People's Democratic Republic of Algeria
Ministry of Higher Education and Scientific Research

TLEMCEN UNIVERSITY
Faculty of Natural and Life Sciences and Earth and Universe Sciences

Department of forest resources

MEMOIR

Presented by

BENSAHRAOUI Mohamed

In order to obtain the

Master's Degree

In forestry (forest management and development)

Topic

Application of "GIS – Remote sensing" for forest fire risk mapping, case of the coastal region of Chlef

Defended on September 22nd 2020, in front of the committee composed of:

Chairman	**Pr. Haddouche Driss**	Prof.	TLEMCEN UNIVERSITY
Supervisor	**Mrs. Rabah Fissa Amina née Abdelbaki**	MAA	TLEMCEN UNIVERSITY
Examiner	**Mrs. Korso Lamia**	MAA	TLEMCEN UNIVERSITY

University year 2019/2020

ملخص: تطبيق "نظم المعلومات الجغرافية - الاستشعار عن بعد" لرسم خرائط مخاطر حرائق الغابات، حالة المنطقة الساحلية لولاية الشلف

تعاني المنطقة الساحلية لولاية الشلف من حرائق الغابات ونقص البحث العلمي في هذا الموضوع، لذا في محاولة لعلاج ذلك، جاء الاختيار على بلدية الظهرة كعينة في دراسة قائمة على نظم المعلومات الجغرافية والاستشعار عن بعد لرسم خرائط لمخاطر حرائق الغابات.

النموذج المستخدم يجمع بين العوامل المختلفة المسببة لحرائق الغابات لترسيم خريطة منطقة مخاطر حرائق الغابات. باستخدام العديد من البرامج والاعتماد على العديد من المواقع الإلكترونية لجمع البيانات، تم اشتقاق المتغيرات التالية لمنطقة الدراسة: رطوبة الغطاء النباتي، والمنحدر، والجانب، والارتفاع، والمسافة من الطرق، وجوار المستوطنات على شكل طبقات مرجحة.

نتيجة تراكب طبقات التغطية هي مؤشر الخطر النهائي، والذي أظهر مساحة 103 كيلومتر مربع بنسبة خطر حريق منخفضة جدا، ولكن من ناحية أخرى، فإن معظم السطح المتبقي يمثل مخاطر عالية إلى عالية جدًا مع تغطية 42٪ و9٪ على التوالي. تتمثل الخلاصة في أن مهمة إدارة حرائق الغابات في هذه المنطقة مرهقة للغاية وتتطلب قدراً هائلاً من الجهد.

الكلمات المفتاحية: نار؛ خطر؛ رسم الخرائط؛ نظم المعلومات الجغرافية؛ الاستشعار عن بعد، الظهرة – الشلف.

Abstract: Application of "GIS – Remote sensing" for forest fire risk mapping, case of the coastal region of Chlef.

The coastal region to the Wilaya of Chlef suffers from both forest fires and the lack of scientific research in the subject, so in an effort to remedy that, the choice came to Dahra commune as a sample for a GIS and Remote sensing-based study for mapping forest fire risk.

The model used combines different wildfire-causing factors for demarcating the forest fire risk zone map. Using a multitude of software and relying on several websites for data collection, the following variables were derived for the study area: vegetation moisture, slope, aspect, elevation, distance from roads and the vicinity of settlements in the form of weighted layers.

The result of the coverage layers overlay is the final risk index, which showed an area of 103 Km² with very low fire risk, but on the other hand most of the remaining surface represents high to very high risk with 42% and 9% coverage respectively. The main take away is that the forest fire management task in this area is super onerous and requires a tremendous amount of effort.

Key words: Fire; risk; mapping; GIS; remote sensing, Dahra-Chlef.

Résumé : Application des SIG & Télédétection pour la cartographie des risques d'incendie de forêt, cas de la région côtière de Chlef.

La région côtière de la Wilaya de Chlef souffre à la fois d'incendies de forêt et du manque d'étude scientifique sur la région, Notre choix s'est porté sur la commune de Dahra comme échantillon pour une étude basée sur le SIG et la télédétection pour la cartographie des risques d'incendie de forêt.

Le modèle utilisé combine différents facteurs à l'origine des incendies de forêt pour élaborer une carte des zones à risque d'incendies de forêt. À l'aide d'une multitude de logiciels et en s'appuyant sur plusieurs sites Web, les variables suivantes ont été superposées : humidité de la végétation, pente, exposition, élévation, éloignement des routes et la proximité des habitations, sous forme de couches pondérées.

Le résultat de la modélisation faite est l'indice de risque final (carte), qui a montré une zone de 103 Km² risque d'incendie très faible, alors que la majeure partie de la surface restante représente un risque élevé à très élevé avec une couverture de 42% et 9% respectivement.

Mots clés : Feu; risque; cartographie; SIG; télédétection ; Dahra-Chlef.

Acknowledgment

All thanks and praises are to god for providing me the will and power to see this project through.

Foremost I would like to express my sincere gratitude to my adviser Mrs. Rabeh for the continued support of my study, for her patience, motivation, enthusiasm and for helping me on this research.

I wish to thank my committee members, chairman Pr. Haddouche and examiner Mrs. Korso for being more than generous with their expertise and precious time, helping shape this memoir to its final form with their input.

I would also like to express my appreciation for the Chlef conservation of forests and its staff for their cooperation.

Dedication

I dedicate my dissertation work to my family.

A special feeling of gratitude to my loving parents, Kamel and Yamina BENSAHRAOUI whose words of encouragement and push for greatness ring in my ears. My sister Fatima, my Brothers Youcef Ilyes and Yacine who have never left my side and are very special.

I also dedicate this dissertation to my many friends who have supported me throughout the process. I will always appreciate all they have done.

I dedicate this work and give special thanks to my high-school English teacher Leila BENELHADJ DJELLOUL for this memoir would not be possible if not for her genuine honest work.

Table of contents

List of figures

List of tables

List of acronyms

GIS: Geographic Information System.

SWIR: Short-wave infrared.

NIR: near infrared.

NDMI: Normalized Difference Moisture Index.

RI: Risk index.

DFCI: défense des forêts contre les incendies.

ONM: office national de météorologie.

P.P.R: plan de prévention des risques naturels.

A.S.Al: Algerian space agency.

General Introduction

General introduction

Our planet earth functions according to a very delicate system based on balance between its components, one of which is the forest, providing fresh air, habitat and shelter to animals and storing carbon from the atmosphere in the trunks of its trees. With those benefits to nature and humans, forests are to be protected against the numerus dangers threatening their existence.

One of the highly destructive phenomena are forest fires, with their indiscriminating violence and incontrollable outbreaks, they claim each year hundreds of square kilometers around the world. A recent example comes to mind with the Australian wildfires of 2020 claiming 186,000 km² and the lives of nearly a billion vertebrates alone as mentioned in a news article (Burton, 2020).

The severity of those wildfire warrants a more reliable system of prediction so measures of prevention can be taken before it's too late.

The analysis of the results of forest fires in the Wilaya of Chlef during the period "2009 - 2019" reveals a financial loss of 980 772 714 DA, caused by 1110 fires sweeping 6483.99 ha. The most affected formation is the forest (66% of which are state-owned). (Addadi, 2020).

This study knocks on a specific type of prediction based on geographical data assessment and remote sensing to establish an index mapping zones more prone to fires, with the aim of assisting decision makers in Dahra commune north-west of Chlef – Algeria get the best result with infrastructure and manpower placement.

The memoir is structured around 4 chapters starting with the bibliographical synthesis then the area of study, materials and method and finally results and analysis.

Chapter I
Bibliographical synthesis

Chapter I- Bibliographical synthesis

1- General overview on the problem of forest fires in Algeria

1-1 Introduction to forest fires

Forests are considered a major natural resource, which plays an important role in maintaining natural ecological balance. The health of a forest in any given area is a true indicator of the ecological conditions, habitat composition and species richness prevailing in that area (Datiko et Bekele, 2014).

One of the phenomena that effect these habitats is forest fire and it is one that has been present on earth ever since the development of terrestrial vegetation and has played an important role in maintaining the dynamics of disturbances in certain ecosystems.

However, the serious forest fires that have broken out in different parts of the world have had very negative consequences for the environment and have attracted international attention, like the recent amazon bush fires of 2019.

Fire is the primary cause of forest degradation on a planetary, local and regional scale, as is the case for the Algerian and Mediterranean forest. It plays a major role in modifying our environment.

1-2 Definition

The forest fire feeds on all possible fuels and thus spreads until they are exhausted. They are triggered in areas of tree, shrub and herbaceous vegetation which spread over at least one hectare to be considered as such (Trabaud ,1992).

A fire is a phenomenon that escapes human control, both in duration and in extent, it arises from the meeting of a heat source whose temperature exceeds 600 ° C and flammable vegetation.

Once the fire is lit, a flame front forms, which moves all the more quickly as the vegetation is dried. This will form a curtain higher than the trees, which sweeps the forest while passing a "Heat wave" in front of in, which is a mixture of gas and hot air (Megrerouche, 2006).

1-3 Causes of forest fires in Algeria

The risk of forest fire in Algeria is managed by the Directorate General of Forests (DGF), which reports to the Ministry of Agriculture; in collaboration with meteorological services, civil protection, all local communities and most recently with the Algerian space agency (ASAL).

The causes of forest fires vary from country to country and are very difficult to identify with certainty. They also vary over time, anthropogenic influence remains the main cause of fires in the world, since, 90% of forest fires are linked to human activities whether by accident, agriculture, deforestation and arsonists. (Alexandiran et Gouiran,1990).

1-3-1 Natural causes

the only known natural cause in the countries of the Mediterranean Basin is lightning. According to the (P.P.R., 2000) guide, it only contributes 4 to 7% to the number of fires starts in the heart of the massifs during the summer.

1-3-2 Human causes

Controlling the human causes of fires is becoming increasingly difficult. Statistically the human causes are the most numerous and represent the main part of the origins of forest fires, we find involuntary causes and voluntary causes. (Dong, 2003).

1-3-3 Unintentional causes

Among the known causes, those which are involuntary (negligence or accidents) come first in all countries, except in Turkey where voluntary ignitions seem to be the majority (Canakcioglu, 1986).

The majority of fire outbreak areas are located at the interfaces between natural and urban spaces. Urban populations are particularly insensitive to the danger of fires and their potentially dangerous consequences. Many city dwellers do not see forest fires as a threat, even in mid-summer. Accidents and carelessness are also the most common causes of fires. Accidental causes vary from country to country: there are those linked to fixed installations (power lines, garbage dumps, etc.) (Info. DFCI, 1998) and those directly linked to human activity (charcoal burners, poorly controlled burns, smokers, campfires, shepherds' fires) (Favre, 1992).

1-3-4 Voluntary causes

Arson is usually the most important because the man who started it chooses the most flammable site inside the forest at a time of high temperature. Arsonists who ignite for fun or play, this arson is more or less sickly, depending on the degree of responsibility of the individual.

Fire, can also be a tool for revenge following a dispute with the administration (hunters) or with a neighbor, social exclusion (dismissed workers). Forest fires can also be caused for economic and political reasons

(Leone, 1990). In order to lower the price of wood, for example, fires caused by revenge for conflicts over rights to hunt, to property in forests or even forestry policy. In other areas, fires are lit to keep pests away.

1-4 Risk of forest fire

Control of fire is difficult, but it is feasible to map fire risk by geospatial technologies and thereby minimize the frequency of fire occurrences and damages caused by fire. Effective planning is essential to the success of fire management programs in order to achieve the goals of fuel hazard reduction and fire regime restoration and maintenance (Keifer et al., 1999). The terms hazard and risk have been formally associated with fire management in the United States since the inception of modern fire science in the 1920s (Hardy, 2005).

Generally, forest fire management contains four steps of analysis and assessment of effective response to fires, namely, mapping both potential fire hazard and risk, detecting hot spots, monitoring active fires and assessing post-fire degradation (Roy, 2003).

Several environmental factors, including fuel load (vegetation cover), climate condition and physiography (elevation and slope), have major impacts over the creation, propagation and intensity of forest fires. Many fire risk models have been developed based on environmental factors that influence wildfire (Mohammadi et al., 2014).

1-5 Fire risk indices

The risk assessment of forest fires has been the subject of several studies, which led to the establishment of several fire risk indices.

1-5-1 The Canadian method

It consists of four subsystems:

- IFM system = forest-weather index

It has six standardized indices. The first three indicate the daily variations in the water content of the three types of forest fuels with different drying rates and the other three relate to the behavior of fire, which represents the speed of propagation, the quantity of fuel burned and the intensity of fire.

- PCI system = method for predicting fire behavior.

It's a vegetation risk assessment model. it describes the four behaviors of the fire: propagation speed, fuel consumption, intensity of the fire downwind and description of the fire (surface or crown).

- POI system = method for predicting fire occurrences

Includes several approaches to predict the number of fires started by lightning or by man, depending on the region.

- Humidity system of secondary fuels

Their main role is to facilitate particular applications or to meet the special requirements of the other three main systems.

1-5-2 French method:

This method is based on a model developed by (Dagorne et Duché, 1994)**,** on similar areas on the north side of the Mediterranean. It aims to give an objective value to the risk of forest fires by taking into account the specific characteristics of the vegetation, the support space and the human occupation of the soil. The model involves the three main factors for the assessment of the risk of forest fire, namely: topo morphology, fuel and human activities (Bousmal et Ezzedami, 2018).

The model is based on the following formula:

IR = 5.IC + 2.IH + IM

IR: forest fire risk index; IC: combustibility index;

IH: human occupation index;

IM: topological morphological index

1-5-3 Turkish method

Based on a fire risk mapping model that has been developed by Turkish academics (Erten, et al., 2002). For the risk assessment of fires, the model involves 5 factors:

$$RC = 7*V_T + 5*(S+A) + 3*(D_R+D_S)$$

In this equation, RC is the numerical index of forest fire risk zones where V_T indicates vegetation type with 5 classes, *S* the slope factor with 5 classes, *A* the aspect variable with 4 classes, D_R and D_S indicate distance factor from road and settlement.

2- Geomatics

2-1 Remote sensing

2-1-1 Definition

Remote sensing can be broadly defined as the collection and interpretation of information about an object, area, or event without being in physical contact with the object. Aircraft and satellites are the common platforms for remote sensing of the earth and its natural resources (Kairu, 1982).

In the present context, the definition of remote sensing is restricted to mean the process of acquiring information about any object without physically contacting it in anyway regardless of whether the observer is immediately adjacent to the object or millions of miles away. It is further required that such sensing may be achieved in the absence of any matter in the intervening space between the object and the observer. Consequently, the information about the object, area or any phenomenon must be available in a form that can be impressed on a carrier vacuum. The information carrier, or communication link, is electromagnetic energy. Remote sensing data basically consists of wavelength intensity information acquired by collecting the electromagnetic radiation leaving the object at a specific wavelength and measuring its intensity (Reddy, 2008).

2-1-2 Basic principles of remote sensing

Figure 1 schematically illustrates the generalized processes and elements involved in electromagnetic remote sensing of earth resources.

The two basic processes involved are data acquisition and data analysis. The elements of the data acquisition process are energy sources (a), propagation of energy through the atmosphere (b), energy interactions with earth surface features (c), retransmission of energy through the atmosphere (d), airborne and/or spaceborne sensors (e), resulting in the generation of sensor data in pictorial and/or digital form (f).

In short, we use sensors to record variations in the way earth surface features reflect and emit electromagnetic energy. The data analysis process (g) involves examining the data using various viewing and interpretation devices to analyze pictorial data and/or a computer to analyze digital sensor data. Reference data about the resources being studied (such as soil maps, crop statistics, or field-check data) are used (Lillesand et al., 1979).

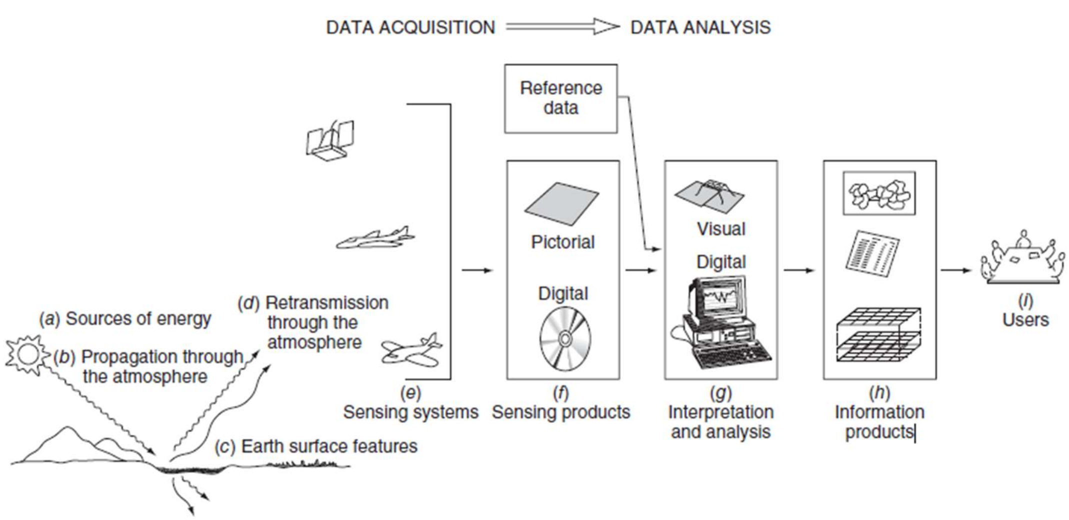

Figure 1: Electromagnetic remote sensing of earth resources.

2-1-3 Electromagnetic radiation and spectrum

Visible light is only one of many forms of electromagnetic energy. Radio waves, ultraviolet rays, radiant heat and X-rays are other familiar forms. All this energy is inherently similar and propagates in accordance with basic wave theory. This theory describes electromagnetic energy as traveling in a harmonic, sinusoidal fashion at the “velocity of light” C. The distance from one wave peak to the next is the wavelength λ and the number of peaks passing a fixed point in space per unit time is the wave frequency v (Lillesand et al., 1979).

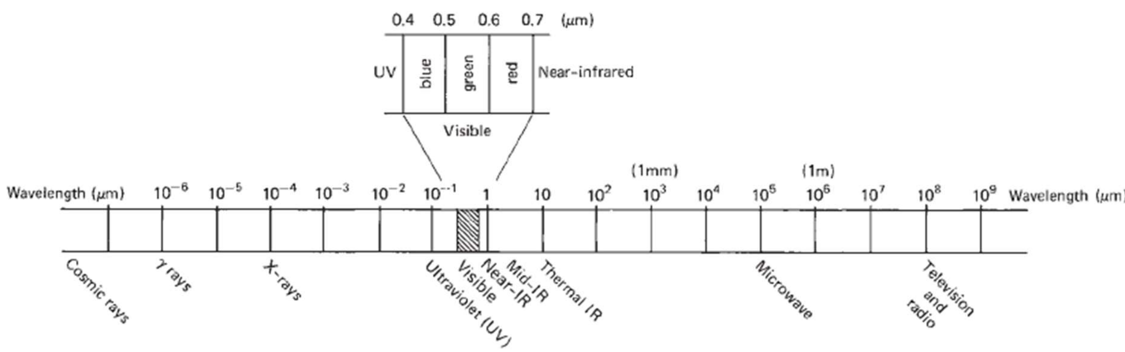

Figure 2: Electromagnetic spectrum.

In brief, the electromagnetic spectrum is the continuum of energy that ranges from meters to nano-meters in wave length, travels at the speed of light and propagates through a vacuum like the outer space (Sabins, 1987).

2-1-4 Radiation / matter interactions

As reported by Reddy (2008) when electromagnetic energy is incident on any feature of earth's surface, various fractions of energy get reflected, absorbed and transmitted as shown in Figure 3. Applying the principle of conservation of energy, the relationship can be expressed as:

$$E_I(\lambda) = E_R(\lambda) + E_A(\lambda) + E_T(\lambda)$$

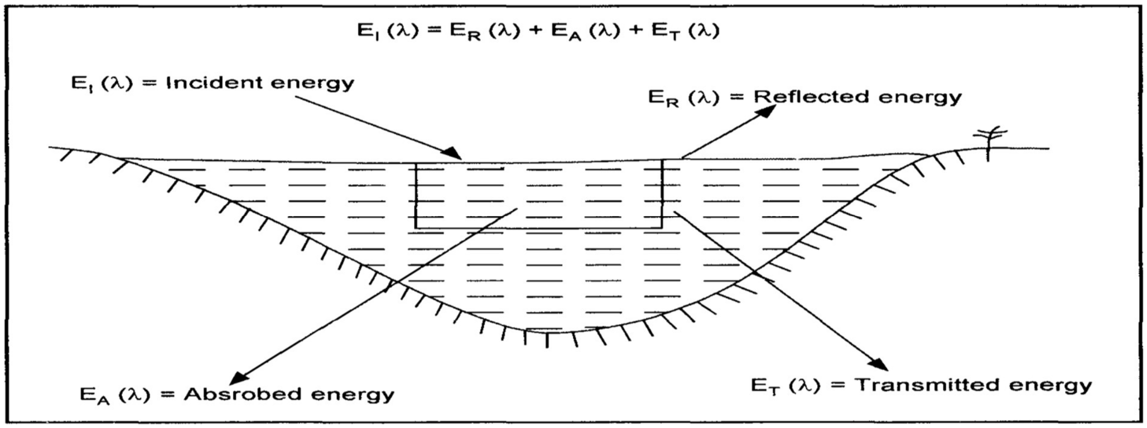

Figure 3: Basic interactions between Electromagnetic Energy and the earth's surface

2-2 Geographic information systems

2-2-1 Definition of a GIS

GIS are decision support computer-based systems for collecting, storing, presenting and analyzing geographical spatial information. These systems are spatially referenced databases giving users the potentiality to control queries over space and usually through time.

GIS is much more advanced than Computer Aided Design (CAD)or any other spatial data system. The basic output of GIS or spatial data analysis system is a map. The need to analyze maps to compare and contrast patterns of earth related phenomena (Reddy, 2008).

The need to place information in a geographical context pervades many aspects of human activity. In public and commercial organizations, many of these activities are concerned with the recording and planning of the human-made environment, with monitoring and managing the natural environment, with transport and navigation and with understanding social structures. It is an inevitable consequence of the revolution in information technology that we should attempt to build computing systems to handle this geographical information.

The results of these technological efforts are reflected in the fields of geographical information systems (GIS) and computer cartography GIS is a generic term denoting the use of computers to create and depict digital representations of the Earth's surface (Jones, 1997).

2-2-2 Structure of a GIS

According to Hessas (2005) the geographic information systems are structured around four main features:

- The acquisition of input data;
- Storage, recovery and management of databases;
- Data manipulation and analysis;
- Display of data allowing the user to understand spatial phenomena.

2-2-3 Functioning of GIS

According to (Reddy, 2008) GIS is a computerized database system for capture, storage, retrieval, analysis and display of spatial data. It is a general-purpose technology for handling geographic data in digital form and satisfying the following specific needs, among others:

I- the ability to preprocess data from large stores into a form suitable for analysis, including operations such as reformatting, change of projection, resampling and generalization;

II- direct support for analysis and modeling, so that form of analysis, calibrations of models, forecasting and prediction are all handled through instructions to the GIS;

III- post processing of results including such operations as reformatting, tabulation, report generation and mapping.

2-2-4 Data modes in GIS

Burrough (1986) observed that the human eye is highly efficient at recognizing shapes and forms but the computer needs to be instructed exactly how spatial patterns should be handled and displayed. Computers require precise and clear instructions on how to turn data about spatial entities into graphical representations. The process is the second stage in designing and implementing a data model.

At present there are two main approaches in which computers can handle and display spatial entities. They are the raster and vector approaches (Reddy, 2008).

2-2-5 Application areas

Since GIS are management tools that help in decision making and work organization, their field of application is large and diverse. Examples for areas and businesses that use geographic information system:

- Risk Management;
- Claims Analysis;
- Customer Analytics;
- Territory Creation;
- Routing;
- Supply Chain Analysis;
- Asset Tracking and Monitoring;
- Customer Service Portals;
- Regulation / Policy Compliance;
- Safety and Security;
- Workforce Management.

Chapter II

The area of study

Chapter II- The area of study

1- introduction to the area of study

1-1 The choice of the area

As this study has for objective the employment of knowledge, information and skills acquired throughout the university curriculum, it is also necessary to consider enriching and adding to the collective good of the region when choosing the study area. With that in mind the Dahra commune was chosen as it is part of the costal line of the Wilaya of Chlef which is gravely impacted by forest fires.

The choice of the area was mainly taken for the lack of other scientific inquires in the region, especially when it comes to those forest fires even though they are an interesting part of the overall dynamic.

1-2 Geographical location

Dahra commune with an area of 240 Km² is the farthest to the northwest of the coastal line of Chlef , it is bordered by the communes of Negmaria, Ouled Boughalem and Achâacha (Mostaganem) to the west, by Mediouna and Sidi M'hamed Ben Ali (wilaya of Relizane) to the south, by Taougrite to the east, to the north by the Mediterranean Sea and to north-east by the commune of El Mersa.

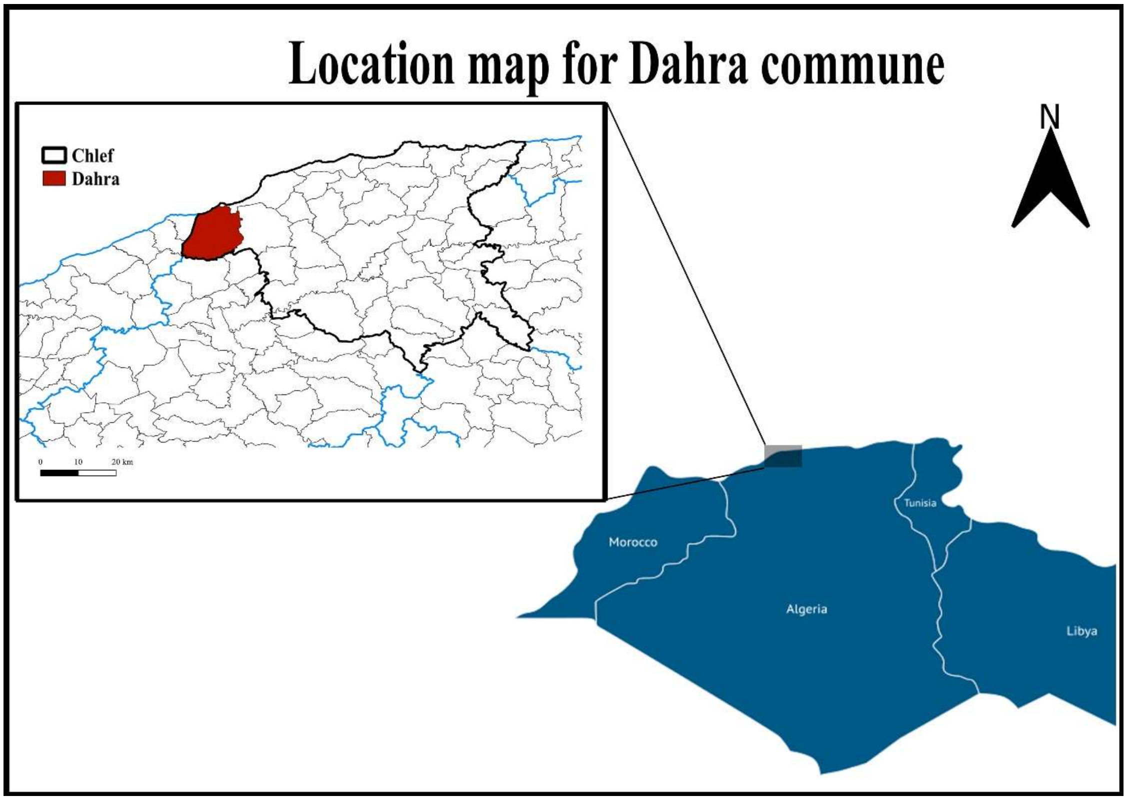

Figure 4: Geographical location of the Dahra commune

2- Climatic characteristics:

For the climatic study, data from the Ténès meteorological station was analyzed and studied to give a representative and accurate result in respect of temperature and precipitation.

2-1 Precipitation

Table 1: Average monthly precipitation (mm), NASA (1989-2019)

Month / Station	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	year
Ténès (mm)	50.70	43.98	43.65	43.80	29.47	7.29	2.89	9.07	24.37	37.70	58.70	43.79	395.42

power.larc.nasa.gov

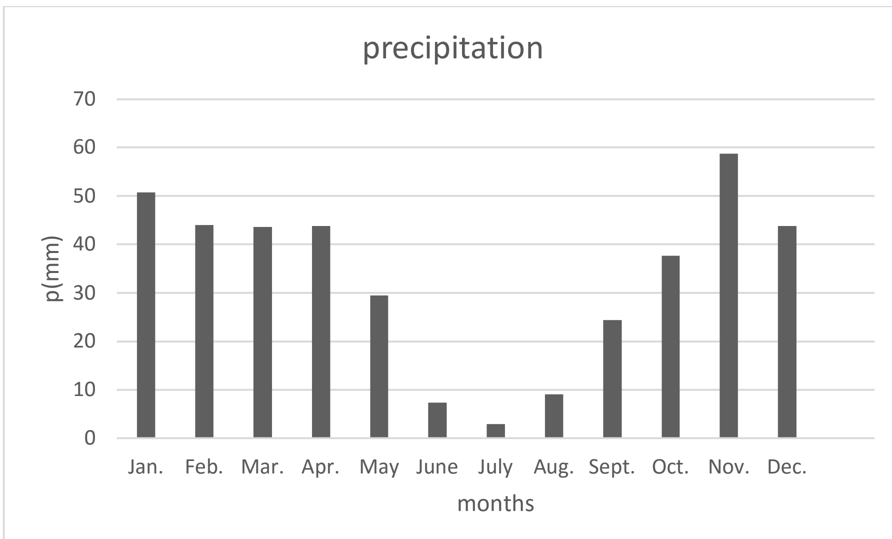

Figure 5: Histogram of monthly average precipitation

The rainfall regime is based on the calculation of precipitation per season (autumn, winter, spring and summer). Then a precipitation ranking from highest to lowest to characterize the climate type, which is W.A.Sp.S in this region.

2-2 temperature

Table 2: Monthly average temperatures, NASA (1989-2019)

Month	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	year
m (°C)	9.08	9.19	10.77	12.58	15.56	19.11	22.25	23.32	20.86	17.42	13.13	10.42	15.31
M (°C)	15.33	16.03	18.27	20.19	23.54	27.53	31.04	31.65	28.16	24.41	19.34	16.46	22.70
T (°C)	11.81	12.23	14.17	16.14	19.36	23.17	26.40	27.14	24.09	20.42	15.82	13.02	18.68

power.larc.nasa.gov

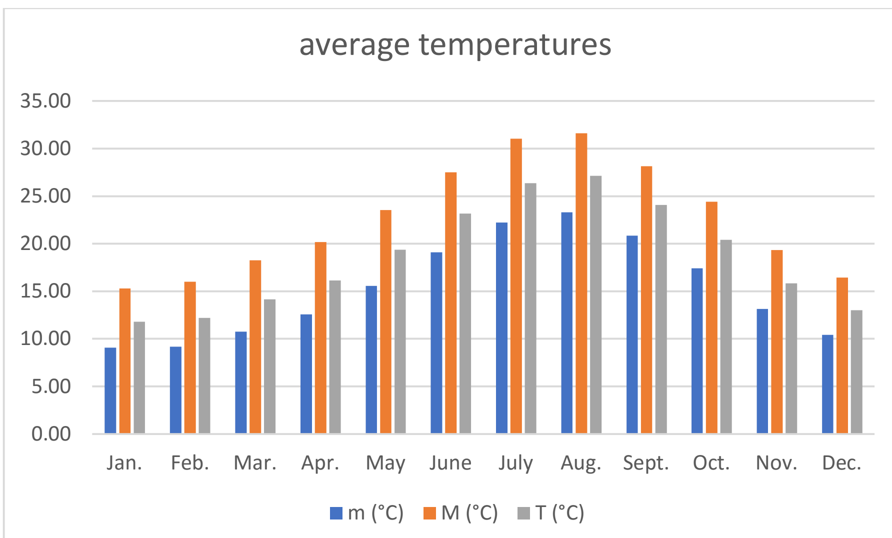

Figure 6: Histogram of monthly average temperatures.

The thermal regime of the region is characterized by elevated temperatures in the summer and relatively low temperatures in the winter.

3- Climate synthesis

To better comprehend the climatic data at hand scientists established indices that combine the elements of climate into one quantifiable factor.

3-1 Bagnouls and Gaussen ombrothermal diagram (1935)

This diagram allows the determination of the dry season by a graphic representation showing the months of the year on the abscissa, the temperature on the right and the precipitation on the left; while adopting the scale **P ≤ 2T**

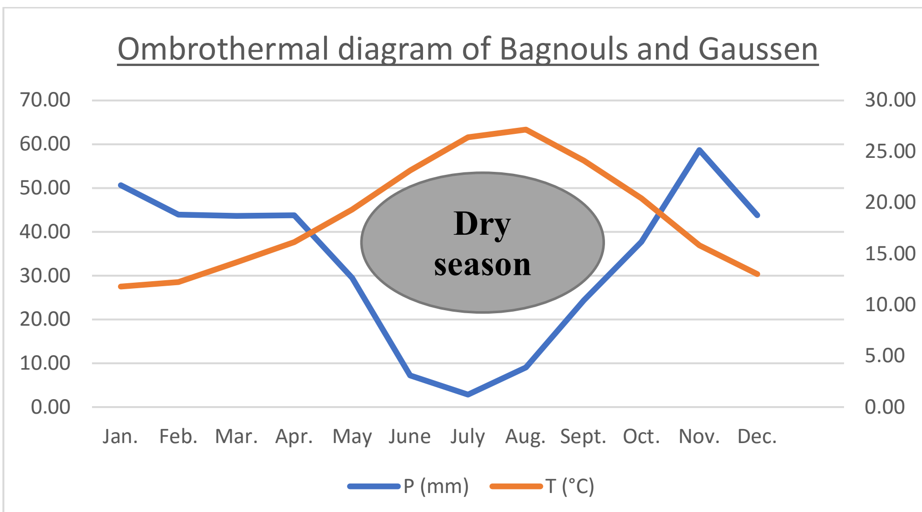

Figure 7: Ombrothermal diagram of Bagnouls and Gaussen.

The chart in figure 7 demonstrates the dry season, where the temperature curve is higher than the precipitation's curve. This graphic representation helps determine the dry months which are April to October.

3-2 EMBERGER's pluviothermic quotient

In 1952 Emberger's proposed the simplest formula, valid for the Mediterranean region where evaporation is of particular importance, based on the criteria related to the average annual precipitation P (mm), to the average minimum of the coldest month of the year (m ° C) and the average of the maximum of the hottest month (M ° C) defined by the expression:

$$Q2 = \frac{1000p}{\frac{M+m}{2}(M-m)} = \frac{2000P}{M^2 - m^2}$$

Where:

P = Average annual precipitation in (mm)

M = Average of the maxima of the hottest month in (° K)

m =Average of the minima of the coldest month in (° K)

T°K = T ° C + 273.15

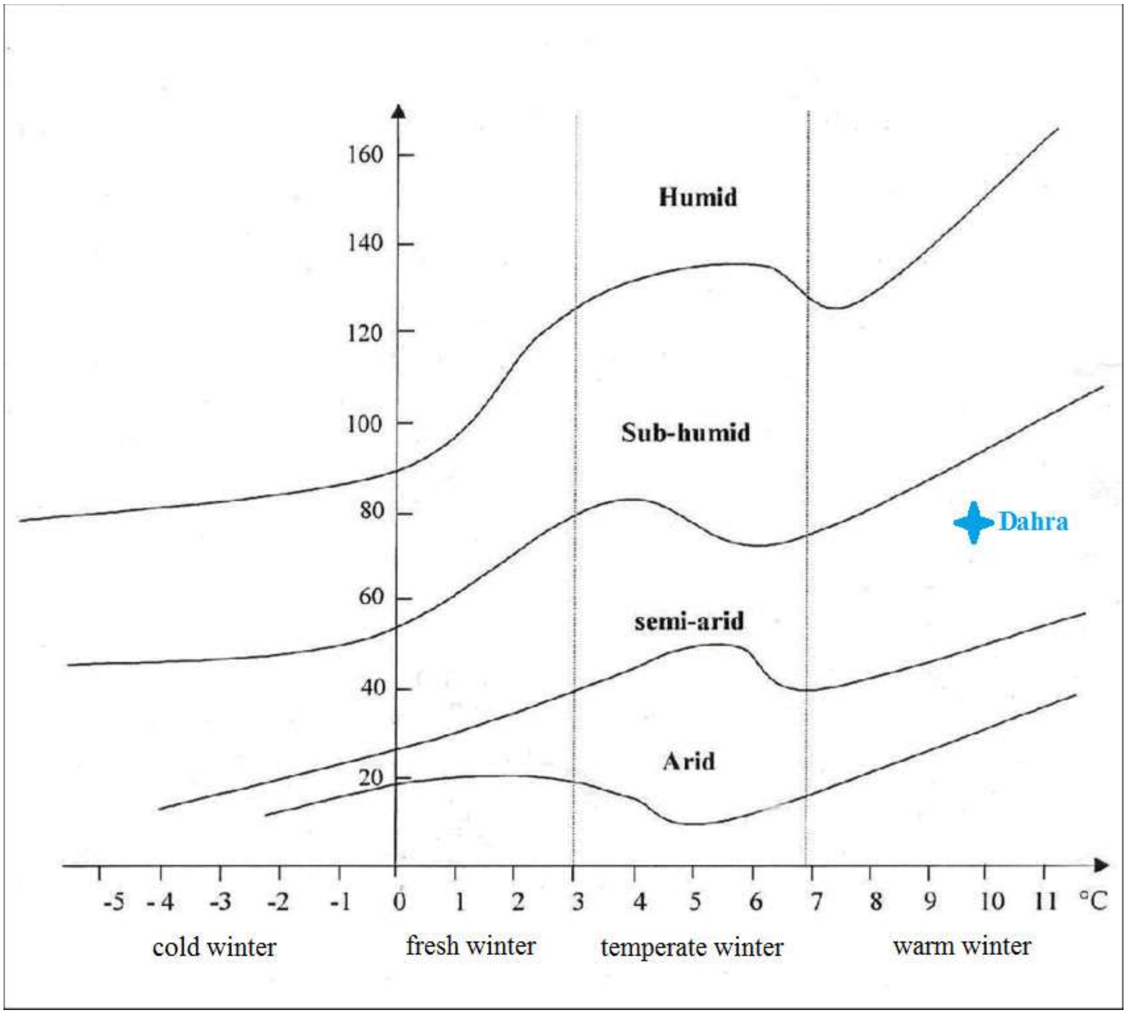

Figure 8: Emberger pluviothermic Climagram

Based on EMBERGER's climagram, Dahra with Q_2=59.68 and m =9.08°C is situated in the semi-arid bioclimatic floor with a warm winter.

4- Geology

A rich and well-developed soil is the base for any vegetation life and as the quality of such important component is directly linked to the geology of the region the map on figure 9 shows that geological composition.

5- Land features

Additional land characterizing attributes for the region are illustrated in figures 10 thru 13, elevations, aspects, slopes and moisture respectively.

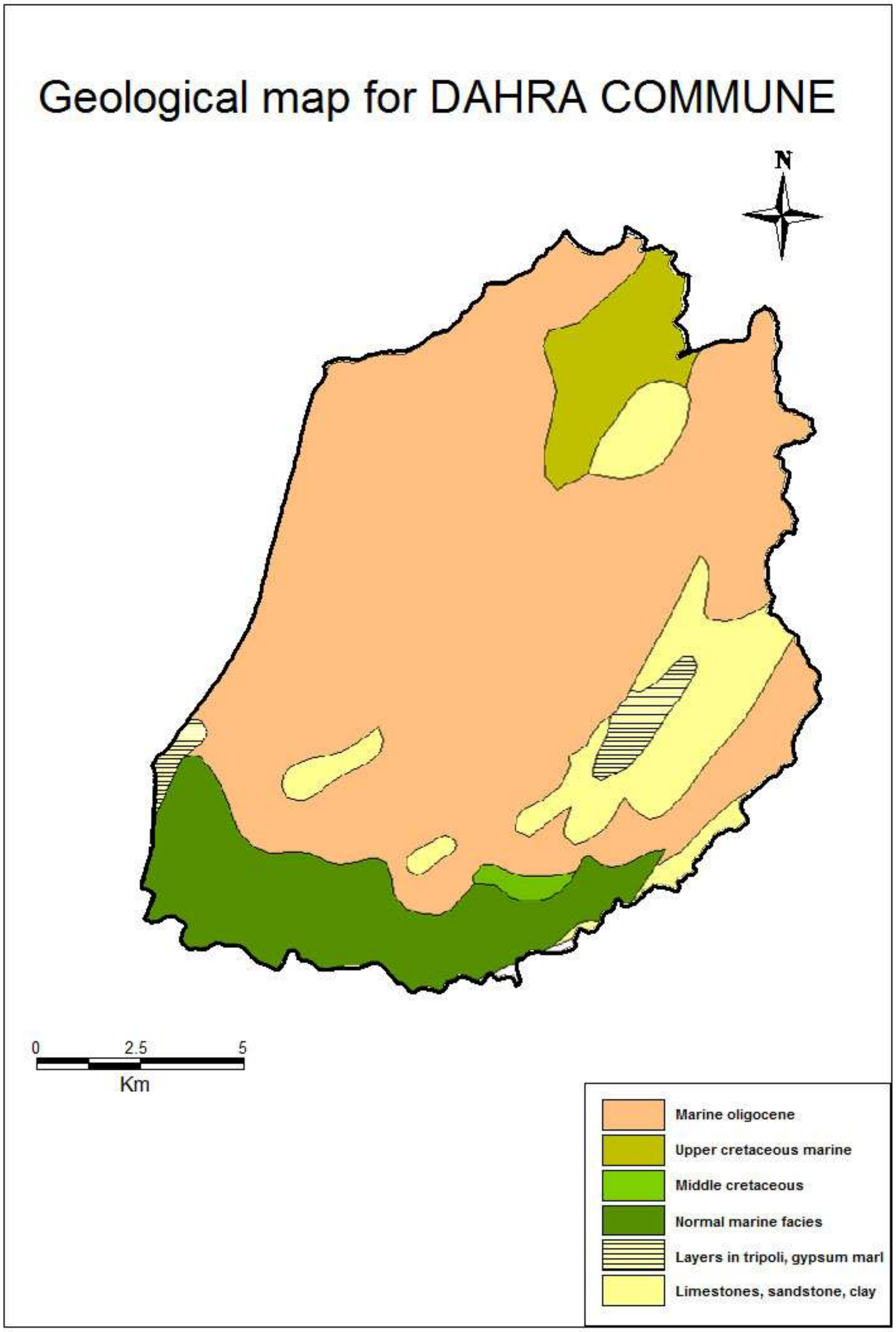

Figure 9: Geological map of Dahra commune

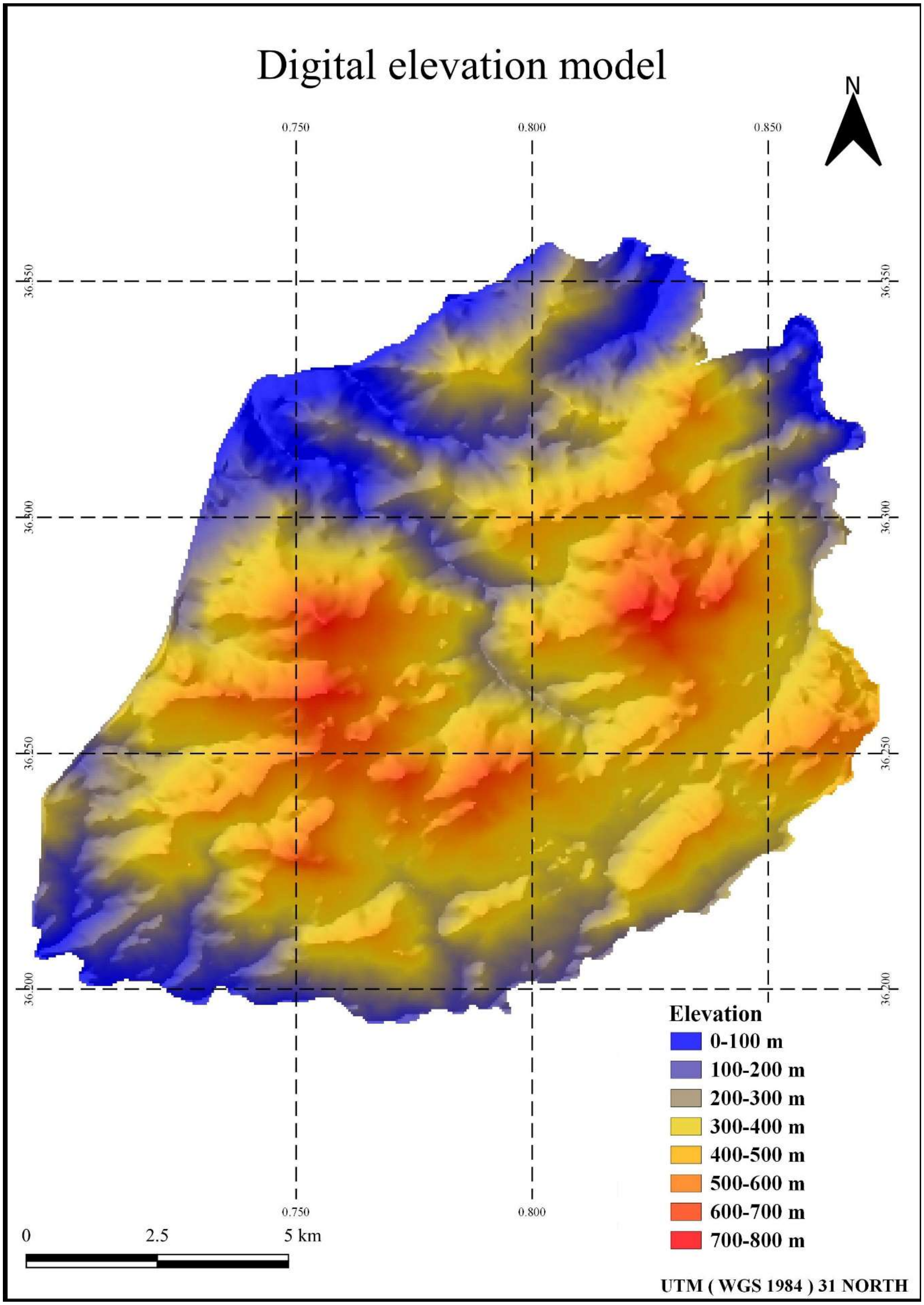

Figure 10: Representation of the elevations

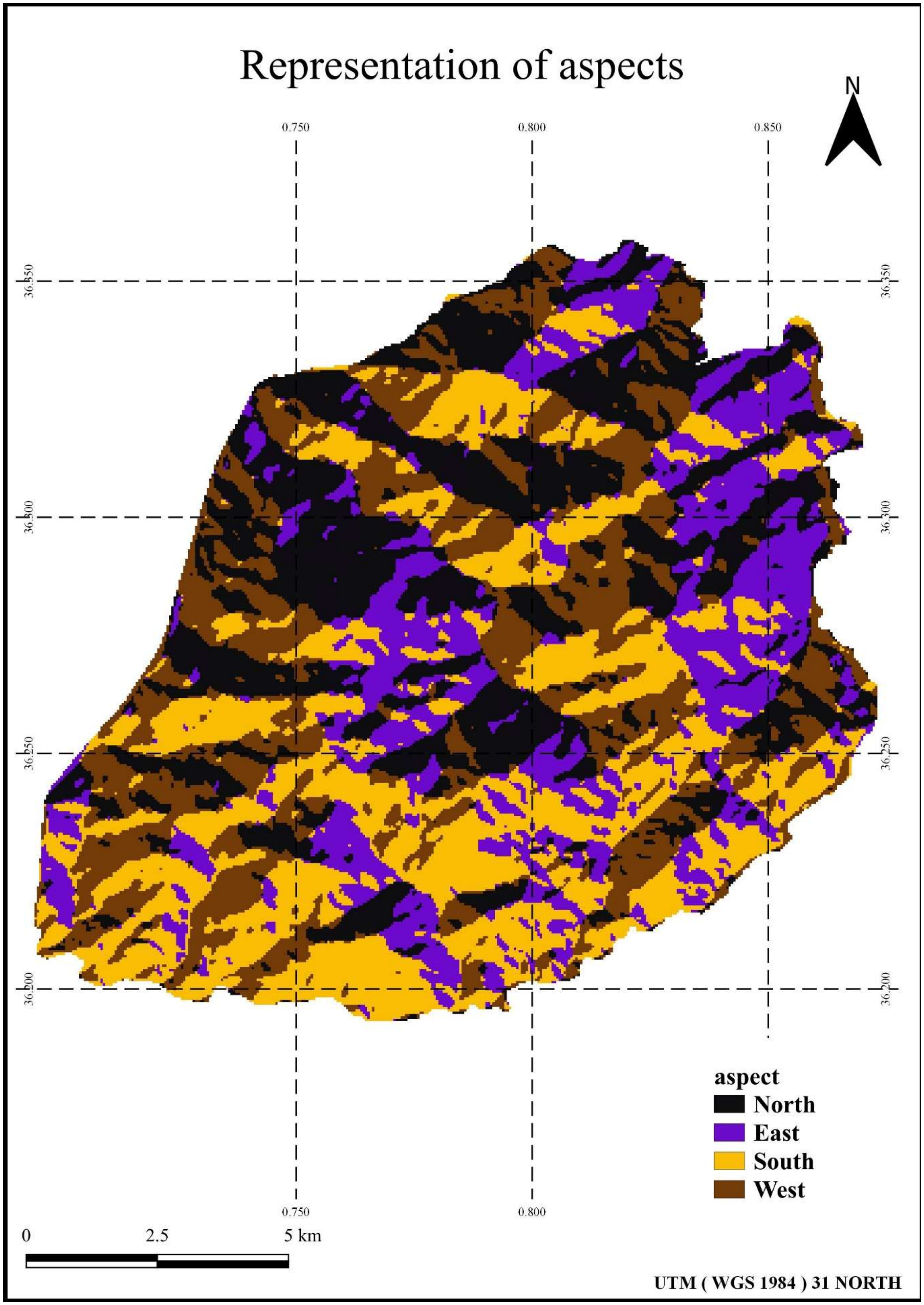

Figure 11: Representation of the aspects

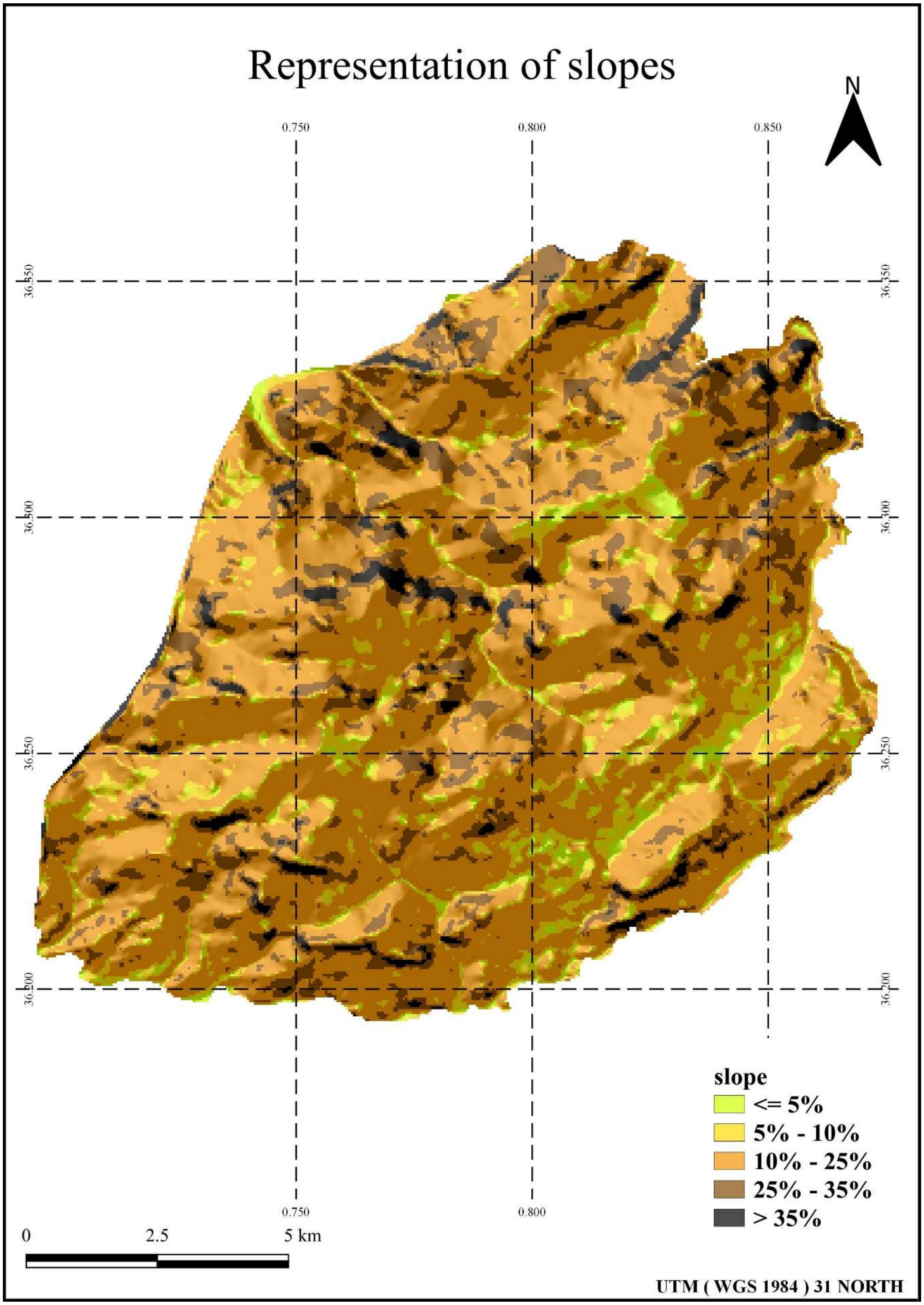

Figure 12: Representation of the slopes

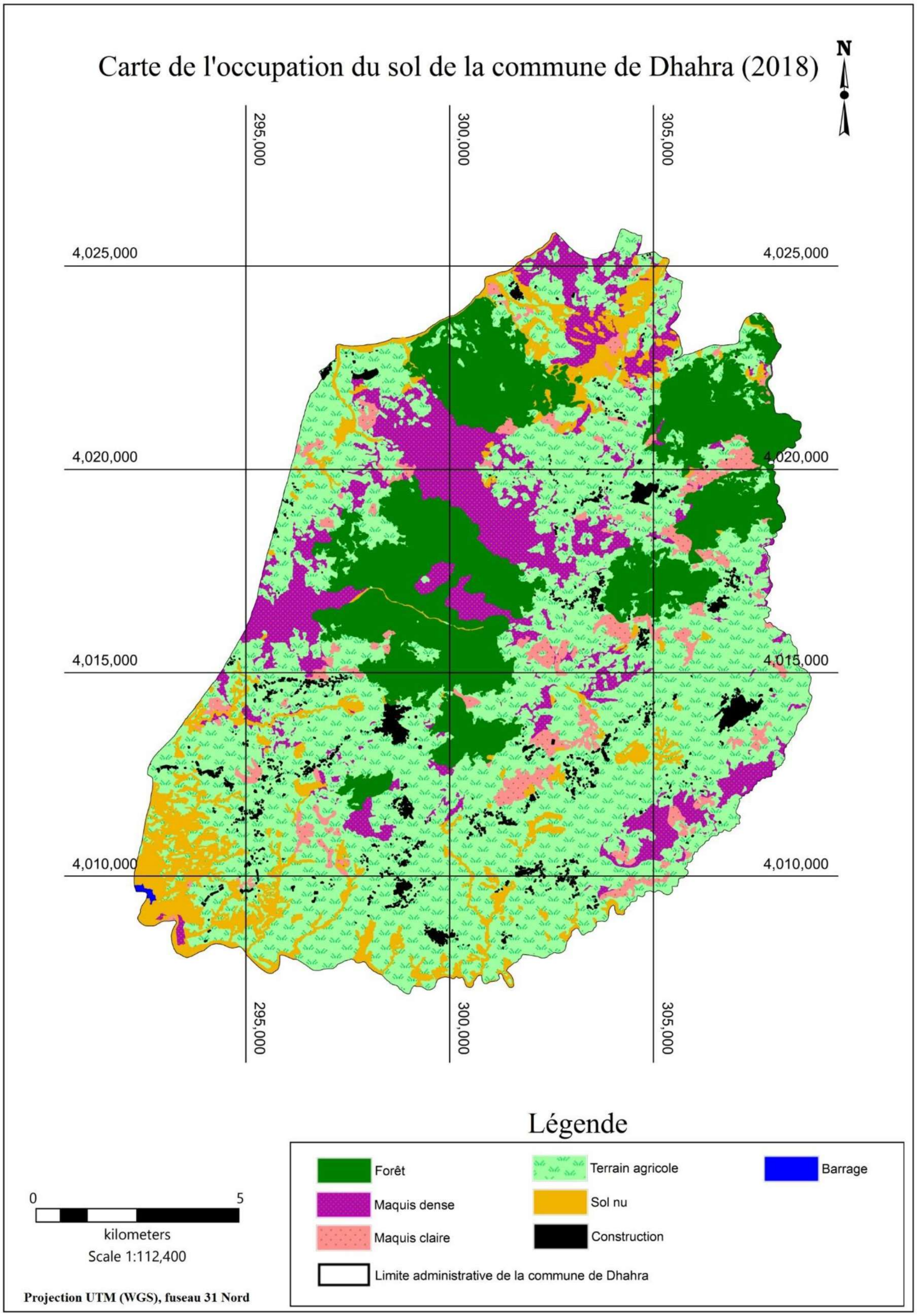

Figure 13: Soil occupation map (2018) (Aini, 2019)

Chapter III

Materials and method

Chapter III- Materials and method

1- Objectives of the study

This study mainly focuses on mapping forest fire risk areas, giving authorities something to base their infrastructure placement on, by highlighting zones corresponding to certain risk degrees. This mapping was done with previously established models that combine various criteria to get as accurate as possible.

2- Materials

2-1 Software

The main criteria in choosing the software was familiarity, availability compatibility and accessibility.

2-1-1 MapInfo 8.0

MapInfo was one of the Geographic Information systems of choice, being available, accessible and compatible with the topographical support used in this research.

2-1-2 ARCGIS 10.3

The diversity of features offered by ArcGIS make it a useful addition to the project and an indispensable tool in many stages of the scientific inquiry.

2-1-3 QGIS 3

This rather new software offers new possibilities for independent researchers, being opensource and having access to a wide range of public databases, which helps shorten the data acquisition process.

2-2 Websites

2-2-1 earthexplorer.usgs.gov

This web site is the ideal platform to download opensource satellite images for scientific inquiries as it provides a vast legacy library containing older as well as new images.

2-2-2 www.bbbike.org

Urban areas and road network maps are available for free in vector mode on this website for the whole world.

2-2-3 www.gpsvisualizer.com

When faced with geographic data that consists only of latitudes and longitudes and a need for the altitudes as well, this website serves as tool to provide the missing attribute.

3- Method

As mentioned before, GIS modes were implemented in this research, which required specific data to be inputted, data that had to be constructed and updated based on several supports then edited to allow the final overlay. The key steps of the procedure are illustrated in figure 14.

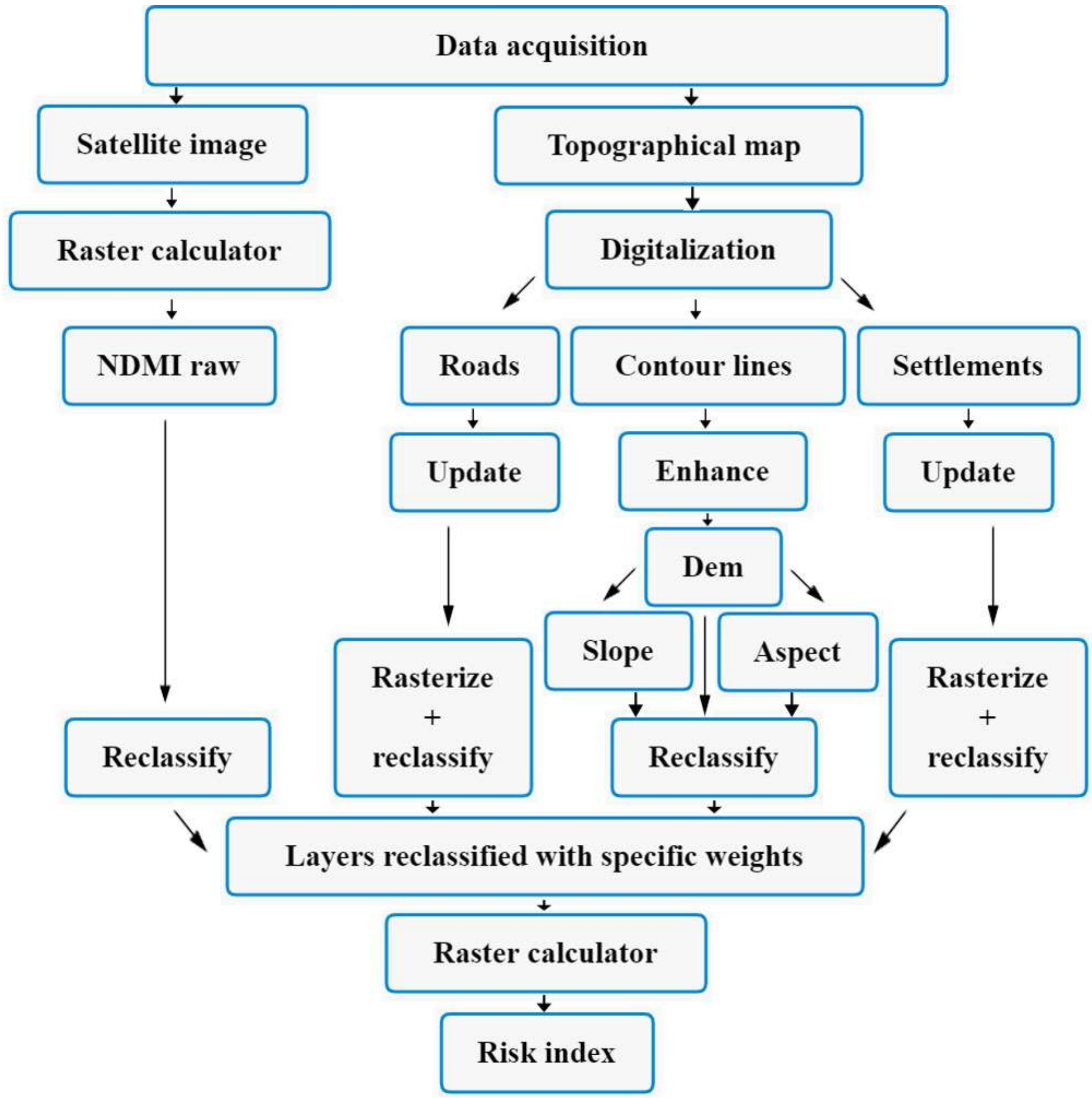

Figure 14: organizational chart of the key steps

3-1 Data acquisition

3-1-1 Topographical maps

After two visits to the forest conservation in Chlef, some data was acquired such as fire reports and some memoirs done in the region, however the actual raster support was provided by the thesis supervisor.

The raster support (topographical map) was used on MapInfo to create three vector layers that play part in the GIS model's formula.

3-1-2 Satellite images

The Landsat 8 satellite images were downloaded from the earth explorer web site, for the research area from summer 2019 and then used in conjunction with the raster calculator tool on QGIS software to create the NDMI as control layer for the vegetation component of the index.

3-2 Data update

3-2-1 Road network update

The QGIS plugin extension "openstreet" was used to get the up to date layout of the road map for a better analysis of the current fire risk areas.

3-2-2 Urban areas update

The urban areas of the region have had changes since to the time the initial raster support of our project was established, which warranted an update that was realized using the website BBBIKE.com.

3-3 Buffer zones

Buffer zones were created around the roads and settlements and assigned specific weights before rasterization, which was done on QGIS with the raster converter tool.

3-4 Raster reclassification

This step consisted of changing pixel values using the spatial analysis tool "reclassify" on ARCGIS

4- GIS model

The model deals to combine geospatial data by GIS technology to construct the fire risk index. The following variables were derived for the study area: vegetation moisture, slope, aspect, elevation, distance from roads and vicinity of settlements. Those variables were weighted based on their impact on the fire risk (Adab et al., 2011).

4-1 Model components

Terrain characteristics such as altitude, aspect, slope, soil type and condition, organic content, stream proximity (topographic wetness index) and ridgeline proximity (topographic position index) are useful indicators in the prediction of fire (Shijo et al., 2009).

4-1-1 Vegetation moisture

Dryness is one of the most critical parameters in fire risk because it increases the flammability of the land.

In order to assess the moisture of the vegetation the Normalized Difference Moisture Index (NDMI) is commonly used. The NDMI index highlights areas of healthy green vegetation with high moisture content by exploiting the strong absorption of SWIR radiation by thin layers of canopy and soil water and the high reflectance of NIR radiation by healthy green vegetation; it is described by the following equation (Siachalou et al., 2009). The risk rating is illustrated in figure 15.

$$NDMI = (NIR-SWIR)/ (NIR+SWIR)$$

4-1-2 Slope

Topography is an important physiographic factor, which is related to wind behavior and hence, affects the fire proneness of the area. Fire travels most rapidly up slopes and least rapidly down slopes (Jaiswal et al., 2002).

As the slope increases so does the rate of the fire spread (Siachalou et al., 2009). The risk rating is illustrated in figure 16.

4-1-3 Aspect

Another important component is the aspect; south facing slopes have greater sun exposure in the North hemisphere, resulting in drier soil that is more receptive to ignition (Siachalou et al., 2009). The risk rating is illustrated in figure 17.

4-1-4 Distance from roads

Human, animal and vehicular movement and activities on roads provide ample opportunities for accidental/man-made fires (Jaiswal et al., 2002).

The risk of fire is higher in areas where many people and vehicles daily move (Siachalou et al., 2009). The risk rating is illustrated in figure 18.

4-1-5 Vicinity of settlements

Forested areas near habitats/settlements are more prone to fire because the habitation and cultural practices of the inhabitants can lead to accidental fire (Jaiswal et al., 2002). The risk rating is illustrated in figure 19.

4-1-6 Elevation

Altitude plays a vital role in spreading fire (Jaiswal et al., 2002). The risk rating is illustrated in figure 20.

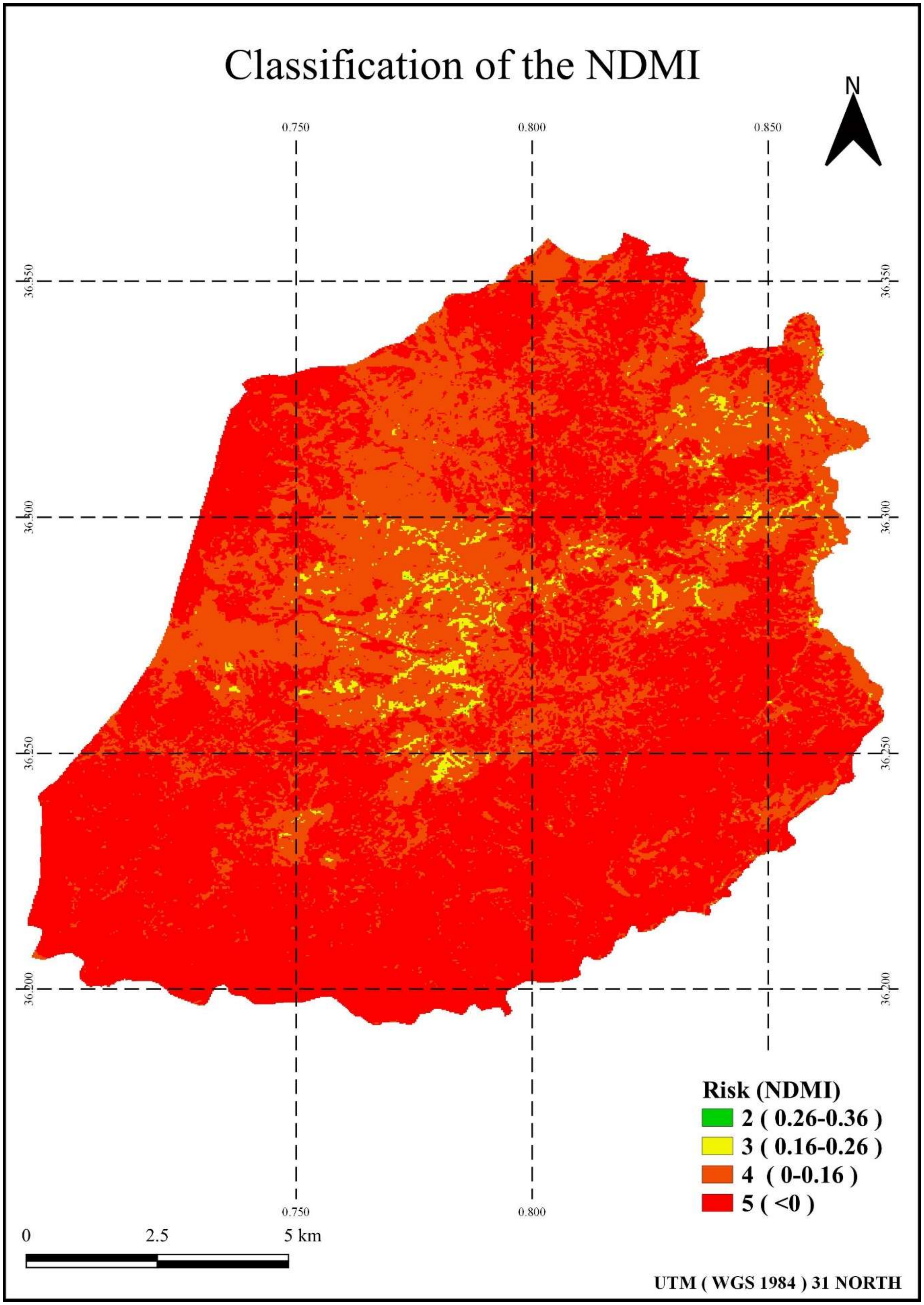

Figure 15: Risk rating of the NDMI

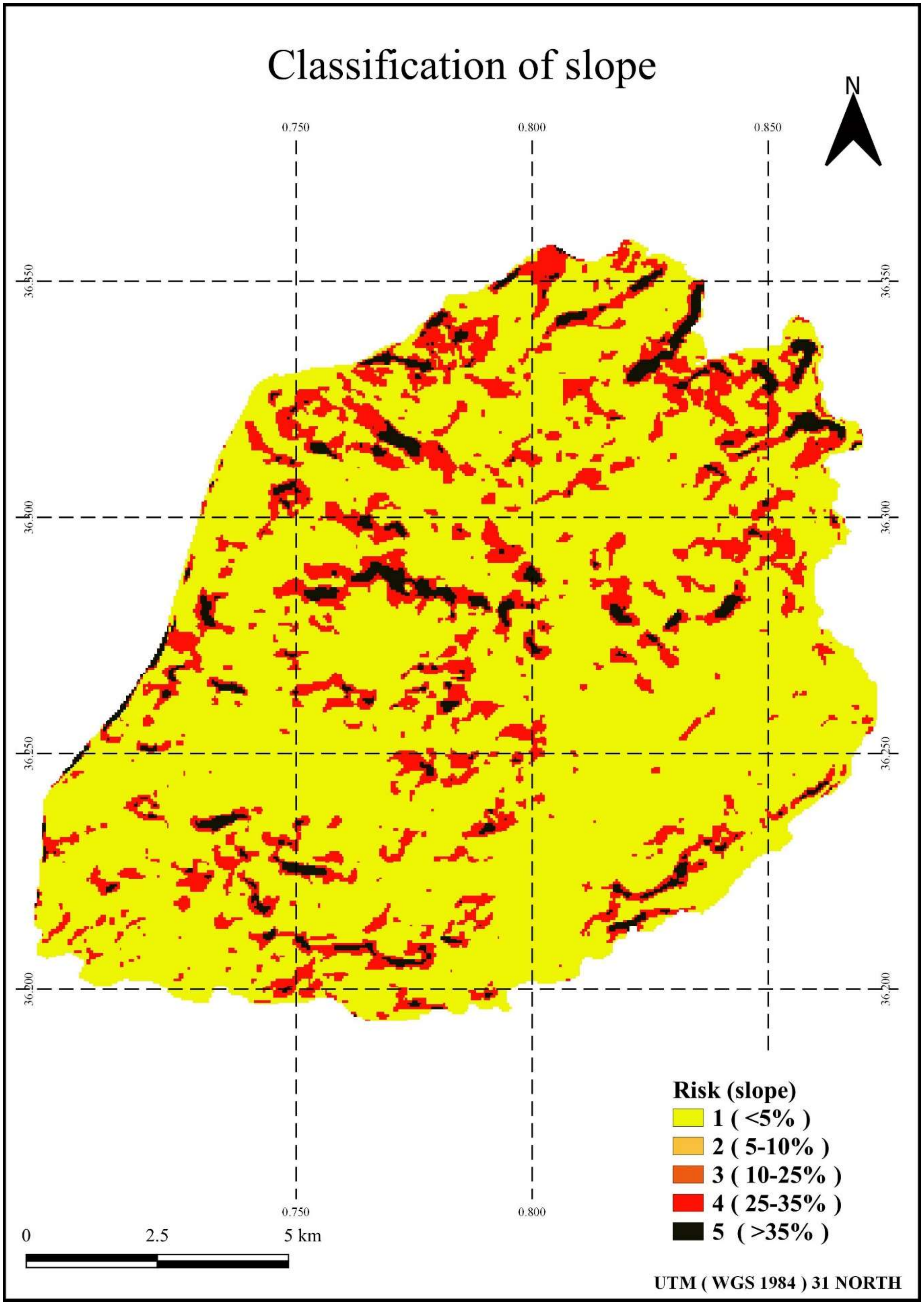

Figure 16: Risk rating of the slope

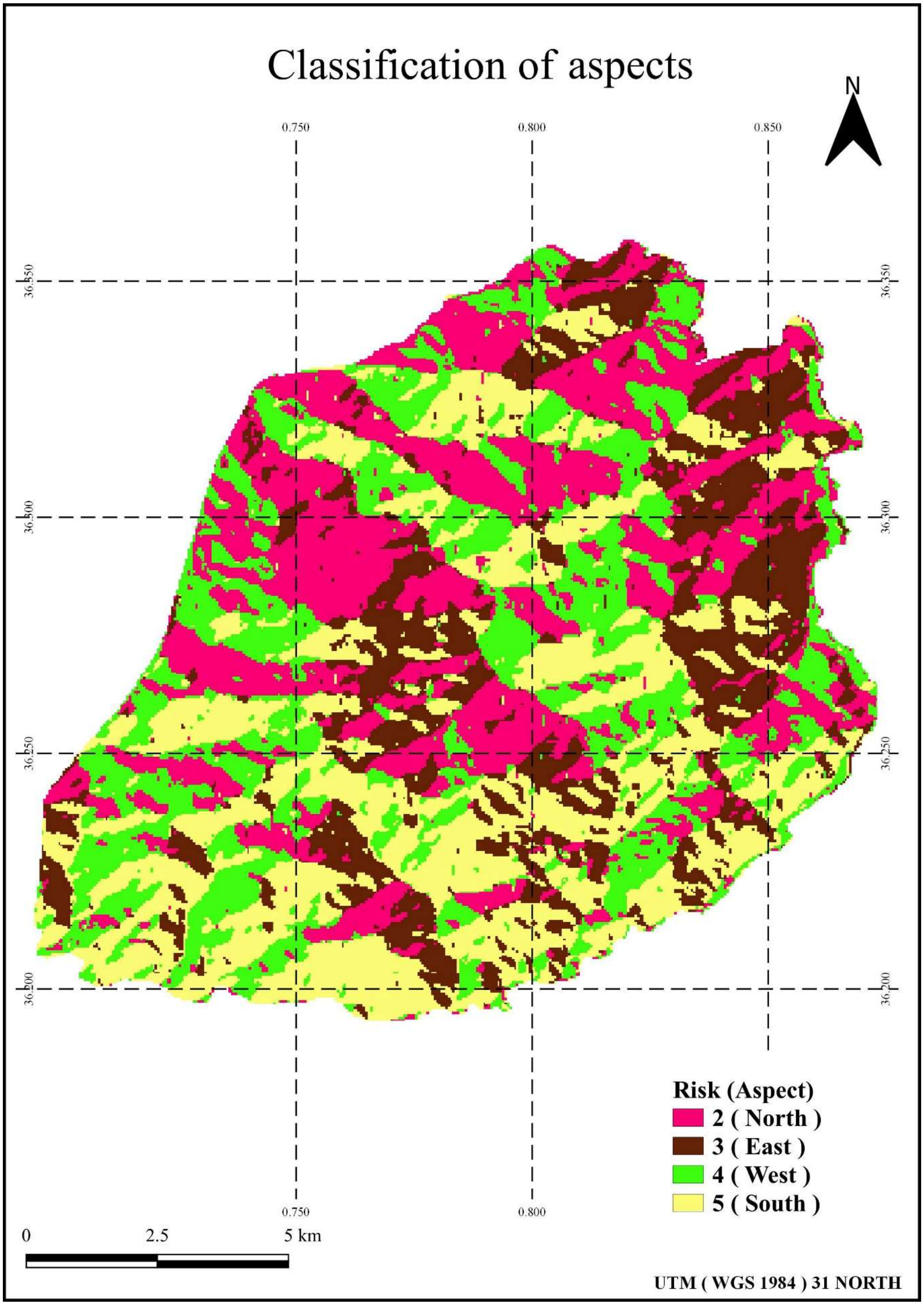

Figure 17: Risk rating of the aspect

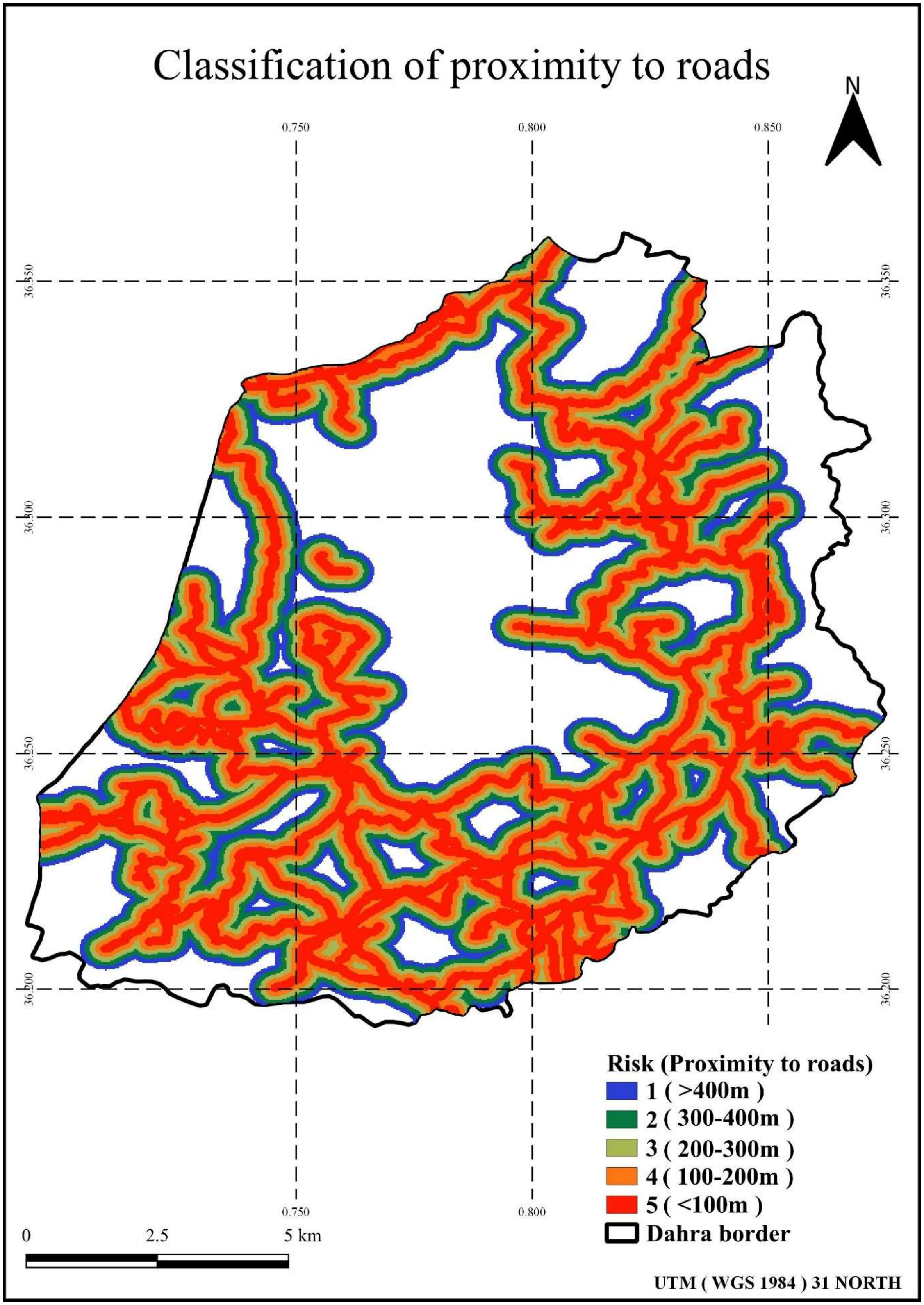

Figure 18: Risk rating of the proximity to roads

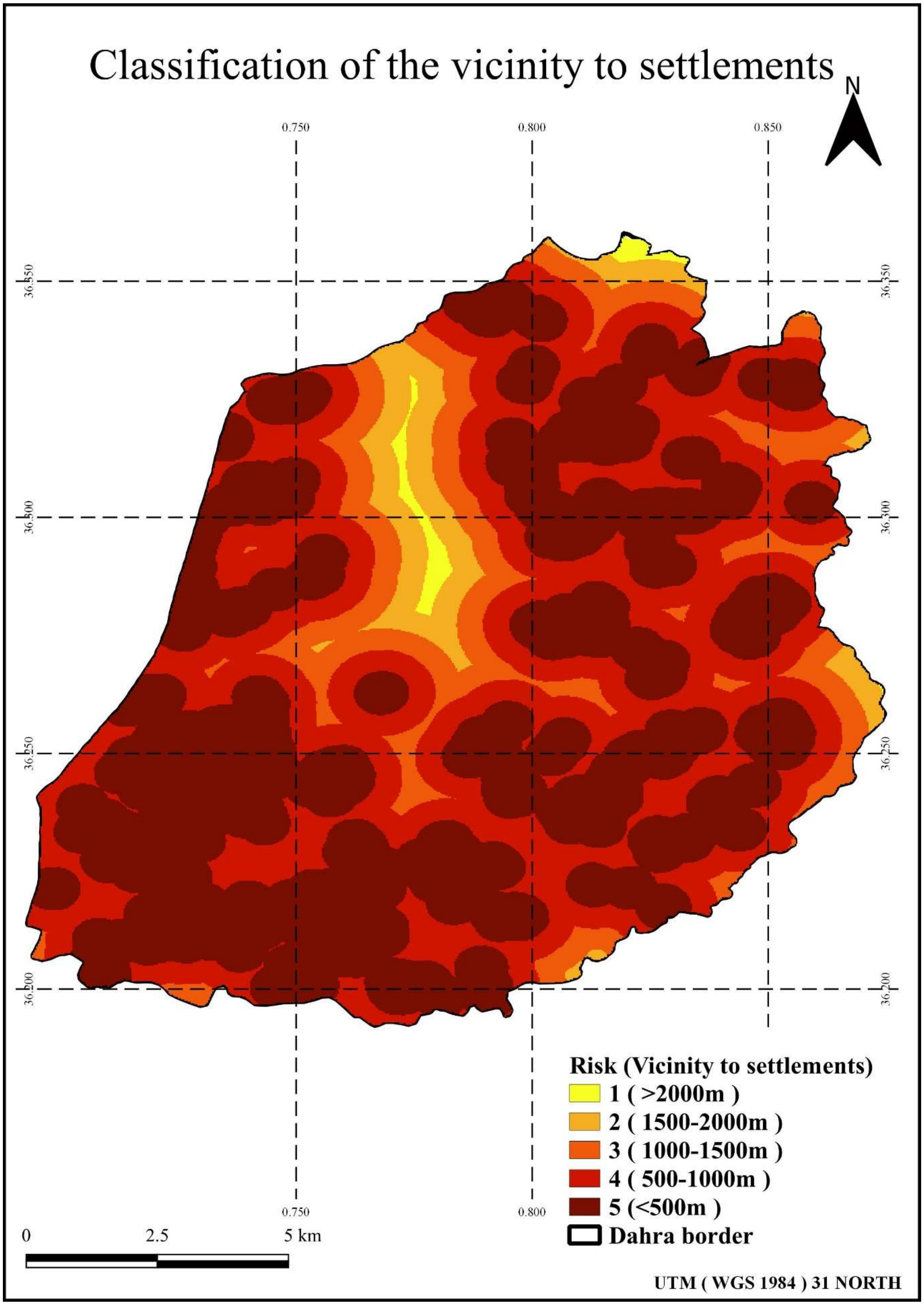

Figure 19: Risk rating of the vicinity to settlements

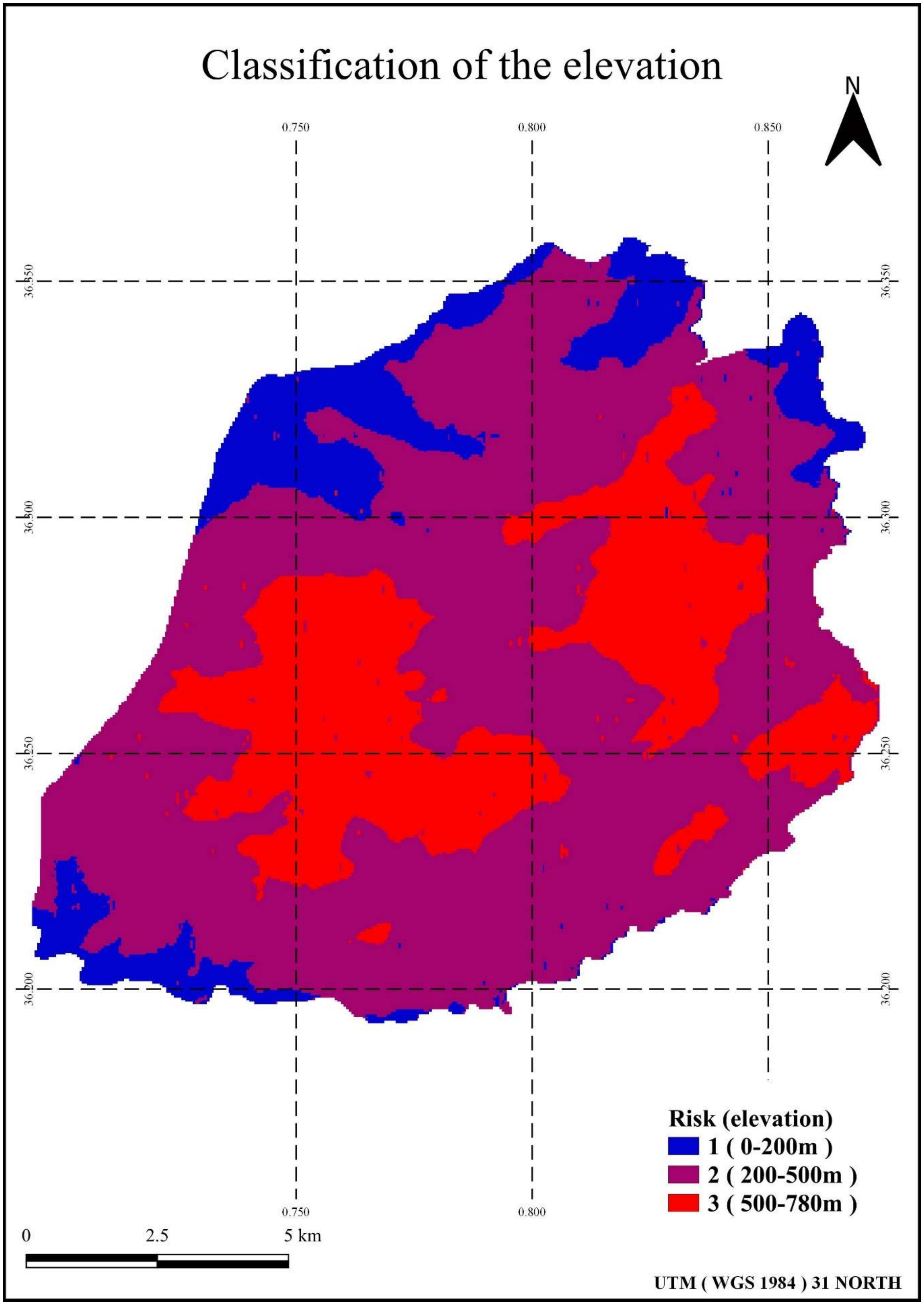

Figure 20: Risk rating of the elevation

4-2 Weight assignment

Table 3: Weights assigned to variables and classes for forest fire risk modelling

Variables	Classes	Ratings of hazard	Fire sensitivity
NDMI	>0.36,0.26_0.36,0.16_0.26,0_0.16, <0	1,2,3,4,5	Very Low, Low, Medium, High, Very High
Elevation	>2000,1000_2000, 500_1000, 200_500, <200	1,2,3,4,5	Very Low, Low, Medium, High, Very High
Slope	<5%, 10_5%, 25_10%, 35_25%, >35%	1,2,3,4,5	Very Low, Low, Medium, High, Very High
Aspect	North, East, West, South	2,3,4,5	Very Low, Low, Medium, High, Very High
Distance from roads	>400, 300_400, 200_300, 100_200, <100 m	1,2,3,4,5	Very Low, Low, Medium, High, Very High
Distance from settlements	>2000, 1500_2000, 1000_1500, 500_1500, <500 m	1,2,3,4,5	Very Low, Low, Medium, High, Very High

4-3 Model formula

In order to map fire risk, a new fire risk index was introduced based on six parameters. This is called Hybrid Fire index. The model is described by following equation;

$$HFI=(100v+50s+25a+10\times(r+c)+5e)/10 \quad (2)$$

Where; v, s, a, r, c and e indicate vegetation moisture, slope, aspect, distance from road and distance from settlement and elevation. A rate of 1, 2, 3, 4 or 5 is given to each level from low to high fire danger as an input (Adab et al., 2011).

Chapter IV

Results and analysis

Chapter IV- Results and analysis

1- Results

1-1 Model output range

The models range of output goes from 22.5 (Very low risk) to 100 (Very high risk) when all the variables in the equation are inputted with the extreme values (1 or 5) as it is shown in table 4.

Table 4: the definition of risk level

v	s	a	r	c	e	Risk index	rating of hazard
1	1	2	1	1	1	22.5	very low
2	2	2	2	2	2	40	low
3	3	3	3	3	3	60	medium
4	4	4	4	4	4	80	high
5	5	5	5	5	5	100	very high

1-2 Output range in the research area

Based on the model formula and the values of each pixel in the area of interest on the different input layers, the resulting index has values ranging from 41 to 99, indicating three rating of fire risk 41 – 60 with medium risk, 60 – 80 with high risk and 80 – 99 with very high risk.

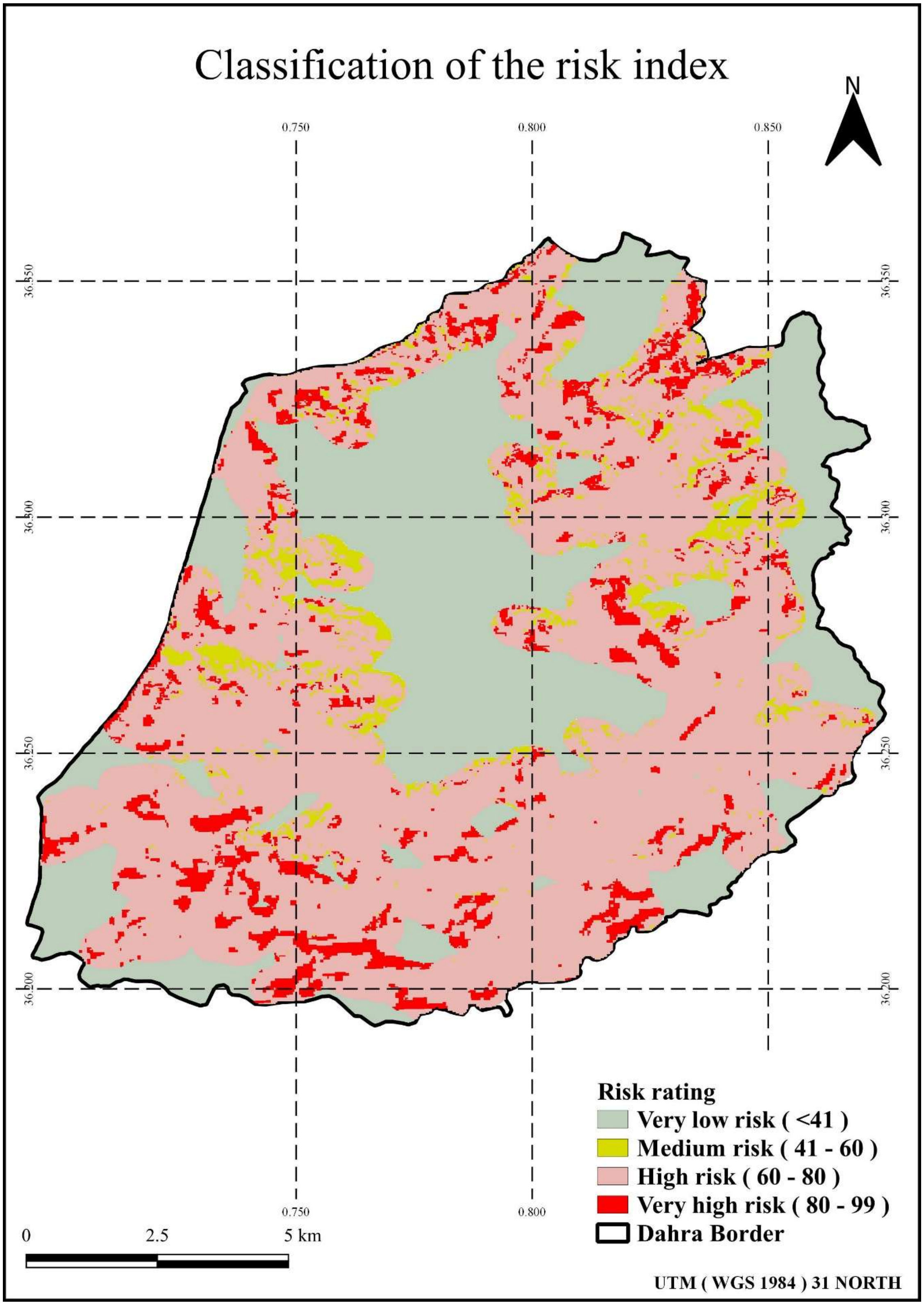

Figure 21: Classification of the risk index

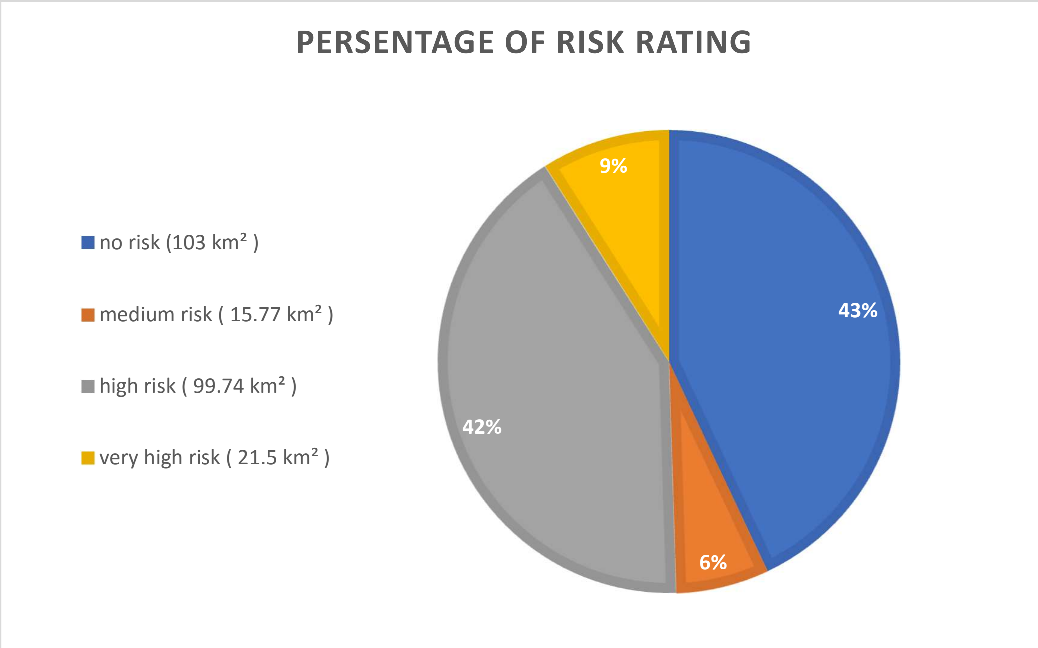

Figure 22: Pie chart of risk rating percentage

2- Analysis

The index on figure 21 shows:

A pale green area in the center, which represents the null values on the output raster, occupying 103 km² of the total area and corresponding with the absence of both the road network and any near settlements, a low elevation and a flatness of the terrain accompanied by high values of NDMI, those factors combined mean a very low fire risk.

The remaining area of 137 km² is covered in pixels with different risk values. The percentages demonstrated in figure 22 where:

- the very low risk zone occupies 43% of the total area;
- followed closely by the high-risk factor with 42%;
- the very-high-risk rating with 9%;

- lastly the medium risk claiming only 6% of the study area.

3- Management proposition

Based on the findings of the research a series of management decisions can be taken concerning infrastructure installation and manpower distribution favoring zones with higher risk.

- Water points can be established to facilitate the provisioning in water during the fires.
- Surveillance towers can be located according to higher risk rating making the process all the more efficient
- Trails and tracks providing accessibility to the areas most endangered by the fire.
- Reenforcing active efforts such as patrols.

4- Public awareness

The human factor is a major one in forest fire, both starting it and helping it propagation, to limit the unvoluntary fires caused by ignorance local authorities can focus on more public awareness campaigns insisting on the notion of risk and showing interactive maps and charts.

General Conclusion

Conclusion

The present study was an attempt to integrate remote sensing data and GIS concept to determine risky places and to plan forestry management. Fire risk models are a great approach for precautionary measures for the environmental protection of the forests (Adab et al., 2011).

The fire risk in the study area reflects both the likelihood of ignition and the risk of spreading. The slope, altitude and aspect factors, which influence the risk of spreading, thus increase the fire risk in the present model. An interesting feature of the model is that it explains the important fact that even if a forest type has a low risk weighting, the probability of a forest fire occurring there can be moderate due to other factors.

The commune of Dahra represents a high proneness to forest fires due to its slopy terrain and vegetation moisture levels as well as the high elevations, the south facing aspects and the proximity to roads and urban areas making it so that the risk index highlighted most of the commune's territory as potential hot spots with significant risk ratings, concentrated around the road network as well as urban agglomerations.

From a management point of view, the fire fighting and prevention infrastructures should focus on the locations with higher risk, providing accessibility for first responders, water points for quick refills and surveillance towers for earlier detection of forest fires.

Bibliographical references

Bibliographic references

ADAB H., KANNIAH K D., & SOLAIMANI K., 2011. GIS-based Probability Assessment of Fire Risk in Grassland and Forested Landscapes of Golestan Province, Iran. In: International Conference on Environmental and Computer Science, Singapore. vol. 19. p. 170-175.

ADDADI M., 2020. Analyse des incendies de forêts de la Wilaya de Chlef, période « 2009-2019 » Master's degree memoir, Tlemcen university. 64p.

AINI A., 2019. APPORT DES SIG POUR LE SUIVI DE L'OCCUPATION DE SOL DANS LA REGION DE DHAHRA (CHLEF). Master's degree memoir, Tlemcen university. 63p.

ALEXANDIRAN, D & GOUIRAN, M, 1990. Les causes d'incendie : levons le voile. In : *Revue Forestière Française*. 1990. p. 33-41.

BOUSMAL Z. & EZZEDAMI H., 2018. *Cartographie du risque d'incendie de forêt dans la région de Ténès, Chlef*. Masters degree memoir, Khemis Miliana university. 88p.

Burton J., 2020. It's a line of fire coming at us. Local news article www.busseltonmail.com consulted 9/9/2020.

CANAKCIOGLU H., 1986. The importance of fuel management for eliminating the large forest fires in Turkey. In: *Seminar on methods and equipment for the prevention of forest fires,* Valencia - Spain: 29 octobre 1986. 10p.

DAGORNE A. & DUCHÉ Y., 1994. Protection des forêts contre l'incendie & Système d'infonnation géographique. In : *forêt méllitermnéenne*. Vol. 15, n° 4, p. 409-420.

DATIKO D. & BEKELE A., 2014. Habitat association and distribution of rodents and insectivores in Chebera Churchura National Park, Ethiopia. In : Tropical Ecology. Vol. 55 n° 2. p. 221-229.

DONG W., 2003. Comment faire participer toute la population à la prévention des incendies de forêt : les politiques chinoises de la dernière décennie. In : *FAO* 2003.

ERTEN E., KURGUN V., & MUSAOGLU N., 2002. FOREST FIRE RISK ZONE MAPPING FROM SATELLITE IMAGERY AND GIS A CASE STUDY. In : *reaserch gate*. 7p.

FAVRE P., 1992. Feux et forêts. In : *Forêt Méditerranéenne*. Vol. 41, n° 3, p. 31-40.

HARDY C., 2005. Wildland fire hazard and risk: Problems, definitions and context. In: *Forest Ecology and Management*. Vol. 211, n° 1-2, p. 73-82.

HESSAS N., 2005. *Evaluation cartographique et évolution diachronique par télédétection du risque incendie de forêt. Simulation de la propagation du feu dans le bassin versant du Paillon, Nice, Alpes-Maritimes.* Doctorate thesis. GRENOBLE I – JOSEPH FOURIER university. 438p.

INFORMATION DFCI, 1998. Les feux d'origine électrique dans le département du Var. In : *Info. DFCI*. Vol. 40. 5p.

JAISWAL R. K., MUKHERJEE S., RAJU K. D. & SAXENA R., 2002. Forest fire risk zone mapping from satellite imagery and GIS. In: *International Journal of Applied Earth Observation and Geoinformation*. Vol. 4, n° 1. p. 1-10.

JONES C. B., 1997. *Geographical information systems and computer cartography*. Harlow, England: Longman. 310p.

KAIRU E. N., 1982. An introduction to remote sensing. In: *GeoJournal*. 1982. Vol. 6, n° 3. 35p.

KEIFER M., CAPRIO A., LINEBACK P. & FOLGER K, 1999. Incorporating a GIS model of ecological need into fire management planning. In : Joint Fire Sciences Conference and Workshop, Boise, Idaho, June 15-17, 1999. 12p.

LEONE V., 1990. Causes socio-économiques des incendies de forêts dans la région de Bari (Pouilles, Italie). In: *Revue Forestière Française*. 1990. n° S, p. 332-236.

LILLESAND T. M., KIEFER R. W. & CHIPMAN J. W, 1979. *Remote Sensing and Image Interpretation*. Wiley, USA. 720p.

MEGREROUCHE R., 2006. *Sensibilité de la végétation forestière aux incendies*. Magistere thesis. Constantine university. 106p.

MOHAMMADI F., BAVAGHAR M. P. & SHABANIAN N., 2014. Forest Fire Risk Zone Modeling Using Logistic Regression and GIS: An Iranian Case Study. In: *Small-scale Forestry*. Vol. 13, n° 1. p. 117-125.

PLAN DE PRÉVENTION DES RISQUES NATURELS (P.P.R.), 2000. *Recueil des démarches d'information et de communication lors de l'élaboration des P.P.R. MATE*. S.l. : s.n. ISBN 978-2-84586-859-5.

REDDY A., 2008. *Textbook of remote sensing and geographical information systems*. BS Publications, Hyderabad India. 453p.

ROY P. S., 2003. FOREST FIRE AND DEGRADATION ASSESSMENT USING SATELLITE REMOTE SENSING AND GEOGRAPHIC INFORMATION SYSTEM. In: *Satellite Remote Sensing and GIS Applications in Agricultural Meteorology*. p. 361-400.

SABINS F., 1987. *Remote Sensing-Principle and Interpretation*. Freeman and Co., New York, USA. 246p.

SHIJO J., ANITHA K. & MURTHY, M. S. R., 2009. Forest fire in India: a review of the knowledge base. In: *Journal of Forest Research*. Vol. 14, n° 3. p. 127-134.

SIACHALOU S., DOXANI G. & TSAKIRI-STRATI M., 2009. INTEGRATING REMOTE SENSING PROCESSING AND GIS TO FIRE RISK ZONE MAPPING: A CASE STUDY FOR THE SEIH-SOU FOREST OF THESSALONIKI. In: Research gate. 10p.

Trabaud L., 1992. Community dynamics after fire disturbance: Short-term change and long-term stability. In: EKISTICS. Vol. 59, No. 356. p287-292.