Abstract—Forest fires are one of the major causes of ecological disturbance and environmental concerns in North- West of Iran. In this study, fuzzy set theory was used integrated with decision-making algorithm in a Geographic Information Systems (GIS) framework to map forest fire risk. Fuzzy set theory implements classes or groupings of data with boundaries that are not sharply defined (i.e. fuzzy) and consists of a rule base, membership functions, and an inference procedure. In this study, the Landsat 8 (OLI sensor) image was used(18th August 2013) in conjunction with topographic, vegetation, climate and distance to road, cities and villages datasets to infer the causative factors of fires. Spatial-level data on these biophysical parameters have been aggregated at the district level and have been organized in a GIS framework. A risk model for fire spreading is set up for Kaleybar city as a zone that continually faces with forest fire problem. Two important results for this study was recognized that including : (1), the south- west, southwest regions have the most potential and north- east, north regions have the lowest potential for forest fire. (2), potential of multi criteria analysis integrated with GIS as an effective tool in assessing "where" forest fires will most likely occur.

Keywords—Satellite images, Fuzzy set, Forest Fire Risk, Kaleybar

I. INTRODUCTION

Over the past few decades, forest fires in Iran have received increasing attention because of the wide range of ecological, economic, social, and political impacts. It is possible to map risk zone and thereby to minimize the frequency of fire and avert damage. Forest fire risk zones are locations where a fire is likely to start, and from where it can easily spread to other areas. Forest plays an important role in the creation and maintenance of landscape structure, composition, function, and ecological integrity [1][2][3] and can influence the rates and processes of ecological succession and encroachment. A great range of techniques have been used to model fire risk, from pure “crisp” mathematical models (usually based on the Rothermel(1983) equations), to cellular automata and computational intelligence techniques [4]. The more complex fire models require spatial information that is furnished by remote sensing and Geographic Information Systems (GIS) [5] Additionally, 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 [6]. MCDM is believed to be powerful technique for the analysis and prediction. It also provide a rich collection of technique for structuring decision problem and designing, evaluating and prioritizing alternative decision [7]. A precise evaluation of forest fire problems and decision on solutions can only be satisfactory when a fire risk zone mapping is available[8]. Understanding the behavior of forest fire, the factors that contribute to making an environment fire prone, and the factors that influence fire behavior are essential for forest fire [9] In the present study, an attempt was made to prepare a forest fire risk zone map by integrating a satellite image, topographical and other ancillary data from a geographic information system (GIS) for the Kaleybar forest where is one of the most forest fire sensitive area in Iran. Such maps will help forest department officials prevent or minimize fire risk activities within the forest and take proper action when fire breaks out [10].

II. METHODOLOGY

In this study, fuzzy logic was used, in a participatory decision-making framework to rank and prioritize the causative factors of fire risk in the study area. Our methodology consisted of three different components: (1), A Fuzzy Inference System for forest fire risk (2), Fuzzy Degree Membership Functions, (3) Performing Scenarios.

A. Fuzzy Inference System for Forest Fire Risk

Fuzzy logic is an intelligent control technique which was firstly introduced by Lotfi A. Zadeh in 1968 that enables the user to develop models that embody the experts experience and the available measurements through a set of easy to follow rules[11][12]. Fuzzy logic is a human Knowledge embodying tool through operational algorithms. Several intelligent Systems have been developed globally to estimate forest fire risk on an annual basis [13] and also for the estimation of risk due to natural hazards. In this study, topographic, vegetation, climatic, and distance from road,
cities and villages parameters was used for evaluating the fire risk using Fuzzy inference system. Detailed explanation for causative factors of fires is given below.

1. Topography

a. Slope: 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 [14].

b. Aspect: 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.

Vegetation Parameter

The Normalized Difference Vegetation Index (NDVI) is one of the oldest, most well known, and most frequently used VIs. The combination of its normalized difference formulation and use of the highest absorption and reflectance regions of chlorophyll make it robust over a wide range of conditions. Reason for use NDVI as a parameter for forest fire risk mapping was vegetation effect in forest fire starting and area with dry vegetation has highly likely for fire.

\[
NDVI = \frac{NIR - RED}{NIR + RED}
\]

2. Distance to settlements (cities and Villages) and Roads

Forests located near settlements can be said to be more fire prone since the people living there can cause an accidental fire. Crowded settlements are located within the forest in the study area, so they can cause forest fires [15]. In this study for considering effect of distance to settlements we made map of distance to villages and cities. In this map everywhere that be closer is more dangerous and these area need more attention. Forests that are accidental man-made can be resulted by the movements of humans, animals and vehicles. Thus, forests that are near roads are fire prone. This makes people and animals grazing there the cause of fire in the forest. With consider above issue we make map of distances, these maps consist of both road of settlements.

B. Fuzzy Degree Membership Functions

There is no optimal method for choosing the most appropriated FMFs (Fuzzy Membership Functions) and their respective parameters; these generally selected according to the preference of the decision makers [16]. In this respect, two types of membership function was used including: a) Near Fuzzy b) Fuzzy Linear (Based on four expert opinion).

1. Fuzzy Linear

The Fuzzy Linear transformation function applies a linear function between the user-specified minimum and maximum values. Anything below the minimum will be assigned a 0 (definitely not a member) and anything above the maximum a 1 (definitely a member). If the minimum is greater than the maximum, a negative linear relationship is established. (Fig.1)

2. Fuzzy Near

The Fuzzy Near transformation function is most useful if membership is near a specific value. The function is defined by a midpoint defining the center of the set, identifying definite membership and therefore assigned a 1. As values move from the midpoint, in both the positive and negative directions, membership decreases until it reaches 0, defining no membership. The spread defines the width and character of the transition zone. (Fig.1)

Fig.1: fuzzy based membership functions including: (Type 1) Near FMF for a) aspect (Type 2) Linear FMF for b) distance to city c) distance to road d) vegetation condition e) slope f) distance to village

C. Performing Scenarios

Geographic Information System (GIS) has also developed functions such as analyzing available information and using them as a decision and a support system as well as it compiles
the information as a whole and stores it (Jaiswal et al. 2001). In this study for produce final map GIS software with overly method of fuzzy overlay (type of and) was used. After producing final map, this map divided to four parts (very high, high, moderate and low) that demonstrate severity of forest fire probability.

III. RESULTS

A. Fuzzification of parameters

The Fuzzy Membership tool reclassifies or transforms the input data to a 0 to 1 scale based on the possibility of being a member of a specified set. 0 is assigned to those locations that are definitely not a member of the specified set, 1 is assigned to those values that are definitely a member of the specified set, and the entire range of possibilities between 0 and 1 are assigned to some level of possible membership (the larger the number, the greater the possibility). In this study, according of our primary maps (slope, aspect, distance to road, cities, villages, vegetation status maps) Linear and Near Fuzzy membership functions were selected. Linear function for slope, aspect, distance to settlements (cities and villages) and roads, vegetation status fuzzification was used. The Fuzzy Linear transformation function applies a linear function between the user-specified minimum and maximum values. For select minimum and maximum values expert opinions were used that including: 40 degree as a minimum value and 10 degree as a maximum value for slope, for village 500 m as a minimum and 5000 m as a maximum, for cities 1000 m as a minimum and 7000 m as a maximum, for road 200 m as a minimum and 3000 m as a maximum. There are obviously difference between Linear function that was used for slope and others (such as distance and vegetation status maps). In slope, the minimum degree set is greater than the maximum and a negative linear relationship is established. Near fuzzy transformation function was as a Secondary membership function that was used for aspect fuzzification. The Fuzzy Near transformation function is most useful if membership is near a specific value. The function is defined by a midpoint defining the center of the set, identifying definite membership and therefore assigned 1. As values move from the midpoint, in both the positive and negative directions, membership decreases until it reaches 0, defining no membership. The spread defines the width and character of the transition zone. With considering this fact that Southern aspects receive more direct heat from the sun, drying both the soil and the vegetation, therefore 1 degree set to south aspect (180 degree) (fire probability in this area is highly likely) as values moved from south degree in both positive and negative direction, membership decrease until it reaches.

B. Produce of forest fire risk map

For produce final map of forest fire risk, two important steps was done, that including: namely: (1) overlay different layer was done based on Fuzzy overlay method. After overlaying, final map was created that indicate probability of forest fire risk and area with high value (maximum 1) showed that these area has high probability for fire and area with low value (minimum 0) showed that these area has a low possibility for forest fire. (2) for make final map more intelligible, it divided to three section that including: high, modified and low probability. Probability of forest fire in Very high area is more than other. this area are near to roads, villages, cities and slope is more than 40 degree and are in south-facing with vegetation that are under stress. In low probability area condition be reverse, namely area are very far from roads, villages and cities, vegetation growing quickly, and are in north-facing and slope is less than 10 degree.

IV. CONCLUSION

This study has shown that forest fire possibility in South-West and South-East regions are high and these are need to more protection in advance. This result is absolutely correspond with maps provided by environment organisation of Tabriz, Iran that was done by field work and pervious remote sensing investigations that were carried out.
REFERENCE


http://dx.doi.org/10.1126/science.284.5421.1782a.

http://dx.doi.org/10.1071/WF01032.

http://dx.doi.org/10.1126/science.284.5421.1782a.

http://dx.doi.org/10.1080/10807030590949717


http://dx.doi.org/10.1016/0034-4257(89)90023-0.

http://dx.doi.org/10.1080/026937996138070

http://dx.doi.org/10.1016/S0019-9958(65)90241-X


http://dx.doi.org/10.1016/S0378-1127(97)82929-5


**Khalil Omran** is a student (MS) in Tabriz University, Tabriz, Iran. His main research interests include methodological issues in geoinformatics, integration of GIS and Remote Sensing for evaluation of groundwater potential in the hard formation and land suitability analysis. He has practiced developing methodology for GIS based Multicriteria Decision Analysis (GIS-MCDA), tourism programing, modeling and thermal Remote Sensing image processing. He has published more than 10 scientific publications. He has been teaching (workshop) in the different departments in both Remote Sensing and GIS.

**Siavash Shamsi Khosroshahi** is a student (MS) in Tabriz University, Tabriz, Iran. His main research interests include methodological issues in geoinformatics, integration of GIS and Remote Sensing for evaluation of groundwater potential in the hard formation and land suitability analysis. He has practiced developing methodology for GIS based Multicriteria Decision Analysis (GIS-MCDA), modeling and thermal Remote Sensing image processing. He has published more than 10 scientific publications. He has been teaching (workshop) in the different departments in both Remote Sensing and GIS.

**Khalil Valizadeh Kamran** is a Professor at the University of Tabriz. His research interests include methodological issues of the integration of GIS, remote sensing and image processing also with evaluation of actual evapotranspiration. He has practiced developing methodology for GIS and RS based DTM (Digital Terrain Model), programing (Vb.Net), cartography and thermal Remote Sensing image processing. He has published more than 25 scientific publications including 18 journal publications. He is author, co-author or editor of 2 books and has been teaching in both Remote Sensing and GIS.