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FOREST FIRE HAZARD MAPPING USING FUZZY AHP AND GIS STUDY AREA: GILAN PROVINCE OF IRAN

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Abstract- Forests are one of the important natural resources that have various ecological, economic, educational and social benefits. This valuable resource has been recently degraded by numerous causes, whether man made or natural. Forest fires can be named as one of these factors, which are putting forests in danger all around the world. Although fires are in some cases beneficial but due to increasing human-caused forest fires, it is crucial to define an efficient system that enables planners to prevent and control the fires. The purpose of this paper is to achieve a fire hazard map, indicating fire prone regions that are prepared by integrating several data such as: Slope, Elevation, Insolation, Vegetation Density, Distance from Roads etc. Gilan Province in north of Iran was selected as the study area due to its high density of Forest and frequent fire reports. As far as all these factors are not equally impressing fire ignition and spread, a multi criteria model was used to grade the factors. FAHP (Fuzzy Analytical Hierarchy Process) was the method used in this research to weigh the parameters between 0 to 1. Then, all the weighted layers were overlaid in GIS. To assess the accuracy of forecasted combustion regions, the final hazard map was compared with another layer including areas with high frequency of fire according to 5 years fire history data of studied area. The agreement between these two maps shows the reliability of this method. In accordance with results, proximity to roads and villages are the main factors that influence even topographic parameters and play main role in ignition and consequently forest demolishing.

Keywords: Forest Fire Hazard Mapping, Fuzzy Logics, Analytical Hierarchy Process, GIS, Forest Management.

I. INTRODUCTION

Forests are crucial for the well-being of humanity. They provide foundations for life on the Earth through ecological functions, by regulating the climate and water resources, and by serving as habitats for plants and animals. Forests also furnish a wide range of essential goods such as wood, food, fodder and medicines, in addition to opportunities for recreation, spiritual renewal and other services. Today, forests are under pressure from expanding human populations, which frequently leads to the conversion or degradation of forests into unsustainable forms of land use. When forests are lost or severely degraded, their capacity to function as regulators of the environment is also lost, increasing flood and erosion hazards, reducing soil fertility, and contributing to the loss of plant and animal life.

As a result, the sustainable provision of goods and services from forests is jeopardized [12]. Forest covers in recent times have been subjected to pressures not only from human beings, but also from natural calamities such as fire, floods and cyclone. Frequent occurrences of uncontrolled forest fires have caused adverse impacts [5]. On one hand, fire plays an important role in the creation and maintenance of landscape structure, composition, function, and ecological integrity and can influence the rates and processes of ecological succession and encroachment [28]. On the other hand, forest fires are considered to be a potential hazard with physical, biological, ecological and environmental consequences [15]. The total damage from the forest fires is very large [24]. The impact of fires at local, regional, and global scales has been recently reviewed in Stolle and Lambin (2003) and Lentile et al. (2006). For example, at the local scale, fire can stimulate soil microbial processes and combust vegetation ultimately altering the structure and composition of both soils and vegetation [18]. Also, at the regional and global scales, combustion of forest and grassland vegetation releases large volumes of radiatively active gases, pyrogenic aerosols, and other chemically active species that significantly influence the Earth's radiative budget and atmospheric chemistry, impacting air quality and raise concern about risks to human health. Considering these impacts, understanding the causative factors of fire including fire effects and ecosystem response is a challenge to research and management [28].

The causes of the forest fires can be classified into three main categories (i) natural causes, (ii) intentionally/deliberately caused by man and (iii) unintentionally/accidentally caused by man [15]. A major problem for forest management is that little is known of current fire frequencies and affected areas. It is essential to map forest fire risk zones to minimize frequency of fire by taking appropriate fire prevention measures, avert damage, etc [26]. Most importantly, the overriding role of anthropogenic factors in regulating fire events in addition to climate, vegetation, and topographic factors makes fire risk prediction highly challenging [28]. Dependence of forest fire on such spatial parameters has made the application of GIS techniques feasible for classifying a geographical area into different degree of fire risk. GIS has been known as a wonderful tool in analyzing different layers to come up at a conclusion.

According to FAO's terminology, forest "fire risk is the chance of a fire starting as determined by the presence and activity of any causative agent" [12].To put it in other words, forest fire risk zones are locations where a fire is likely to start, and from where it can easily spread to other areas [15]. Anticipation of factors influencing the occurrence of fire and understanding the dynamic behaviour of fire are critical aspects of fire management. A precise evaluation of forest fire problems and decisions on solution methods can only be satisfactorily made when a fire risk zone map is available [15].

During the last decades, several fire risk indexes have been introduced using different techniques. Fire risk assessment has matured in the last two decades ago [7] as evidenced by the increasing number of such studies. This can be attributed to greater availability of digital and statistical information incorporated within geographical information systems (GIS) and the advancement in remote sensing technology [8]. Many of the fire risk or hazard evaluation studies using GIS have applied probabilistic methods such as logistic regression (e.g. Hernandez-Leal et al. 2006), fuzzy logic (e.g. Iliadis 2005), neural networks [30], and classification trees [19].

Integration of multi-criteria decision making (MCDM) methods in spatial domain provides a novel framework for addressing several environmental problems, including quantifying "fire risk." For example, MCDM methods have been developed to solve conflicting preferences among criteria [16]. Rational decision making requires combining both objective and subjective criterion [23]. Of the several algorithms, since fuzzy linguistic models permit the translation of verbal expressions into numerical values, MCDM methods based on fuzzy relations were used quite successfully [21]. Fuzzy set theory is an extension of classical set theory. Fuzziness is a type of imprecision, associated with sets in which there is no sharp transition from membership to nonmembership [32]. The membership grade of an object can range from 0 to 1. The value of 1 denotes full membership, whereas the closer the value is to 0, the weaker the object's membership is in the fuzzy set. Fuzzy set eliminates the sharp boundary, which divides members and nonmembers in a crisp set, by providing a transition between the full membership and nonmembership [19].

Continuous fuzzy classes can be constructed based on the central concepts of classes that are defined a priori using experience and scientific or heuristic knowledge. The linguistic knowledge can be used to summarize information about a complex phenomenon and then converting to numerical data for further processing [31].

II. STUDY AREA

Gilan Province lies along the Caspian Sea, just west of the province of Mazandaran, east of the province of Ardabil, north of the provinces of Zanjan and Qazvin. Gilan has a humid subtropical climate with by a large margin the heaviest rainfall in Iran (Figure 1): reaching as high as 1,900 millimeters (75 in) in the southwestern coast and generally around 1,400 millimeters (55 in). Rainfall is heaviest between September and December because the onshore winds from the Siberian High are strongest, but it occurs throughout the year though least abundantly from April to July. Humidity is very high because of the marshy character of the coastal plains and can reach 90 percent in summer for wet bulb temperatures of over 26 °C (79 °F). The Alborz range provides further diversity to the land in addition to the Caspian coasts.

The area studied in this paper consists of 3 zones; 17, 18 and 19 named respectively "Shaft", "Rasht" and "Rudbar" according to National Forestry Department. This study area covers an area of 695 Km^2.

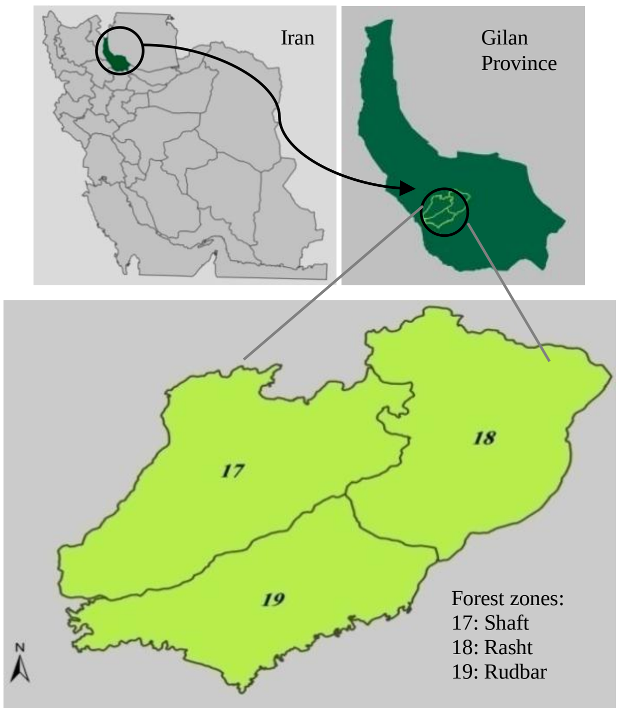

Figure 1. Location map of study area

III. METHODOLOGY

In this study, Saaty's (2000) analytical hierarchy process was utilized, a MCDM methodology in conjunction with fuzzy logic, in a participatory decision-making framework to rank and prioritize the causative factors of fire risk in the study area. Our methodology consisted of four different components: (A) hierarchical structure development of fire risk criteria, (B) weights determination at different levels of hierarchy using linguistic variables and fuzzy sets, (C) assigning criteria weights in GIS and mapping the fire hazard, (D) assessing the agreement between Fire Hazard Map and Fire History Map.

A. Hierarchical Structure Development of Fire Risk Criteria

Figure 2 shows the hierarchical structure of fire danger mapping. In order to estimate the wild fire potential, different factors were used, involved:

A.1. Topographic Factors

For the past several years, fire behavior models have incorporated the interaction of fire spread with fuels, weather, and terrain [1]. The effect of terrain attributes on forest survival following wildfire has been assessed by Kushla and Ripple (1997) and others [1, 8, 14, 28]. Topography is one of the main factors included in any fire hazard rating system [7]. We used three topographic factors, as:

a. Slope: Slope is considered as the crucial factor. It is an indicator of rate of change of elevation (degrees). Slope affects both the rate and direction of the fire spread. Fires usually move faster uphill than downhill [28].

b. Aspect: Describes the direction of the maximum rate of change in elevation between each cell and its neighbors. A slope with an east aspect will get direct sunlight earlier in the day than a slope with a west aspect. Also, a north-facing slope receives less sunlight than a south facing slope. Thus, Southern aspects receive more direct heat from the sun, drying both the soil and the vegetation [28].

c. Elevation: It is an important physiographic factor that is related to wind behavior and hence affects fire proneness. Fire travels most rapidly up-slope and least rapidly down-slope (Figure 3).

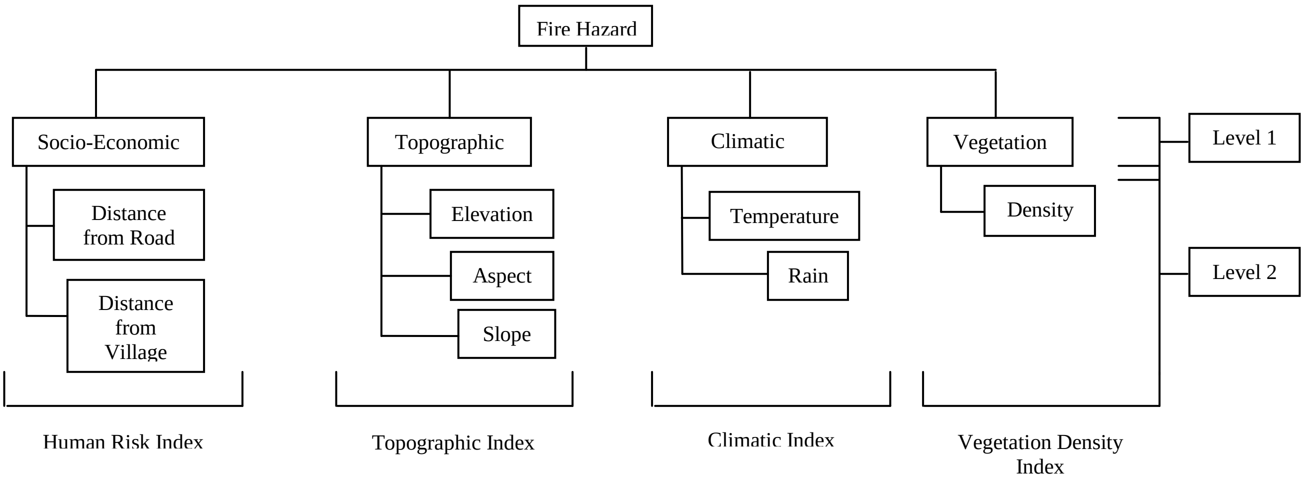

Figure 2. Hierarchiacal structure of fire danger mapping

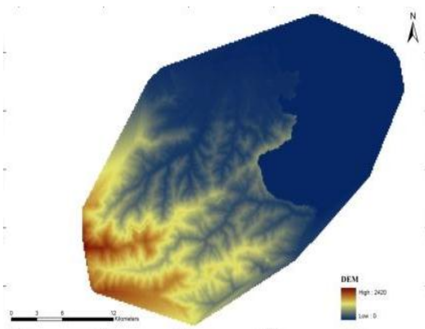

Figure 3. Digital elevation model of study area

A.2. Socio-Economic Factors

Because of complex essence of wild fires, not only physical factors, but also other factors influencing it, must be taken into consideration. One of them is Socio-Economic factors that are related to the tribal people dwelling in the vicinity of the forests and their livelihood depends on timber. On the other hand, road network is the other crucial factor, related to human existence in forest regions. In order to assign these factors into Fire hazard map, distance from village and distance from road were selected as a index of socio- economic factors.

a. Distance from Village: The nearest to villages, the highest the danger of combustion. Studies reveal that dwellers fire the forests deliberately to provide enough fields for pasture and cultivation (Figure 4).

b. Distance from Road: Forest fires are ignited either by people or some natural agents such as lightning. The areas nearer to roads were considered more hazardous compared to others (Figure 5).

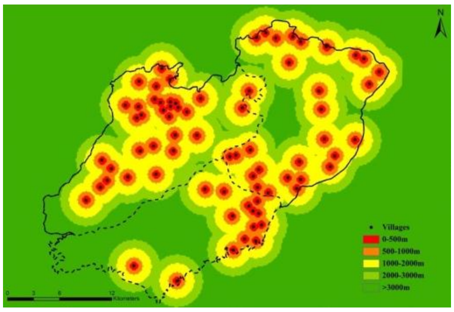

Figure 4. Distance from villages map

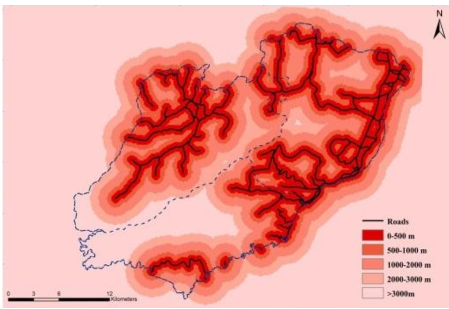

Figure 5. Distance from roads map

A.3. Climatic Factors

Fire occurrence, frequency, as well as intensity are primarily dependent on climate, directly through weather conditions, which allow ignition, and indirectly through the supply of sufficient vegetation fuel load to sustain fire. Climatic and weather factors also play an important role in fire spread and behavior. In this study, we used temperature as well as precipitation as modulating parameters of forest fires in the study region [28] (Figures 6 and 7).

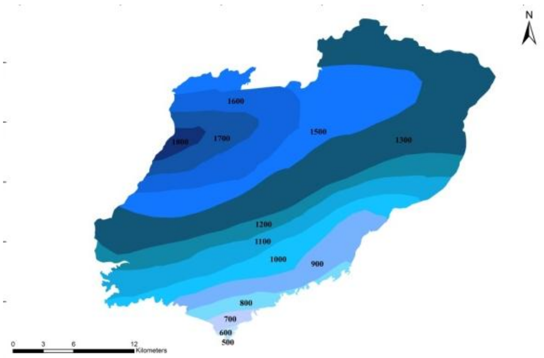

Figure 6. Iso rain map

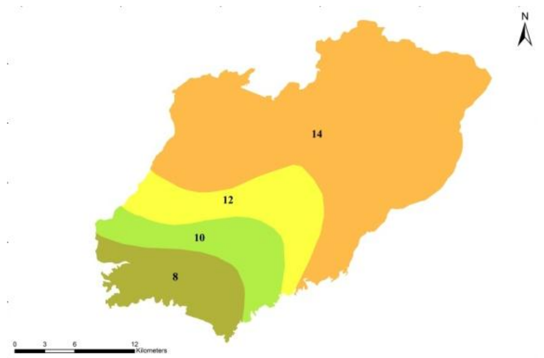

Figure 7. Iso temperature map

A.4. Vegetation

The forest density is largely responsible for the weight and compactness of fuel load which determines the amount of biomass available for burning [5]. Vulnerability of the forest fuels to fire has been mapped based on vegetation density map (Figure 8).

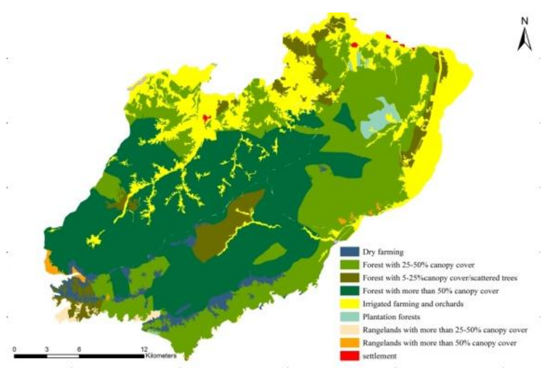

Figure 8. Vegetation density map

B. Weights Determination at Different Levels of Hierarchy Using Linguistic Variables and Fuzzy Sets

Saaty`s (2002) analytical hierarchy process was used to rank the causative factors and prioritize them verbally. This process took place in Expert Choice software, enabling us to lead the pair wise comparisons with acceptable inconsistency rate of less than 0.1 in 3 levels between the primary factors including: Topographic, Socio-Economic, Climatic and Vegetation; secondary factors that are the different classes of each primary factor and finally the third level of factors that are sub-classes of each secondary factor.

The core of the AHP Saaty's (2000) method is an ordinal pair wise comparison of all criteria. In other words, it addresses preference statements. Per pair of criteria, a group of experts were asked to determine to which degree a criterion is more important than the others. By means of these comparisons, the method defines the relative position of one criterion in relation to all other criteria. By using an Eigen value matrix technique, quantitative weights can be assigned to the criteria.

The Saaty's method employs a semantic nine-point scale for the assignment of priority values. This scale relates numbers to judgments, which express the possible results of the comparison in qualitative terms. In this way, different elements can be weighed with a homogenous measurement scale. Through this method, the weight assigned to each single criterion reflects the importance which every expert involved in the project attaches to the objectives. Although the discrete scale of 1 to 9 has the advantages of simplicity and ease of use, it does not take into account the uncertainty associated with mapping of one's perception (or judgment of a number).

Table 1. Saaty's AHP rating (Saaty, 2000) and their fuzzy equalities

Linguistic Variables	Triangular Fuzzy Numbers	Reciprocal Triangular Fuzzy Numbers	Explanation
Extremely Strong	(8,8,9)	(0.11,0.11,0.13)	The evidence favoring one over the other is of highest possible validity
Very Strong	(6,7,8)	(0.13,0.14,0.17)	Experience and judgment very strongly favour one over the other. Its importance is demonstrated in practice
Strong	(4,5,6)	(0.17,0.2,0.25)	Experience and judgment strongly favour one over the other
Moderately Strong	(2,3,4)	(0.25,0.33,0.5)	Experience and judgment slightly favour one over the other
Equally Strong	(1,1,2)	(0.5,1,1)	Two factors contribute equally to the objective
Intermediate	(7,8,9); (5,6,7); (3,4,5); (1,2,3)	(0.11,0.13,0.14); (0.14,0.17,0.2); (0.2,0.25,0.33); (0.33,0.5,1)	When compromise is needed

In order to deal with vagueness of human thought, Zadeh (1965) first introduced the fuzzy set theory. Fuzzy logic (FL) is defined as the logic of human thought, which is much less rigid than the calculations computers generally perform [2]. A fuzzy set is a class of objects with a continuum of grades of membership. Such a set is characterized by a membership function which assigns to each object a grade of membership ranging between zero and one [32]. A fuzzy set is an extension of a crisp set. Crisp sets only allow full membership or nonmembership at all, whereas fuzzy sets allow partial membership. In other words, an element may partially belong to a fuzzy set [10].

Fuzzy sets and fuzzy logic are powerful mathematical tools for modeling: uncertain systems in industry, nature and humanity; and facilitators for commonsense reasoning in decision-making in the absence of complete and precise information. Their role is significant when applied to complex phenomena not easily described by traditional mathematical methods, especially when the goal is to find a good approximate solution [3]. A fuzzy subset *A* of a universe of discourse *U* is characterized by a membership function μ_A [27]. That is,

$$\mu_A : U \to [0,1] \tag{1}$$

where $\mu_A(x)$ is the membership of *x* in *A*; that is, μ_A serves as the membership function by which a fuzzy set *A* is defined (Bellman and Zadeh 1970).

Multiple methods can be used to determine the membership values, e.g., depending on the amount of a priori information available [28]. In this study, triangular fuzzy function was utilized. Triangular fuzzy numbers can be defined as a triplet (l,m,u). The parameters *l*, *m*, and *u* respectively, indicate the smallest possible value, the most promising value, and the largest possible value that describe a fuzzy event. A triangular fuzzy number M is shown in Figure 9.

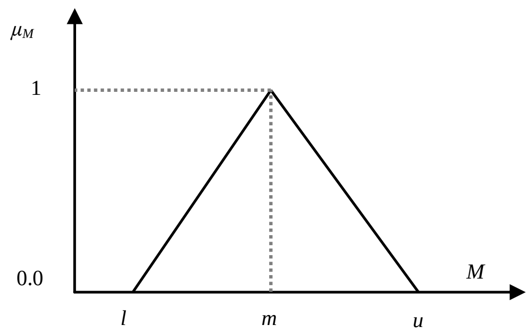

Figure 9. A fuzzy triangular number

The first study of fuzzy AHP is proposed by Van Laarhoven and Pedrycz (1983), which compared fuzzy ratios described by triangular fuzzy numbers. Buckley (1985) initiated trapezoidal fuzzy numbers to express the decision maker's evaluation on alternatives with respect to each criterion. Chang (1996) introduced a new approach for handling fuzzy AHP, with the use of triangular fuzzy numbers for pair-wise comparison scale of fuzzy AHP, and the use of the extent analysis method for the synthetic extent values of the pair-wise comparisons. Fuzzy AHP method is a popular approach for multiple criteria decision-making and has been widely used in the literature.

The steps of Chang's extent analysis can be given as in the following [6]:

Step 1: The value of fuzzy synthetic extent with respect to the i.th object is defined as:

$$S_i = \sum_{j=1}^{m} M_{gi}^{i} \otimes \left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^{i} \right]^{-1} \tag{2}$$

To obtain $\sum_{j=1}^{m} M_{gi}^{i}$ the fuzzy addition operation of *m* extent analysis values for a particular matrix is performed such as:

$$\sum_{j=1}^{m} M_{gi}^{i} = \left(\sum_{j=1}^{m} l_j, \sum_{j=1}^{m} m_j, \sum_{j=1}^{m} u_j \right) \tag{3}$$

and to obtain $\left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^{i} \right]^{-1}$, the fuzzy addition operation of values is performed such as:

$$M_{gi}^{i}(j = 1, 2, ..., m) \tag{4}$$

and then the inverse of the vector above is computed, such as:

$$\left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^{j} \right]^{-1} = \left(\frac{1}{\sum_{i=1}^{n} u_i}, \frac{1}{\sum_{i=1}^{n} m_i}, \frac{1}{\sum_{i=1}^{n} l_i} \right) \tag{5}$$

Step 2: As $M_1 = (l_1 + m_1 + n_1)$ and $M_2 = (l_2 + m_2 + n_2)$ are two triangular fuzzy numbers, the degree of possibility of $M_1 = (l_1 + m_1 + n_1) \geq M_2 = (l_2 + m_2 + n_2)$ is defined as:

$$V(M_2 \geq M_1) = \overset{\sup}{y \geq x} \left[\min(\mu_{M_1}(x), \mu_{M_2}(y)) \right] \tag{6}$$

and can be expressed as follows:

$$V(M_2 \geq M_1) = hgt(M_1 \cap M_2) = \mu_{M_2}(d) =$$

$$= \begin{cases} 1, & m_2 \geq m_1 \\ 0, & l_1 \geq u_2 \\ \dfrac{l_1 - u_2}{(m_2 - u_2) - (m_2 - l_1)}, & \text{otherwise} \end{cases} \tag{7}$$

Figure 10 illustrates Equation (7) where d is the ordinate of the highest intersection point *D* between μ_{M_1} and μ_{M_2}. To compare M_1 and M_2, we need both the values of $V(M_1 \geq M_2)$ and $V(M_2 \geq M_1)$.

Step 3: The degree possibility for a convex fuzzy number to be greater than *k* convex fuzzy $M_i (i = 1, 2, ...k)$ numbers can be defined by:

$$V(M \geq M\_1, M\_2, \cdots, M\_k) =$$

$$V\left[(M \geq M\_1), (M \geq M\_2), \cdots, (M \geq M\_k) \right] =$$

$$\min(V(M \geq M\_1)), i = 1, 2, 3, \cdots, k$$

Assume that $d(A_i) = \min V(S_i \geq S_k)$ for $k = 1, 2, ..., n; k \neq i$. Then the weight vector is given by:

$$W' = (d'(A_1), d'(A_2), ..., d'(A_n))^T \tag{8}$$

where $A_i = (i = 1, 2, ..., n)$ are n elements.

Step 4: Via normalization, normalized weight vectors are:

$$w = [\frac{d(A_1)}{\sum_{i=1}^{n} d(A_1)}, \frac{d(A_2)}{\sum_{i=1}^{n} d(A_2)}, ..., \frac{d(A_n)}{\sum_{i=1}^{n} d(A_n)}]^T \tag{9}$$

where w is a non-fuzzy number. Appendix shows FAHP weights of effective factors, used in this research.

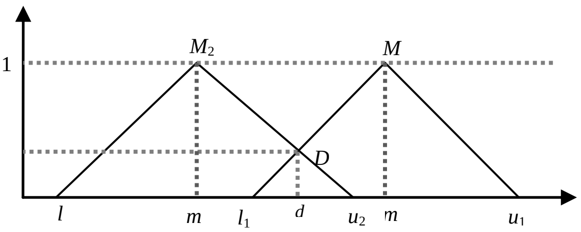

Figure 10. The degree of possibility

C. Assigning Criteria Weights in GIS

After calculating the weights of effective factors in 3level using fuzzy analytical hierarchy approach, they were assigned to each data layer in GIS; hence weighted map of each of them was gained. Regarding numerous factors, they were categorized into 4 Indexes:

1) Human Risk Index (*HRI*): consists of two secondary factors that are distance from village and distance from roads and their subclasses (Figure 11).

2) Topographic Index (*TI*): includes Slope, Elevation and Aspect as secondary factors and their subclasses (Figure 12).

3) Vegetation Density Index (*VDI*): different weighted vegetation covers with various densities are encompassed in this index (Figure 13).

4) Climatic Index (*CI*): Weighted Temperature and Rain layers and their subclasses define climatic index (Figure 14).

By weighted overlaying of these 4 indexes in GIS according to Equation (10), Fire hazard map (Figure 15) in study area is gained, which is classified in 5 categories due to value of danger from very low to very high. Fire danger index is equal to

$$FDI = HRI * 0.519 + TI * 0.382 + VDI * 0.075 + CI * 0.023 \tag{10}$$

Figure 16 shows the percentage of each class that occupies the studied area.

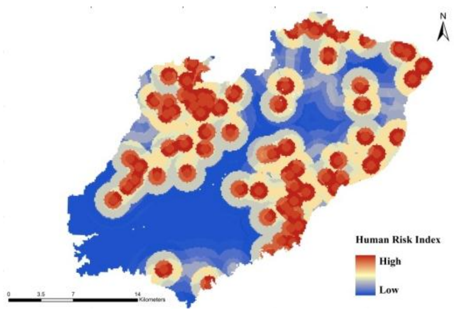

Figure 11. Human risk index map

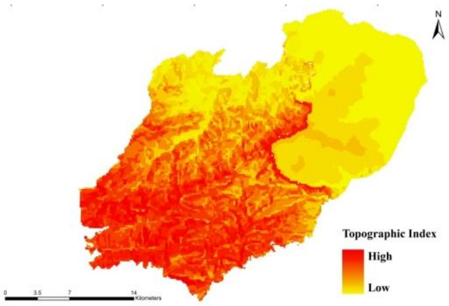

Figure 12. Topographic index map

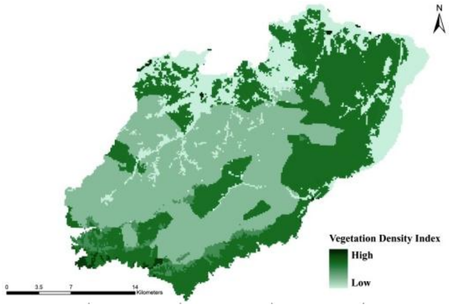

Figure 13. Vegetation density index map

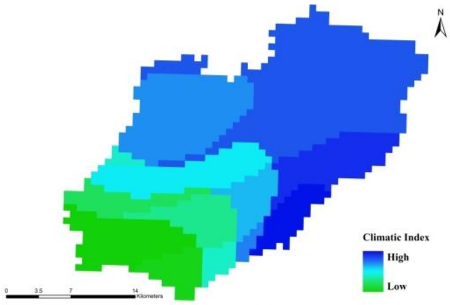

Figure 14. Climatic index map

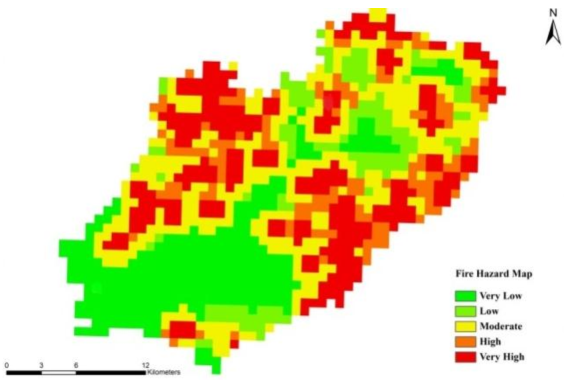

Figure 15. Fire hazard map

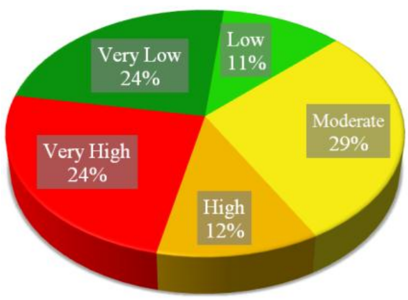

Figure 16. Area occupied by each fire class

D. Assessing the Accuracy of Fire Hazard Map

In order to assess the accuracy of estimated fire prone regions, 5 years histories of recorded fires in study area were collected and georeferenced, enabling us to have an independent map layer. To avoid taking accidental fires into account, only regions with high frequency of combustion during these 5 years were selected as crucial fire points. By overlaying this layer on Fire Hazard Map, 66% agreement between these two maps was recognized, denoting liability of these method and high accuracy of selected factors and their weighting.

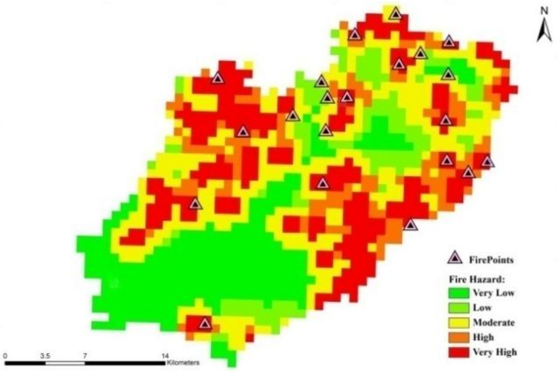

Figure 17. Agreement between fire hazard map & fire history data

IV. DISCUSSIONS

The above results clearly suggest highly dynamic and spatial nature of fire events in the study area. To manage growing forest fires and associated fire hazards, as well as to prioritize prescription efforts, it is essential to improve our understanding of the causative factors of fires. Earlier research relating to forest fire risk involved identifying the potentially contributing variables and integrating them into a mathematical expression, i.e., an index.

In creating such an index, most of the earlier researchers focused on using meteorological data alone [13] or vegetation parameters [22]. Predicting the nature of "fires" may not be easy through using such indices alone. The fuzzy AHP-integrated GIS model attempted in our study takes a different approach, compensating MCDM through codifying the expert knowledge for forest fire risk variables and combining it with the human biophysical dimension.

During this research, we came up with this result that, Social-Economic factors have the highest impact on fire ignition and spread in study area. Although other factors play enormous role in combustion, because of high density of roads and villages in northern part of area, as shown in figure 10 most crucial fire points are located there, this means, more attention must be paid to these parts to decline fire danger. There is a low agreement between Topographic Index map and fire history map that reveals the overestimated role of this index, because this factor has been overcome by human risk index. The acceptable agreement between Climatic and Vegetation density indices and fire history map determines precise indices should be taken into account while mapping fire danger.

V. CONCLUSIONS

Wildfires are the result of several underlying factors. In this study, we quantified fire risk as a function of topographic, vegetation, climatic, and socioeconomic attributes. To address the "fuzziness" in the spatial datasets and also to include the subjective judgments in the modeling process, we implemented fuzzy analytical hierarchy approach in GIS to assess fire risk in the study area. Results were quite useful in delineating potential "fire risk" zones at a district level. These results can be used both as a strategic planning tool to address broad-scale fire hazard concerns and also as a tactical guide to help managers in designing effective fire control measures at local level. In overall, this study demonstrates the potential of GIS technology and its viability in integrating objective as well as subjective data using fuzzy-AHP approach for assessing fire risk in the study area.

The areas shown under very high, high and moderate 'fire risk' zones are those areas where fire can be unintentionally caused by human activities, and where fire could thus certainly be averted by taking precautionary measures. Hence, despite the fact that no fire prone areas can be demarcated where fire occurs due to natural or intentional human causes, it is advantageous to have a fire risk map to avert possible disasters caused by fire due to human activities. It should be proved to be helpful to the Forest Department, as this type of fire risk zone map would enable the department to set up an appropriate fire-fighting infrastructure for the areas more prone to fire damage. Such a map would help in planning the main roads, subsidiary roads, inspection paths, watch towers etc. and may lead to a reliable communication and transport system to efficiently fight small and large forest fires.

APPENDIX

Weights Assigned to Criteria Affecting Wild Fire Using FAHP Algorithm

Primary Factors	FAHP weights	Secondary Factors	FAHP weights	Subclasses	FAHP weights
Topography	0.382	Slope	0.554	0-4%	0.027
				4-12%	0.060
				12-20%	0.190
				20-30%	0.309
				>30%	0.414
		Aspect	0.118	South	0.559
				East	0.317
				West	0.044

				North	0.068
				Plain	0.012
		Elevation	0.328	0-200m	0.036
				200-500 m	0.144
				500-1000 m	0.246
				1000-1500 m	0.337
				>1500 m	0.237
Socio-economic	0.519	Distance from Village	0.757	0-500 m	0.364
				500-1000 m	0.398
				1000-2000 m	0.222
				2000-3000 m	0.006
				>3000 m	0.021
		Distance from Road	0.243	0-500 m	0.488
				500-1000 m	0.269
				1000-2000 m	0.164
				2000-3000 m	0.061
				>3000 m	0.018
Climate	0.023	Temperature	0. 759	8°C	0.046
				10°C	0.191
				12°C	0.323
				14°C	0.440
		Precipitation	0.241	700-1000mm	0.440
				1000-1300 mm	0.323
				1300-1600 mm	0.191
				1600-1800 mm	0.046
Vegetation	0.075	Dry Farming			0.110
		Irrigated Farming			0.009
		Plantation Forests			0.144
		Forest with more than 50% canopy cover			0.059
		Forest with 25-50% canopy cover			0.144
		Forest with 5-25% canopy cover			0.141
		Rangeland with more than 50% canopy cover			0.149
		Rangeland with 25-50% canopy cover			0.196

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