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Forest fire disaster events in Himalayan state Uttarakhand: An analytical study

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Abstract
Disasters are unacceptable and casual occurring events that cause livelihood, environmental and economic losses. Forest Fire is one of the biggest anthropogenic disaster events in the study area viz., Uttarakhand which is a cause of loss of human beings, flora, and fauna. Personal, intentional and accidental anthropogenic causes triggered forest fire. The study area facing almost every year devastating forest fires in the open forest and near the settlements which are very harmful for livelihood and forest ecosystem. Forest provides shelter and food to human beings, wild animals, birds, reptiles etc. Forest is a home of fresh air, fresh water, medicinal herbs and plants etc. The people of Uttarakhand state are not well aware of the techniques of forest fire mitigation. Due to lack of forest fire mitigation awareness, every year several people lost their life in forest fire events. Present study reveals that the forest fire events are increasing in Uttarakhand state due to global warming and climate change. In 2011, there are total 72 forest fire events were recorded which has increased to 3738 in 2009. The present study shows the pattern and trend of forest fires events in the Uttarakhand and an attempt has been made to find out its consequences and causes. Based on this study a detailed mitigation strategy has been worked out which may be useful for the government for management of forest fire disaster events in future.

Keywords: Forest fire, ecosystem, causes, mitigation, Uttarakhand

1. Introduction
Forest is an indiscernible part of ecosystem. They play an important role in the life of all organisms by producing oxygen which is essential for life on the earth. Apart from this, they provide shelter to all living beings and if we look at the history of human life in their primitive era they were completely dependent on the forest for their food and shelter. In forest areas, fire is a major disaster which affects flora, fauna and humans. Controlled and limited forest fire is good for proper growth and development of the forest while uncontrolled forest fire causes damage to the forest ecosystem. There are two causes of forest fire which are natural and human cause. The 95% of forest fire incidents are caused by the human activities (Satendra *et al*, 2014) [5]. Uttarakhand state is a prone area of forest fire due to its geographical conditions and vegetation types. Forest fire season starts in Uttarakhand stretches from February to June. In these months there is no moisture in the air and soil, so the forests are easily vulnerable to fire (Negi *et al*, 2016) [3]. Frequencies of forest fire incidents are triggered by air temperature, air humidity, wind speed, past rainy days, forest types, slope, road networks etc. Forest fire is the major hazards to forest and wildlife ecosystem (Bargali *et al*, 2017) [1]. Several wildlife conservations have been also affected by forest fire in Uttarakhand, i.e., Corbett National Park, Govind Wildlife Sanctuary and National Park, Nanda Devi Forest Division and Rajaji National park have been affected by forest fire. The past incidents of forest fire incidents are its witness. Wildlife and its habitats have been highly affected by forest fires in previous incidents. Sometimes burning agricultural biomass is becomes the cause of forest fire (Pant *et al*, 2019) [4]. The Major anthropogenic causes of forest fire are use of smoking during travel, mistake by shepherd etc. Kapil *et al*, (2015) [2] studied the forest fire events and found that more than 95% of forest fire events are caused by anthropogenic causes. Uttarakhand state is a one of the state of India which has good forest cover area and provides forest products and oxygen. Several rivers originate from these forest regions. Therefore, for the survival of these rivers it is important to protect forest from fire events.

2. Objectives of the study

Uttarakhand state is known for its forest and water resources. In the recent years, both the resources are badly affected by climate change and global warming. Due to increased temperature and human activities, the forest fire events have increased significantly in the Uttarakhand state. The basic objectives of this research paper are presented below:

i) Study and analyzes the trend of forest fire incidents during last 13 year (2005 to 2017) in Uttarakhand.
ii) Methods of extinguish forest fire and fire vulnerability in forest regions of Uttarakhand
iii) Find out the causes and effects of forest fire in Uttarakhand.
iv) Based on this study a detailed mitigation strategy has been worked out which may be useful for the government for management of forest fire disaster events in future.

3. Methods and Materials

The present study is based on the primary and secondary data. In this study, the interview method has been used to find out the method of extinguishing forest fire. Forest fire data have been used from the Uttarakhand forest department. Quantum Geographical Information System (QGIS) and Arc GIS software has been used for forest fire mapping. Microsoft Excel 2010 has been used to analyse and manipulate data.

4. Location and extent

Uttarakhand is a famous Himalayan state of India it is very famous and known as hill station. Study area covers total area about 53,483 km² and it is located between $28^0$43'N to $31^0$27' N latitudes and $77^0$34' E to $81^0$02' E longitudes in the northern part of India (*Figure 1*) and shares boundaries with China and Tibet in the north, Nepal in the east part, Himachal Pradesh in the west, and UP in the south. Uttarakhand has 86% hill area where the forest area in the state is 24,295 km² which accounts for 45.32% of total geographical area.

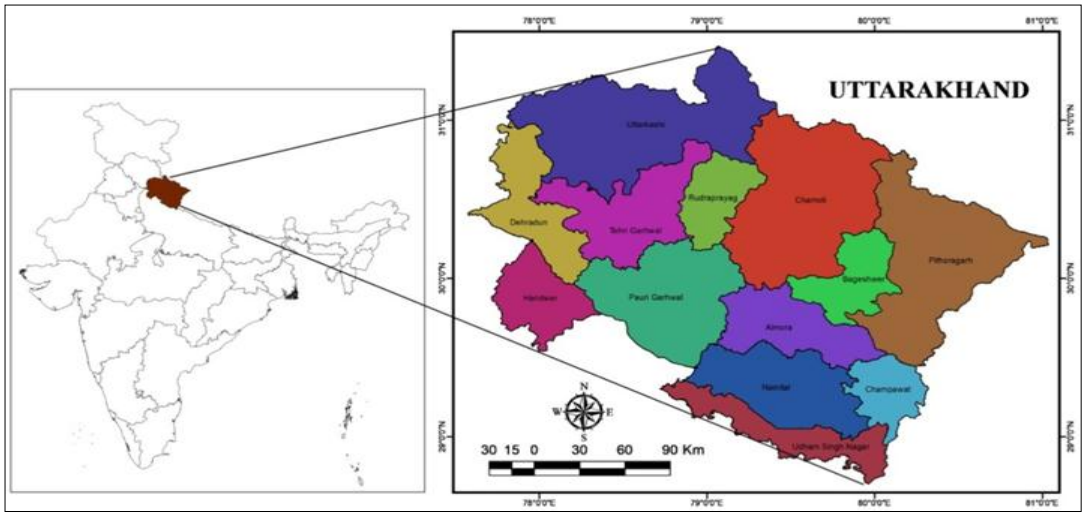


Fig 1: Location and extent of the study area, Viz., Uttarakhand state *(Source: Centre of Excellence for NRDMS in Uttarakhand, Department of Geography, S.S.J. Campus, Almora)*

5. Result and Discussion

In the present study, the last 13 years (2005-2017) forest fire events are analyzed here. A forest fire is a hazardous incident for all living creatures and plants. Almost all the districts of the state are affected by forest fire events every year. Pine forest covers most of the geographical area of Uttarakhand state which serve as fuel for forest fire. Pine needles, locally known as Peerul, fall down like sheets throughout the forest area and these sheets like Pine needles quickly catch the fire. To extinguish the fire in pine forest is a very difficult task because the pine forest supports it. The minimum forest fire incident are recorded 72 in 2011 and the maximum forest fire incidents are recorded 3738 in 2009 (*Table-1*). Most of the area of forest fire comes under this pine forest area (*Plate1*).

The study area is divisible into three forest fire zones based on the total forest fire events. These forest fire zones are: low forest fire zone, moderate forest fire zone and extreme forest zone. The detail of forest fire zone of Uttarakhand is presented in Table-2. The spatial distribution of forest fire zones is presented in the Figure 2. A brief description of these forest fire zones is presented in the following paragraphs.

5.1 Low Forest Fire Zone: The districts having less than 500 forest fire incidents are defined as low forest fire zone. Four districts are fall under this low forest fire zone which are; Pithoragarh, Rudraprayag, Bageshwar and Haridwar (*Fig. 2*). The details of district wise forest fire incidents from 2005-2017 is presented in Table-3. The total area of this forest fire zone is 13664 km^2 which accounts for 25.5% of total geographical area *(Table- 2).* Figure 3 shows the diagrammatic presentation low forest fire zone.

5.2 Moderate Forest Fire Zone: The districts having 500 to 1000 forest fire incidents are defined as moderate forest fire zone. Four districts are fall under this moderate forest fire zone which are; Champawat, U.S. Nagar, Dehradun and Uttarkashi (*Fig. 2*). The details of district wise forest fire incidents from 2005-2017 is presented in Table-3. The total area of this forest fire zone is 16163 km^2 which accounts for 30.2% of total geographical area *(Table-2).* The diagrammatic presentation of moderate forest fire zone is presented in Figure 3.

5.3 Extreme Forest Fire Zone: The districts having more than 1000 forest fire incidents are defined as extreme forest

fire zone. Five districts are fall under this moderate forest fire zone which are; Almora, Chamoli, Tehri Grahwal, Nainital and Pauri Grahwal (*Fig. 2*). The details of district wise forest fire incidents from 2005-2017 is presented in Table-3. The total area of this forest fire zone is 23657 km^2 which accounts for 44.2% of total geographical area (*Table-2)*. The diagrammatic presentation of extreme forest fire zone is presented in figure 3.

Table-3 contains the detail information of forest fire incidents in the districts of Uttarakhand. During the last 13 years, there are total 13201 forest fire incidents are recorded. The minimum number forest fire incident are registered in Pithoragarh district with total of 175 incidents while the maximum number of forest fire incidents are registered in Pauri Grahwal with total of 2894 incidents. The average forest fire incident of the study area is 1015.4. The minimum average forest fire incident are noticed 08 in Pithoragarh district and the maximum average forest fire incidents are noticed 222.6 in Pauri Grahwal district (Table-3).

6. Trend of forest fire

Forest fire is a common occurrence in the Himalayan region of Uttarakhand. The months from March to June are known as fire season. Every person in Uttarakhand is familiar with this word. In 2016, total 31 persons were injured, 6 persons were killed and 7 domestic animals were killed by forest fire in different districts of the state. Figure 2 shows that the trend of forest fire incidents during last 13 year (2005 to 2017). Figure 3 shows a slightly increasing trend of forest fire in Uttarakhand. According to this figure, the minimum forest fire incidents are noticed in 2011 and the maximum forest fire incidents are reported in 2009.

7. Methods of extinguish forest fire

There are four methods are used by locals and forest personnel to extinguish forest fire. These are:

i) The first method is fire line breaking method. In this method, the separation line is created in the forest fuel to control the fire. This method is appropriate useful for breaking the fire line *(Plate 2).*
ii) The use of soil is another method basically used to extinguish forest fire in a forest area where other methods are not accessible.
iii) Counter fire method is the way to prevent fire from spreading elsewhere. In this method a fire is set on the other side of the forest fire line so that the fire does not spread and the line cuts off from the middle.

Use of green twigs to extinguish forest fires *(Plate 3)*

8. Fire vulnerability in forest regions

According to the relief (height) and temperature, the forest of Uttarakhand is divided into sub-tropical forest, temperate forest, sub-alpine/ alpine forest and alpine bush land/ meadows. Sub-tropical forest is mainly found in the Terai–Bhabhar region of Uttarakhand. Different types of vegetation species are found in these forest regions. Sal, Haldu, Semal, Tun, Kher etc vegetations are the commonly found in this region. These forests are highly affected by forest fire incidents.

The temperate forests are mainly found in the mountainous region of Uttarakhand. The area is largely covered by pine forests, somewhere only pine is found throughout the area. Oak forest is found above pine forest. Species of Pine, Oak, Birch, Moru and Kharsu vegetations are found in this region. Pine forests are highly sensitive for fire incidents due to rosin tapping. Sub-alpine and alpine bush land are also affected by fire due to human interference but the occurrence of forest fires in these forest regions is smaller than the other forest regions.

Table 1: Incidents of forest fires (2005-2017) in Uttarakhand (*source: Uttarakhand Forest Department, Official Website).*

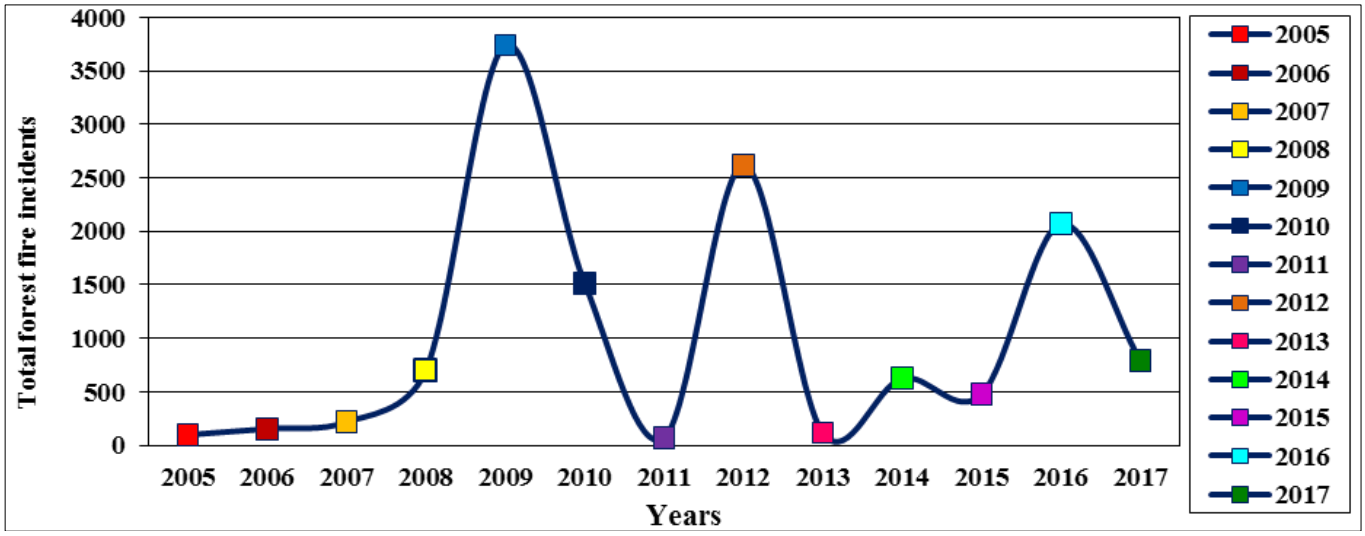
S. N.	District Name	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
1	Pithoragarh	1	0	1	2	8	4	3	8	0	4	4	97	43
2	Rudraprayag	0	0	8	18	122	23	0	78	3	15	10	82	23
3	Bageshwar	3	0	1	7	124	61	7	143	3	16	2	60	43
4	Haridwar	1	10	23	32	85	88	1	92	3	42	20	52	25
5	Champawat	4	9	3	72	116	31	5	136	1	61	20	59	36
6	U. S. Nagar	10	16	15	13	233	65	12	120	4	50	18	16	23
7	Dehradun	6	13	30	7	238	188	1	120	5	9	42	200	65
8	Uttarkashi	1	4	8	7	429	40	10	125	3	55	6	172	14
9	Almora	5	7	6	39	264	100	3	307	11	72	37	195	175
10	Chamoli	3	5	16	36	423	59	5	257	6	67	14	221	33
11	Tehri Garhwal	5	11	33	23	555	36	5	303	11	59	65	247	73
12	Nainital	17	63	20	153	405	366	16	399	39	65	150	266	109
13	Pauri Garhwal	44	17	56	295	736	454	4	530	27	111	90	402	128
Total		100	155	220	704	3738	1515	72	2618	116	626	478	2069	790

Table 2: Details of forest zones of the study area, viz., Uttarakhand state

S.N.	Forest fire zone (Forest fire incidents)	Total district	Total area	Area in %	Remark
1	<500	04	13664	25.5	Low forest fire zone
2	500-1000	04	16163	30.2	Moderate forest fire zone
3	>1000	05	23657	44.2	Extreme forest fire zone
Total		13	53484	100.0	

Table 3: Total and average forest fires incidents in districts of Uttarakhand (2005-2017), *(source: Uttarakhand Forest Department, Official Website).*

S. N.	District name	Total fire incident	Average	S. N.	District name	Total fire incident	Average
1	Pithoragarh	175	13.46	8	Uttarkashi	874	67.23
2	Rudraprayag	382	29.38	9	Almora	1221	93.92
3	Bageshwar	470	36.15	10	Chamoli	1145	88.07
4	Haridwar	474	36.46	11	TehriGarhwal	1426	109.69
5	Champawat	553	42.53	12	Nainital	2068	159.07
6	U. S. Nagar	595	45.76	13	PauriGarhwal	2894	222.61
7	Dehradun	924	71.07	Total		13201	1015.4



Source: Uttarakhand Forest Department, Official Website

Fig 2: Trend of forest fire incidents in Uttarakhand

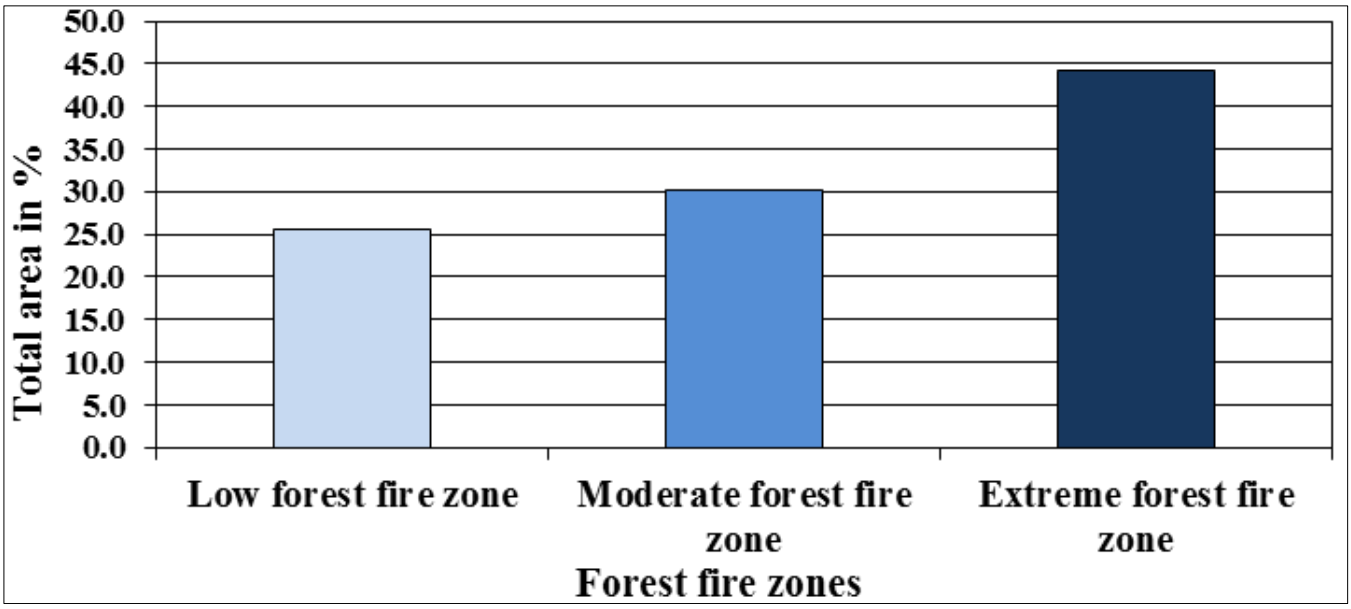
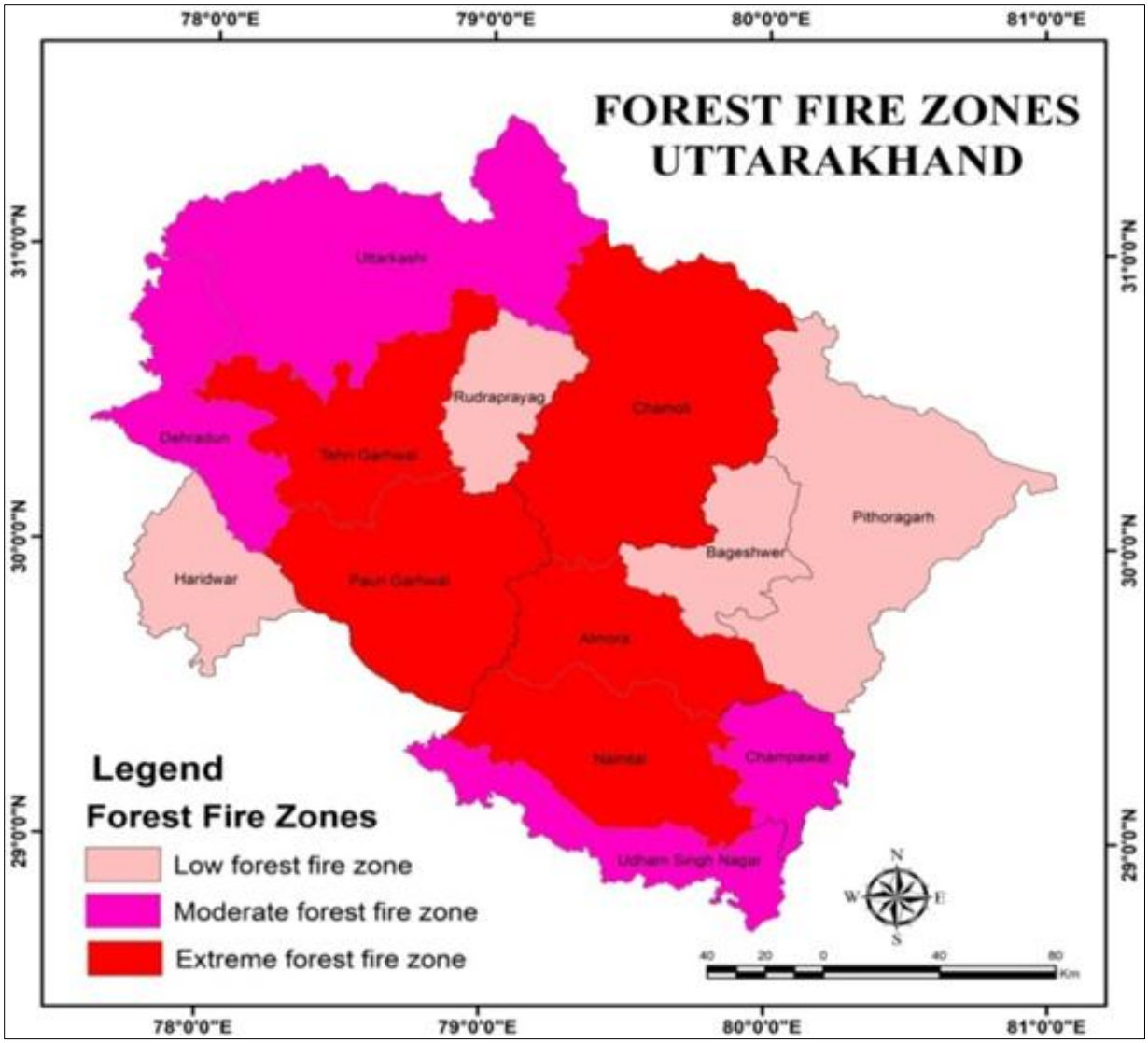


Fig 3: Diagrammatic presentation of forest fire zones of Uttarakhand.



Source: Centre of Excellence for NRDMS in Uttarakhand, Department of Geography, S.S.J. Campus, Almora

Fig 4: Distribution map of forest fire zones in Uttarakhand state

Plate 1: Forest fire incident in pine forest of Uttarakhand state.

Source: Field survey

Plate 2: Fire line breaking method in Rajaji National Park

Source: Field survey

Plate 3: Use of green twigs to extinguish forest fire.

9. Causes of forest fires

There are mainly two causes of forest fire incidents in Uttarakhand which are: natural and human causes. Sky lighting, volcanic eruptions, rolling stone friction are all natural causes of forest fires. There are very few cases of forest fires in Uttarakhand region due to natural causes. The main cause of forest fires in the state is anthropogenic. Human greed, ignorance and need are the cause of more than 90% of forest fire incidents. There are many manmade causes of forest fire some are listed below:

1. Jhuming/shifting cultivation.
2. Burning of the forest for good grass in the forest area.

3. Burning of agricultural biomass waste sometimes causes forest fires.
4. Throwing cigarettes and biddies without damage fire in dry bushes during travelling becomes cause of forest fire incidents. Sometimes campfires are the cause of forest fires.
5. Fire to drive wild animals is also a cause of forest fire.

10 Effects of forest fires

Forest fires have both good and bad effects on humans, flora and fauna. Limited fires are good for proper growth of plants and are also good for crops in terms of land fertilizer but uncontrolled forest fires also have bad consequences-

1. Forest ecosystems are affected by forest fires, many species of vegetation burn in flames that never grow again. Forest fires destroy many flora and fauna species.
2. Wild and domestic animals are badly affected by forest fires. Wild animals, reptiles, birds etc lose their habitat. Forest fires are the biggest disaster for the wildlife ecosystem.
3. Excessive forest fires also effect human life. In 2016, 6 people were killed and 31 were injured by forest fire in the state of Uttarakhand. Forest fire is the major cause of air pollution that affects human health.
4. Land erosion is also increased by forest fires.

11. Forest fire mitigation

1. Electricity lines in forest areas should be kept away.
2. Turn pine into oak forest in the mid Himalayan region because pine trees catch fire very quickly.
3. Stringent rules, laws and policies should be enacted to reduce forest fires.
4. The Uttarakhand government should promote the power generation project using pine needles. Every year fires occur in Uttarakhand forest due to the availability of fuel of pine needles in the pine forest area. If the government uses pine needles for power generation then it will help reduce the incidence of fire and is also worthy for the employment of villagers.
5. In the forest area, there should be a Chal-Khal construction which is useful for storing rainwater and which can be used in fire season.

12. Conclusion

Forest fires are a common occurrence in Uttarakhand. Yearly forest fire incidents occur in this area. The main reasons of forest fires are anthropogenic. We can say that it is a man-made disaster which is very hazardous for all living beings. It is very essential for people to mitigation this problem. Limited fire is good for plant growth but uncontrolled fire is a disaster which is destroys the whole ecosystem of the forest. Forest fire is harmful for human health and also for wild life. Throughout Uttarakhand, forest area suffers from fire incidents from March to June. If the government and people worked at the ground level to extinguish the fire, it is probable to control. Environmental education and awareness are important to reduce fire incidents.

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