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ORIGINAL ARTICLE

Fire analysis and prediction in the Zid-Elmoumen forestry (Northwest Algeria)

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Forest fires have a significant impact on Northern African countries, especially Algeria, each year. Predicting fire behavior based on the shape of the current burned area and fireline is important in controlling subsequent fire in hazard wildfire zones, and it is especially important for forest planning and fire assessment. Weather, topography, and fuels are all variables that influence wildfire behavior. This analysis concentrates on a wild topography, which involves slope, altitude, and aspect under a wind conditions to try their role in shape of burned area. Various shapes of burned area were investigated from the Zid-Elmoumen forest in North-West Algeria between 2014 and 2020 to see just how topographic conditions under wind actions affects the burned area distributions. The burned area increased as the forest floor slope gradient was increased with up-wind and decrease with down-wind. In addition, fire spreading is more sensitive to a direction of steepest slope or aspect and their altitude relative to the imposed wind direction. As a such, the primary objective of this study is to understand a current wildfire behavior and suggest a prediction projected wildfires and susceptible burned area using specific data such as elevation, slope gradient, slope direction, and wind condition.

Keywords: Burned area, Topography factors, Wind conditions, Projected wildfires.

Introduction

Forest fires are classified as serious problems with an impacts on the environment, economics and ecology. Wildfires can be caused by both natural and man-made factors. During the last 200 years, wildfires have burned around 6-7 million Km^2 of forest in the world (Qasim, 2015). Wildfires have been a major environmental hazard in the Mediterranean Basin for the last three decades and are considered as the most dangerous environmental issue (Cramer et al., 2018). Currently, they represent main cause of forest destruction, with an estimated burned area of 80000 Km^2 each year (Toujani et al., 2020). The mediterranean vegetation is characterised by its diversity of tree, shrub, and herbaceous species, the distribution of which is controlled by edaphoclimatic conditions and human action.

The continent of Africa has the annually most burned area (Zubkova et al., 2019). In Algeria, fire burns more than 20,000 hectares of forest each year. The losses are significant in terms of human life as well as property devastation, putting an impact on the environment and local economy (Belgherbi, 2018). In addition, many studies were conducted on the risk analysis of forest fires, and fire is the most dangerous and destructive factor that can destroy Algeria's forests (Meddour, 2015). Wildland fire risk assessment and fuel management methods are already a significant effort in the Forest Service on a global scale, as part of attempts to decrease the financial and ecological impacts of catastrophic wildfires (David, 2011). Unfortunately, there is no national fire risk mapping approach to establish a prevention strategy (Belgherbi, 2018). Actively and preventative forest preservation should thus be a key focus in North Africa through suitable fire risk reduction methods. The battle against forest fire crises asks for important tools for estimating wild fire spread to take the appropriate decision and predict its spread and behavior (Qasim, 2015). Fire risk assessments and fuel management will become progressively crucial as urbanization increases into wildlands and climate change has an influence on fire frequency (Bowman et al., 2020).

Developers have mostly used ad hoc fire behavior modeling tools in their research and applications, and planned methods for model system integration have been postponed. To properly appreciate the potential advantages of fuel management ideas, more advanced landscape fire modeling is required for large-scale risk assessment and fuel management operations.

About a physical code and mathematical models used by scientific communities, Jeffrey et al., (2005) used Moderate Resolution Imaging Spectroradiometer MODIS to evaluate heterogeneity of biomass burning and burning area. A Fire Regime-1.0 code used by Piñol Josep Universitat Autònoma de Barcelona Spain, this software uses the Montecarlo technique to estimate the number of fires, burned area, and fire spread each year under various meteorological circumstances. Fire line rotation model developped by Domingos Xavier Viegas (2009) based to semi-empirical model to describe the movement of surface fires, convection effect under different wind conditions. Dynamic Vegetation Models (DVMs), which account for climate and vegetation-related factors, and Earth System Models (ESMs), which include a limited variable set comprising just climate-related variables, are two projected models of burned area. In the study (Lehsten, 2010), these models were used to simulate the total burnt area of Africa from 1980 to 2060. To predict the danger of fire in a forest stand, a logistic model utilizing the binary logistic method in short for Statistical Package for the Social Science SPSS software might be beneficial.

Over the last seventy years, several fire risk indices have been developed, beginning with the purely empirical meteorological indices of Ångström and Nesterov (Angström, 1949; Nesterov, 1949; Käse, 1969) they used maximum and minimum temperature and precipitation data to calculate the Nesterov index, considered as an indicator for fire weather conditions (Mavrakis and Salvati 2015). However, neither the Nesterov index nor precipitation can account alone for the spatial–temporal variation in burned area delared by Eastaugh (2014). Fuel dryness is associated to the Nesterov fire-hazard-index (Thonicke, 2010). In accordance with the premise that soils drought are likely to be coupled with fuel dryness, Keetch and Byram (1968) have developed a Soil Moisture Deficit (KBDI) indicator for the use of fire agencies. Van Wagner's (1987) propose a more complex Index named a Canadian Forest Fire Weather Index explicitly includes how weather conditions affect the moisture content of various fire fuel layers.

Materials and Methods

Study area

The study area is the forest of Zid-Elmoumen which belongs to the forest management of Sidi Bel Abbes city, in the north-west of Algeria. This forest is one of the most densely populated and fire affected regions in mediterranean. It is located in the southern part of city, between the geographical coordinates of (0°54'14.7190"W, 34°48'11.2426"N and 0°19'52.9390"W, 34°52'53.9645"N) with an area of 4700 Ha including a very important Mediterranean floristic diversity, with forests at different stages of development.

The climate is typically mediterranean, with average yearly rainfall between 800 and1000 mm (Fig. 1). Summers are hot and dry, while maximum precipitation is recoded in winter. Forest fires in the Zid-Elmoumen are oriented by predominantly north or north west winds.

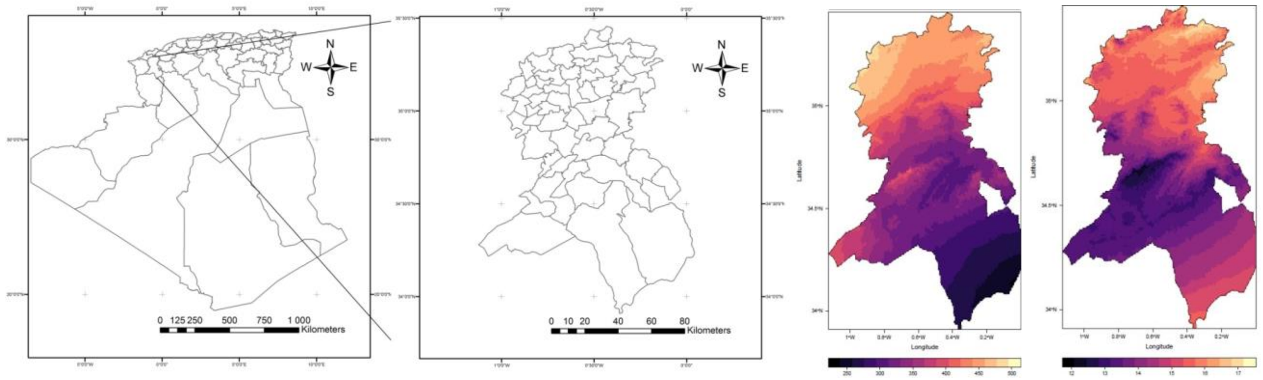

Fig. 1. Precipitation and average temperature of Sidi-bel abbes City (North-west Algeria).

The plant formations of the Zid-Elmoumen forest are composed mainly of *Aleppo pine (Pinus Halipensis)* and *Berber thuja (Tetraclinis Articulata)* in a layer of trees, followed by the maquis, which is a plant formation resulting from a regressive succession forest not exceeding 1 m in height. It is mainly composed of *Holm Oak (Quercus Ilex)*, *Kermes Oak (Quercus Coccifera)*, *Lentiscus (Pistacia Lentiscus)*, *Rosemary (Rosmarinus Tournfortii)* and *Alfa (Stipa Tenacissima)*. The other stations are mainly composed of *white Mugwort (Artemesia Herba Alba)* and other plants containing *Pinus halipensis* regeneration not exceeding 20 cm in height (Benkheira, 2018).

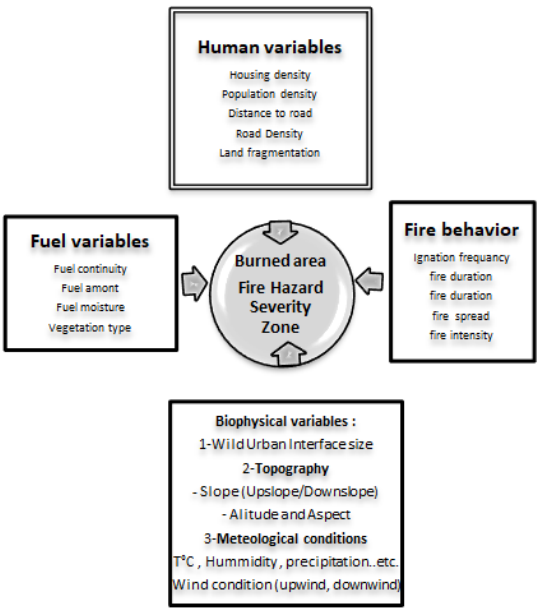

Fig. 2. The major factors controlling burned area.

The main idea of this study is that fire behavior predictions of burned areas and fire lines of projected wildfires are based on an evaluation of the shape of current burned areas and fire lines from existing fires that occurred in a hazard-wildfire region known as the Zid-Elmoumen forest between 2014 and 2016. Various shapes of burned areas were investigated across several stands based on topographical factors such as slope, altitude, and aspect under wind conditions in order to predict fire behavior and obtain consistent prediction of the burned area subsequent to fire. This contribution is crucial for forest planning and fire risk assessment.
the major factors that influence the burned area (Faivre, 2016).The difference in hours between the start and the extinction of a fire can be used to calculate the fire duration (Fig. 2).
In this study, the primary sources of risk were assumed to be related to the topography and wind conditions, as well as site factors. The rate of spread of a fire is measured using the burned area and fire period.

Fire data

The background information used in this study was the official wildfire database from the Algerian Forest Direction (DGF), containing the starting coordinates (ignition) and the resulting burned area of 127 490 fires that occurred in the Zid-Elmoumen Forest between 2014 and 2020. The fire data consisted of the perimeters of forest fires larger than 20 ha for the entire Sidi Bel Abbes region, collected over 6 years. The DGF provided a database of 9127 fires that occurred in Zid-Elmoumen between 2014 and 2019. The burned area in hectares for each event, cartographic coordinates of altitude, aspect, and slope (figure 9), and the number of ignited fires per year (figure date and ignited point final). The phenomenon peaks in the summer season, with more than 80% of fires recorded between May and September.

Geographic information

We used geographic information systems (GIS) to prepare a set of cartographic layers corresponding to the following potentially explanatory variables:
a) Population density:assigning the number of persons per km^2 in considered area;
b) Land cover:cartography identifies number of land cover classes, which were grouped into six major classes:agriculture, forests, shrublands, urban-rural interspersed areas and others;
c) Distance to roads:using a map with the main national and regional roads to calculated the distance (m) from each location of the territory to the nearest road;
d) Elevation.

Topomorphological map data: A Geographic information system (GIS) is a system for the management, analysis, and display of geographic information. Geographic information is represented in datasets that model geography using simple, generic data structures. GIS includes a set of comprehensive tools for working with geographic data (Law and Collins, 2015) (Fig. 3).

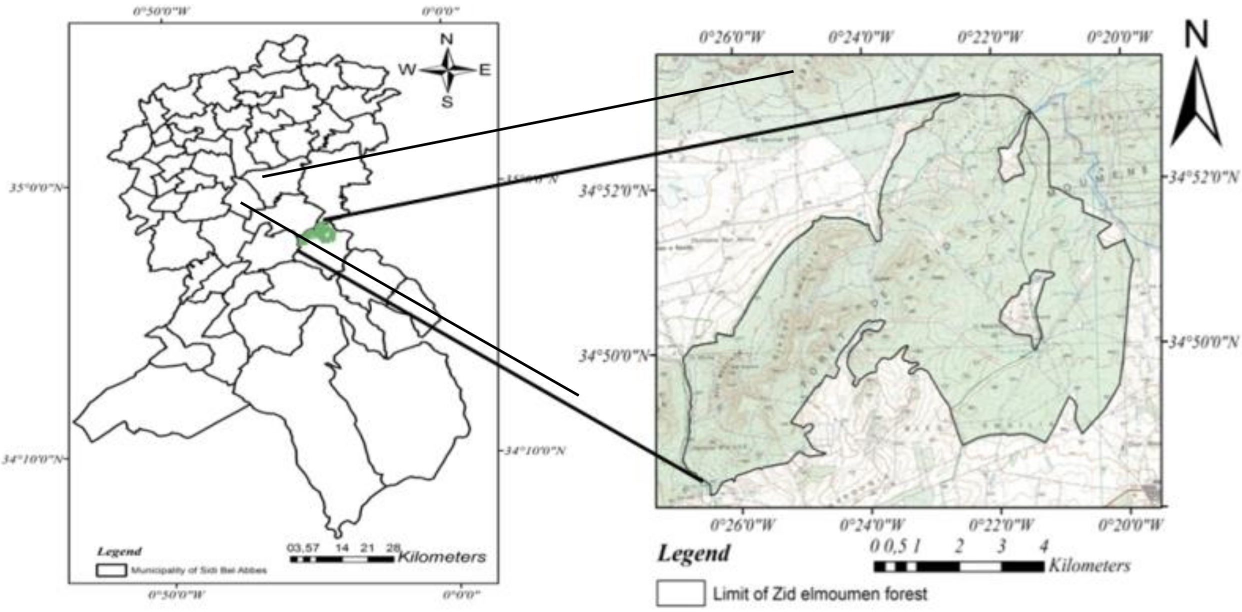

Fig. 3. The geographical map of the study area named Zid-Elmoumen forest of Sidi Bel Abbes (0°54'14.7190"W, 34°48'11.2426"N and 0°19'52.9390"W, 34°52'53.9645"N) North-West Algeria.

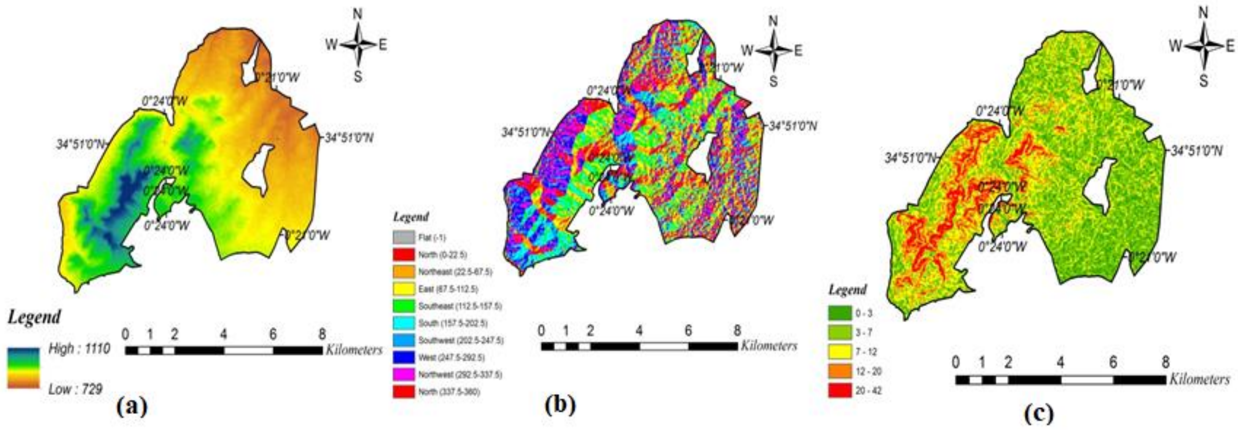

Fig. 4. Topomorphological map description of Zid-Elmoumen forest: (a) Map of altitude, (b) Map of aspect and (c) Map of slope.

A Several perspectives for interacting with geographic data are supported by a geographic information system:

- The Geodatabase View:A Geographic Information System (GIS) is a spatial database that contains datasets that represent geographic data using a general GIS data model (features, rasters, topologies, networks).
- The Geovisualization view:A Geographic Information System (GIS) is a collection of intelligent maps and other views that depict features and their connections on the surface of the planet. Various map views of the underlying geographic data may be created and used as "windows into the database" to assist aeries, analysis, and editing.
- The Geoprocessing view:A Geographic Information System (GIS) is a set of data transformation technologies that create new geographic datasets from existing datasets. These geoprocessing algorithms take data from existing datasets, apply analytical functions, and output new derived datasets.

Mathematical models

The purely empirical method (or statistical), the purely physical method (or deterministic), and an intermediate method (or semi-empirical) are the three types of modeling approaches used in fire modeling.

Semi-ellipse model of fire shape

An empirical model was proposed. This so-called simplified model is a graphical representation of fire spread in vegetation. It is an approximate model, however the prediction, more or less accurate in some cases with lack of fire data like explantation of past fire behavior. This model would be useful for the following applications:

- Tactical fire fighting and control, from the ignition point or a given point on the fire front, it is necessary to predict the direction of the fire's spread in a relatively short period of time.
- Prevention entails identifying the most dangerous areas as well as those that are most vulnerable to fire.
- When the terrain is not too rough, even if the fuel is assumed to be homogeneous or not very heterogeneous, and if the wind does not change instantly on this surface during the fire's development.
- During the sudden intervention of firefighters who seem to have no prior knowledge of the terrain or the detailed distribution of vegetation, necessitating an immediate strategy for fighting the fire.

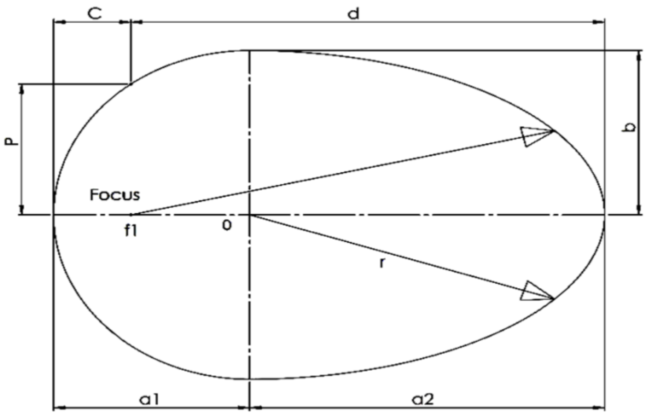

Fig. 5. Description of burned area.

The focus, f_1, represents the origin of the fire and the point from which all measurements to the perimeter can be made. The forward distance traveled with a given rate of spread for a given interval of time is defined by d, the other dimensions are defined as (Fig. 5):

a_1 major axis of semiellipse at the rear of the fire.

a_2 major axis of semiellipse at the front of the fire.

b the common minor axis, the maximum fire spread distance.
c the portion of axis, a_1 that is the backing fire spread.
p semilatus rectum of rear semiellipse and represents the flanking fire at the origin.
d forward distance.
A semi-ellipse model of fire spread in vegetation under different wind velocity can made measurements of the downwind distance from the origin to the perimeter at various angles from the direction of maximum spread and offer a graphical presentation of the fire shape by generation of cross plots for each value of wind velocity, with selected fuel type and caracteristics. The ratio of maximum length to width format beds of vegetation bed can be done by a function of wind velocity by:
(d+c)/b=1.0+0.50 U ……..Eq 1
Where :
$c + d$ total spread distance according to Fig. 5.
b minor axis according to Fig. 1.
U wind velocity in miles per hour(mil/h), at midflame height;
A least-square fit of log regressions for the following dimensions provided equation as functions of windspeed and fraction of the forward spread distance:
b minor semi-axis defined in terms of p and a_1 using a simulatos rectum expression of ellipse and they batter describe it as long function of windspeed. The dimension of fons' curves were reevaluated as fraction of spread distance p.

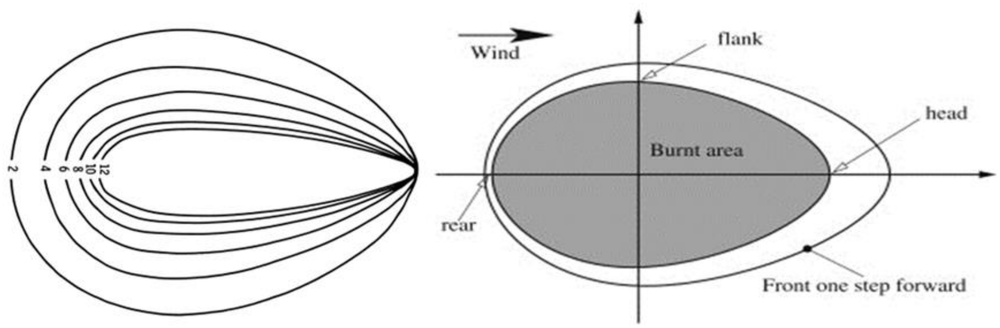

Fig. 6. The shape of the burned area dependent only upon the wind velocity.

$c = 0.492\ e^{[-0.1845\ U]}, r^2 = 0.996$ …….Eq. 2
$S\hat{y}.x = 0.162$
$p = 0.542\ e^{[-0.1483\ U]}, r^2 = 0.993$ ……..Eq. 3
$S\hat{y}.x = 0.140$
$a_1 = 2.502\ [88U]^{-0.30}, r^2 = 0.918$ ……..Eq. 4
$S\hat{y}.x = 0.046$
$a_2 = 1 + c - a_1$ ……..Eq. 5
$b = 0.534\ e^{[-0.1147\ U]}, r^2 = 0.988$ ……..Eq. 6
$S\hat{y}.x = 0.143$

These equations (2-6) provide a means of quantifying important dimensions of the double ellipse representation of fire shape. when these values along with the spread distance are used in equations for area and perimeter, we can estimate fire growth. In addition, the length to width ratio and the envelope of burn area can be estimated. Calculations of area and perimeter require multiplying the fractional expressions of ellipse dimensions by forward spread distance. The following equations have been used or adapted to make estimates of the fire dimensions (Fig. 6).
$\text{Area} = A = \frac{\pi b d^2}{2}(a_1 + a_2);\ ft^2, m^2, etc.$ ……..Eq. 7
$\text{Perimeter} = P = \frac{\pi k_1 d}{2}(a_1 + b) + \frac{\pi k_2 d}{2}(a_2 + b);\ ft, m$ ……..Eq. 8
$k_n = 1 + \frac{M_n^2}{4} + \frac{M_n^4}{64} + \frac{M_n^6}{256}$ ……..Eq. 9
$M_n = \frac{(a_n - b)}{(a_n + b)}$ ……..Eq. 10
Equation 9 can be simplified for ease of computation with a less than 1 percent in accuracy by eliminating the terms after M_n^2.
$k_n = 1 + \frac{M_n^2}{4}$ ……..Eq. 11
For graphical presentation of the fire shape, the perimeter is plotted by using the intercept of the major and minor axes, O, as the origin. This is possible because the minor axis is common to both semiellipses and both semimajor axes can be defined in terms of b, the forward distance traveled along the major axis, and U, the windspread. Any point on the perimeter is defined by:
if $\cos \emptyset \geq 0$ a positive value:
$x = d(a_2 \cos \emptyset)$
$y = d(a_2 \sin \emptyset$
if $\cos \emptyset \leq 0$ a negative value:

$x = d(a_1 \cos \emptyset)$
$y = d(a_2 \sin \emptyset)$
Where $\emptyset$ angular degrees from the forward direction with O as the origin.The origin of the fire is defined as $c - a_1$, the focus of semi-ellipse containing, the backing fire. With these equations and conditional statements, it is possible to predict the area burned by a fire and the distance around its perimeter. Windspeed and the forward rate of spread are the only inputs needed for these simplified model. Working with the simple ellipse we need to use the equations for area and perimeter

$\text{Area} = \pi ab = A, \text{units}^2$ Eq. 12

$\text{Perimeter} = (a + b)k\pi = P, \text{unit}$ Eq. 13

Where

a semimajor axis;

b semiminor axis;

k perimeter

By using the area equation (12) to define b we can substitute into Eq. 13 and reduce it to quadratic equation:

$\pi k a^2 - aP + kA = 0$ Eq. 14

The two axes, a and b can be calculated from:

$a = P + \frac{\sqrt{P^2 - 4\pi k^2 A}}{2\pi k}$ Eq. 15

$b = P - \frac{\sqrt{P^2 - 4\pi k^2 A}}{2\pi k}$ Eq. 16

The advantage of this model is that it gives the opportunity to fire safety agents and investigators of forest fires to estimate the burned area, which is sensitive to wind conditions rapidly in any fuel type. We have adopted this model because we are only interested in the shape of the burned area from past wildfires, not the rate of spread or thermal functions. It suggests a prediction of projected wildfires based on the wind conditions in the simplified fuelbed.

Results and Discussion

The shape and size of the burned area is an important topic. In this paper, it was developed based on data from the maps of the nine burned areas that were presented (Fig. 7). Nine fires in the Zid-Elmoumen forest, situated in the North West of Algeria, occurred between 2014 and 2016. It was developed based on data from selected case studies (Fig. 8). The fires were selected by ArcGis software, such that the burned area represented a variety of sizes and locations. The burned area patterns show a diversity of burned shapes. One fire was selected for further representation, including a map of altitude, of aspect, and a map of slope (Fig. 9).

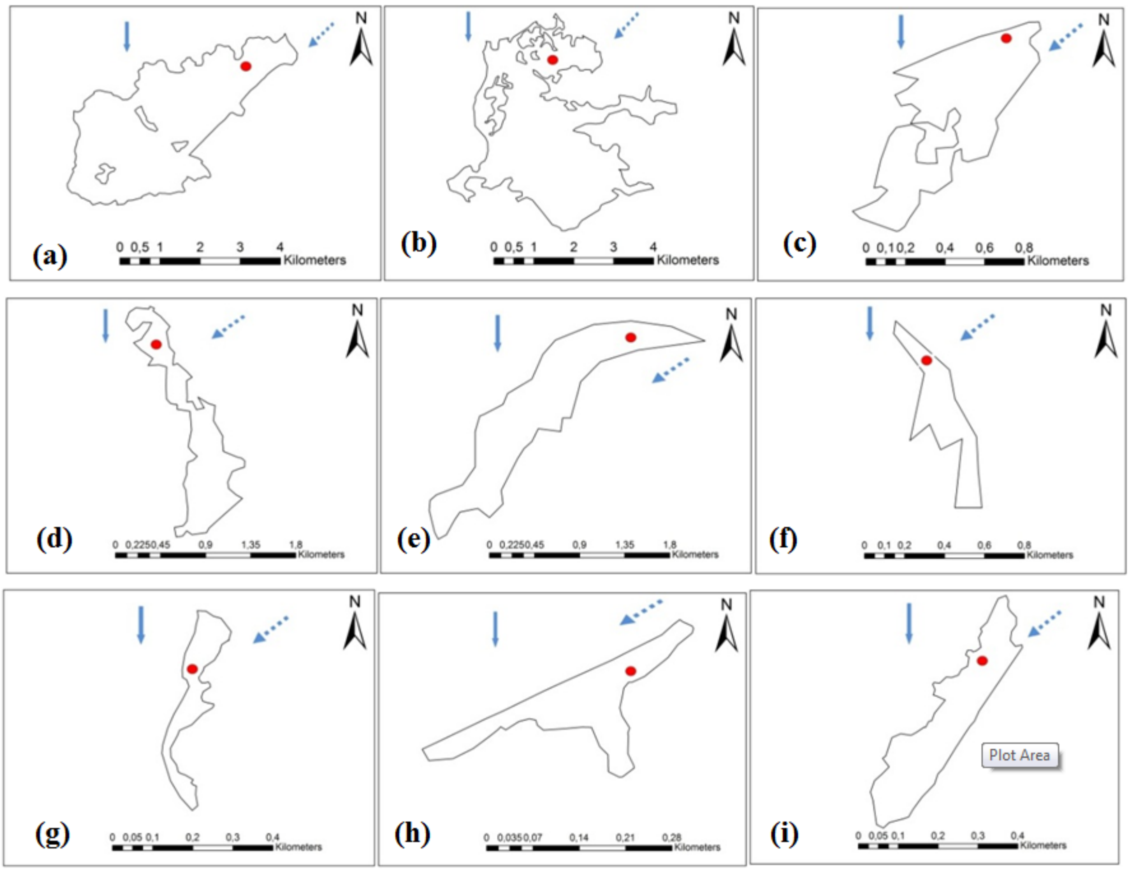

Fig. 7. The shape of various burned area occurred in Zid-Elmoumen forest fire (2014- 2016).

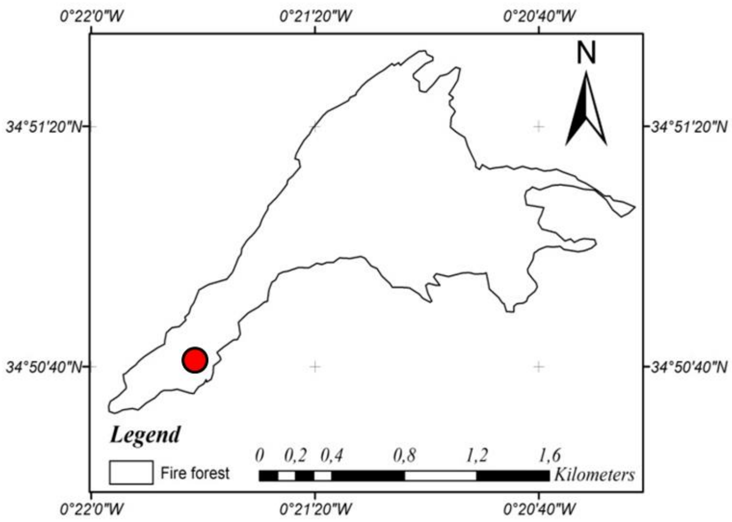

Fig. 8. Map description of burned area of 124.32 ha dated 02-08-2020 in the Zid-Elmoumen forest.

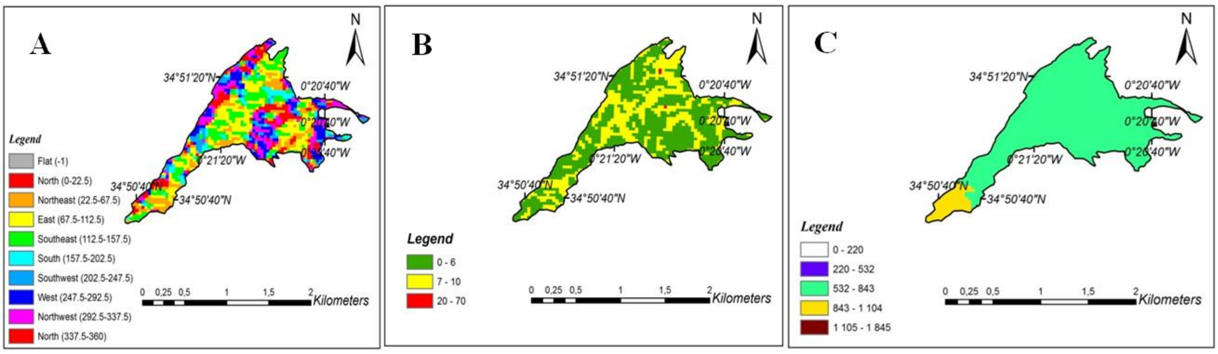

Fig. 9. Burned area description and local ignited source (A) Map of aspect, (B) Map of slope and (C) Map of altitude.

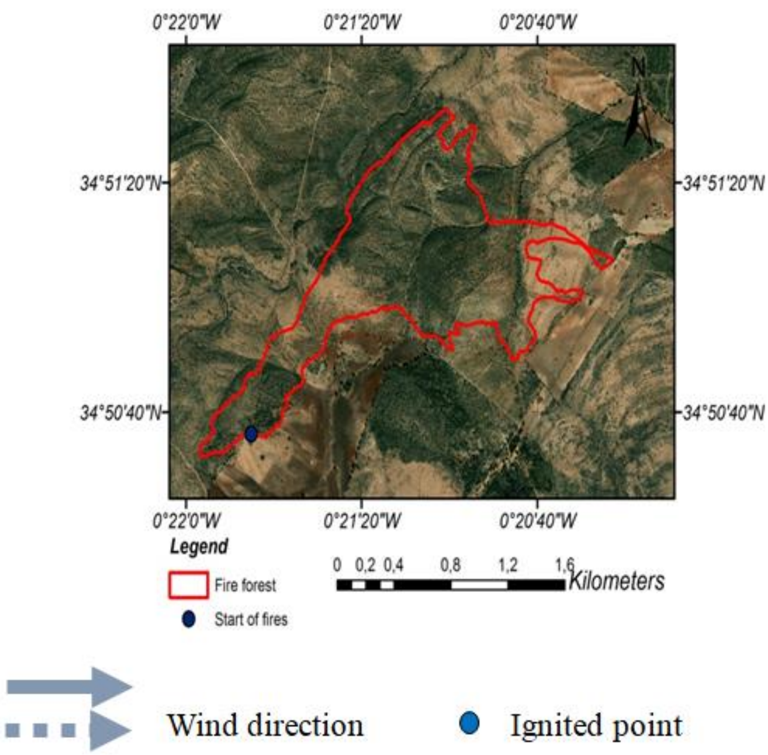

Fig. 10. Satellite image of the burned area.

Determining perimeter and burn area after a fire is often necessary. Average dimensions for a sketch can be obtained by pacing or walking around and through the burn. This method is especially useful for small fires. Global Positioning Systems (GPS) are used for larger fires to determine their shape, area, and perimeter (Fig. 10).

Wildfire anatomy

Our study will focus on the modelling of forest fire behaviour in the study region, more specifically the Zid-Elmoumen forest We caught the fire dated 02/08/2020 which burned an area of 124.32 ha. I was demonstrated that the slope had a significant effect on the surface fire spread (Fig. 11 and 12).

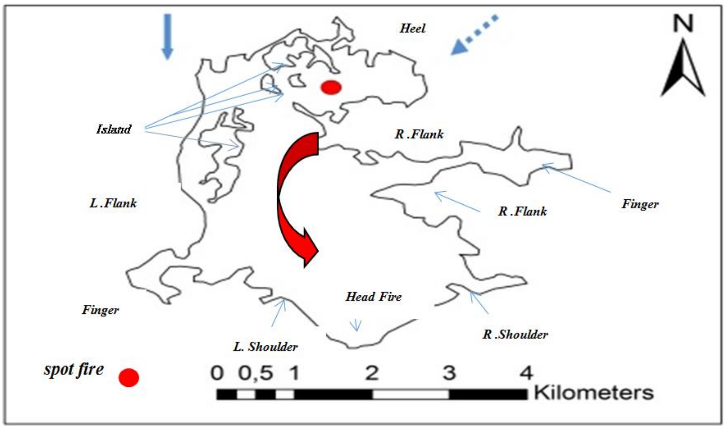

Fig. 11. The anatomical parts of a forest fire.

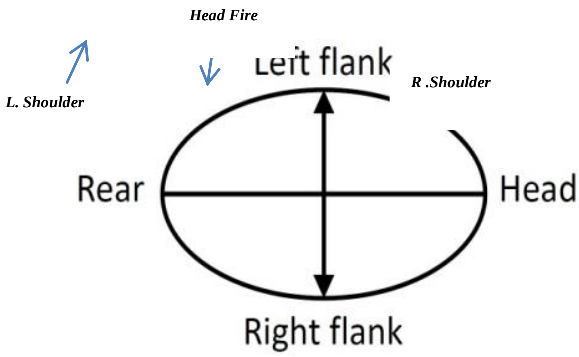

Fig. 12. Parts of fire.

- To use highly detailed terminology to describe the various components of a fire. A typical fire consists of the following elements:
- The perimeter the distance between the fire and the handline is referred to as this. The perimeter of a fire is defined by the lengths of the several lines that encircle the black region of the fire. Because flames frequently burn in unusual forms, such as fingers, the perimeter of a fire can be estimated by assembling a succession of known shapes and lines. A surface fire's spread angle is decreased when the wind velocity is adverse;
- Area (ft^2,yd^2,m^2,acres) refers to the amount of surface area covered inside a certain perimeter and may be used to calculate burnout acreage. The burned area rose in an uneven pattern (%) as the slope gradient increased;
- The "head" of the fire is the fastest-moving section; depending on the fuel and its arrangement, the head usually has the longest flame length, flame depth, and ROS rate of spread ($m.s^{-1}$). This is also where the most aggressive firefighting takes place;
- The edges of a fire that flare outwards into the unburned vegetation are known as the "flanks". The flanks are therefore less wind-aligned than the head, reducing the rate of speed and spread. The intensity of flank firing increases approaching the head, especially where the flanks meet the head, known as the shoulder.
- The "tail" or "heel" of the fire refers to the slowest traveling part.The back of a fire is called the tail or heel and the least amount of fire spreads. The fires on the tail are normally tied to the burnt fire. The tail or thigh is probably the length of a shortest fire's slowest moving portion. Tail fires typically have limited fire activity, but they pose a significant hazard because they burn into areas that are more susceptible to increase fire behavior.
- The origin of the fire is usually near the heel;
- A "finger" is a tiny protrusion from the main body of the fire that may have been the head before the fire expanded in a new direction owing to a wind shift.
- A sliver of unburned fuel inside an active fire's "black" is referred to as a "island" (burned area). When there's a lot of moisture in the air, or the fuels or geography of the area don't lend itself to burning, this happens frequently.
- Spot fires are incandescent or ignited woody particles that can spread to new regions ahead of the moving fire front.

Topography is one of the most important factors in fire behavior. Topography is, in general, unchanging. It's the polar opposite of the weather, that's always changing. Slope, terrain shape, aspect, and obstructions are only a few of the topographic factors that impact fire behavior. The spread of fire is determined in two ways by the slope. The dominance of one mode over the other is determined by the wind direction (upwind or downwind), and the development of new ignited spots is the second factor. A slope's aspect is the direction it faces. The quantity of radiated heat a slope receives from the fire is determined by the direction it faces. Slopes facing various directions get varied amounts of thermal radiation, which affects the time it takes for fires to ignite and burn, as well as the relative humidity, temperature, and vegetation response to moisture loss. In terms of terrain shape, topography has a significant impact on wind conditions. Mountains and ridges act as air barriers. Winds with horizontal movement can be diverted across ridges and mountains, contributing to local up-slope convective winds generated by surface heating from fire. Updrafts from the other side may bend the flames back once they reach the ridge tops. Control lines can be placed on the tops of ridges. Ravines and gullies may alter the flow of air and modify the fire's direction. Heat will dry out fuels on the other side of narrow ravines, making them easy to ignite. Turbulence is caused by intersecting drainages and abrupt turns. Wind will be directed and accelerated by saddles and gaps along a mountain. Winds will be gusty, and spotting will be more common. Fires will tend to burn toward them, intensifying and spreading at a faster pace. This transition may be sudden. Box canyons are ravines that finish at or near the summit of a ridge. They don't have any holes or conspicuous saddles through which the hot air may escape. They allow for strong updrafts to enter the ravine. When the ignition temperature is achieved, heated gases trapped in a ravine or cove might all ignite at the same moment. A dense canopy of trees will also function as a windbreak. It will be pushed over the edge, generating strong winds. Fields, highways, streams, lakes, marshes (if wet), and rocky outcrops are all examples.

The fires recorded in the Zid-Elmoumen forest in the years 2014, 2015 and 2016 represent the largest areas compared to previous years (Fig. 13). This can only be explained by the political instability of the region studied. Other causes may be linked to the riparian population feeding their livestock, which forces them to make forest fires for the biological recovery of vegetation. Even for the use of burnt plots for cereal crops, it is because of the socio-economic situation of the population, with the high unemployment rate in this region. After each intervention against forest fires, the forestry agents measure the fire in the field with Global Positioning Systems GPS, which is then brought back to the office in order to digitize it and deduce the area of the fire. The year 2015 appears to be exceptional in terms of the mean burned area (14.7 ha), as this is more than triple the mean burned area of all other years (4.2 ha). In this sense, year 2011 is representative of the baseline mean burned area, although characterized by a high fire occurrence. 99.8% of fires are of entropic origin, either arson or unintentional.

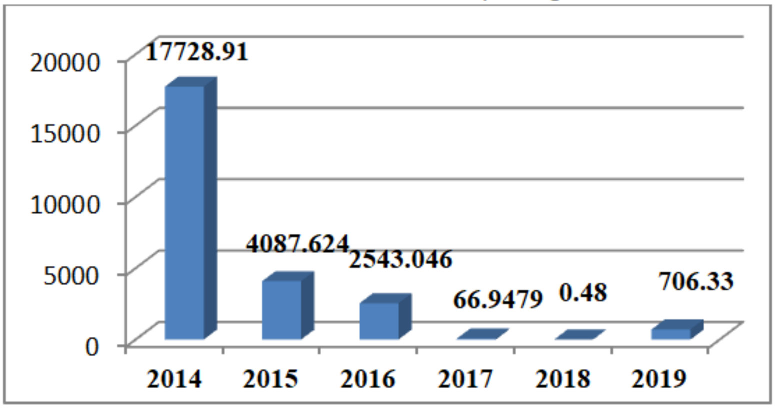

Fig. 13. Area of forest fires per year in Zid-Elmoumen Forest.

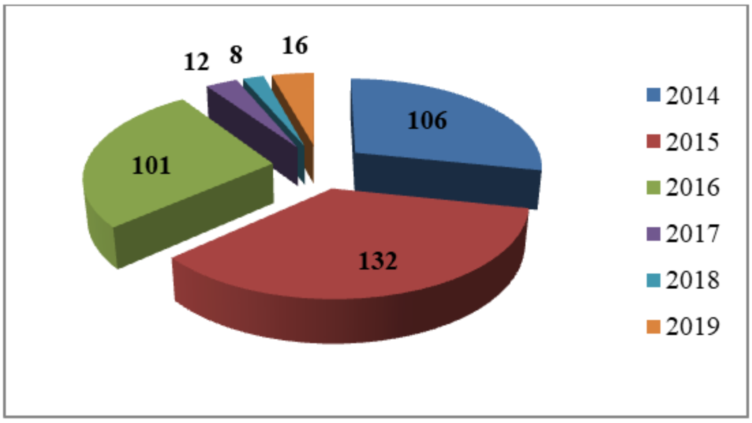

Fig. 14. Number of fires per year (2014-2019) in the Zid-Elmoumen forest.

According to the Fig. 14, we recorded a very high number of outbreaks in the study region in 2015, followed by 2014 and 2016 with respectively 132, 106 and 101 outbreaks, i.e. an average of 4 outbreaks per day. This can only be explained by the fact that intervention in these periods turns out to be very difficult due to the rugged terrain and the flagrant lack of new means of intervention. The only solution was to intervene when the fire emerges from favourable propagation conditions. The years 2017, 2018 and 2019 show a low number of fires compared to previous years. This can be explained by the protocol set by the conservation of the forests of Sidi Bel Abbes city, which is based on vigilance as well as the material and human resources deployed to fight forest fires.

Following a fire, it is preferable to choose trees for removal in order to guarantee that the forest stand regenerates. After a fire, predicting the future of trees that are mostly undisturbed and partially with a restored tree crown becomes increasingly challenging. It might be assumed that a wide range of descriptors are accessible to assess the fire's damage. Because fire behavior varies so much between species and species, it's also more difficult to pick criteria to assess deterioration. The parameters that must be maintained vary depending on the forest organisms. Other factors to consider include the tree's physiological condition during the fire, as well as the site's features. This unpredictability is compounded. However, it is critical to support the diagnostic manager's efforts by implementing easily measurable factors on the ground.

Conclusion

This research will aid managers in determining priority locations for fire prevention sites, vigilance, and resource allocation in order to enhance wildfire predictability. Understanding important components of plant cycles, biological cycling, and pyrogenic pollution across the African continent requires an understanding of current and anticipated wildfires. The predicted fire behavior is estimated based on terrain, wind conditions, and fuel characteristics. For projecting the fire activity level, certain variables such as landscape maps, topography, wind patterns, and historical forest fire records from surrounding land or previously burned areas in the same region are critical. The safest tool is still prevention, which includes all actions aimed at preventing fires, and forecasting anticipated wildfires is part of that plan.

Perspective

The interaction between the fire line, burned area shape, and topographic forest obstacles that oppose the spread of fire, such as terrain shape, aspect, barriers, slope faces, ridges, ravines, gullies, box canyons, tree size, stand structure, and species composition, will be the basis for a new mathematical approche.

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