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Drivers of Change – A Geospatial Study on Fires in Terai Grasslands of Manas Tiger Reserve and World Heritage Site, India

Abstract

The Terai region in the Indian subcontinent is regulated by annual floods and fires which also result in a permanence of a seral stage dominated by tall grasslands. Most of these grassland fires are historically of anthropogenic origin and have resulted in an interesting pattern of fire adapted species of wild flora and fauna. The last remaining habitats of the Terai grasslands are today confined within Protected Areas such as Manas Tiger Reserve, Assam, where this study assessed the temporal and spatial patterns of fire using historical MODIS satellite data. Results indicated that fire was a major driver of landscape dynamics and change within the Terai grasslands. A high concentration (over 63%) of the total incidents of fire was recorded within the core area (National Park) of the Tiger Reserve between 2000-2012, whereas the highest occurrences were recorded between December and March in a given year. The impacts of these annual fires on grassland composition, animal species behavior and the overall management issues have been discussed in the paper.

Key Words: Brahmapurta; Grasslands; Kaziraga National Park; Landscape dynamics; World Heritage site

Introduction

The Terai grasslands located in the flood plains of Ganges and Brahmaputra adjacent to Himalayan foot-hills are among the most productive terrestrial ecosystems in the world. Characterized by flood and fire adapted tall grasses usually >2 m in height, these grasslands support very high biomass of grazing ungulates (Seidensticker et.al., 2010; Plate 15.1). In India, these grasslands extend through the provinces of Uttarakhand, Uttar Pradesh, parts of Bihar, West Bengal and Assam. The area is characterized by heavy rainfall (1800-4000 mm), clayey soil and swamp lands. These grasslands are home to globally endangered species such as greater one-honed rhinoceros (*Rhinoceros unicornis*), Asiatic wild buffalo (Bubalus bubalis), Indian bison or gaur (*Bos gaurus*) and the Asiatic elephant (*Elephas maximus*). Besides, several endemic species adapted to grassland habitats are found in these areas, viz., hispid hare (*Caprolagus hispidus*), pygmy hog (*Porcula salvania*) and the Bengal florican (*Houbaropsis bengalensis*). The apex predator of this ecosystems, i.e., tiger (*Panthera tigris*) is distributed all across these grasslands and some of the well managed protected areas under Terai grasslands in the region such as Kaziranga National Park are known to support the highest densities in the world (Karanth et.al, 2004; Ahmed et.al., 2010) in places such as, India.

Most of the Terai grasslands in India overlap with regions of high human population growth. As a result, the remaining natural grasslands are under heavy anthropogenic pressures leading to fragmentation and degradation. These grasslands have evolved under recurrent fire and flood since millennia (Dabadghao and Shankarnarayan, 1973). These authors have classified the Terai grassland as of the *Phragmites- Saccharum- Imperata* community type. *Phragmites karka* dominates in an undisturbed state. Persistent burning and harvesting exposes the typically wet soil to desiccation, with result that *Saccharum spontaneum* and *Imperata cylindrica* eventually dominate. It has been observed that continued burning and grazing of *Saccharum* and *Imperata*, leads to grassland dominated by *Imperata*. Eventually fire also facilitates woody succession by removing heavy litter accumulation (Lehmkuhl 1989, Sarma et.al., 2008). Thus, frequency, size and intensity of fires, in particular, are such that these regulate the entire floodplain savannah grassland ecosystem in the Indian subcontinent (**Figure 15.1**).

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Figure 15.1 The broad extent of Terai (floodplain) grasslands in the Indian subcontinent

Ecological studies on the impacts of fire on Terai grasslands and associated faunal communities are rather limited (Lehmkuhl 1989). Based on a comprehensive research in Nepal, Peet et al., (1997) concluded that graminoids represent resilient group of plants which recolonize after fire treatment, and the richness of plant species increases slightly after burning these grasslands. Burning of grasslands during the early dry-season (also termed as controlled burning) has been recognized as the optimal method to prevent more serious consequences by wildfire. Wildlife managers, use control burning for two main reasons: to manage the build-up of flammable fuel (live and dead vegetation), consequently reducing the impact and difficulty of suppression of wildfires, and to increase grazing lands for large herbivores in aid of the park's biodiversity and other environmental values. However, the evidence to support this is equivocal, and has shown varying results (Andersen et al., 2005).

Manas Tiger Reserve (MTR; 26°30'N to 26° 45' N latitudes and 89° 45' E to 92° 30' E longitudes), located in the districts of Kokrajhar, Chirang, Buxa and Udalguri in north-west Assam represents one of the prime grassland habitats in India. It forms a contiguous boundary with Royal Manas National Park of Bhutan in the north, while to the west, it is separated from the Buxa Tiger Reserve of West Bengal by the River Sankosh. The Reserve has a total area of 2837.31 sq km out of which 526.22 sq km is the core and 2310.88 sq km is buffer area respectively **(Figure 15.2)**. It reserve has a unique distinction of being a Natural World Heritage Site, a Tiger Reserve, an Elephant Reserve, Biosphere Reserve and Important Bird Area. Evolutionarily, it is the entry point of tigers into India and combined with Buxa-Nameri-Pakke-Namdapha TRs and Protected areas in Bhutan and Myanmar and forms the single largest tiger conservation landscape for tiger in the world (Sanderson et al., 2006).

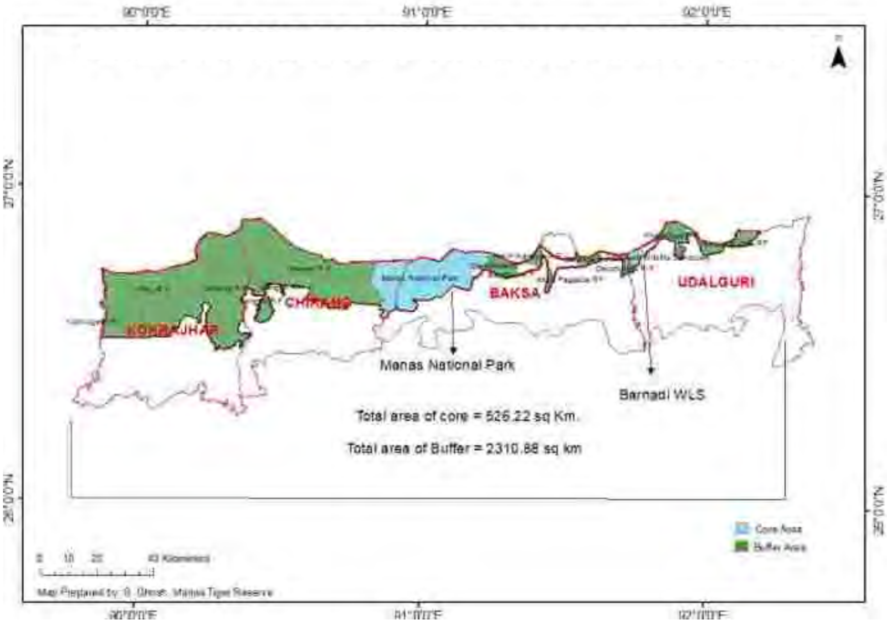


Figure 15.2 Map showing the extent of Manas Tiger Reserve in Assam, India.

According to Champion & Seth (1968), six subtypes of forests occur in the Reserve

- Sub-Himalayan light Alluvial semi-evergreen Forests
- Eastern Bhabhar type Sal (*Shorea robusta*) forest
- East Himalayan moist mixed and dry deciduous forests
- Low alluvial savannah woodlands
- Assam valley semi-evergreen forests
- Eastern wet alluvial grasslands (Terai Forests)

A total of 43 different grass species have been reported with a preponderance of species such as *Imperata cylindrica, Saccharum naranga, Phragmites karka* and *Arundo donax*. There is also a variety of tree and shrub species such as *Dillenia pentagyna* (which dominates the swamp forest), silk cotton Bombax ceiba (a dominant of the savanna woodland), *Phyllanthus emblica*, and shrub species of *Clerodendrum, Leea, Grewia, Premna, Mussaenda, Sonchus, Osbekia* and *Blumeria*. A wide variety of aquatic flora occur along river banks and in the numerous pools some 374 species of dicotyledons, including 89 trees, 139 species of monocotyledons including 43 species of grass, and 15 species of orchid have been identified from the core of the Reserve (Hajra and Jain 1976).

Broadly, the grasslands of MTR are divisible into two types: (i) Low alluvial savanna woodland and (ii) the semi-evergreen alluvial grassland. These are created and maintained by burning, and on a smaller scale, by flooding and grazing animals. The riparian grasslands are the best tiger habitat and also well suited to the Asiatic water buffalo, gaur, swamp deer, elephant and waterbirds (Ghosh 2009). Since both types of grasslands exhibit differential response to fire and other factors, it was pertinent to investigate the dynamics of vegetation at a landscape level. Therefore a study was conducted during 2010 -2013 (Ghosh, 2013) with the following questions in mind:

- How are fires, spatially dispersed within MTR? Are there any areas of high intensity and what causes these?
- What are the spatial and temporal patterns in fires and in what way can they be studied using RS data?
- How does fire influence landscape dynamics and vice versa. Do fires get impacted by anthropogenic sources such as proximity to roads and settlements?

This paper deals with the broad findings based on rapid assessment of grassland habitats using combination of field investigation and remote sensing tools.

Material and Methods

Obtaining the Fire data

Initially, the spatial and temporal patterns of fires within MTR were analyzed over a period of 12 years **(Figure 15.3)**. MODIS active fire data between 2000 to 2012 was downloaded from FIRMS at their website, http://earthdata.nasa.gov/data/near-real-time-data/firms. The dataset downloaded comprised of daily fire observations acquired from the Aqua and Terra satellites. Each overpasses the study area a total of four times daily. Each fire point contained information on the exact time and day of detection, a global georeference system location (longitude, latitude), the brightness of the fire and classified confidence level.

Methods of fire analysis

Temporal patterns -Temporal changes in fire frequency were investigated on a monthly and yearly basis for dry seasons (October-May) from 2000 to 2012. Monthly changes were studied for each season as well as for the twelve seasons combined. For correlations with landcover, the total incidence of fire during the study period was extracted for the four types of landcover (Dense Forest, Open Forest, Grasslands and Wetlands) described above, and fire density calculated as the number of fires per km^2 of the total land cover area. Fire occurrence and density in each land cover type were also obtained for three distinct periods of the dry season viz. early (October–December); mid (January–February), and late (March–May).

Spatial patterns- The effect of distance from roads, rivers, campsites as surrogates of anthropogenic influences within MTR (and therefore increasing the probability of ignition), were used to correlate with fire distribution. Using these line and point vector layers, the minimum distance from a line/ point buffer to the nearest fire point was calculated using ARC GIS software. To investigate the relationship between fire occurrence and distance from each geographical feature, multiple ring buffers (at every 500 m) around each point and line vector layer (Road, water body, settlements and forest camps) was created and the fire frequency counted for each interval to obtain a set of response and explanatory variables; fire frequency and distance, respectively. Each fire point was measured from closest point of line geographical features in meters. The dataset was then analyzed by regression, using a simple linear Regression model. The statistical software MINITAB 15 and MS Excel was used for the analysis.

Fire in relation to bioclimatic variables- To investigate whether rainfall and annual temperature was a factor in predicting fires, the mean annual temperature and mean annual precipitation was obtained from Worldclim that provided free global climate data on a spatial domain (http://www.worldclim.org/bioclim; Hijmans et.al., 2005). The data is provided under BIOCLIM model and has been generated through interpolation of average monthly climate data between 1960-90 periods from global weather stations on a 30 arc-second resolution grid (1 km^2 pixel resolution). Variables included are monthly total precipitation, and monthly mean, minimum and maximum temperature, and 19 derived bioclimatic variables.

Detecting fire intensive areas- To identify areas within MTR that have a high concentration of fire occurrence and evaluate fire distribution patterns at a landscape level, all active fire data were combined together into one layer and converted into a raster dataset for density analysis using a kernel density estimation tool in Arc GIS. Spatial distribution of the fire points collected during all eleven years were modelled as density "kernel" functions which weights frequency of location based on 2-dimensional Gaussian distribution, with the density represented as contour plots on a surface.

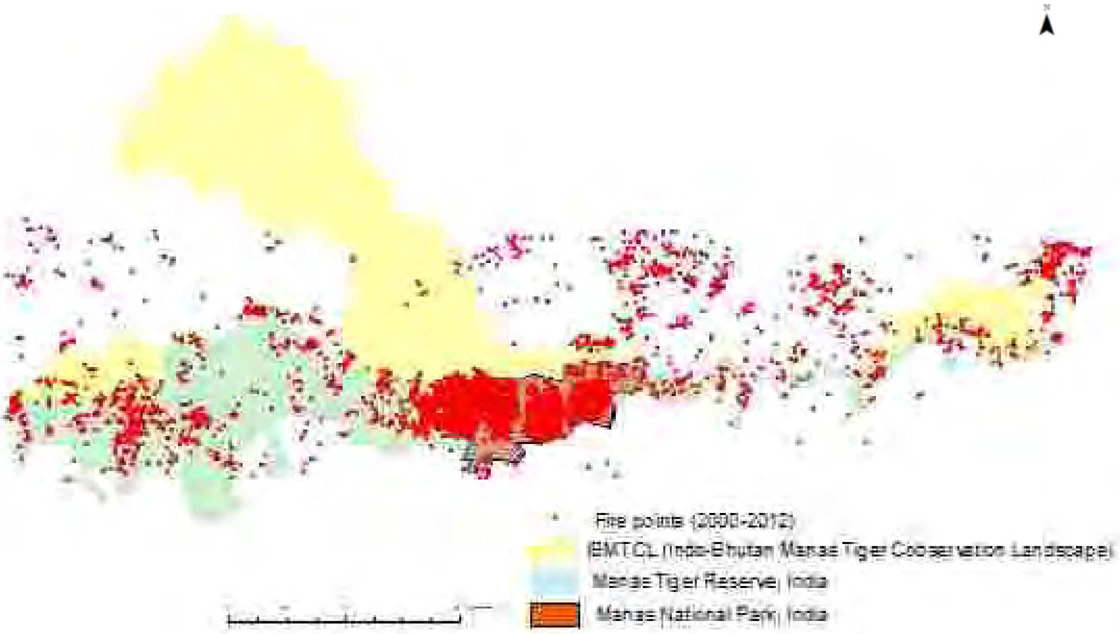


Figure 15.3 Spatial distribution of fires as detected by MODIS between Nov 2000-June 2012.

Results

A total of 2751 fire incidents at 1 km^2 pixel resolution were detected by MODIS in MTR from December 2000 to August 2012 **(Figure 15.4)** . Out of these, 1749 fires (63.57% of the total fires) were within Manas National Park. Almost no fire was detected during the very wet season that ranged from June to September. 71 % of total fires occurred during the mid (January-March) burning season, whereas the late (April-September) burning season accounted for only 2% of the total fires. The highest fire incidents were in the month of March and there was a significant correlation between fire occurrence and distance from roads in MTR. For MNP, Three distinct intensively burnt areas were identified that corresponded with grasslands and wetlands in the MNP.

Temporal patterns of fires

The total yearly number of fires recorded within the MTR increased substantially from around 5 at the start of the study period (Dec 2000) to over 300 in 2004 **(Figure 15.5)**. There was a large inter-annual variation in monthly patterns of fire occurrence; the highest recorded in 2011 (394) during which highest monthly fires were recorded in December (102). The patterns clearly indicated that 2002, 2004 and 2011 were exceptionally dry years when high incidents of fires were recorded. The transitional period before and after the monsoon season (the first and the last two months of the-dry season) experienced fewer fires. The common pattern of fire occurrence was a distinct increase from December to January after a low during October-November, with the number of fires declining after February and dropping even

further from April to May. December-March had the highest frequencies of fire and accounted for bulk of the fire occurrences.

Fires also have a strong correlation to land cover as is evident from **(Figure 15.5)**. The temporal distribution of fires expressed as proportions of fire frequencies during the early, mid- and late periods varied greatly among the land cover types. For example, fire frequency in wetlands and grasslands was highest in the mid- season (Jan-Feb), whereas in case of dense forest and open forest it was the late and early burning season respectively **(Figure 15.6 & 15.7)**. The likely explanation for this is that the grasses growing in water bodies and the grasslands region mature and reach senescence possibly between January and February. The open forest areas are covered with scrub which is likely to be intentionally burnt at the onset of the winter season by cattle graziers to provide fresh fodder to livestock during the lean and dry period. The dense forests are semi-evergreen and hence are prone to fires only when there are excessive dry conditions during the late burning season.

Figure 15.4 Temporal distriution of Fires as detected by MODIS between Nov 2000-June 2012

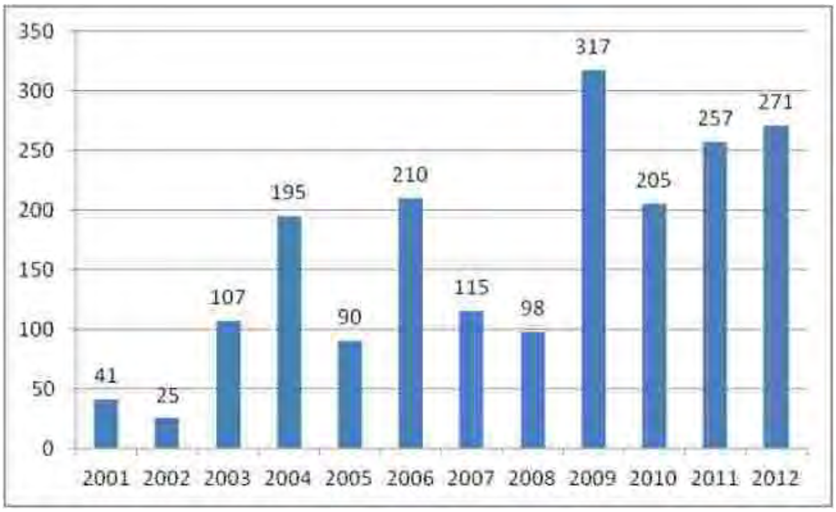


Figure 15.5 Annual Fires in relation to land cover in Manas Tiger Reserve

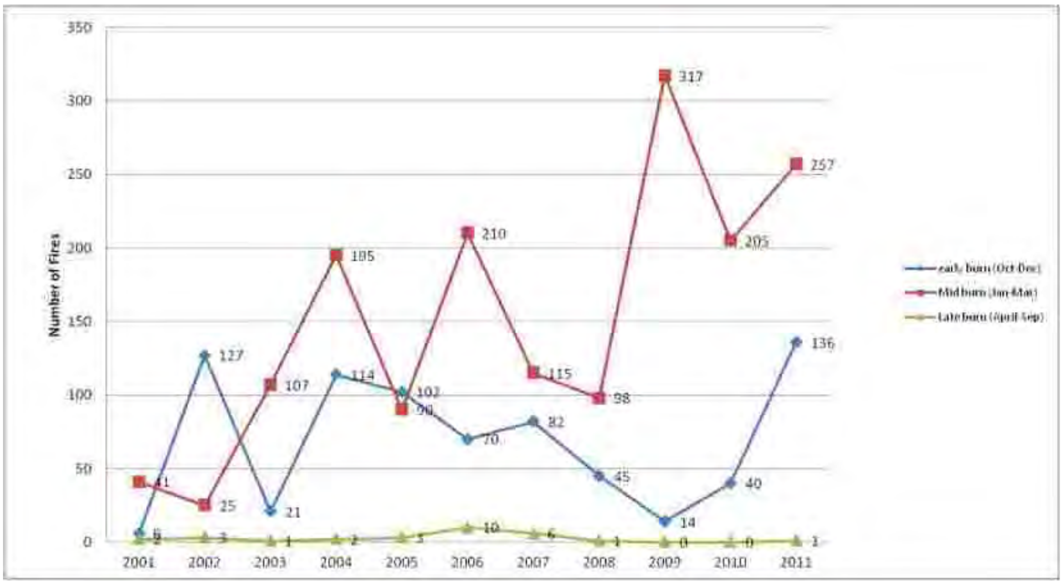
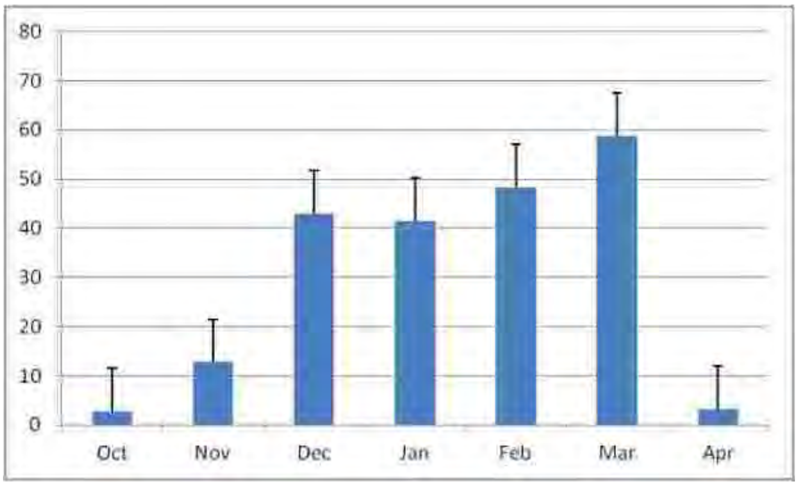


Figure 15.6 Temporal patterns of early, mid and late fires within Manas Tiger Reserve



	Oct	Nov	Dec	Jan	Feb	Mar	Apr
Mean	2.92	12.77	42.92	41.46	48.38	58.69	3.31
SE	0.99	3.99	10.74	8.31	10.45	18.47	2.21

Figure 15.7 Mean and (1 standard error) of monthly fire records in MTR from 2000 to 2012.

More than half of the total land area in the MTR is covered with closed canopy dense forest and they reported the highest incidents of fire (42%) but the lowest density of fire at 0.64/ km^2. Whereas, grasslands occupied only 15.05% of the total area but accounted for the highest density of fires (at 5.13/km^2) even wetlands had highest density of fires compared to dense forests indicating the presence of dry and combustible grassland areas in the river islands. Open forests also had high incidents of fires clearly indicating the anthropogenic influence of fire origins. There was also a difference in the number of fires reported per month in each land-cover type. The means of fires reported varied as 8.7 ± 4.25 fires per month in dense forests, but was more regular in grasslands, open forest and wetlands. Overall, highest incidents of fires were in the month of March making it a critical period for fire-protection.

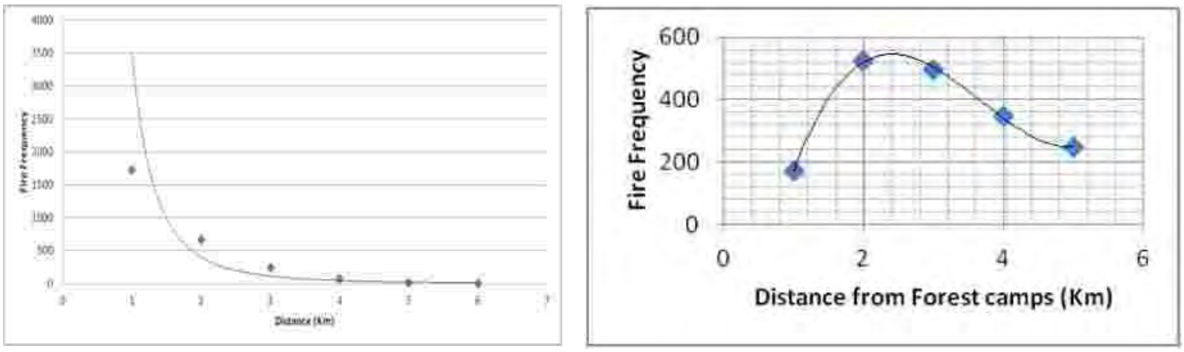
Spatial patterns of Fire

Fires were greatly influenced by distance from anthropogenic influences within the Tiger Reserve. There were statistically significant ($p<0.05$) correlations between fires and distances to some of the geological features. The closest fit between the observed and predicted fire frequencies was found for the fire- road and wetland-fire datasets .

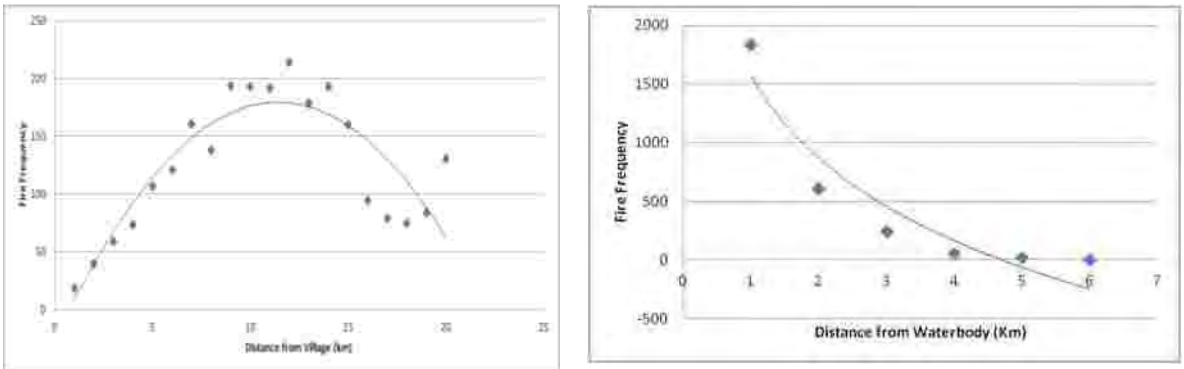
Fires were inversely correlated with roads and waterbodies and the highest frequency was detected within one km of the variable. Roads are known to be a major cause of wildlife incidents worldwide and the prime reason for this is the human presence and the accidental/ deliberate firing of dry areas in the vicinity for utility purposes.

In case of waterbodies, the river islands and sand banks support grasslands of fodder value and it is likely that they are also burnt for livestock in the winter season. No significant relationship was found between fires and villages although the trend line indicates that, large uncontrolled fires are often encouraged within 5-10 kms of a village. This way, the free ranging livestock is able to easily access new fodder and yet be confined as when required.

Fire incidents were reduced closest to the vigilance camps put up by the forest department. However, they increased with distance from camps before gradually declining in areas where possibly there was no human presence (**Figure 15.8**).



Distance from roads **Distance from forest camps**



Distance from villages **Distance from water bodies**

Figure 8 Spatial Distribution of fires with respect to anthropogenic variables in Manas Tiger Reserve

Fire in relation to Bioclimatic variables

The mean annual temperature in the fire areas was found to be in the range of 23.6 - 24.5 degree Celsius. Highest number of fires was recorded at 24.3 degrees although no statistical correlation could be established.

The mean annual rainfall in the fire areas was found to be between 3003 - 3485 mm. The number of fires were highest at 3251 mm, although again no statistically significant relationship could be found. The average rainfall of the area in the past 8 years indicates that excessive dry conditions do influence higher incidents of fire in the park. For example, the highest incidents of fires (N= 271) was recorded for 2011 which was also comparatively a dry year (< 2675 mm).

Detecting Fire intensive areas

The fire density map **(Figure 9)** for MTR indicates that fire locations were not evenly or randomly distributed throughout the Reserve. In fact, fire was concentrated (over 63%) within MNP where four distinct areas of heavy burning could be located. The largest concentration was located along the western part of the park under Panbari range, while the others were spread across the grasslands along Manas-Beki rivers and low lying grassland areas of Bansbari and Bhuyanpara ranges. Almost all the forest fragments on the eastern side of the Reserve in Barnadi Wildlife Sanctuary, Dhansiri and Udalguri forest divisions were influenced by medium occurrences of fire. Incidents of fire along the Bhutan border in Kachugaon and Haltugaon forest divisions were also low as these were largely covered with dry deciduous and semi-evergreen forest types. Such high concentration of fire within 300 sq km of the reserve clearly indicates the impact of fire on regulating the landscape dynamics.

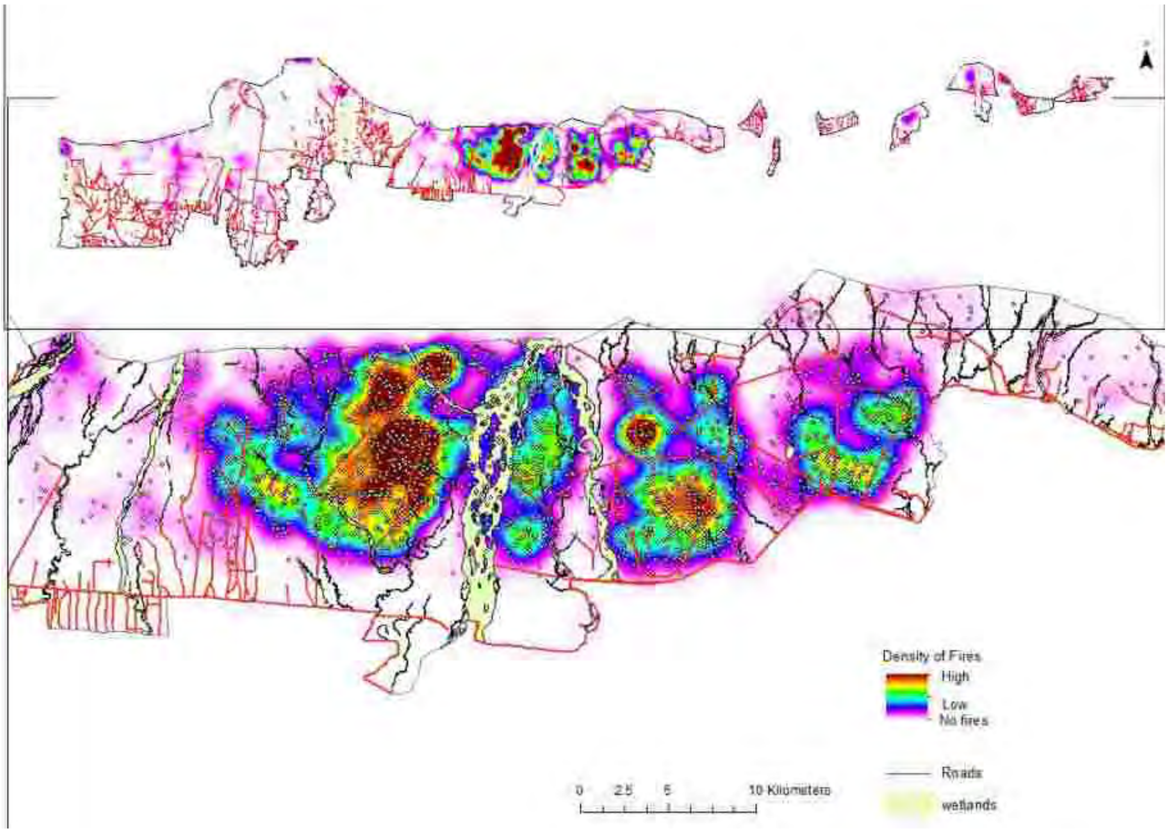


Figure 15.9 Density of fire occurrence in MTR during 2000-2012

Discussion

Although active fire data from MODIS has been claimed as a 'snap-shot measurement, it is a practical tool that can be used to identify areas at risk of fires by giving park managers information about where uncontrolled burning takes place.

There are however a few limitation of remote sensing for fire detection in the tropics, as it was observed during this study. The major issue is in the use of derived products and the associated incidence of omission errors (Eva and Lambin 1998). Oversight of fires can be likely if the duration of a fire was shorter than six hours, since fire observations are made four times a day from the Terra AM (10:30 and 22:30). Similarly, small scale (< 500 m^2) fires as in the case of shifting cultivation may not be detected or flagged by the coarse resolution of the MODIS sensor (Roy and Behera, 2005). *Jhum* or shifting cultivation is prominent and quite common in the Bhutan forest areas; however they were not detected in the present study. In a survey to test fire detectability by MODIS, Jin et al., (2003) recorded twice as many fires on the ground as were registered by MODIS. Whether this is the case for the data gathered for the Manas National Park (MNP) will need to be established.

Another major limitation in the study was the lack of information on the size of fire-affected areas essential to estimate fire impact on vegetation or landscape changes. This would have ultimately effected the animal movement and some supplemental research has been undertaken through the detection of burn scars using higher resolution radiometers, such as AVHRR and ASTER (Eva & Lambin 1998). Despite this limitation, MODIS active fire data has been most useful in identifying temporal patterns of burning in the MTR, and for detecting seasonal and yearly variation in the number of fires.

Landscapes in the MTR were classified broadly for this analysis, as more refined analyses of variation within habitats (e.g. different grasslands classified by height or composition) was not possible. However, results from this study clearly showed that most fires occurred in grassland areas. Moreover, distance analyses reveal that most fires occurred closest to roads, and waterbodies. Yearly changes in the number of fires in the Reserve indicated that a significantly higher number of fires were recorded during 2002-2003. Before this period (since 1989), the park was inaccessible to local people due to political insurgency. On the other hand, because the fire records used in this study could not discriminate between controlled and uncontrolled burning, it is also possible to assume that the increase in fires reflects the use of prescribed fires started by park staff. The detection of illegal burning within the park would be possible, only if records of prearranged fires (including time and exact location) were kept by park staff, to contrast with data supplied by MODIS.

Conclusion

The present study clearly indicates that fire is a major driver of landscape dynamics and change within Terai grasslands. Their high concentration (over 63%) as in case of a small core area of 500 sq. km in Manas National Park also indicates the co- evolution of fire-climax vegetation types that are periodically regulated by fires on an annual basis. This fire-climax vegetation mainly comprises of tall and short grasslands associations as have been reported by field studies earlier (Lahkar, 2008). Such tall and short grasslands are true representative of the Terai region and have been mostly converted to agriculture elsewhere. It is only in Protected Areas that they are able to exist as patchy fragments albeit in a natural state, and hence of high conservation value. These grasslands are regulated by fires in the dry season and floods during the wet season thereby making them highly productive throughout the year. This also attracts a large number of herbivore prey that in turn supports large carnivores such as tigers. Therefore protection and management of such fire-intensive areas will be critical for survival of tigers and other large carnivores in the area.

The highest occurrences of fires were recorded between December and March indicating this being the crucial season for fire management. Fires were triggered by anthropogenic sources such as roads and they are in all likelihood for deliberate reasons such as improved access and for grazing by livestock. Fires also occur in the wetland areas indicating the seasonal nature of these water bodies. A very dry season combined with draught can perhaps lead to water scarcity and therefore suggests the need to build and manage permanent waterholes in areas where highest number of fires are periodically recorded. In areas outside the National Park, fires are also along roads and in the vicinity of human settlements. Law enforcement and vigilance during the fire season has found to be very effective in controlling accidental fires and it is in this case that remote sensing can aid in forest protection measures.

Plate 15.1 A Rhino in the *Saccharum* grassland © Karma C. Bhutia

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