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Forest fire and Plant Invasion: Exploring the agents of Land Degradation in a Tropical Deciduous forest Landscape

Land degradation is one of the major environmental concerns of the 21st century. Forest fires and the spread of invasive alien plant species have been considered as major drivers of forest degradation which have led to changes in the structure and composition of the forest, and also have led to a decline in the productivity of the forest. The study explores a possible association of forest fires and the prevalence of invasive species in a tropical forest landscape. The present study has been conducted in the fire-affected areas of tropical moist deciduous forest dominated by Shorea robusta and also evaluates the effect of forest fire severity on invasion by invasive plants in and around Doon valley, Uttarakhand.The fire severity was mapped using the differenced Normalized Burn Ratio, and was used as a proxy for understanding the impact of fire. Ecological data analysis was done through field study and Importance Value Index (IVI), and diversity indices were calculated. The results revealed the shrub diversity was higher in moderate fire severity regions. The occurrence of fire was observed to affect the presence of invasive species in a one-way ANOVA using total IVI of invasive species as the single factor per site. A clear association between total IVI of invasive species was observed and the presence of fire regardless of its severity, but a clear association between total IVI of invasive species and the severity of fire was not observed. The study infers that while the effect of the severity of fire is not clear on the presence of invasive species, but the presence of fire helps in the establishment of invasive species. The study recommends long-term monitoring to understand if there is existing positive feedback between these two nefarious agents of forest degradation. The study would help future forest managers in developing management plans for sustainable management and restoration of the forests to its prime state.

Key words: Forest degradation, Sustainable forest management, Fire severity, Invasive alien plants

The linkages between the different severity levels of fire and the presence of invasive species were not established, whereas it was evident that the presence of fire helps in the establishment of invasive species.

Introduction

The Food and Agricultural Organization (FAO) has flagged the present decade as the Decade for Ecosystem Restoration as restoration ecology has emerged to be the last ace up civilization's sleeve to save our pristine natural habitats. One of the primary pre-requisites of restoration is identifying the potential agents of ecosystem degradation, and evaluating the impacts of such agents both qualitatively and quantitatively. In a complex ecological setting, the agents of degradation act not only in solitary fashion, but also in association with one another resulting in compounding the effects of each on the ecosystem.

The degradation of forests is an environmental issue of global concern. At present, it is predicted that almost a third of world's human population is affected by degradation of terrestrial ecosystems which includes forests (UNEP, 2007). Degradation of forests in the tropics is profound and estimations suggest that about five hundred million hectares of forest land is in a degraded state in the tropics (ITTO, 2012). The addressal of such a major issue needs a holistic defining of forest degradation. In general, forest degradation is defined as the loss of a

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certain characteristic, function, or service as a result of disturbance (Ghazoul *et al.,* 2015). However, there are multiple existing definitions of forest degradation due to its spoked nature and its consequent perceptions in a variety of domains (Ghazoul *et al.,* 2015). Thus, the need for exploring potential associations of agents of degradation is imperative. Forest fires and invasive alien plant species are two well defined nefarious agents of changing forest structure and drivers of forest degradation (Kumar *et al*., 2022).

In India, forest fires are considered to be a primary source of forest degradation. Every year, around 35 million hectare of forest area is affected by forest fire in India (Satendra and Kaushik, 2014) and 36 per cent of the forest cover of India is reported to be prone to forest fire (Kumar *et al.*, 2019). Over 0.84 per cent, 0.14 per cent, 5.16 per cent, and 43.06 per cent of the forest areas are affected by very heavy fire, heavy fire, frequent forest fire, and occasional fire effects, respectively (Satendra and Kaushik, 2014).

Fire is known to facilitate the invasion of many non-native plant species, but it does not always lead to an increase in the pace of invasion into burned areas (Klinger *et al*., 2006). Invasion in burnt areas varies along with some other factors also, like; environmental gradients, which had a stronger effect on patterns of non-native species distribution, abundance and species composition than burning. In a study of western montane ecosystems, it was found that species richness had significant negative correlations with elevation, the number of years after a burn, and the cover of woody vegetation, while species cover and species richness of non-natives had significant positive correlations with slope (steepness) and herbaceous cover (Klinger *et al*., 2006). It would be premature, to say that non-native species cannot have an impact on these systems' post-fire succession patterns. Even in highly protected locations, high rates of invasion, establishment, and dissemination could still occur due to short fire-return intervals, high fire intensity, increased propagule pressure from heavily populated areas (Klinger *et al*., 2006). Fire severity has no universal definition (Cocke *et al.*, 2005) but for our study it can be defined as the magnitude of change occurring in the vegetation cover of an area post forest fire (Babu *et al.*, 2018; Bar *et al*., 2020; White *et al.*, 1996). The low, moderate and high severity is classified based on the magnitude of change while low severity depicting the minute changes in the vegetation cover postforest fire and high severity depicting the large changes in the vegetation cover post fire. Unburnt sites were those where no change were observed.

Invasive Alien Species (IAS) are non-native species whose introduction and/or spread outside their natural past or present ranges pose a risk to biodiversity. IAS have been identified as the second-most significant threat to biodiversity at the global level, and they pose a significant obstacle to the conservation and sustainable use of biodiversity at all levels - global, regional, and local (Kettunen *et al*., 2008; Kumar *et al*., 2019). After climate change, biological invasion is one of the biggest dangers to biodiversity (Chandra *et al*., 2012). Species extinction, hydrological changes, and ecosystem function are all brought on by invasive species, which reduce biodiversity (McGeoch *et al.,* 2010). Exotic plant species differ from native plant species in terms of their needs, methods of resource acquisition, and level of consumption, which may result in alterations to the soil's structure, profile, decomposition, nutrient content, moisture, and other factors. It has major negative effects on the biodiversity and ecosystem (Chandra *et al*., 2012). The establishment and spread of invasive species are significantly influenced by the landscape, which is characterised by its heterogeneity of structure, forms, human interferences, and environmental circumstances (Kumar and Prasad, 2014). Disturbances plays a significant role in invasion of a landscape by alien plant species. However, changes in the disturbance regime are frequently the primary cause of invasion rather than disturbance. The relationship and feedback mechanism between the occurrence of fire and invasive species was studied in the forests of central India by Hiremath and Sundaram (2005). Even while the community in some fire-adapted shrublands is quite resilient to intense, rare fires, changes in the fire regime that result in shorter fire intervals could make these communities more vulnerable to invasive plant species (Keeley and Brennan, 2012). These modifications affect the ratio of native to non-native species, the functional types of plants - from deeply rooted shrubs to shallow-rooted grasses and forbs - the frequency of fires due to the rise in fine fuels, and the capacity of the environment to store carbon (Keeley and Brennan, 2012). Correlations do exist between vegetation condition, composition, fire frequency, and invasion (Fisher *et al*., 2009). Frequent fire was associated with loss of native resprouting shrub cover, drop in native cover, richness, and variety, switch from native to introduced species, and changes in the relative importance of fire response categories.

The present study is aimed to understand the role of fire events in the dynamics of tree species diversity, stand structure, regeneration, and whether or not a relationship exists between forest fires and the prevalence of invasive plant species.

Material and Methods

Study area

The study sites lie in the Doon Valley (area lies between 30°00'- 30°35' N latitude and 77°45'-78°15'E longitude) in the city of Dehradun, the capital of Uttarakhand state (Fig. 1). The valley of Doon is surrounded by Shiwaliks in south-west and lesser Himalaya in north-east direction. The climate of the area is tropical; the average maximum and minimum

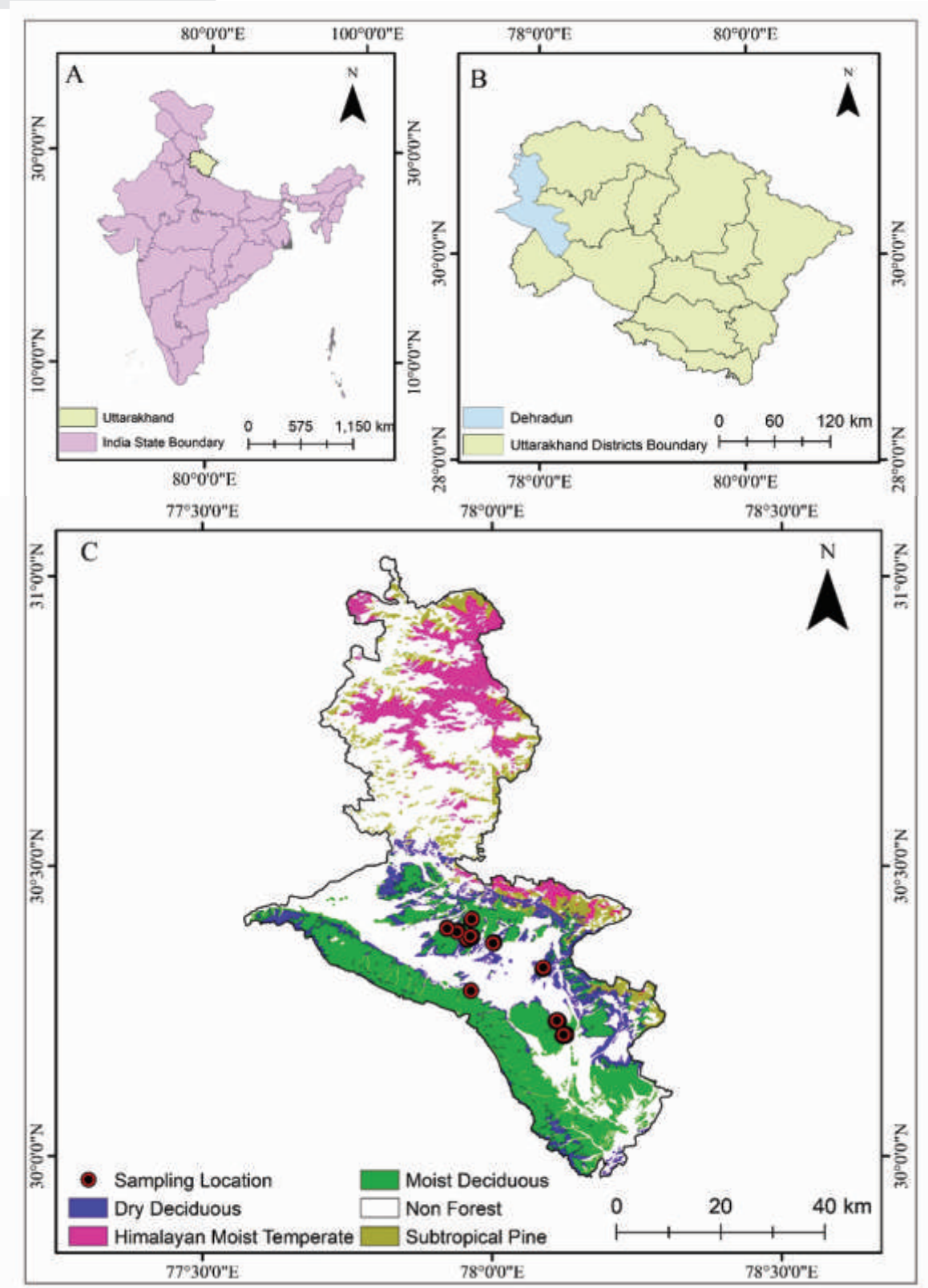

Fig. 1: A) Location of Uttarakhand on India map, B) Location of Dehradun on map of Uttarakhand, C) Map of sampling location along with forest type of the Dehradun district

temperatures are 27.6 °C and 13.8 °C, respectively, and the average annual rainfall is 202.5 cm. The soils are developed on the deep alluvial deposits with the parent material derived from the Doon alluvium. About 52 percentage of the Doon valley encompasses subtropical moist deciduous Sal forest (Gautam *et al*., 2014). Champion and Seth (1968) have classified the Doon valley into three types on the basis of Sal (*Shorea robusta* Gaertn.f.) forests, *viz.*, Moist Shiwalik Sal forest, Moist Bhabhar Doon Sal forests and Dry Shiwalik Sal forests. In these subtropical dry deciduous forests, sal is the dominant over story species with *Mallotus philippensis* as codominant tree species and *Clerodendron viscosum* and *Lantana camara* as understory associate species. All past studies clearly distinguished four different layers in these forests, with Sal and *Terminalia alata* occupying the top story followed by *Syzygium cumini* in the middle story, and *M. philippensis* and *Ehertia laevis* in the lowermost tree canopy, and the understory shrub and herb layer (Chauhan *et al*., 2008).

Methods

The methodology broadly involves two aspects. Firstly, the forest fire severity for 2021 was mapped for the tropical forest region of the Doon valley using the remote sensing approach. Secondly, the classified fire severity map was used to identify the sites for collection of primary field data. The entire methodology is elucidated through Fig. 2.

Forest fire severity mapping

Sentinel 2A and 2B satellite data sets of pre and post fire episode of fire affected months of March, April and May was downloaded and Bands 3, 8 and B12 were used to map the severity of burnt area. The Bands 3 and 8 are having 10 m spatial resolution, therefore these two bands were resampled into 20 m to match with the spatial resolution of band 12. After resampling, Normalized Burn Ratio (NBR) for the pre and post fire event were calculated. The NBR has been used to highlight the burnt areas, and is calculated from the NIR and SWIR bands, in case of sentinel, bands 8 and 12 were used (Key and Benson, 1999). NBR is calculated by using the equation (i) for sentinel 2A and 2B satellites.

$$NBR = \frac{Band\,8 - Band\,12}{(Band\,8 + Band\,12)} \quad \text{(i)}$$

Generally, NBR values range from -1 to +1. Healthy vegetation has very high reflectance in NIR region, where as the burnt areas show low reflectance. In contrast, burnt areas show higher reflectance and healthy vegetation show lower in SWIR region. Therefore, the higher NBR value indicates healthy vegetation and lower value for burned areas.

Difference between pre and post fire NBR (dNBR) has been used by several authors to estimate the fire severity (Cocke *et al*., 2005). The dNBR can be calculated from the NBR of pre and post fire event following equation (ii). The pre and post imagery before and after fire event of the month of March, April and May of 2021 were undertaken to map the fire severity of the study area. The threshold for dNBR classification were adopted from Cocke *et al.* (2005) and the classified map were subject to validation as perBabu *et al.* (2018).

$$dNBR = NBR_{prefire} - NBR_{postfire} \quad \text{(ii)}$$

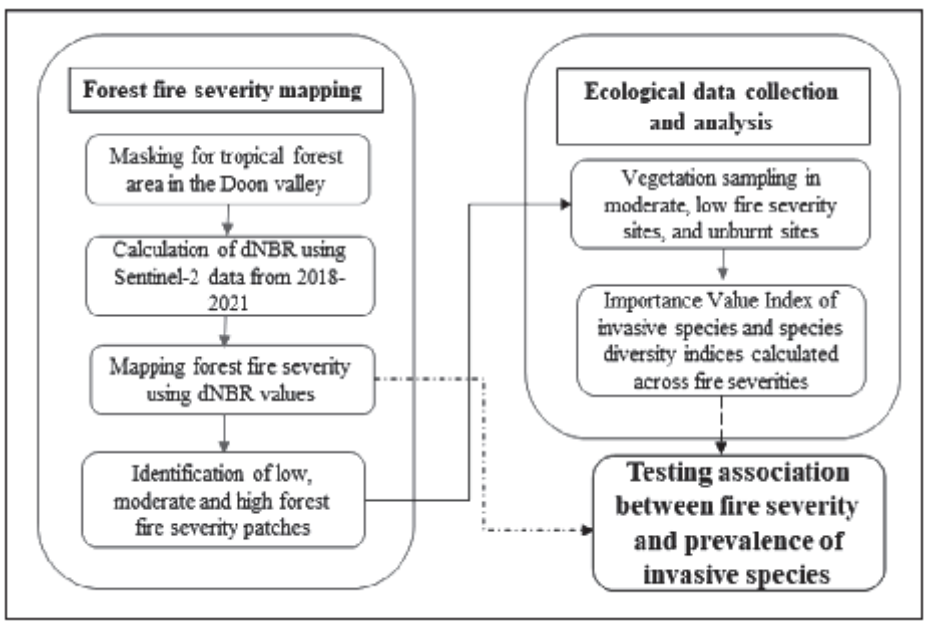

Fig. 2: : Schematic diagram showing the methodology

Validating the forest fire severity using the ground truthing is complex and unfeasible. Active fire hotspot are well used proxy for actual fire points for validating the classified forest fire severity maps (Babu *et al.*, 2018). Active fire hotspot data of Moderate Resolution Imaging Spectro radiometer (MODIS) and Visible Infrared Imaging Radiometer Suite (VIIRS) available as point shapefile were used to validate the burned area obtained using the forest fire severity map. The active fire hotspots were downloaded from Fire Information for Resource Management (FIRMS, 2020). The prepared fire severity map has been showcased in Fig. 3(A) and also to provide reference, the forest type group map has also been added Fig. 3(B). The site thus identified were randomly selected from unburnt, low severity and moderate severity class for further field sampling.

Data collection and analysis

In totality, six sites each of moderate and low fire severity were studied. The data was collected in the month of March and April, 2022. Six unburnt patches in the above sites were studied for comparison. The data collected from the field *i.e.*, diameters at breast height (DBH) and number of individuals were used to calculate species density, species frequency, species abundance, relative density, relative frequency, relative dominance, IVI, species richness, and species diversity for both moderate and low fire severity sites.

The species richness is the number of species per unit area (Whittaker, 1972). The vegetation data were quantitatively analyzed for abundance, density and frequency following Curtis (1959). The relative values of frequency, density and dominance were determined following Phillips (1959). Importance Values Index (IVI) which is the integrated measure of relative frequency, relative density and relative dominance was computed for each species (Curtis, 1959).

Density = (Total number of individuals of species in all quadrats /Total number of quadrats studied)

Frequency (%) = (Number of quadrats in which a species occured/ Total number of quadrats studied) x 100

Abundance = (Total number of a species in all quadrats/Total number of quadrats in which the species occurred)

Basal Area (BA) = $\pi d^2/4$, where d = DBH

Relative Density (%) = (Number of individuals of the species / Number of individuals of all the species) x 100

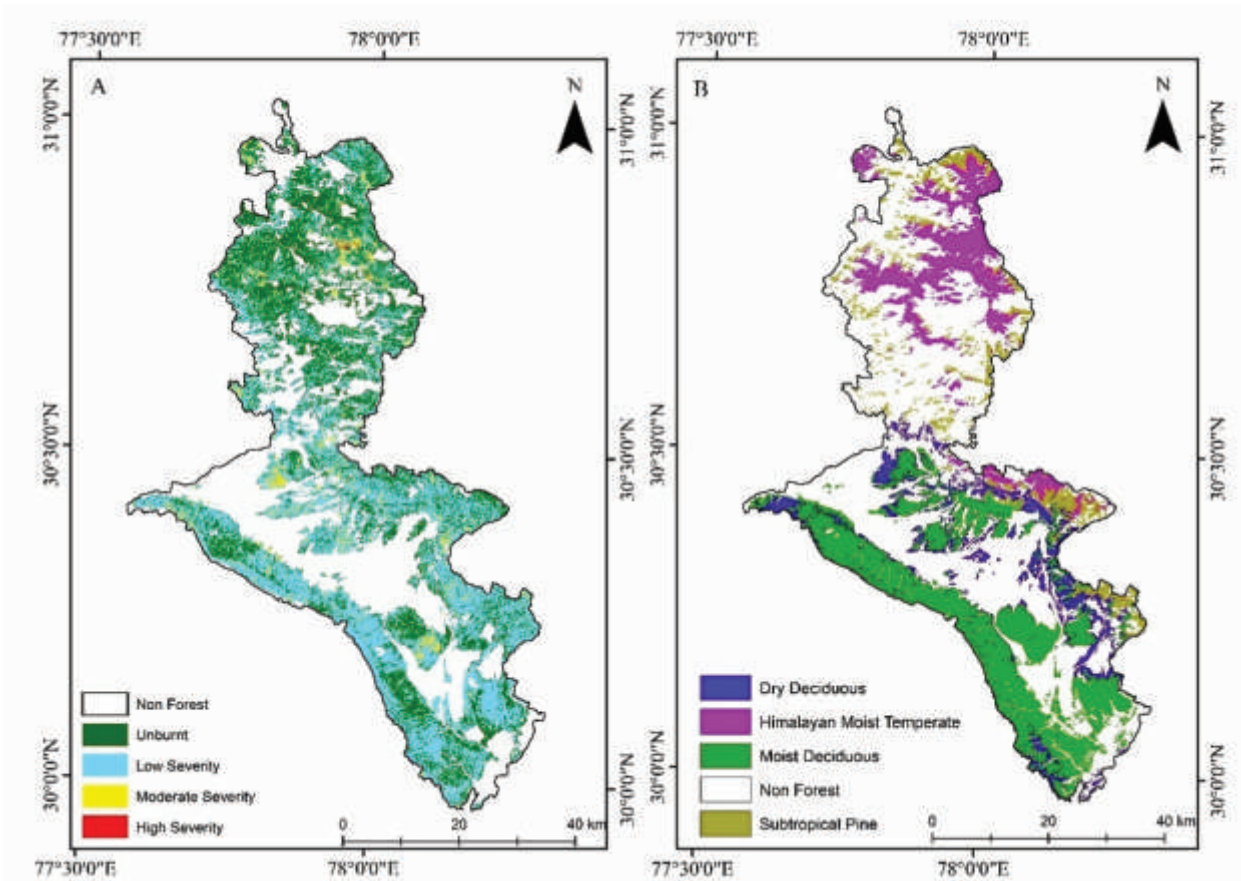

Fig. 3: A) Classified forest fire severity map of Dehradun district for the month of March, April and May, 2021 B) Forest type group map of Dehradun districts

Relative Frequency (%) = (Number of occurrences of the species / Number of occurrences of all the species) x 100

Relative Dominance (%) = (Total basal area of the species / Total basal area of all the species) x 100

Importance Value Index (IVI) = % Relative Frequency + % Relative Density + % Relative Dominance

Structural diversity

The index of diversity was calculated after Shannon and Wiener (1963). If pi is the proportion of individuals (from the sample total) of species *i.e.*, then diversity (H′) is,

$$H' = -\sum_{i=1}^{s}(pi)(\ln pi)$$

Where, s = the number of species in the sample, *pi* =relative abundance of ith species (ni/N), N = total number of individuals of all kinds, *ni* = number of individuals of *ith* species and ln = natural log.

Dominance

Concentration of dominance (CD) was measured by Simpson's index (Simpson, 1949). Denoted as D, this index is calculated as:

$$D = \Sigma n_i(n_i\text{-}1) \ / \ N(N\text{-}1)$$

Where,n_i = The number of organisms that belong to species I, N: The total number of organisms

The value for Simpson's Diversity Index ranges between 0 and 1. The higher the value, the lower the diversity.Since this interpretation is a bit counterintuitive, we often calculate Simpson's Index of Diversity (sometimes called a Dominance Index) (Simpson, 1949), which is calculated as 1 – D. The higher the value for this index, the higher the diversity of species**.**

The distribution and dominance of invasive species will be determined on the basis of their IVI. Shannon-Wiener Index and Simpson Index is calculated to understand species richness and dominance index of the species in sample.

Statistical analysis

Statistical Analysis was done to determine the effect of fire on alien plant species invasion. Data analysed by One-way analysis of variance (ANOVA), using total IVI of invasive species per site as a single factor.

Results

Species richness, Diversity and Concentration of Dominance within moderate and low fire severity forest sites

In the shrub layer, species richness was high in moderate fire severity areas as compared to low fire severity areas. In moderate fire severity forest sites, the maximum species richness was recorded in Site 2 (10) and Site 9 (10) and in low fire severity forest sites, the maximum species richness was recorded in Site 11 (09). For the herb layer also, species richness was high in moderate fire severity areas as compared to low fire severity areas. The maximum richness was recorded for site 1 (6) and Site 5 (5) for moderate and low fire severity forest sites respectively (Table 1).

The variations in Shannon and Wiener diversity index are presented in Table 1. The shrub layer in moderate fire severity areas exhibited greater diversity than that in low fire severity areas. Among moderate fire severity forest sites for shrubs, site 9 exhibited greater diversity (2.24) and among low fire severity forest sites, Site 11 exhibited highest diversity (2.08). For the herb layer also, species diversity was high in moderate fire severity areas as compared to low fire severity areas. Highest diversity was recorded for Site 10 (1.58) and Site 5 (1.49) for moderate and low fire severity forest sites respectively (Table 1).

The Concentration of dominance (CD) in the shrub layer of moderate fire severity areas, ranged between 0.78 (site 3) to 0.88 (site 9 and 10) across the sites and for low fire severity areas, the value was maximum in site 11 (0.86) and minimum in site 5 (0.74). For the herb layer, in moderate fire severity areas, the value ranged between 0.79 (site 10) to 0.69 (site 1), and for low fire severity areas, it ranges between 0.49 (Site 6) and 0.76 (Site- 5). Both shrub and herb layer in moderate fire severity areas exhibited a greater Concentration of Dominancethan that in low fire severity areas (Table 1).

Effect of different fire severity on invasion

A total of 11 invasive alien plant species, namely *Ageratum conyzoides, Alternanthera sessilis*, *Ardisia japonica*, *Asparagus recemosus, Berberis aristata*, *Cyperus iria, Flacourtia indica, Lantana camara, Nelsonia canescens, Parthenium hysterophorus, Sida cordifolia* was recorded from study sites. Total IVI of the invasive species per site was calculated separately for 6 of the moderate fire severity study sites and 6 of the low fire severity study sites. In the shrub layer, it was observed that *Lantana camara* had the highest density followed by the seedlings of *Shorea robusta* (Sal) in moderately burnt sites. *Lantana camara* is an invasive species and it hints at the competition it is providing to the regeneration of the Sal tree which is a major timber species (Fig. 4(a)). In areas of low fire severity, the regeneration of the Sal forest was observed to be good, with seedlings of Sal having the highest density.

The herb layer in both, regions of moderate and low fire density showed *Ageratum conyzoides* to have the highest density, which is an invasive species in the region the study was conducted. Thereby, indicating the role of fire in determining the invasion dynamics of a landscape.

In order to gain a holistic understanding of the ecological implications of fire, and the extent of invasion in the region, importance value index (IVI) of the shrubs and herbs was calculated (Fig. 5 - a and b). Amongst shrubs, the seedlings of *Shorea robusta* was observed

Table 1: Species richness, species diversity (H), concentration of dominance (CD) in different forest sites

Fire severity	Site	Species richness	Species diversity (H)	Concentration of dominance (CD)
Shrub layer				
Moderate	1	8	1.82	0.82
	2	10	2.06	0.86
	3	6	1.62	0.78
	4	7	1.92	0.85
	9	10	2.24	0.88
	10	9	2.16	0.88
	Average	8.33	1.97	0.84
Low	5	6	1.53	0.74
	6	6	1.65	0.78
	7	7	1.71	0.78
	8	6	1.64	0.77
	11	9	2.08	0.86
	12	8	1.94	0.83
	Average	7	1.75	0.79
Herb layer				
Moderate	1	6	1.19	0.61
	2	4	1.14	0.63
	3	5	1.21	0.62
	4	4	1.29	0.70
	9	4	1.35	0.74
	10	5	1.58	0.79
	Average	4.66	1.29	0.68
Low	5	5	1.49	0.76
	6	2	0.68	0.49
	7	3	1.09	0.67
	8	4	1.35	0.74
	11	4	1.37	0.74
	12	3	1.09	0.66
	Average	3.5	1.17	0.67

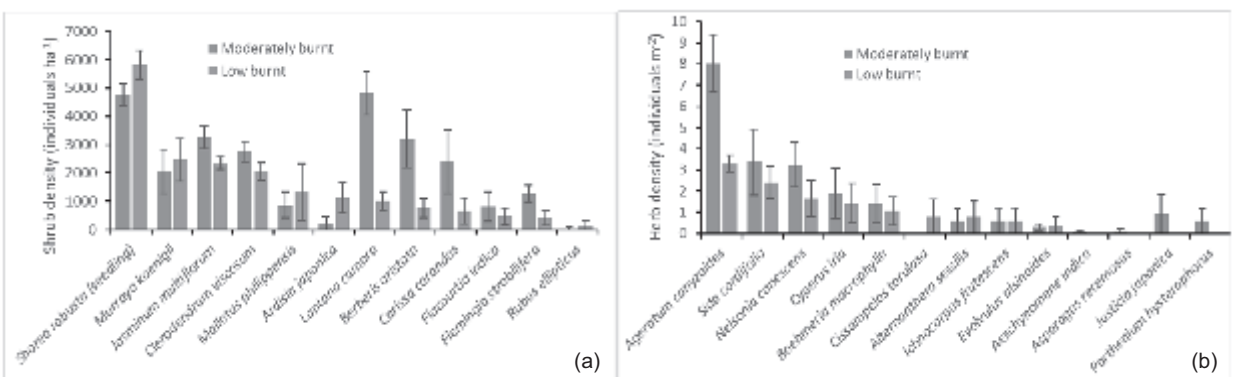

Fig. 4: (a) Density of shrub species across fire severities, (b) Density of herb species across fire severities

to have the maximum IVI in both moderate and low fire severity regions. The major invasive species observed was *Lantana camara.* The herb layer was dominated by the invasive, *Ageratum conyzoides.*

Due to the inherent normalisation and its ability to be easily compared, IVI was used to understand the impacts of fire on invasion dynamics in the region. One-way analysis of variance (ANOVA) was performed to analyze the effect of fire severity on invasive species occurrence between moderate and low fire severity study sites by taking cumulative IVI per site as a single factor. No such significant difference ($p > 0.05$) in invasive species occurrence (cumulative IVI per site)

has been observed between moderate and low fire severity study sites (Table 2).

Relationship between fire and occurrence of Invasive alien plant species

A total of 11 invasive alien plant species, namely *Ageratum conyzoides, Alternanthera sessilis*, *Ardisia japonica*, *Asparagus recemosus, Berberis aristata*, *Cyperus iria, Flacourtia indica, Lantana camara, Nelsonia canescens, Parthenium hysterophorus* and *Sida cordifolia* were recorded from study sites. Total IVI of the invasive species per site was calculated separately for 6 of the burnt site and 6 of the unburnt sites. One-way Analysis of Variance (ANOVA) was performed for comparing Invasive species occurrence between burnt and unburnt study sites by taking cumulative IVI per site as a single factor. A highly significant ($p < 0.05$) difference in invasive species occurrence (cumulative IVI per site) has been observed between burnt and unburnt sites (Table 3).

Discussion

Impact of forest fire on vegetation composition

Sal forests of Doon valley are characteristically homogeneous in distribution due to various silvicultural operations carried out in the past (Negi *et al*., 2002), but the values of concentration of dominance in the present study are much less than the previous studies. This

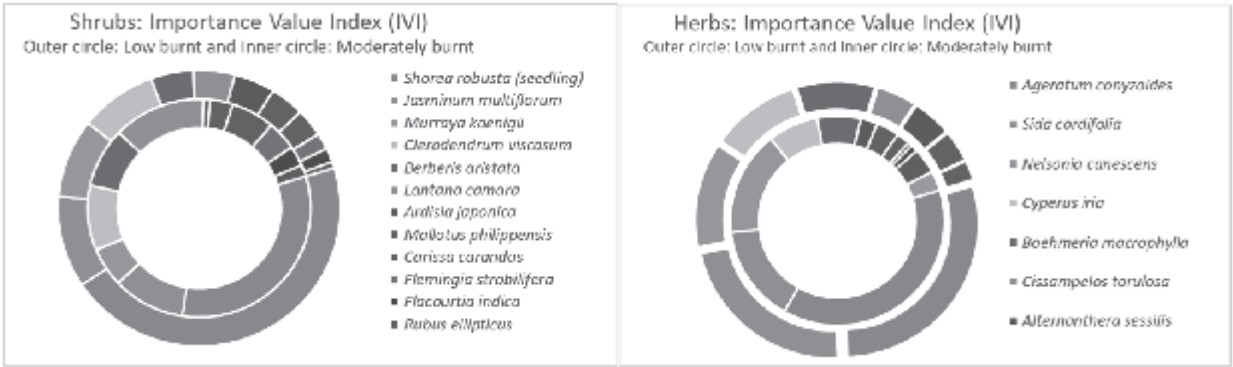

Fig. 5: (a) Diagrammatic representation of the IVI of shrub species across fire severities, (b) Diagrammatic representation of the IVI of herb species across fire severities

Table 2: Performing One-way Analysis of Variance (ANOVA) for comparing Invasive species occurrence between moderate and low fire severity study sites

SUMMARY						
Groups	***Count***	***Sum***	***Average***	***Variance***		
Moderate fire severity sites	6	1971.64	328.606667	5323.7682		
Low fire severity sites	6	1621.58	270.263333	1619.7959		
ANOVA						
Source of Variation	***SS***	***df***	***MS***	***F***	***P-value***	***F crit***
Between Groups	10211.834	1	10211.8336	2.941381	0.1171027	4.964603
Within Groups	34717.82	10	3471.78205			
Total	**44929.654**	**11**				

Table 3: Performing One-way Analysis of Variance (ANOVA) for comparing Invasive species occurrence between burnt and unburnt study sites

SUMMARY						
Groups	***Count***	***Sum***	***Average***	***Variance***		
Burnt site	6	1621.58	270.263333	1619.79587		
Unburnt site	6	358.6	59.7666667	189.754667		
ANOVA						
Source of Variation	***SS***	***df***	***MS***	***F***	***P-value***	***F crit***
Between Groups	132926.54	1	132926.54	146.916638	2.658E-07	4.9646
Within Groups	9047.75267	10	904.775267			
Total	**141974.293**	**11**				

means that the Sal forests of the valley are moving towards heterogeneity. The reason for this may be various disturbances prevailing in these forests *viz.* collection of fodder and fuelwood, grazing of cattle, urbanization and most importantly forest fire that has increased by many folds in the last few years which in turn also related to alien plant invasion. However, the plant species present, regeneration of tree species, species richness and species diversity explain the future of the vegetation composition.

Forest fires alter the diversity, structure and regeneration of species in the dry deciduous Sal forest of Doon Valley. Data persuaded that the higher species richness has been recorded in moderate fire severity study sites as compared to low fire severity areas, which explains the fact that forest fire is important for growth as well as regeneration with higher species richness and higher species diversity. In burnt plots, seedling and sapling densities were noticeably higher and steadily rising. It implies that a single fire event might be advantageous for tree regeneration. The increased number of seedlings and saplings may be due to increased nutrient availability, decreased pathogen population, breaking of seed dormancy, and opening of mineral soils. The results of this studyis also supported by the studies of Kennard *et al*. (2002). They have also found the increased number of seedlings and saplings in burnt patches compared to unburnt patches.

Linkage between Forest fire and Alien plant invasion

Non-native species, elevation percentage of bare ground, lower soil nutrient levels, and lower canopy cover were all linked to sites with higher fire severity in general (Freeman *et al*., 2007). Fire is an important factor that affects stand structure and alien seed banks. When fire regimes are altered, a different selective environment is produced. All these depict that presence of fire favour aliens (Keeley *et al*., 2005). The historical use of prescribed fire to convert shrublands to more useful grazing lands has led to severe annual grass invasion (Keeley, 2006). If such changes promote the dominance of the invaders, then an invasive plant fire regime cycle can be established (Brooks *et al*., 2004). Data from this study in various fire affected sites showed that, there is no such significant difference in the occurrence of invasive plant species in moderate fire severity areas as compared to low fire severity sites but data from burnt and unburnt sites showed that there was a remarkable presence of alien plant species in burnt sites as compared to unburnt sites. Unburnt areas had no such species or very few of them. The rate of alien species reproduction and the speed at which the shrublands regenerate into their former closed-canopy state determine the extent of an alien invasion in burnt lands or areas.

Fire has a significant impact on the vegetation's pattern, affecting everything from plant growth to seedling regeneration to the maintenance of the forest's understory. On the one hand, fire can promote the growth of certain tree species, but on the other, fire can drive native species to extinction. Additionally, fire can kill seedlings. Fire can lead to plant community succession, but it can also foster community persistence. The frequency of fires can have both positive and negative effects on the forest.

Conclusion

The study indicates that the prevalence of invasion by non-native species is higher in burnt areas. Fire is definitely a major type of disturbance that could affect the establishment and spread of invasive species. However, the analysis indicates that invasion rate by non-native species is higher in burnt areas and also depicts the density increase within a site, which includes spread within a site as well as increases in abundance in colonized areas. The dominance of invasive species in burnt areas as compared to unburnt sites, implies not only the establishment of substantial abundance but also the suppression of native species. A fire-*Lantana* cycle was proposed for the positive feedback between the occurrence of fires and growth of invasive alien plant, *Lantana camara* for the forests of central India. Continuous monitoring is recommended to assess the presence of any such association in the forests of the Doon valley. As, such an association would help the forest managers in drawing up a management plan in a cost-effective manner whereby only the enforcing agent of degradation will need to be controlled. This research provides baseline information about the existing status of the association between forest fires and the prevalence of invasive alien plant species in fire-affected forests. Further research evaluating the effect of invasive life forms on vegetation composition in fire-affected areas is recommended to guide management efforts to conserve and restore native plant communities, ensure sustainable land management, and restore the forest productivity to its pristine state.

वन की आग और पौधों का आक्रमण : उष्णकटिबंधीय पर्णपाती वन परिदृश्य में भूमिक्षरण के एजेंटों की खोज

सुपर्णा दास, शुभम सिंह, अगनीश कुमार दास, निर्मल्या बाला और भूपेंद्र सिंह अधिकारी

सारांश

भूमि क्षरण 21 वीं सदी की प्रमुख पर्यावरणीय चिंताओं में से एक है। वन की आग और आक्रामक विदेशी पौधों की प्रजातियों के प्रसार को वनक्षरण के प्रमुख चालकों के रूप में माना गया है, जिसके कारण वन की संरचना में बदलाव आया है, और इससे वन की उत्पादकता में भी गिरावट आई है। इस अध्ययन द्वारा वन की आग और उष्णकटिबंधीय वन परिदृश्य में आक्रामक प्रजातियों के प्रसार के संभावित सहयोग की पड़ताल करता है। वर्तमान अध्ययन *शोरिया रोबस्टा* के प्रभुत्व वाले उष्णकटिबंधीय नमपर्ण पाती वन के आग प्रभावित क्षेत्रों में आयोजित किया गया है और दून घाटी, उत्तराखंड में और उसके आसपास आक्रामक पौधों द्वारा आक्रमण पर वन की आग की गंभीरता के प्रभाव का भी मूल्यांकन किया गया है। अलग-अलग

सामान्यीकृत जलाअनुपात का उपयोग करके आग की गंभीरता को मैप किया गया था, और आग के प्रभाव को समझने के लिए प्रतिनिधि के रूप में इस्तेमाल किया गया है। पारिस्थितिक डेटा विश्लेषण क्षेत्र अध्ययन और महत्व मूल्यसूचकांक (आईवीआई) के माध्यम से किया गया था, और विविधता सूचकांकों की गणना की गई थी। परिणामों से पता चला कि मध्यम आग की गंभीरता वाले क्षेत्रों में झाड़ी की विविधता अधिक थी। आक्रामक प्रजातियों के कुल IVI के बीच एक स्पष्ट संबंध मध्यम और कम आग की गंभीरता के क्षेत्रों के बीच नहीं देखा गया था, लेकिन आग लगने की घटना को एक तरह से ANOVA में आक्रामक प्रजातियों की उपस्थिति को प्रभावित करने के लिए देखा गया था, जिसमें आक्रामक प्रजातियों के कुल IVI का उपयोग एकल के रूप में किया गया था। अध्ययन का अनुमान है कि आक्रामक प्रजातियों की उपस्थिति पर आग की गंभीरता का प्रभाव स्पष्ट नहीं है, लेकिन आग की उपस्थिति आक्रामक प्रजातियों की स्थापना में मदद करती है। अध्ययन यह समझने के लिए दीर्घकालिक निगरानी की सिफारिश करता है कि क्या वन विनाश के इन दो प्रतिनिधियों के बीच मौजूदा सकारात्मक प्रतिक्रिया है। अध्ययन भविष्य के वन प्रबंधकों को स्थायी प्रबंधन के लिए प्रबंधन योजना विकसित करने और वनों को उनके प्रमुख राज्य में बहाल करने में मदद करेगा।

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