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ASSESSMENT OF FOREST FIRE RISK AND FORESTRY SPECIES DEGRADATION USING GIS AND REMOTE SENSING IN WESTERN OF ALGERIA

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Abstract

These last years, the forest ecosystems of the Mediterranean basin have experienced remarkable fires destroying the forest areas from one year to another. Algeria does not escape from this problem. Every year, about 36000 ha are burned due to fires which more than 13414 ha recorded in 2017 by the General Directorate of Forests (DGF). In the western part of Algeria, the forest massif represents more than 29% of the Algerian forest heritage where fires remain the most devastating factor. To meet against this alarming situation, fighting and fire prevention seem to be the most effective way. These can only be realized through a spatialization of the Forest Fire Risk (FFR) and the delimitation of the very vulnerable areas. Assessment of FFR can be done basing on several factors of both qualitative and/or quantitative nature such as forest vegetation density, topographic factor (Slope, Aspect) and human activities. The evolution of geospatial techniques such as Geographic Information Systems (GIS) and Remote Sensing has effectively improved solving this type of problem. In this context, this paper aims to assess and spatialze the risk of Forest Fires using GIS and Remote Sensing by the application of a model that integrates different factors weighted according to their influence on fire spread. These factors are introduced into a GIS environment as thematic layers to produce a synthetic fire risk map. This study is conducted in the forest of Gharrous located in the southeast of the wilaya of Mascara in western of Algeria. The obtained results show a dominance of High and Very high risk levels with more than 43% of the total forest area. These results are compared to the burned area extracted from Google Earth according to the historical fires dates. The statistical analysis demonstrates that most of the burned areas were located in the Moderate, High and Vey high risk levels with a rate of 35.31%, 46.23% and 12.40% respectively. This study shows the effective contribution of GIS and remote sensing to provide a very useful solution for forest decision-makers.

Keywords: *Forest fire, GIS, Remote sensing, Gharrous, Algeria*

Introduction

Forest ecosystems are the most important natural source for our environment (Hasheminasab *et al.*, 2017). They play a major role in the ecological balance and the preservation of fauna and flora species. These last years, the forest ecosystems of the Mediterranean basin have experienced a remarkable degradation due to fires that continue to destroy the forest areas from one year to another. These fires are the main cause of destruction of Mediterranean forests (Vélez, 1999).

Algeria does not escape from this problem. It is considered as a country that is very affected by this phenomenon (Belgherbi *et al.*, 2018), which in more than 80% of their causes are anthropogenic (Meddour-Sahar *et al.*, 2014). Every year, about 36000 ha are burned due to fires (Arfa *et al.*, 2009) where more than 13414 ha were recorded in 2017 by the General Directorate of Forests (DGF) (Benguerai *et al.*, 2019).

In the western part of Algeria, the forest massif represents about 29% of the Algerian forest heritage (DGF, 2018). Of all the problems in the region, fires remain the most devastating factor (Khader *et al.*, 2009).

The Mediterranean climate characterized by an extremely hot summer and the expansion of human activities such as overgrazing and clearing have amplified the situation.

To meet against this alarming situation, fighting and fire prevention seem to be the most effective way. These can only be realized through a spatialization of the Forest Fires Risk (FFR) and the delimitation of areas that are very vulnerable. The evolution of geospatial techniques such as Geographic Information Systems (GIS) and Remote Sensing has effectively improved solving this type of problem.

In this context, this work aims to assess the risk of forest fires using geomatics tools (GIS and Remote Sensing). The approach consists of a spatialization of the FFR by applying a model that integrates different factors characterizing topography, fuel and human activities. These factors are introduced into a GIS environment as thematic layers to produce a synthetic fire risk map which reflects the forested areas according to their sensitivity level to fire. The study was conducted in the forest of Gharrous located in the southeast of the wilaya of Mascara in western Algeria.

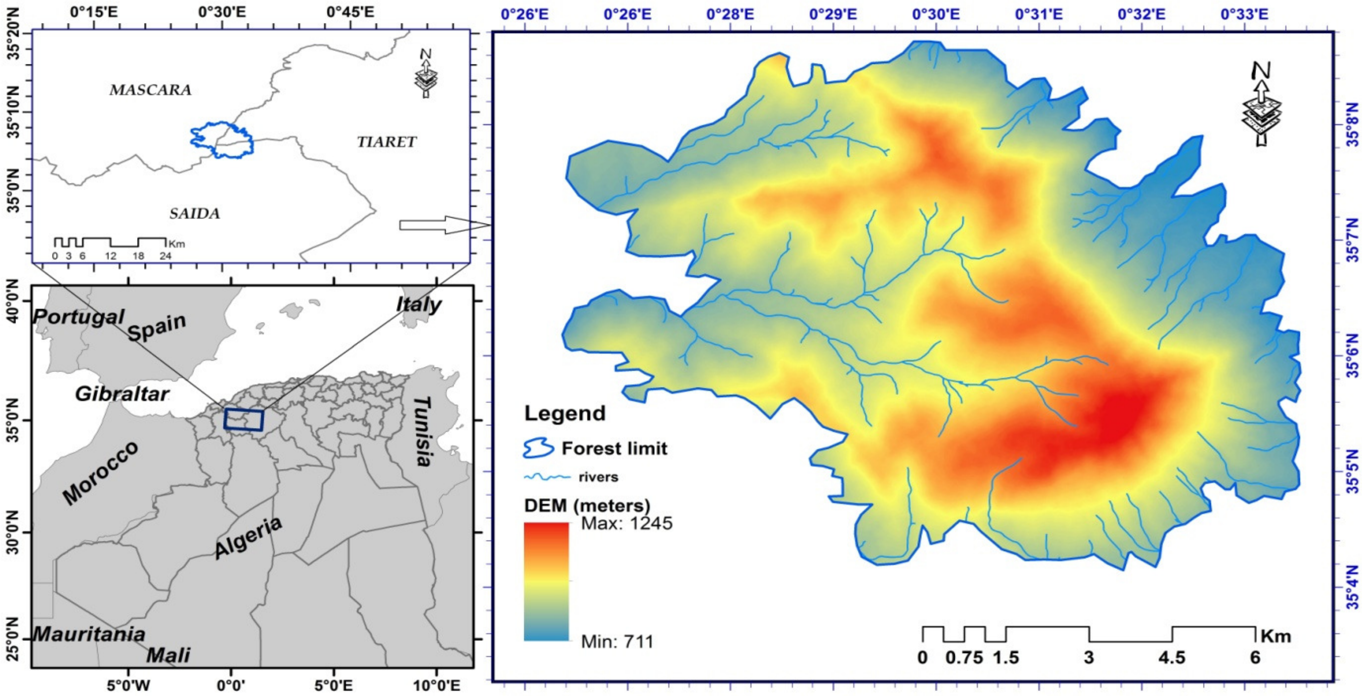

Fig. 1: Geographic location of the forest of Gharrous

Materials and Methods

Study area

The forest of Gharrous is located in Oued Taria watershed in northwestern Algeria and it is part of Saida Moutains. It is geographicly located between 0.439° and 0.559° East Longitude and between 35.069° and 35.145° North Latitude (Fig. 1).

It is characterized by an altitude ranging from 711 to 1245 m with an area of approximately 5912 ha which extends over three wilayas Mascara, Saida and Tiaret. Over 61% of the study area is characterized with a slope gradient of 15-60%.

The forest of Gharrous belongs in the semi-arid climatic floor with a two important periods: cold from November to April and hot and dry from May to October.

The forest vegetation cover is mainly dominated by *Pinus halepensis* specie and moderately by *Pistacia lentiscus*, *Tetraclinis articulata* and *Calicotome spinosa* species.

Data sources

To achieve this work, several data sources were used in particularly:

- Digital Elevation Model (DEM) of ALOS Palsar Radimetric terrain Corrected (RTC) product with a spatial resolution of 12.5 m. This DEM was used to derive parameters characterizing topography of the study area (Slope, Aspect).
- Satellite image issued from Sentinel 2 MSI (Multi Spectral Imager) sensor. It was used to extract from surface reflectance useful information about forest fuel type.
- Historical data of the occurred fires in Gharrous forest for several years. These data are collected from the General Directorate of Forests of Mascara (table 1).
- Roads and Settlements location obtained from the digitization using Google earth Software.
- Burned area limit from 2010 to 2018 extracted as vector layer from Google earth historical images.

Table 2 describes the characteristics of these data.

Table 1: The historical of fires occurrence in the forest of Gharrous (source: DGF)

Fire date	Place	Burned species
22/07/2010	Djebel Lakhdar	Pinus halepensis, Pistacia lentiscus, Tetraclinis articulata
10/10/2013	Djebel Lakhdar	Pinus halepensis, Pistacia lentiscus, herbaceous strata
13/08/2016	Makamette	Pinus halepensis, herbaceous strata
31/07/2018	Djebel Henaifia	Tetraclinis articulata, Pistacia lentiscus, herbaceous strata

Fire risk modelling

In order to spatialize and map the FFR, this latter must be modelled and assessed. Several researchers proposed different models FFR assessment such as Dagorne *et al.* (1994), Mariel (1995), Xu *et al.* (2006), Hasheminasab *et al.* (2017) and Sakellariou *et al.* (2019). These models differ by their input parameters and conditions where they were applied.

In this research, the model proposed by Sakellariou *et al.* (2019) has been adopted. It takes into account 02 different types of factors involving in the fire process: Natural factors (Fuel type, Slope and Aspect) and anthropogenic factors depending on human activities (Distance from roads and settlements proximity). This model is used and tested in the Mediterranean basin. Thus, the FFR can be evaluated through the following formula:

$$FR = 4.5\times F + 1.5\times(S + A) + 1.5\times R + T \qquad ...(1)$$

Where :

FR: Fire Risk ,

F: Fuel type

S: Slope factor

A: Aspect factor

R: Distance from roads

T: Settlements Proximity

Each of these factors is weighted according to its influence on the fire spread and propagation (Gettouche et al, 2011).

Vegetation and Fuel type

Guettouche *et al.* (2011) notes that among the factors that strongly influence the forests fires, the fuel type and phytomass are considered as an important factor in the fire spreading. When interferes with the climate factor, it can create favourable conditions to hatching forest fires (Assali *et al.*, 2016).

The spatial structure of the fuel, the type of dominant species and their density are the main criteria that involved in fire ignition (Belhadj-Aissa et al, 2003). Several researchers such as Saatchi *et al.* (2007), Arroyo *et al.* (2008), Arellano-Pérez *et al.* (2018) and Filipponi (2019) show the role of remote sensing as en effective tool to estimate forest fuel type.

For this purpose, a remotely sensed data with high spatial resolution were used to carry out the fuel type of the study area. They consist of a multispectral image acquired on 23/05/2019 by the Sentinel 2 MSI sensor with a high spatial resolution of 10m. It's a Sentinel 2 L1C product which corresponds to the top of the atmosphere (TOA) reflectance image. In order to get the bottom of atmosphere (BOA) reflectance, an atmospheric correction is needed. This action was done using the Sen2Cor prototype which is an algorithm that converts L1C data to L2A data which corresponds to the BOA reflectance according to Uwe (2016).

The fuel type mapping was done through the classification of Soil Adjusted vegetation Index (SAVI) derived from Sentinel 2 image using the Red and Infra red bands with the following equation:

$$\mathrm{SAVI} = \frac{\mathrm{NIR} - \mathrm{R}}{\mathrm{NIR} + \mathrm{R} + \mathrm{L}} \times (1 + \mathrm{L}) \qquad ...(2)$$

Where:

NIR: Near Infra Red reflectance band

R: Red reflectance band

L: 0.5

The processing tasks of the Sentinel 2 image were carried out with Sentinel Application Platform (SNAP) developed and distributed by European Space Agency (ESA).

Topographic factors

The topographic factor characterizes the effect of the topography parameters such as slope and asect on the fire spread. They have a significance relation with sunshine and wind behaviour (Setiawan *et al.*, 2004) therefore they are considered as important factors.

The effect of slope can be explained by its steepness and direction. According to Dong *et al.* (2005), the chance of fire ignition increases in steepest slope and decreases in gentle one. More over, the fire spreads faster in up-slopes area and slowly in down-slopes (Suryabhagavan *et al.*, 2016).

The influence of aspect can changed according to geographical localization of the study area (Talbi *et al.*, 2018). The fire propagation is indirectly affected by aspect due to its role on vegetation condoning, sunshine duration and the influence of wind. Generally, the south facing slopes present the most favourable conditions for rapid ignition and for the propagation of flames (Prasad *et al.*, 2008).

Table 2: Characteristics of used data sources

Data	Format	Characteristics	Source
satellite Image	Raster (GeoTiff)	SENTINEL 2 MSI L1C TOA Reflectance Product Spatial Resolution : 10 m Spectral Resolution: 13 bands Projection: UTM/WGS84 30N Acquisition Date : 2019/05/23	United States Geological Survey Global Visualization Viewer (GloVis) (https://glovis.usgs.gov/app?fullscreen=0)
Digital Elevation Model	Raster (GeoTiff)	ASF Radiometrically Terrain Corrected high Resolution ALOS PALSAR products Spatial Resolution : 12.5m Projection: UTM/WGS84 30N	Dataset: ASF DAAC (https://vertex-retired.daac.asf.alaska.edu/)
Roads/Settlements	VECTOR (Shp)	Format: Polyline/Polygon Projection: UTM/WGS84 30N	Google Earth Pro
Fires area limits	VECTOR (Shp)	Format: Polygon Projection: UTM/WGS84 30N	Google Earth Pro

The slope and aspect parameters were easily extracted from ALOS PALSAR RTC DEM with a spatial resolution of 12.5mx12.5m issued by Alaska Satellite Facility (ASF) freely online via the link (https://vertex-retired.daac.asf.alaska.edu).

Human activities factor

The human activities reflect the anthropogenic influence on forest fires occurrence. They expressed as the result of several factors such as distance from roads and settlements proximity.

In most cases, forest fires are basically due to the intense human activities (Adab *et al.*, 2012). The density of roads allowing people to attend or to be inside the forest area is considered as a potential parameter for fire ignition (Jaiswal *et al.*, 2005). Also, the presence of settlements within the forest increases the probability to start fires and makes forest areas more vulnerable.

In this work, to evaluate human activities impact on fire risk, roads and settlements located inside or close to the study area are digitized from Google Earth Pro. The obtained layers were used to establish the distance from roads and settlements proximity as an Euclidean distance with a GIS environment.

Classification and weighting of fire risk factors

After the creation of the layers of the five factors used in the model, they were re-sampled to the same resolution of 10m. Each factor was classified into several classes with a specific weight from 1 to 10 and the corresponding fire risk level: Very low, Low, Moderate, High and very high. As result, the FFR values vary from 0 to 100.The assignment of different weights was done basing on the thresholds described in table 3.

Table 3: Classification and weighting of the forest fire risk factors

Fuel type	**Fire risk**			**Weight**	
No or very little fuel	Very low			1	
Little fuel	Low			3	
Surface fire-Torching	Moderate			5	
Crown fire	High			7	
Full crown fire	Very high			9	
Slope (degrees)	**Fire risk**	**Weight**	**Aspect**	**Fire risk**	**Weight**
0 - 3	Very low	2	Smoot ground	Close to nil	1
3 - 5	Low	3	North	Extremely low	2
5 - 10	Moderate	5	North east	Very low	3
10 - 15	High	7	North west	Below mean	4
15 - 35	Very high	9	East	Moderate	5
> 35	Extremely high	10	South east	Higher the mean	6
			West	High	7
			South west	Very high	8
			South	Extremely high	10
Distance from roads (m)	**Fire risk**	**Weight**	**Settlements proximity (m)**	**Fire risk**	**Weight**
>400	Very low	1	>4000	Very low	1
300 - 400	Low	3	3000-4000	Low	3
200 - 300	Moderate	5	2000-3000	Moderate	5
100 - 200	High	7	1000-2000	High	7
<100	Very high	9	<1000	Very high	9

Results and Discussion

Fuel type map

The fuel type map of the study area was obtained from an estimation using the SAVI layer derived from the Sentinel 2 image (Fig. 2.a). The corresponding fuel type map was classified into five classes weighted according to their fire risk level (Fig. 2.b).

Values of the derived SAVI index vary from -0.052 to 0.448. Lowest values correspond to nude soil and urban area where highest values represent totally cover forest. The spatial distribution of the obtained fuel type shows that over 40 % of the study area is characterized with a high and very high risk located generally in the central part of the forest and corresponds to closed cover trees of *Pinus halepensis* specie (Aleppo Pine). The moderate level area occupies 24% formed from a mixture of *Pistacia lentiscus* (*Pistachio lentisk*), *Tetraclinis articulata* (*Barbary thuja*) and *Calicotome spinosa* (*Thorny calicotome*) species with a moderate density cover. The low and very low risk levels correspond to pastoral/agricultural lands and nude soil respectively with an area rate of less than 37%.

Topographic factors map

The extraction of the slope and the aspect from the DEM let us to establish digital maps of these parameters (Fig. 3.a, Fig. 4.a). The terrain morphology with steep slopes (> 10 degrees) represents 50% of the total study area against 15.2% for the gentle slopes. Therefore, high, very high and extremely high fire risk levels based on the slope steepness dominate our research study. The steepest zones which are exposed to high fire risk are located in the north and eastern location (Fig. 3.b).

The South and West aspect which correspond to high risk levels (fire risk weight > 6) occupy an area of 2751.17 ha which equals to 46.30% of total study area. They correspond to regions located in the north, northeast and southwest (Fig. 4.b). The rest is characterized by moderate and low fire risk levels corresponding to less than 54% of the study area.

The combined effect of slope and aspect can provide very favourable conditions for fire occurrence and accelerating spread speed.

Distance from roads and settlements proximity maps

Roads and foot-paths facilitate access to footprint in the forest area. Also, the areas close to settlements may have intentionally human activities which cause forest fires.

The roads network and the settlements location for the study zone were used to compute distance from them using Euclidean distance function of Spatial Analyst toolbox of ArcGis software. The resulting maps are presented in fig. 5.

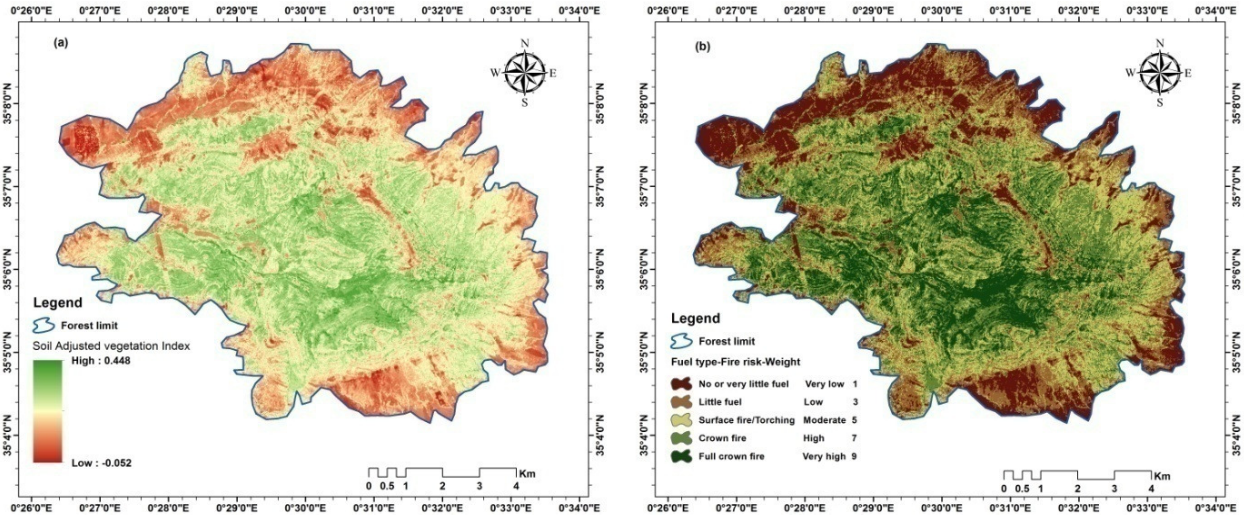

Fig. 2: (a) SAVI gradient map and (b) Fuel type map

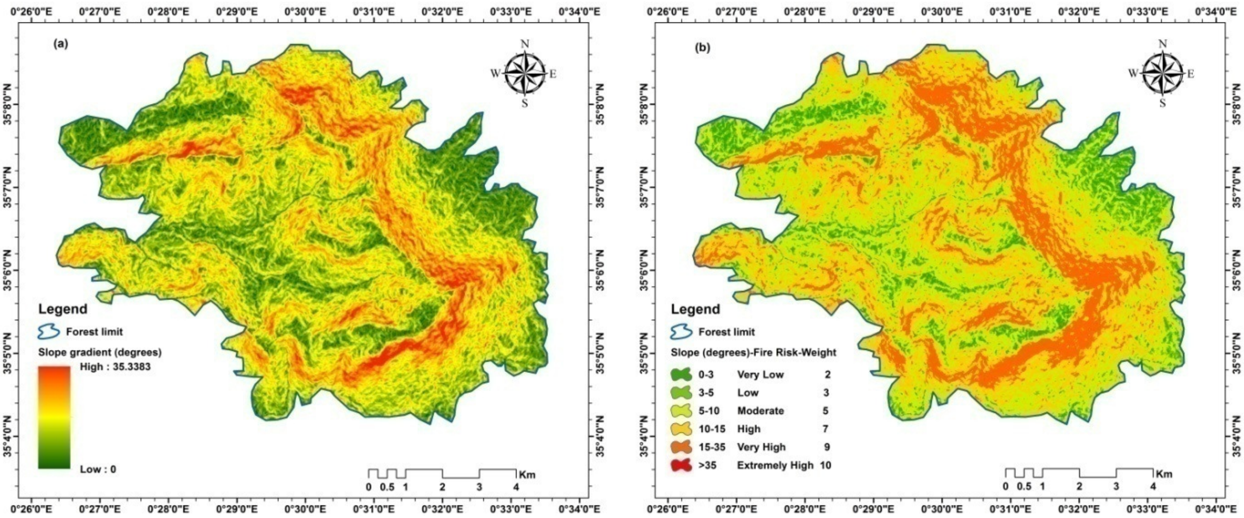

Fig. 3: (a) slope gradient map (b) Fire risk level and weighting map

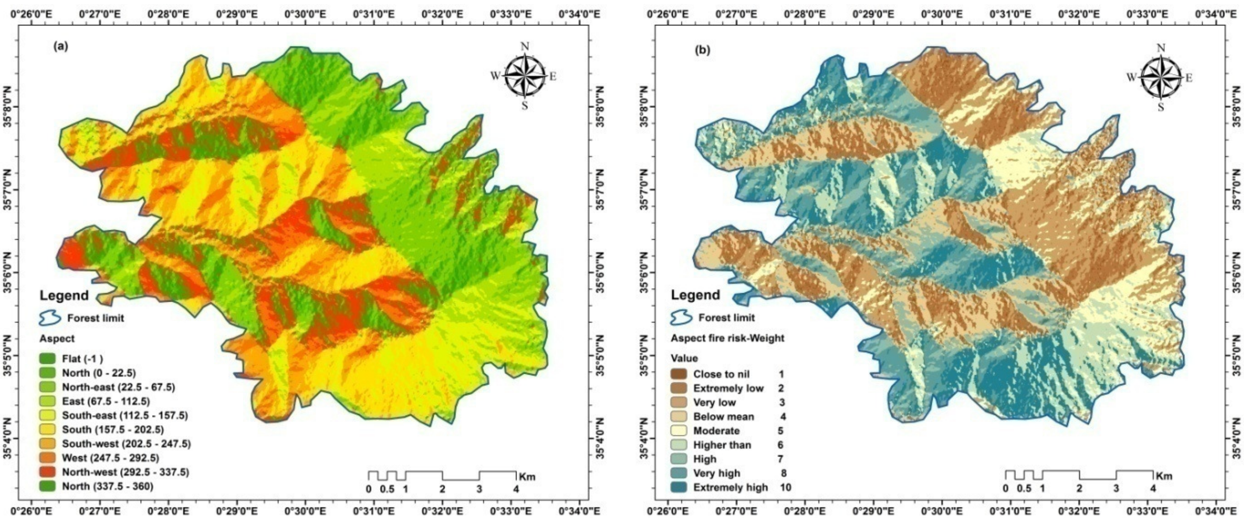

Fig. 4: (a) Exposure orientation map and (b) Aspect fire risk map and weighting

Forest fire risk map

Based on the application of equation 1, the assessment of FFR was done by involving vegetation fuel type factor, topographic factors (Slope and Aspect) and anthropogenic factors (Distance from road and settlements proximity). These factors were introduced into AcrGis software as raster layers to calculate FFR values and classified to produce a synthetic FFR map with five levels (Fig. 6). The FFR values range of the Gharrous forest is between 8.5 and 92.608 corresponding to zones with very low and very high FFR levels respectively. The high and very high risk levels occupy more than 43% of the total forest area prior to the moderate risk level with 41.36% and the low and very low risk levels with a percentage of less than 16% (Table 4). Also, it should be noted that classes of high risk level are located especially at the central part of the forest massif, places with closed crown trees and close to foot-paths. These results can be explained by the dominant of *Pinus halepensis* specie which has a great sensibility to fire risk due to its high flammability and combustibility. In addition, the strongest topographical conditions, the easier accessibility to forested area and the farming activities (fires starting by beekeepers, set fire to agricultural residues) inside enhance this risk.

Validation of FFR modelling

A validation of the obtained results through an overlay between FFR map and the delimitation of burned areas occurred in our study area since 2010. The burned areas are located and digitized from the historical images of Google Earth. A zonal statistics were performed for the limit of burned area layer using Tabulate Intersection function of the Analysis toolbox of ArcGis Software. The area in ha of each class of FFR for the different limits of burned area was calculated (Table 5).

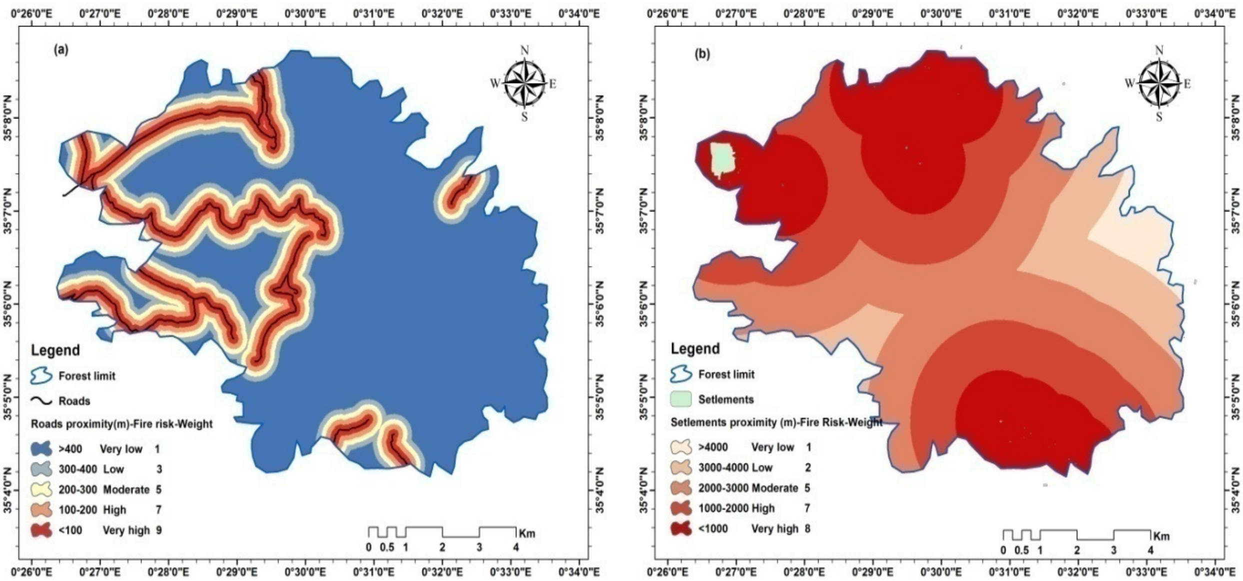

Fig. 5: FFR map based on (a) Distance from roads (b) Settlements proximity

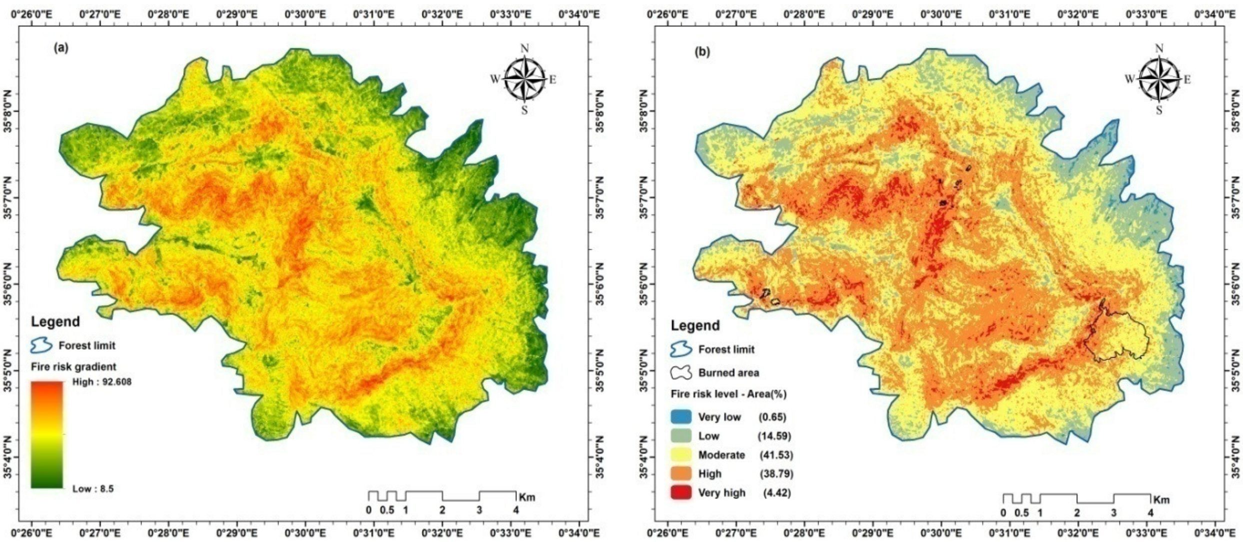

Fig. 6: (a) FFR gradient map (b) FFR levels map of Gharrous forest

The validation results indicate that Moderate, High and Very high FFR levels dominate burned area with a rate of 35.31%, 46.23% and 12.40% respectively. This analysis reveals the degree of sensitivity to fire ignition in the forest of Gharrous that sould be taken earnestly by decision mekers. The FFR map resulting from the application of the present model shows that the method is useful to spatially locate areas which can be very vulnerable to forest fire and suggest an intervention plan to fight against this danger.

Table 4: Area of FFR classes of the study area

Fire risk classes	Risk level	Area (ha)	Area (%)
0-20	Very low	41.75	0.71
20-40	Low	870.53	14.72
40-60	Moderate	2445.72	41.36
60-80	High	2273.47	38.45
>80	Very High	281.31	4.76
Total		5912.78	100.00

Table 5: Area of FFR levels in Burned zones in Gharrous forest

Fire date	Risk level	Area (ha)	Area (%)
2010	Low	1.80	1.70
	Moderate	58.96	55.57
	High	42.07	39.65
	Very high	3.26	3.08
2013	Moderate	0.22	19.99
	High	0.68	62.70
	Very high	0.19	17.31
2016	Moderate	0.03	2.37
	High	0.85	68.42
	Very high	0.36	29.21
2018	Low	0.92	22.57
	Moderate	2.57	63.29
	High	0.57	14.13
Total	Low	2.72	6.07
	Moderate	61.78	35.31
	High	44.18	46.23
	Very high	3.82	12.40

Conclusion

Forest fires represent a very serious problem which continues to destroy and degrade environmental ecosystem in western of Algeria. Fixable and effective diagnostic of forest fires become indispensable in the proposition of appropriated forest management plan. Thereby, the assessment and mapping of the forest fire vulnerable area is unavoidable mostly to prevent and fight fires.

In this work, an approach applying a FFR model is done. This model takes into account five factors considering as responsible of the forest fire ignition. Geomatics tools such as GIS and remote sensing were used to extract and make up thematic layer for each factor and to produce a synthetic FFR map. The resulting map showed a high sensitivity of Gharrous forest with over than 43% of the area as highly and Very highly risked zones.

Assessing and spatializing FFR can successfully help forest managers to get an idea about spatial distribution of the vulnerable zones to fires. Through out this study, we note the effective contribution of GIS and remote sensing to provide a very useful solution for decision-makers for better planning and prioritization of forest management and conservation works.

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References

Adab, H.; Kanniah, K.D. and Solaimani, K. (2012). Modelling forest fire risk in the Northeast of Iran using remote sensing and GIS techniques. Nat Hasards, 65: 1723−1743.

Arellano-Pérez, S.; Castedo-Dorado, F.; López-Sánchez, C.A.; González-Ferreiro, E.; Yang, Z.; Díaz-Varela, R.A.; Álvarez-González, J.G.; Vega, J.A. and Ruiz-González, A.D. (2018). Potential of Sentinel-2A Data to Model Surface and Canopy Fuel Characteristics in Relation to Crown Fire Hazard. Remote Sens, 10(10): 1645.

Arfa, A.M.T.; Benderradji, M.E.H. and Alatou, D. (2009). Analyse des bilans des incendies de forêt et leur impact économique en Algérie entre 1985-2006. New Medit, 8(1): 46-51.

Arroyo, L.A.; Pascual, C. and Manzanera, J.A. (2008). Fire models and methods to map fuel types: The role of remote sensing. Forest Ecol. Manag., 256: 1239-1252.

Assali, F.; Alaoui, H.M.; Rouchdi, M. and Badraoui, M. (2016). Modélisation et cartographie du risque d'éclosion d'incendie de forêt dans le nord-ouest du Maroc (région de Chefchaouen-Ouazzane). Revue d'écologie. 71(2): 111-128

Belgherbi, B.; Benabdeli, K. and Mostefai, K. (2018). Mapping the risk forest fires in Algeria: Application of the forest of Guetarnia in Western Algeria. Ekologie, 37(3): 289-300.

Belhadj-Aissa, M.; Belhadj-Aissa, A. and Smara, Y. (2003). Application du SIG et de la Télédétection dans la Gestion des feux de Forets en Algérie. 2nd FIG Regional Conference Marrakech, Morocco, 16.

Benguerai, A.; Benabdeli, K. and Harizia, A. (2019). Forest Fire Risk Assessment Model Using Remote Sensing and GIS Techniques in Northwest Algeria. Acta Silvatica et Lignaria, 15(1): 9-21.

Dagorne, A.; Duche, Y.; Castex, J.; Ottavi, J.; Dallier, C. and Coster, A. (1994). Protection des forêts Contre les Incendies & Système d'Information Géographique. Application à la Commune d'Auribeau sur Siagne (Alpes Maritimes). Forêt Méditerranéenne. XV, n 4: 416-419.

DGF (2018). Direction Générale des Forêts : Les Feux de Forêts en Algérie, Analyse et Perspectives.

Dong, X.; Li-min, D.; Guo-fan, S. (2005). Forest fire risk zone mapping from satellite images and GIS for Baihe Forestry Bureau, Jilin, China. Journal of Forestry Research, 16: 169–174.

Filipponi, F. (2019). Exploitation of Sentinel-2 Time Series to Map Burned Areas at the National Level: A Case Study on the 2017 Italy Wildfires. Remote Sens, 11(6): 622.

Guettouche, M.; Derias, A.; Boutiba, M.; Bounif, M.; Guendouz, M. and Boudella, A. (2011). A Fire Risk Modelling and Spatialization by GIS. Journal of Geographic Information System, 3(3): 254-265.

Hasheminasab *et al.* (2017). Fire Risk Potential Checking in Forests using Fire Risk Model. International Journal of Constructive Research in Civil Engineering, 3(4): 67-75.

Jaiswal, R.K.; Krishnamurthy, J. and Mukherjee, S. (2005). Regional study for mapping the natural resources prospect and problem zones using remote sensing and GIS. Geocarto Int, 20(3): 21−31.

Khader, M.; Benabdeli, K.; Mederbal, K.; Fekir, Y.; Rami, G. and Mekkous, B. (2009). Etude du risque incendie à l'aide de la géomatique: cas de la forêt de Nesmoth (Algérie). Revistas Mediterránea. 20: 205-234.

Mariel, A. (1995). Cartographie du niveau de risque d'incendie : exemple du massif des Maures Mapping the level of fire risk: example of the Maures massif. Cemagref report..

Meddour-Sahar, O.; Meddour, R.; Leone, V. and Derridj, A. (2014). Motifs des incendies de forêt en Algérie : analyse comparée des dires d'experts de la Protection

Civile et des Forestiers par la méthode Delphi. *VertigO*, 14(3).

Prasad, V.K.; Badarinath, K. and Eaturu, A. (2008). Biophysical and anthropogenic controls of forest fires in the Deccan Plateau. India. J. Environ. Manage, 86: 1–13.

Saatchi, S.; Halligan, K.; Despain, D. and Crabtree., R. (2007). Estimation of Forest Fuel Load From Radar Remote Sensing. IEEE Transactions on Geoscience and Remote Sensing, 45(6): 1726-1740.

Sakellariou, S.; Tampekis, S. and Samara, F. (2019). Determination of fire risk to assist fire management for insular areas: the case of a small Greek island. J. For. Res. 30: 589–601.

Suryabhagavan, K.V.; Alemu, M. and Balakrishnan, M. (2016). GIS-based multi-criteria decision analysis for forest fire susceptibility mapping: a case study in Harenna forest, southwestern Ethiopia. Tropical Ecology, 57(1): 33-43.

Setiawan, I.; Mahmud, A.; Mansor, S.; Shariff, M. and Nuruddin, A. (2004). GIS-grid-based and multi-criteria analysis for identifying and mapping peat swamp forest fire hazard in Pahang, Malaysia. Disaster Prev Manag, 13(5): 379-386.

Talbi., O.; Benabdeli, K.; Benhanifia, K. and Haddouche, D. (2018). Cartographie des zones de risque de feux de forêt dans la commune de Doui Thabet, Saïda, Algérie. International Journal of Environmental Studies, 75(4): 543-552.

Uwe, M.W. (2016). Sentinel-2 MSI – Level-2A Prototype Processor Installation and User Manual, S2PAD-VEGA-SUM-0001, Issue 2.2. https://step.esa.int/thirdparties/sen2cor/2.2.1/S2PAD-VEGA-SUM-0001-2.2.pdf. Accessed 15 December 2018.

Vélez, R. (1999). Protection contre les incendies de forêt : principes et méthodes d'action. In : Vélez R. (ed.). Protection contre les incendies de forêt : principes et méthodes d'action. Zaragoza : CIHEAM 1999. p. 1-18 (Options Méditerranéennes : Série B. Etudes et Recherches; n. 26)

Xu, D.; Shao, G.; Dai, L. (2006). Mapping forest fire risk zones with spatial data and principal component analysis. Sci China Ser E, 49: 140–149.