Spatial and temporal pattern of the human-caused forest fire occurrences in Korea

Han-Bin Kwak[1], Woo-Kyun Lee[1**], Myoung-Soo Won[2], Kyo-Sang Koo[2], Myung-Bo Lee[2], Sang-Chul Lee[1*]

[1]*Environmental Science and Ecological Engineering, Korea University, Seoul, Korea*
[2]*Department of Forest Environment, Korea Forest Research Institute*

[*]attractive37@korea.ac.kr
[**]Corresponding Author:leewk@korea.ac.kr

ABSTRACT

Nationwide forest fire occurrences which reported between 1996 and 2006 by the Korea Forest Research Institute are classified by occurrence, extinguished date, address, cause, and damage area. Spatial intensity of forest fire was analyzed using Kernel intensity index. Using Ripley's K function, which summarizes the point data pattern, the clustering pattern of forest fire was analyzed in relation to distance. The probability map of forest fire occurrence was drawn by applying the Poisson Regression to geographical factors (population density, distance from road), topographical factors(elevation, slope, aspect) and climate factors(temperature, relative humidity, precipitation) can influence forest fire occurrence. Poisson Regression result showed that population density, distance from road, slope, elevation and relative humidity are highly related to forest fire occurrence.

Key words : forest fire, spatial analysis, Kernel intensity estimation, Ripley's K function, Poisson Regression

1. Introduction

Forest fires occur by natural or anthropogenic causes globally every year and bring large-scale of damages to the nature. Therefore, many countries are researching forest fires to prevent or minimize their damage. Krishna et al. (2005) analyzed the spatial distribution of forest fires using SPOT satellite datasets. Pew and Larsen (1999) analyzed spatial and temporal patterns of human-caused fire using GIS. Yang et al. (2006) analyzed the spatial patterns of human-caused fire occurrence using inhomogeneous Poisson process model.

Most forest fires were caused by anthropogenic factors and occurs in spring season in Korea. And most forest fires occur in needle-leaf forest which is burn easily compared to broadleaf which havs fire-resistant qualities. In this paper, we investigated the spatial and temporal pattern of forest fire occurrence in Korea.

2. Data

Forest fires data which were reported between 1996 and 2006 by the Korea Forest Service, The data set has the information of date of occurrence, extinguished date & time, address of occurrence location, causes and damaged area. We made point-based GIS database of forest fire

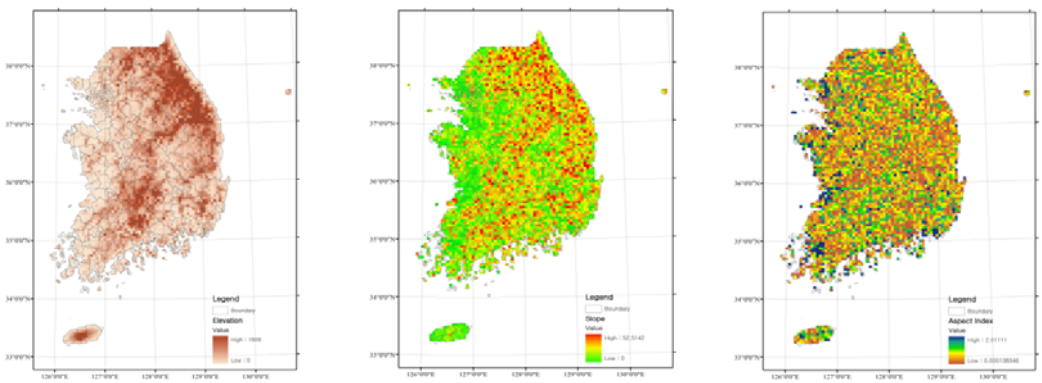
occurrence. Using the dataset relationship between forest fire occurrence and the geography, topography and climate was analyzed.

The grid size of all data was re-sampled to 5km×5km. The number of fire occurrence is included in 0~23 data per a grid and independent variables are geographical factors (population density, distance from road), topographical factors (elevation, slope, aspect and aspect index) and climate factors (temperature, relative humidity, precipitation). Aspect data of 360。 degree was converted using (Eq. 5). 0 means south, 2 means north.

$$AI = 2\left|1 - \frac{(Aspect)}{180}\right| \qquad \textbf{(Equation 1)}$$

Climate data from 75 stations was spatially interpolated using IDSW(Inverse distance squared weighted) method. Especially, the rate of lapse is applies to temperature data. The below is general IDSW equation.

$$W = \frac{\sum \frac{W_i}{d_i^2}}{\sum \frac{1}{d_i^2}} \qquad \textbf{(Equation 2)}$$



(a) elevaton (b) slope (c) aspect index

Figure 1. Analysis o f factors caused forest fire

3. Method

3.1 Kernel Intensity estimation

Using the spatial statistics, the spatial intensity of forest fires was analyzed. The deviation value of each variable divided by the Smoothing parameter(h) is applied to Kernel, probability intensity function. Finally the average of the kernel is drawn as below.

$$\hat{f}_n(x) = \frac{1}{Nh}\sum_{i=1}^{N} K\left(\frac{x - x_i}{h}\right) \qquad \textbf{(Equation 3)}$$

K is a Kernel and h is a smoothing parameter. Most commonly used K is a Gaussian Function that has an average of 0 and deviation of 1. In this study, we used Gaussian Function as Kernel(K), and the equation of the Gaussian Kernel is as follows.

$$K(x) = \frac{1}{\sqrt{2}} e^{-\frac{1}{2}x^2} \qquad \textbf{(Equation 4)}$$

3.2 Ripley's K function

Ripley's K function is a tool for analyzing spatial point process data which are usually recorded by two dimensions. Ripley's K function is used to summarize a point pattern. For many point processes, the expectation in the numerator of the K function can be analytically evaluated, so the K function can be written in closed form. The simplest, and most commonly used, is K(t) for a homogeneous Poisson process, also known as *complete spatial randomness* (CSR). If it is bigger than CSR, it is considered as cluster, otherwise it is a dispersion.

3.3 Poisson Regression

Poisson distribution is a discrete probability distribution to estimate distribution of event occurrence ratio in probability and statistics. It was also used to estimate the probability of an event that handles values such as dimension and volume in special distance.

$$P(Y) = \frac{e^{-\lambda}\lambda^{k}}{k!} \qquad \textbf{(Equation 5)}$$

$$\log(\lambda) = \alpha + \beta_1 E + \beta_2 S + \beta_3 P + \beta_4 D + \beta_5 H \qquad \textbf{(Equation 6)}$$

E: elevation, S: slope, P: population density, D: distance from road, H: relative humidity

The Poisson Regression applied to geographical factors (population density, distance from road), topographical factors (elevation, slope, aspect) and climate factors (temperature, relative humidity, precipitation) on forest fires occurrence.

4. Results and Discussion

4.1 Kernel Intensity estimation

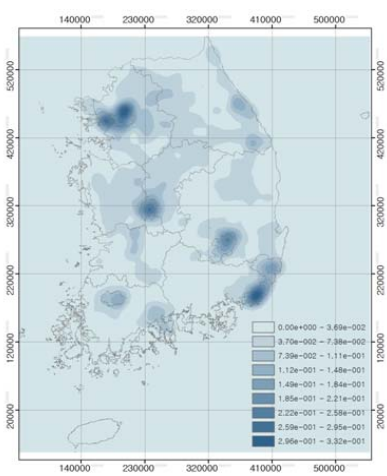


Figure 2. Kernel intensity of all data

The intensity analysis results showed that the most forest fires are concentrated on metropolitan areas (Figure 2.). From each causes, the result can be classified to two groups. One group is concentrated on the area where population density is high. The other group is dispersed all over the country. Climber's fire, arson, children's fire are concentrated on the metropolitan areas. The cause of field incineration, agricultural wastes incineration and trash incineration occurred throughout the whole nation(Figure 3.). Because the most forest fires were caused by humans, it is observed that the result of spatial analysis is related to population density. Affected factors and unaffected factors related to population density were divided by detailed origins.

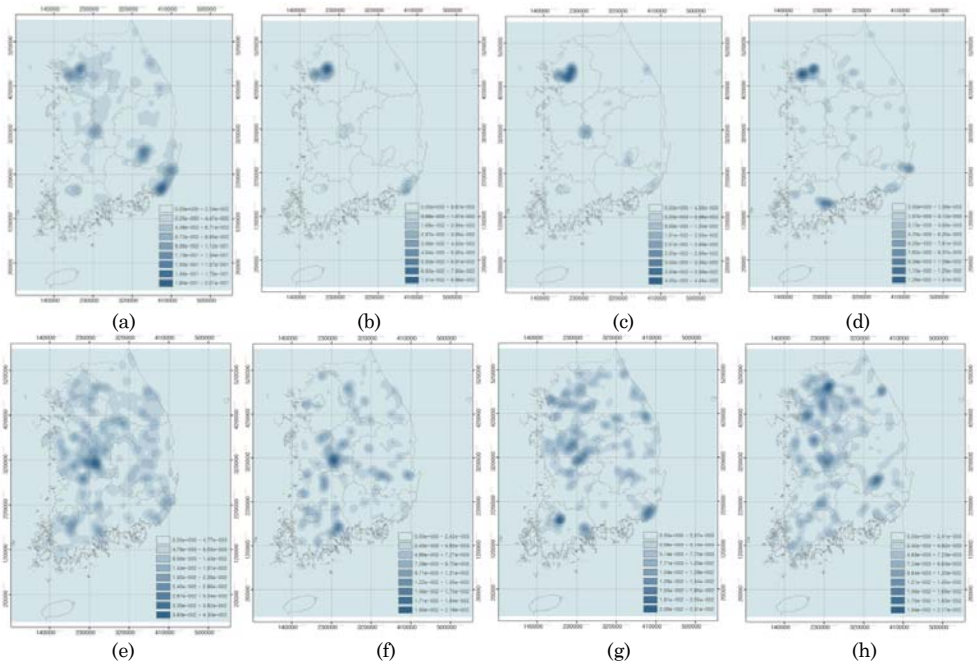


Figure 3. Kernel intensity of each (a) climber's fire (b) cigarette (c) children's fire (d) arson (e) field incineration (f) agricultural waste incineration (g) trash incineration (h) mistakes of visitors to ancestral tomb

4.2 Ripley's K function

All data indicate that clustering was high throughout the whole country. Through the Ripley's K analysis, we could recognize the point concentration depend on distance of each fire occurrence. Forest fire occurred by trash incineration and mistakes of visitors to ancestral tombs was highly clustered between 50km and 60km. Forest fires caused by cigarette formed cluster in the distance of 34.54km. Forest fire occurred by children's accidental fire has high clustering in the distance of 31.09km.

Ripley's K function supposes homogeneous space, and considers all points as equivalent. This makes it difficult to apply to real topography. To overcome this problem, we can use Generalized K function. It used in inhomogeneous space. However it is necessary to verify probability map.

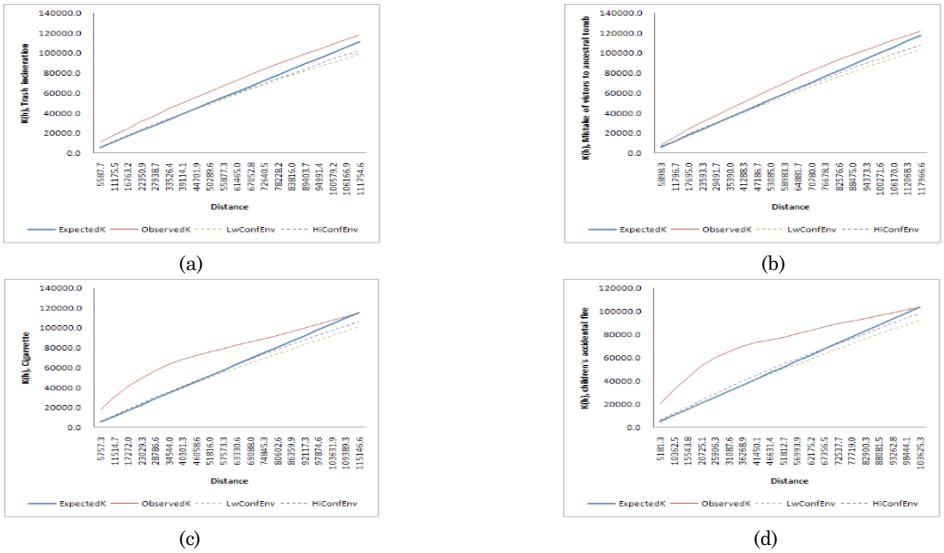


Figure 4. Ripley's K Function (a) trash incineration (b) mistakes of visitors to ancestral tomb (c) cigarette (d) children's fire

4.3 Poisson regression

Table 1 showed the result of Poisson regression. Forest fire occurrences are statistically proven to be influenced by elevation, slope, population density, distance from road, relative humidity.

Table 1. Estimated coefficients of Poisson regression

Variable	Coefficient	S.E	Pr > |Z|
Constant	1.0350	0.1251	<.0001
Elevation	-0.0003	0.0001	0.0014
Slope	0.0045	0.0020	0.0270
Population density	0.0002	0.0000	<.0001
Distance to nearest road	-0.0116	0.0059	0.0467
Relative humidity	-0.0056	0.0021	0.0068

Forest fire probability map was drawn from results derived by probability function of Poisson regression.

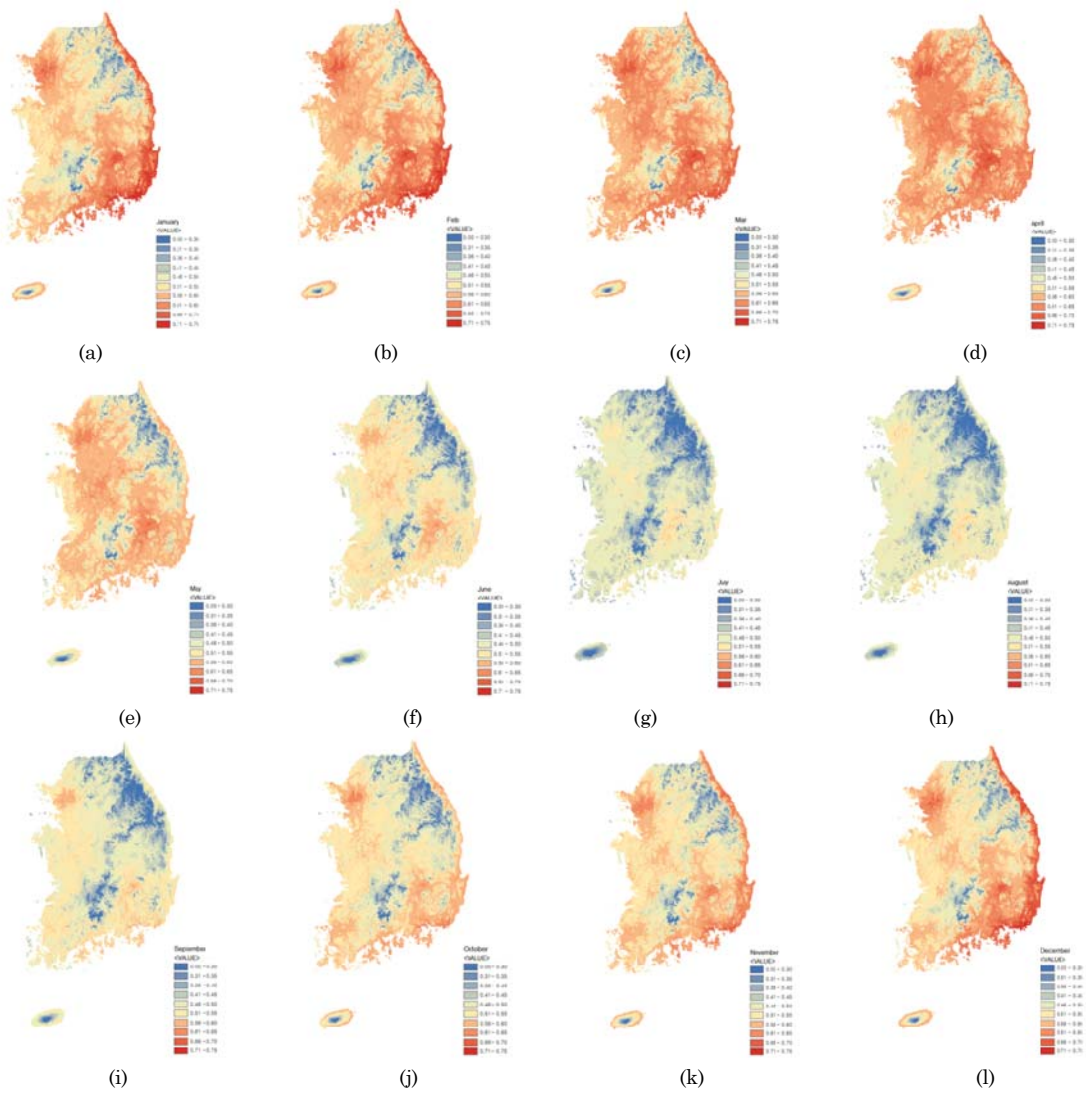


Figure 5. Forest fire risk map of each month (a) January (b)February (c)March (d)April (e) May (f) June (g) July (h) August (i) September (j) October (k) November (l) December

5. Reference

Dixon P. M., 2002, Ripley's K function, Encyclopedia of Environmetrics, 1(3): 1796-1803

Larsen C. P. S., 1997, Spatial and Temporal Variations in Boreal Forest Fire Frequency in Alberta, Journal of Biogeography, 24(5): 663-673

Marcon E. and Puech F., 2009, Generalizing Ripley's K function to inhomogeneous populations, Working Papers halshs-00372631_v1, HAL

Moore J., 2000, Forest fire and human interaction in the early Holocene woodlands of Britain, Palaeogeography, Palaecoclimatology, Palaeoecology 164: 125~137

Pew K.L. and Larsen C.P.S., 2001, GIS analysis of spatial and temporal patterns of human-caused wildfires in the temperate rain forest of Vancouver Island, Canada, Forest Ecology and Management 140: 1-18

Skold M., 1996, Kernel Intensity Estimation for marks and crossing of differentiable stochastic process, Theory of Stochastic Processes, 2(18): 273-284.

Syphard A. D., Radeloff V. C., Keeley J. E., Hawbaker T. J., Murray K., Stewart S. I., Hammer R. B., 2007, Human Influence on California Fire Regimes, Ecological Applications, 17(5): 1388-1402

Yang J., He H. S., Shifley S. R., Gustafson E. J., 2007, Spatial Patterns of Modern Period Human-Caused Fire Occurrence in Missouri Ozark Highlands, Forest Science 53(1): 1-15