Identification and Assessment of Forest Fire in Similipal Tiger Reserve (STR) with GIS

Forest fire is a major environmental issue, creating economical and ecological damage while endangering human lives. Similipal, situated at the Indian state of Odisha, is the only tiger reserve in the world, where the melanistic form of tiger is found and is properly conserved. The paper has tried to identify and evaluate the forest fire incidences in Similipal Tiger Reserve (STR) using Remote Sensing (RS) and GIS technique for four years, such as 2006, 2009, 2013 and 2016. Primary fire incidences data were collected from respective meteorological offices along with location coordinates with prevailing weather conditions. The forest fire incidences are mapped in Arc GIS 10.1 software environment. It shows unusual distribution of forest fire incidences in STR. The year 2009 has the maximum number of forest fire incidences in STR underlined by extremely hot weather and low precipitation condition. Groundtruthing in the STR shows disturbances due to anti-social activities in some patches of the area, limiting the scope for preventive measures, caused large number of forest fires incidences. Forest fire caused by local people (man-made) associated with the presence of Particularly Vulnerable Tribal Groups (PVTGs) also are increased in numbers. Forest fire incidences can be reduced drastically with future planning and using modern technologies under most unfavourable climatic conditions.

Key words: Forest fire, STR, GIS, Climate change, Forest resources.

Introduction

Forest is one of the most important renewable natural resources and plays a significant role in human life, energy, maintaining biological diversity, mitigating climate change, protecting land and water resources, providing recreation facilities, enhance air quality and alleviatingpoverty. The increasing counts of extreme natural phenomena, which are related to the climate variability and are mainly caused by anthropogenic factors, escalate the frequency and severity of natural disasters. Forest fire is one of the most important sources of land degradation that leads to deforestation and desertification process. Forest fire is a major environmental issue, creating economical and ecological damage while endangering human lives. In recent years, prolonged dry weather together with rapidly expanding exploitation of tropical forests and the demand for conversion of forest to other land uses have resulted significant increase in forest fire cases, frequency and its related environmental impacts. Forest fire is widely recognized as a major factor in global carbon budgets, since they have a great impact on vegetation disturbance and succession, as well as on worldwide greenhouse gas emissions (Chuvieco, 2008). The observations in the last twenty years show that the intensity and spreading of forest fires in Asia are largely related to rise in temperature and decline in precipitation in combination with increasing intensity of land use changes (IPCC, 2007). The present day knowledge about the forest fire situations in India has been reviewed by Joseph et al.(2009),

Forest fire mapping assists in protecting life and property by identifying the vulnerable areas

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that shows about 2-3% of the forest area getting affected annually by fire and on an average over 34,000 ha forest area are burnt. Some of them are incidental, but majority are deliberately caused (Kunwar and Kachhwaha, 2003). Forest mapping of burnt areas at the global scale is critical, since fire is one of the principal disturbing factors that affects the basic structure of the ecosystems, carbon budgets, and nutrients cycles, as well as one of the significant causes of greenhouse emissions (Roy et al., 2008). At a regional scale, burnt area maps can give a spatial assessment of economic and environmental effects of the fire while facilitating improvements of pre-fire planning (Giri and Shrestha, 2000) followed by postfire rehabilitation efforts (Vafeidis et al., 2005). Conversely, when uncontrolled, they can devastate huge areas, degrade the environment and diminish the natural resources (Johanna and Landsberg, 1997).

Forest burnt area size, spread and intensity has a critical impact on the climate as well as biodiversity. Forest fire is recognised as one of the major reasons of the global change in terrestrial ecosystems (Rudel et al., 2005) affecting the biodiversity. Biomass burning is regarded as the second largest source of trace gases in the global atmosphere and strongly affected by climate change (Bond et al., 2004). Remote sensing and GIS are important tools for mapping and monitoring of forest fire. It is recommended to acquire, analyse and understand multi-year and multi-seasonal satellite data in order to create a fire history of the area and to capture all forest fire events of the season. It is also recommended to produce a GIS database consisting of bio-physical and socio-economic variables required for hazard mapping and forest fire simulation.

A precise evaluation of forest fire problems and decision on solutions can only be satisfactory when a fire risk zone mapping is available (Jaiswal et al., 2002). Forest fire research is one of many appropriate GIS/remote sensing imagery applications. It provides a quick evaluation of the vegetation status, as well as a survey of the effects of fire upon the environment. People studied forest fire risk zones (FFRZ) with a variety of mapping methods. Most of them mapped forest fire risk zones by directly using remote sensing and Geographic Information Systems (GIS) that contain topography, vegetation, land use, population, and settlement information (Jaiswal et al., 2002). RS/GIS play an important role in detecting the active forest fire locations, as well as helping in assessment of the fire risk based on several factors, such as topography, climate and other biological factors. Satellite data plays a vital role in identifying and mapping forest fire and in recording the frequency at which different vegetation types/zones are affected. GIS can be used effectively to combine different forest-fire causing factors for demanding the forest fire risk zone map. Estimation of the vulnerability of an

area to fire is essential to the "prediction" of future possible fire outbreaks and "prevention" is accomplished by taking proper action in high risk areas. Satellite remote sensing can contribute to the "prediction" of fires and the protection of forests by offering up to date information about the Earth's surface. Remote sensing application is able to provide post-fire data immediately after a fire breaks covering forest area in various scales. Now-a-days the implementation of innovative methodologies with the high resolution satellite data has made possible the accurate classification even of the types of burned vegetation (Mitri and Gitas, 2006). Several GIS applications have been developed in the last decade to improve management of forest fire.

GIS provides tools for spatial interpolation of weather data, and so a more complete view of the geographical diversity of fire danger can be obtained. GIS-based models which cover a small area at high resolution typically from 50 to 100 m grid size (Van Wyngarden and Dixon, 1989).

Forest fire in India

The Forest Survey of India (FSI) data on forest fire attribute around 50 percent of the forest areas as fire prone. This does not mean that fires affect country's 50 per cent area annually. Very heavy fire, heavy fire, frequent forest fire and occasional fire damage is noticed only over 0.84 per cent, 0.14 per cent, 5.16 per cent and 43.06 per cent of the forest areas, respectively. Only 6.17 per cent of the Indian forests are subjected to severe fire damage annually. In absolute terms, out of around 63 million hectares of forests, an area of around 3.73 million hectares can be presumed to be affected by fire annually (Satendra and Kaushik, 2014). Forest fire in India is mostly anthropogenic (Giglio et al., 2010; IFFN, 2002); however, the intensity of fire depends on climate, fuel type, the wind, topography, and demography. There are shreds of evidence towards increased frequency of anthropogenic fires than in the past in Indian forests (Kodandapani et al., 2004; Krishna and Reddy, 2012).

The objective of the paper is to identify and evaluate the forest fire incidences in Similipal Tiger Reserve (STR) in 21st Century using RS and GIS techniques.

Study Area

The Similipal Tiger Reserve is a compact block of elevated plateau located in the central portion of the Mayurbhanj district, at the northern most part of Odisha State, and lies between S20°17' and 22°34' north latitudes and 85°40' and 87°10' east longitudes. The core and buffer encompasses an area of 1194.75 km² and 1555.25 km² respectively, with the total area of the tiger reserve being 2750km² (Fig. 1). The terrain is mostly undulating and hilly, interspersed with open grasslands and wooded areas. Similipal is located in the Deccan Peninsular Bio-geographic Zone,

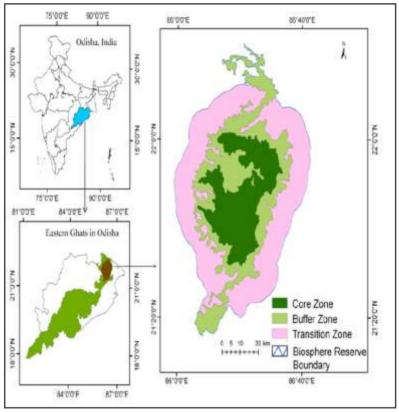


Fig. 1: Study area

Chhotanagpur Province and Mahanadian

biogeographic region. An astounding 1078 species of plants, including 94 species of orchids, are reported from the park. The vegetation is a mix of different forest types and habitats, with northern tropical moist deciduous dominating some semi-evergreen patches. Similipal harbours a unique blend of Eastern Ghats with elements from Western Ghats and Sub-Himalayan plant species. Sal is the dominant tree species here. There are 55 species of mammals, 361 species of birds, 62 species of reptiles, 21 species of amphibians, 38 species of fishes and 164 species of butterflies recorded from the Park. Similipal harbours the largest population of elephants in Odisha, more than 500 in number. Gaur is found in few localised pockets and in small herds. The major ungulate species found in Similipal are sambar, chittal, barking deer and mouse deer. Poaching of prey animals is still reported and urgent mitigation measures are required to mitigate it. The major carnivores here include tiger and leopard: other carnivores are leopard cat, fishing cat, jungle cat, and wolf. This is the only Protected Area in the world where the melanistic form of tiger is found. This tiger population is showing signs of increase and urgent mitigation measures are being taken to ensure the safety of this population.

The South–West monsoon remains active from mid-June to end of September. Tropical cyclones are very common, which affects Similipal Tiger Reserve during October-November. The minimum temperature dips to 2 to 3° C in December, whereas May is the hottest month with the highest temperature touching 39-41°C. Pre-monsoon showers moderate the temperature of Similipal in the last week of May. The average temperature of December month ranges between 18 – 20 ° C, whereas in the month of May it ranges between 32 - 36°C.

Methodology

Collection of data

The forest fire incidences along with their location information was collected (as secondary data from Office of the Field Director STR, Baripada, Odisha records along with spatial information through groundtruthing) for the year 2006, 2009, 2012, 2013 and 2016 having maximum number of incidences so far in 21st Century. The fire incidence mostly occurs between the months of March to June. These data for selected five years were transferred to the GIS software (Arc GIS 10.1) Environment for further analysis. The STR map with a scale of 1:50,000 was collected from the divisional meteorological office. The map was digitized using nearly eight ground control points (GCPs). The yearwise fire incidences data along with their latitude and longitude information were recorded. The map is projected to WGS UTM-

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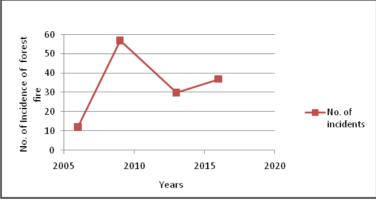


Fig. 2: Trend of fire incidence in STR

1984 for zone 45 for mapping in GIS software environment.

Mapping in GIS

Arc GIS 10.1 software was used for all mapping of information on forest fire incidences. The forest fire sites were represented as point data in the study area map for the mentioned years. The point data showing fire incidences were mapped in the base of the study area. The map is developed for all the mentioned years separately. The images are overlayed to analyze the intents of occurrence of forest fire in the region.

Weather information collection

The weather information for the study area was collected from the Baripada, Odisha weather station to understand the underlined reasons of increased number of forest fire incidents in the mentioned years. The weather information includes precipitation rate, temperature variation etc for the study area. Statistical graphs (SPSS and MS Excel) were developed for the years against the prevailing climate conditions during forest fire occurrences (mostly during summer time). Critical analysis was carried out to understand the conditions in a better way.

Ground truthing

Groundtruthing was carried out to find the real situation in the area having higher incidence of fire in a particular year. Discussion was carried out with the local people and officials to find out any specific reason behind the fire incidence. Some interesting facts were revealed during one-to-one discussion atfact finding operation.

Results and Discussions

Forest fire status in STR

The major fire incidences in the Similipal Tiger reserve were recorded along with location information (Table 1). The forest fire incidence pattern against the year was presented graphically (Fig. 2). The zig zag graphical pattern showed no specific trend of incidences of fire in STR as recorded in different years. We can not safely conclude that, the incidences of fire is going down or will be going down in future. So, special attention has to be taken to monitor and control the incidences of forest fire in STR.

Table	1:	Major	fire	incidents	in	Similipal	tiger reserve
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SI. No.	Year	No. of fire incidences
1	2006	12
2	2009	57
3	2013	30
4	2016	37

Forest fire incidence distribution

To visualize distribution of fire incidence in the STR, mapping was carried out in GIS environment for the mentioned years. The base map was developed using the existing STR map. Eight ground control points were used to digitize and projected into WGS UTM -1984 for zone 45.

Forest fire incidences mapped in GIS environment is very much suitable to get overall distribution of the incidents. These maps can guide future plan of action to combat accidental fire at greater peace. This will also support the administration to make preparedness for future incidences. As expected in the year 2009. maximum number of forest fire incidences can easily be observed from the maps. In year 2016, there is also more numbers of forest fire incidences compared to other years. Upper Barah Kamuda (UBK) is located in the south central part of Similipal shows more number of forest fires. Similarly, Jenabil and Nawana south areas located in the Northern part of STR have got more incidence of forest fire in the underlined years. Groundtruthing can enlighten the underlined reason of forest fire in various locality of STR.

Climate data analysis

Climate data for the study area was collected for the underlined years for better understanding of the situations. The quarterly average rainfall was estimated for the mentioned years for the study area (Table 2) and Fig. 4. The graphical representation of quarterly average rainfall for March quarters and June

SI. No.	Year	Quarter ending March	Quarter ending June	Quarter ending September	Quarter ending December
1	2006	9.43	281.23	308.50	7.93
2	2009	2.73	169.80	224.80	7.10
3	2013	32.49	289.99	425.71	0.52
4	2016	29.09	186.49	240.64	7.11

Table 2: Average rainfall for the study area (Quarterly Average rainfall, mm)

quarters, for the year 2009 shows very low precipitation compared to other years. Low rainfall may be associated with dry weather in the region. This can partially explain the maximum number of forest fire incidence for the year 2009 (Fig. 3).

Weather information during summer season, particularly temperature variation was analyzed for the underlined years to get clear picture of the ground situation in the study area. The temperature values for 2009 are in higher ranges for all the summer months (except March, Table 3). The graphical representation shows the trend of high temperature throughout the summer season (Fig. 4). As high temperature can promote fire incidences in locality and forest, this may be the one of the major reasons causing maximum number of fire incidences in the year 2009 in STR following dry period with low precipitation (Fig. 3).

Groundtruthing

Groundtruthing was carried out to explore the unusual distribution of fire incidences in different locality of STR during the summer season. Also, it is required to look into vary causes of forest fire at ground level.

The year 2009 was the second most hot year of India with annual mean land surface air temperature of about 0.84 degree Celsius above the 1961-1990 average. This was in line with the warmer-than-normal global climate during the period. 2009 also recorded

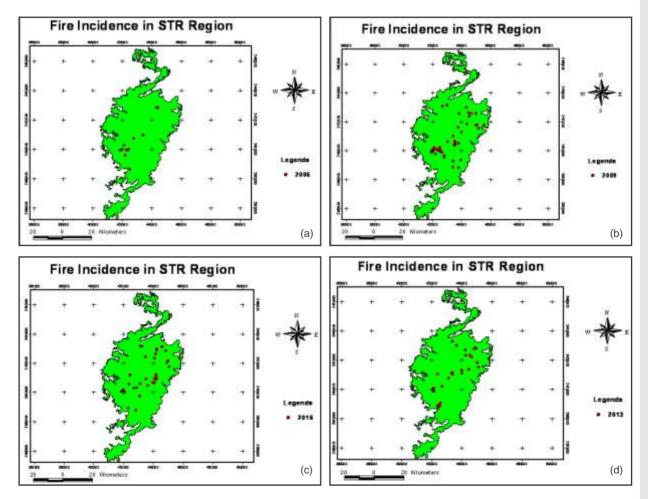


Fig. 3: Distribution of forest fire incidences in STR; a) 2006; b) 2009; c) 2013 d) 2016.



	March	April	Мау	June
2006	29.20	31.00	30.50	30.05
2009	28.90	32.10	32.55	31.15
2013	26.90	29.00	29.05	27.30
2016	26.50	31.10	31.50	30.85

Table 3: Temperature variation in summer seasons in the study area

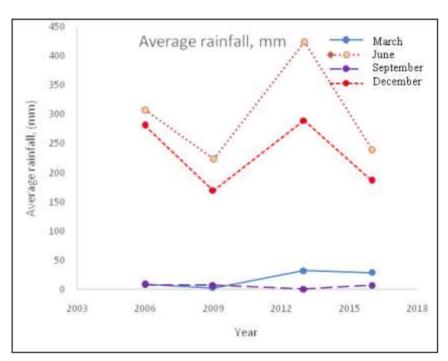


Fig. 4: Quarterly rainfall distribution for the region

the third-worst rainfall since 1901, behind 1918 when there was a 25% deficiency of the long-period average. 2009 was an El-Nino year and India faced severe drought with rainfall being 22% below the 50-year average.

Upper Barah Kamuda (UBK), located in the south central part of Similipal, the core of the Critical Tiger Habitat area is the wildlife rich area of the tiger reserve. The buffer area surrounding was drastically affected by forest fire in 2009, so the UBK range also got the maximum negative impact of forest fire. The anthropogenic fire lit by local poachers in search of herbivores during so called Akhand Shikarweek (week of mass hunting of animals) in the month of March-April 2009 is also another reason for forest fire. The massive naxalite attacks on Similipal in the month of March, 2009 resulted in catastrophic events like mass poaching of wild animals, forest fires, torching of camp sites which resulted in withdrawal of Forest field personnel, fire watchers from Similipal for more than 12 months. UBK range had 2 tribal hamlets i.e. UBK and Bahaghar during 2009, the primitive tribal populations of those two hamlets were also responsible for more of such fire incidents.

Similarly, the repercussions of Naxal attacks also hampered the forest fire management in other two

core ranges *i.e.* Jenabil and Nawana south. The villages like Jamuna, Bakua, Budhabalang, Saruda, Nigirdha having Particularly Vulnerable Tribal Groups (PVTGs) and other tribal groups took advantage of withdrawal of Forest personnel. Along with the extreme weather conditions of 2009 summer, these localized anthropogenic reasons resulted in massive forest fires.

Conclusion

Forest fire is a major environmental issue, creating economical and ecological damage, while endangering human lives. Similipal, Odisha is the only tiger reserve in the world, where the melanistic form of tiger is found and properly conserved.

Primary fire incidences data were collected from respective offices along with location co-ordinates considering prevailing weather conditions for four year, such as year 2006, 2009, 2013 and 2016. The forest fire incidences are mapped in Arc GIS 10.1 software environment. It shows unusual distribution of forest fire incidences in STR. The year 2009 has the maximum number of forest fire incidences (56 nos) in STR underlined by extremely hot weather and low precipitation condition. Groundtruthing in the STR

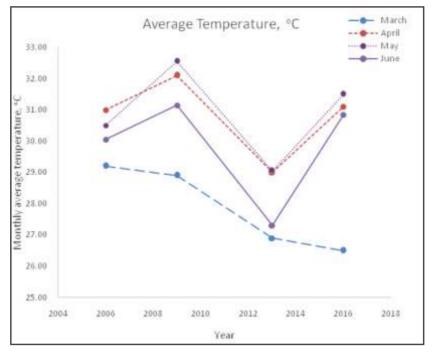


Fig. 5: Average summer temperature in the study area

shows disturbances due to anti-social activities in some patches of the area, limiting the scope for preventive measures, causes large number of forest fires. Forest fire created by local people associated with the presence of PVTGs also increased the number of incidences. Forest fire incidences can be reduced drastically with future planning and using modern technologies, such as drones quick assessment, and commercial helicopters for extinguishing the fire etc. under undulating topography and unfavourable climatic conditions.

सिमिलीपाल बाघ रिजर्व में जी.आई.एस. के साथ वनाग्नि की पहचान और मूल्यांकन

संजय कुमार स्वेन और किशोर चन्द्र स्वेन .

सांराश

वनाग्नि एक प्रमुख पर्यावरणीय विषय है, जो आर्थिक और पारिस्थितिकीय क्षति उत्पन्न कर रही है और साथ ही यह मानवीय जीव को संकट में डाल रही हैं। उड़ी़सा राज्य में स्थित सिमिलीपाल विश्व में अकेला ऐसा बाघ रिजर्व है, जहाँ श्यामता रूप का बाघ पाया जाता है और इसे उचित तरीके से संरक्षित किया गया है। इस शोध पत्र में चार सालों, यथा-2006, 2009, 2013 और 2016 के लिए स्टूरू संवेदी (आर.एस.) और जी.आई.एस. तकनीक का उपयोग करके सिमिलीपाल बाघ रिजर्व में वनाग्नि के प्रभावों को पहचान और मूल्यांकन का प्रयास किया गया है। वर्तमान मौसम अवस्थाओं के साथ स्थान समन्वयकों के साथ संबंधित मौसम विज्ञानीय कार्यालयों से प्राथमिक अग्नि प्रभावों से संबंधित आंकडे लिए गयें। वनाग्नि प्रभावों को आर्क जी.आई.एस. 10.1 सॉफ्टवेयर वातावरण में मानचित्रित किया गया। यह सिमिलीपाल बाघ रिजर्व में वनाग्नि प्रभावों की असामान्य वितरण को दर्शाता है। वर्ष 2009 में अत्यधिक गरम मौसम और निम्न वृष्टिपाल अवस्थाओं द्वारा अधोरेखांकित सिमिलीपाल बाघ रिजर्व में वनाग्नि प्रभावों की अधिकतम संख्या थी। सिमिलीपाल बाघ रिजर्व में धरातली सच्चाई क्षेत्र के कुछ खंडो़ में असामाजिक गतिविधियों के कारण विक्षोपों को दर्शाती है, जो बडे पैमाने पर वनाग्नियों के प्रभावों से उत्पन्न संरक्षात्मक उपायों के लिए अवसरों को सीमित कर देती है। विशेषकर संवेदी जनजातीय समूहों की उपस्थिति के साथ सम्बद्ध स्थानीय लोगों (मानव निर्मित) द्वारा सृजित वनाग्नि भी संख्या में बढ़ी है। सबसे प्रतिकूल जलवायवीय अवस्थाओं के अन्तर्गत आधुनिक प्रौद्योगिकियों का उपयोग करके और भावी योजना के साथ वनाग्नि प्रभावों को काफी हद तक घटाया जा सकता है।

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