Fire Simulation and Fire Spreading Zoning in Forest Ecosystem Using FARSITE Model (Case Study: Ilam Province Forests)

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1. Introduction

Wildfires cause substantial losses of property and human lives in ecosystems in Iran and all around the world. Every year, about 6000 ha of forests are affected by fires in Iran (Jahdi, Salis, Darvishsefat, Mostafavi, Alcasena, Etemad, Lozano, & Spano, 2015).These fires can occur naturally due to climate change or abnormally caused by human activities in the forests. In fact, fire is one of the most important factors in disrupting the structure and dynamics of forest in natural conditions that produces a large amount of dead wood caused by the destruction of trees (Coban & Mehmet, 2010). As a result, there are significant costs to prevent fire every year in countries it takes place, and managing ecosystems is a way to reduce the effects of fire on war and maintain perspectives. To manage fire in forests, understanding the behavior of the fire and the factors causing it in a prone environment and factors affecting its behavior are essential (Artes, Cencerrado, Cortes, & Margalef, 2013). One way to manage fire is FARSITE model. This model has become popular due to its steady structure and simplicity of popularity in the modeling of fire spreading. This model is considered as one of the main fire simulation systems used to describe the behavior and release of horrific fires and is a semi-experimental model (Shen, Prince, Gallacher, Fletcher, & Fletcher, 2017).

2. Material and Methods

For the FARSITE Fire Extender simulator, we need 5 layers of GIS height, slope, direction, fuel type, and canopy. All of these spatial data describe the landscape of the area. Topographic data (elevation, slope and tilt direction) were extracted from 1: 25000 maps of the country's mapping organization, which were converted to ASCII (Kanga & Singh, 2017) format using ArcGIS10 to prepare for entering the FARSITE model. Meteorological data is another input similar to the FARSITE firewall, which includes the degree of heat, relative humidity, and wind speed. To obtain climatic data, synoptic stations in Ilam province were recorded at 3-hour intervals. The appropriate burning

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model of the research area was selected based on the description of 53 standard burning model developed on the basis of the fire extension model. This selection was made using vegetation maps, map coverage of the area and observations and field studies based on similarity of the existing vegetation characteristics and description of this model. In the last step, in order to simulate the GIS layers (slope, direction, height, combustion and canopy), the FARSITE model was entered in an appropriate format. Then, the area was classified according to the extent of the fire.

3. Results and Discussion

The results showed that fire in four areas where it occurred had different behaviors, which is also due to different natural conditions in these areas. Also, fire hazard zoning, in the province of Ilam shows that, 1.5% of the area has a high risk of fire. Therefore, it can be stated that the study of different factors (topography, vegetation, burning and climatic conditions) in the studied areas shows the complexity of fire behavior in these areas. It is under the control of various factors. To identify the behavior of the fire, all the parameters and influential factors must be considered together and in conjunction with each other.

4. Conclusion

Also, according to the results of FARSITE simulation and its accuracy evaluation in the region, using kappa coefficient, all points are in agreement with real values, which indicates the performance of the model in this region, and in none of the regions the coefficient value Kappa has not been negative. Therefore, the implementation of this model is a useful guide for forest fire management, and based on it, a fire prevention crisis management program can be implemented in the three phases of initial operations or pre-occurrence measures (prevention plan), action plans (coping plan), and post-operation operations (recovery plan).

Keywords: Fire, Forest, FARSITE, Topography, Climate, Combustion, Ilam

References (in Persian)

Eskandari, S. (2015). تحلیلی بر روش‌های مدل‌سازی و شبیه‌سازی گسترش آتش‌سوزی در جنگل‌ها [An analysis of modeling and simulation methods of forest fire spread]. *Journal of Human and Environment*, *34*, 67-88.

Gaemirad, T., & Karimi, M. (2015). ارزیابی عملکرد مدل‌سازی گسترش آتش‌سوزی جنگل با استفاده از اوتوماتای سلولی (پژوهش موردی: جنگل‌های بخش لاکان شهرستان رشت) [Evaluating the performance of modeling forest fire spread using cellular automata (Case study: Forests of Lakan section of Rasht city)]. *Journal of Iranian Forests and Spruce*, *23*(1), 64-78.

Jahdi, R., Darvishsefat, A. A., & Etemad, V. (2015). تهیه نقشه ماده سوختنی و پیش‌بینی رفتار آتش سطحی با استفاده از FARSITE [Preparation of fuel map and prediction of surface fire behavior using FARSITE]. *Journal of Wood and Forest, 22*(2), 207-225.

Matkan, A. A., Shakiba, A. R., Mirbagheri, B., & Bazari Jamkhaneh, M. (2013). شبیه‌سازی گسـترش Paper presented at .(مطالعه موردی: جنگل‌هـای شهرسـتان نکـا)FARSITE آتش‌سوزی در عرصه‌های طبیعی با استفاده از *National Conference on Environmental Research of Iran*. Shahid Mofteh University (NCER). Hamedan, Iran.

References (in English)

Adab, H., Devi Kanniah, K., & Solaimani, K. (2012). Modeling forest fire risk in the northeast of Iran using remote sensing and GIS techniques. *Natural Hazard*, *65*(3), 1723-1743.

Ager, A. A., Preisler, H., Arca, B., Spano, D., & Salis, M. (2014). Wildfire risk estimation in the Mediterranean area. *Environmetrics*, *25*, 384–396.

Arca, B., Duce, P., Pellizzaro, G., Laconi, M., Salis, M., & Spano, D. (2006). Evaluation of FARSITE simulator in Mediterranean shrub land. *Forest Ecology and Management*, (234), 110-110.

Artes, T., Cencerrado, A., Cortes, A., & Margalef, T. (2013). Relieving the effects of uncertainty in forest fire spread prediction by hybrid MPI-OpenMP parallel strategies. *Procedia Computer Science*, *18*, 2278-2287.

Brun, C., Artes, T., Cencrrrado, A., Margalef, T., & Cortes, A. (2017). A High performance computing framework for continental-scale forest fire spread prediction. *Procedia Computer Science, 108*, 1712-1721.

Coban, H. O., & Mehmet, E. (2010). Analysis of forest road network conditions before and after forest fire, FORMEC 2010. *Forest Engineering: Meeting the Needs of the Society and the Environment, 125*, 11-14.

Denham, M., Wendt, K., Bianchini, G., Cortes, A., & Margalef, T. (2012). Dynamic Data-Driven Genetic Algorithm for forest fire spread prediction. *Journal of Computational Science, 3*: 398-404.

Duane, A., Aquilue, N., Gil-Tena, A., & Brotons, L. (2016). Integrating fire spread patterns in fire modelling at landscape scale. *Environmental Modeling & Software*, 86, 219-231.

Finney, M. A. (2004). FARSITE: Fire Area Simulator Model Development and Evaluation. *nited States Department of Agriculture Forest Service Rocky Mountain*, 52.

Ghobadi, G. J., Gholizadeh, B., & Dashliburun, O. M. (2012). Forest fire risk zone mapping from geographic information system in Northern forests of Iran (Case study: Golestan Province). *International Journal of Agricultural Crop Science*, *4*(12), 818-824.

Guo, F., Su, Z., Wang, G., Sun, L., Tigabu, M., Yang, X., & Hu, H. (2017). Understanding fire drivers and relative impacts in different Chinese forest ecosystems. *Science of the Total Environment*, *605*, 411-425.

Hao, y. (2018). California wildfire spread prediction using FARSITE and the comparison with the actual wildfire maps using statistical methods. *UCLA, 12*(50), 1-20.

Herrera, G. V. (2016). Mexican forest fires and their decadal variations. *Advances in Space Research, 58*(10), 2104–2115.

Jafarzadeh, A. A., Mahdavi, A., & Jafarzadeh, H. (2017). Evaluation of forest fire risk using the Apriori algorithm and fuzzy c-means clustering. *Journal of Forest Science*, *63*(8), 370–380.

Jahdi, R., Darvishsefat, A. A., Etemad, V., & Mostafavi, M. A. (2014). Wind effect on wildfire and simulation of its spread (Case study: Siahkal forest in Northern Iran). *Journal of Agricultural Science and Technology*, *16*, 1109-1121.

Jahdi, R., Salis, M., Darvishsefat, A. A., Mostafavi, M. A., Alcasena, F., Etemad, V., Lozano, O., & Spano, D. (2015). Calibration of FARSITE simulator in northern Iranian forests. *Natural Hazards Earth System Sciences*, 15, 443–459.

Kanga, S., & Singh, S. K. (2017). Forest Fire Simulation Modeling using Remote Sensing & GIS. *International Journal of Advanced Research in Computer Science*, 8(5), 326-332.

Kanga, S., Sharma, L. K., & Nathawat, M. S. (2015). Himalayan Forest Fires Risk Management: A Geospatial Approach. *Lambert Academic Publishing*, *67*, 171-188.

Liu, Y., Goodrick, S.L, & Stanturf, J.A. (2013). Future U.S. wild fire potential trends projected using a dynamically downscaled climate change scenario. *Forest Ecology and Management, 294*, 120-135.

Marozas, V., Racinskas, J., & Bartkevicius, E. (2007). Dynamics of ground vegetation after surface fires in hemi boreal Pinus sylvestris forests. *Forest Ecology and Management, 250*(1-2), 47–55.

Moon, K., DuffaK, T. J., & Tolhurst, G. (2016). Sub-canopy forest winds: Understanding wind profiles for fire behaviour simulation. *Fire Safety Journal, 24*, 311-320.

Morales, J., Mermoz, M., Gowda, J., & Kitzberger, T. (2015). A stochastic fire spread model for north Patagonia based on fire occurrence maps. *Ecological Modelling, 300*, 73-80.

Nuryanto, D. E. (2015). Simulation of forest fires smoke using WRF Chem Model with FINN Fire Emissions in Sumatera. *Procedia Environmental Sciences*, *24*, 65-69.

Nyatondo, U.P. (2010). Fire Spread Modeling in Majella National Park Italy. *MSc thesis, Twente University*, 205.

Pinto, R, Benali, A., Sa, A., Fernandes, P., Soares, P., Cardoso, R., Trigo, R., & Pereira, J. (2016). Probabilistic fire spread forecast as a management tool in an operational setting. *Springerplus*, *5*(1), 1205-1212.

Rothermel, R.C. (1972). A mathematical model for prediction fire spread in wild land fuels. *USDA Forest Service*, *48*.

Rwanga, S. S., & Ndambuki, J. M. (2014). Application of geographical information systems and FARSITE in fire spread modeling. *International Journal of Environment and Sustainable Development, 13*(2), 1105-1120.

Salis, M., Ager, A. A., Alcasena, F., Arca, B., Finney, M. A,. Pellizzaro, G., & Spano, D. (2015). Analyzing seasonal patterns of wildfire likelihood and intensity in Sardinia, Italy. *Environ.Monitoring Assess, 187*, 1–20.

Sanjuan, G., Brun, C., Margalef, T., & Cortes, A. (2014). Wind field uncertainty in forest fire propagation prediction. *Procedia Computer Science*, *29*, 1535–1545.

Shen, C., Prince, D., Gallacher, J., Fletcher, M., & Fletcher, T. (2017). Semi-empirical model for fire spread in chamise and big sagebrush shrubs with spatially-defined fuel elements and flames. *National Combustion Meeting Organized by the Eastern States Section of the Combustion Institute*, *124*, 1-6.

Williams, B. J., Song, B., & Williams, T. M. (2013). Visualizing mega-fires of the past: A case study of the 1894 Hinckley Fire, east-central Minnesota. *Forest Ecology and Management*, *294*, 107-119.

Wu, Z., He, H. S., Liu, Z., & Liang, Y. (2013). Comparing fuel reduction treatments for reducing wildfire size and intensity in a boreal forest landscape of northeastern China. *Science of the Total Environment*, *454*, 30–39.

Yin, H., Jin, H., Zhao, Y., Fan, Y., Qin, L., Chen, O., Huang, L., Jia, X, Liu, L., Dai ,Y., & Xiao, Y. (2018). The simulation of surface fire spread based on Rothermel model in wind throw area of Changbai Mountain (Jilin, China). *AIP Conference Proceedings, 19* (1), 124-135.

Zarekar, A., Vahidi, H., Kazemi Zamani, H., Ghorbani, S., & Jafari, H. (2012). Forest fire hazard mapping using fuzzy AHP and GIS, Study area: Gilan province of Iran. *International Journal on Technical and Physical Problems of Engineering, 12*(3), 47-55.

Zheng, Z., Huang, W., Li, S., & Zeng, Y. (2017). Forest fire spread simulating model using cellular automaton with extreme learning machine. *Ecological Modeling*, *348*, 33–43.