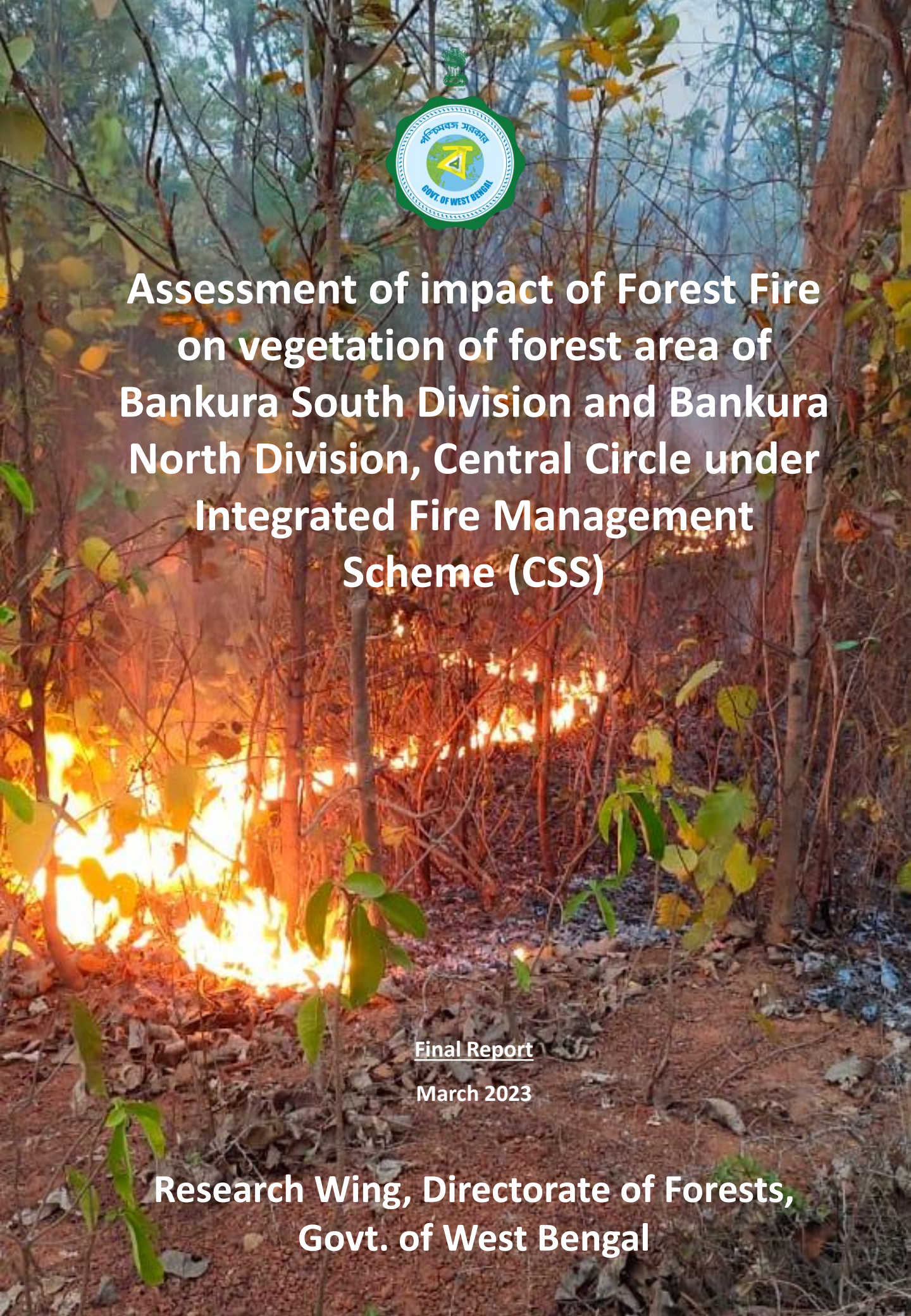


Assessment of impact of Forest Fire on vegetation of forest area of Bankura South Division and Bankura North Division, Central Circle under Integrated Fire Management Scheme (CSS)

Final Report

March 2023

Research Wing, Directorate of Forests, Govt. of West Bengal

Assessment of impact of Forest Fire on vegetation of forest area of Bankura South Division and Bankura North Division, Central Circle under Integrated Fire Management Scheme (CSS)

Final Report

March 2023

Conducted by

Research Wing, Directorate of Forests,

Government of West Bengal

and

Nature Environment & Wildlife Society (NEWS)

Executing Team

Dr. J. R. B. Alfred, President, Nature Environment & Wildlife Society

Mr. Biswajit Roy Choudhury, Secretary, Nature Environment & Wildlife Society

Mr. Umar Imam, IFS, Divisional Forest Officer, Bankura North Division, Directorate of Forests, Govt. of West Bengal

Mr. E. Vijaya Kumar, IFS, Divisional Forest Officer, Bankura South Division, Directorate of Forests, Govt. of West Bengal

Dr. Saikat Manna, Field Botanist, Nature Environment & Wildlife Society

Ms. Ranjana Saha, Field Biologist, Nature Environment & Wildlife Society

Mr. Tayan Das, Field assistant, Nature Environment & Wildlife Society

Mr. Ayan Roy Chowdhury, Field assistant, Nature Environment & Wildlife Society

Acknowledgements

We are grateful to the Directorate of Forests, Govt. of West Bengal for assigning this project to NEWS. We are indebted especially to Mr. Piar Chand, IFS, Principal Chief Conservator of Forests, Research Monitoring and Development Wing, Govt. of West Bengal for his constant support and according the necessary approvals to undertake the work in this project.

We are thankful for the help given by Mrs. Pratibha Raj, IFS, Additional Principal Chief Conservator of Forests, Research and Monitoring, Directorate of Forests, Govt. of West Bengal.

We are also thankful to Dr. Debanshu Mallick, IFS, Chief Conservator of Forests, Research and Development, Directorate of Forests, Govt. of West Bengal for his support in the present project.

We are very grateful to Mr. Bidyut Sarkar, IFS, Conservator of Forests, Research Circle, Directorate of Forests, Govt. of West Bengal, for all the help rendered in our work and specially for providing all the necessary arrangements.

We are thankful to Mr. Bhaskar J.V., IFS, Conservator of Forests, Working Plan & GIS, Directorate of Forests, Govt. of West Bengal, for proving us the necessary maps and archive data, related to this project.

We also thank Mr. Umar Imam, IFS, Divisional Forest Officer Bankura North Division, Directorate of Forests, Govt. of West Bengal and Mr. E. Vijaya Kumar, IFS, Divisional Forest Officer, Bankura South Division, Directorate of Forests, Govt. of West Bengal for their guidance and for providing us the necessary permission, related to this project.

We are grateful to all the Ranger Officers, Beat officers and other Departmental staffs for their spontaneous guidance and information to conduct the field surveys.

Last but not the least we express our sincere gratitude to all the JFMC members and the resource persons and the local people for providing valuable information and sharing their experience regarding the forest fire and their management strategies.

Index of Contents

1. Introduction

Fire is an ecological disturbance factor in forest and creates a myriad of environmental, social and economic impacts. The problem of wild fire is a universal phenomenon which is dominant disturbing factor in all types of vegetation throughout the world. Though Forest fire has traditionally been an essential mechanism in generating ecological succession by acting like an environmental filter, selecting species and shaping ecosystem communities (Parashar and Biswas, 2003; Satendra, 2014) while helping the vegetation by organizing physical and biological attributes, influencing energy flows and biological cycles, yet it is known to be a major ecological event that affects a substantial proportion of the world's terrestrial ecosystems across a wide range of regions and biomes (Bond and Keeley, 2005; Certini, 2005; Kutiel, 2012).

Due to various natural and human induced factors, the severity of forest fires in general is increasing day by day. The adverse impacts of increased forest fire and its severity have placed this in the category of other natural disasters like floods, droughts, earthquakes etc., especially the recent decades witnessing frequent fires with high intensity causing permanent changes to the ecosystem and its components (Cha et al., 2020).

Forest fires are common in almost all types of vegetation. In the temperate and northern boreal forests, it occurs regularly during the dry summers. Though equatorial rain forests are moist, however extreme droughts associated with other human induced activities make it vulnerable to fire hazard. In tropical forests, fire is a regular phenomenon at the short interval of one to five years. The Tropical Submontane Conifers Forests due its specific vegetation (pine), rich in resin and susceptible to fire, are subjected to forest fire regularly. Dry tropical forests are considered to be more vulnerable to recurrent fires than any other forest across the world mostly during the dry season when deciduous/semi-deciduous trees shed their leaves (Murphy and Lugo, 1986; Kauffman et al., 2003; Janzen 1988).

Globally, biomass fires are burning between 3-4.5 million Km^2 per year (Chatenoux and Peduzzi, 2012). Forest fires are responsible for 17.4% of Green House Gasses global emissions (Solomon et al., 2007). Thus, fires smoke has direct impact on the surface energy budget and increase atmospheric temperatures (Wang and Christopher, 2006). In South Asia, more than half of the forested areas have been lost to forest fire during 2003- 2017 and is regarded as the forest fire hotspots in the world (Reddy et al. 2020a). During 2001-2019, 119 million hectares of tree cover were lost globally due to fires.

Indian forests are broadly classified into 16 types (Champion and Seth, 1968). Forest fires are widespread phenomena in Indian forests and dry deciduous forest shows significantly high burnt area, followed by thorn forest, broadleaved forest, dry savannah, Scrub and grasslands (Krishna and Reddy, 2012). Maximum forest fires in India have been reported in tropical dry deciduous followed by tropical moist deciduous forest and tropical semievergreen forest (FSI 2012).

Among South Asian countries, India has the second highest number of forest fire hotspots (32%) following Bangladesh (34%) (Reddy et al. 2020b). According to a Forest Survey of

India report, about 50 percent of forest areas in the country are fire-prone and about 6 percent of the forests are prone to severe fire damage.

In India, 8,645 forest fire incidences have been reported during 2004-2005; 20,567 during 2005-2006; 16,779 during 2006-2007; 17,264 during 2007-2008; 26,180 during 2008-2009; 30,892 during 2009-2010 and 13,898 during 2010-2011, respectively. The country also reported with 3,45,989 forest fire events during November 2020-June 2021 with Odisha recorded the highest fire events (51,968) followed by Madhya Pradesh (47,795), Chhattisgarh (38,106), Maharashtra (34,025), Jharkhand (21,713) and Uttarakhand with 21,487 events (Anon., 2021). Forest fire occurrence is mostly seen during summer between February and May and the most affected forest type is the tropical deciduous forest found in Odisha, Chhattisgarh, Bihar, Telangana, Andhra Pradesh, Jharkhand, and West Bengal (Priyadarshini and Mohapatra 2022). In West Bengal, 0.98% of total forest cover is very highly fire prone while 4.33% is highly fire prone and 10.72% is moderately fire prone and 33% of forest area is subject to repeated annual fires (Lal 2004).

Studies suggest that 90% of vegetation fires in India may be man-made, and about 3.73 million ha of forest areas are affected by forest fires annually (Srivastava and Garg 2013). The annual losses from forest fires in India for the entire country have been moderately estimated at Rs. 440 crores. This estimate does not include the loss suffered in the form of biodiversity, nutrient and soil moisture and other intangible benefits. India witnessed the most severe forest fires during the summer of 1995 in the hills of Uttaranchal and Himachal Pradesh in north west Himalaya. An area of 677,700 ha was affected by fires. The quantifiable timber loss was around Rs. 17.50 crores.

To save the forest from scourge of fire is a central responsibility of forest managers. From conservation point of view, maintaining and sustaining all forest types is important as they harbor high biodiversity of not only plant species, but are also a preferred habitat for several wild animals. To assess the current situation of forest fire in West Bengal, the State Forest Department has taken the initiative to prepare a comprehensive document on the effect of fire on forest vegetation with specified objectives.

2. Objectives

1. To assess the impact on the total vegetation of forest i.e., trees, shrubs, herbs etc. affected by forest fire.
2. To assess the ecological benefits or disbalance due to forest fire on floral species.
3. To reduce the risk of forest fire in fire prone areas.
4. To identify the plant species which are most affected by the forest fire.
5. To assess the loss of biomass in the fire prone zone.

3. Materials and methods

3.1. Study area

The study was conducted in Tropical Dry Deciduous Forests of Bankura South and Bankura North Forest Divisions under Bankura district at the Western plateau region of the State (Figure 1).

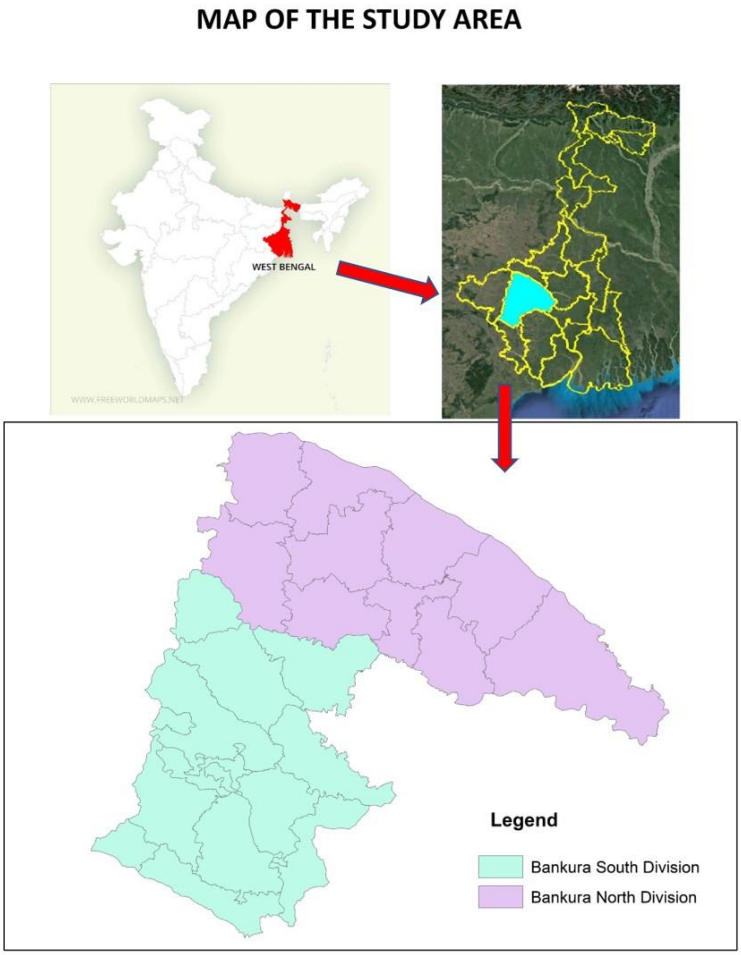


Figure 1:The Study Area

I. **Location and boundary** - The project site is confined to the geographical range of 22° 38' and 23° 38'N latitude and between 86° 36' and 87° 46' E longitude covering an area of 6,882 km^2. Geographically, Bankura district is surrounded by Purba Bardhaman district and Paschim Bardhaman district in the North, Purulia district in the West, Jhargram district and Paschim Medinipur district in the South, and some part of Hooghly district in the East.

II. **Topography** – The district is generally characterized by undulating topography of Chhotanagpur plateau region. The landscape is characterized by

a) **High hilly region / Hard rock area:** Found at the western most part of the district collectively covering 176915 Ha. Biharinath is the highest hill (451 m) of the district followed by Susunia (442 m).

b) **Uneven lands / Hard rock ring area:** These are the uneven lands covering 150611 Ha as whole.

c) **Even alluvial lands / alluvial area:** The landmass with evenly distributed alluvium covering 56970 Ha area at the Eastern part of the district.

III. **Soil –** In general, soils are mostly sedentary and acidic in nature. Three types of soils have been recognized in this district *viz.* (1) Red soil derived from weathering of granites, gneisses and schist found in undulated uplands at the south central, southeastern and south western parts of the district. Red soil is shallow, gravelly, coarse having low water holding capacity, (2) Lateritic soil in the uneven lands. Such soils are distinguished from the red soils by the occurrence of ferruginous concretions in a definite layer, whereas in the red soils they are distributed throughout the profile and (3) Alluvial soil is enriched by silt deposition during floods and found only in valley bottom in very narrow strips along the rivers, mostly in the fringe areas and in the valleys.

IV. **Climate -** The district of Bankura experiences an extreme climate with high range of temperature. Being a part of tropics, the climate of the area is generally hot and humid and experiences three distinct seasons – Summer, Monsoon and Winter. There is marked difference between the winter and the summer temperatures. in summer with average daily maximum temperature varies between 26ºC and 39ºC. Rainfall in the district of Bankura is generally scanty even though good rainfall occur on the eastern part of the district. Average annual rainfall ranges from 1300 mm – 1400 mm, 90% of which falling only in the monsoon months (June to September) mostly at the Eastern part of the district. Relative humidity is generally high throughout the year.

V. **River systems –** Bankura is drained by three major rivers e.g., Damodar, Darkeswar and Kangsabati along with their tributaries as Gandheswari, Silai and Kumari flowing from the North-West to the South-East direction roughly parallel to one another and ultimately merge with the Hooghly River. All these rivers are mostly rain water fed and originate from the hills of the West. These rivers come down in floods after heavy rains and subside as rapidly as they rise. In summer, their sand beds are almost always dry.

VI. **Forest -** Total Forest cover is estimated 20.65% of total geographical area of the districts. About 48% of the forest in this district is degraded type. The forests are mainly tropical dry deciduous type with predominance of Sal tree (*Shorea robusta*). Other tree species found in the forests are Mahua (*Madhuca longifolia*), Piyal (*Buchanania lanzan*), Vella (*Semecarpas anacardium*), Dhaw (*Anogeissus latifolia*), Kendu (*Diospyros excelsa*), Piyasal (*Pterocarpus marsupium*), Bahera (*Terminalia bellerica*), Haritaki (*Terminalia chebula*), Amloki (*Phyllanthus emblica*) etc. The landscape has a rich wildlife heritage of mammals including carnivores like Leopard (*Panthera pardus fusca*), Sloth bear (*Melursus ursinus*), striped hyena (*Hyaena hyaena*), Indian grey wolf (*Canis lupus pallipes*), Bengal fox (*Vulpes bengalensis*), Golden jackal (*Canis aureus*) and other smaller mammals like Indian wild boar (*Sus scrofa cristatus*), Indian pangolin (*Manis crassicaudata*), Porcupine (*Hystrix brachyura*), Indian hare (*Lepus nigricollis*) etc.

3.2. Methodology:

Impact of forest fire on vegetation has been measured by comparing the difference between vegetation of burned area and adjacent unburned area in terms of values of several parameters *viz.* diversity, richness, heterogeneity, community similarity/dissimilarity and gain/loss of plant species before fire and after fire (Hilwan, 2020).

3.2.1. Selection of sampling sites and Size of sampling plots

Forests of Ranibandh and Pirargari Ranges under Bankura South Forest Division and Beliatore, Radhanagar and Sonamukhi Ranges under Bankura North Forest Division are found to be affected by frequent fire in the consecutive past three years (Table 1). Vegetation data has been collected from two sample plots of 50m X 50m size each (one in burned area and one in unburned area, adjacent to the burned area) from each of the above-mentioned forest ranges (Figure 2 & 3).

Table 1:Forest area visited for assessing the impact of Forest Fire on vegetation

Forest Division	Range	Area Affected (Ha)			No. of Sample Plot (50m X 50m)	
		2019-2020	2020-2021	2021-2022	At Burned area	At Unburned area
Bankura South	Ranibandh	10	16	17	1	1
	Pirargari	64.5	0.3	119	1	1
Bankura North	Beliatore	3.76	30.33	53.04	1	1
	Radhanagar	1.25	12.15	10.83	1	1
	Sonamukhi	3.85	15.29	29.11	1	1

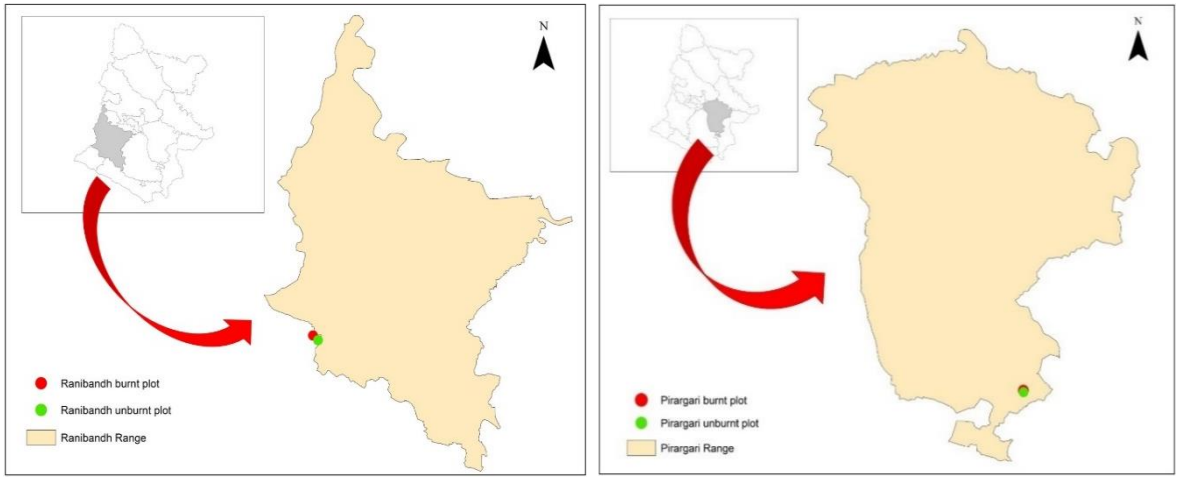


Figure 2 Location of sample plots in Ranobandh and Pirorgari Ranges under Bankura South Forest Division.

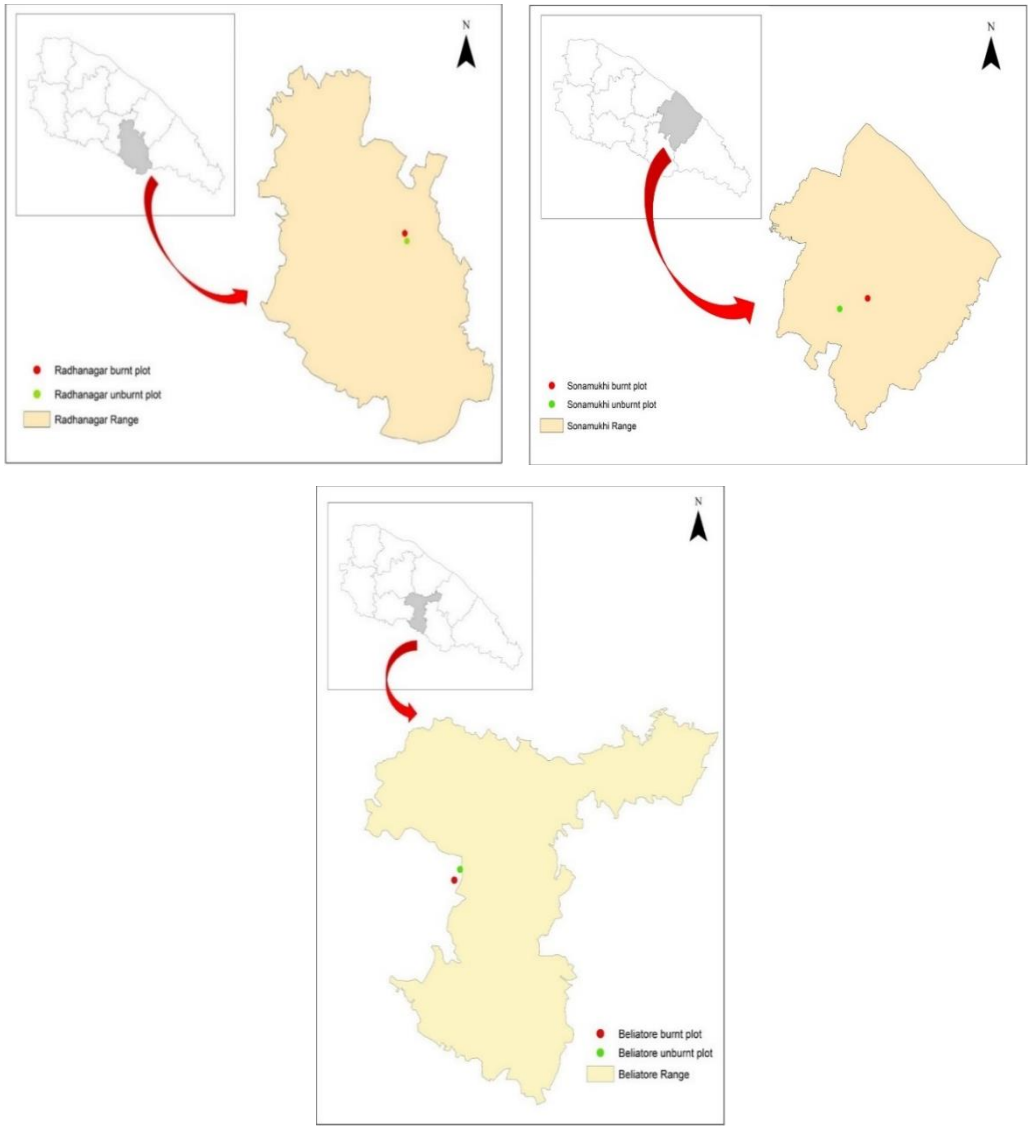


Figure 3: Location of sample plots in Sonamukhi, Beliatore and Radhanagar Ranges under Bankura North Forest Division.

3.2.2. Materials and equipment used

Materials and equipment which are used for recording field data are - field map, compass and GPS, measuring tape (1.5m and 20m), rope, note book and pen, machete and camera.

3.2.3. Collection of vegetation data

From each sample plot, plant species diversity (tree, shrub, climber/liana, herb and grasses) has been documented and plant species population data will be collected.

3.2.4. Data analyses

Data collected both from burned forest area and unburned forest area has been processed and analysed to estimate the impact of forest fire on vegetation using following formulas.

1. $Species\ Density\ (D) = \frac{Number\ of\ individuals\ of\ a\ species}{Total\ area\ of\ sampling\ plot}\ (Per\ unit\ area)$

2. $Margalef\ Species\ Richness\ Index\ (Dmg) = \frac{Number\ of\ plant\ species - 1}{\ln Total\ number\ of\ individuals}$

3. $Shannon - Wienner\ Species\ Heterogeneity\ Index\ (H) = -\sum\left[\left(\frac{n}{N}\right) * \ln\left(\frac{n}{N}\right)\right]$

   Where, 'n' denotes number of individuals of a species and 'N' denotes total number individuals of all species.

4. $Sorenson\ Similarity\ Index\ (S) = \left[\frac{2c}{a+b+2c}\right]$

   Where, 'a' denotes the number of species only occurred in location A, 'b' denotes the number of species only occurred in location B and 'c' denotes the number of species occurred in both the locations.

5. $Species\ Gain\ (G) = \left[\frac{Number\ of\ species\ obtained\ in\ burnt\ location}{Number\ of\ species\ occuered\ in\ both\ burnt\ and\ unburnt\ locations}\right] * 100\ \%$

6. $Species\ Lost\ (L) = [\frac{Number\ of\ species\ lost\ in\ burnt\ location}{Number\ of\ species\ occured\ in\ both\ burnt\ and\ nonburnt\ locations}] * 100\ \%$

4. Results

4.1. Forest areas: most vulnerable to fire

In Bankura North Division Beliatore Range is the most affected region, followed by Sonamukhi Range. In both the Ranges huge fires occurred for three consecutive years. In 2021-22 fire season more than 50 ha area was affected by Forest Fires in Beliatore Range while in Sonamukhi Range nearly 30 ha area had been affected.

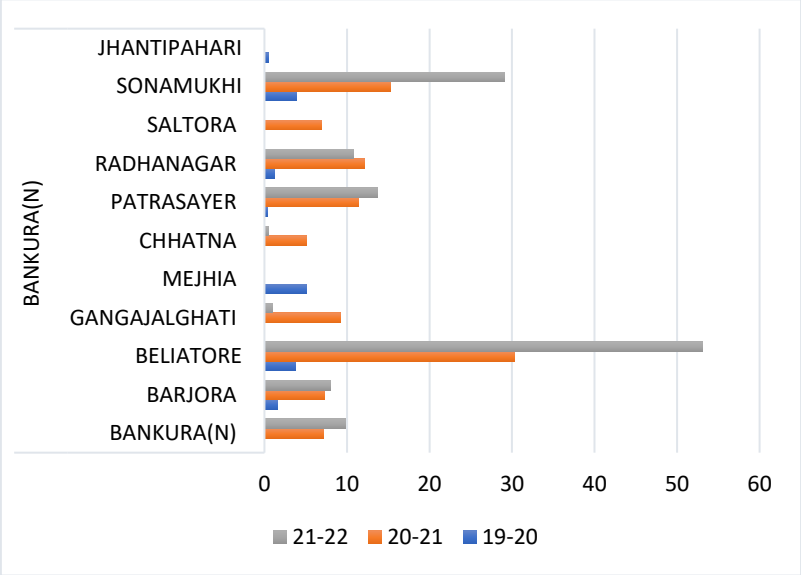


Figure 4: Area affected by Forest Fire in Bankura North Division

Ranibandh Range of Bankura South Division was affected by Forest Fire for last three consecutive years while the Jhilimili Range nearly 165 ha in 2019-20 and 62 ha in the last year was affected and the area affected in the Pirargari Range was 64 ha in 2019-20 and 119 ha in 2021-22.

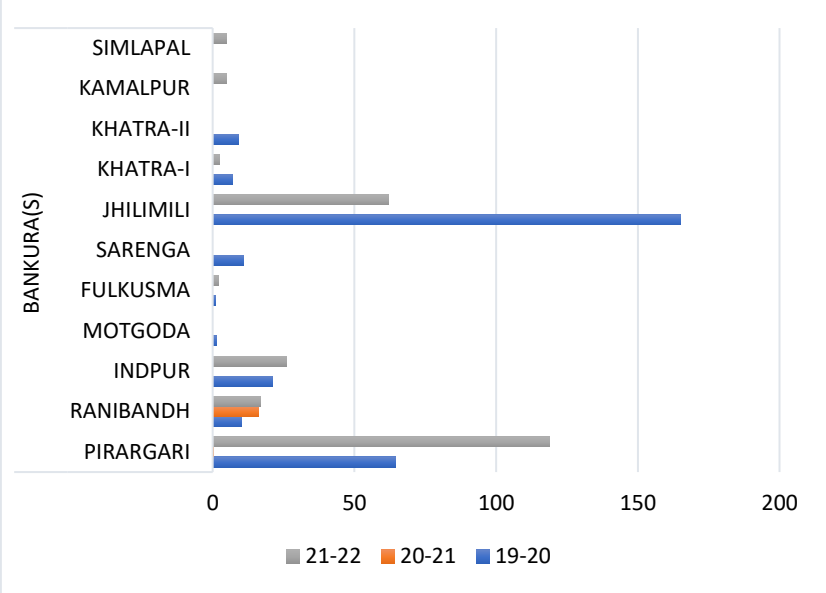


Figure 5: Area affected by Forest Fire in Bankura South Division

4.2. Forest fire vulnerability map

From the archive data a vulnerability map has been prepared where the areas, most vulnerable to fire, are shown with different colour codes.

Based on the total fire affected area (fire spread area) for consecutive three years, the Forest Ranges of both Bankura North and Bankura South Divisions are classified in 5 distinct classes *viz*. less fire-prone forest area (0-10 ha affected area), Moderately fire-prone forest area (10.1-20 ha affected area), Highly fire-prone forest area (20.1- 50 ha affected area), Very highly fire-prone forest area (50.1- 100 ha affected area) and Extremely fire-prone forest area (100.1- to 250 ha affected area)

Beliatore Range under Bankura North falling under the category of extremely fire-prone forest area having a massive total affected area for three consecutive years. Jhilimili and Pirargari Ranges under Bankura South Forest Division, are very highly prone to forest fires (Figure 6 & 7).

Sonamukhi, Radhanagar, Patrasayer Range under Bankura North Division and Ranibandh and Indpur Ranges under Bankura South Division fall under the category of Highly fire-prone forest area (Figure 6 & 7).

Rest of the ranges shows either moderate or less proximity to the forest-fire as the total affected area for these ranges are less than 20 ha in three consecutive years (Figure 6 & 7).

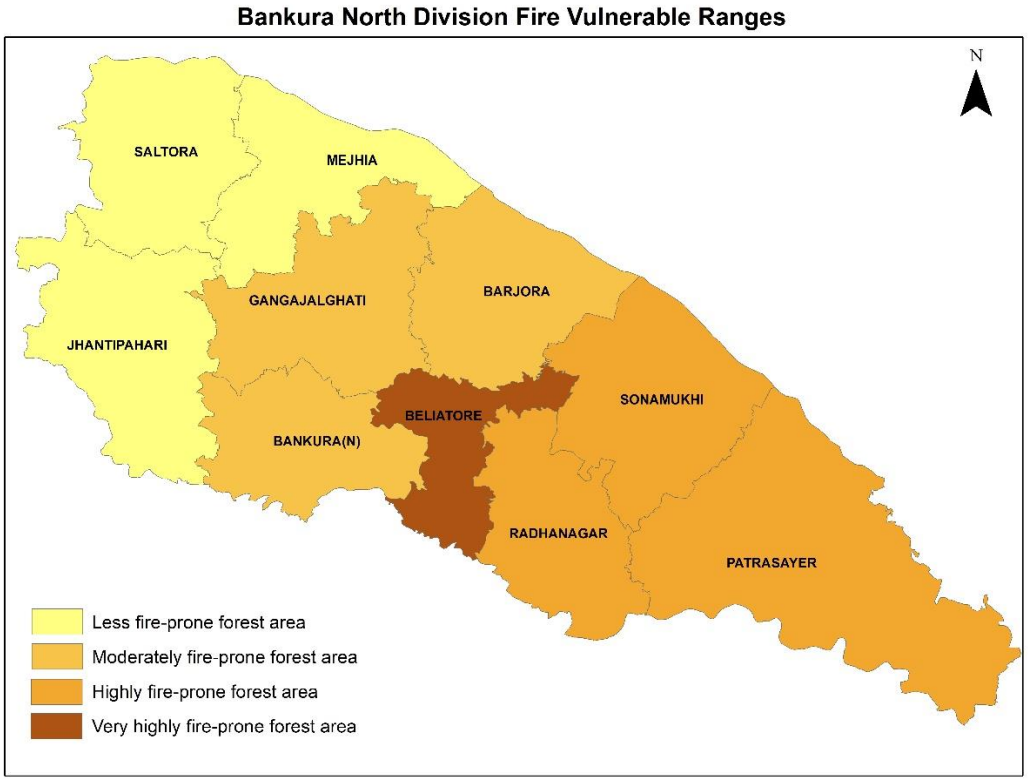


Figure 6: Most Fire vulnerable Ranges of Bankura North Division

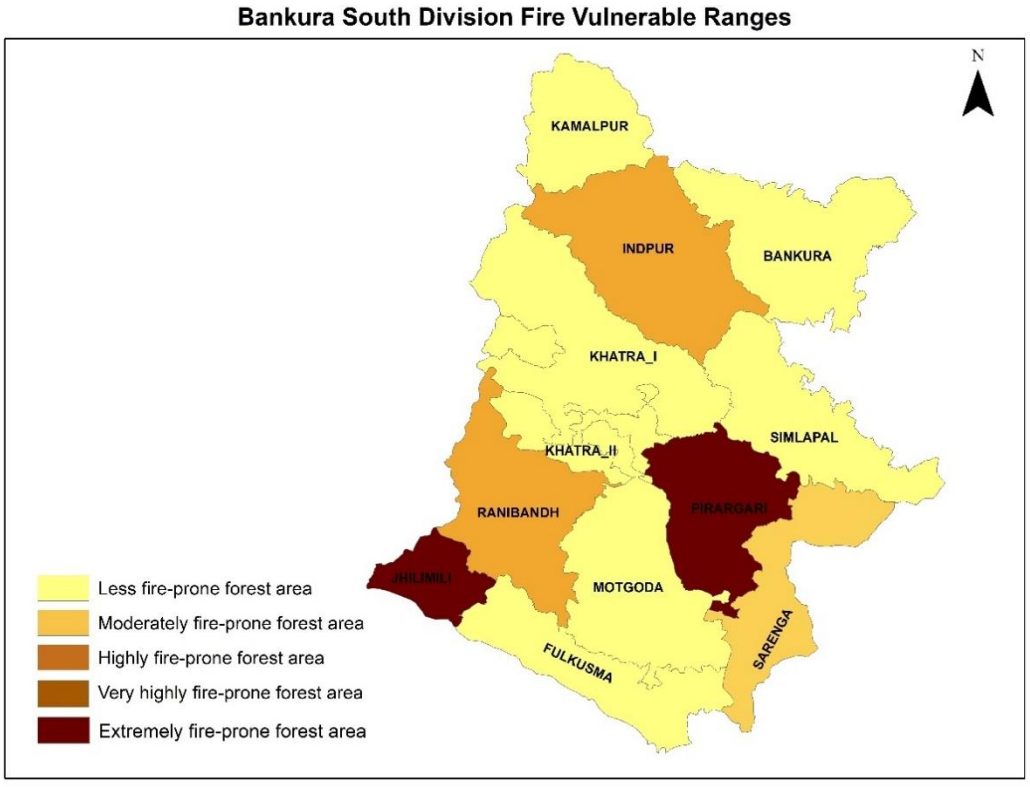


Figure 7: Most Fire vulnerable Ranges of Bankura South Division

4.3. Impact of Forest Fire on Forest Vegetation

In tropical dry deciduous forests, recurrent fires play significant role on forest establishment and stratification. Forest fires strongly affect the species composition of plant communities (Danthu *et al.* 2003) and can alter the structure of forest vegetation by influencing different aspects of growth and development like phenology, regeneration, seed dispersal and germination, seedling establishment and plant mortality (De Luis *et al*. 2005, Walters *et al.* 2004).

4.3.1. Plant species diversity: burnt vs unburnt plots

Among the burnt plots, maximum plant species diversity was noted at Ranibandh Range (39) followed by Radhanagar Range (25), Sonamukhi Range and Beliatore Range (24), and Pirargari Range (22). While, among the unburnt plots, maximum plant species diversity was noted at Ranibandh Range (48) followed by Sonamukhi Range (35), Pirargari Range (27), Beliatore Range (26) and Radhanagar Range (24) (Figure 8).

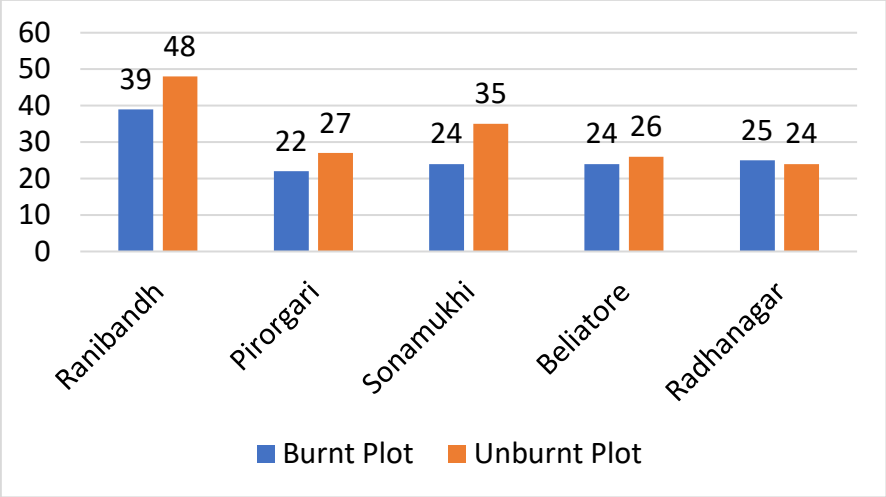


Figure 8: Comparison of plant species diversity between burnt and unburnt plots.

A. Tree species diversity

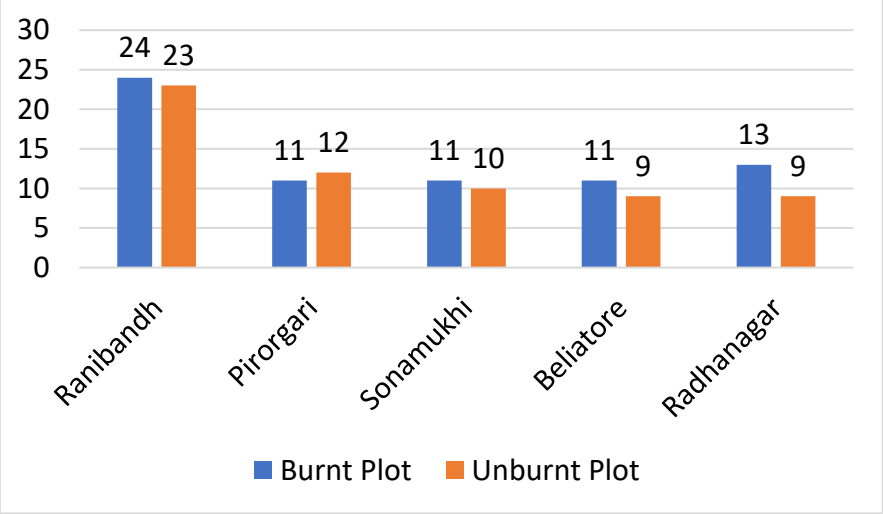


Figure 9: Comparison of tree species diversity between burnt and unburnt plots.

Among the burnt plots, maximum tree species were noted at Ranibandh Range (24) followed by Radhanagar Range (13). Sonamukhi Range, Beliatore Range and Pirargari Range exhibited eleven tree species each. Among the unburnt plots, maximum tree species were noted at Ranibandh Range (23) followed by Pirargari Range (12) and Sonamukhi Range (10). Beliatore Range and Radhanagar Range exhibited nine tree species each (Figure 9).

B. Climber species diversity

Among the burnt plots, maximum climber species were noted at Ranibandh Range (7) followed by Beliatore Range (6). Sonamukhi Range, Radhanagar Range and Pirargari Range exhibited five climber species each. Among the unburnt plots, maximum climber species were noted at Ranibandh Range (9) followed by Sonamukhi Range (8), Pirargari Range and Beliatore Range (6), and Radhanagar Range (5) (Figure 10).

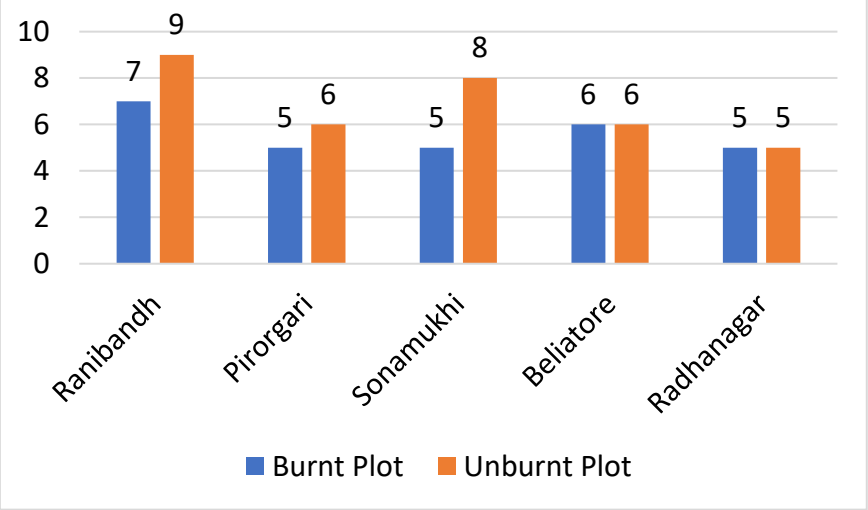


Figure 10: Comparison of climber species diversity between burnt and unburnt plots.

C. Shrub species diversity

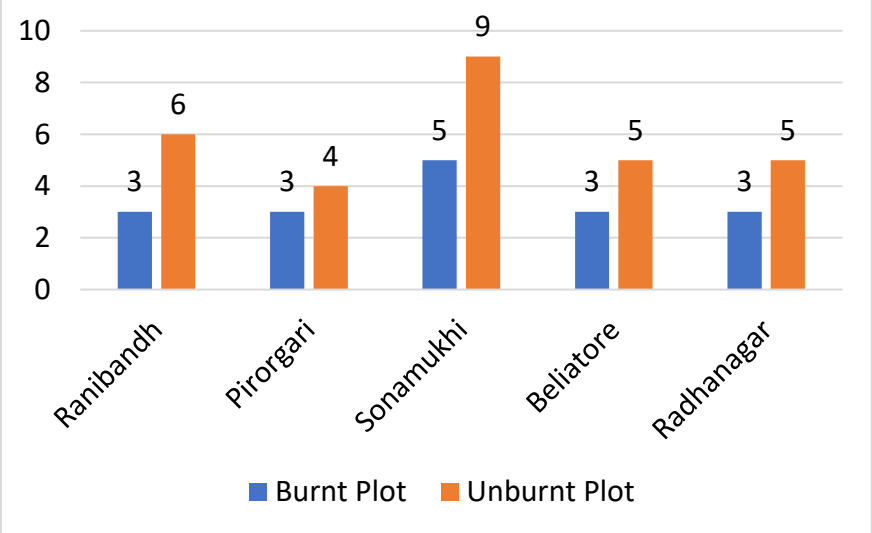


Figure 11: Comparison of shrub species diversity between burnt and unburnt plots.

Among the burnt plots, maximum shrub species were noted at Sonamukhi Range (5). Rest of the studied plots exhibited three shrub species each. Among the unburnt plots, maximum shrub species were noted at Sonamukhi Range (9) followed by Ranibandh Range (6), Radhanagar Range and Beliatore Range (5), and Pirargari Range (3) (Figure 11).

D. Herb species diversity

Among the burnt plots, maximum herb species were noted at Ranibandh Range (5) followed by Beliatore Range (4). Pirargari, Sonamukhi and Radhanagar Ranges exhibited minimum herb species diversity. Among the unburnt plots, maximum herb species were noted at Ranibandh Range (9) followed by Sonamukhi Range (8) and Beliatore Range (6). Both, Sonamukhi and Pirargari Ranges exhibited five herb species each (Figure 12).

The only epiphytic species *Dendrophthoe falcata* was recorded from the burnt plot at Radhanagar Range and unburnt plot at Ranibandh Range.

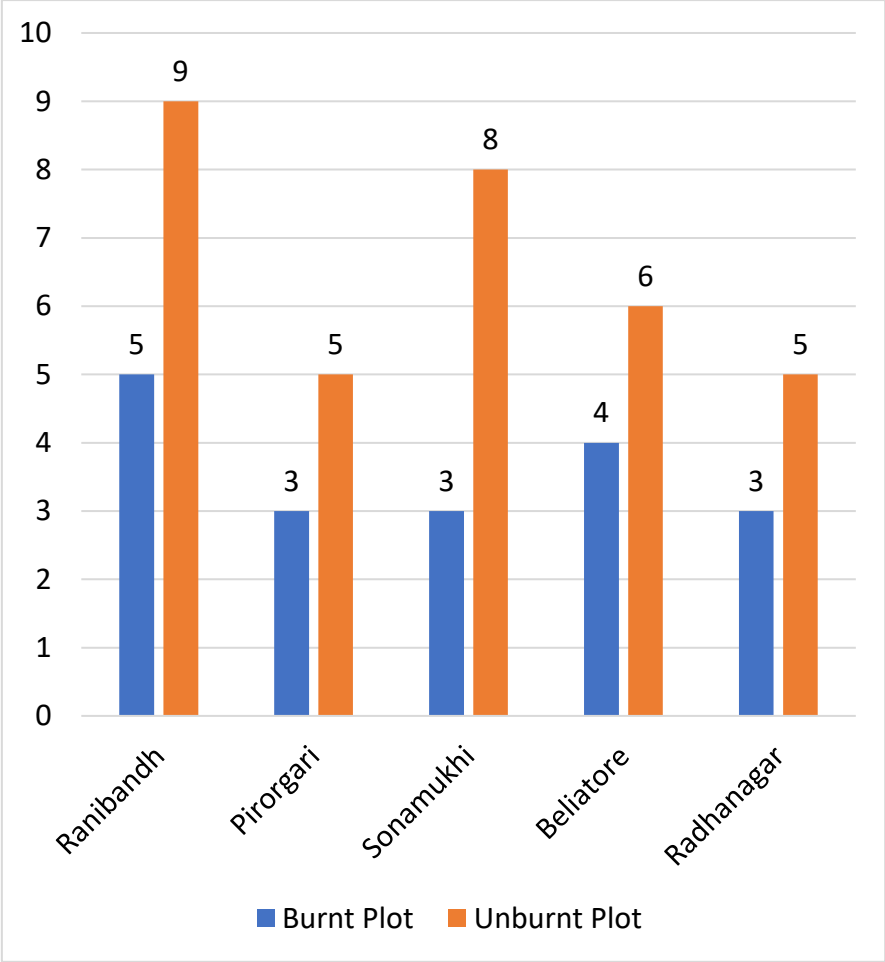


Figure 12: Comparison of herb species diversity between burnt and unburnt plots.

4.3.2. Plant species (canopy and ground) density: burnt vs unburnt plots

A. Ranibandh Range:

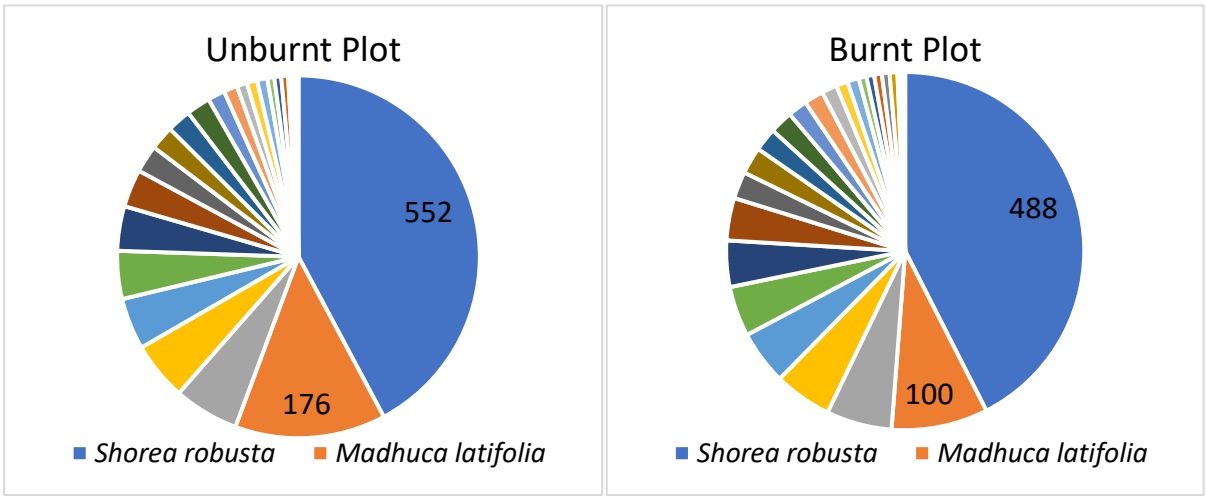


Figure 14: Tree species with maximum density/ha at canopy strata: Unburnt Plot vs Burnt Plot

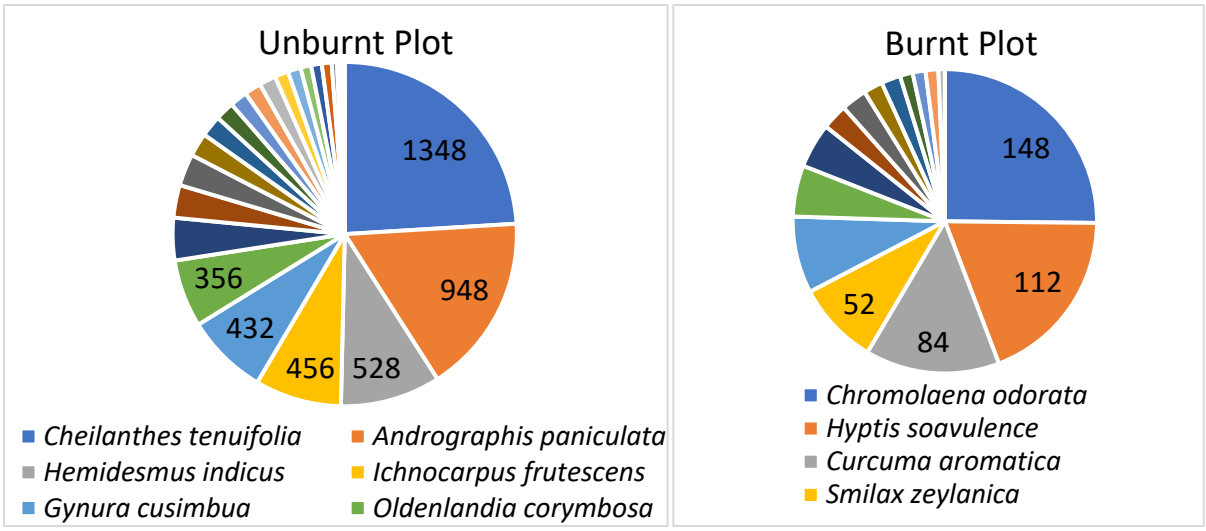


Figure 13: Plant species with maximum density/ha at ground strata: Unburnt Plot vs Burnt Plot

At canopy strata in both unburnt and burnt plots *Shorea robusta* exhibited the maximum density of 552/ha and 488/ha respectively followed by *Mathuca latifolia* (Figure 13).

In the ground strata of the unburnt plot, indigenous fern *Cheilanthus tenuifolia* exhibited maximum density (1348/Ha) followed by *Andrographis panniculata* (948/Ha), *Hemidesmus incicus* (528/ha), *Ichnocarpus frutescens* (456/ha), *Gynura cusimbua* (432/ha) and *Oldenlandia corymbosa* (356/ha). No invasion by exotic species was found (Figure 14).

On the other hand, the exotic herbaceous plant *Chromolaena odorata* exhibited maximum density (148/ha) at ground strata of burnt plot followed by another exotic herb *Hyptis soavulence* (112/ha). Native herb *Curcuma aromatica* and liana *Smilax zeylanica* also found with high density at ground strata (Figure 14).

B. Pirargari Range:

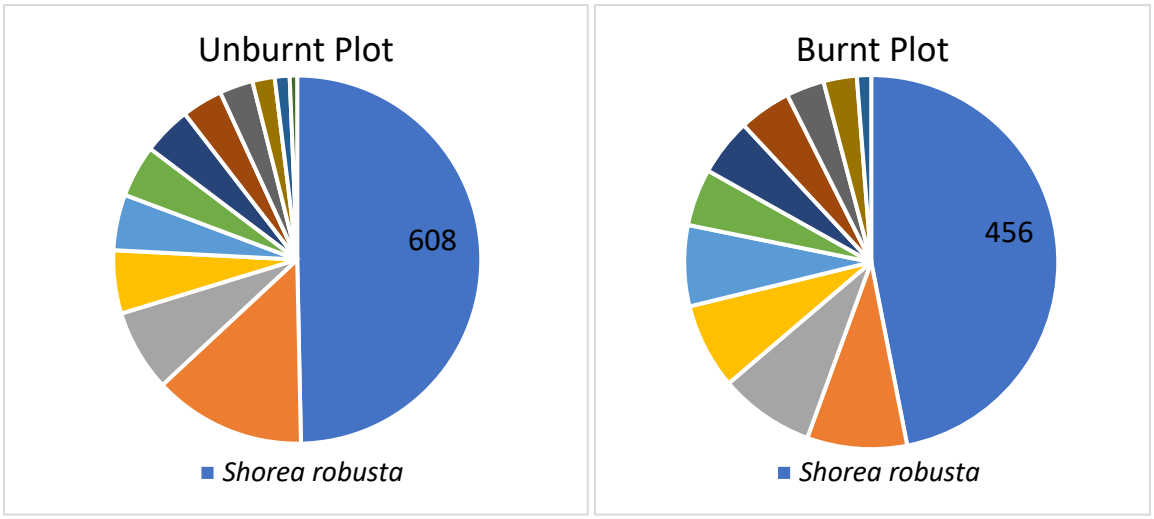


Figure 15:Tree species with maximum density/ha at canopy strata: Unburnt Plot vs Burnt Plot

In both unburnt and burnt plots *Shorea robusta* was found to dominate at the canopy strata with maximum density of 608/ha and 456/ha respectively (Figure 15). Nearly 50% of total stems in both plots was found to be contributed by *Shorea robusta*.

Native herb species *Oplismenus compositus* and *Andrographis paniculata* exhibited maximum density of 2308/Ha and 1164/Ha respectively in ground strata of the unburnt plot (Figure 16).

Whereas, in the burnt plot exotic shrub *Clerodendrum infortunatum* exhibited the maximum density (1692/Ha) at ground strata closely followed by exotic herb *Chromolaena odorata* (1144/Ha). Liana species *Combretum decandrum* and *Ziziphus oenoplia* found to proliferate well with density of 432/ha and 332/ha respectively (Figure 16).

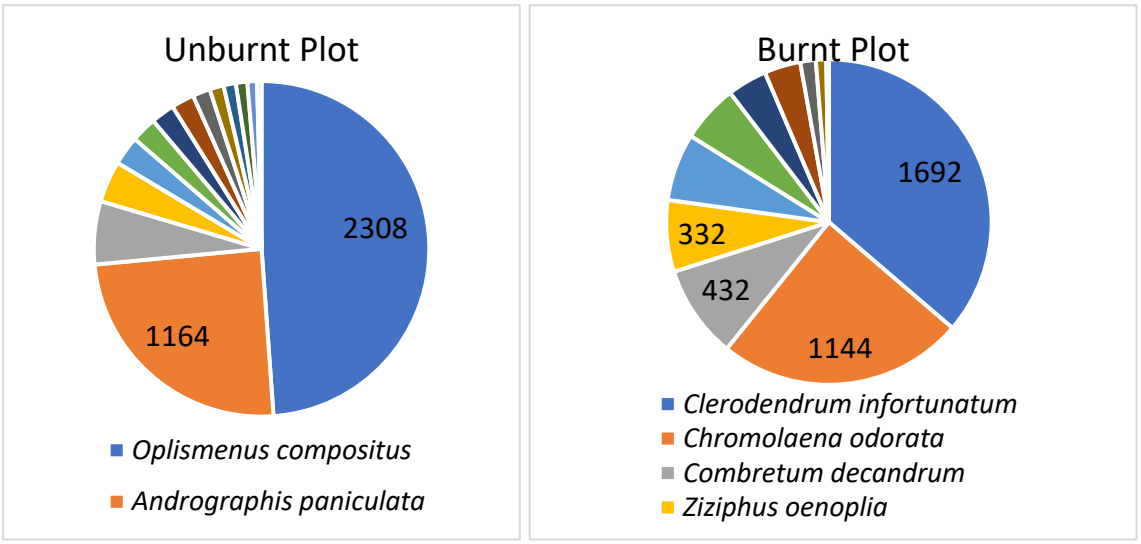


Figure 16: Plant species with maximum density/ha at ground strata: Unburnt Plot vs Burnt Plot

C. Sonamukhi Range:

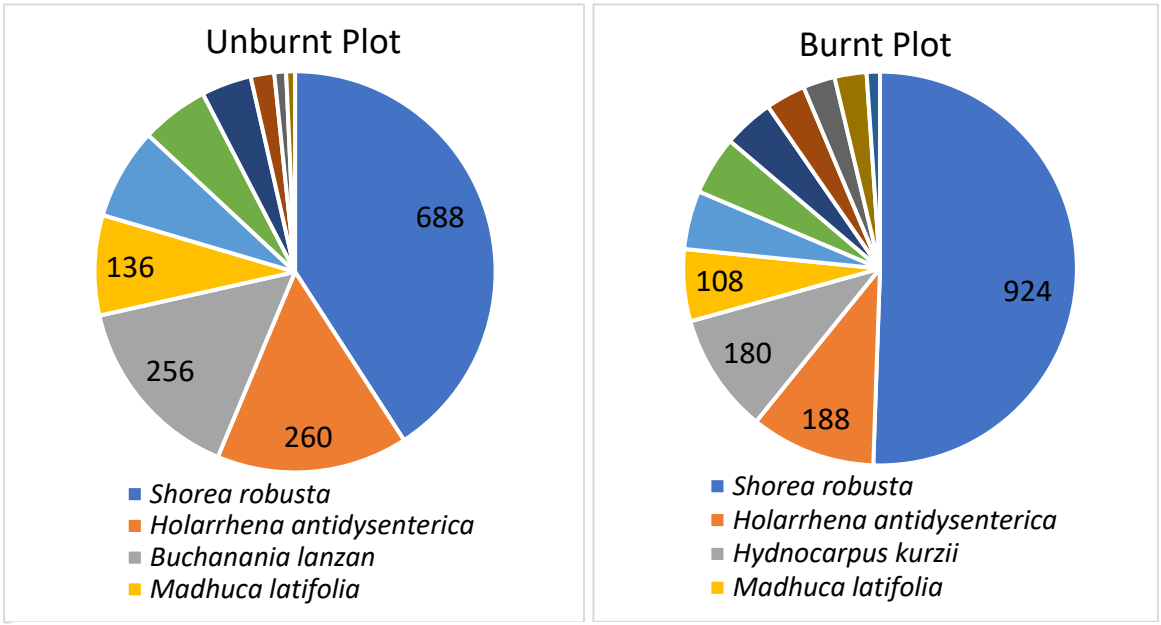


Figure 18: Tree species with maximum density/ha at canopy strata: Unburnt Plot vs Burnt Plot.

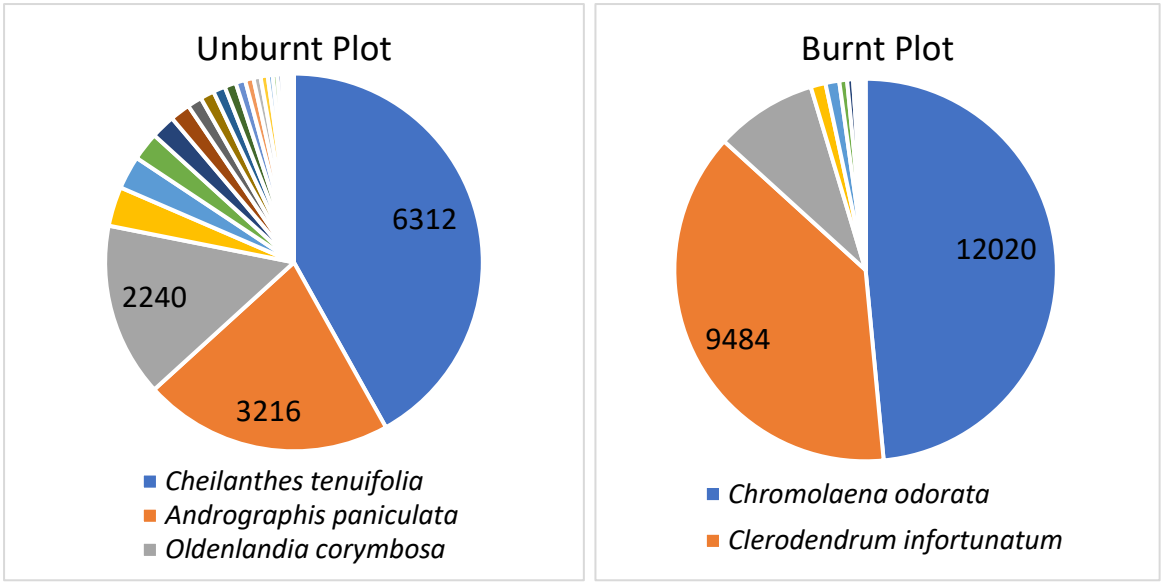


Figure 17: Plant species with maximum density/ha at ground strata: Unburnt Plot vs Burnt Plot.

The canopy of both unburnt and burnt plots was found to be dominated by *Shorea robusta* having slightly higher density at the burnt plot (924/ha) than that of the unburnt plot (688/ha). In the unburnt plot *Holarrhena antidysenterica*, *Buchanania lanzan* and *Madhuca latifolia* also contributed to the canopy strata with moderate density. In terms of tree density, the burnt plot only differs from unburnt one by the presence of *Hydnocarpus kurzii* in place of *Buchanania lanzan* (Figure 17).

At the unburnt plot, native herb (fern) species *Cheilanthes tenuifolia* was documented with maximum density (6312/Ha) followed by *Andrographis paniculata* (3216/Ha) and *Oldenlandia corymbosa* (2240/Ha). Whereas, large scale invasion by exotic species

Chromolaena odorata (12020/Ha) and *Clerodendrum infortunatum* (9448/Ha) was observed at the burnt plot (Figure 18).

D. Beliatore Range:

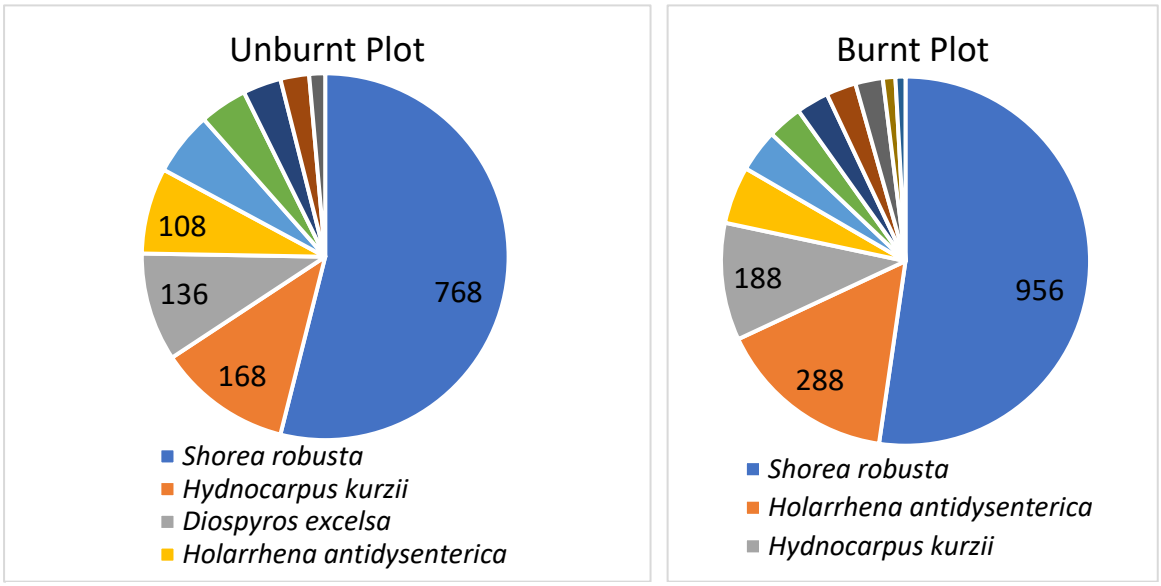


Figure 20: Tree species with maximum density/ha at canopy strata: Unburnt Plot vs Burnt Plot.

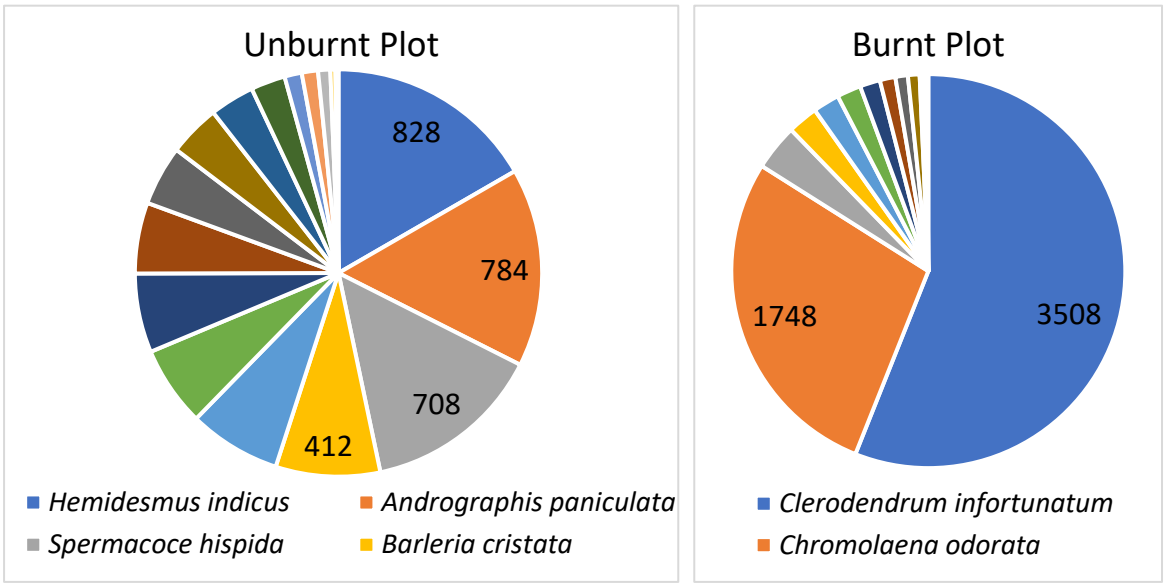


Figure 19: Plant species with maximum density/ha at ground strata: Unburnt Plot vs Burnt Plot.

Shorea robusta tree was found to dominate the canopy strata of both unburnt and burnt plots and documented with maximum density of 768/ha and 956/ha respectively, contributing more than 50% of total tree population in both. *Holarrhena antidysenterica* and *Hydnocarpus kurzii* also exhibited high density in both the studied plots (Figure 19).

In the unburnt plot, native climber species *Hemidesmus indicus* was documented with maximum density of 828/Ha followed by *Andrographis paniculata*, *Spermacoce hispida* and *Barleria cristata* at the ground strata. On the contrary, in the ground strata of the burnt plot

dominance of exotic species *Clerodendrum infortunatum* and *Chromolaena odorata* was observed with maximum density (3508/Ha and 1748/Ha respectively) (Figure 20).

E. Radhanagar Range:

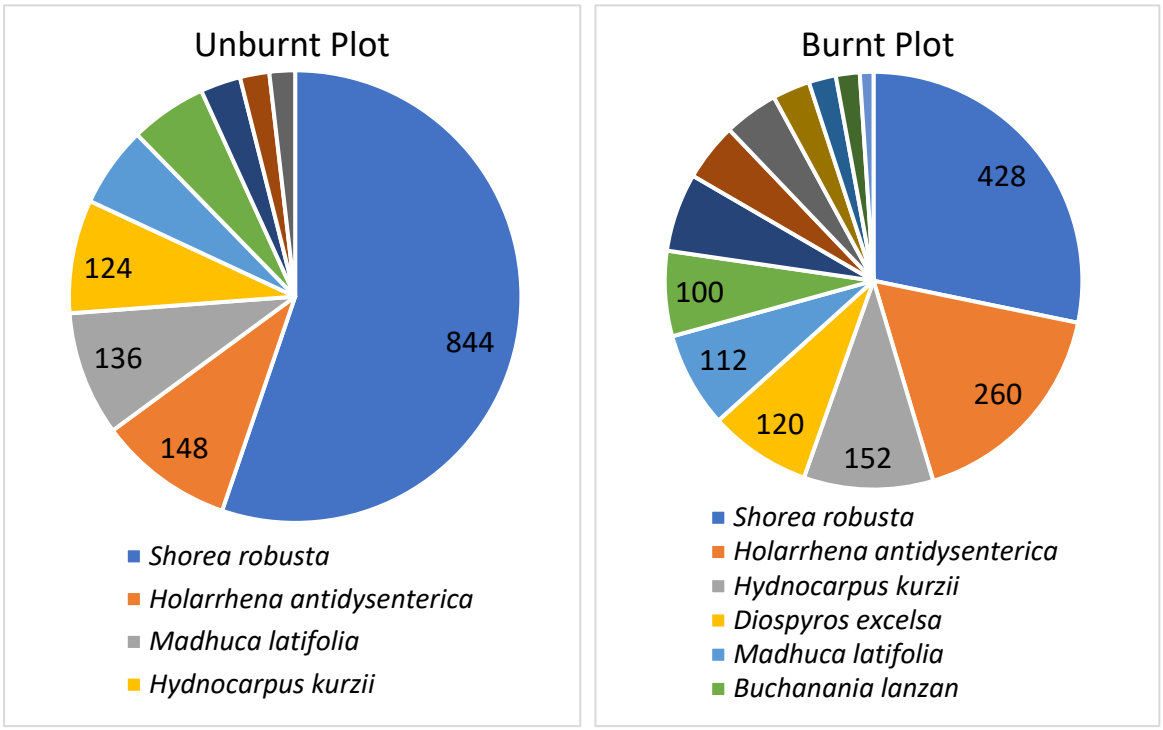


Figure 21: Tree species with maximum density/ha at canopy strata: Unburnt Plot vs Burnt Plot.

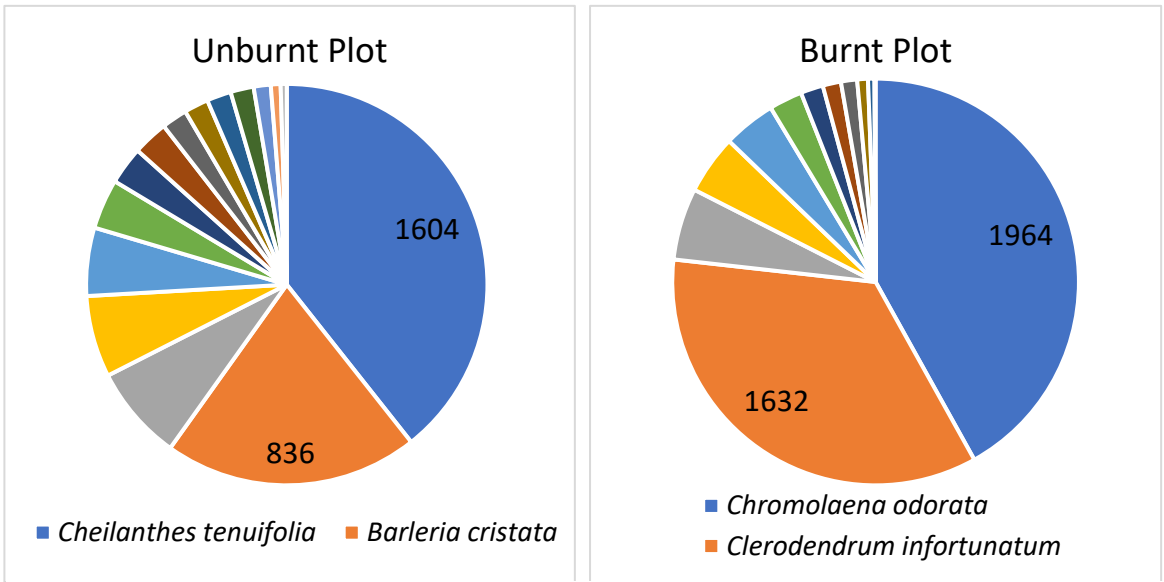


Figure 22: Plant species with maximum density/ha at ground strata: Unburnt Plot vs Burnt Plot.

Here at canopy strata of the unburnt plot predominance of *Shorea robusta* was found with nearly 60% stem contribution and much higher density (844/ha). *Holarrhena antidysenterica*, *Madhuca latifolia* and *Hydnocarpus kurzii* also contributed to the canopy at unburnt plot with the density of 148/ha, 136/ha and 124/ha respectively. Whereas, in term of stem contribution,

codominance of *Shorea robusta* and *Holarrhena antidysenterica* was found at canopy strata of burnt plot followed by *Hydnocarpus kurzii*, *Diospyros excelsa*, *Madhuca latifolia* and *Buchanania lanzan* (Figure 21).

In the unburnt plot, the native herb *Cheilanthus tenuifolia* exhibited maximum density (1604/Ha) followed by the *Barleria cristata* (836/ha) at the ground strata. On the other hand, the burnt plot exhibited massive invasion of exotic species *Chromolaena odorata* and *Clerodendrum infortunatum* having high density of 1964/Ha and 1632/Ha respectively (Figure 22).

4.3.3. Vegetation similarity, species gain and species loss

A. Species gain vs loss

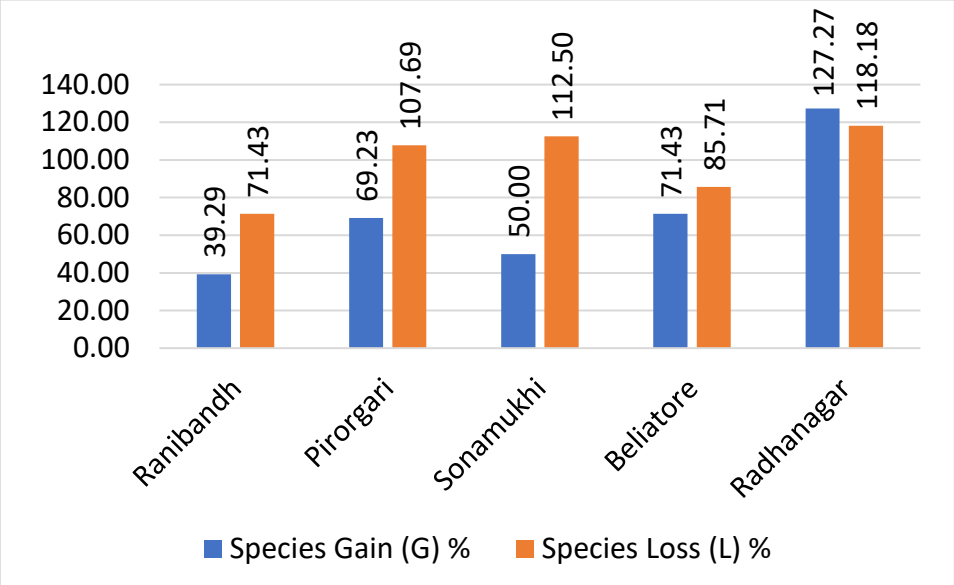


Figure 23: Comparison of plant species gain and loss is studied forest ranges.

Maximum percentage of species gain (127.27%) and species loss (118.18%) was obtained at fire affected forest areas of Radhanagar Range indicating high intensity of recurrent forest fire in the forest area. Extreme negative effect of forest fire on vegetation was also observed by 112.50% species loss in Sonamukhi Range and 107.69% species loss in Pirargari Range. Overall, in all the studies forest areas species loss was higher than species gain except Radhanagar Range (Figure 23).

B. Vegetation similarity between burnt and unburnt plots

At Ranibandh Range, 64% vegetation similarity was observed between burnt and unburnt plot which was the highest among all studied areas due to less species gain and loss. Whereas, at Radhanagar Range, minimum 45% vegetation similarity was found between burnt and unburnt plot due to high percentage of species gain and loss. Rest of the Forest Ranges exhibited almost similar vegetation similarity between burnt and unburnt plots (Figure 24).

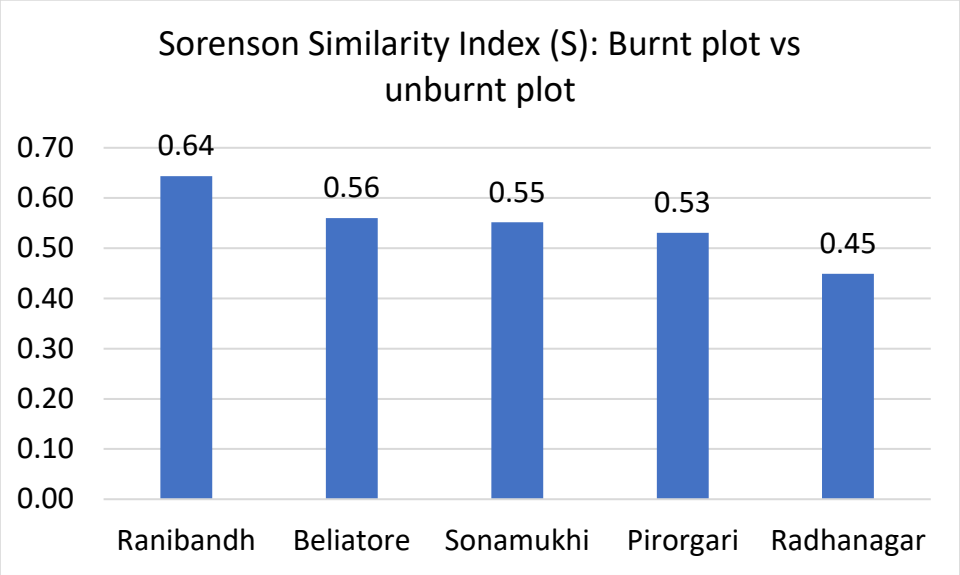


Figure 24: Comparison of vegetation similarity between burnt and unburnt plots of studied forest areas.

4.3.4. Species richness and heterogeneity: burnt vs unburnt plots

A. Species Richness

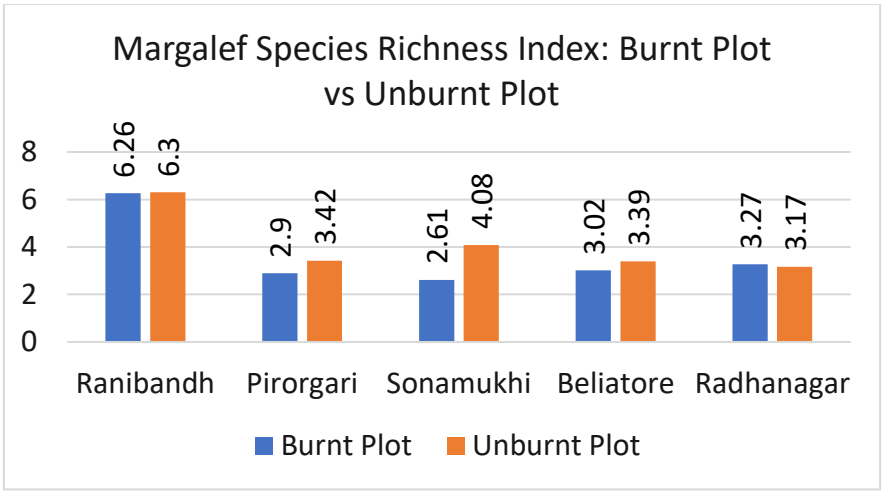


Figure 25: Comparison of species richness between burnt and unburnt plots of studied forest areas.

Maximum species richness was observed at both the burnt and unburnt plots accounting Margalef Species Richness Index 6.23 and 6.3 respectively at Ranibandh Range. The burnt and unburnt plots at Radhanagar range exhibited low and almost similar species richness. In rest three forest ranges lower species richness was observed at burnt plots than that of the unburnt plots. Species richness of the unburnt plot is much higher (4.08) than the burnt plot (2.61) at Sonamukhi Range (Figure 25).

B. Species Heterogeneity

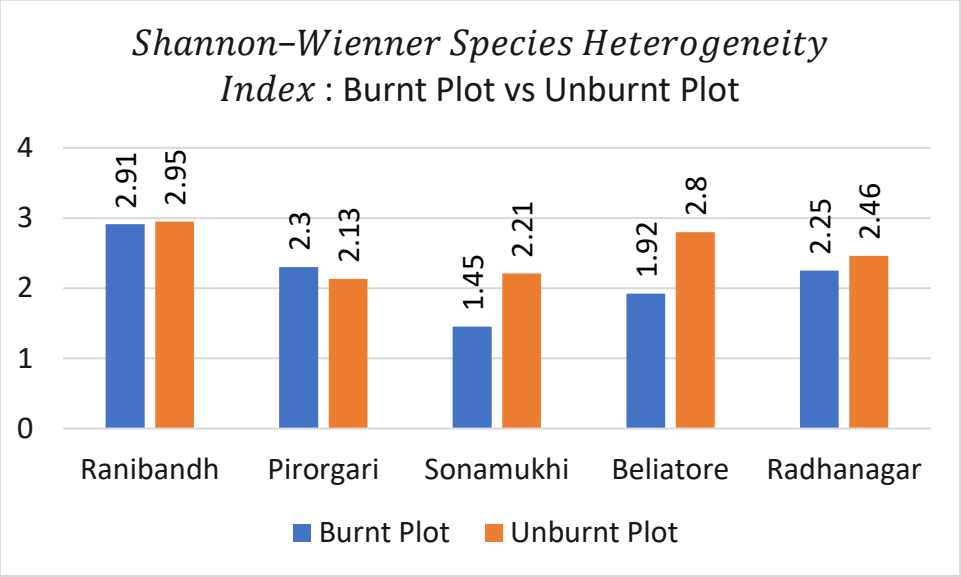


Figure 26: Comparison of species heterogeneity between burnt and unburnt plots of studied forest areas.

Maximum species heterogeneity was found in both burnt and unburnt plots at Ranibandh Range. The burnt plots at Sonamukhi and Beliatore Ranges exhibited much less species heterogeneity that the unburnt plots. Almost similar heterogeneous vegetation condition was observed at both burnt and unburnt plots of Ranibandh, Pirargari and Radhanagar Forest Ranges respectively (Figure 26).

5. Discussion

5.1. Most vulnerable area

From the vulnerability map it is observed that the most Fire-prone ranges are from Bankura South and Panchet, but as per the total area affected by the Forest Fire for three consecutive years Bankura South has the highest area (Total affected area 544.6 ha) that has been affected by fire, followed by the Bankura North Division (Total affected area 247.01 ha) and the lowest area (Total affected area 42.55 ha) that has been affected from the fire is Kangsabati South Division.

5.2. Impact of Fire on Forest Vegetation

In this study, overall plant species diversity of unburnt forest areas was higher than the areas experiencing recurrent forest fires. In both unburnt and burnt areas of all the forest ranges almost similar tree species diversity with dominance of *Shorea robusta* tree at canopy strata was observed as fire is restricted to the ground surface level, not at the crown/canopy level. The deciduous or semideciduous trees have some adaptive traits like thick bark, fast healing of fire scars, fire-stimulated sprouting, modified seed dispersal and germination mechanism, resistance to rotting, modified seedling structure and thick heat-resistant buds to survive recurrent forest fire (Khan and Tripathi 1986, 1989; Myers, 1990; Abrams, 1992; Bond and Van Wilgen, 1996; Wade et al., 2000).

Undergrowth vegetation is found to be affected most by forest fires in this study. In burnt areas massive destruction of ground vegetation was observed. Shrub, herb and ground dwelling climbers were completely wiped out from the areas with recurrent forest fires. However, after fire occurrence, reduction of shrub cover was observed followed by invasion of exotic species like *Chromolaena odorata*, *Clerodendrum infortunatum*, *Lantana camara* etc. (Wienk *et al*., 2004, Sheuyange *et al.* 2005). Gaps created by high-intensity fires are particularly susceptible to invasion by exotic plant species having ability of mass seed production, wide range of seed dispersal, prolonged seed viability and fast seed germination and easily out-compete the native plant species with rapid growth and proliferation (Zouhar *et al*. 2008). Thus, fire is directly linked to non-native plant invasions. Thus, fires have negative impacts on native plant diversity in forests and may facilitate their localized extinction (Kittur *et al*., 2014).

Disturbances in habitat condition created by recurrent forest fires led to establish opportunistic liana species (woody climber) like *Combretum decandrum*, *Ericybe paniculate*, *Ventilago denticulate* etc. especially at Pirargari and Radhanagar Ranges (Sahu *et al*., 2008; Mishra *et al*., 2008).

High rate of species loss, especially herbs, shrubs and ground dwelling climbers in fire prone forest areas is resulted by severe destruction of vegetation at ground strata. Whereas, high rate of species gain, mostly exotic and liana, after fire is indicative of altered habitat condition. Thus, forest fires were found to regulate vegetation structure and successional pattern in dry deciduous forests of South-West Bengal by suppressing certain species and encouraging other species (fire tolerant) (Syaufina and Nuruddin 2011).

Moreover, in all the study areas considerable alteration in vegetation composition and structure was observed in the forest areas with recurrent fire events especially at the ground strata by invasion of exotic plant species and establishment of liana species replacing native herbs and shrubs.

6. Conclusion:

Surface fire at ground strata is the most common phenomena in the dry deciduous forests of Bankura district during the dry season (February-March). Thick layer of dry leaves at forest floor, shed by deciduous/semi-deciduous trees (mostly Sal), acts as principal fuel once fire is placed (in most of the cases purposefully). This kind of fire spreads in a rapid pace and can destroy acres of forest area with few hours. As fire is restricted only to the ground surface, no harm to the mature trees was observed both in term of diversity and density, though seedling regeneration may be hindered subsequently. This indicates that fire events do not have any adverse effect on the canopy shape of the forests and timber stock is secured. After fire events, considerable reduction in shrub cover occurs followed by establishment of liana species and invasion of exotic ones. Thus, fires have negative impacts on native plant diversity (except tree) in forests and may facilitate their localized extinction.

Moreover, forest fires may regulate the successional pattern through altering vegetation structure especially at the ground strata by suppressing certain species and encouraging other species which are especially adaptive to the altered edaphic and microclimatic condition.

From management perspectives, a multidisciplinary participatory approach should be adopted involving all the stakeholders viz. Forest Department, Research Institutes, NGOs, FPCs, JFMCs and the common people for maintaining ecological stability and species heterogeneity of the forests. Use of advanced communication system, state of the art tools, fire lines, fuel breaks, fuel load removal and mapping of fire sensitive areas may be considered as key principles to minimize fire risk. Above all awareness generation among common people about cons and pros of forest fire is needed at mass scale to reduce the fire events in forests.

7. Limitations:

Due to lack of previous data on effect of fire on forest vegetation from the dry deciduous forest of the State and the Country as well, it is difficult to understand and explain about the change in forest vegetation type from past to present condition (if occurred).

For better understanding about the successional pattern in fire prone forest ecosystem compared to unburnt forest area this kind of study is needed for at least consecutive three years and more.

Along with this study, detailed study on effect of forest fire on tree regeneration, seedling germination, soil condition and microclimate are essential.

8. References:

Abrams, M.D. 1992. Fire and the development of oak forest. *Bioscience*, 42(5): 346–353.

Anonymous. 2021. *Indian State Forest Report 2021*. Forest survey of India, Ministry of Environment Forest and Climate Change, Dehra Dun.

Bond, W.J. and Keeley, J.E. 2005. Fire as a global 'herbivore': the ecology and evolution of flammable ecosystems. *Trends in Ecology & Evolution*, 20(7): 387-394.

Bond, W.J. and Van Wilgen, B.W. 1996. *Fire and plants*. London: Chapman and Hall. 272 pp.

Certini, G. 2005. Effects of fire on properties of forest soils: a review. *Oecologia*, 143(1): 1-10.

Cha, S., Kim, C.B., Kim, J., Lee, A.L., Park, K.H., Koo, N., Kim, Y.S. 2020. Land-use changes and practical application of the land degradation neutrality (LDN) indicators: a case study in the subalpine forest ecosystems, Republic of Korea. *Forest Science and Technology*, 16(1): 8-17.

Champion, H.G. and Seth, S.K. 1968. *A revised survey of forest types in India*. Government of India Publication, and New Delhi.

Chatenoux, B. and Peduzzi, P. 2012. *Biomass fires: preliminary estimation of ecosystems global economic losses*. UNEP/GRID-Geneva. pp. 1-11.

Danthu, P., Ndongo, M., Diaou, M., Thiam, O., Sarr, A., Dedhiou, B., Vall, A.O.M. 2003. Impact of bush fire on germination of some West African acacias. *Forest Ecology and Management*, 173:1–10.

De Luis, M., Raventos, J., González-Hidalgo, J.C. 2005. Factors controlling seedling germination after fire in Mediterranean gorse shrublands. *Implications for fire prescription J Environ Manage*, 76: 159–166.

FSI. 2012. *Vulnerability of India's forest to fires*. MOEF, Dehradun. Pp. 7.

Hilwan, I. 2020. Method of Estimating Forest Fire Impact on Vegetation. IOP Conference Series: *Earth and Environmental Science*, 504(1): 012004. DOI: https://doi.org/10.1088/1755-1315/504/1/012004.

Janzen, D.H. 1988. Tropical dry forests. *Biodiversitas*, 15: 538.

Kauffman, J.B., Steele, M.D., Cummings, D.L. and Jaramillo, V.J. 2003. Biomass dynamics associated with deforestation, fire, and, conversions to cattle pasture in a Mexican tropical dry forest. *Forest Ecology and Management*, 176: 1-12.

Khan, M.L. and Tripathi, R.S. 1986. Tree regeneration in a disturbed sub-tropical wet hill forest of north-east India: effect of stump diameter and height on sprouting of four tree species. *Forest Ecology and Management*, 17(2–3):199–209.

Khan, M.L. and Tripathi, R.S. 1989. Effects of stump diameter, stump height and sprout density on the sprout growth of four tree species in burnt and unburnt forest plots. *Acta Oecologia*,10(4):303–316.

Kittur, B., Jhariya, M.K. and Lal, C. 2014. Is the forest fire can affect the regeneration and species diversity. *Ecology, Environment and Conservation*, 20(3): 989-994.

Krishna, P.H. and Reddy, C.S. 2012. Assessment of increasing threat of forest fires in Rajasthan, India using multi-temporal remote sensing data (2005-2010). *Current Science*. 102(9): 1288-1297.

Kutiel, H. 2012. Weather conditions and forest fire propagation—the case of the Carmel fire, December 2010. *Israel Journal of Ecology & Evolution*. 58(2-3): 113-122.

Lal, R. 2004. Soil carbon sequestration to mitigate climate change. *Geoderma*, 123: 1-22.

Mishra, R.K., Upadhyay, V.P. and Mohanty, R.C. 2008. Vegetation Ecology of the Simplipal Biosphere Reserve, Orissa India. *Applied Ecology and Environment Research*, 6(2): 89-99.

Murphy, P.G. and Lugo, A.E. 1986. Ecology of tropical dry forest. *Annual Review of Ecology and Systematic*, 17: 67-68.

Myers, R.L. 1990. *Scrub and high pine*. In: Myers, R.L. and Ewel, J.J., eds. Ecosystems of Florida. Orlando, FL: University of Central Florida Press; 150–193 pp.

Parashar, A. and Biswas, S. 2003. *The impact of forest fire on forest biodiversity in the Indian Himalayas (Uttaranchal)*. In: XII World Forestry Congress. Vol. 358.

Priyadarshini, A. and Mohapatra, A.K., 2022. A review of India scale analysis of forest fire and toxic emission. *EcoEvoRxiv*, DOI: https://doi.org/10.32942/osf.io/bfuw9

Reddy, C.S., Unnikrishnan, A., Bird, N.G., Faseela, V.S., Asra, M., Manikandan, T.M. and Rao, P.V.N. 2020a. Characterizing Vegetation Fire Dynamics in Myanmar and South Asian Countries. *Journal of the Indian Society of Remote Sensing*, 48:1829–1843.

Reddy, C.S., Bird, N.G., Sreelakshmi, S., Manikandan, T.M., Asra, M., Krishna, P.H., Jha, C.S., Rao, P.V.N. and Diwakar, P.G. 2020b. Identification and Characterization of Spatio-Temporal Hotspots of Forest Fires in South Asia. *Environmental Monitoring and Assessment*, 191: 791.

Sahu, P.K., Sagar, R. and Singh, J.S. 2008. Tropical forest structure and diversity in relation to altitude and disturbance in a Biosphere Reserve in central India. *Applied Vegetation Science*, 11: 461–470.

Satendra, K.A. 2014. *Forest fire disaster management*. National Institute of Disaster Management, Ministry of Home Affairs, New Delhi.

Sheuyange, A., Oba, G. and Weladji, R.B. (2005). Effects of anthropogenic fire history on savanna vegetation in northeastern Namibia. *Journal of Environmental Management*, 75: 189–198.

Solomon, S., Qin Manning, D.M., Chen, Z., Marquis, M., Averyt, K.B., Tignor, M. and Miller, H.L. 2007. *The physical science basis-contribution of working group-I to the fourth assessment report of the inter-governmental panel on climate change*. Cambridge Univ. Press, Cambridge, U.K., New York, USA.

Srivastava, P. and Garg, A. 2013. Emissions from Forest Fires in India-as assessment based on MODIS Fire and Global land cover products. *Clim Cha and Enviro Sust*, 1(2):138–144.

Syaufina, L. and Nuruddin, A.A. 2011. Impacts of fire on South East Asia tropical forests biodiversity: a review. *Asian J Plant Sciences*, 10(4): 238–244.

Wade, D.D., Brock, B.L., Brose, P., Grace, J.B., Hoch, G.A. and Patterson, W.A. 2000. *Fire in eastern ecosystems.* In: Brown, J.K. and Smith, J.K., eds. Wildland fire in ecosystems: effects of fire on flora. Gen. Tech. Rep. RMRS-GTR-42-vol. 2. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station; 53–96 pp.

Walters, M., Midgley, J.J., Somers, M.J. 2004. Effects of fire and fire intensity on the germination and establishment of *Acacia karroo*, *Acacia nilotica*, *Acacia luederitzii* and *Dichrostachys cinerea* in the field. *BMC Ecology*, 4(1): 1.

Wang, J. and Christopher, S.A. 2006. Mesoscale modeling of Central America smoke transport to the United States: Smoke radiative impact on regional surface energy budget and boundary layer evolution. *Journal of Geophysical Research-Atmospheres*, 111: D14S92, doi: 10.1029/2005JD006720.

Wienk, C.L., Sieg, C.H. and McPherson, G.R. 2004. Evaluating the role of cutting treatments, fire and soil seed banks in an experimental framework in Ponderosa Pine Forest of the Black Hills. South Dakota. Forest Ecology & Management, 192: 375-393.

Zouhar, K., Smith, J. K., and Sutherland, S. 2008. *Effects of fire on nonnative invasive plants and invasibility of wildland ecosystems.* In: Zouhar, Kristin; Smith, Jane Kapler; Sutherland, Steve; Brooks, Matthew L. Wildland fire in ecosystems: fire and nonnative invasive plants. Gen. Tech. Rep. RMRS-GTR-42-vol. 6. Ogden, UT: US Department of Agriculture, Forest Service, Rocky Mountain Research Station. p. 7-32, 42.

ANNEXURE I

Population of plant species documented in sample plots at respective forest Ranges

Sl. No.	Plant Species	Number of individuals documented from 50 m X 50 m (0.25 Ha) plots									
		Bankura South Forest Division				Bankura North Forest Division					
		Ranibandh Range		Pirargari Range		Sonamukhi Range		Beliatore Range		Radhanagar Range	
		Burnt Plot	Unburnt Plot	Burnt Plot	Unburnt Plot	Burnt Plot	Unburnt Plot	Burnt Plot	Unburnt Plot	Burnt Plot	Unburnt Plot
A.	**Tree**										
1	*Acacia auriculiformis*				41						
2	*Adina cordifolia*			12	6						
3	*Aegle mermalos*						3			4	
4	*Alangium salviifolium*			18	17						
5	*Albizia lebbeck*			17	14						
6	*Alstonia scholaris*			8							
7	*Anogeissus latifolia*		2								
8	*Azadirachta indica*			12	4	12	4	4	5	11	
9	*Bauhinia purpurea*		1								
10	*Borassus flabellifer*			7	2						
11	*Bridelia retusa*	4									
12	*Buchanania lanzan*	17				19	64	12	20	25	7
13	*Careya arborea*		3								
14	*Cassia fistula*					5				7	
15	*Cleistanthus collinus*	5	7								8
16	*Cochlospermum religiosum*		1								
17	*Dillenia pentagyna*	1	8								
18	*Diospyros excelsa*	7	13			22	23	14	34	30	21
19	*Flacourtia jangomas*	7	7								
20	*Gardenia gummifera*	13	3								
21	*Gardenia latifolia*	2									
22	*Holarrhena antidysenterica*	2				47	65	72	27	65	37
23	*Hydnocarpus kurzii*	2	3		22	45	31	47	42	38	31
24	*Ixora arborea*	2	4			22			12	8	
25	*Lagerstroemia parviflora*							13	15	17	11
26	*Lannea coromandelica*			20	13						
27	*Madhuca latifolia*	25	44			27	34	23		28	34
28	*Mangifera indica*			3							
29	*Morinda citrifolia*	2	14			15					
30	*Nyctanthes arbor-tritis*	1									
31	*Oroxylum indicum*		1								
32	*Phoenix sylvestris*			11	9						
33	*Phyllanthus emblica*		2								
34	*Pterocarpus marsupium*	3	7								
35	*Semecarpus anacardium*	6	17				17	11		16	

ANNEXURE I

Population of plant species documented in sample plots at respective forest Ranges

Sl. No.	Plant Species	Number of individuals documented from 50 m X 50 m (0.25 Ha) plots									
		Bankura South Forest Division				Bankura North Forest Division					
		Ranibandh Range		Pirargari Range		Sonamukhi Range		Beliatore Range		Radhanagar Range	
		Burnt Plot	Unburnt Plot	Burnt Plot	Unburnt Plot	Burnt Plot	Unburnt Plot	Burnt Plot	Unburnt Plot	Burnt Plot	Unburnt Plot
36	*Shorea robusta*	122	138	114	152	231	172	239	192	107	211
37	*Soymida febrifuga*	15	15								
38	*Syzygium cumini*	6	11			12	8		9		
39	*Syzygium jambos*			21	11			17		23	22
40	*Terminalia arjuna*	14									
41	*Terminalia bellirica*	5	5					5			
42	*Terminalia chebula*	3	2								
43	*Terminalia tomentosa*	11	19		15						
44	*Wendlandia tinctoria*	12									
B.	**Climber**										
1	*Acacia ferniciana*					78	2			49	
2	*Aristolochia indica*		13			3					
3	*Asparagus racemosus*	2	22		20		91	4	70		41
4	*Bauhinia vahlii*	4	1								
5	*Cajanus scarberioides*										19
6	*Combretum decandrum*			108				59		67	
7	*Ericybe paniculata*	8		46			1	34			
8	*Hemidesmus indicus*	3	132		72	41	65	15	207	10	21
9	*Ichnocarpus frutescens*		114	67	27	21	78	26		15	56
10	*Lygodium flexuasum*	1	42								
11	*Pergularia daemia*				13						
12	*Rivea hypocrateriformis*		18				39		79		
13	*Smilax zeylanica*	13	3				14		5		
14	*Tiliacora acuminata*									17	
15	*Tylophora indica*				26			2	12		
16	*Ventilago denticulata*			12							
17	*Ziziphus oenoplia*	3	7	83	14	31	23		16		20
C.	**Shrub**										
1	*Abutilon indicum*									6	
2	*Azanza lampas*		17								
3	*Breynia vitis-idea*	2	14		29		15				
4	*Carissa spinarum*						45		17		31
5	*Cerescoides turgida*	4	31		33	72	16	16	34	21	29
6	*Clerodendrum infortunatum*			423	5	2371		877		408	
7	*Croton oblongifolius*								51		
8	*Desmodium trifolium*						27				

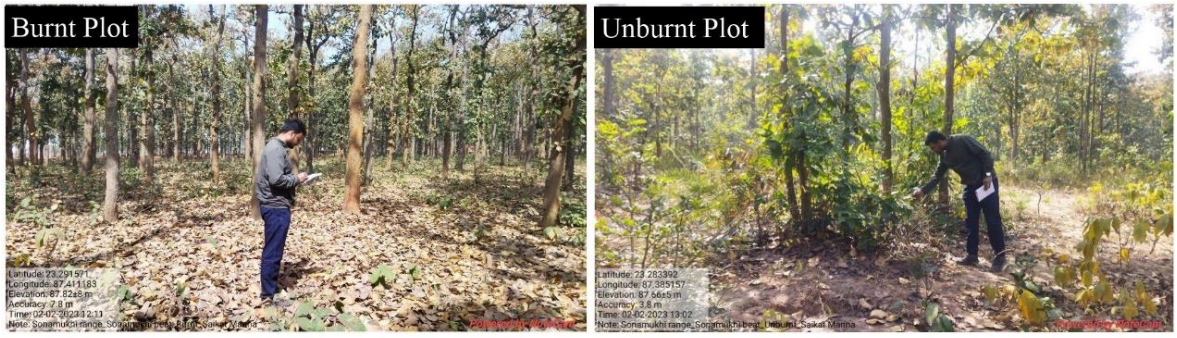
ANNEXURE I

Population of plant species documented in sample plots at respective forest Ranges

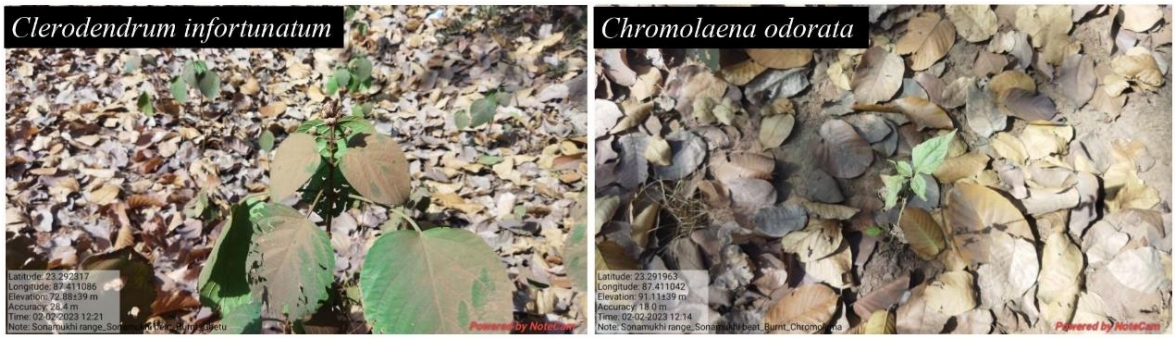
Sl. No.	Plant Species	Number of individuals documented from 50 m X 50 m (0.25 Ha) plots									
		Bankura South Forest Division				Bankura North Forest Division					
		Ranibandh Range		Pirargari Range		Sonamukhi Range		Beliatore Range		Radhanagar Range	
		Burnt Plot	Unburnt Plot	Burnt Plot	Unburnt Plot	Burnt Plot	Unburnt Plot	Burnt Plot	Unburnt Plot	Burnt Plot	Unburnt Plot
9	*Flacourtia indica*					14	12				8
10	*Grewia helicterifolia*						9				
11	*Helicteres isora*		5								
12	*Lantana camara*			42							
13	*Phoenix acaulis*	2	28	18	16	7	23		44		20
14	*Urena lobata*						8				
15	*Woodfordia fruticosa*		25								
16	*Ziziphis rugosa*							5			
17	*Ziziphus mauritiana*					3	7		3		5
D.	**Herb**										
1	*Achyranthus aspera*				47						
2	*Andrographis paniculata*		237		291		804		196		
3	*Anisomeles indica*		14								
4	*Aristida adscensionis*			78			47		59	31	
5	*Barleria cristata*						107	20	103		209
6	*Centratherum anthelminticum*		43								
7	*Cereus pterogonus*			3							
8	*Cheilanthes tenuifolia*		337			534	1578	31	78	55	401
9	*Chromolaena odorata*	37		286	11	3005		437		491	
10	*Crotalaria prostrata*					17					
11	*Curculigo orchioides*	7	23				37				
12	*Curcuma aromatica*	21									
13	*Desmodium trifolium*		22								
14	*Evolvulus nummularius*						31				14
15	*Gynura cusimbua*		108								
16	*Hyptis soavulence*	28									
17	*Oldenlandia corymbosa*		89				560		91		78
18	*Oplismenus compositus*				577						
19	*Sida rhombifolia*	12	56								
20	*Spermacoce hispida*						127	39	177		67
E	**Epiphyte**										
1	*Dendropthe falcata*		1							1	
Total		**434**	**1729**	**1409**	**1487**	**6654**	**4187**	**2022**	**1598**	**1550**	**1401**

ANNEXURE II

Photographic documentation of plants and field work during the study



Field Survey in Burnt Plot and Unburnt Plot at Sonamukhi Forest Range, Bankura North Division



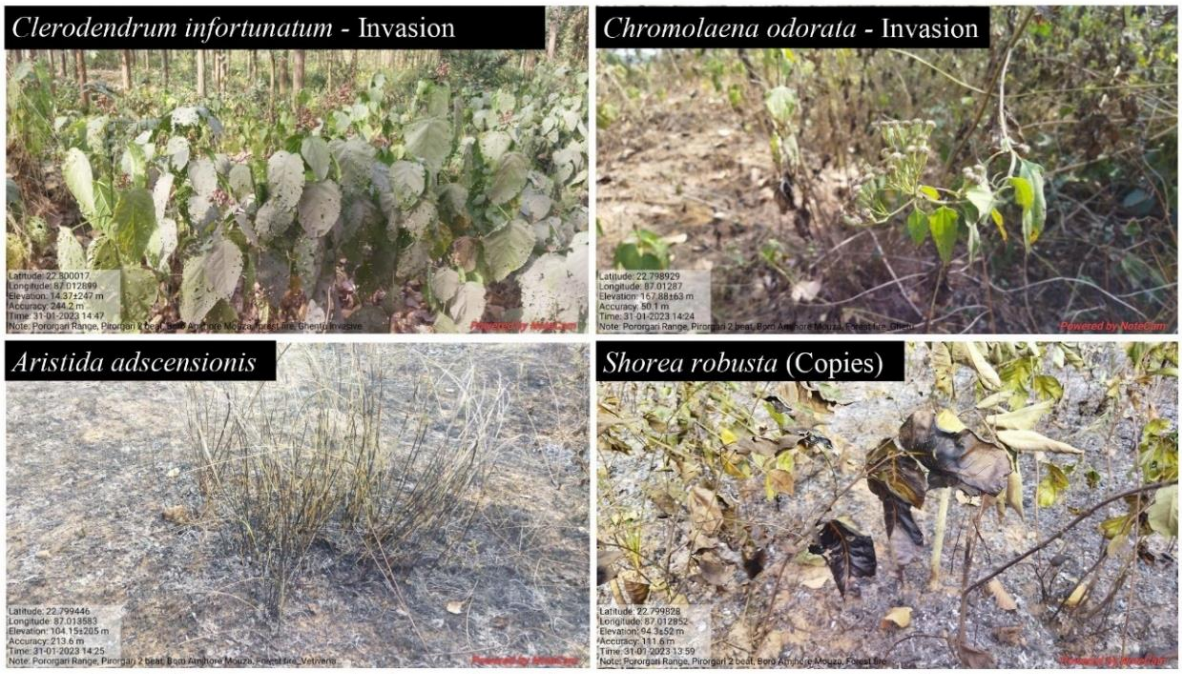
Invasion of Exotic Species in Burnt Plot at Sonamukhi Forest Range, Bankura North Division

Shrub and Herb Species in Unburnt Plot at Sonamukhi Forest Range, Bankura North Division

ANNEXURE II

Photographic documentation of plants and field work during the study

Forest Fire During Field Survey at Pirorgari Forest Range, Bankura South Division



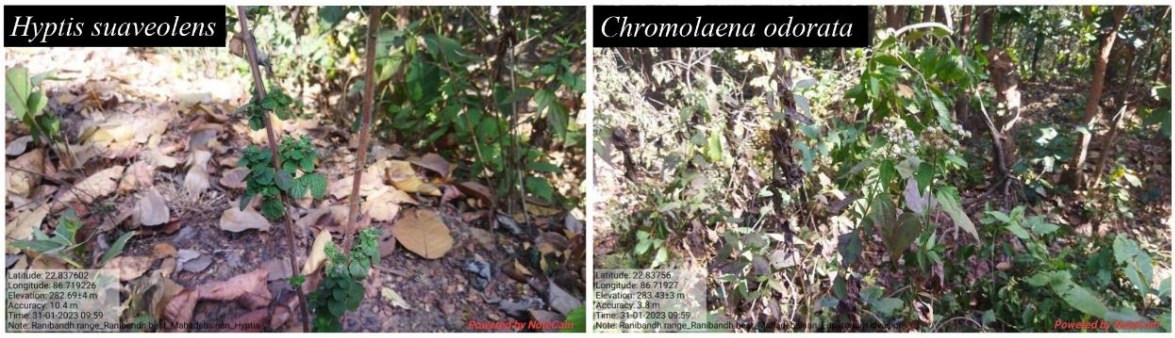
Floristic Components in Burnt Plot at Pirorgari Forest Range, Bankura South Division

Floristic Components in Unburnt Plot at Ranibandh Forest Range, Bankura South Division

ANNEXURE II

Photographic documentation of plants and field work during the study

Field Survey in Burnt Plot and Unburnt Plot at Ranibandh Forest Range, Bankura South Division



Invasion of Exotic Species in Burnt Plot at Ranibandh Forest Range, Bankura South Division

Shrub and Herb Species in Unburnt Plot at Ranibandh Forest Range, Bankura South Division

ANNEXURE II

Photographic documentation of plants and field work during the study

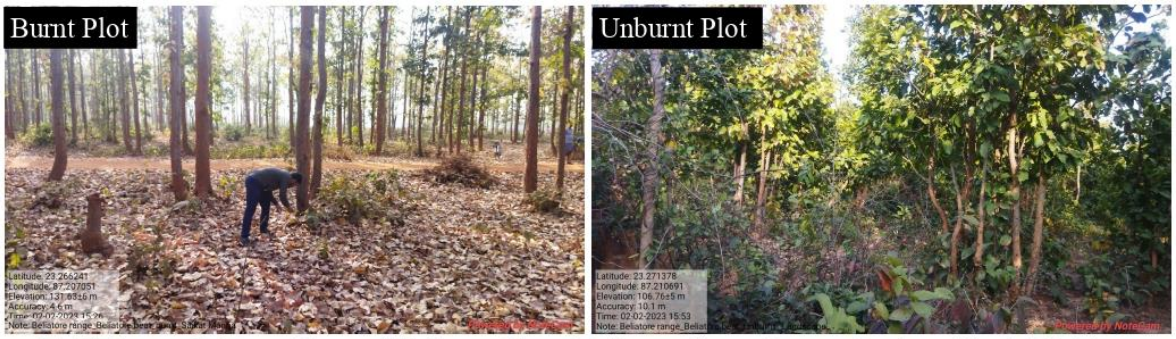
Floristic Components in Burnt Plot at Radhanagar Forest Range, Bankura North Division

Invasion of Exotic Species in Burnt Plot at Radhanagar Forest Range, Bankura North Division

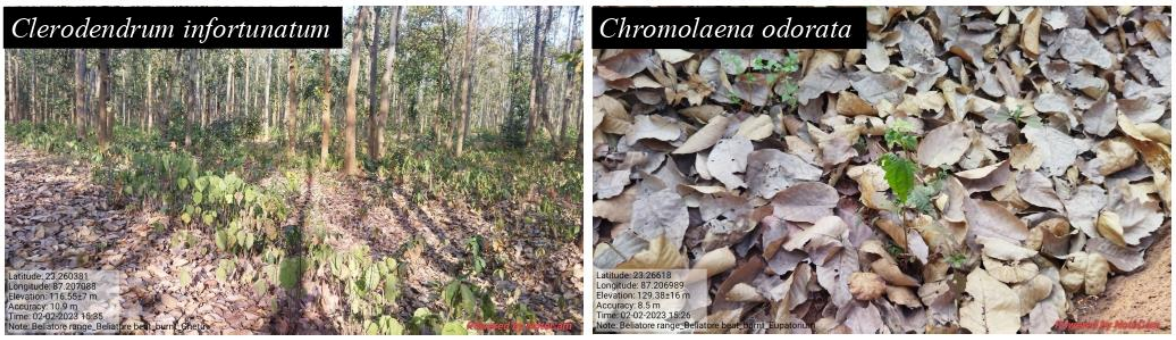
Floristic Components in Unburnt Plot at Radhanagar Forest Range, Bankura North Division

ANNEXURE II

Photographic documentation of plants and field work during the study



Field Survey in Burnt Plot and Unburnt Plot at Beliatore Forest Range, Bankura North Division



Invasion of Exotic Species in Burnt Plot at Beliatore Forest Range, Bankura North Division

Floristic Components in Unburnt Plot at Beliatore Forest Range, Bankura North Division