Spatial and temporal distribution of forest fires in Nepal

Conference Paper · September 2015

7 authors, including:

Ashok Parajuli
Ministry of Forests and Environment

Deepak Chand
Ministry of Forests and Environment Nepal

Bishal Kumar Rayamajhi
Tribhuvan University

Rajendra Khanal
International Union for Conservation of Nature

XIV WORLD FORESTRY CONGRESS, Durban, South Africa, 7-11 September 2015

Spatial and temporal distribution of forest fires in Nepal

Ashok Parajuli[1], Deepak Bahadur Chand[1], Bishal Rayamajhi[1], Rajendra Khanal[1], Sony Baral [1], Yam Malla[1] and Shambhu Poudel[2]

[1]International Union for Conservation of Nature, Kathmandu, Nepal
[2]Kathmandu Forestry College, Kathmandu Nepal

Abstract

Uncontrolled forest fire is an important driver of forest degradation throughout the country. Recurrent forest fires severely damage and prohibit regeneration and growth of seedlings, destroy non-timber forest products and, in some cases, encourage invasive species. Although quantitative information is not available, forest fires are definitely degrading biodiversity, enhancing soil erosion and inducing floods and landslides due to the destruction of the natural vegetation in Nepal. In this study, we scrutinized forest fires activity in Nepal using the Moderate Resolution Imaging Spectroradiometer (MODIS) active fire datasets. We assessed fire magnitude, distribution, seasonality and risk zone in diverse geographical area. MODIS data from 2000 to 2013 revealed an average 2159 fire counts per year with the highest during 2012. Fire season in Nepal extends from January to June with the peak during April. Using Kernel density model, identified hotspot regions of fire in diverse regions of Nepal. Multi-collinearity diagnostic procedure was implemented by examining tolerance and Variance Inflation Factor (VIF). VIF values for each of the predictor were below two, which suggests low or moderate multi-collinearity. These results on forest fires will be useful to stakeholders to address the impact of forest fire in Nepal.

Keywords: Forest fire, spatial, temporal

Introduction, scope and main objectives

Uncontrolled forest fire is an important driver of forest degradation throughout the country. Recurrent forest fires severely damage and prohibit regeneration and growth of seedlings, destroy non-timber forest products and, in some cases, encourage invasive species (MFSC 2010).

The spatial pattern of forest fire occurrence is a key factor in understanding forest fire dynamics, and presence of a forest fire is determined by several biotic and non-biotic factors, however, the effects of each factor vary between ecosystems and within spatial and temporal scales (Yang et al, 2007). Climatic regime determines the region's vegetation and hence, plays a dominant role in creating fire prone areas. An increase in temperature increases the chances of fire, whereas rainfall and humidity have the opposite effect (M.G.R. Cannel, 1999). A detailed understanding of the spatial patterns of natural and human-induced processes is important to be able to identify forest fire prone areas.

The use of the GIS approach facilitates in integrating several variables in order to establish and focus on the problem. At the same time, it makes possible to update or retrieve spatial information in different ways included in the database, to develop various models. It has been stated that when it comes to spatial decision aid, the analytical capability of the GIS has to be enhanced in respect of semi-structured problems involving subjective judgments (Beedasyl et al, 1999).

In this study, an effort was made to access forest fire prone area using GIS. Incidence of forest fire in the area from 2000-2013 were acquired from the FIRMS(Fire information for resource management system),which integrates remote sensing and GIS technologies to deliver global MODIS hotspot fire location and burned area information to natural resource managers and other stakeholders around the world. This major objective of this study was to find out spatial and temporal distribution of forest fire in Nepal.

Study Area

Whole country Nepal was chosen for the study extends 885 Km from east to west and 145-241 km from north-south. It lies between latitudes 26°.22' and 30^0 27'N, and longitudes 80° 40' and 88° 12'E (fig 1). Nepal is divided into three physiographic areas: Mountain, Hill and Terai. Climatic zones vary from tropical to Artic zone corresponding to the altitudes which varies from 57m to 8,848m.

Source: http://worldjournos.com/detail.php

Figure 1 Study Area

Methodology

Data collection and analysis

Moderate Resolution Imaging Spectroradiometer (MODIS) active fire datasets were extracted through FIRMS (ftp://ba1.geog.umd.edu/Collection51) in Shape (*.shp) format) dated from 2000 to 2013 A.D. And a digital layer data of Nepal was extracted from Department of Survey, Nepal. Data obtained from MODIS were imported in ArcGIS 10.2.2 and area for each polygon according to year (or month) basis was calculated to identify the magnitude for each year. To identify the temporal distribution, centroid point for each polygon was calculated using ArcGIS and point for each year/month was counted. Following working flow was adopted for analysis (fig 2).

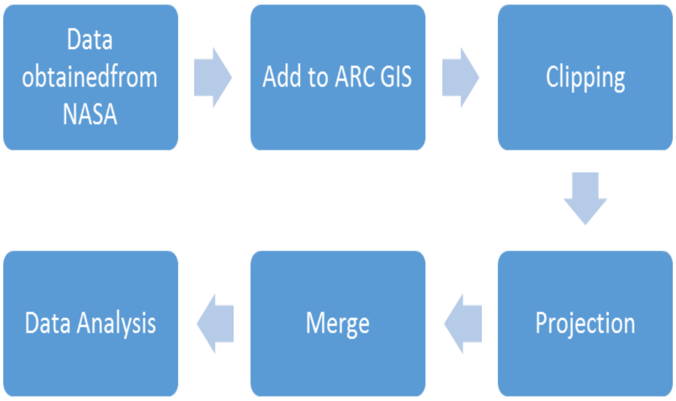

Figure 2 Methodological process

Fire Sensitive Zonation:

Kernel density model were used to find out the high medium and low risk zone. KDE has been widely used for hotspot analysis and detection. The objective of KDE is to produce a smooth density surface of point events over space by computing event intensity as density estimation (Xie ZX et al, 2008, Serra-Sogas et al, 2008)

Development of fire burnt areas model:

Digital elevation model, distance of sun from earth according to burn date, longitude, latitude and aspect were used to find out the regression. Slope and aspect image were generated using the DEM data. Aspect and slope plays a vital role in spreading of the fire. Fire travels most rapidly up-slopes and least rapidly down-slope. Southern slopes are more vulnerable to catching fire.

To ensure whether there are colinearity between the variables or not, collinearity diagnostic procedure was implemented. Multicollinearity was assessed by examining tolerance and Variance Inflation Factor (VIF). All variables in the linear relationship have small tolerance. The Variance Inflation Factor (VIF) measures the impact of collinearity among the variables in a regression model. The Variance Inflation Factor (VIF) is 1/Tolerance, it is always greater than or equal to 1. There is no formal VIF value for determining presence of Multicollinearity. The higher the value of VIF the greater is the degree of collinearity. In regression analyses, burnt area was considered as dependent variables whereas other remaining variables were considered as independent variables.

Rule of Thumb: If any of the VIF values exceeds 5 or 10, it implies that the associated regression coefficients are poorly estimated because of multicollinearity (Montgomery, 2001).

Results

Magnitude of Burnt Area in Nepal

A total of 30220 hotspots were recorded over the study area. About 65 percent of the hotspot falls under Mid-Western Development Region. A total of 13, 09,969.714 hectares were burnt throughout the period. Mean and standard deviation of the fire is 43,461.0821 and 6, 71,056.690 respectively.

Although the maximum number of forest fire was in 2012 the area were burnt more in 2009 covering (11.63%) 1, 52,408.14 hectares (fig 3). The minimum loss was 43, 278.21 hectares in 2013

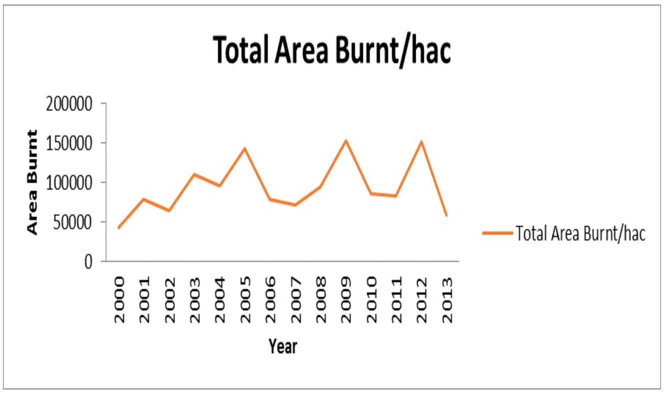

Figure 3 Total area burnt per year

Fire Distribution in Nepal

Temporal changes of fire frequency for the whole area were investigated on a monthly and yearly basis from 2000-2013.Monthly changes were studied for each year. The annual fire occurrence during the recent 14 years (2000-2013) is shown in fig 4. The total yearly number of fires recorded within Nepal substantially from around 1052 at the start of the study period (2000). Fig 4 shows that the most fires occurred in 4 different years in 2003, 2005, 2009 and 2012. Total 2865, 3260, 3287 and 3518 fires were occurred in 2003, 2005, 2009 and 2012 respectively. These 4 different years contribute 42.78% of the total fires. There was a large inter-annual variation in average monthly patterns of fire occurrence; the most significant being April which had the highest number of fires (fig 5).

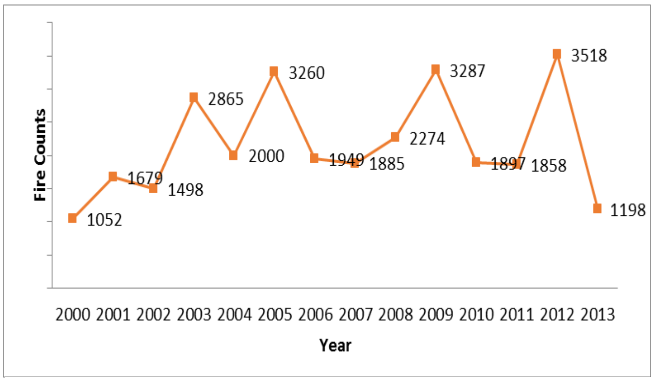

Figure 4 Fire counts per year

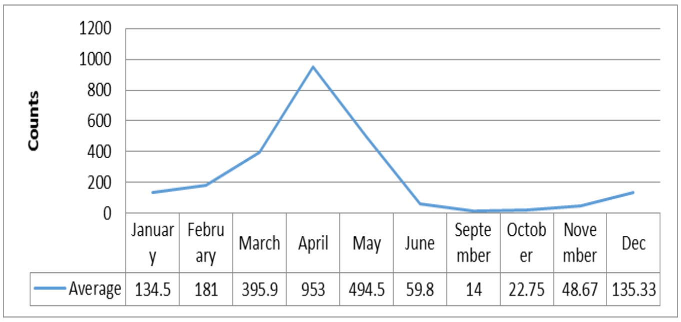

Figure 5 Average counts of forest fire per month

From Fig 6 it is possible to determine the month(s) with the highest fire incidence. In Nepal, fires were most mainly in three months March, April and May had a noticeable number of fires but only few fires in September, October and November.

During the study period, over 7280 fires were detected in alpine pasture (fig 7); over 24.09% of the total fire records. The number of fire detection was in Alpine pasture because local herders set fire intentionally to get new succulent grass for the livestock. After alpine pasture the number were high in Hill Sal forest and chir-pine forest respectively with the lowest incidence in Riverine forest.

As already mentioned above in High Mountain the frequency is very high because of alpine pasture .The most interesting part is that in Terai there is low occurrences of forest fire as compared to Himalayan areas (fig 8).

Seasonality of fires

The times that fires occur with monthly for the 14 years period from 2000-2013 was analyzed. For all years combined, a total of 73.86% of fires occurred between January to June. The transitional period before and after the monsoon (the first two months and the last month of the dry-season) experienced fewer fires. Fig 9 shows that in hot and dry season the number of forest fire is very high which reached 22323 counts.

Fire sensitive zone in Nepal

The forest risk map is shown in figure 10. The whole area was characterized as high, medium and low fire risk areas. The highest concentration was located alone the mid-western and far-western part of Nepal

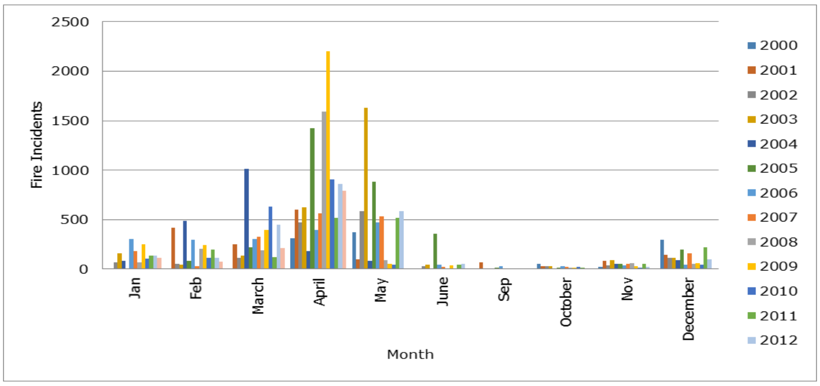

Figure 6 Monthly distribution of forest fire in Nepal

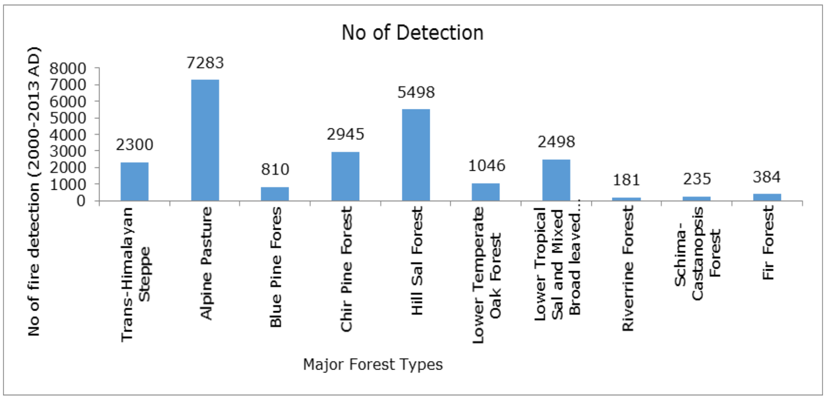

Figure 7 Number of fire detection according to major forest types

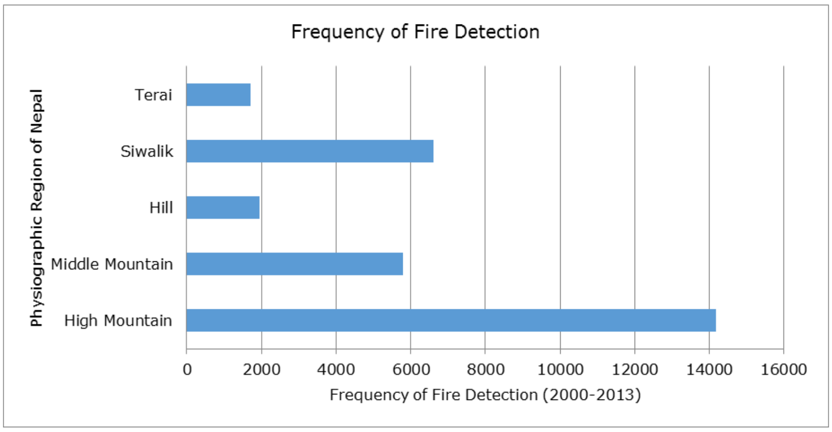

Figure 8 Frequency of fire detection according to physiographic region of Nepal

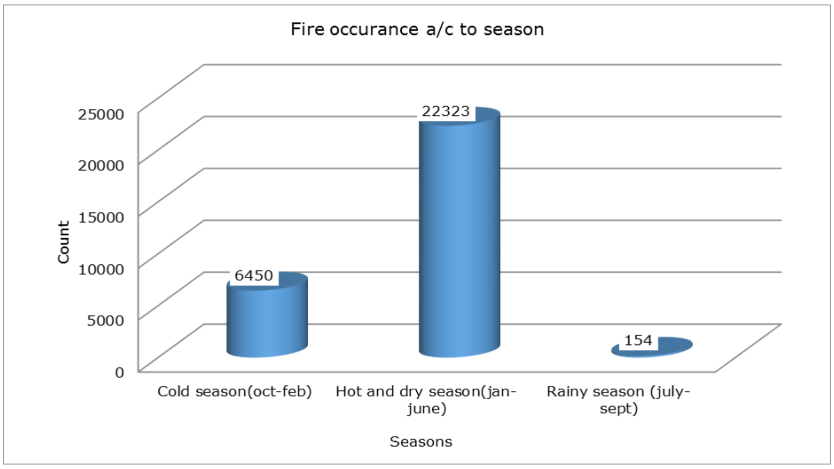

Figure 9 Number of fires detected according to season

which occupies 8, 70,134.44 hectares, medium fire risk zone occupies 44, 88,297.79 hectares, and low fire risk zone occupies 61,52,535.18 hectares. Fig 10 shows that fire with high risk zone is in the Mid-western development region while there is low risk zone in Eastern region of Nepal.

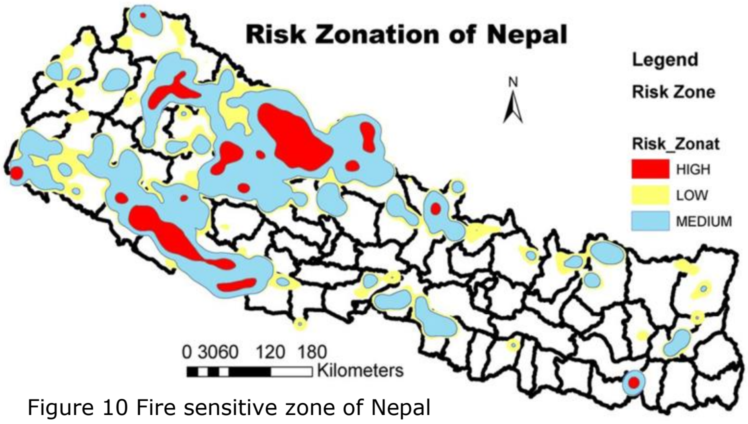

Figure 10 Fire sensitive zone of Nepal

Table 1 Sensitive zone calculated from the result of Kernel density Estimation presents the graduation of colors showing the degree of intensity of fires

Risk Value	Color	Area(hac)
High	Red	870134.44
Medium	Blue	4488297.79
Low	Yellow	6152535.18

Multicollinearity regression:

Both the values of the Wald *F* and $\chi 2$ test statistics are statistically significant if a significance level of 5% is used. Hence, there is sufficient evidence to conclude that burn date, distance between sun and earth, aspect of the burned surface, longitude and latitude of the burned area influence the fire sensitive area. This finding is supported by the significant *z* test statistic values for the significance of the individual parameters.

Table 2 Regression

Statistic	Value	Den. DF	Num. DF	P Value
Adjusted Wald F	171.1924	5	30204	0
Wald Chi-square	856.0752	5		0

Estimated Regression Weights

By using the results above, the estimated model may be expressed as

Sensitive area= 5734955-61.5*BD+400237.95*DSE+31.4*A-0.77*LOG-1.62*lati

= 6135161.01 m^2

Therefore total sensitive forest fire area is 6135161.01 square meters.

Table 3 Estimated Regression Weights

Parameter	Estimate	Standard Error	z Value	P Value
Intercept	5734955.53		18.6369	0
Burn Date	-61.5176	35.2828	-1.7436	0.0812
Distance from sun	400237.96		1.3287	0.1839
Aspect	31.4465	3.0061	10.4609	0
Longitude	-0.779	0.0379	-20.5456	0
Latitude	-1.6208	0.071	-22.8155	0

In table 4, burn date was taken as dependent variables whereas all other remaining variables were taken as independent variables. According to thumb rule if any of the VIF values exceeds 5 or 10, it implies that the associated regression coefficients are poorly estimated because of multicollinearity so according to the above result VIF values are not more than 2 that mean there is low correlation between all the above variables.

Table 4 Coefficients

Model	Collinearity Statistics	
	Tolerance	VIF
Burn Date	0.985	1.015
Distance from sun	0.992	1.008
Aspect	0.999	1.001
Longitude	0.868	1.152
Latitude	0.871	1.148

Discussion

The use of remote sensing fire data

Fires influence global change and tropical ecosystems through their impact on land-cover dynamics, atmospheric composition, and the global carbon cycle. As such, many institutions are interested in the use of satellites to monitor and quantify fire occurrence in a variety of landscapes. However, the major issue in the use of remotely detected fire data is limitations of the derived products and the incidence of omission errors (Eva & Lambin, 1998). Oversight of fires was 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). 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 Nepal is not known. However, significant fires, both in distribution and frequency were investigated using MODIS. Furthermore, one of the strengths of MODIS is the synoptic source of information derived from regular observation in a precise time frame from satellite (Reeves et al, 2006). Yearly changes in the number of fires in the Nepal indicated that a significantly higher number of fires were recorded during 2009 but high areas were burnt in 2012 but the fire records used in this study could not discriminate between controlled and uncontrolled burning.

Temporal distribution of forest fire

Many studies have shown that late dry-season burning has more significant impacts on vegetation cover than burning in the early season (Bucini & Lambin, 2002). For example, in a study in the Kruger National Park, South Africa, the severity of fires was shown to be greatest at the end loads (Govender et al, 2006). Additionally, the significant factor is always fuel moisture content, which is generally lower during the dry-season and therefore material is more flammable (van Wilgen et al, 2004).Here the result too shows that most of the fires were in hot and dry season. Meanwhile in Higher Himalayan there is maximum intentional fire in dry season the reason could be that weather is perfect for the local herders to migrate in pasture land during dry season.

Distribution of forest fire in relation to physiographic zone

The forest or pasture may be deliberately set on fire by mountain people to induce succulent grass growth for domestic animals. In addition to this, natural vegetative systems sometimes get extensively damaged when fires spread uncontrollably from burning operations carried out in the adjoining agricultural fields. Another common practise is the burning of wild grass or undergrowth to search for wild animals. Unextinguished campfires of trekkers, shepherd camps or roadside charcoal panners may also spread and cause forest fires. Unextinguished cigarette butts and matchsticks are other important causes of accidental forest fires, especially in areas of dry forests. Besides, lightning or sparks from electric poles in dry areas also causes fires. Up to 90 per cent of the Himalayan forest fire is caused by reckless anthropogenic activities (Bajracharya [undated], Chetri, 1994).

Since the establishment of Langtang National Park in 1970 there have been more frequent and intense fires caused by banning of local fire management regimes (Campbell, 1999). The local people used fire to improve grazing on pastures and in secondary scrub forest areas. After the ban on controlled burning, the resulting flush of growth produced not only grasses, but also provided perfect conditions for many types of wild flowers to flourish. The limitation of the study was that because of lack of data this study couldn't distinguish whether the fire was actually in forested land or non-forested land that could be the reason which shows high number of intense fire in alpine pasture.

Risk zone of Nepal

Forest fires generally occur from November to June. High atmospheric temperatures, dryness and at times prolonged winter offer favourable circumstance for a fire to start. The severity of the fire varies greatly depending upon fire weather, fuel conditions, and physiographic. Once the monsoon is established, usually by the middle of June, the fire problem gradually disappears. It is important to learn that monsoon rainfall is greater in Eastern Indian Himalaya than in its western counterpart (Khawas B, 2007).My study too shows that there is maximum numbers of fire in western region and very low in eastern region.

Regression Model Development:

We detected inflated standard errors by looking at the variance inflation factor (VIF), as multicollinearity is indicated by fluctuating standard errors. Generally, VIF values greater than ten may indicate multicollinearity among variables. VIF values for each the predictors were below two, which suggests low or moderate multicollinearity. This means that means any one of them could play vital role in forest fire without the dependence of other. Correlation analyses among the different variables indicated that a low correlation in independent variables. The adjusted model confirms that the explanatory variables are closely related to the dependent variables.

Conclusion

The study has analysed forest fire in Nepal in the period 2000-2013 using information from MODIS data. Based on GIS techniques, the study shows that there were 30220 hotspots throughout the study period. The year 2005, 2009 and 2012 forest fires left historically largest annual burnt area in Nepal due to severe fire occurrence. Three active fire periods in March, April and May also triggered the largest burnt area under drought conditions whose averages were 395.9, 953 and 494.5 counts. Out of 30220 hotspots in Nepal 7283 hotspots were in Alpine pasture areas. A total of 73.86% of fires occurred between January to June that is on hot and dry season. Most of the fires were found at Himalayan regions due to alpine pasture; 24.09% fires were detected in alpine pasture. After alpine pasture the number were high in Hill Sal forest and chir-pine forest respectively with the lowest incidence in Riverine forest. Fire with high risk zone was mostly in the Mid-western development region while there is low risk area in Eastern region of Nepal because there is high precipitation in eastern development region. These results on forest fires will be useful to forest managers and stakeholders to address the impact of forest fire in Nepal.

Acknowledgements

We acknowledged support of Mr. Shambhu Paudel and Mr. Sundar Sharma for their valuable technical guidance. We also extend our thanks to UNISDR-Regional South Asia Wildland Fire Network for providing me the financial support for the research work and NASA for providing the data of forest fire since 2000.

References

Acharya, K. P., & Dangi, R. B. (2009). Forest degradation in Nepal: Review of data and methods.

Aguado, I., Chuvieco, E., R. Boren, R., Nieto, H. (2007). Estimation of dead fuel moisture content from meteorological data in Mediterranean areas. Applications in fire danger assessment. Int. J. Wildland Fire. 16, 390-397.

Anon, 1999. Aviation and forest fire management

Atkinson, E.J., Therneau, T.M., (2000). An introduction to recursive partitioning using the RPART routines, The Mayo Foundation, Rochester, Minnesota August 1997 (pp. 127−183). Alcala de Henares, Spain: Universidad de Alcala

Bajracharya, K.M (2001). The forest fire situation in Nepal. *Int. Forest Fire News* 26

Beringer, J. Hutley, L. B., Tapper, N. J., Coutts, A., Kerley, A., and O'Grady, A. P., (2003). Fire impacts on surface heat, moisture and carbon fluxes from a tropical savanna in northern Australia. International Journal of Wildland Fire, 12, pp. 333−340

Beverly JL,Herd EPK Conner JCR (2009) Modeling fire susceptibility in Forest ecology and management 258, 1465-1478

Bolgiano, C., (1998). The Appalachian Forest: A search for roots and renewal. Stackpole Books, Mechanicsburg, Pennsylvania

Bucini, G. and Lambin, E. F. (2002). Fire impacts on vegetation in Central Africa: a remote-sensing-based statistical analysis. Applied Geography 22: 27–48

Butry, D.T., Pye, J.M., Prestemon, J.P. (2002). Prescribed fire in the interface: separating the people from the trees, in: Outcalt, K.W. (Ed.), Proceedings of the eleventh biennial southern silviculture research conference. USDA Forest Service, Asheville, NC, pp. 132-136 (General Technical Report GTR-SRS-48).

Campbell, B. Contribution to internet mountain forum, April 1999

Cardille, J.A., S.J. Ventura (2001). Occurrence of wildfire in the northern Great Lakes region: effects of land cover and land ownership assessed at multiple scales. International Journal of Wildland Fire 10(2): 145-154

Cardille, J.A., Ventura, S.J., Turner, M.G. (2001). Environmental and Social Factors influencing Wildfires in the Upper Midwest, United States. Ecol. Appl. 11, 111-127

Chuvieco, E., Salas, F.J., Carvacho, L., Rodriguez-Silva, F., 1999. Integrated fire risk mapping, in: Chuvieco, E. (Ed.), Remote sensing of large wildfires in the European Mediterranean. Springer-Verlag, Berlin, pp. 61-84

D.W.M. Kenney, D. Yemshanov, G. Fox, E. Ramlal, Cost estimates for carbon sequestration from fast growing poplar plantations in Canada, Forest Policy and Economics 6 (2004) 345-358

Darmawan and Mulyanto (November 2001). Forest fire hazard model using remote sensing and geographic information system towards understanding of land and forest degradation in lowland areas of East Kalimantan, Indonesia. 22nd Asian Conference on Remote Sensing, 5-9 November 2001.

Das A.N, Causes, consequences and management strategy for wildfires in Nepal

De Torres Curth, M., Biscayart, C., Ghermandi, L., Pfister, G., 2012. Wildland-urban interface fires and socioeconomic conditions: A case study of a Northwestern Patagonia city. Environ. Manage. 49, 876-891

Diaz-Delgado ,Lloret F.Pons X(2004) Spatial patterns of fire occurrence in Catalonia,NE,Spain.Landscape Ecology 19,731-745

Dlamini WM (2010) A Bayesian belief network analysis of factors influencing wildfire occurrence in Swaziland. *Environmental Modelling & Software* 25, 199-208.

Donoghue LR, Main WA (1985) Some factors influencing wildfire occurrence and measurement of fire-prevention effectiveness. *Journal of Environmental Management* 20, 87-96. 20

Donoghue LR, Simard AJ, Main WA (1987) Determining the economic relationship between law-enforcement activities and arson wildfires - a feasibility study in Arkansas. *Journal of Environmental Management* 25, 377-393.

Eiji.N et al, 2007. Forest and field fire search system using MODIS Data

Eva, H. and Lambin, E. F. (1998). Burnt area mapping in Central Africa using ATSR data. International Journal of Remote Sensing 19:3473–3497

Fearnside, P. M., Righi, C. A., Graça, P. M. L., Keizer, E. W. H., Cerri, C. C., Nogueira, E. M., et al. (2009). Biomass and greenhouse-gas emissions from land-use change in Brazil's Amazonian "arc of deforestation": The states of Mato Grosso and Rondônia. Forest Ecology and Management, 258(9), 1968-1978.

Finney M, McHugh C, Grenfell I (2005) Stand- and landscape-level effects of prescribed burning on two Arizona wildfires. *Canadian Journal of Forest Research* 35, 1714-1722.

Gellrich, M., Baur, P., Koch, B., Zimmermann, N.E., 2007. Agricultural land abandonment and natural forest re-growth in the Swiss mountains: A spatially explicit economic analysis. Agr. Ecosyst. Environ. 118, 93-108.

Gonzalez-Olabarria, J.R., Pukkala, T (2011). Integrating fire risk considerations in landscape-level forest planning. Forest. Ecol. Manag. 261, 278-287.

Goldammer, J. G. (2000). International Forest Fire News: United Nations Economic Commision & Food and Agriculture Organization

Goldammer, J.G. (2007). *Wildland Fires: Global and South Asian Perspectives on International Cooperation*. In: Kanel, K.R., Shrestha, K.R., Acharya, K.P., Pachhai, I.B. and Sharma,S.P. (eds.). National Round Table (RT) for Development of Strategy for Wildland FireManagement in Nepal, Proceedings of a meeting held in Kathmandu, 16 December 2007, Nepal (in press).

Govender, N., Trollope, W.S.W., and Van Wilgen B.W. The effect of fire season, fire frequency, rainfall and management on fire intensity in savanna vegetation in South Africa. 2006. Journal of Applied Ecology 43:748–758

Hochkirch, A. and Adorf, F(2007). Effects of prescribed burning and wildfires on Orthoptera in Central European peat bogs. *Environmental Conservation*, 34(3), pp.225-235

IFFN. (2006). Participatory Forest Fire Management Approach. Retrieved on the 27th of May 2010 from http://www.fire.uni-freiburg.de/iffn/iffn_34/06-IFFN-34-Nepal-2.pdf/

Jin, Y., Schaaf, C.B., Gao,F., Li, X., Strahler, A.H., Lucht, W. and Liang, S. 2003.

Jurskis V., Decline of eucalypt forests as a consequence of unnatural fire regimes, *Aus. For.*, 68(1), 257–262,(2005a).

Jurskis V., Eucalypt decline in Australia and a general concept of tree decline and dieback, *For. Ecol. Mgmnt.*, 215(1),1–20,(2005b).

Karkee, T.B. (1991). *Forest Fire-Causes and its Relationship with Economic Variables*. Nepal Journal of Forestry, 6(2):75-80.

Khawas B (2007) .Environmental challenges and human security in the Himalaya

Koutsias, N., Martinez, J., Chuvieco, E., Allgower, B., 2005. Modelling Wildland Fire Occurrence in Southern Europe by Geographically Weighted Regression Approach, in: De la Riva, J., Perez-Cabello, F., Chuvieco, E. (Eds.), Fifth International Workshop on Remote Sensing and GIS Applications to Forest Fire Management: Fire Effects Assessment, Zaragoza, pp. 57-60.

Kuhlken, R.(1999). Settin' the woods on fire: rural incendiarism as protest. Geogr. Rev. 89, 343- 363

Le Houérou, H.N.(1987). Vegetation wildfires in the Mediterranean basin: evolution and trends. Ecologia mediterranea. 13(4), 13-24

Leone, V., Lovreglio, R., Martinez-Fernandez, J.(2002). Forest fires and anthropic influences: a study case (Gargano National Park, Italy), in: Viegas X (Ed.), Forest fire research and wild-land fire safety. Mill Press, Rotterdam, pp. 11-28.

Lloret, F., Calvo, E., Pons, X., Diaz-Delgado, R., (2002). Wildfires and landscape patterns in the Eastern Iberian Peninsula. Landscape Ecol. 17, 745-759.

M.G.R. Cannel, Growing trees to sequester carbon in the UK:Answers to some questions, Forestry 72 (1999)

MacDonald, D., Crabtree, J.R., Wiesinger, G., Dax, T., Stamou, N., Fleury, P., Gutierrez Lazpita, J., Gibon, A., (2000). Agricultural abandonment in mountain areas of Europe: environmental consequences and policy response. J. Environ. Manage. 59, 47-69

Maingi, J.K., Henry, M.C. (2007). Factors influencing wildfire occurrence and distribution in eastern Kentucky, USA. Int. J. Wildland Fire. 16, 23 33.

Martinez J, Vega-Garcia C, Chuvieco E (2009) Human-caused wildfire risk rating for prevention planning in Spain. *Journal of Environmental Management* 90, 1241-1252.

Mercer, D.E., Prestemon, J.P (2005). Comparing production function models for wildfire risk analysis in the wild-land–urban interface. Forest Policy Econ. 7, 782-7959

Narendram, K. (2001). *Forest fires: Origin and Ecological Paradoxes*. General article. Resonance, November

NASA/University of Maryland, (2002) MODIS Hotspot / Active Fire Detections. Data set. MODIS Rapid Response Project, NASA/GSFIC

NBS. (2002). Nepal Biodiversity Strategy. Kathmandu, Nepal: Ministry of Forest and Soil Conservation

Pausas, J.G.(2004). Changes in fire and climate in the eastern Iberian Peninsula (Mediterranean basin). Clim. Change. 63 (3), 337-350 2007. Plant persistence fire traits along a productivity and disturbance gradient in Mediterranean shrublands of SE Australia. Global Ecol. Biogeogr. 16, 330-340.

Pazienza, P., Beraldo, S.(2004). Adverse effects and responsibility of environmental policy: the case of forest fires. Corporate Social Responsibility and Environmental Management. 11, 222-231.

Pereira, J. M. C., Chuvieco, E., Beaudoin, A., & Desbois, N. (1997). Remote sensing of burned areas: A review. In E. Chuvieco (Ed.), A review of remote sensing methodsfor the study of large wildland fires. Report of the Megafires Project ENV-CT96-0256,

Pew, K.L., Larsen, C.P.S., (2001). GIS analysis of spatial and temporal patterns of human-caused wildfires in the temperate rainforest of Vancouver Island, Canada. Forest Ecol. Manag. 140, 1-18.

Pinol, J., Terradas, J., Lloret, F., (1998). Climate warming, wildfire hazard, and wildfire occurrence in coastal eastern Spain. Clim. Change. 38, 345-357

Rawat, G.S, November (2003), Fire risk assessment for forest fire control management in Chilla forest range of Rajaji national park, Uttaranchal, India *International Institute for GeoInformation* Science and Earth Observation (ITC) Enschede The Netherlands M.Sc Thesis 2003t fire fundamentals, Ontario Ministry of Natural Resources, 1999. (www.mnr. gov.ca)

Reeves, M. C., Zhao, M and Running, S.W.(2006). Applying improved estimates of MODIS Productivity to characterize grassland vegetation dynamics. Rangeland Ecology & Managemant. 59:1-10

Ripu M. Kunwar, Sarala Khaling (2006): Forest fire in the Terai, Nepal causes and community management interventions published on International Forest Fire News (IFFN) No. 34 (January – June 2006, 46-54

Romero-Calcerrada, R., Perry, G.L.W. (2004). The role of land abandonment in landscape dynamics in the SPA 'Encinares del rio Alberche y Cofio, Central Spain, 1984-1999. Landscape Urban Plan. 66, 217-232.

Roy, D. P., Giglio, L., Kendall, J. D., & Justice, C. O. (1999). A multitemporal active-fire based burn scar detection algorithm. International Journal of Remote Sensing, 20,

Roy, D. P., Jin, Y., Lewis, P. E., & Justice, C. O. (2005a).

Prototyping a global algorithm for systematic fire affected area mapping using MODIS time series data. Remote Sensing

Roy, P.S. (2004). *Forest fire and degradation assessment using satellite remote sensing and geographic* information system. Satellite Remote Sensing and GIS Applications in Agricultural Meteorology, pp. 362-

Schmidt-Vogt, D. Fire in high altitude forests of the Nepal Himalaya. In Goldammer, J.G. and M.J. Jenkins(eds), *Fire in ecosystem Dynamics, Proceedings of the third international Symposium on Fire Ecology,Freiburg, FRG. May 1989*

Serneels, S., Lambin, E.F., (2001). Proximate causes of land-use change in Narok District, Kenya: a spatial statistical model. Agr. Ecosyst. Environ. 85, 65-81.

Serra-Sogas N, O'Hara PD, Canessa R, Keller P, Pelot R. Visualization of spatial patterns and temporal trends for aerial surveillance of illegal oil discharges in western Canadian marine waters. Mar. Pollut. Bull. 2008;56:825–833

Sharma, S.P. (1996.a). *Forest fire behaviour study in sal dominated natural forest in terai*. Forest Management and Utilization Development Project (FMUDP) / FINNIDA / His Majesty's Government of Nepal (GMGN), Working Paper No. 23, Kathmandu

Syphard AD, Radeloff VC, Keuler NS, Taylor RS, Hawbaker TJ, Stewart SI, Clayton MK (2008) Predicting spatial patterns of fire on a southern California landscape. *International Journal of Wildland Fire* 17, 602-613.

Syphard, A.D., Radeloff, V.C., Keeley, J.E., Hawbaker, T.J., Clayton, M.K., Stewart, S.I., Hammer, R.B. (2007). Human influence on California fire regimes. Ecol. Appl. 17, 1388-1402

Tacconi, L., Moore, P., and Kaimowitz, D. (2007). Fires in tropical forests – what is really the problem? Lessons from Indonesia. mitigation and adaptation strategies for Global Change, 12(1), 55-66.

Trouet V., Taylor, A.H., Carleton, A.M., Skinner, C.N., 2006. Fire-climate interactions in forests of the American Pacific coast. Geophys. Res. Lett. 33, 1-5.

Vadrevu, K.P., Eaturu, A., Badarinath, K.V.S.(2006). Spatial distribute on of forest fires and

controlling factors in Andhra Pradesh, India using Spot Satellite Datasets. Environ. Monit. Assess.

Van Wilgen, B.W., Govender, N., Biggs, H.C., Ntsala, D and Funda, X.N. (2004). Response of savanna fire regimes to changing fire management policies in a large African National Park. Conservation Biology 18: 1533–1540.

Wade,D and J.Lundsford (1990).Fire as forest management too;prescribed burning in the southern states, Unasylva 162,28-38

Wagle.S (2011), Problem of forest fire and its prevention

Weinstein DA, Woodbury PB (2006) Review of methods for developing probabilistic risk assessments. Part 1: Modeling fire. In Advances in threat assessment and their application to forest and rangeland management, Boulder, Colorado, USA, July 2006.' pp. 285-302. (Pacific Northwest Research Station, USDA Forest Service)

Whalley, W., (2005). Grassland regeneration and reconstruction: the role of grazing animals.

Wotton BM (2004) Predicting forest fire occurrence in Ontario. PhD thesis, University of Toronto.

Wotton BM, Martell DL (2005) A lightning fire occurrence model for Ontario. *Canadian Journal of Forest Research* 35, 1389-1401

Wotton, B.M., Martell, D.L., Logan, K.A., (2003). Climate Change and people caused forest fire occurrence in Ontario. Clim. Change. 60, 275-295

Xie ZX, Yan J. Kernel Density Estimation of traffic accidents in a network space

Yang J, He H S, Shifley S R, (2007). Spatial patterns of modern period human-caused fire occurrence in the Missouri Ozark Highlands. *Forest Science*, 53(1): 1–15.

Websites:

http://earthdata.nasa.gov/data/nrt-data/firms

http://worldjournos.com/detail.php

http://en.wikipedia.org/wiki/Nepal

http://en.wikipedia.org/wiki/Moderate-Resolution_Imaging_Spectroradiometer
http://worldjournos.com/detail.php

http://modis.gsfc.nasa.gov/