community upon handover of management responsibility and use right to local user, the growing stock in the forest has increased in the forest of each CFUG. However, due to protection of plants in recent years, the dead materials, particularly leaf litter, has also increased especially on the fire prone period. As a result, amount of the fuel is increasing in the community forests in Central Siwalik area.

Fire weather

Weather alone is not sufficient to determine fire behavior, yet it is prime factor. It interacts with other factors and results in the actual fire behavior. The magnitude and seasonal distribution of weather factors have tremendous impact on fire (Omi, 2005). Temporal distribution of precipitation can have pivotal role in understanding occurance of fire in forest (Alencar et al., 2006). Unimodal rainfall distribution can be observed in the Central Siwalik of Nepal. The daily data of 30 years from 1981 to 2010 shows that November, December, January, February and March are dry months in both the station (Fig 4). These months receive less than four percent of total annual rainfall i.e. 3.42% and 3.73% in Hetauda and Rampur respectively. Even though Hetauda station gets higher amounts of precipitation than Rampur, the pattern of distribution of precipitation is not different in both the stations.

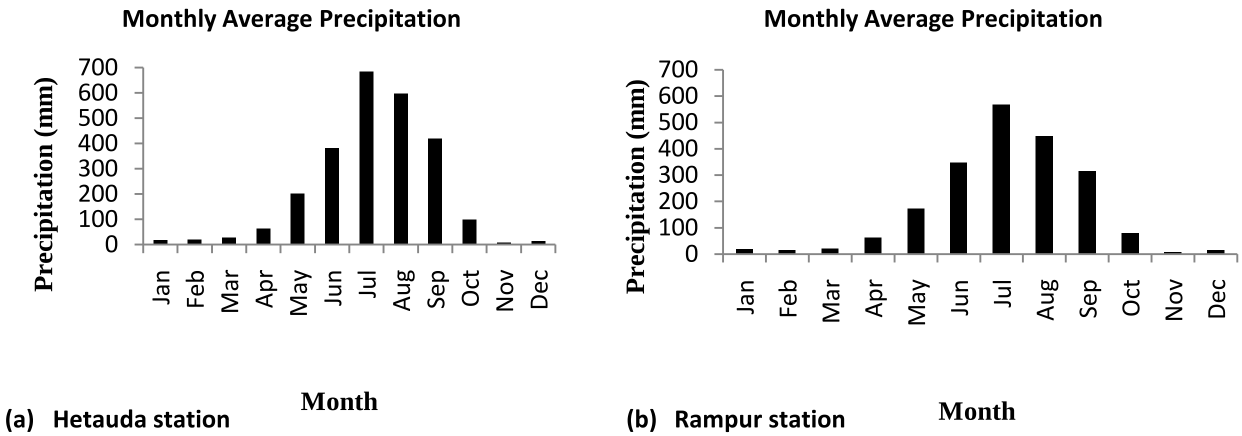


Fig 4 Monthly Average Precipitation in (a) Hetauda station and (b) Rampur station based on daily precipitation data of 30 years

Analysis of precipitation data showed that total annual precipitation in Central Siwalik area is 2267.3 mm (2463.5 mm and 2071.1 mm in Hetauda and Rampur respectively), which is higher than the national average of 1600 mm (ICIMOD, 2007). T-test revealed that, under 0.01 level of significance, the total annual precipitation in Rampur is significantly higher than that in Hetauda station. However, both the station witnessed increasing trend in total annual rainfall (Fig 5).

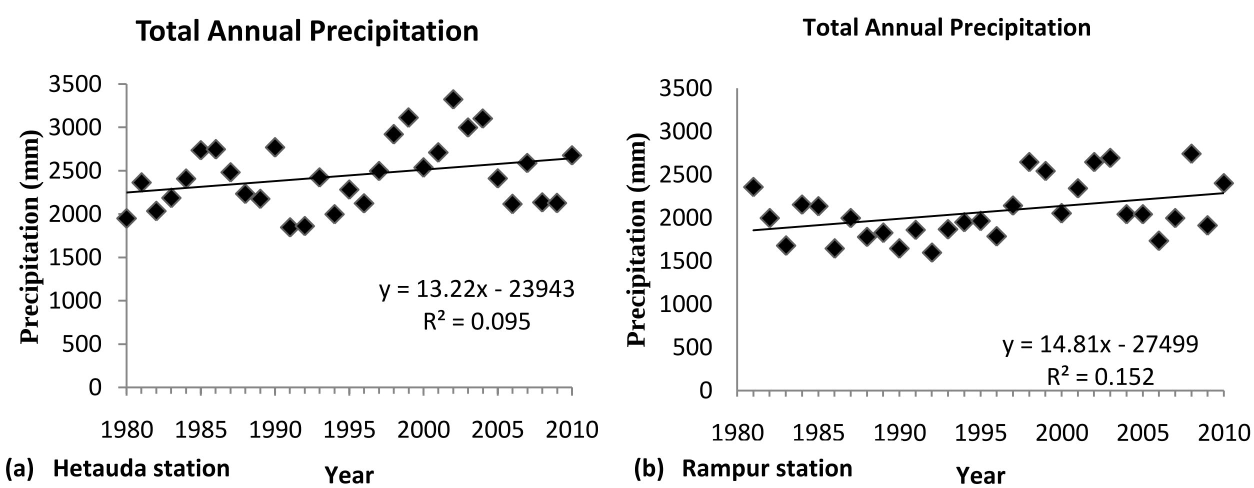


Fig 5 Total annual precipitation in (a) Hetauda station and (b) Rampur station based on daily precipitation data of 30 years

Similarly, Maximum numbers of consecutive dry days (days receiving less than 1 mm of precipitation) in each year for from 1981 to 2010 were found to follow no clear pattern. Fig 6 shows that the maximum numbers of consecutive dry days are showing greater fluctuation in recent years than in the past. The diagram points out that number of consecutive dry days over the period ranged from 28 days in 2004 to 141 days in 1999 for Hetauda station; whereas, it ranged from 43 days in 1987 and 1995 to 170 days in 2009 in Rampur station. However, t-test showed no significant difference in mean of the maximum consecutive dry days in both stations; mean of maximum number of consecutive dry days in Hetauda and Rampur stations are 71.33 and 74.03 respectively. The trend analysis of both the station shows increasing number of consecutive dry days. Likewise, maximum numbers of consecutive dry days were mostly observed in months of November, December, January and February.

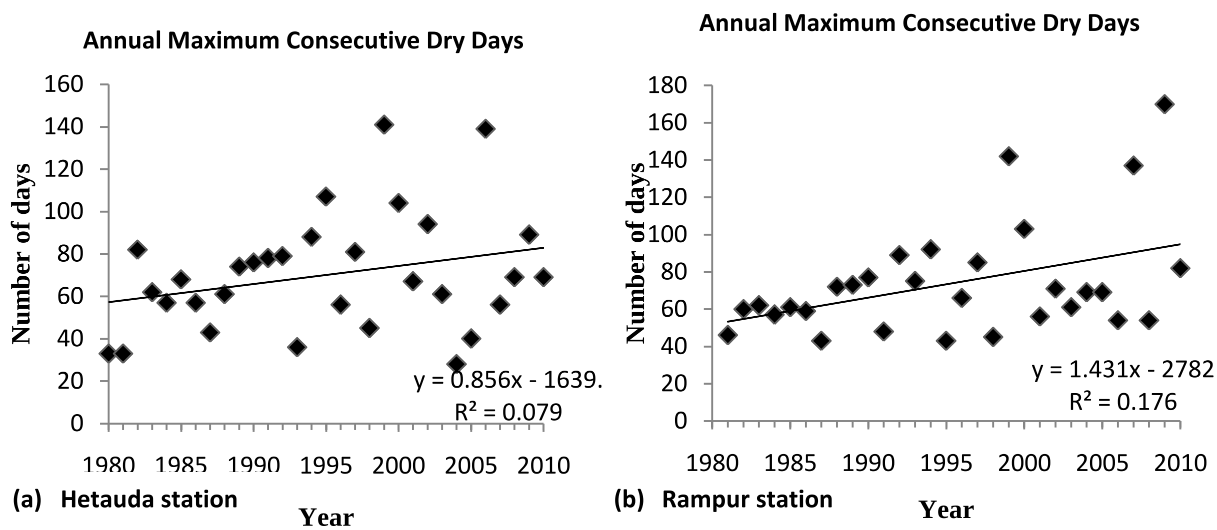
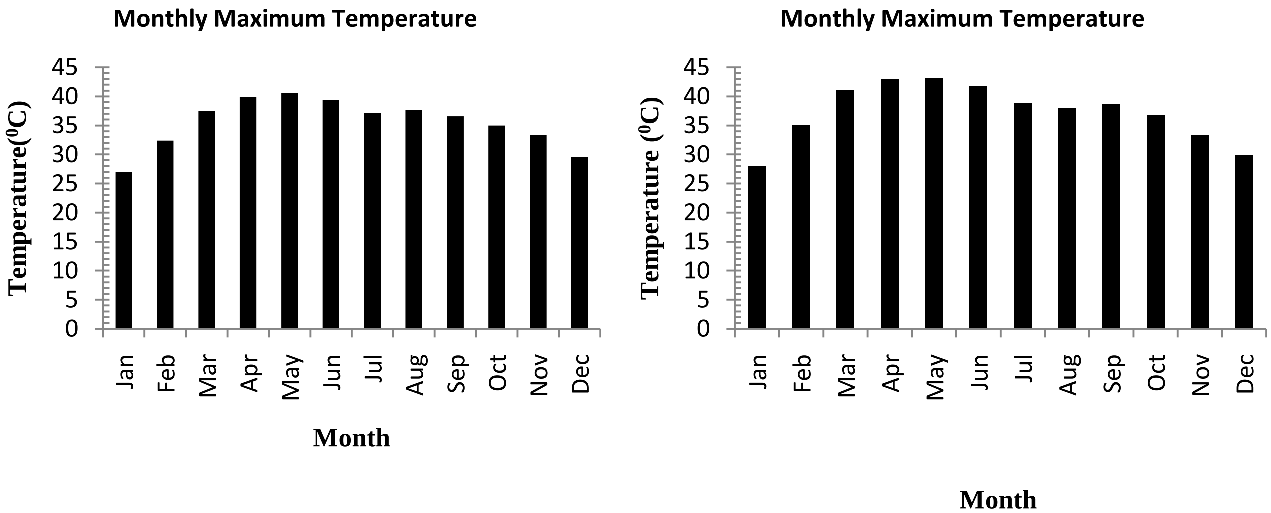


Fig 6 Maximum consecutive number of dry days in (a) Hetauda station and (b) Rampur station based on daily precipitation data of 30 years

The analysis of temperature data suggested that the temperature could reach as high as 43.2 ^{0}C in Rampur and 40.6 ^{0}C in Hetauda in the Month of May. The maximum temperatures in 12 months in 30 years on those stations were found as shown in Fig 7. Although the temperature is significantly higher in Rampur, as depicted by t-test under 0.01 level of significance with mean temperature 38.41^{0}C and 40.63^{0}C at Hetauda and Rampur respectively, the pattern of distribution is nearly similar in both the stations. According to the diagram, the maximum temperature reaches its peak in the month of May followed by April, June and March respectively.

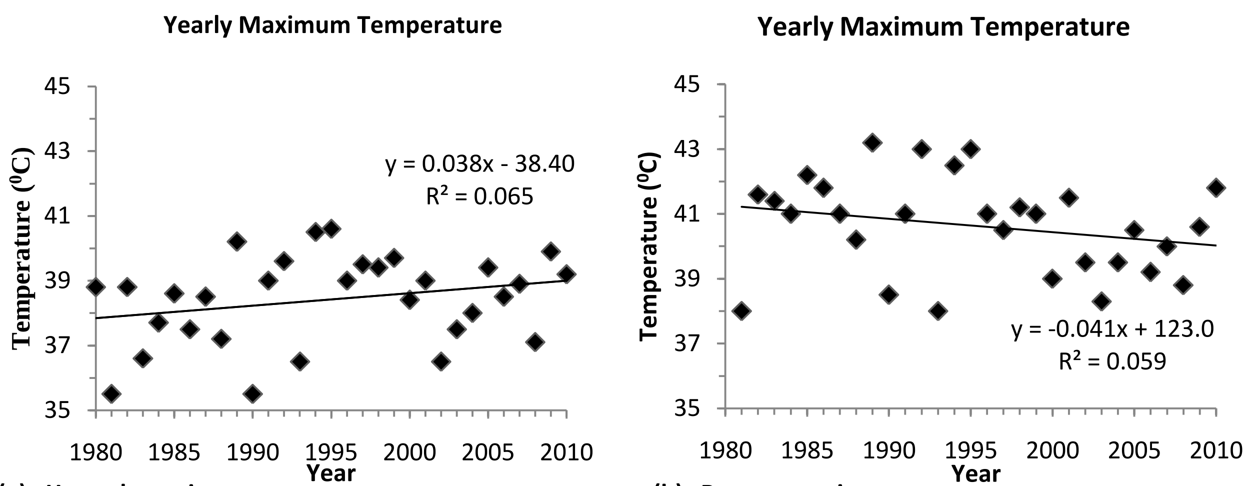
By desiccating all the dead and fallen parts of plant to the maximum level, the higher temperature favors the occurrence and spread of fire in the forest making fuel available for the fire. Despite this, May and June, among the hottest months, receive considerable precipitation and are less prone to fire due to unavailability of fuel because of excessive moisture at the period. February was found to have maximum number of consecutive dry days. Therefore, February including March and April was found to have favorable weather for fire to occur.



(a) Hetauda station (b) Rampur station

Fig 7 Monthly maximum temperature in (a) Hetauda station and (b) Rampur station based on daily temperature data of 30 years

Likewise, no regular and easily understandable pattern was observed in yearly maximum temperature distribution in both the stations (Fig 8). The maximum temperature ranged from 35.5^{0}C to 40.6^{0}C and 38^{0}C to 43.2^{0}C in Hetauda and Rampur stations respectively. According to t-test, the stations did not show significant difference in monthly maximum temperature; the mean monthly temperatures at Hetauda and Rampur stations are 35.50^{0}C and 37.28^{0}C respectively. Surprisingly, the yearly maximum temperature followed increasing trend in Hetauda station while it showed opposite trend in Rampur station.



(a) Hetauda station (b) Rampur station

Fig 8 Yearly maximum temperature in (a) Hetauda station and (b) Rampur station based on daily temperature data of 30 years

The prolonged period of drought is always favorable for forest fire to occur given other conditions are constant (Ricklefs, 2008). The analysis shows most of the drought occurs during the fire prone season. Despite increasing trend of total annual precipitation, the maximum number of dry days in each year shows increasing trend which poses the increasing challenge for management of wild fire.

The temperature in Nepal is rising by 0.05^0C/year (APN, 2005). Forest fire is robustly connected with weather and climate (Johnson & Miyanishi, 2001). In the face of global warming and complex environment it creates, drought is likely to amplify. Rising atmospheric temperature has adverse effect on rain factors and wind in Nepal (PSPL & FECOFUN, 2010). Important factors of forest fire weather, temperature and rain have serious implication in forest fire. The increase in drought period and its intensity automatically leads to more fuel availability and ultimately the increased incidence of fire occurrences

Occurrence of Forest Fire

Remotely sensed data is largely used to detect and monitor forest fire hot spots (Stolle et al., 2004). Data of fire spots received from FIRMS showed that fuel and fire weather have direct association with number of fire spots in community forests of Central Siwalik region. As shown in the Figure 9, 330 fire spots were detected by MODIS from January 2001 to December 2011; of which 202 fire spots in the area were detected in March alone. April is second most vulnerable month for forest fire with 83 spots. Likewise, February and January got fire in 42 and 3 spots respectively. However, for the duration from 2001 to 2012 there were not any fires detected in other months.

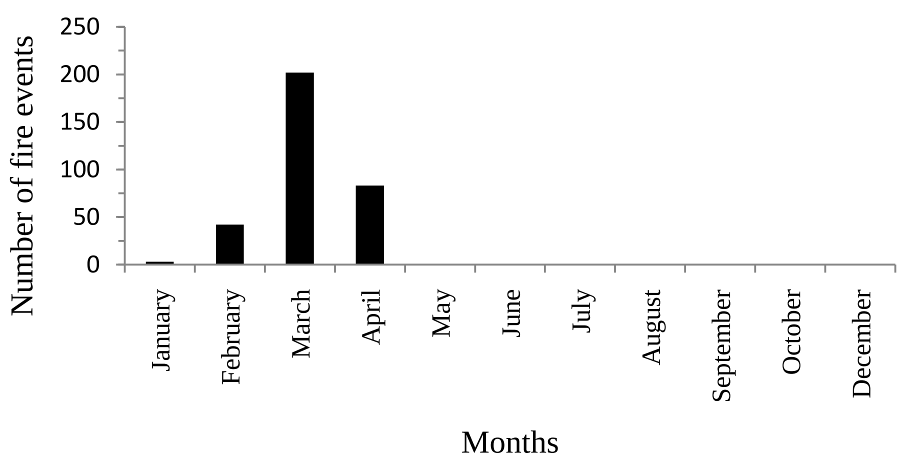


Fig 9 Total number of fire spots detected by MODIS from 2001-2011

Similarly, the total number of fires spots from 2001 to 2011 showed fluctuation with occasional peak. The highest number of fire i.e. 59 was found in 2010 whilst the lowest was five in 2002. However, the total number of fire events in each year shows an upward trend as presented in Figure 10.

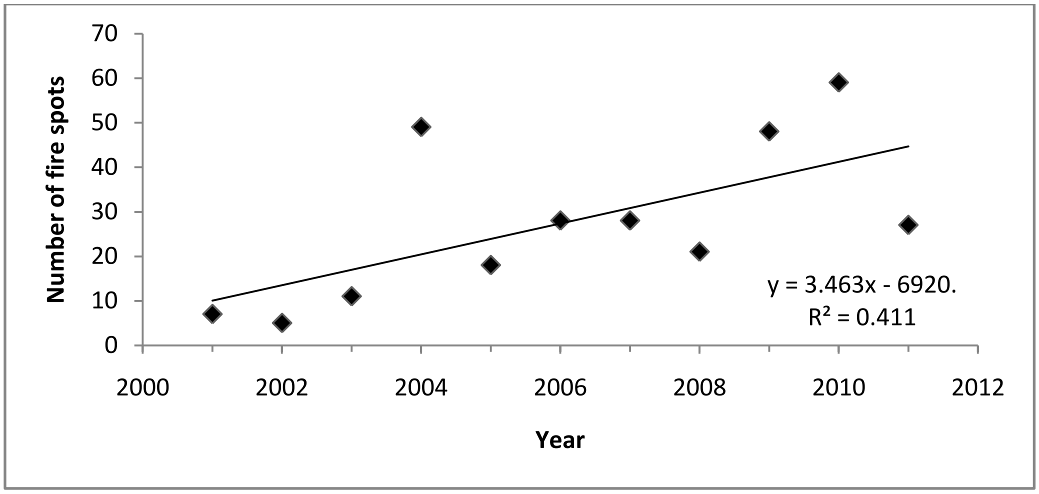


Fig 10 Total number of fire spots detected by MODIS in each year from 2001-2011

Causes fire in community Forests

The majority of fires are initiated by human action, and the fire system is the product of social, economic, and biophysical factors operating with feedbacks and interactions across spatial scales (Dennis et al., 2005, Sorrensen, 2009). Since setting fire in forest is defined by Forest Act, 1993 as a serious crime, arsonists were rarely caught. Also, controlling fire in community forest falls under responsibility of CFUGs. However, CFUGs were unable to exactly identify cause of forest fire in their forest. Discussion with users of CFUGs listed one or many of the causes of fire in their forest from the following list:

Natural Causes

- Rolling stone as an ignition source
- Lightening as an ignition source

Accidental causes

- Children for enjoying
- Source of fire such as inextinguished cigarette stabs by trespassers
- Spreading of fire from adjoining forest

Intentional causes

- By shepherds to incite growth of succulent needed for livestock
- By hunters to catch prey such as wild boars and rabbit
- By trespassers to kill insects and snakes on road and ease movement

- By households residing near forest to minimize likelihood of catching fire in difficult situation
- By unsatisfied people to take revenge of punishment from CFUG

We found that the majority of existing studies did not explicitly identify landholders, yet almost all fire in tropical forests is caused by people, and local agents therefore play a significant role in the system (Giri & Shrestha, 2000; Kull, 2002). The causes of fire in the community forests of Central Siwalik are not very different from the causes of fire in overall tropical region identified by FAO, 2006b. It was found that in user's perception the fire from carelessness, followed by fire set by herders to promote the succulent growth of grass is the main cause of fire in the community forests of Siwalik region. Individual users did not differ largely on their understanding about the causes of fire in community forest. Instead it was found that users were familiar with the causes of fire in their community forest.

Forest Fire Management in Community Forests

Fire management techniques comprise the activities that can reduce and prevent fire occurrence such as early burning, firebreaks and control lines, technical management fires (MFAF, 2007). All of the CFUGs claimed that their forests are getting more attention and care in reducing source of fire and escalating suppression effort, although their activeness in doing so and effectiveness, thus achieved, differ. However, effort of most CFUGs is limited to exclusion and suppression of wildfire as the fire management approach in their respective community forest.

Even though the country is on the way to community based fire management (GoN, 2010), management of fire was not found prioritized in operational plan of 95% of CFUGs. Only one CFUG was found proactive in managing fire in its forest; it had prepared a detailed fire management plan and arranged enough fire fighting tools and trained user to manage and fight fire. However, some of them have launched some activities targeting fire management in their forest. The key activities are (i) awareness raising; (ii) construction and maintenance of fire line; (iii) monitoring and detection of fire; and (iv) suppression of fire.

(i) Awareness raising

Among 20, six CFUGs were found to organize events related to wild fire. The events included training to users, dissemination of information via posters and broadcasting awareness raising advertisement through local radio station. Some of the financially weak CFUGs but concerned about the problem of wildfire cooperate with DFO to get posters and pamphlets illustrating the way to keep fire out of their forest.

(ii) Construction and maintenance of fire Line

Most common activity of CFUGs to protect their forest from fire was construction of fire line. Among 20 studied community forests, 12 CFUGs had constructed fire line. However, the length of fire line in those community forests varied significantly; it ranged from 18 Km to 0.3 km. Research revealed that the fire line was, nevertheless, constructed without proper planning and was too insufficient to contain fire. Likewise, not all the CFUGs cleared the fire line before dry season and during leaf litter fall. Instead, some CFUGs reported the fire line was not effective in controlling fire due to cover of fire line by large amount of leaf litter due to leaf fall within a short span of time.

(iii) Monitoring and detection of forest Fire

Users and local people were the only source of forest fire monitoring in community forests. Some financially strong CFUGs appointed and deployed forest watchers to monitor anomalies within the boundary of their community forest. In most CFUGs, the responsibilities of the watchers is not limited to monitoring fire in the forest but to control and report other illegal activities within their territory. So, most CFUGs employing the watchers mobilize them for the all year around, not only in dry season. The number of watchers employed depends on the capacity of CFUGs to pay them and also the threat their forests face. One CFUG appointed forest watcher only in fire prone season. Up to nine forest watchers-CFUGs were employed by each of two CFUGs.

CFUGs depended on not only paid watchers, but also by users only in one CFUG. Users from every household monitored at least one day in every two months. Because of this rule, in that CFUG around 15 users patrol the community forest daily. Considering fire risk, some CFUGs increased monitoring activities in the fire prone season. Four CFUGs reported that they increase the number of watchers in dry season especially focusing the monitoring and control of fire.

Though the forest watchers are employed to detect fire, due to dependency of watchers on other sources for their livelihood because of limited payment by CFUGs in most instances, they do not give their all times to monitor forest and particularly in the evening and night when the fire starts. So, forest watchers are less common sources of forest fire detection. In this case, users have to rely on people passing through that area or other villagers for information on occurrence of fire on their forest.

(iv) Suppression of forest fire

It starts with detection of fire and includes communication with responsible personnel, mobilization of fire fighters and suppression of fire in the forest. Development in communication technology such as cell phone has been proved boon for communication regarding fire. It is used by all the CFUGs in reporting to leaders and mobilizing fire fighters for suppression. However, fire fighting in community forest in Siwalik area is a difficult task because of its undulated topography. Fire fighting method varied across the CFUGs, particularly based on settlement pattern, topography of forest and skill and tactfulness of users.

Very few CFUGs have designed a formal mechanism to fight fire. Most of the CFUGs depended on voluntary participation of users in control of fire. Only one CFUG designed fire fighting strategy and implemented the plan effectively. In that CFUG all the fire fighting tools are stored in office of CFUG which is near to the forest. Most of the users are trained on using the firefighting tools and adopting precautionary measures in case of fire in case of fire. Users are informed on occurrence of fire and requested for help with the hand mike in case of fire by some users after getting the information from fire detector. Upon receiving of information of fire in their forest all the users present at home go for suppressing fire. To provide access to fire fighting tools, the representatives from different village clusters are distributed the key of storehouse in fire prone season.

Users are equally active in some other CFUGs but their activities are not organized beforehand. In five CFUGs, leaders in different village clusters are informed about occurrence of fire using cell phone and they spread the message and mobilize the nearby users to control the fire. In those CFUGs, all the users present at home take part in fire fighting voluntarily. However, in case of other four CFUGs, only users residing near the incident site get mobilized and take part in controlling fire. Likewise, some CFUGs, which have very weak users' participation, have assigned responsibility of fighting fire to some groups such local youth club by paying in cash or other kind.

Fire fighting methods in CFUGs

Users of most community forest were not aware about the technical aspect of fire suppression. Extinguishing fire by beating up using green branches was the common across all the community forests. However, users reported beating up of fire was not effective when there was high flame, upward moving fire or windy condition. Second most common but more effective method according to user was exclusion of fuel from fire during fire. At the time of fire, users clear fuel from surface making stripe on forest so as to disconnect fire with the dry fuel. However, CFUGs with high level of participation were only successful in using this method as large number of people required to carry out this task quickly. Some CFUGs trained by forest staff and other expert practice counter burning to control forest fire. However, it was found that counter burning was less known across the community forests.

Rules for managing fire in community forests

All the CFUGs have some sort of rule in their operational plan to discourage people setting fire in their forest. The fine for arsonist in the studied community forest ranged from NRs. 200 to NRs. 2000 excluding with compensation for the loss. However, discussion with most CFUGs revealed that the rule did not come from users in all CFUGs. It was found even executive members of users' committee were also unaware about the procedure and extent of punishment to the arsonist. Even though almost all community forest suffer from fire by people but CFUGs reported that arsonist were never identified. Four CFUGs were able to catch the arsonist in their

CFUGs in their forests in last few years. However, all of them did not proceed with the rule mentioned in their operational plan. Though, users reported that they have rule for banning entry with source of fire to the forest but that was not found documented in their operational plan. Even though integrated fire management requires use of fire and acknowledge of socio-economic necessities and impacts of forest fire (Myers, 2006), the rules were biased towards exclusion and suppression of fire.

Other initiatives to reduce forest fire danger

Two CFUGs have recently started to use *Lantana camara*, another source of fuel in forest of Siwalik, and other weeds for making bio-briquette. This not only provided the source of income to the CFUGs themselves but also reduced the possibility of fire by removing fuel from ground level. The initiative of the CFUGs was less than a year old so the effectiveness of the initiative was yet to be measured but the management of dried biomass beforehand the consumption by fire in the forest is expected to result in reduced occurrence of fire in the community forest. Likewise, a CFUG had opened its forest to any outsiders for collection of leaf litter from its floor with the objective to reduce amount of fuel available for fire. However, the leaf fall during its period is so high that the amount of leaf fall exceeds many more times than that is revoded from forest by users and outsiders.

Likewise, other initiative included the networking of CFUGs for protection of community forests from threats. This type of one network was found in Chitwan district where 10 CFUGs including three CFUGs under study were communicating and cooperating to protect their forests from the threats that might affect many community forests. Another network was found in Makwanpur in Bhaise range post but was not so active. But in recent years CFUGs have started to collaborate to fight against fire. In addition, CFUGs were cooperating with nearby security forces and DFO to control fire in their forests.

Change in Fire Regime

Fire regime is described in terms of fire frequency, periodicity, intensity, size, pattern of landscape, season of burn and depth of burn (Kilgore, 1987). It acknowledges the concept that characteristics of ecosystem are consistent with pattern of behavior, timing and interval of fires (Bond & Keeley, 2005). The CFUGs reported that out of 5854.61 ha area of studied community forests about 1811 ha gets burned annually. 90% of the CFUGs reported their forest is less suffering from fire since they took the reign of the conservation and management of the forest. Similarly, in recent five years six community forests got their entire area burnt while one community forest reported it totally prevented fire in its forest.

Among community forest suffered from fire, most of them got 2 fire events every year. Both of the fires occurred at the dry season; usually one at the mid period of leaf litter fall and another after the litter fall of *Shorea* concluded for the year. The community forests having weak fire control system but abundant fuel were reported to suffer fire up to three times a year. On an average one part of community forest is burnt 1.75 times in a year according to data. All of the CFUGs reported the type of fire there occur is surface fire. However, one CFUG reported that *Pinus roxburghii* dominated forest strata in the community forest sometimes gets crown fire as well. But all of the CFUGs mentioned that crown fire is very rare in *Shorea* dominated forest.

Interaction with CFUGs pointed out that, as shown in Fig 11, among studied community forests, extent of the forest fire was reduced significantly in five community forests after handover to the community. Similarly, extent of fire got reduced, though not significantly, in nine community forests. However, despite the handover to the community, there was no change in extent of fire in other community forests. Likewise, the frequency of fire was reduced significantly in four community forests, reduced slightly in other seven community forests while no change in frequency was observed in eight community forests. Surprisingly, frequency of fire was reported to increase in a community forest. The reason for this variation is attributed to the trades off between the effort to exclude fire and the increase of pressure of people.

In spite of change in extent and frequency of forest fire in community forest, the height of flame remained unchanged in most of the community forests. Only one community forest reported the reduced height of fire in its forest. Similarly, intensity of fire in those community forests was found stable in almost all community forests. It increased only in a community forest with no reduction in any community forest. Severity also showed same trend with intensity of fire in the community forests.

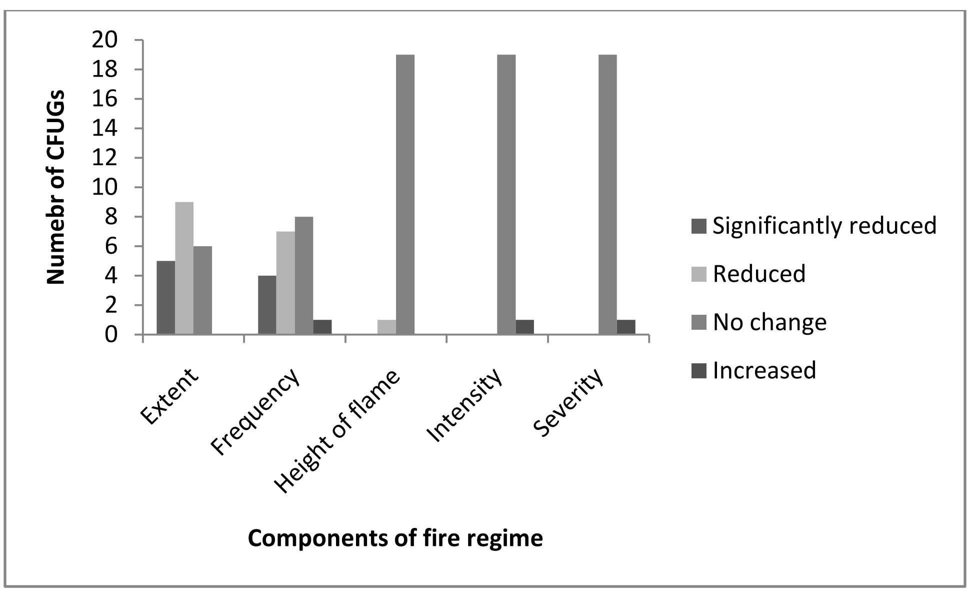


Fig 11 Change in fire regime in CF after handover to community

Sustainability of Current Fire Management Approach

Two factors, according to users, are playing major role in determining the status of fire in the community forest. On one hand, CFUGs are becoming more and more active day by day due to raised awareness level, pressure from forest management offices, strengthened capacity of CFUGs due to development of infrastructure and coordination with other CFUGs, decreasing dependency of users on forest, etc. Increased population and thus the pressure to the forest, anomaly in precipitation and increasing dry days and temperature in fire prone season, on the other hand, are diluting effectiveness that comes from the increased activeness of users and concerned users. All the CFUGs whose activities surpassed the threat of fire have been able to demonstrate the decreased fire event while others were suffering more.

It was found that CFUGs are giving more priority to fire management program in recent years. However, in absence of technical support from line agencies, the fire management is narrowly limited to awareness raising, exclusion and suppression of fire from forest. Awareness alone reduced 90 % of fire outbreaks in India (FAO, 2007) but is less effective in Nepal. This could have been result from less effort or inappropriate methods used.

Suppression of fire is largely considered expensive method and may not be sustainable (FAO, 2007). However, most CFUGs rely on suppression of fire than to prevent it. Therefore, despite the effort of CFUGs, many CFUGs suffered fire every year. The fire in the forests of Siwalik is not serious as it is ground fire and occurs every year except where CFUG prevented. However, if the seedlings could be protected from unfavorable conditions such as occurrence of fire, the growth of the forest is rapid (FAO, 2002). Therefore, it can be said that productivity of forest could be increased by protecting forest from fire.

In the face of increasing precipitation, number of consecutive dry days, growing stock in forest and human pressure and increasing activeness from CFUG in fire management, the accurate prediction of the future of forest fire is difficult. From the current experience it can be said, unless the fuel accumulates in the forest floor in huge amount for years, any fire occurred may not bring devastation as fire is common there every year from historic past. However any unstudied and not properly planned intervention to the ecosystem has a high risk of being counterproductive.

In spite of report of some CFUGs that their activity on fire management was severely constrained by their weak financial condition, the activeness in the some CFUGs is overwhelming. There is need of careful consideration over the factors affecting users' participation in the future; only then it can be said what type of activity users will demonstrate in the future. With institutional maturity the activeness of users might continue where the users are active and it will increase where users are less active at present. Nevertheless, with change in society fueled by development and external factor, the possibility of users losing interest on fire management cannot be denied.

The forest is shaped by environmental variables, where time since fire explained most of them (Drever et al, 2006). Therefore, focusing just on exclusion and suppression of fire ignoring fuel management as a viable option of managing fire makes the future more uncertain. The practices may force the ecosystem to go to the alternative state if the practice becomes successful. The incongruence between fire causes and management solutions proposed by researchers reflects the complex and spatially scaled interactions of cause and effect in coupled human-environment systems (Wilbanks, 2006) and further highlights the need for interdisciplinary research designs.

Conclusion

Different factors work together to determine fire environment in community forest of Siwalik in Nepal. The factors affecting fire vary in their direction. Conservation effort by local communities as a result of practice of community forestry has played positive role in increasing biomass in the forest and thus in increasing fuel. Similarly, precipitation shows conflicting effect on Siwalik area; the total amount of precipitation is increasing but consecutive number of dry days, mostly in fire prone season, is increasing. Similarly, temperature also show varied pattern; it shows increasing trend in Hetauda whilst it is decreasing in Rampur. Nonetheless, very less precipitation and high temperature in the months of February, March and April provide very conducive environment for fire in the community forests of Central Siwalik.

Human activity is the source of most of the fires in the community forests of Siwalik region. Rule itself is not sufficient to keep fire out of forest. Despite banning the setting the fire in community forest by government and CFUGs, various groups are still using fire in the community forest intentionally and accidentally; however, due to procedural difficulty and mismatching of rule with fire culture the offenders are rarely identified. Fire still in use by users in forest compounded by favorable condition created by uni-modal leaf fall and high drought makes February, March and April highly fire sensitive month. CFUG practicing technically weak and reactive measures are not practicing sound forest fire management system. Active CFUGs in fire management, however, have developed diverse rules to ensure not only the fire remains out of the forest but also users from every household take part in fire fighting.

In sum, weather and human activity has been more favorable for fire to occur in community forests of Central Siwalik Nepal. However, CFUGs have been largely successful in reducing fire events in community forests in Central Siwalik. Despite this, effort of communities is limited exclusion and suppression of fire; despite effectiveness the use of fire offers in managing fire and serving cultural needs of people and ecological role in the forest, policy of Government of Nepal is keeping users from using fire in forest fire management. Given the complexity of the fire system, “cure-all” policy instruments are unlikely to be effective (Ostrom et al., 2007) although they are repeatedly attempted. The lack of contextual social data in the literature hinders the formulation of management strategies that are aligned to the local reality (Hayes and Rajão, 2011). Therefore, the government should play leading role in paving the way for integrated fire management and should act to remove unfavorable legal conditions and other technological limitations. It should reconsider the total banning of use of fire in forest. Instead the government should make mechanism to monitor the use of fire in the community forest to minimize the possible misuse.

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