



**Assessment of impact of Forest Fire  
on forest fauna within the forest  
area of Purulia Division and  
Kangsabati North Division, South  
West Circle under Integrated Fire  
Management Scheme (CSS)**

Final Report

March 2023

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

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**Conducted by**

**Research Wing, Directorate of Forests,  
Government of West Bengal**

**and**

**Nature Environment & Wildlife Society (NEWS)**

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## 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 as well as the animals throughout the world. Forest fires are considered as one of the most widespread hazards in a forested landscape. They have a serious threat to forest and its flora and fauna. Wildfires destroy not only flora (tree, herbs, grassland, forbs, etc.) and their diversity but also considerable long term negative impact on fauna including wild endangered species (Jhariya and Raj, 2014).

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).

Globally, biomass fires are burning between 3-4.5 million Km<sup>2</sup> 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., 2021b). 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 Forest 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.

The purpose of study is to review the impact of wildfire on fauna in Purulia and Kangsabati North Divisions of South West Circle of West Bengal Forest Department, which are important in maintaining healthy ecosystem.

## **2. Objectives**

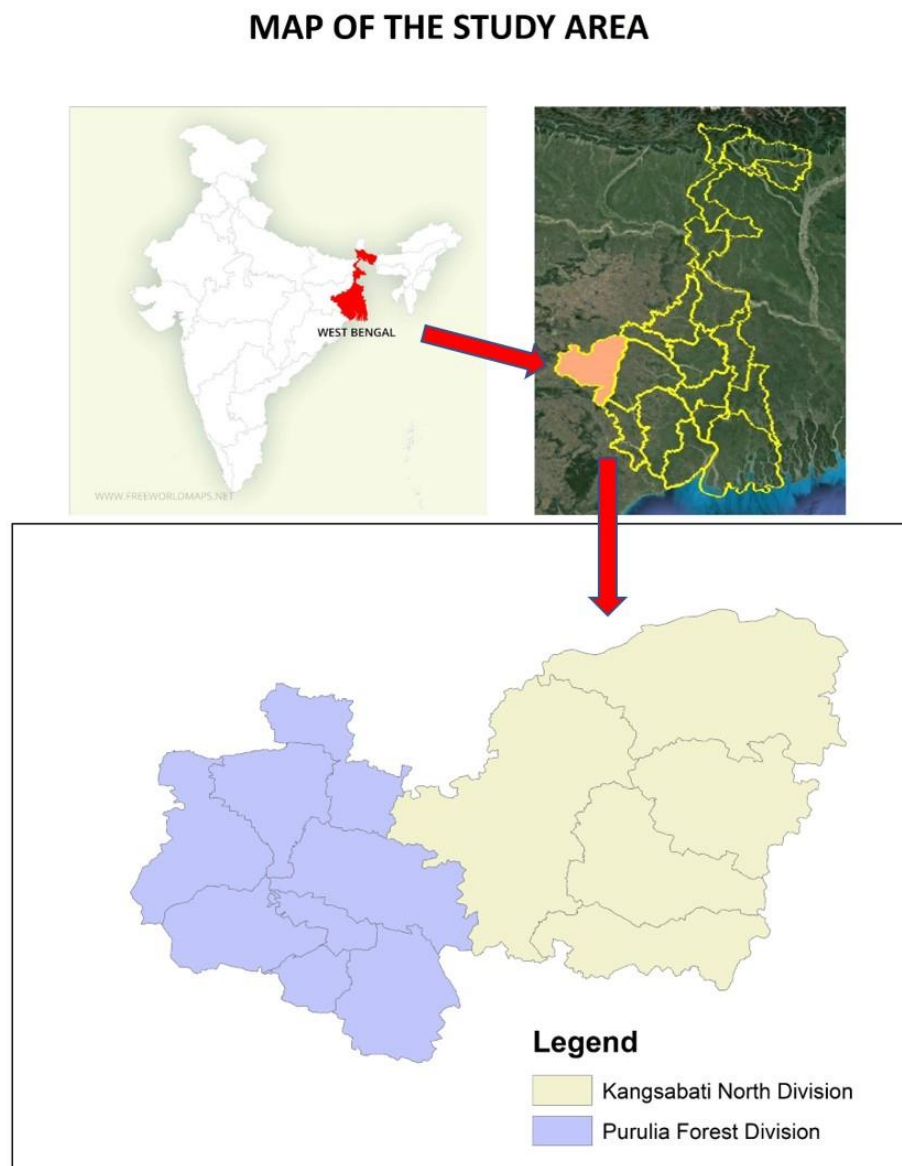
1. To assess the impact on forest fauna due to forest fire.
2. To reduce the risk of forest fire in fire prone areas.
3. To identify the animal species which are most affected by the forest fire.

### 3. Materials and methods

#### 3.1. Study area

Our study area lies in the District of Purulia, under West Bengal. Purulia came into being as a district of West Bengal in 1956. Purulia is the westernmost district of West Bengal with all-India significance because of its tropical location, its shape as well as function like a funnel. It funnels not only the tropical monsoon current from the Bay to the subtropical parts of north-west India, but also acts as a gateway between the developed industrial belts of West Bengal and the hinterlands in Orissa, Jharkhand, Madhya Pradesh and Uttar Pradesh.

This study area is in the Tropical Dry Deciduous Forests at the Western plateau region at Purulia, Kangsabati North Forest Divisions which fall under Purulia District (Figure 1).



*Figure 1: The Study Area*



**Location and boundary** - The project site is confined to the geographical range of 85° 45' E to 86°54' E longitude and 23°38' N to 22°15' N latitude. The Eastern boundary of the area is demarcated by the district of Bankura. The Northern boundary is demarcated by Paschim Bardhaman district and the neighboring state of Jharkhand. The state of Jharkhand also demarcates the Western boundary, while the Southern boundary of the area is demarcated by another Forest Division called Kansabati South.

**Topography** - The area characterized by undulating topography with rugged hilly terrains in the western and southern parts. It is well known as a drought prone district and falls within the semi-arid region of the state. The study area is situated within the agro-climatic region of Eastern Plateau and Hills and sub-region Chhotonagpur south and West Bengal plateau. The Ajodhya hill is the highest peak reaching an altitude of 670 m.

**Climate** - 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. The study has a sub-tropical climate and is characterized by high evaporation and low precipitation. Average annual rainfall varies between 1100 and 1500 mm. The relative humidity is high in monsoon season, being 75% to 85%. But in hot summer it comes down to 25% to 35%. Temperature varies over a wide range from 7° Celsius in winter to 48.50° Celsius in the summer.

**Soil** - Soil erosion is the most prominent phenomenon of the district resulting huge deposition of fertile soil in the valley region. Vast areas of land remained uncultivable wasteland.

**River systems** – The total area drains into two major river system, Kangsabati, Subarnarekha rivers and their tributaries. All these rivers are mostly rain water fed and originate from the hills of the West (Jharkhand state).

**Forest** - As per classification, the forest under Purulia Forest Division and Kangsabati North Division falls under Northern tropical Dry Deciduous Forest (5B/C 1c). Mostly coppice Sal (*Shorea robusta*) forest mixed with misc. species like Palash (*Butea monosperma*), Kusum (*Schleichera oleosa*), Mahua (*Madhuca longifolia*), Neem (*Azadirachta indica*), Kend (*Diospyros excelsa*). Major source for timber, pole, small wood, NTFP, firewood, medicinal plant to local people. 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 mammals like Indian elephant (*Elephas maximus*), Indian wild boar (*Sus scrofa cristatus*), Indian pangolin (*Manis crassicaudata*), Porcupine (*Hystrix brachyura*), Indian hare (*Lepus nigricollis*) etc.

### 3.2. Methodology:

#### I. Archive data collection from the GIS cell and analysis:

Archive data on forest fire for the last three consecutive years for the two Forest Divisions viz. Purulia and Kangsabati (N) has been collected from the GIS cell, Forest Department and analyzed accordingly.

#### II. Preparation of GIS map:

From the collected archive data, a general purpose, fire affected area map (Figure:2) and fire vulnerable ranges map for all the two Forest Divisions was prepared with the help of Google Earth and Arc GIS.

Table 1: Software Used

Software	Functions
Arc GIS 10.8	Preparation of thematic map, Analysis, Conversion of KML files to shape files
Google Earth Imagery Pro	Vector layer creation, creating KML files and verifying of GPS generated points

FOREST FIRE EFFECTED AREAS IN KANGSABATI NORTH AND PURULIA DIVISION

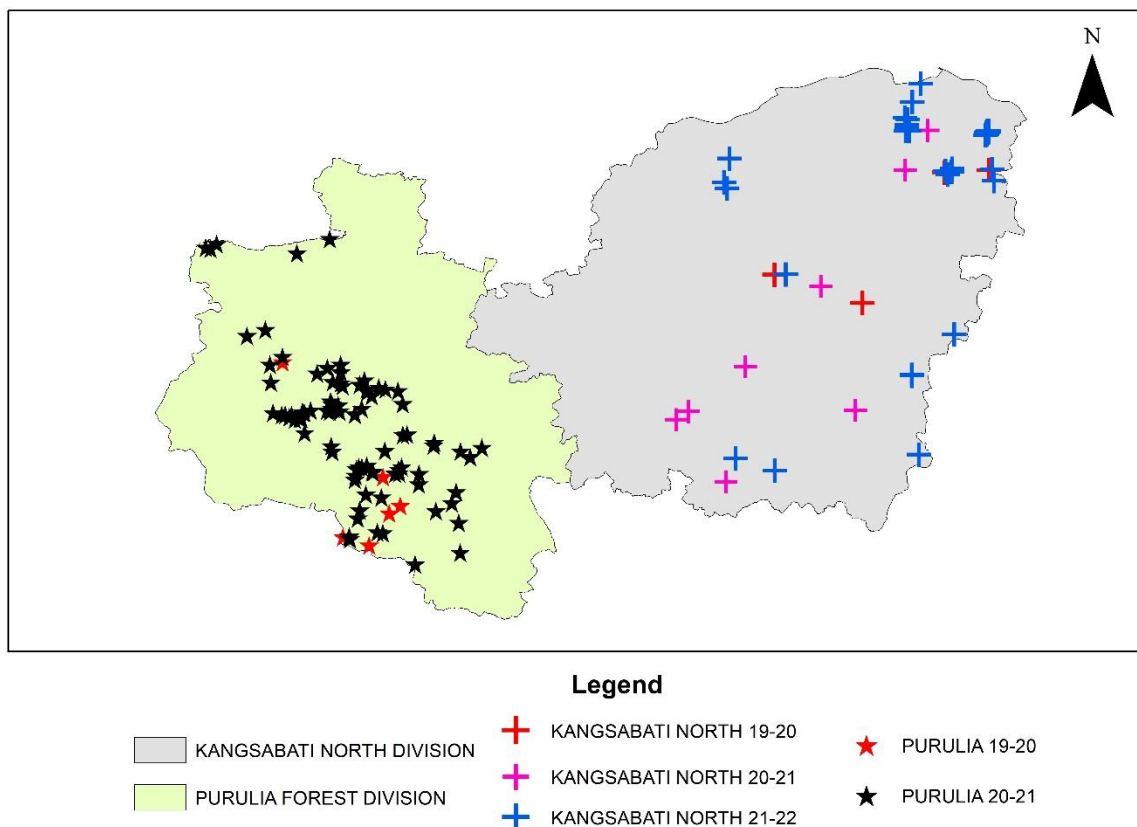


Figure 2: Forest Fire affected areas of consecutive three years in Kangsabati North and Purulia Forest Divisions

#### IV. Methodology for field data collection:

##### a. Methodology for estimating impact of Forest Fire on Forest Fauna:

Archival data available on faunal damage has been collected from the respective beat and the range offices.

Forest department officials, ground staffs and local villagers have been consulted for understanding the impact of Forest Fire on forest fauna.

##### ▪ Selection of sampling sites

Forests of Ajodhya, Bagmundi and Matha Range under Purulia Forest Division and Raghunathpur Range under Kangsabati North Forest Division are found to be affected by frequent fire in the consecutive past two to three years and also the number of fire incidents are higher than the other ranges (Table 2).

Table 2: Forest area visited for assessing the impact of Forest Fire on fauna

Forest Division	Range	Area Affected (Ha)		
		2019-2020	2020-2021	2021-2022
Purulia	Ajodhya	1.5	20.2	1.2
	Bagmundi	6.86	46.1	0
	Matha	1.5	13	0
Kangsabati North	Raghunathpur	0	1.5	40

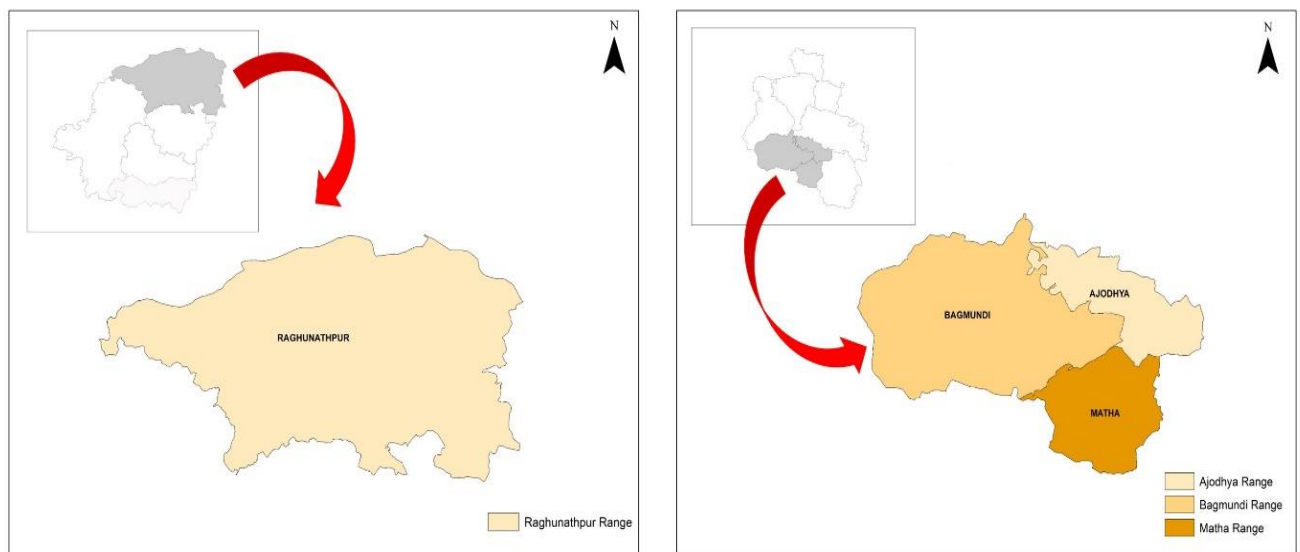


Figure 3: Ranges visited to assess the impact of Forest Fire on Fauna

## 4. Results:

### 4.1. Assessment of most vulnerable area Range wise:

From the recorded data it is observed that for the last three years (2019 to 2022) most of the Fire incidents occurred during forest fire season Purulia Forest Division (116), and in the year 20-21 the incident was as high as 99 incidents while Kangsabati North Forest Division had lower incidents (59) than Purulia Division in total but in 2021-22 it has much more incident (42) than the Purulia (7) (Figure: 4).

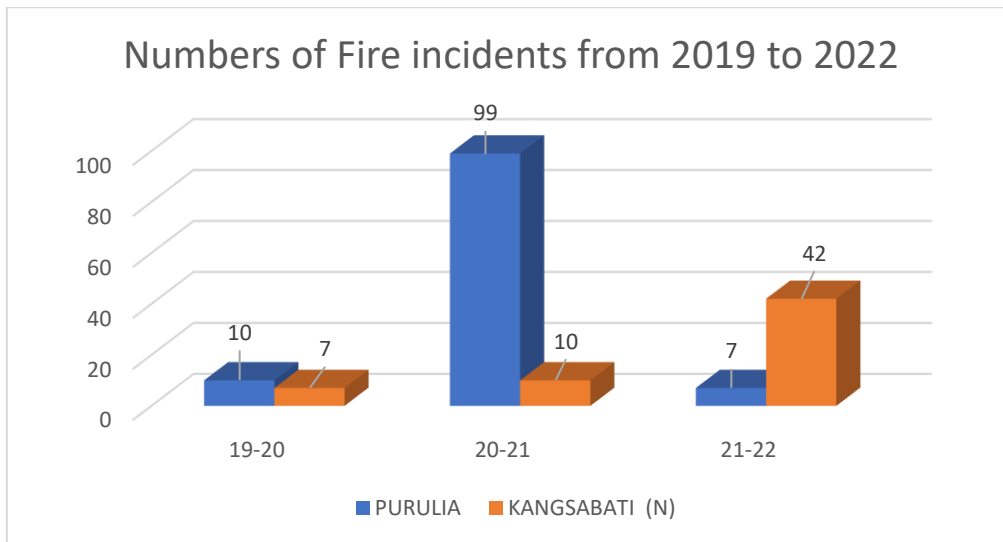


Figure 4: Numbers of Fire incidents in six Forest Divisions

The data has been further analysed range wise where the most affected ranges within a Forest Division are tabulated and presented graphically.

In Purulia Forest Division Bagmundi Range recorded the most vulnerable area for Forest Fire in 2019-20 and in 2020-21 where approximately 7 ha and 46 ha areas had been affected by the Forest Fire. But surprisingly there was no incident of fire in the last year. Only in Joypur (20 ha) and in Ajodhya Range (1.2 ha) the Forest Fire occurred.

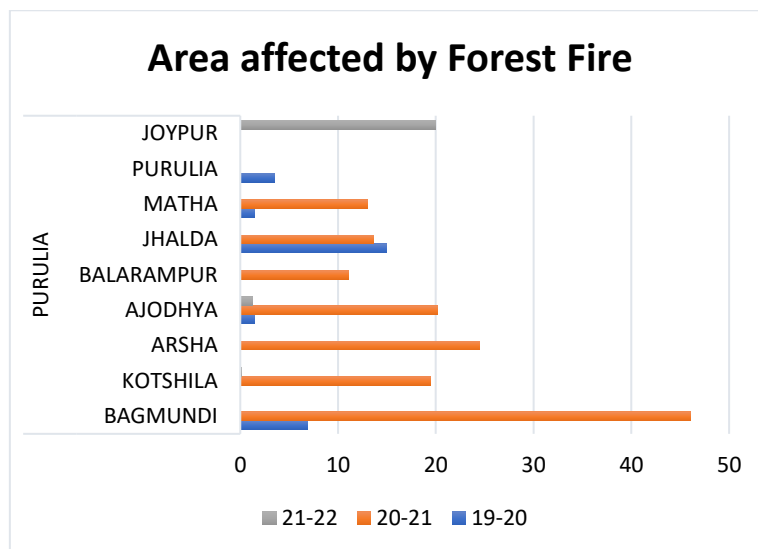


Figure 5: Area affected by Forest Fire in Purulia Division

In 2021-22, Raghunathpur Range of Kangsabati North Division was mostly affected in Forest Fire in the whole Division. Near about 40 ha area had been affected due to Forest fire.

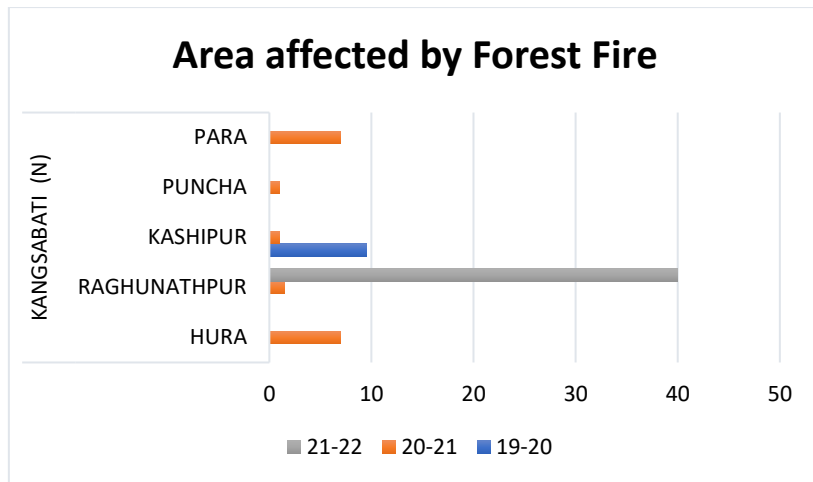


Figure 6: Area affected by Forest Fire in Kangsabati North Division

From the archive data a vulnerability map has been created where the most vulnerable ranges are being shown with different colour codes.

In the vulnerability map 3 years fire affected area has been accumulated range wise and classified in 4 distinct classes as per the severity of the affected area 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) and Very highly fire-prone forest area (50.1- 100 ha affected area).

From the vulnerability map (Figure 7 and 8) it is clear that the most vulnerable area within these two divisions, is only Bagmundi Range area which is coming under very highly fire prone zone, with a total affected area of 52.96 ha in three consecutive years. Whereas, Jhalda (28.63 ha), Arsha (24.5 ha), Ajodhya (22.9 ha) Range from Purulia Division and Raghunathpur Range (41.5 ha) from Kangsabati North Division shows high proximity to forest-fire. 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.

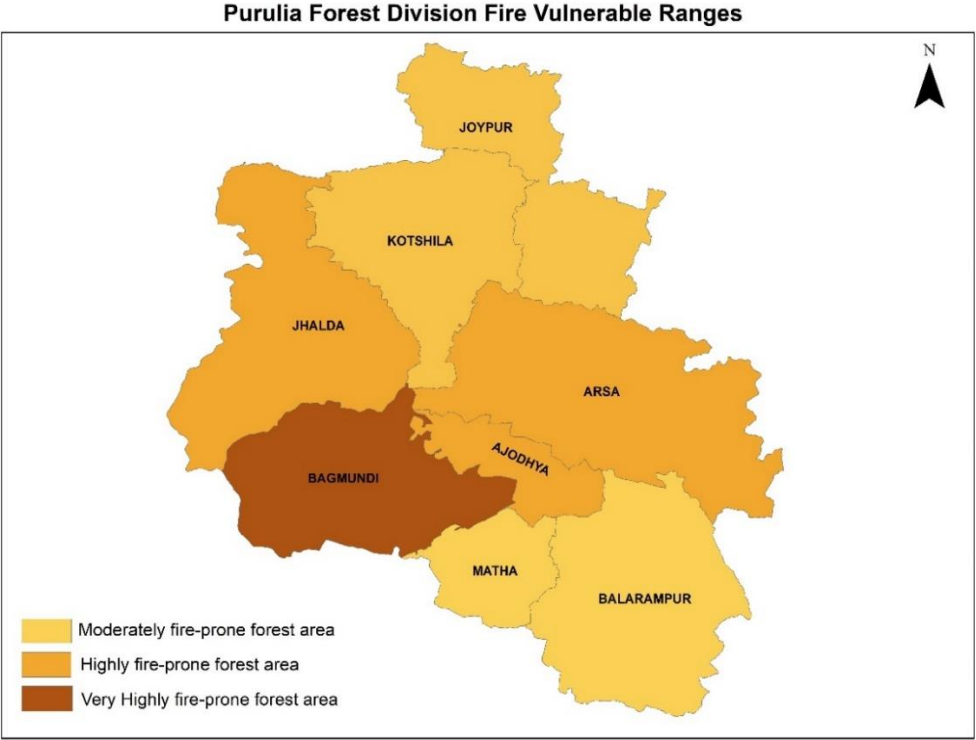


Figure 7: Most Fire vulnerable Ranges of Purulia Division

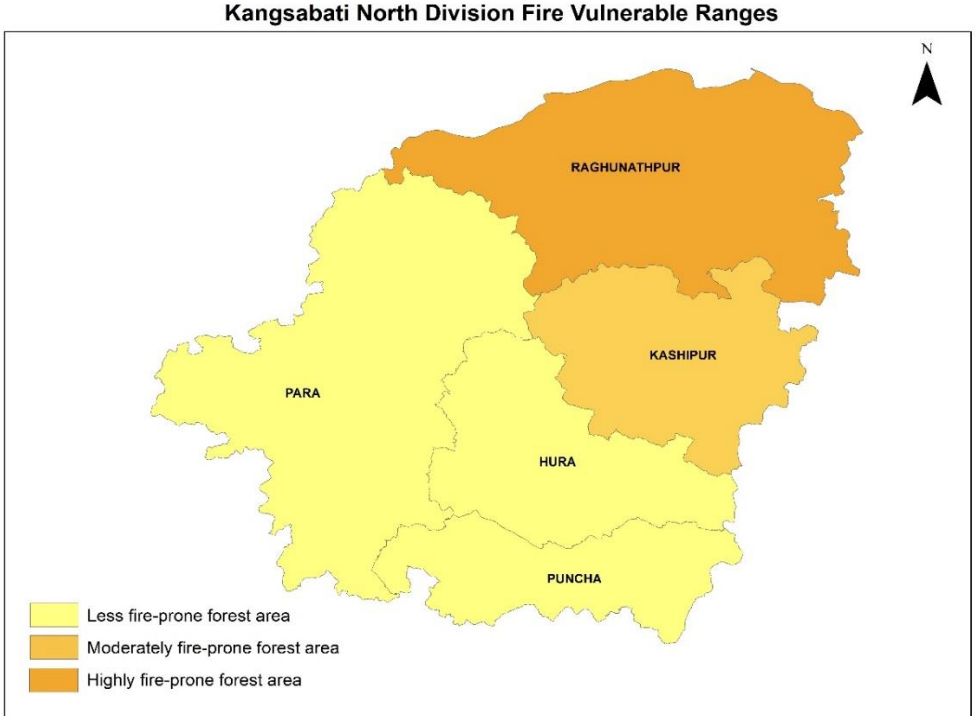


Figure 8: Most Fire vulnerable Ranges of Kangsabati North Division

## 4.2. Assessment of impact of Forest Fire on Forest Fauna:

Ajodhya, Bagmundi, Matha Range offices under Purulia Division and Raghunathpur Range office under Kangsabati North Division have been visited for collection of archival data available on faunal damage as well as the field data collection. Field data collection was not possible as no fire occurred this year so far. Therefore, mostly it is dependent on archival data, but most of the Range offices/ Beat offices don't keep any faunal damage data as the primary damages occurs mostly in arthropod level.

Due to non-availability of archival data on faunal damage due to forest fire, forest officials and ground staffs as well as local villagers (where available) has been interviewed. Total 15 people including Range officers, Beat officers, CDL, forest guards and local people have been consulted for any information regarding the faunal loss. As a result, most of the people informed that when the forest fire occurred, the mega fauna mostly ran away and take shelter in safer places.

As per the people, only few bird nests are being impacted due to forest fire and those are mostly the nests of ground dwelling birds like long-tail nightjar (*Caprimulgus climacurus*), Grey Francolin (*Ortygornis pondicerianus*), Red wattled lapwing (*Vanellus indicus*), Eurasian thick-knee (*Burhinus oedicephalus*) and middle tier and bush dwelling birds like Paradise flycatcher (*Terpsiphone paradisi*), Bulbul, Tailor bird (*Orthotomus sutorius*). Also, some small reptiles like Garden lizard, Geko are being directly impacted due to the forest fire.

Only in Bagmundi Range there are few incidents happened during the forest fire of 19-20 and 20-21, where one Indian rat snake (*Ptyas mucosa*) and one Indian hare (*Lepus nigricollis*) was rescued from the fire site, immediately treated and released in the same forest in safe zone. No abundant den or animal carcass has been recorded till date.

### 4.2.1. Effects of Forest Fire on animal habitat and feeding behaviour:

Forest Fire also influence the composition, structure and landscape patterns of animal habitat. Wildlife may be affected by the forest fire both through direct casualty or habitat alteration (Lyon *et al.*, 2000b). After forest fire, the vegetation structure of forest can be altered, and as a result, food, shelter and hiding cover for wild-animals also get hampered. The ground dwelling animals like Wild boar, Pangolin, Porcupine, Shrew and also reptiles who dig out the ground for their food and also for shelter got effected as forest fire destroys mainly the ground as well as some underground vegetations. Larger mammals like elephant, who dependent upon ground vegetation like grasses as well as mid-tier vegetation also lost their feeding habitat due to forest fire and they could not feed upon from the same area unless until the vegetation get restored after the monsoon.

Many bird species have the longer-term responses due to primary structural changes of vegetation or changes to food resources, as affected by fire severity (Huff and Smith, 2000; Kirkpatrick *et al.*, 2006). Ground-nesting birds could be killed prior to fledging (Reinking, 2005) and forest floor arthropods in the egg or larval stages may be more vulnerable to loss (Niwa and Peck, 2002). The shelter of many birds, reptiles, amphibians and arthropods got affected due to the fire.

Fire also has some positive effects on forest fauna. Fire attracts some animals in search of food. Birds attracted to fire probably use the smoke column as the visual cue and feed on insects that are carried high into the air (Komarek 1969, Gillon 1971, Gandar 1982, Frost 1984, Braithwaite and Werner 1987).

Snags or dead wood on the ground is an essential habitat component for many birds, small mammals and even large mammals (Bull and Blumton, 1999). Fire cause large dead logs on the ground, harbour many invertebrates and are particularly of ants; they also provide shelter and cover for small mammals, amphibians and reptiles (Jhariya and Raj, 2014).

#### **4.2.2. Methods are undertaken to reduce the risk of Forest Fire:**

According to the report most of the Forest Fire occurs due to anthropogenic pressure. Which can be accidental or intentional. To reduce the risk of occurring Forest Fire the local Forest Department along with other Governmental Bodies like BDO, Panchayet, local Police Department etc. conduct public announcements, awareness programme, meetings, Naka checking, distribution of leaflets, flex display (Annexure I) in forest fringe villages as well as in the road which are going through the forest areas, to sensitize the local people about the risk of the Forest Fire. In the study area, hunting of wild animal is an age-old practice as it is mostly inhabited by the tribal community and it was recorded earlier that most of these hunting always followed by setting fire in the forests. Sometimes these kind fires cause more damage than the hunting in the forest areas. But now a days the local tribal people don't practice this hunting method after getting continuous awareness from the Forest Department, local Government agencies as well as some NGOs.

## **5. Discussion**

### **5.1. Assessment of most vulnerable area**

From the vulnerability map generated it is observed that the most Fire-prone ranges are Bagmundi, Jhalda, Arsha and Ajodhya from Purulia Division and only Raghunathpur Range from the Kangsabati north Division. Division wise also Purulia Division is more fire prone than the Kangsabati North as the number of incidents as well as area affected by the forest fire for three consecutive years.

In both Divisions, the ranges which are more prone to forest fire are also very rich with the forest fauna. In Purulia Divisions most of the fire occurred around Ajodhya Hill, which is the habitat for most of the wild animal in this region. Same as the Purulia Division, in Kangsabati North, Raghunathpur is the most fire prone area where the Garh Panchkot Hill is situated, which harbours most of the wild animals in this region.

### **5.2. Assessment of impact of Forest Fire on Forest Fauna**

The hazardous effects of fire on animals can be direct and immediate, although some effects, such as shortened lifespan or impaired fitness of wounded individuals following a fire event, may play out over years or decades (R. Todd Engstrom, 2010). Physiological effects of short



exposure to fire on animals are poorly known, but some inferences can be made from studies of responses of animals to high ambient temperatures. The highest body temperature that animals can tolerate is about 50°C. Above this temperature, cells undergo denaturation of proteins, enzymes become inactive faster than they can be re-formed, and membrane structure degrades (Schmidt-Nielson, 1979). In addition to this heat related factors, oxygen depletion and exposure to toxic compounds following smoke inhalation may be critical factors to animal survival during exposure to fire. The length of time that an organism is exposed to high temperature, anoxia, or smoke is critical; thus, fire detection and avoidance are essential behaviours for survival, especially for less-mobile animals (Whelan, 1995).

Fires that would affect a large portion of a population because of temporary immobility of individuals, or a fire-susceptible condition, such as ecdysis, are important exceptions to the generalization. Fire-caused changes to habitat for animals over time and space are composed of many first-order effects on vegetation.

To save the forest from the fire it is a responsibility of forest managers. For conservation aspects, maintaining and sustaining all-forest types is important as they harbour high biodiversity of not only plant species, but are also a preferred habitat for several wild animals.

In this study it was seen that most of the forest fire that has occurred in these Divisions are restricted to the ground fire and surface fire and mega fauna like, Elephant, Deer, Jackals etc that are the residents of these forest area sense it before it could harm them and they run away to a safer place. So, there is not much direct impact of forest fire on mega fauna but the ground dwellers and the mid-tier bird nest got severely affected by the fire. But it is also true that fire affect animals mainly through effects on their habitat, so indirect effects of forest fire are more than the direct effect.

## **6. Limitations**

In this study it was seen that most of the forest fire that has occurred in these Divisions are restricted to the ground surface and mega fauna like, Elephant, Deer, Jackals etc that are the residents of these forest area sense it before it could harm them and they run away to a safer place. But the long-term effects of injured animals or the habitat alteration effects on animals is still unknown for this area due to lack of time.

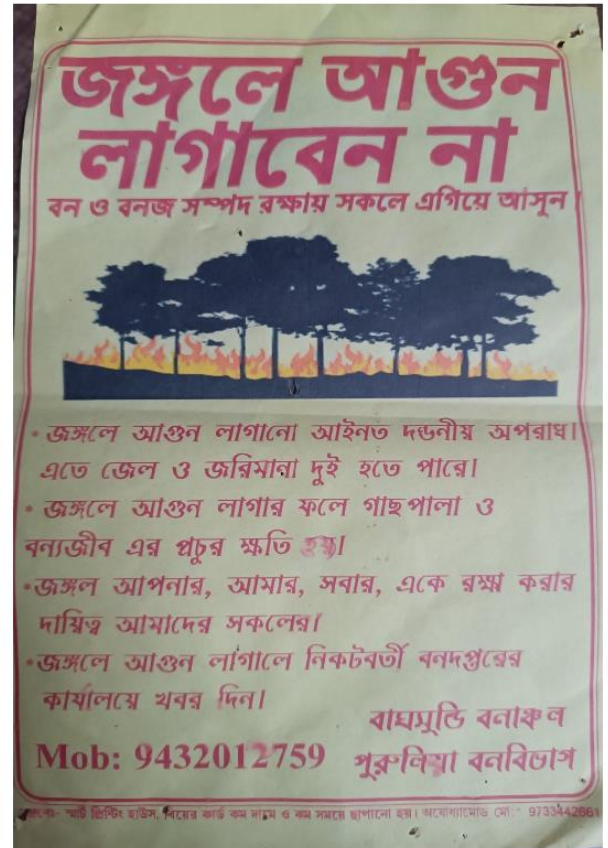
Moreover, there is no record on faunal damage, mortality or habitat alteration in the Forest Divisions as well as in the Range or Beat offices which causes the lack of enough evidence to make a statement on the actual impact on the ground.

## 7. References:

1. Anonymous. (2021b). *Indian State Forest Report 2021*. Forest survey of India, Ministry of Environment Forest and Climate Change, Dehra Dun
2. Braithwaite, R.W., and P.A.Werner. (1987). *Firebirds of the Top End*. Australian Natural History 22: 298-302.
3. Bull, E.L. and Blumton, A.K. (1999). *Effect of fuels reduction on American martens and their prey*. Res. Note PNW-RN-539. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 9 pp.
4. 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.
5. Champion, H.G. and Seth, S.K. (1968). *A revised survey of forest types in India*. Government of India Publication, and New Delhi.
6. Chatenoux, B. and Peduzzi, P. (2012). *Biomass fires: preliminary estimation of ecosystems global economic losses*. UNEP/GRID-Geneva. pp. 1-11.
7. Engstrom, R.T. (2010). *First-order fire effects on animals: review and recommendations*. Fire Ecology 6(1): 115-130. doi: 10.4996/fireecology.0601115
8. Frost, P.G.H. (1984). *The responses and survival of organisms in fire-prone environments*. Pages 273-310 in: P.deV. Booysen and N.M. Tainton, editors. Ecological effects of fire in South African ecosystems. Springer-Verlag, New York, New York, USA.
9. FSI. (2012). *Vulnerability of India's forest to fires*. MOEF, Dehradun. Pp. 7.
10. Gandar, M.V. (1982). *Description of fire and its effects in the Nysley Nature Reserve: a synthetic report*. South African National Scientific Report Series 63: 1-339.
11. Gillon, Y. (1971). *The effect of bush fire on the principal pentomid bugs (Hemiptera) of an Ivory Coast savanna*. Tall Timbers Fire Ecology Conference 11: 419-471.
12. Huff, M.H. and Smith, J.K. (2000). *Fire effects on animal communities*. In: Smith, J.K., ed. *Wildland fire in ecosystems: effects of fire on fauna*. Gen. Tech. Rep. RMRS-GTR-42-vol. 1. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station; 35-42 pp.
13. Jhariya, M.K. and Raj, A. (2014). *Effects of wildfires on flora, fauna and physico-chemical properties of soil-An overview*. Journal of Applied and Natural Science 6 (2): 887 - 897
14. Kirkpatrick, C., Conway, C.J. and Jones, P.B. (2006). *Distribution and relative abundance of forest birds in relation to burn severity in south eastern Arizona*. Journal of Wildlife Management, 70(4): 1005-1012
15. Komarek, E.V. (1969). *Fire and animal behavior*. Tall Timbers Fire Ecology Conference 9: 161- 207.
16. 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.
17. Lal, R. (2004). *Soil carbon sequestration to mitigate climate change*. Geoderma. 123: 1-22.

18. Lyon, L.J., Telfer, E.S. and Schreiner, D.S. (2000b). *Direct effects of fire and animal responses*. In: Smith, J.K., ed. Wild land fire in ecosystems: effects of fire on fauna. Gen. Tech. Rep. RMRS-GTR-42-vol. 1. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station; 17–23 pp.
19. Niwa, C.G. and Peck, R.W. (2002). *Influence of prescribed fire on carabid beetle (Carabidae) and spider (Araneae) assemblages in forest litter in southwestern Oregon*. Environmental Entomology, 31(5): 785-796.
20. 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>
21. 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.
22. 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.
23. Reinking, D.L. (2005). *Fire regimes and avian responses in the central tall-grass prairie*. Studies in Avian Biology, 30: 116–126.
24. Schmidt-Nielson, K. (1979). *Animal physiology: adaptation and environment*. Cambridge University Press, United Kingdom.
25. 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.
26. 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.
27. 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.
28. Whelan, R.J. (1995). *The ecology of fire*. Cambridge University Press, United Kingdom.

# ANNEXURE I



Prevention of Forest Fire and awareness campaign through leaflet and signboard by the Forest Department