



## Incidences of wildfire hazard and its effects on forest cover change in Chitwan National Park, Nepal.

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### Abstract

Forest fire is one of the major drivers of forest cover change which can be devastating and frequently causes loss of property and human life. Landsat imageries of 2013 early February (before fire) and April, 2013 (after fire) were used to analyze, interpret and quantify the effect of fire on forest cover changes in Chitwan National Park, Nepal. Semi-structured questionnaires survey and focused group discussions has been carried out to collect the perceptions of respondents regarding the causes and consequences of wildfire. Satellite image analysis showed that 1.33 percent of forest cover is decreased due the fire occurred in between February and April 2013. Most of the fires evidences occurred deliberately by the local peoples to collect 'KharKhadai' (*Saccharum* spp.) while other causes are accidental and carelessness as responded form the local people. Majority of respondents (43%) believed that loss of biodiversity was the major consequences of wildfire.

**Keywords:** Wildfire; Forest Cover Change; Chitwan National Park; Landsat Image; deliberate

### 1. Managerial and policy implication

Keeping records and maintaining proper data base system regarding control fire and determining actual burnt area as well as identifying factors responsible for fire incidences is most essential to reduce wildfire hazard and manage the grasslands in controlled manner. Similar techniques can be applied to monitor and maintain database regarding the wildfire hazard, detecting forest cover change and associating causes and consequences. Legal instruments relating to fire prevention and control regarding Forest Fire Management Strategy, 2010 should be strengthened and effectively followed and existing human resources with local users should be trained and mobilized in fire prevention and controlling activities. Re-occurrences of the forest cover after monsoon is sure in non forest area and we cannot forget the fact that there should be recovery potential of forest once it was destroyed by fire. In this study it was excluded due to the limitation of time. At least 5 years time period is required to detect the recovery potentiality of forest by which we can generalized the loss and

recovery trends of forest cover change due to wildfire.

### 2. Introduction

Forests cover 31% of total land area of the earth; the world's total forest area is just over 14 billion ha, which corresponds to average of 0.6 ha per capita. The rate of deforestation shows sign of decrease, but are still alarmingly high: Around 1.3 million ha of forest were converted to other uses or lost through natural causes each year in the last decade compared with 16 million ha per year in 1990s (FAO, 1998). Legally established protected areas cover an estimate of 13 percent of the world's forests: The area of forest within a protected area system has increased by 94 million hectares since 1990. Two thirds of this increase has been since 2000. Forest Fire is severely underreported at global level: Forestfires can be devastating and also frequently cause loss of property and human life. Nepal's forests have faced and continue to face threats from deforestation and degradation. This has accelerated the rate of land cover change. For example, from the 1970s to the 1990s,

degradation of forestland into shrub land was occurring at a rate of 5.5% per year (Acharya and Dangi 2009), with deforestation for agriculture progressing at 1.3% per year (Rothermel 1972). As mentioned, wildfire predominantly occurs within Terai region, with districts such as Chitwan, Nawalparasi and Palpa particularly badly affected (ICIMOD 2010).

Forest cover change due to wildfire and peoples' perceptions about consequences of wildfires in CNP were needed to be explored because this is the fire prone area, oldest National Park of Nepal and rich in bio-diversity (DNPWC, 2011). To achieve this requirements, Satellite data have been used to monitor biomass burning at regional to global scale for more than two decades using algorithms that detect the location of active fires at the time of satellite overpass, and in the last decade using burned area mapping algorithms that map directly the spatial extent of the areas affected by fires. The National Aeronautics and Space Administration (NASA) Moderate Resolution Imaging Spectro-radiometer (MODIS) on the Terra (morning) and Aqua (afternoon) satellites has specific features for fire

monitoring and has been used to systematically generate a suite of global MODIS land products (Justice *et al.*, 2002) including a 1 km active fire product (Kaufman *et al.* 1996; Giglio *et al.*, 2003) and more recently a burned area product that maps the approximate day and extent of burning at 500 m resolution (Roy *et al.*, 2005).

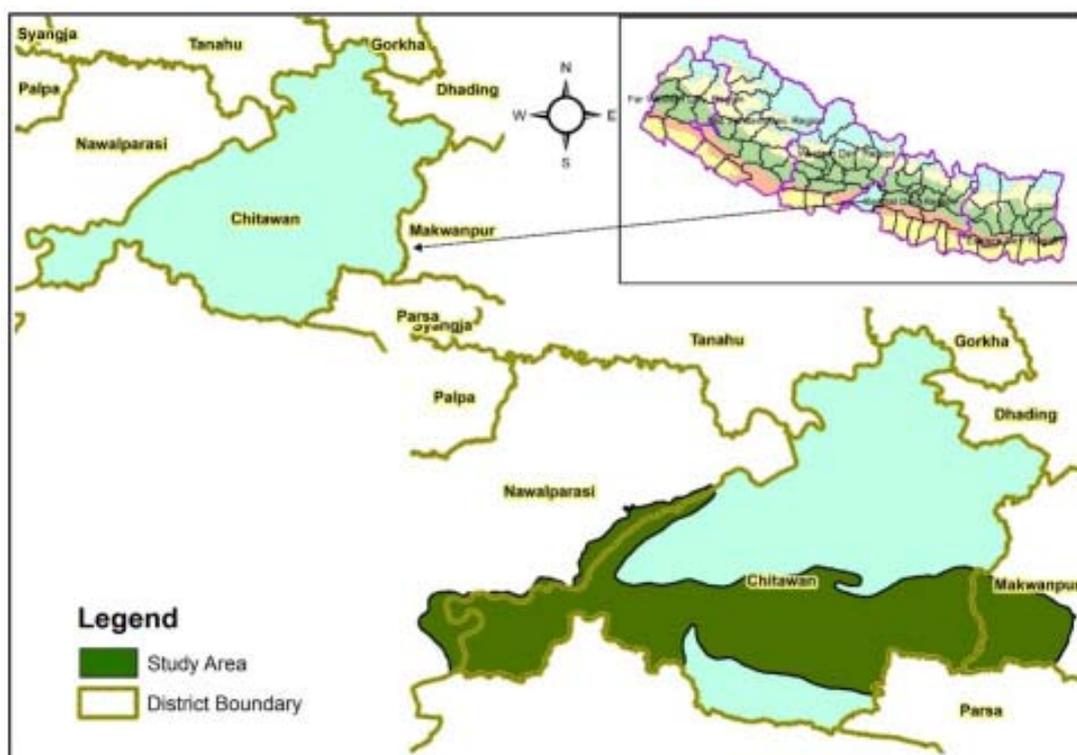
### 3. Materials and methods

#### 3.1 Study area

Chitwan National Park was established in 1973 which is included in the World Heritage site in 1984, situated in lowland of inner Terai central region of Nepal. It covers an area of 932 km<sup>2</sup> and lies between 27°16'23.63" - 27°42'28.42" Latitudes and 84°50'13.83" - 84°46'152.2" Longitudes. The Chitwan valley consists of tropical and subtropical forests. *Shorea robusta* (Sal) covers 70 percent of the park area and the remaining 20 and 10 percent is covered by grassland and other lands respectively. There are more than 50 species of grasses, including elephant grass (*Saccharum* spp.) renowned for its immense height.

**Table 1:** Summary of respondent perception according to gender and distance category

Chi-Square Table					
Gender perception of causes of wildfire in Chitwan National Park					
	Value	d.f.	Asymp.sig (2-sided)	Category	
Pearson Chi-square	5.617a	3	0.132	Male	Female
No. of valid cases	83				
Distance wise people's perception of causes of wildfire in Chitwan National Park					
	Value	d.f.	Asymp.sig (2-sided)	Category	
Pearson Chi-square	0.257a	3	0.968	Distant	Neighbors
No. of valid cases	83				
Gender perception of consequences of wildfire in Chitwan National Park					
	Value	d.f.	Asymp.sig (2-sided)	Category	
Pearson Chi-square	1.431a	3	0.698	Male	Female
No. of valid cases	83				
Distance wise people's perception on consequences of wildfire in Chitwan National Park					
	Value	d.f.	Asymp.sig (2-sided)	Category	
Pearson Chi-square	3.122a	3	0.373	Distant	Neighbors
No. of valid cases	83				



**Fig 1:** Study area (Chitwan National Park)

The park is home to 68 species of mammals, 544 species of birds, 56 species of herpeto-fauna and 126 species of fishes (DNPWC, 2011).

### 3.2 Data collection

#### MODIS fire data

MODIS fire data description and pre-processing MODIS fire hot spots data (thermal anomalies/fire 8-day L3 global 1 km sin grid v005) were obtained from Warehouse Inventory Search Tool (WIST). The yearly fire dataset consists of 46 data tiles for both Terra and Aqua satellites. Data tiles were acquired for before fire season (January/February) and after fire season (April/May) from the Fire Information and Resource Monitoring System (FIRMS) website.

### 4. Landsat image for forest covers change detection

Two Landsat “browsing picture” February 2013 (before fire season) and April 2013 (after fire season) with 30 m pixel size; sub set (bands 1, 2, 3, 4, 5 and 7) were downloaded from the United States Geological Survey (USGS) website. Vector files are used to locate the study area and to analyze the forest cover change of Chitwan National Park (CNP) of central inner Terai, Nepal.

### 4.1 Training sample

Seven Global Positioning System (GPS) locations of each land use classes were collected as ground control points for accurate image classification. Thus, altogether 35 GPS observations were measured for 5 land cover classes.

### 4.2 Focus group/ key informants survey

Semi-structured questionnaire survey was conducted with the group members of the buffer zone user groups, nearby users and other related authority to communicate with one another, exchange ideas and comments on each other’s experiences or point of views about the major driving forces for wildfire and its consequences on forests and society. Focused group representing major stakeholders of the study area were randomly selected and discussed separately using the same parameters of preference ranking to conclude about the issues regarding driving force of wildfire and to determine its causes and consequences.

## 5 Data analysis

### 5.1 Fire frequency determination and hazard mapping

MODIS fire hot spots data was fed to Geographic Information System (GIS) format using Quantum GIS

(1.7.4). Raster data have been converted to vector points with an attribute table containing the grid values (x-coordinate, y-coordinate and the fire mask value). Each MODIS hotspot/active fire location represents the center of a 500 m pixel, flagged as containing one or more actively burning hotspots within that pixel. The hotspot fires are detected using data from the MODIS instrument, on board NASA's Aqua and Terra Satellites using a specific fire detection algorithm that makes use of the thermal band detection characteristics of the sensor. Fire spots detected more than 30% confidence level was only included for further analysis and mapping.

## 5.2 Landsat image analysis and interpretation

Vector files located in the study area was used to clip the satellite image by area of interest and to analyze and calculate the forest cover change of CNP of central inner Terai, Nepal. Landsat Thematic Mapper (TM) of February 2013 and April 2013 were loaded in ERDAS Imagine software as a raster layer and 7 bands were stacked together while the vector layer of study area was added in Quantum GIS (QGIS) for further analysis. After visualizing the Landsat of February 2013 satellite image, it was changed to raster layer Red Green Blue (RGB) color as Red band = band 4; Green band = band 3; and Blue band = band 2 and from the combo box we have selected Min/Max and also followed the same procedure to visualize Landsat image of April 2013. Then, coordinate properties were extracted to find the right CRS (WGS 1984 UTM45N) for the study area. Next task was to include Geographic Resource Analysis Support System (GRASS) software, in Quantum GIS. The fire data was then imported to GIS software and joined to a polygon layer with study area.

## 6. Change detection

Forest cover change was analyzed on spatial analyst extension in QGIS comparing the consecutive image of two different times. We stepped to GRASS GIS TclTk integration and created image groups. GRASS GIS was used as not all the GRASS GIS functions can be seen in QGIS GRASS toolbox. So, it needs to create so called image group in GRASS before it is possible to make satellite image classification and this function (i.group) was unfortunately lacking from Quantum GIS GRASS toolbox module list. GRASS GIS TclTk version 6.4 was used again to open a stand-alone version of GRASS GIS version 6.4.0 svn. Then, it was necessary

to create separate map set and enter into GRASS GIS from where the menu create edit group and add all the image bands of February 2013 and again back to i.group to do the similar procedure for image of April 2013. After that, GRASS GIS and unsupervised classification of satellite images were clustered. Both images have been clustered and made possible to make Maximum Likelihood Classification (MLC). The algorithm clustered 6 band Landsat images to spectrally equal group and in the output layer there we could see 15 groups as we have defined in i.cluster module. Image classification procedures for each season were carried out. Once spatial clusters were generated, we interpreted and determined the nature of the clusters and provided a classification rule as 1 and 13 thru 15 = 1 forest and 2 thru 12 = 2 non forest) for February image and 1 thru 3 = 3 forest and 4 thru 15 = 4 non forest) for the image of April. Then, visualizing MLC images in GRASS GIS was carried out. Image clearly showed that how the clustering operation was able to define the different land cover types as the signatures deviated from more homogeneous spectral signature information. According to the spectral reflection each pixel in the image has been classified to a value ranging from 1 to 15 and they have a specific color. They have been inspected by using query tool. Further the raster image was converted into vector to calculate the forest and non-forest area using the grass module where we can find report and statistics and option to choose 'calculate raster to vector area'. Areacalculation in different units can be obtained in few minutes by using these tools and thus area in square kilometers, ha and percentage was calculated. With the help of forest and non-forest data of two consecutive scenes charts and figures of the forest cover change of the study area has been prepared and displayed.

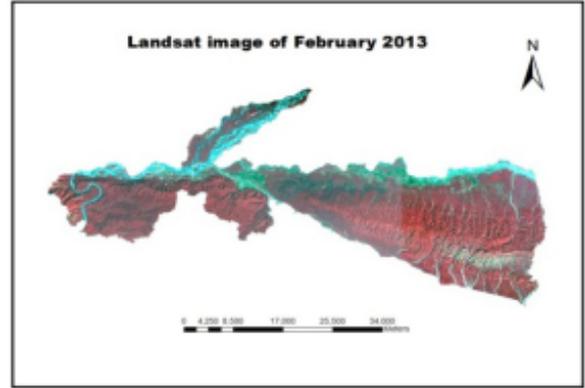
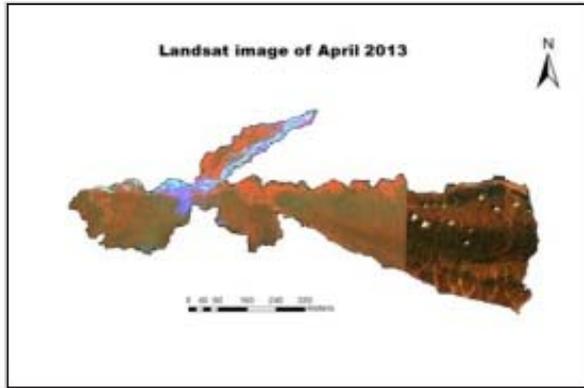
## 7. Results and discussions

### 7.1 Forest cover change detection

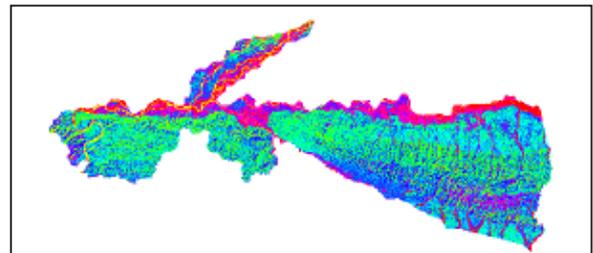
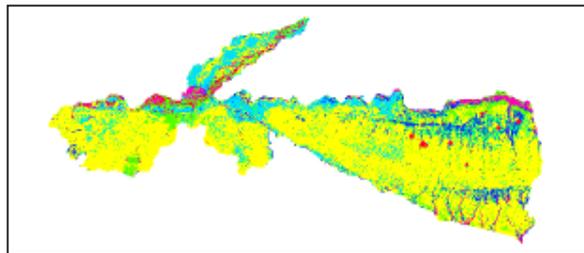
Forest cover change was analyzed on spatial analyst extension in QGIS comparing the consecutive image of two different times. Next stepped to GRASS GIS TclTk integration and creating image groups from the available satellite images of the study area fig (4&5). We used GRASS GIS as not all the GRASS GIS functions can be seen in Quantum GIS GRASS toolbox. Image group was generated by combining all bands and made a composite band image. After creating image groups it is possible to proceed to image clustering. First task done for image clustering is to fix the number of classes to make easy understanding of

the features of the study area. Mosaicked and clipped satellite images were presented below in fig (2 and 3).

Clustered image of the study area was shown in fig (4 & 5).



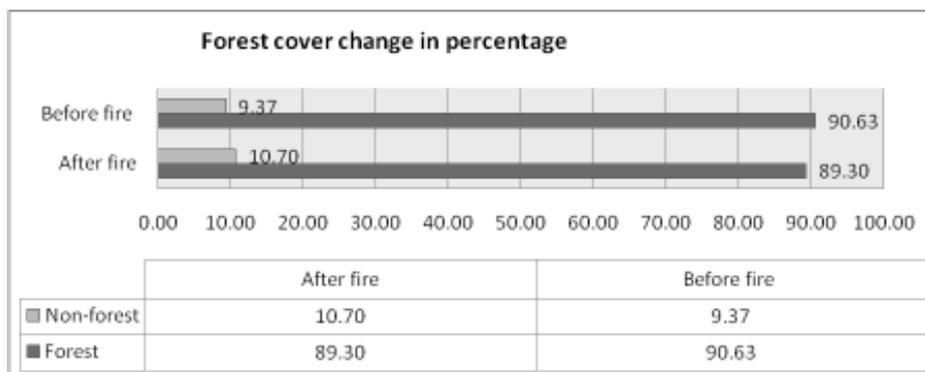
**Fig. 2&3 :** Clipped satellite image of the study area for February and April 2013.



**Fig. 4&5 :** Visualizing unsupervised classification clustered map of Feb and April 2013 layer in GRASS GIS.

After preparing the clustered map new reclassified maps are produced. These maps are limited to show forest and non-forest map of the study area of two different times. The total land area of study area was 121203.84 ha. Among this land area, 109847.04 ha was detected as forest land and rest of the land 11356.79 ha as non-forest area before fire season *i.e.* on early February 2013. Within the period of four months forest cover in CNP changed significantly. Similarly, forest cover after fire season *i.e.* in late April 2013 was 108235.02 hectares and non-forest area detected was 12968.82 ha. Forest covers before fire season was 90.37 % but within four months period on late April 2013 it was limited to 89.30 %. An

overall change between before and after fire season was decreased by 1.33% in total forested areas. Total of 1612.98ha forest cover was converted into non-forest area after fire season. Thus, it can be said that the forest loss is the effect of fire as there was no any other natural calamities, fungal and viral infection, insects attacked and any other deforestation activities reported on the area during that time period. This study was focused on just to detect the forest cover change and the total cover is categorized into forest and non-forest area. Forest covers imply grassland, shrub land and forest land where as non-forest includes water body, rocky area, sand and pebbles, barren lands, marshy places and unidentified feature classes.



**Fig. 6 :** Chart showing the forest/non-forest area in percentage.

## 8. Major causes and consequences of Wild-fire

Key informants and focus group were randomly selected in such a way that they will represent the overall perception of the respondents of the study area. Nearby village development from the core area of CNP (buffer zone, VDCs will be randomly selected), Key Informant Interview was carried out from the park staffs, district forests, Federation of Community Forestry Users Nepal (FECOFUN), Community Forest User Groups, Local leaders.

### 8.1 People's perception towards the causes and consequences of wildfire in CNP

Local people played a major role in setting fire in the area as they were highly dependent to forest products. Especially in Elephant grass (*Saccharum* spp.) which is around 2.5 m tall for making fence, thatched the roof and even wall the houses. Fire serves as seasoning to the Elephant grass locally called "KharKhadai" and also to collect fuel wood and to get well sprout of grasses.

It was found that loss of biodiversity was the major consequences of the wildfire in the study area. Many insects, small mammals, nesting birds, fungus, amphibians and reptiles have been lost. Likewise, many species of plants, grasses, medicinal plants, fungi, weeds, and climbers was destroyed by the wildfire. Wildlife habitat loss was the next consequences, it happens due to loss of water and food in the area.

### 8.2 Summary of distance and gender wise perception regarding causes and consequences of wildfire in CNP (Chi-square test)

From the above calculation, it can be said that neither there is any remarkable difference between the perceptions of distant and neighboring people nor any significant difference of understanding among gender regarding the causes and consequence of wildfire. All respondent categories believe that major causes of fire incidence were local users and it was deliberately caused to fulfill the basic requirements of local forest product locally called "KharKhadai" (*Saccharum* spp.). Second causes was park staffs, they also deliberately caused fire to maintain the grasslands. Majority of people believe that loss of biodiversity was the major consequences of wildfire followed by loss of wildlife habitat.

## 9. Conclusion

Altogether more than 30 % confidence levels of 305 fire hotspots were detected in the study area. Fire peaks during March and April accounts 86 % of total forest fires incidences in the area. Forest cover was decreased significantly between two time series (before and after fire season) which was recorded as 1.33% of Forest area changed into non-forest area and attributed to net loss of 1612.94 ha. Distance to people from the park area and gender did not have any remarkable difference in their perception regarding the causes and consequences of wildfire. Local users are the most causal factor responsible for wildfire incidence. The major driver to set up fire is the dependency of local users on "KharKhadai" (*Saccharum* spp.) which is used for fencing, housing, thatching and hut construction and fire serves as seasoning for the longevity of the materials.

## References

Acharya, K.P. and Dangi, R.B., 2009. *Case studies on measuring and assessing forest degradation. Forest degradation in Nepal: review of data and methods, Rome*. Available online at: <http://www.fao.org/docrep/012/k6869e/k6869e00.pdf>; last accessed Aug. 22, 2010.

DNPWC. 2011. *Protected area of Nepal. Department of National Park and Wildlife Conservation (DNPWC)/Ministry of Forest and Soil Conservation, Kathmandu Nepal. 52+ pp. (Nepali version)*. Available online at <http://www.dnpwc.gov.np/publications/pustika>; last accessed Jan. 20, 2012.

FAO 1998. *Countries pasture / forage resource profiles*. Available online at: <http://www.fao.org/ag/AGP/AGPC/doc/Counprof/nepalhtm#3>; last accessed Nov. 10, 2010.

Giglio, L., Descloitres, J., Justice, C.O., Kaufman, Y., 2003. An enhanced contextual fire detection algorithm for MODIS. *Rem. Sen. of Env.* 87, 273–282.

ICIMOD, 2010. Monitoring forest fires in Nepal ICIMOD. Available online at: <http://geoportalicimod.org/NAE/NewsDetail.aspx?mTab=homeandNLnk=newsandNewsID=225>; last accessed: Sep. 9, 2010.

Justice, C.O., Giglio, L., Korontzi, S., Owens, J., Morisette, J.T., Roy, D.P., Descloitres, J., Alleaume, S., Petitcolin, F., Kaufman, Y., 2002. The MODIS fire products. *Rem. Sen. of Env.* 83, 244–262.

Kaufman, Y., L. Remer, R. Ottmar, D. Ward, L. Rong-R, R. Kleidman, R. Fraser, L. Flynn, D. McDougal, and G. Shelton. 1996. *Relationship between remotely sensed fire intensity and rate of emission of smoke: SCAR-C experiment, in Global Biomass Burning.* pp. 685–696, MIT Press, Mass.

Rothermel, R., 1972. *A mathematical model for predicting fire spread in wildland fuels, Research Paper INT - 115.* US Department of Agriculture, Forest Service, Intermountain forest and Range Experiment Station, Ogden, UT.

Roy, D.P., Jin, Y., Lewis, P.E., Justice, C.O., 2005. Prototyping a global algorithm for systematic fire-affected area mapping using MODIS time series data. *Rem. Sen. of Env.* 97, 137–162.

