ECOPERSIA

DOI: 10.18869/modares.Ecopersia.5.3.1859 **2017, 5 (3):1859-1873**

Development of a Web GIS System Based on the MaxEnt Approach for Wildfire Management: A Case Study of East Azerbaijan

Hamid Ebrahimy[1]*, Aliakbar Rasuly[2, 3], Davoud Mokhtari[2]

[1] *Former Master Student, Department of Remote Sensing and GIS, University of Tabriz, Tabriz, Iran*
[2] *Professor, Department of Remote Sensing and GIS, University of Tabriz, Tabriz, Iran*
[3] *Professor, Department of Environmental Sciences, Macquarie University, Sydney NSW 2109, Australia*

* *Corresponding author: Former Master Student, Department of Remote Sensing and GIS, University of Tabriz, Tabriz, Iran, Fax: +98 413 35 6513 , Tel: +98 937 305 3477, E-mail: hamdebrahimy@gmail.com*

Received: 24 January 2017 / Accepted: 16 April 2017 / Published Online: 23 September 2017

Background: The online and efficient information about the spatial distribution of wildfire susceptibility and occurrence has a major role in improving of fire prevention activities.
Materials and Methods: In this study a maximum entropy (MaxEnt) approach was used for modeling wildfire susceptibility in East Azerbaijan Province and a webGIS system called fire susceptibility webGIS system (FSWS) was developed to easily share and utilize data and facilities among local people and managers. The methodology was composed of three different phases. First, dependent and independent variables were produced by several methods including image processing technique, interpolation method and GIS analysis. Next, the wildfire susceptibility was analyzed by using a MaxEnt approach to predict the possibility of wildfire occurrence based on history of wildfire data and environmental variables (anthropogenic, topography, climate and vegetation datasets) during 2005–2015 and the model performs well in terms of accuracy, with an area under ROC curve (AUC) value of 0.909. Finally, the webGIS system was developed by up to date and proper information.
Results: This webGIS system was provided from the spatial database of variables, wildfire susceptibility map, fire occurrence layers and base maps. FSWS was set up based on ArcGIS component and provided the facilities and capabilities of a web application that would be used by any user even without any prior knowledge of the GIS field.
Conclusions: By FSWS, the environmental authorities will be able to design many operational plans to control the wildfires, supporting conservation managers in improving pre-fire management and raise the awareness among the local people.

Keywords: *Data Sharing, Environmental Management, GIS, Iran, Wildfire Susceptibility*

1. Background

With East Azerbaijan Province experiencing one of the most severe droughts over the past few years, the average size and extent of burned area had increased intensively in this region, which is significantly posing threats to wildland, people, property and destroying environmental infrastructure. Beside the regional damages, wildfires can also have a major role in global warming. Unique environmental conditions in East Azerbaijan, such as climate, topography, population density and vegetation diversity, make its forests and rangelands highly susceptible to wildfire occurrence. From 2005 to 2015, 2,646 wildfires, covering 245,000 ha across the province, have been reported by the East Azerbaijan Department of Environmental Resource Protection (EADERP).

Wildfire management is a complicate process with two primary objectives: (i) restoring and maintaining wildfires as a necessary disturbance with some benefits, like regeneration, soil nourishing etc., (ii) decreasing the dangers that wildfire poses to people and the environment (1). In order to assist and contribute to this process, environmental risk and resource managers look toward web-based geographic information systems (GIS) and machine learning algorithms, like maximum entropy (MaxEnt) to better understand the spatial and temporal distribution of wildfires and sharing the data and information with web technology to support wildfire management activities.

Understanding the spatial distribution of wildfires and the characteristic factors behind this distribution is generally based on the analysis of historical wildfire locations (2). Some studies had focused on modeling the probability of natural wildfire by using only environmental variables (3, 4, 5). Since human activities have recently been playing an important role in wildfire occurrence, realistic estimations require that spatial models incorporate human factors (6, 7 and 8). Thus, there is a powerful need for an integrative model that considers environmental and anthropogenic factors simultaneously (9). Various approaches have been applied to modeling wildfire susceptibility, including different regression techniques (10) and nonparametric methods, like CART and RandomForests (2). Some authors concluded that machine learning algorithms, like maximum entropy (MaxEnt), performed with high accuracy for modeling wildfire susceptibility (11, 7, 12, 13).

By associating GIS abilities and the web technologies, end-users have a direct access to different type of geographical information and facilities (14). Development of webGIS system with environmental applications has several benefits like ease in access and data sharing, platform independency, better visualization and cost effectiveness. Access to web-based GIS on environmental solutions can facilitate the local communities participation in the management of environmental problems, like wildfire that directly or indirectly affect them. The role of webGIS in wildfire management has been emphasized in the areas of spatial data infrastructures (15), where it can provide valuable data, information and guide for users about risk knowledge, prevention methods, management schemes and sharing information (16, 17).

2. Objective

Accurate data and information is the main part of an efficient webGIS system. Therefore, the use of machine learning algorithms with high accuracy and performance in modeling wildfire susceptibility would be an essential step in developing a webGIS system for wildfire management in environmental areas based on public participation. The purpose of this study was to use wildfire observations (from 2005 to 2015), a wide variety of variables, and MaxEnt approach for modeling wildfire susceptibility in East Azerbaijan province and sharing map and other helpful information on the Internet with development of a webGIS system called Fire Susceptibility WebGIS System (FSWS).

2. Material and Methods

2.1. Study Area

The East Azerbaijan Province (36° to 39° N and 45° to 48° E) exetends over 47,000 km^2 with a variety of vegetation types, topographical and climatic conditions. It is bounded by Republic of Azerbaijan and Armenia to the north, Ardabil Province to the east, Zanjan and West Azerbaijan provinces to the south and Urmia Lake to the west (

Figure **1**). The climate in the study area based on the De Martonne aridity index is semi-arid, average annual precipitation and temperature are 315.2 mm and 10.2 °C, respectively (18), and elevation ranges from 160 to 4811 meter.

2.2. Methods

To accomplish this study, several key steps were necessary in development of a webGIS system based on the MaxEnt approach for wildfire management, including preparation of wildfire occurrence database, environmental and anthropogenic map production, modeling wildfire susceptibility, analysis and validation of result and development of FSWS with an appropriate user interface.

Figure **2** depicts the three phases comprising this methodology; the first phase applies the several methods such as image processing techniques, GIS analysis, and interpolation methods for producing the dependent and independent datasets. The second phase, based on a MaxEnt approach, the 851 wildfire occurrences location has been compared with a range of 11 independent variables for wildfire susceptibility modeling. In order to find out the main driving parameters of the spatial wildfire distribution, evaluation of the prediction accuracy was done with the area under the curve (AUC) as predictive power measure calculated from the receiver operating characteristic (ROC) analysis and delimit areas of particular susceptibility. The third phase included design and implantation of a webGIS system (FSWS) with ArcGIS component for providing easy access to a variety of information and facilities through a web-based platform.

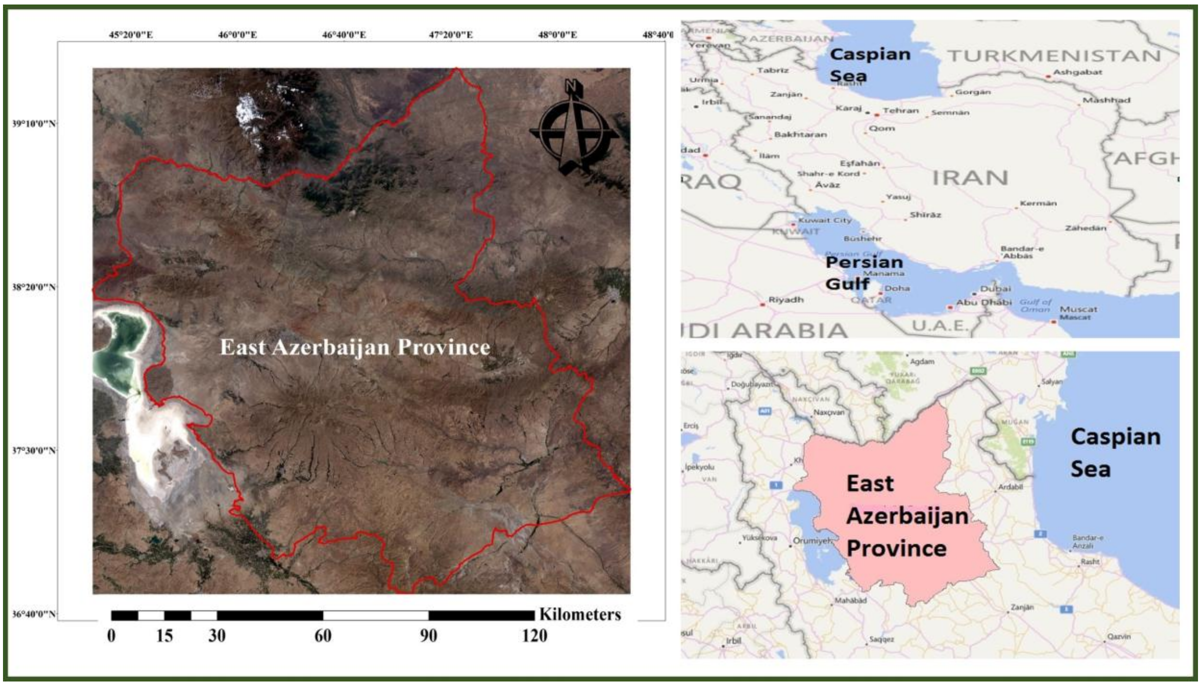

Figure 1 Location of the study area

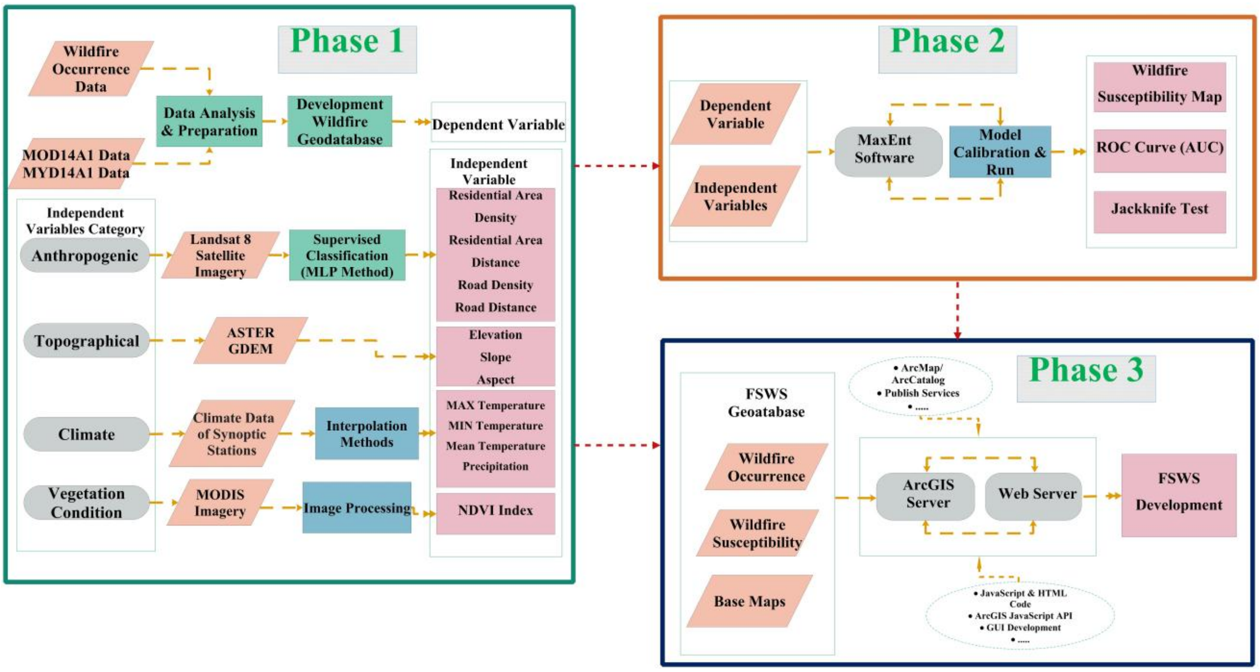

Figure 2 Methodology scheme and workflow

2.3. Maximum Entropy Model

The principle of MaxEnt is to estimate the probability distribution of maximum entropy, which is below a collection of constraints (environmental and anthropogenic conditions), the most spread-out or closest to uniform (19). It is a sophisticated approach to modeling the probability distribution from the n-dimensional environmental space using occurrence locations data and iteratively evaluates the contrasts between the values of those occurrences and those of a background consisting of the mean occurrence over the entire study area, as sampled from a large number of points (20). MaxEnt has the capability to fit highly complex response functions by combining many function types (linear, quadratic, product, threshold, and hinge) and make predictions from incomplete information (21). By applying this algorithm, the most uniform distribution will be recognized and selected from several possible distributions (22), moreover it can specify a per-pixel susceptibility to wildfire occurrence which might be used as an essential tool for environmental hazard management in forest and rangeland.

2.4. Data Preparation

2.4.1. Wildfire Data

Wildfire occurrence data were collected from two main sources, including EADERP and MODIS active fire product (23, 24, 25). The Collection 5, Level 3, 8-day MODIS Terra and Aqua active fire product (MOD14A1 & MYD14A1) was used during this study. This product detects fires in 1 km MODIS pixels that are actively burning at the time of satellite overpass (26). Due to inconsistencies in reporting throughout the province, small fires (<75 ha) were omitted from the wildfire database. Eventually, the information from 851 wildfire records during 2005-2015 period was used in this paper that included geographical coordinates, size and the time of occurrences in the forest and rangeland of East Azerbaijan province.

2.4.2. Independent Variables

The influential environmental and anthropogenic factors in the wildfire occurrence and their data sources considered in the present study are described in Table 1. In the data preparation phase, ASTER Global-DEM with 28.5 meter spatial resolution was used to generate maps of elevation, slope and aspect by using ArcGIS. Climate maps (max and mean temperature, and precipitation) were created through the interpolation of data gathered by several meteorological stations in the region (Ahar, Bostanabad, Bonab, Tabriz, Jolfa, Sarab, Sahand, Shabestar, Charoimagh, Ajabshir, Kaleybar, Maragheh, Marand, Malekan, mianeh, Varzeghan and Heris). The kriging technique was used to create the maps of max and mean temperature (27) and Inverse Distance Weighted (IDW) was used to produce Precipitation map (28).

A detailed land use/land cover map derived from LANDSAT 8 satellite images, using multi-layer perceptron (MLP) neural network method in image processing (29). The overall accuracy for the MLP algorithm was 89% (Kappa=0.78). Then, with kernel density and Euclidean distance algorithms, anthropogenic variables were created. Eventually, map of Normalized Difference Vegetation Index (NDVI) was derived from MODIS satellite imagery. Maps of all variables throughout the study area illustrated in

Figure **3**.

Table 1 List of the independent variables

Variable Category	**Variable Name**	**Data Source**	**Original Resolution**	**Unit**	**References**
Anthropogenic	- Residential Area Density	LANDSAT 8 Satellite Imagery (OLI, 2015)	30 m	- Points per sqkm	
	- Residential Area Distance			- Meters	
	- Road Density			- Points per sqkm	
	- Road Distance			- Meters	
Climate	- MAX Temperature	Iranian Meteorological Organization	Averaged Data	Numeral Value	
	- Mean Temperature				(30, 9, 13, 25 and 31)
	- Precipitation				
Topography	- Elevation	ASTER G-DEM	28.5 m	- Meters	
	- Slope			- Degrees	
	- Aspect			- Class Value	
Vegetation	- NDVI	MODIS Satellite Imagery (2015)	0.5 km	Numeral Value	

[DOR: 20.1001.1.23222700.2017.5.3.3.5]

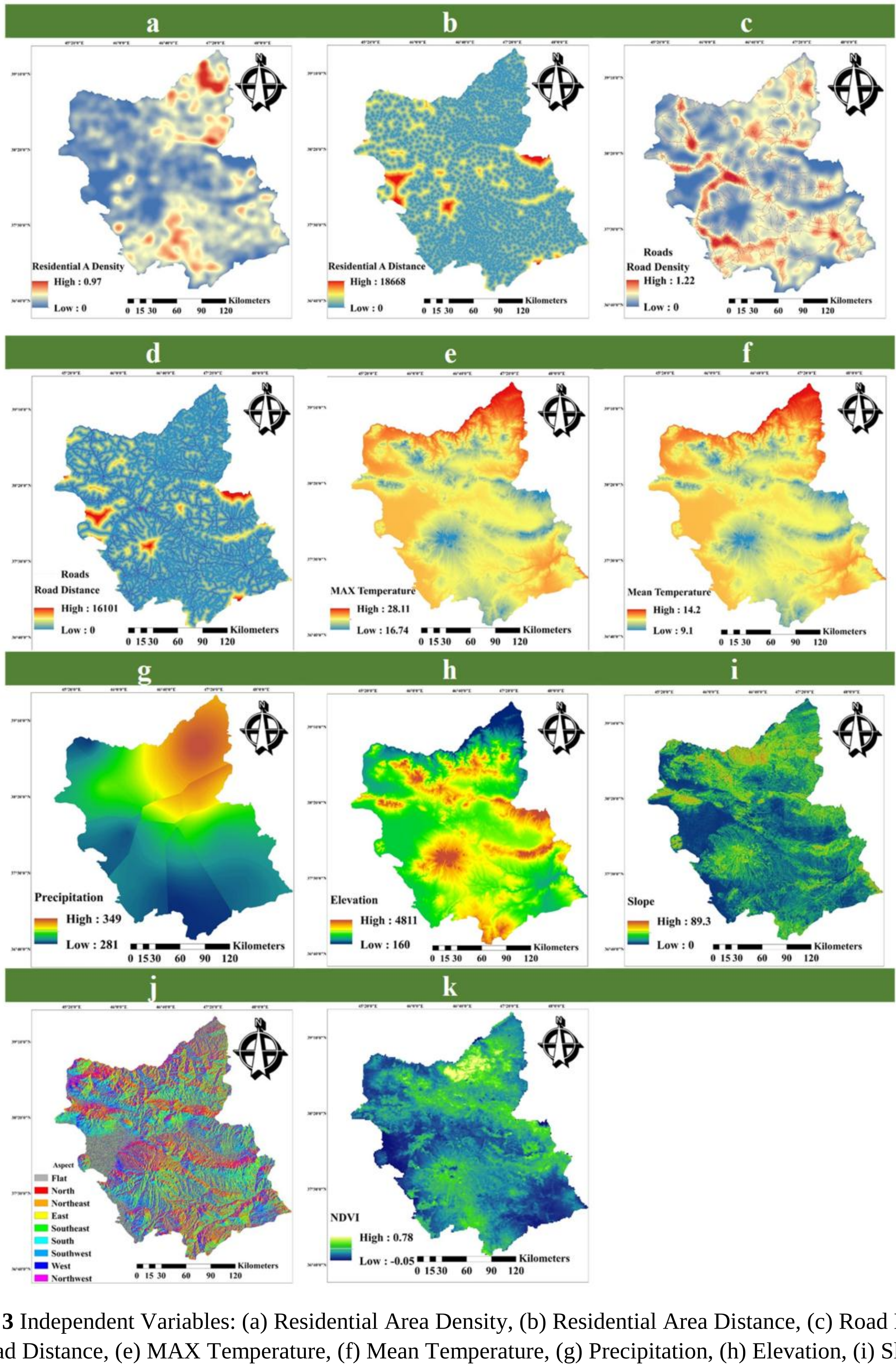

Figure 3 Independent Variables: (a) Residential Area Density, (b) Residential Area Distance, (c) Road Density, (d) Road Distance, (e) MAX Temperature, (f) Mean Temperature, (g) Precipitation, (h) Elevation, (i) Slope, (j) Aspect, (k) NDVI

2.5. Model Run

MaxEnt software (version 3.3.3 k) was used to analyse the wildfire susceptibility; this software requires wildfire location data to be formatted in comma-separated values (CSV) and all of independent variables should be in ASCII format. Throughout the model run and especially in the calibration phase, 638 (75%) of the wildfire occurrence were randomly chosen using the random selection algorithm for model training and 213 (25%) for model validation. The MaxEnt model is a common machine learning technique that allows for examination of the relationship between a dependent variable and several independent variables, which in our work are wildfire occurrence (851 event) and 11 environmental and anthropogenic factors. The main output from the model is a wildfire susceptibility map, in which the value of every pixel represent an estimate of relative susceptibility ranging from 0 to 1, and a high value of the MaxEnt output at a specific location indicates that it is fire-prone location.

2.6. WebGIS Structure

With the proliferation of the internet, exploration, visualization and dissemination of geographic data can be simply obtained these days through appropriate web-based GIS platforms, which have become a very low-cost and simple approach of disseminating geographical information and processing tools (32 and 14). The capability of web GIS for interacting dynamically in distributed environment from cross platform to client/ server computing system made it more interesting to develop and use for accessing spatial data. The basic approach for deploying webGIS application depends on the end-user requirements and developer goals.

Figure **4** shows the components used in design and development of FSWS, which summarizes the general framework adopted in the design of the system that complies with a standard web GIS architecture (33 and 14).

The users of FSWS mainly establish connections to web/application server in order to reach the web-mapping interface of the system. In this model, the GIS server bears the responsibility of providing data services for users, the primary functionality comprised on the server side and on the client side; users send requests to the server side, via a Web-based graphic user interface (GUI). The server carries out the corresponding functionality and conveys the results to the client side for visualization and other functionality. ArcGIS software components include ArcCatalog and ArcMap used for creation and managing of all the required spatial data. Data are uploaded into a geodatabase and published as GIS web services through the ArcGIS server. Additionally, Bing Maps services was integrated with the system as an external data source.

[DOR: 20.1001.1.23222700.2017.5.3.3.5]

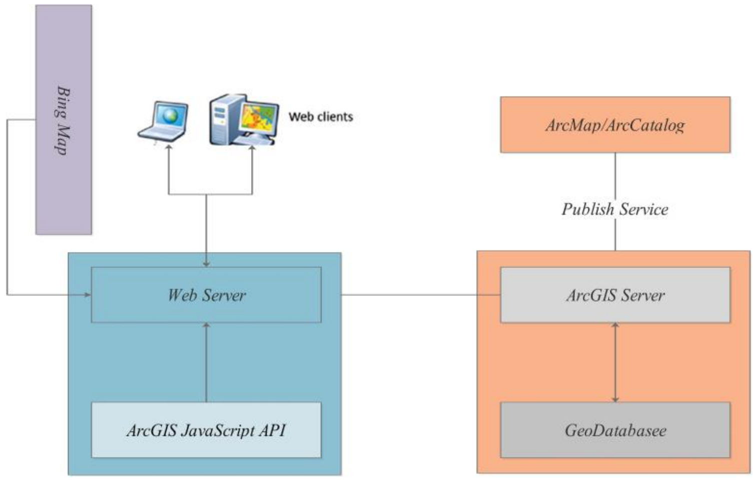

Figure 4 FSWS system architecture

3. Result and Discussion

3.1. Wildfire Susceptibility

The Wildfire Potential Map (WPM) of forest and rangeland in East Azerbaijan was produced using MaxEnt model (

Figure **5**), which was classified into five classes (very low, low, moderate, high, and very high) using natural breaks (jenks) classification scheme. Based on the result, 80.55% of the known wildfire fell in the 'very high' and 'high' susceptibility zones, followed by 17.15% and 2.3% in the 'medium' and 'low" susceptibility category, respectively. No known wildfire existed in the 'very low susceptibility' category. The AUC value of testing dataset was considered to measure the performance of the predicted model. As shown in Figure 6, the AUC for the MaxEnt models was 0.909, which in AUC classification it is highly accurate in modeling wildfire susceptibility.

Jackknife test was performed to assess the significance or relatively importance of each independent variable in model result (20 and 34). In order to accomplish test, model sequentially eliminated independent variables to calculate the gain contribution of each. It also ran each of them individually, thus identifying the one that contributed the highest gain. Renard *et al.* (12) found out that the importance of different variables highly depended on the region and extent of the area. In this study jackknife test showed that residential area density was the most important variable in determining model prediction. This variable increased and decreased the gain more than any other variable when added and omitted to the jackknife test respectively. An estimate of the contribution of each predictor variable to the model showed that after residential area density, road density and NDVI Index contributed most to the model (Table 2). The result of jackknife test shows that anthropogenic factors are the most important drivers in wildfire occurrence, which means many of the wildfire occurrences in East Azerbaijan are associated with human activities, which have also been found in other studies as well (2 and 10). The significance of anthropogenic factors becomes evident from the equally high ranking of residential area density and road density in jackknife test.

Based on the the result of accuracy assessment by using area under curve (AUC), which was calculated from receiver operating characteristic (ROC), our analysis indicated the maximum entropy as machine learning algorithm were efficient predictors (AUC =0.909) for wildfire susceptibility in East Azerbaijan. Similar result have also been observed in some studies (7 and 13).

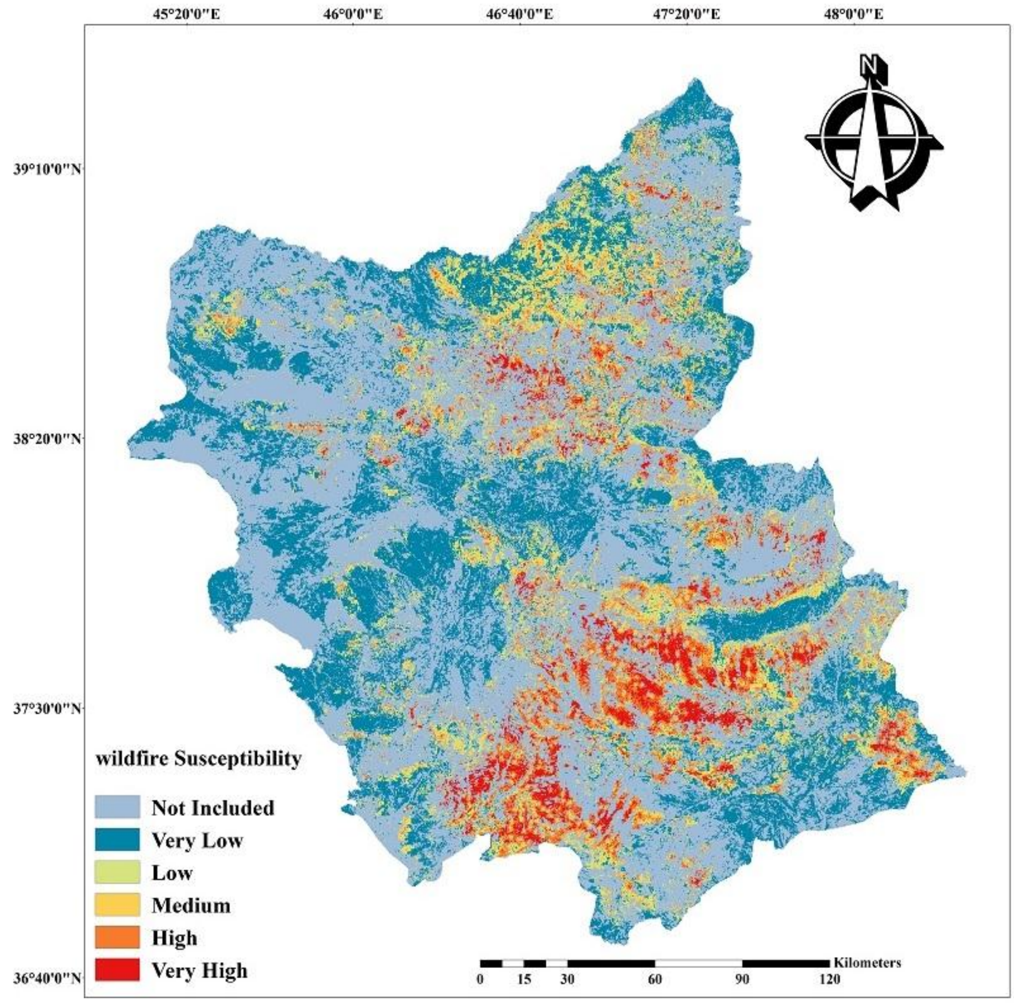

Figure 5 Wildfire Susceptibility of forest and rangeland in East Azerbaijan province

3.2. FSWS Implementation

Fire Susceptibility WebGIS System (FSWS) set up based on ArcGIS server in the role of GIS server and ArcGIS JavaScript API in the role of the web-programming framework. The input data for the FSWS provided from the previous steps, including the wildfire potential map, fire occurrence layers and base map, which, has been published as an interactive map service. The map service provides a series of functionalities in respect to the spatial framework design and characteristics. Functionalities are served by the ArcGIS server and ArcGIS JavaScript API respectively based on ArcGIS REST API specifications.

With a number of on-screen activities, users can utilize the facilities which provide interacting through a Graphical User Interface (GUI), which enables users to easily turn on/off several map layers, download/upload data, query task, several visualization instruments, go to XY, zoom in/out and other useful tools (

Figure 7). Additionally, system provides active communication between users and supervisors for reporting and recording wildfire

[DOR: 20.1001.1.23222700.2017.5.3.3.5]

events through GUI or e-mail messages and then, specifies its relative position and estimated intensity. In this part, users after placing sampling points on the map (by clicking or X Y), FSWS users complete pop-up forms to enter information and additional attachment for the new records.

The FSWS system is an extensible system and proposing integration for additional functions, data and map layers from different data sources. Although system is available through its web-mapping framework, all of data and information can be accessed with other softwares, such as ArcGIS desktop or any framework, which uses Web Mapping Service (WMS) and Web Feature Service (WFS) standards, simply with establishing a connections to FSWS.

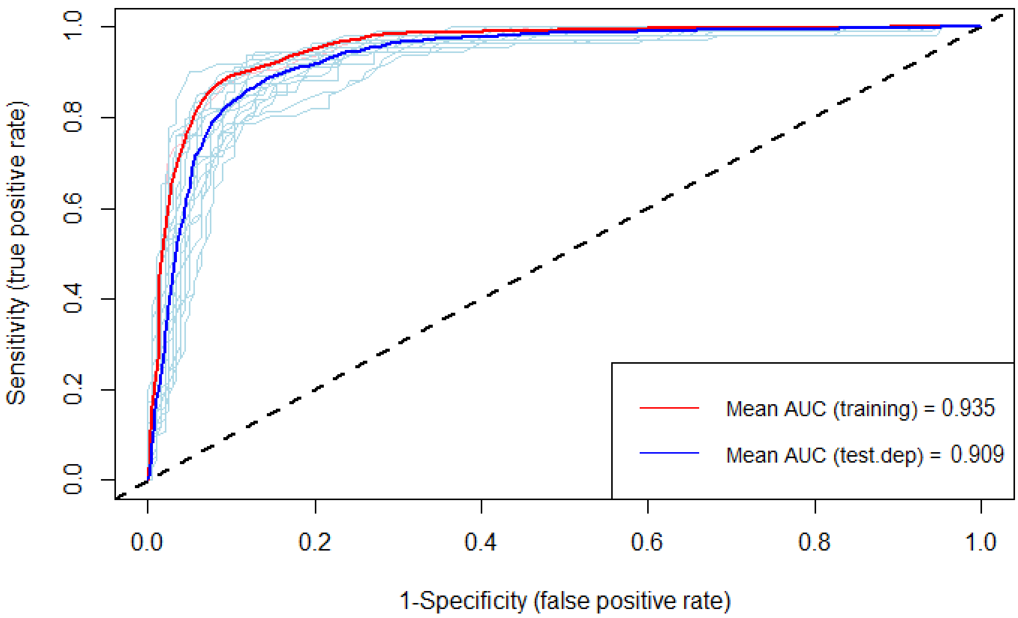

Figure 6 MaxEnt result: ROC curve for WSM

Table 2 Contribution and permutation of independent variable

Variable	Contribution (%)	Permutation (%)
Residential Area Density	23.2	28.3
Road Density	17.4	21.9
NDVI	17.3	13.8
Slope	14	11.1
Elevation	9.2	8.8
MAX Temperature	9.1	6.9
Residential Area Distance	4.3	3.9
Aspect	2.9	2.3
Precipitation	1.4	0.7
Road Distance	0.7	1.7
Mean Temperature	0.5	0.6

[DOR: 20.1001.1.23222700.2017.5.3.3.5]

In the present study, an attempt was made to develop a webGIS based for wildfire management using the maximum entropy alghorithm. Fire Susceptibility webGIS System (FSWS) provides easy access to a variety of tools and information by using the geographical representation of the wildfire probability and high-risk areas at different local regions through a web-based platform. FSWS enables end-users to query from databases and get answers immediately, locate points of interest in high-resolution satellite images and download or upload fire occurrence data and another facilities. FSWS has a flexible and transformative architecture which has the capability to perform and excute numerous function. FSWS is compatible with all web browsers, such as Internet Explorer, Mozilla Firefox and Google Chrome and it does not require any additional software installed from the client side, the only requirement for end users is a web browers.

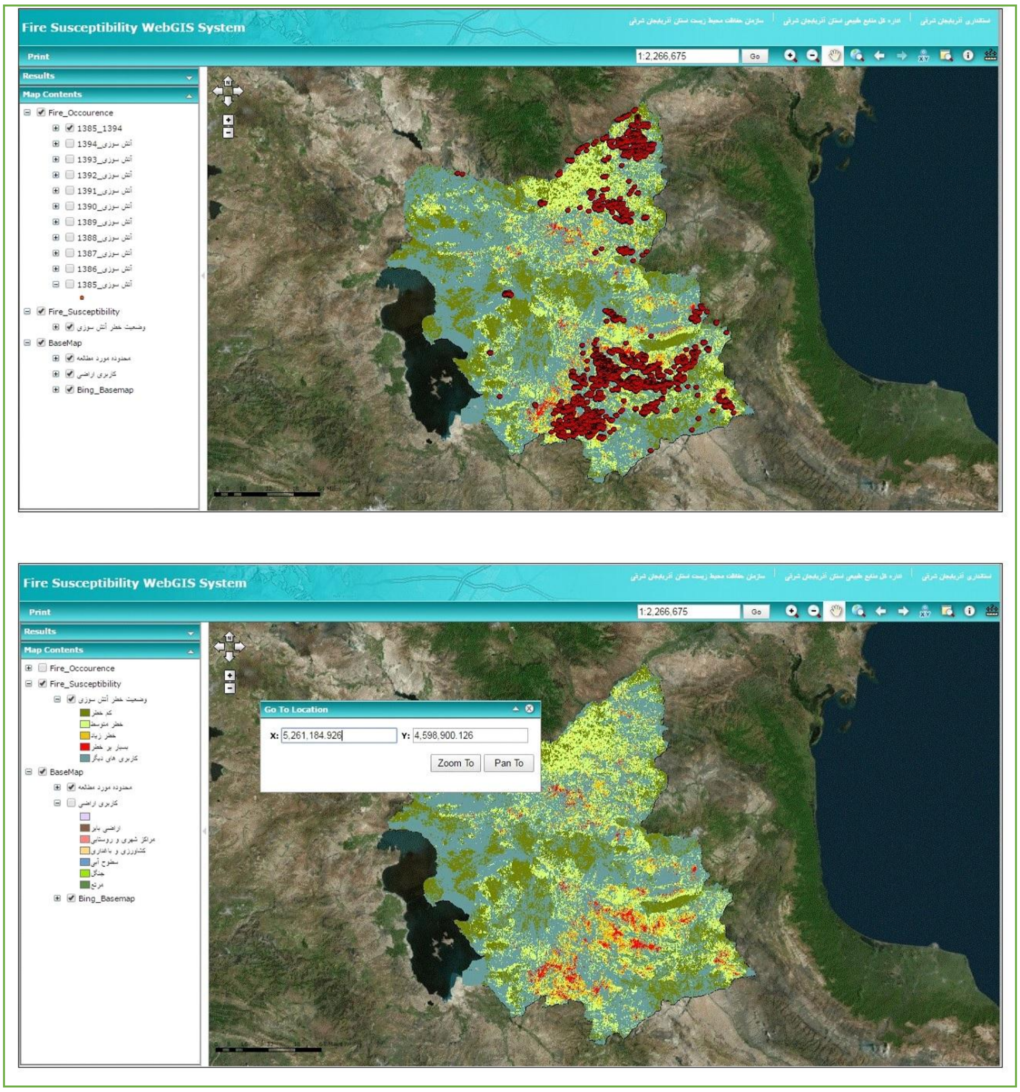

Figure 7 User interface of the FSWS system

4. Conclusion

Due to increasing risk of wildfire and the destruction of the natural resources over the past few years in East Azerbaijan, attention to wildfire management becomes an essential action. In this case, the combination of advanced method and web-based GIS have a very useful and impressive role in effective management, preventing harmful activities and also raising awareness in local communities to use their participations. Based on the wildfire occurrence data and some influential variables, the MaxEnt was found to have a high accuracy performance in modelling wildfire susceptibility in forest and rangeland of East Azerbaijan. Anthropogenic factors were also found to be the most important of all the tested variable in the model. The FSWS was specifically designed for environmental authorities and local people with limited access to GIS software, and will improve the actions of fire managers and other operational institutions in raising awareness among the local pepole.

We see some areas for future research. First, providing a web based application for modeling wildfire behavior and fire spread simulation to support other aspects of wildfire problems. Second, using statistical analysis to modeling and investigation on the most influencing factor in wildfire occurrence for a long period of time. Finaly, we should mention that some software components of FSWS are commercially off-the-shelf (COTS) products, and development of a completely open-source application and framework would be remained as a future reaserch.

Conflict of Interest

The authors declare that there is no conflict of interest.

Acknowlegment

The authors are thankful for assistance provided by the University of Tabriz, especially Faculty of Geography and Planning, East Azerbaijan Department of Environmental Resource Protection (EADERP) and NASA's Distributed Active Archive Centers (DAACs), which are parts of the Earth Observing System Data and Information System (EOSDIS) managed by the NASA Earth Science Data and Information System (ESDIS) project. Finally, the invaluable comments and suggestions provided by the editorial board and anonymous reviewers are greatly appreciated.

Authors’ Contributions

Each of the authors equally contributed to conception, analysis, interpretation and design of this resserch.

Funding/Support

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

References

1. Zaksek M, Arvai JL. Toward improved communication about wildfire: mental models research to identidy information needs for natural resource management. Risk Anal, 2004; 24(6): 1503-1514.
2. Massada A, Syphard AD, Stewart S. Wildfire ignition-distribution modelling: a comparative study in the Huron e Manistee National Forest. Int J Wildfire. 2012; 22(2): 174-183.
3. Parisien MA, Moritz MA. Environmental controls on the distribution of wildfire at multiple spatial scales. Ecol Monogr. 2009; 79(1): 127-154.
4. Littell JS, McKenzie D, Peterson DL, Westerling AL. Climate and wildfire area burned in western US ecoprovinces, 1916-2003. Ecol Appl. 2009; 19: 1003-1021.

5. Ariapour A, Shariff ARBM. Rangeland Fire Risk Zonation using Remote Sensing and Geographical Information System Technologies in Boroujerd Rangelands, Lorestan Province, Iran. ECOPERSIA, 2014; 2(4): 805-818.

6. Syphard AD, Radeloff VC, Hawbaker TJ, Stewart SI. Conservation threats due to human-caused increases in fire frequency in Mediterranean-climate ecosystems. Conserv. Biol., 2009; 23(3): 758-769.

7. Parisien MA, Snetsinger S, Greenberg J, Nelson C, Schoennagel T, Dobrowski S. et al. Spatial variability in wildfire probability across the western United States. Int. J. Wildfire., 2012; 21: 313-327.

8. Hosseini A, Esmaeili Sharif M, Amoozad M, Shirani K, Gorgandipour M. The Effect of Forest Road Distance on Forest Fire Severity (Case Study: Fires in the Neka County Forestry). ECOPERSIA. 2016; 4(2): 1331-1342.

9. Chuvieco E, Aguado I, Yebra M, Nieto H, Salas J, Martín MP. Development of a framework for fire risk assessment using remote sensing and geographic information system technologies. Ecol Model. 2010; 221: 46-58.

10. Oliveira S, Oehler F, San-Miguel-Ayanz J, Camia A, Pereira JM. Modeling spatial patterns of fire occurrence in Mediterranean Europe using Multiple Regression and Random Fores. Forest Ecol Manag. 2012; 275: 117-129.

11. Ferrarini A. Why not use niche modelling for computing risk of wildfire ignition and spreading?. Environmental Skeptics and Critics., 2012; 1(4): 56-60.

12. Renard Q, Pélissier R, Ramesh BR, Kodandapani N. Environmental susceptibility model for predicting forest fire occurrence in the Western Ghats of India. Int J Wildland Fire., 2012; 21: 368-379.

13. Arpaci A, Malowerschnig B, Sass O, Vacik H. Using multi variate data mining techniques for estimating fire susceptibility of Tyrolean forests. Appl Geogr, 2014; 53: 258-270.

14. Fu P, Sun J. Web GIS: principles and applications. Esri Press. 2010; 310 P.

15. Friis-Christensen A, Bernard L, Kanellopoulos L, Nogueras-Iso J, Peedell S, Schade S, Thorne C. Building service oriented applications on top of a spatial data infrastructure — a forest fire assessment example. 9th AGILE International Conference — Shaping the Future of Geographic Information Science in Europe, 2006; 19-127.

16. Athanasis N, Kalabokidis K, Vaitis M, Soulakellis N. Towards a semantics-based approach in the development of geographic portals. Comput Geosci, 2009; 35: 301-308.

17. Kalabokidis K, Xanthopoulos G, Moore P, Caballero D, Kallos G, Llorens J, Vasilakos C. Decision support system for forest fire protection in the Euro-Mediterranean region. European Journal of Forest Research. 2012; 131: 597-608.

18. Zarghami M, Abdi A, Babaeian I, Hassanzadeh Y, Kanani R. Impacts of climate change on runoffs in East Azerbaijan, Iran. Global Planet Change. 2011; 78: 137-146.

19. Deblauwe V, Barbier N, Couteron P. The global biogeography of semiarid periodic vegetation patterns. Global Ecol Biogeogr. 2008; 17: 715-723.

20. Phillips SJ, Anderson RP, Schapire RE. Maximum entropy modeling of species

geographic distributions. Ecol Model, 2006; 190: 231-259.

21. Moreno R, Zamora R, Molina JR, Vasquez A, Herrera MA. Predictive modeling of microhabitats for endemic birds in South Chilean temperate forests using maximum entropy (maxent). Ecol Infor, 2011; 6: 364-370.
22. Phillips SJ, Dudik M. Modeling of species distributions with Maxent: New extensions and a comprehensive evaluation. Ecography. 2008; 31: 161-175.
23. Maeda EE, Arcoverde GF, Pellikka PK, Shimabukuro YE. Fire risk assessment in the brazilian amazon using modis imagery and change vector analysis. Appl Geogr. 2011; 31: 76-84.
24. Adab H, Kanniah KD, Solaimani K. Modeling forest fire risk in the northeast of iran usingremote sensing and gis techniques. Nat Hazards, 2013; 65: 1723-1743.
25. Eskandari S, Chuvieco E. Fire danger assessment in Iran based on geospatial information. Int J Appl Earth Observ Geoinf., 2015; 42: 57-64.
26. Giglio L, Descloitres J, Justice CO, Kaufman YJ. An enhanced contextual fire detection algorithm for MODIS. Remote Sens Environ. 2003; 87: 273-282.
27. Wu T, Li Y. Spatial interpolation of temperature in the United States using residual kriging. Appl Geogr, 2013;44: 112-120.
28. Chen FW, Liu CW. Estimation of the spatial rainfall distribution using inverse distance weighting (IDW) in the middle of Taiwan. Paddy Water Environ. 2012;10(3): 209-222.
29. Shao Y, Lunetta RS. Comparison of support vector machine, neural network, and CART algorithms for the land-cover classification using limited training data points. ISPRS J Photogramm. 2012; 70: 78-87.
30. Chuvieco E, Cocero D, Riano D, Martin P, Martınez-Vega J, de la Riva J, Pérez F. Combining NDVI and surface temperature for the estimation of live fuel moisture content in forest fire danger rating. Remote Sens Environ. 2004; 92(3): 322-331.
31. Chang Y, Zhu Z, Bu R, Li Y, Hu Y. Environmental controls on the characteristics of mean number of forest fires and mean forest area burned (1987-2007) in China. Forest Ecol Manag, 2015; 356: 13-21.
32. Kowal KC. Tapping the web for GIS and mapping technologies: for all levels of libraries and users. Information Technologies and Libraries. 2002; 21: 109-114.
33. Peng ZR, Tsou MH. Internet GIS: distributed geographic information services for the internet and wireless networks. John Wiley and Sons. 2003; p. 720.
34. Park, NW. Using maximum entropy modeling for landslide susceptibility mapping with multiple geoenvironmental data sets. Environ Earth Sci. 2015; 73(3): 937-949.
35. Eastman JR. IDRISI Kilimanjaro. Guide to GIS and Image Processing. Worcester, MA: Clark University Press. 2003; p. 305.

طراحی سامانه WebGIS براساس مدل حداکثر بی‌نظمی به‌منظور مدیریت آتش‌سوزی (مطالعه موردی؛ استان آذربایجان‌شرقی)

حمید ابراهیمی[۱*]، علی‌اکبر رسولی[۲،۳]، داوود مختاری[۲]

۱- کارشناس ارشد سنجش از دور و سیستم اطلاعات جغرافیایی، دانشگاه تبریز، ایران

۲- استاد، گروه سنجش از دور و سیستم اطلاعات جغرافیایی، دانشگاه تبریز، تبریز، ایران

۳- استاد، گروه علوم محیطی، دانشگاه مک‌کواری، سیدنی، استرالیا

تاریخ دریافت: ۵ بهمن ۱۳۹۵ / تاریخ پذیرش: ۲۷ فروردین ۱۳۹۶ / تاریخ چاپ: ۱ مهر ۱۳۹۶

مقدمه: اطلاعات آنلاین و دقیق در رابطه با توزیع مکانی مناطق مستعد آتش‌سوزی نقش مهمی در ارتقا فعالیت‌های پیش‌گیرانه در راستای مدیریت آتش‌سوزی در جنگل‌ها و مراتع را فراهم می‌آورد.

مواد و روش‌ها: در این پژوهش با بهره‌گیری از الگوریتم حداکثر بی‌نظمی به بررسی خطر آتش‌سوزی در جنگل‌ها و مراتع استان آذربایجان شرقی پرداخته و سپس سامانه تحت وب FSWS برای به اشتراک‌گذاری اطلاعات و ابزارهایی برای استفاده مدیران و کاربران را فراهم می‌کند. پژوهش حاضر در سه مرحله به انجام رسیده است؛ ابتدا متغیرهای مستقل و وابسته مدنظر با بهره‌گیری از تکنیک‌های مختلف ایجادشده، در مرحله بعدی با استفاده از داده‌های مربوط به آتش‌سوزی‌های رخداده در دوره ده ساله مورد بررسی و متغیرهای زیست‌محیطی- انسانی تحت الگوریتم حداکثر بی‌نظمی با دقت (AUC= 0.909)، نقشه خطر آتش‌سوزی در جنگل‌ها و مراتع استان آذربایجان شرقی تولید گردید. در مرحله پایانی، سامانه WebGIS به بهره‌گیری از داده‌ها و اطلاعات حاصل از مراحل قبلی طراحی و توسعه داده‌شده است.

نتایج: سامانه تحت وب طراحی شده شامل لایه‌های مکانی محیطی، نقشه خطر آتش‌سوزی، نقاط وقوع آتش سوزی‌های رخ داده و نقشه‌های پایه از منطقه می‌باشد. این سامانه برخی قابلیت‌های GIS را برای کاربران بدون نیاز به دانش و مهارت در حوزه GIS فراهم می‌آورد.

بحث و نتیجه‌گیری: با بهره‌گیری از قابلیت‌های سامانه مدیران و برنامه ریزان امکان طراحی و سازمان‌دهی برنامه‌های مربوط به مدیریت آتش‌سوزی و برنامه‌های کنترلی را دارا بوده، هم‌چنین امکان استفاده از ظرفیت‌های مردمی نیز امکان‌پذیر خواهد بود.

کلمات کلیدی: اشتراک‌گذاری اطلاعات، ایران، خطر آتش‌سوزی، GIS، مدیریت زیست‌محیطی

[DOR: 20.1001.1.23222700.2017.5.3.3.5]