

# An Innovative Method For Forest Fire Risk Zoning Map Using Fuzzy Inference System And GIS

<sup>[1]</sup> A.poonguzhali, <sup>[2]</sup> Sushmitha B.R, <sup>[3]</sup> Swati Nagaraj Mesta, <sup>[4]</sup> Soundarya R, <sup>[5]</sup> Vanajakshi M  
Department of Electronics and Communication Engineering  
Sri Sairam College Of Engineering, Anekal

**Abstract:** - Forest Fire causes considerable environmental damage and brings about a significant change in the ecosystem of the region. It is a humanistic and a national duty to protect against fire the forests. Most of such forest fire incidents result from human nonchalance. Other causes such as thunderstorm, glass objects and etc. are also considered as triggers of such incidents, this paper mainly focuses upon the human factor. The considered parameters such as distance from the road, residential areas, river, slope, climate and type of vegetation, and GIS play a significant role in the analysis and determining the factors impacting fire incidents. GIS was used for the analysis and calculations required in regard with these parameters. Therefore the locations with fire risk are determined by a combination of experimental model, fuzzy inference system and GIS. The obtained results indicate high accuracy and good efficiency. The results discussed extensively in the paper. To evaluate the proposed method, the obtained results were compared with fire incidents of past years. The comparison results indicate an improvement in predication by this method in comparison with other methods

**Keywords:** Forest Fire Risk Zoning Map, GIS, Fuzzy Inference System, Experimental Model.

## I. INTRODUCTION

Forest fire is not dependent on a specific season, but most of forest fire incidents of Golestan Province have occurred when trees have been dry and the ground has been thick with dead leaves. The fact that the region is frequented by tourists has led to widespread fire incidents in Golestan Forest. Tourists' disregard of safety regulations such as not putting out their fire before leaving the region and etc. has led to many undesired and serious fire incidents [1]. The biggest fire incident happened in November 2010 which lasted for several weeks and burned a large area of the forest. Repeated fire incidents have destroyed the soil texture of the region which in some cases has destroyed some plant species and has generally made the plant growth problematic. Studies on the behavior of fire and its impact factors will certainly prepare us for prevention and protection against such incidents [2]. Many countries make use of satellite images for monitoring fire incidents and detecting the burning regions. Forest fires are generally categorized into two types: ground fire and crown fire. Ground fires mostly consume the dead leaves, shrubs and small trees. This type of fire is used in several regions such as Africa for prevention of unwanted fires. In this system,

the speed and direction of wind are simulated by various methods such as Cellular Automata to extinguish fire in certain areas [3]. The second type of fire, the crown fire, is considered as one of the most dangerous and detrimental types of fire[4]. Most of the fires experienced in Golestan forest have unfortunately been of crown type. Controlling this type of fire is of great difficulty and requires advanced equipment. For on-time and optimum allocation of resources and equipment during fire incident, a fire spread simulation system is required. Various factors, such as density and type of vegetation, humidity, temperature, slope, distance from road and residential area, may trigger and affect fire incidents. Such factors can be found more in lawns and bushy areas than in forest areas with oak and beech trees. Humidity, on the other hand, as one of the significant impact factors, has a greater effect on bushy areas than on forests. In case the flammable materials (e.g. the grass) are humid, the risk of fire for such materials reaches its minimum [5]. In general, fire incidents can be classified into three groups: natural fire incidents, intentional man-made fires and unintentional man-made fires caused by human carelessness [6]. The second group, intentional man-made fires, is taken into consideration in this study for preparation of the fire map. The risk potential has been prepared according to fuzzy inference method and using factors such as slope,

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climate, vegetation, and distance from road, river and residential areas. This potential risk map can be used for preventive operations as well as for optimum and timely allocation of resources and equipment during such incidents. More patrols and sentinels can be deployed in regions with high fire risk during fire seasons. With regard to unprotected regions with great fire potential, access roads can be built to such areas so the transfer time of resources to these regions during fire incidents reaches its minimum. According to Adab [7] can be mentioned as one of the Iranian studies carried out on this subject. They conducted the zoning of fire potential in forest areas of Mazandaran province per all seasons of 2005 as well as a 15- year period based on the Molgan predictive index and using GIS. To evaluate the efficiency of the model, the results of the year 2005 was compared with the number of test fire incidents and then the correlation of the year in question with the past 15 years.

The obtained results indicated that the model was of significant efficiency for all seasons save for winter and for all years from a spatial viewpoint. Akbari [8] proposed a simple model for mapping fire risk and fire alarm in forest areas using remote sensing. Regions with high fire risk can be recognized by this model and using satellite images and topographic model of the region. Regions with high risk are determined by formulation of the three factors namely the slope, direction of slope and Normalized Difference Vegetation Index (NDVI), which have an impact on the above issue, and their application on the image. Eskandari [9] assessed the model proposed by Dong, Li-min [10] by its application on Neka area forests as well; the model proved efficient for this area. They conducted the zoning of the area using parameters such as vegetation, slope, geographical direction, height above sea level, and distance from roads and residential areas. Eskandari [9] ultimately showed that 34 percent of the region in question was critically high risk and high risk. He also showed that 40 percent of the area was involved in past year fire incidents. Chuvieco and Congalton [11] can be mentioned as a sample of non-Iranian studies carried out on this subject. They prepared the map of the regions on Spanish Shores critically exposed to fire risk using a combination of TM Image Processed Data and other input in GIS environment. The layers were merged according to AHP. The obtained map of regions was mapped to the regions which were consumed by the real fire incident. The mapping results indicated that 22 percent of the pixels which were situated on high risk areas were actually burnt in past year fires while only 3.47 percent of the low risk areas were involved in the real fire incidents. Alimedia [12] also made a map of Portugal forest regions with high risks of fire based on parameters such as forest species, slope, geographical direction, distance from roads and permanent rivers. The

variables were categorized based on their risk ratio and the data were analyzed in GIS environment. The obtained result was 5 classes of risk for the region. The risky regions had slopes of more than 40 percent, direction of 135 to 225 degrees, covered with trees and bushes and were located 30 meters from permanent rivers. Giri and Shrestha [13] studied the causes of forest fires which took place in 1998 in Huay Kha Khaneg resort of Thailand using TM satellite images. Then the burned areas were depicted by interpretation of TM images. For assessing the accuracy and effects of fire, several samples were taken from burned and unburned areas using GPS. The results indicated 88.3 percent classification accuracy for the burned areas. The obtained results suggested various reasons for the fire incident in this resort but most of the causes were determined as unintentional. It was finally suggested to create a database in GIS, comprising variables influencing fire incidents, for topography of high risk areas as well as simulation of forest fire incidents. [10] developed a hybrid method comprising GIS and RS for topography of high risk regions in Baihe Forest area of China; therefore, topographic data were obtained from DEM of the region and information related to vegetation type and application of lands (roads, residential areas, and etc.) were extracted from Landsat ETM+ images. Then the high risk areas were determined by assigning reasonable weights to all layers. The history of fire incidents which had taken place from 1974 to 2001 in the under study forest was reviewed for the efficiency of the method. The results indicated that high risk regions were situated in areas which had already been involved in actual fire incidents. Esra Erten [14] mapped the high risk areas of Gali Puli forests in Turkey using data obtained from GIS and satellites. TM images were used before and after the fire incident. The remaining data were gathered from topographic map (1:25000) and were merged in GIS environment per their weight and significance in fire ignition. The results showed that fire potential is highest in regions which are covered with dry vegetation, have steep slope, face south, and are close to roads and residential areas.

## II. MATERIALS AND METHODS

### 2.1 Parameters Influencing Fire Risk Potential

As mentioned before, various parameters contribute to forest fires. The most important parameters are direction of slope, vegetation, climate, distance from road, river and residential areas [11].

#### 2.1.1 Slope

Observations made in regard with actual fire incidents, both ground fires and crown fires, which had happened in all regions, indicate the fact that fire spreads faster on upward slopes rather than downward slopes [15]. When a pixel is

burning, the distance between the flame and ground surface decreases on an upward slope and this leads to heat calorie transfer to the forward pixels. In contrast, when the fire spreads downward, the angle between the flame and ground surface increases which ultimately leads to a decrease in fire spread rate on downward slopes. This has been supported by both experimental and laboratory findings. In fact, the direction of slope and the height of the region play an important role in fire spread.

**2.1.2 Vegetation Cover**

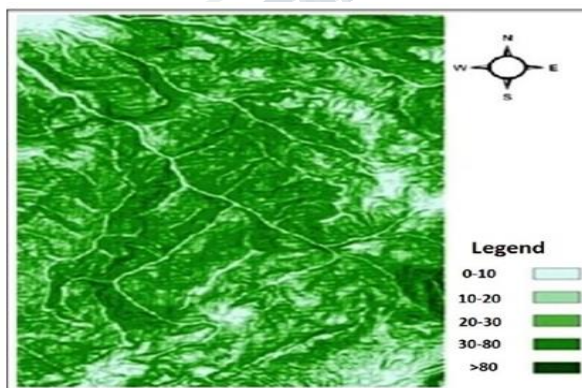
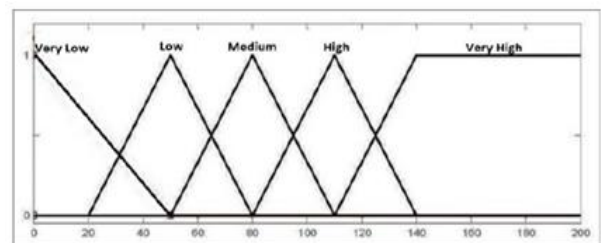
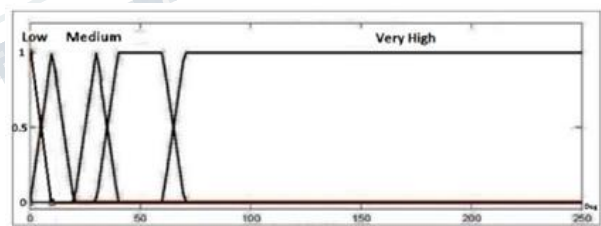
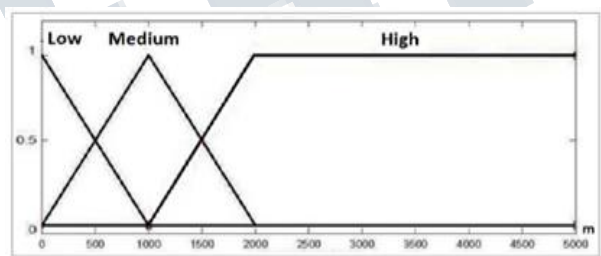
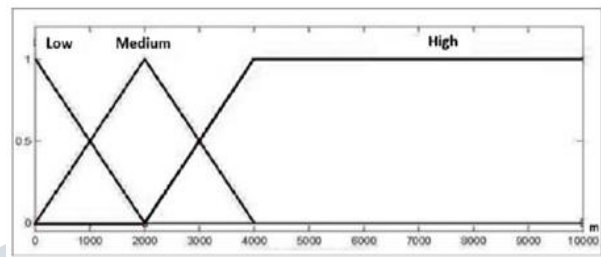
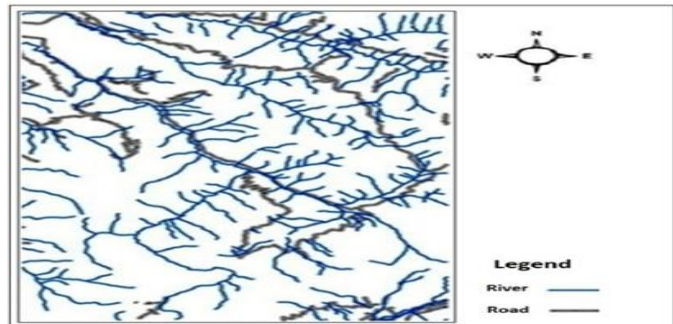
The most common vegetation cover of the region is dense crown top trees. Other different covers such as shrubs, agricultural lands, bushes and residential areas were also found in the region. Vegetation cover is one of the most significant fire factors. In most of the studies, vegetation is considered as the flammable material [15]. The flammability of each pixel is determined based on the type of vegetation cover. In fact, when the vegetation type is grass, in general and without considering the humidity, the flammability increases, Flammability decreases when approaching the crown trees with thick trunks.

**2.1.3 Climate**

Significant rainfall and humidity changes is observed from west to east of Golestan province. The Western part of the province, in comparison with the east side, is of greater humidity as it is closer to Caspian Sea. The humidity level of a region can be classified by different methods among which the Do Martin and Karimi Method can be mentioned of which the former method, the Do Martin Method, is employed in this study. According to this method, the region is classified into 6 classes.

**2.1.4 Distance from Residential Areas**

Residential areas located by the side of forests as well as villages situated inside forests are counted as threats to forests. The inhabitants' inattention, especially during dry seasons and autumn



when trees are prone to catching fire, and when large dead leaf litters spread on forest ground, the fire risk heights dramatically [11].

### 2.1.5 Distance from Roads

Needless to say, roads are the main channels of a country and most of the trips are land trips made on roads. What makes this issue important for Golestan Province and the region under study is the fact that roads pass through or by forests. Apart from roads leading to tourist destinations, the transit road of Mashhad-Gorgan also passes through Golestan forests. From a tourist viewpoint, this is an ideal opportunity, but from an environmental viewpoint, this counts as a potential threat to the forest as it may cause fires. Tourist and travellers' inattention to safety rules regarding not starting any fire in the forest or making sure to put out the fire after leaving their camp are considered as the main factors causing fire incidents [4].

## III. RESULT AND DISCUSSION

The region under study is part of Golestan province forests with an area of 55 thousand hectares spreading in Minoodasht town. Minoodasht is surrounded by Semnan and Khorasan province from south, Khorasan province from east, Gonbad-e-Kavoos from west and Kalale town from north. The geographical specification of the region under study is as follows: (Figure 2 shows a view of the region under study). The coordinate system is UTM (WGS 84 Ellipsoid) and zone number is 40.

## IV. CONCLUSION & RECOMMENDATIONS

This study yielded a fire risk potential map based on a combination of GIS and fuzzy inference engine and by incorporating important human factors which play a role in fire forests. The results show that combination of GIS, fuzzy inference systems and experimental model can be of great avail as a proposed model for management and prediction of forest fires. In fact, the capability of this model for incorporation and modeling of parameters impacting forest fire risk makes the utilization of this model as a tool for management of forest fires inevitable. As results show, most of the regions exposed to fire risk are located in the vicinity of rivers and roads as places which are frequented by tourists and travellers more than other sites. This map can be utilized for efficient allocation of facilities and fire-fighting resources. Regions with higher risks are of greater priority. Also more patrol resources and watchtowers can be employed in fire-prone seasons in regions with higher risks. With regard to unprotected regions with great potential of fire, access roads can be built to such areas so the transfer time of resources to these regions during fire incidents reaches its minimum. Parameters such as slope, climate, vegetation cover, and distance from rivers, roads and residential areas are taken

into consideration in this study. Other parameters such as annual rainfall level, direction and speed of wind, and etc. can also be considered for a better result. The fire risk potential map can even be calculated for various seasons. Factors mentioned in this study take the share of human factor into account more. Risk of natural phenomena such as thunder can also be considered in future studies. Although the mentioned phenomenon has a smaller share of fire incidents occurred to date, it can be studied as one of fire triggers. It is also recommended to use the proposed model for other regions to verify its accuracy for other regions as well.

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