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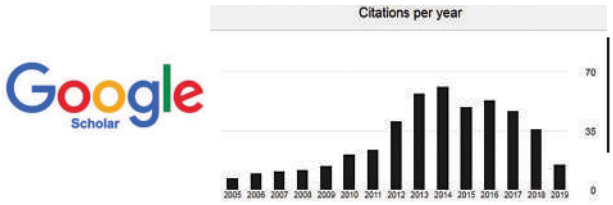

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ROLE OF CHIR PINE (*PINUS ROXBURGHII* SARG.) IN THE FOREST FIRE OF UTTARAKHAND HIMALAYA

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ABSTRACT
The Uttarakhand Himalaya has rich and diverse forests; but in the recent decades fire has become a regular phenomenon in Uttarakhand. Every year the Chir Pine forests face forest fire. Research carried out by various authors pointed out that pine needles are highly inflammable and prone to fire due to several anthropogenic factors. This paper presents an overview of forest fire on Uttarakhand with the emphasis on the role of Chir Pine in forest fire. Currently, fire is a very critical disturbance to the vegetation and forests of Uttarakhand Himalaya. Forest fire causes adverse ecological, economic and social impacts. The outcome of the paper concludes that the main reason of forest fire in the Uttarakhand Himalaya is accumulation of inflammable pine needles on forest floor during dry summer and prone to man-made accidental and intentional fire. Suitable strategy to avoid the forest fire by using this resource for bio-energy or other environment-friendly products is emphasized.

Keywords: Chir pine (*Pinus roxburghii*), Uttarakhand Himalaya and Forest fire.

INTRODUCTION
Forests are considered as one of the most important terrestrial ecosystems that provide habitat provisioning for biodiversity and many goods and services to the rural communities. These indispensable resources are prone to constant degradation and exploitation due to anthropogenic activities and changes in the climatic conditions (Pokhriyal *et al*., 2020). The Indian Himalayan Region (IHR) has a rich and diverse forested area and thus globally forests are now considered to be as the major repository of nature and needs to be conserved and managed for posterity, and not to be regarded solely as an important source of revenue (Negi *et al*., 2012). Forest fire is a regular phenomenon in Uttarakhand forest ecosystems depleting most valuable flora and fauna due to frequent incidences of forest fires. More than 50% of mountain forests in Uttarakhand are prone to high incidence of fire, during the months of March to June every year. Forest fire is a major cause of changes in forest structure and function. Fire changes the dynamics of vegetation in the forests. Forest fires are as old as forests themselves. Currently, fire is a very important disturbance to worldwide vegetation cover, affecting terrestrial ecosystems on a large scale (Hussain *et al*., 2018). In terrestrial forest ecosystems, fire can be of natural origin such as lightning, volcanic eruption etc. or man caused (intentional or unintentional), and are further categorized as surface fires, ground fires and crown fires. Due to severe recurrent forest fires, various negative impacts on the environment and ecosystem occur. It destroys flora and fauna, timber wealth of forests and biodiversity, accelerate soil erosion, changes physico-chemical as well as biological characteristics of the soil, cause air pollution and increase air temperature due to emission of green house gases. According to the Forest Survey of India, about 50% of the forest area in the country is fire prone, and about 6% is prone to severe fire annually. Every year, close to 18,000 forest fire incidents are reported in India affecting an area of some 1.14 Mha. So, the effective forest fire management is necessary to mitigate these frequently occurring forest fires in Uttarakhand. Fire activity is strongly influenced by factors such as: air temperature, relative humidity, wind speed, previous day rainfall, dew point temperature, air pressure, potential evapotranspiration, land surface temperature, precipitation rate, forest type, slope, aspect, elevation, normalized difference vegetation index, enhanced vegetation index, albedo, terrain ruggedness index and road network, rail network, human interference (Bargali *et al*., 2017). The man-caused intentional fire has been found to be the major reason behind forest fire in Uttarakhand. Forest fire is one of the major disasters in the forests of Uttarakhand that adversely affects the indigenous and endangered species of flora and fauna (Negi *et al*., 2017). Chir Pine forests are mainly responsible for the spread of forest fires. Chir pine covers an area of 8900 km^2 in India and is regarded as one of the most important timber tree in forestry plantations (Tiwari 1994). The chir pine tree is rich in resin content that makes it economically important species. However, the same property makes its needle litter highly inflammable and vulnerable to forest fires. Pine forests face fire every year to remove the needle litter, which becomes

slippery for humans and cattle to go around in the forests (Chandran *et al*., 2016). Chir pine, scientifically known as *Pinus roxburghii*, also known as three-needled Indian pine, a native of the Himalayas is spread across India, Nepal, Pakistan and Afghanistan. This is a large evergreen tree with elongated crown and attains a height of up to 50 meters, with about 3.5 meters in girth, and forms a straight cylindrical bole. It grows between a lower elevation of 500 meters to higher elevation of 2,200 meters and forms a pure forest. About 16.36% of forest area is occupied by Chir Pine forests between 1000 and 1800 m above sea level in Uttarakhand (Fig. 1).

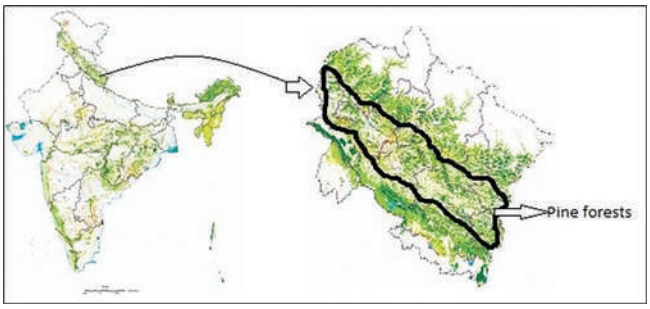

Fig. 1. Map showing the forest are covered by Pinus roxburghii prone to forest fire in Uttarakhand (Source: Chandran *et al*., 2016)

Chir pine is used for timber, fuel wood, torch wood, funeral wood and furniture. Its leaves are used for livestock bedding and field mulching. The bark of chir pine is a source of charcoal, resin and coal tar. The leaves of coniferous tree of pine catches fire easily and thus accelerates the forest fire in Uttarakhand.

METHODS

Based on an extensive review of literature, research articles, reports from numerous databases, such as Google scholar, Research gate, Taylor and Francis online, Springer-link, the present communication has been divided into three sections: (1) history of forest fires in Uttarakhand Himalaya, (2) the role of Chir Pine in forest fire of Uttarakhand Himalaya, and (3) analysis of research along with preventive measures. The online search was carried out using keywords such as "forest fire", "fire history", "role of chir pine in forest fires, "tree mortality due to forest fires" along with the name of Uttarakhand Himalaya.

RESULTS

History of forest fires in Uttarakhand Himalaya

In India, forest fires were considered as the significant and prominent contributory factors in the degradation process altering ecological balance of nature. The most susceptible stretches of the world to fire are the youngest mountain ranges of Himalayas. Human induced forest fires in Uttarakhand have been a regular and historic feature. Major forest fires have been recorded in Uttarakhand in 1911, 1921, 1930, 1931, 1939, 1945, 1953, 1954, 1957, 1958, 1959, 1961, 1964, 1966, 1968, 1970, 1972, 1995, 1999, 2012, 2016, 2019 and 2020. Forest fires are an annual occurrence in Uttarakhand but from past few years it is proving devastating for local people and causing irreparable damage to valuable natural resources of the state (Dobriyal *et al*., 2017). First time, fire protection was initiated in the chir pine forests by the Forest Department in 1912. In Uttarakhand, the periodicity, spatial coverage and severity of forest fire vary temporally and these fires are associated with heavy accumulation of chir pine needles on the forest floor. These mostly man-made forest fires in Uttarakhand are also a potent source of pollutants especially black carbon, being a major cause of glacier melt in the Himalaya, and also alter the regional climate (Singh *et al.,* 2016). In 2016, a total of 1327 forest fire incidents took place with total area affected 4423 ha. Forest fire also causes air pollution and leads to rise in temperature in hilly areas of Uttarakhand and destroys a large amount of flora, fauna and wealth of forests.

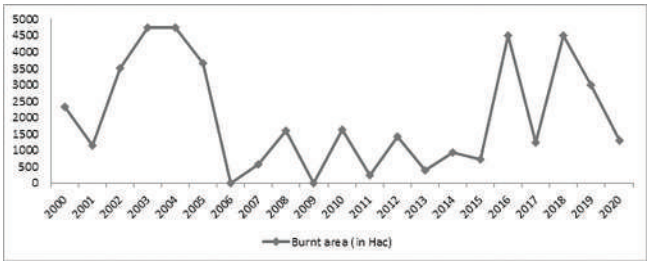

Fig. 2. Yearly trend of area burnt (in hac.) of Uttarakhand Himalaya due to fire (2000-2020); (Source: State Forest Department, Uttarakhand)

Role of Chir Pine in the forest fire

The major causes of forest fire in Uttarakhand are: continued dry weather and lack of moisture in the forests, traditional practice of burning of forests by the local villagers to remove Chir Pine needles accumulated on forest floor to allow growth of herbage and unsustainable forest conservation policy (Dalei 2016). In Uttarakhand, about 4 lakh ton Pine needles are dropped annually in the forests, accelerating the inflammability of the forest floor due to rise in ambient temperature during summer (Negi 2019). Fire incidents mostly take place between 12-4PM and 4-8PM. The major reasons for forest fires in Himalayas are the highly inflammable material of dry chir pine needles and the dry-leaf litter of broad-leaved trees on the forest floor associated with chir pine. The man-caused intentional fire has been found to be the major reason behind forest fire in Uttarakhand. People also ignite fire to remove unwanted grass and to obtain better forage for livestock, extraction of honey from the bee hives and wild edibles among several other reasons (Negi 2019). Fire behavior changes with weather, topography and fuel

of particular landscape and its movement is controlled by conduction, convention and radiation factors (Bhatia *et al*., 2020). Human activities on agricultural land are the most common causes of fires. Today, 95% of all cases of forest fires are caused due to anthropogenic activities. Natural factors that influence the occurrence and spread of forest fires are climatic elements, combustible material, geological characteristics of the terrain and the type of vegetation (Siljkovi *et al*., 2016).

Effects of forest fire in Uttarakhand Himalaya

Forest fire is a potential hazard that leads to physical, biological, environmental and ecological consequences. Forest fire does not depend on any single factor. Due to forest fire many ecological and socio-economic impacts occur (Savita *et al*., 2017). Forest fire alters the ecology of forests, reduces biodiversity and changes plant community composition of the forests. The major impact of forest fire on flora are reduction of the productivity, alteration of regeneration rate that detoriatres the physico-chemical characteristics of soil, thus making the soil infertile. Along with flora, a large number of endemic and endangered species of fauna also get affected. Uttarakhand state has abundant forest resources, and is regarded to have high potential for the economic development of the state, but due to forest fire a large impact occurs on socio-economic aspects of the people (Sati *et al*., 2018). Forest fires destroy not only flora (tree, herbs, grassland etc.), but also creates long term negative impact on fauna including wild endangered species. Due to forest fire, air pollution, various pollutants like NOx, SOx, CO and black carbon increase leading to various air borne diseases. Forest fire reduces the abundance, density and distribution of many species from microbes to mammalia (Dennis *et al*., 2001). Reduction in the level of regional biomass stock occurs and hydrological cycle gets disturbed. The photosynthetic activity is reduced due to the increased concentration of smoke and various pollutants in the environment thus deteriorate the health of human being and animals (Turvey 1994).

CONCLUSION

The chir pine forests are the major forest type in Uttarakhand Himalayas as it covers about 16% forest area. Due to resin rich leaves, it becomes a main contributor to forest fire in Uttarakhand. Therefore, regular elimination of pine leaves and proper looping of the lower branches of pine trees from roads and fire sensitive areas can be performed both by forest department as well as by local people. Plantation of fire resistant and adapted species such as *Carissa spinarum* and *Pyrus pashia* need to be done. Pine needles accumulated on the forest floor during extreme summer season can be utilized for industrial purposes (e.g., making paper to prepare file covers, file folders, note pads, carry bags, greeting cards, envelops, smokeless bio-briquettes etc.), electricity generation, oil extraction etc. for gainful employment in the region (Arya *et al*., 2020). The forest department of Uttarakhand utilizes the pine needles for making check dams in the forest for conserving soil and water, that ultimately moisten the forest floor and reduces the spread of forest fire (Chandran *et al*., 2016). Activities of local people of burning agricultural lands or other actions promoting wildland fires should be regulated. Regular patrolling of forests should be done, as maximum forest fire is incidents are human induced and for better management of forest fire, research in the field of fire detection and fire ecology need to be initiated. Strong collaboration between the forest department and local people needs to be established to reduce the incidents of forest fire and save our forests and biodiversity.

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