*The Scientific Journal of Cihan University – Sulaimaniya* **PP: 147-162**
Volume (6), Issue (2), December 2022
ISSN 2520-7377 (Online), ISSN 2520-5102 (Print)

# Wildfire Potential Mapping Using Remotely-sensed Vegetation Index, Case Study: Kurdistan Region, Iraq

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***Abstract:***

A numerous wildfires have been recorded in the forests and grasslands of Kurdistan Region (KR) during recent years. Wildfires are a source of environmental, economic and social problems, human and population safety, and a real threat to human life at various scales and severities in different parts of the world. From an ecological point of view, fire is an important factor that plays a fundamental role in determining the diversity and dynamics of vegetation. Since (KR), located in north of Iraq, is almost the only area in the country where forests and vegetation seemed abundantly. The forests of (KR) play a vital and effective role in the vital, economic and touristic ecosystem of the region. Accordingly, it is very important to create and develop an accurate, rapid, and reliable spatial maps for understanding, interpreting and analyzing the causes and consequences of these fires. This study, which shows the possibility of fires in different areas of the study area, also aims to take precautionary measures in advance. Today, remote sensing data and technologies are among the most reliable mechanisms that provide spatial and temporal coverage of biomass burning, and determination of vegetation index (VI), without the complex, costly and stressful field procedures. Among these factors, the use of the normalized difference vegetation index (NDVI) was highly suggested as a useful tool for estimating the susceptibility of vegetation to fire. Accordingly, maps and data have been benefited from previous years, as this study attempted to prepare and develop a fire danger map by integrating satellite and field data for the Kurdistan Region. Times-series of MODerate resolution Imaging Spectroradiometer (MODIS) 250m, taken in 2010, were used for (NDVI) information layer. The developed map displayed a great consistency between the danger map, developed based on the 2010 image, and the site-recorded fire recorded from 2014 to 2015. The output map revealed that (RS/GIS) technology were of very high potential to be a valuable tool for managing, studying and controlling hazardous natural phenomena, such as wildfires, and reducing their risks and consequences.

**Key words: (**GIS), Remote Sensing (RS), Vegetation Index (VI), (NDVI), Forest fire, wildfire.

DOI: http://dx.doi.org/10.25098/6.2.31

The Scientific Journal of Cihan University – Sulaimaniya PP: 147-162
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ISSN 2520-7377 (Online), ISSN 2520-5102 (Print)

**الملخص:**

تم تسجيل العديد من حرائق الغابات في غابات ومراعي إقليم كوردستان خلال السنوات الأخيرة. تعتبر حرائق الغابات مصدرًا للمشاكل البيئية والاقتصادية والاجتماعية، وسلامة البشر والسكان، وتهديدًا حقيقيًا للحياة البشرية على مستويات وشدة مختلفة في أجزاء مختلفة من العالم. من وجهة نظر بيئية، يعتبر الحريق عاملاً مهمًا يلعب دورًا أساسيًا في تحديد تنوع وديناميكيات الغطاء النباتي. نظرًا لأن (KR) الواقعة في شمال العراق، هي المنطقة الوحيدة تقريبًا في البلاد التي بدت فيها الغابات والنباتات بكثرة. تلعب غابات (KR) دورًا حيويًا وفعالًا في النظام البيئي الحيوي والاقتصادي والسياحي في المنطقة. وفقًا لذلك، من المهم جدًا إنشاء وتطوير خرائط مكانية دقيقة وسريعة وموثوقة لفهم وتفسير وتحليل أسباب ونتائج هذه الحرائق. تهدف هذه الدراسة، التي تظهر احتمالية نشوب حرائق في مناطق مختلفة من منطقة الدراسة، إلى اتخاذ الإجراءات الاحترازية مسبقًا. اليوم تعد بيانات وتقنيات الاستشعار عن بعد من بين الآليات الأكثر موثوقية التي توفر تغطية مكانية وزمانية لحرق الكتلة الحيوية، وتحديد مؤشر الغطاء النباتي(VI) ، دون الإجراءات الميدانية المعقدة والمكلفة والمرهقة. من بين هذه العوامل، تم اقتراح استخدام فهرس الفرق المعياري للغطاء النباتي (NDVI) كأداة مفيدة لتقدير قابلية الغطاء النباتي للحريق. وعليه فقد تم الاستفادة من الخرائط والبيانات من السنوات السابقة، حيث حاولت هذه الدراسة إعداد وتطوير خريطة مخاطر الحريق من خلال دمج البيانات الفضائية والميدانية لإقليم كوردستان. تم استخدام سلسلة زمنية لمقياس طيف التصوير ذو الدقة المتوسطة 250 ( MODIS) مترًا، تم التقاطها في عام 2010، لطبقة معلومات .(NDVI) أظهرت الخريطة المطورة اتساقًا كبيرًا بين خريطة الخطر التي تم تطويرها بناءً على صورة عام 2010 والحريق المسجل في الموقع المسجل من 2014 إلى 2015. كشفت خريطة المخرجات أن تقنية (RS / GIS) كانت ذات إمكانات عالية جدًا لتكون أداة قيمة لإدارة الظواهر الطبيعية الخطرة ودراستها والسيطرة عليها، مثل حرائق الغابات، وتقليل مخاطرها وعواقبها

**الكلمات المفتاحية:** (GIS)، الاستشعار عن بعد(RS) ، فهرس الغطاء النباتي(VI) ، (NDVI)، حرائق الغابات.

**پوختە:**

لە ماوەی ساڵانی ڕابردوودا ژمارەیەکی زۆر لە ئاگرکەوتنە سروشتیەکانی دارستان و لەوەرگاکانی هەرێمی کوردستان تۆمارکراون. ئاگری سروشتی سەرچاوەی کێشەی ژینگەیی و ئابووری و کۆمەڵایەتی و سەلامەتی مرۆڤ و دانیشتووان و مەترسییەکی ڕاستەقینەیە بۆ سەر ژیانی مرۆڤ بە قەبارە و توندی جۆراوجۆر لە ناوچە جیاجیاکانی جیهان. لە ڕوانگەی ژینگەییەوە ئاگر فاکتەری گرنگە کە ڕۆڵێکی بنەڕەتی دەگێڕێت لە دیاریکردنی فرەچەشنی و داینامیکی ڕووەک. بەو پێیەی (KR) کە دەکەوێتە باکووری عێراق، نزیکەی تاکە ناوچەیە لە وڵاتەکەدا کە دارستان و ڕووەک بەزۆری تێدا دەرکەوتووە. دارستانەکانی (KR) ڕۆڵێکی گرنگ و کاریگەر دەگێڕن لە سیستەمی ژینگەی ژیانی و ئابووری و گەشتیاری ناوچەکەدا. بەم پێیە زۆر گرنگە نەخشەی شوێنی ورد و خێرا و متمانەپێکراو دروست بکرێت و پەرەی پێبدرێت بۆ تێگەیشتن و لێکدانەوە و شیکردنەوەی هۆکار و دەرئەنجامەکانی ئەم ئاگرکەوتنەوانە. ئەم توێژینەوەیە کە ئەگەری ئاگرکەوتنەوە لە ناوچە جیاوازەکانی ناوچەی لێکۆڵینەوەکە نیشان دەدات، ئامانجیشی ئەوەیە پێشوەختە ڕێوشوێنی خۆپارێزی بگرێتەبەر. ئەمڕۆ داتا و تەکنەلۆژیاکانی هەستکردن لە دوورەوە لە جێی متمانەترین میکانیزمەکانن کە ڕووپۆشێکی فەزایی و کاتی سووتانی بایۆماس، و دیاریکردنی پێوەرەکانی ڕووەک (VI) دابین دەکەن، بەبێ ڕێکارە مەیدانییە ئاڵۆز و تێچووناوی و سترێسییەکان. لە نێوان ئەم هۆکارانەدا، بەکارهێنانی پێوەرەکانی ڕووەکی جیاوازی ئاسایی (NDVI) زۆر پێشنیار کرا وەک ئامرازێکی بەسوود بۆ خەمڵاندنی ئامادەیی ڕووەک بۆ ئاگر. بەم پێیە نەخشە و داتاکان سوودیان لە ساڵانی پێشوو وەرگرتووە، بەو پێیەی ئەم توێژینەوەیە هەوڵی ئامادەکردن و پەرەپێدانی نەخشەی مەترسی ئاگرکەوتنەوە دراوە بە یەکخستنی داتاکانی مانگی دەستکرد و مەیدانی بۆ هەرێمی کوردستان. زنجیرە کاتییەکانی MODerate resolution Imaging Spectroradiometer (MODIS) 250m، کە لە ساڵی 2010 گیراوە، بۆ چینە زانیاری (NDVI) بەکارهێنرا. نەخشەی پەرەپێدراو یەکدەنگییەکی گەورەی لە نێوان نەخشەی مەترسییەکان نیشان دا، کە لەسەر بنەمای وێنەی ساڵی 2010 پەرەی پێدراوە، و ئاگرکەوتنەوەی تۆمارکراوی شوێنەکە کە لە ساڵی 2014 تا 2015 تۆمارکراوە ئامرازێکی بەنرخە بۆ بەڕێوەبردن، لێکۆڵینەوە و کۆنترۆڵکردنی دیاردە سروشتییە مەترسیدارەکان، وەک ئاگرکەوتنەوەی کێوییەکان، و کەمکردنەوەی مەترسی و دەرئەنجامەکانیان.

**کلیلە ووشە:** GIS ، هەستکردن لە دوورەوە(RS) ، پێوەرەکانی ڕووەک(VI) ، (NDVI)، ئاگرکەوتنەوە لە دارستانەکان، ئاگری کێوی، .(MODIS)


DOI: http://dx.doi.org/10.25098/6.2.31

## 1. Introduction

Wildfires are an important environmental and economic issue in many forest regions of the world. The magnitude of this phenomenon can range from a small and local fires with a few impacts to a very large fires with severe consequences on a large scale [1]. Fire, from the ecological point of view, is considered as a decisive factor that plays a fundamental role in determining vegetation in terms of diversity and spatio-temporal dynamics of vegetation cover [1]. In addition, wildfires release an appreciable amount of particulate and aerosols, and greenhouse gases into the atmosphere, which increases anthropogenic CO2 emissions which is regarded as a global concern [2].

Kurdistan Region (KR), in north of Iraq, is the only region in Iraq where forests still alive [3]. They have played a critical role in the ecosystem and, are an important economic source for rural communities [4]. Moreover, these forests have served, in the past, as habitats for a variety of native species [5]. Kurdistan natural resources have also been extensively destroyed during the political conflict [6]. These incidents have resulted in the burning of forest areas and farmland, as well as forcing millions of rural habitats to abundant rural areas [6]. Several attempts including a campaign of reforestation and forest fire control were carried out by the Kurdistan Regional Government (KRG) which unfortunately was unsuccessful due to poor planning and lack of experience [4]. Forest fires can, at times, become very disastrous after 15-20 minutes. Therefore, it is really important to develop fast and accurate danger maps to detect where have the most potential to be fired. A number of modern technologies have recently been used for fire detection, such as airborne fire detection where people notice large areas during flight and record location information using the Global Positioning System (GPS). Another way is the watchtower where large areas can be seen. However, the most easy, cost-effective and efficient tool is what is nowadays proposed by Remote Sensing (RS). Today, satellite remote sensing is the main source of data which mostly used for fire risk mapping, forest fuel estimation, and wildfire monitoring, as well as post-fire damage assessment [7, 8, 9,10,11]. As proven in many studies, (RS) data is one of the most suitable and supposedly applicable tools for this purpose. Providing temporal and spatial coverage of biomass burning, the use of remote sensing data offers the most economic ways carried out in wildfire management [12]. The produced information by (RS) is easily suitable for integrating in a Geographic Information System (GIS) that allows storing, processing, and displaying a lag amount of spatial information [12], as well as producing spatial analysis [13]. With respect to forest fires, (RS) provides information on environmental situation before, during, and after the fire [14]. At local to global scales, the satellite-based detection of fired areas has traditionally been carried out by the Advanced High-Resolution Radiometer (AVHRR) due to the high temporal resolution [15]. However, the Medium Resolution Imaging Spectrophotometer (MODIS)sensor offers a new opportunity in remote sensing of burned areas [15]. (MODIS)is a sensor located on the Terra and Aqua (NASA) (National Aeronautics and Space Administration) satellites with more than 30 narrow bands in visible to thermal infrared wavelengths and with variable spatial resolution (250-1000 m) [16]. Different studies in the field of forest fire investigation by (RS) in different study areas have led to different indicators. Table (1) shows some of the remote sensing indicators that have been developed to study the different aspects of the forest fire phenomenon.

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**Table (1)**: RS Indices Have been used in forest fire studies

| RS Indices | References |
|---|---|
| Land Surface Temperature (LST) | [17], [18] |
| Fuel Moisture Content (FMC) | [19], [20] |
| Normalized Differential Vegetation Index (NDVI) | [19], [21], [22], [23] |
| Enhanced Vegetation Index (EVI) | [24] |
| Grassland Fire Danger Index (GFDI) | [25] |
| Normalized Burn Ratio (NBR) | [26] |

Although satellite imagery has been widely used to evaluate fire-related studies at the local scales [27, 28], regional scales [29, 30], and global scale and standards [31], there are still a rare number of environmental research in Kurdistan Region which have been conducted using (RS). This research aims to provide a map to show the potential of fires among forest and grassland covers in (KR) using (RS/ GIS).

The factors that can generally cause wildfires and grassland fires are identified as follows [32]:
- Fires in dry plants caused by lightning.
- Fires due to the magnifying objects (e.g., bottle), as these objects sometimes act as magnifiers and ignite plants.
- Plants are self-combusting due to extreme heat and drought among forage pastures.
-Human activities.

The last factor, human activities, is the most common cause of ignition in the forest areas of Kurdistan. This problem appears to be more serious when the recorded wildfires exceed the expected statistics, just as what occurred in this study area, where more than 100 wildfires occurred in almost 4 months in the recent decade. Wildfire management, on the other hand, is classified into three phases; pre-fire phase, which includes risk estimation and prevention. The second stage is the fire impact stage which includes response and mitigation, and the last stage is the post fire stage, which is involved in damage assessment and rehabilitation policy [33].

This study is focusing on the first phase, to map the areas which are most likely to encounter wildfires. Since fires, in the study area, mostly occur during the dry and hot period, this study was limited to from June to September. During this period, the mass of grass and pasture gradually dries up and the trees' water content also decreases. As a result, there will be a large mass of combustible fuel between the forest areas. The main issue, in the first step, is the spatial propagation of that mass of fuel. Accordingly, research mainly focuses on mapping most vulnerable vegetation, as a dynamic source of fire fuel, which is the main source and cause of fire in the occurrence and spread of fires [34].

## 2. Study Area

According to official report [35], (KR) is located in northern Iraq (Fig.1). It is bordered by Turkey to the north, Syria to the west, and Iran to the east, respectively, and lies on a fertile plain that meet the Zagros Mountains [35]. It is crossed by the Great Zab and Little Zab, and the Sirwan River [35]. This area covers an area of about (40,643) km² [35], is inhabited by approximately 5.4 million


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residents [36], and has an annual rainfall of (375-724) mm [37]. It is also mentioned that the climate of the Kurdistan Region is semi-arid and semi-continental. This means that the weather is cold and humid in winter, and very hot and dry in summer. In particular, the summer months from June to September are very hot and dry. July and August are the hottest months, the average high temperature is (39-43 °) C, often reaching close to (50 °) C [35]. This condition can lead to wildfires. Besides, the average height of the mountains of the Kurdistan Region is about (2,400) meters, and they rise to (3000-3300) meters in some places. The highest peak, Halgurd, is located near the border with Iran and measures (3660) meters [38].

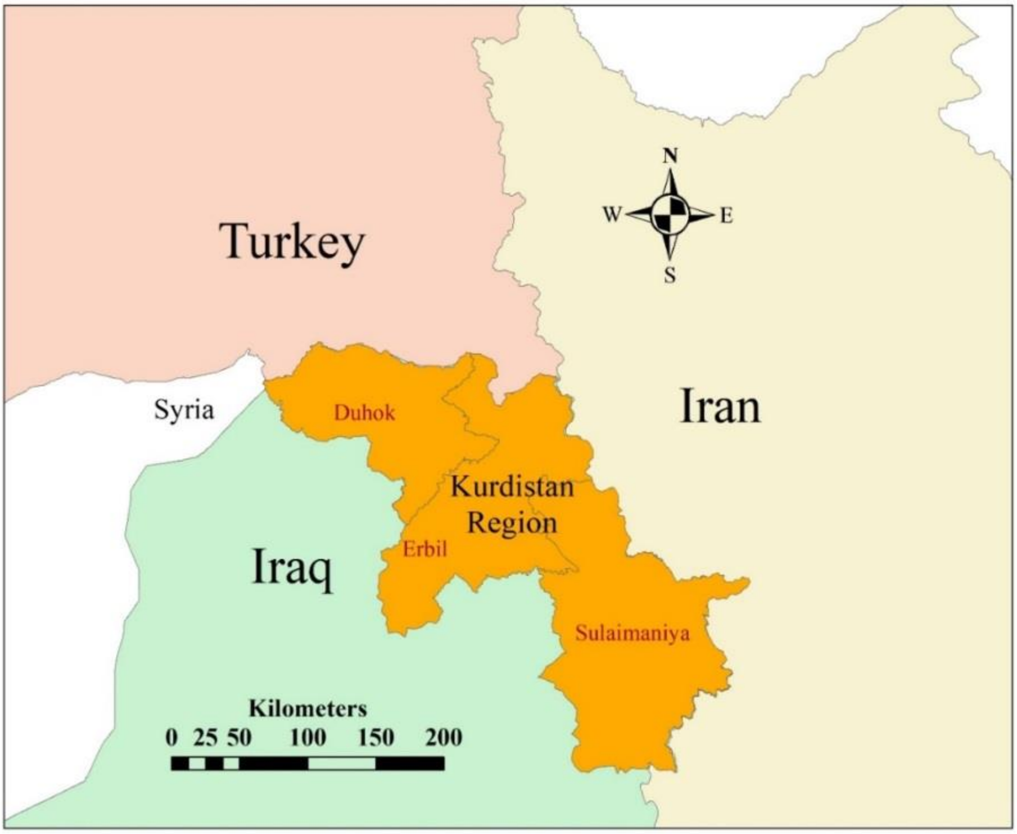


**Fig. 1:** Study area, Kurdistan Region, located in the North of Iraq. It is created in Arc GIS [Researchers].

### 2.1. Kurdistan forests

Most of the mountains of Kurdistan, based on the historical evidence, were covered with well-groomed and healthy forests compared to the conditions of presently degraded forests [3], [39]. Nasir mentioned that the forest cover in Kurdistan begins in the northwestern part of the country from the Zakho region, near the Turkish border, between (37° 08 '22' N 42° 40 '30' E) and (34° 40 '50' N 45° 30 '45' E) to the Horin Shirin at the Iranian border [39]. Natural forests were restricted mostly to the mountainous areas, covering 4% of the total area (438,466 km²), and about 60% of the total mountainous area - about (30,000) km² [4]. Furthermore, broadleaf oak forests constitute the largest proportion of the total forest area (around 90%), and other forest types such as pine, river, plantation, etc., encompass the remaining area (about 10%). [3, 39]. The broadleaf forests are known to be resistant to the harsh and grazing climatic conditions of the region, especially during the hot and dry

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summer. However, these forests have been suffering from various natural and man-made disturbances especially shifting cultivation, fires (wild and artificial), logging, etc. [3, 39].

## 3. Methods and materials

### 3.1. Used Data

In this study, two main set of data were used. Field data, primarily, including the date and location of forest fires between the borders of Sulaymaniyah Governorate, was prepared by the Sulaymaniyah Agriculture and Forestry Department. On the other hand, (MODIS) vegetation products time-series 250 m are the other used datasets which is launched on the Terra platform. These images were provided by the (NASA) website (http://(MODIS).gsfs.nasa.gov/). The data downloaded for the period of early spring to mid-September, 2008 to 2012. The L3 correction-level is applied on them, so they don't need preprocessing. This data includes the blue (469 nm), red (645 nm), near-infrared (NIR: 858 nm), mid-infrared (MIR) bands, and two (NDVI) and (EVI) products.

### 3.2. Method

The occurrence of fire is closely in relation with vegetation status, including fuel temperature (FT), and fuel moisture content (FMC) at a given time and place [34]. Several studies have suggested the application of (NDVI) behavior in order to estimate susceptibility of vegetation to fire [34, 40, and 41]. (FMC) is a critical dynamic factor to predict and map initiating fire, burning efficiency and fire speed and propagation [42]. Furthermore, (FT) is proved to be one of the major factors that can lead vegetation cover to fire [42]. (MODIS) products, such as (NDVI) and thermal products, have been widely used to assess (FT) and (FMC) in several studies [20].

Together with vegetation status, topographical variables characterizing landscape characteristics and weather behavior are highly recommended for inclusion in the modeling of fire occurrence [34]. The accessibility of a particular location can be an influencing factor, as well, that usually determines where and when a fire can happens, especially for human-caused fires, especially in touristic areas. Dynamic and static predictors used to model fire incidents have been reported as shown in (**Fig.2**) [43].

(RS) is a very powerful tool for estimating the factors mentioned in **(Fig.2)**, and preparing thematic maps to show each one independently, as well as, together. The ability to identify where fire trend to happen is an important in fire management [47]. As the most important factor in wildfires, (MODIS) offers one of the best products to monitor vegetation cover, therefore, the presence and content of fuels in forest and grassland areas [47]. In this study, the main focus is on using (MODIS)-based (NDVI) (Equivalent 1) as a reliable indicator for demonstrating and modeling vegetation status and how this will help us learn about places that may be more likely to experience wildfires.


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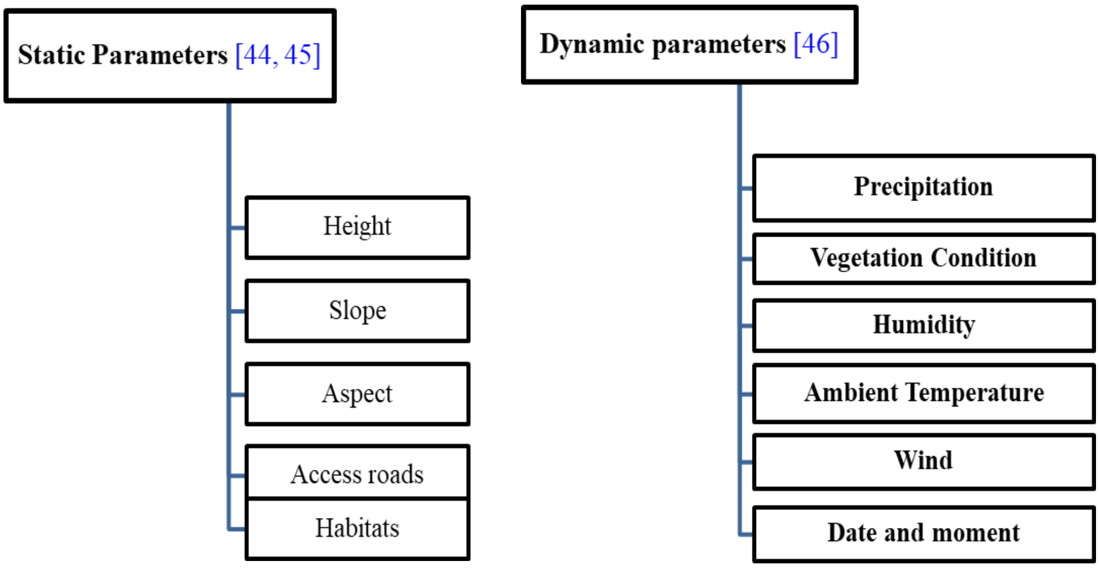


*Figure 2: Static and Dynamic factors which considered as influencing variables affect fire occurrence and control [44, 45, 46]*

$$NDVI = \frac{NIR - RED}{NIR + RED}$$ (Eqe. 1) [48]

RED and NIR are the red (620-670 nm), and near infra-red (841-876 nm, *NIR*) portion of the electromagnetic spectrum, respectively. (NDVI) values differ from -1 to +1. Since the high reflectance of the near infrared red (NIR) in the electromagnetic spectrum for healthy plants, they are represented by high (NDVI) values between 0.05 and 1. In contrast, non-vegetated area, such as water bodies, present zero or even negative (NDVI) values. (NDVI) values for bare soil are close to 0 due to the high reflectance in both the visible and NIR portions of the electromagnetic spectrum [48]. Each pixel of the satellite image is related to a particular area with particular vegetation, that would show a particular value of (NDVI) which depends on a number of parameters, such as I) density and type of vegetation cover, II) plant health condition, and III) the level of water content in plant tissues. Increasing in (NDVI) values can be resulted from an increase in leaf area, canopy closure, or leaf biomass, and vice versa. These characteristics can be used to estimate vegetation susceptibility to fires and access forest damage following hurricanes and fires [19].

By integrating field and satellite data, the following graph (**Fig.3**) can simply illustrate the steps needed to prepare the outputs of this study.

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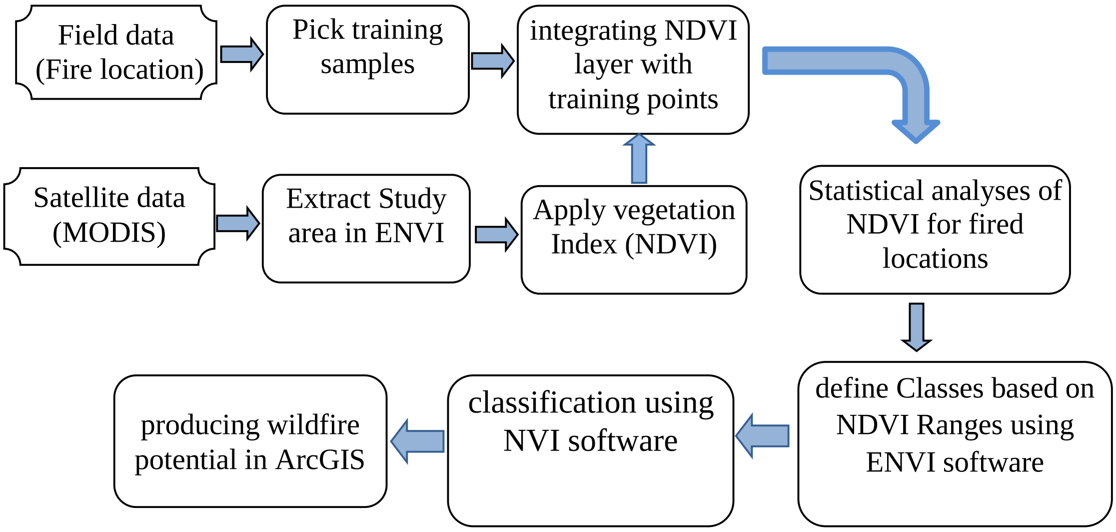


**Fig. 3**: An overview of the proposed methodology for wildfire potential mapping [Researchers]

Field data, including burned forests recorded in 2014 and 2015, are divided into two main groups. The first set, including 20 points, which was used to train the model and other field records, which are used to check the accuracy of output map. The study area was extracted from the satellite image using (ENVI) software. The average (NDVI) value extracted from (MODIS) image extracted for training sites, from late winter to early autumn, (**Fig. 4**), reveals that (NDVI) meets its highest value in April and May, as the area is covered with fresh grasslands, green and healthy forest, and then gradually decreases to its lowest level around August, when the only green cover is trees. It is tried to pick out training data from different locations with different firepower to find out their (NDVI) value. (NDVI) values extracted from satellite-based data for these sites show that the higher the (NDVI) value during April and May, the greater the degree of destruction and wider fire scar during summer.

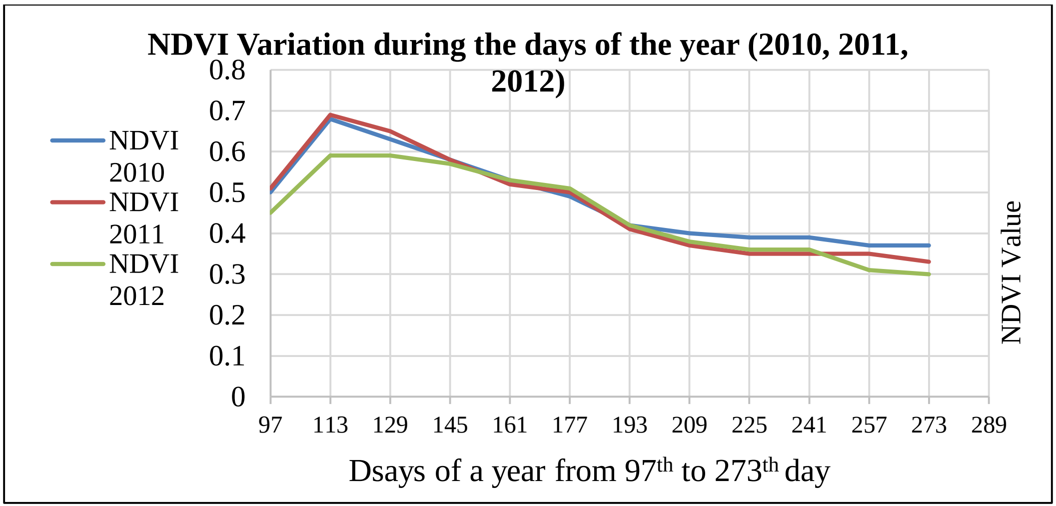


**Fig. 4**: Average (NDVI) value of training points during 2010, 2011, and 2012 [Researchers]


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The tendency of scorched forests and grassland areas to follow the (NDVI) value, for a period of three years, was used as an indicator to show the distribution of vegetation and the (FMC) seems to be very useful in classifying the study area into some nominal categories based on the different (NDVI) ranges to show the level of probabilistic fire. Four classes are defined as shown in (**Table 2).**

**Table (2)**: (NDVI) ranges for defining classes [Researchers]

| Classes | (NDVI) value |
|---|---|
| **Very Hight Potential** | (NDVI) > 0.6 |
| **High Potential** | 0.45 <(NDVI)< 0.6 |
| **low potential** | 0.3 <(NDVI)< 0.45 |
| **No potential** | (NDVI)< 0.3 |

These ranges are derived based on the (NDVI) trends (**Fig. 3**). These values do not necessarily coincide with the behavior of (NDVI) for other years, given the different trends of vegetation conditions in different years with respect to precipitation and weather. ENVI 4.8 IDL software was used to analyze and manipulate the satellite image. Supervised classification, maximum like-hood, was applied on (NDVI) image to classify I, regarding the categories specified in (**Table.2)**. The categorized image is then loaded into (Arc GIS) software for further analysis including rendering, scaling, and adding other layers. The satellite image and the rest of information were not in the same coordinate system, so, they were all transferred to the same coordinate system, the geographic coordinate system. Finally, Residence layers, urban areas, sub-provinces, etc. added to the produced danger map.

## Results

The satellite image used was taken in 2010, four years before the field data which recorded on wildfire (place and date). The categories included the (NDVI) bands (designated in Table. 2). As shown in (**Fig. 5**) the final map, which is made from applying supervised classification on the (NDVI) layer, as indicated on the map, display some important information. The black circles, which are the buffer of locations of forest burnt area from 2014 to 2015, closely matched the red and yellow areas on the map that were named as very high potential and high potential, respectively. Based on the developed map, Penjwen, located to the west of the map, had the most wildfires potential due to the red and yellow. Gharadakh, Amedi,Soran, choman, Zakho, Pishdar, and Dokan are other areas considered to be areas with high potential for facing forest fires. Surprisingly, the officially reported data for Dukan, Gharadakh, Pishdar and Halabja (black circles) also coincide with the prediction made by the developed map, however, the lack of data for the northern and central part of the study area will not allow us to make a correct report on these areas. The green and white areas on the map, which show the categories with medium and low potential, are also fully consistent with the recorded field statistics.

DOI: http://dx.doi.org/10.25098/6.2.31

The Scientific Journal of Cihan University – Sulaimaniya PP: 147-162
Volume (6), Issue (2), December 2022
ISSN 2520-7377 (Online), ISSN 2520-5102 (Print)

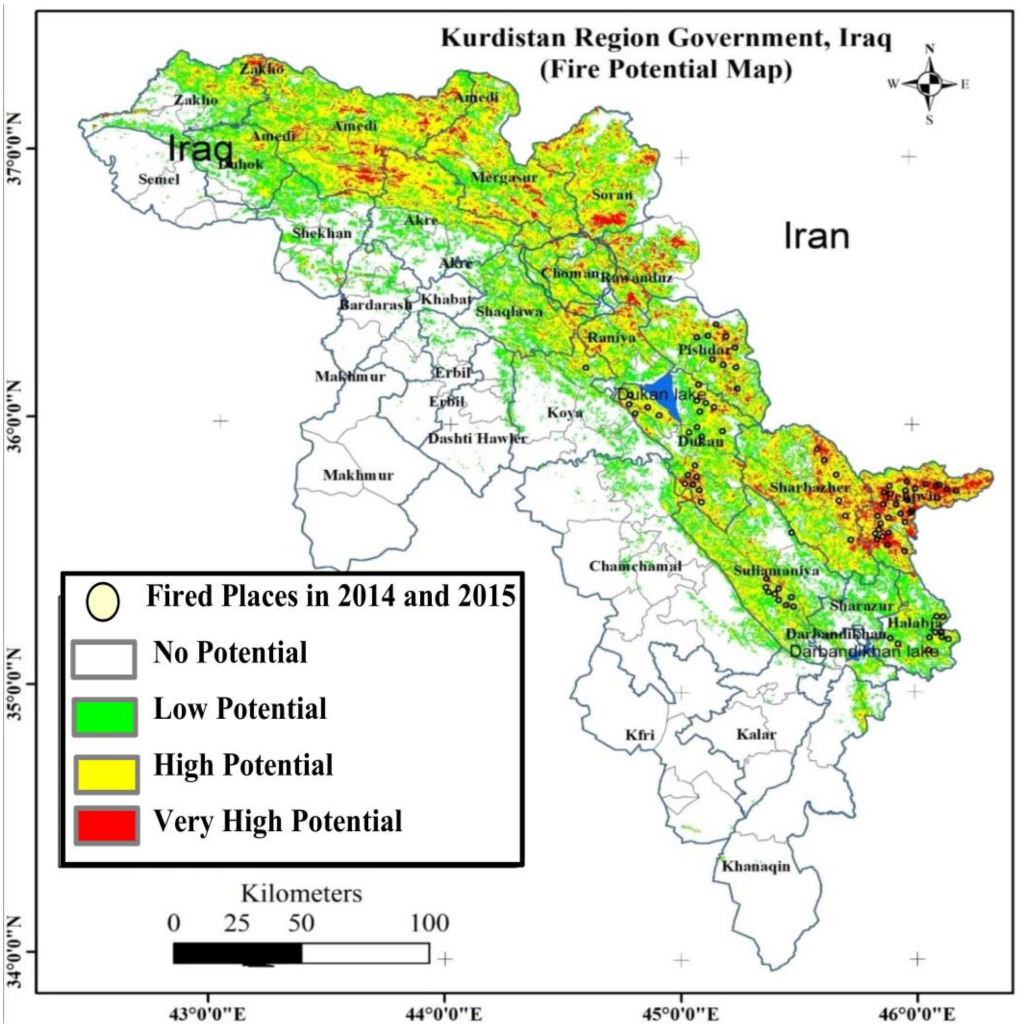


**Fig. 5:** Fire danger map developed by supervised classification. The used satellite image belongs to 2010, while the black circles are a **1000 m** buffers of fired areas among Sulaimaniyah province's forests and rangeland areas. [Researchers]

The study also showed that less than (15%) of the Kurdistan Region has a serious potential for facing forest fires, therefore, given the importance of forests in the environment of Iraq, preventive measures should be seriously considered. (**Fig.5)** shows the truth from a closer perspective. As we have seen, dark circles lie roughly in areas that is predicted as high potential and very high potential areas, especially, the western part of Penjwin and Sherbazher. The same can be observed in the areas of Pishdar and Dokan. The map reveals that the denser and wider the level of the red and yellow zone was between the study area, the more fire incidents were recorded in subsequent years. In (**Fig. 6)**, the occupied regions within the circles simply reveal the high-level presence of yellow and red pixels which represent high and very high potential regions, respectively. Therefore, the map, which was developed based on an image taken in 2010, can determine the probability of fire in the forest and grassland areas of the study area. For a better view, (**Fig.7)** was also developed which specifically focused on the burned areas only.


DOI: http://dx.doi.org/10.25098/6.2.31

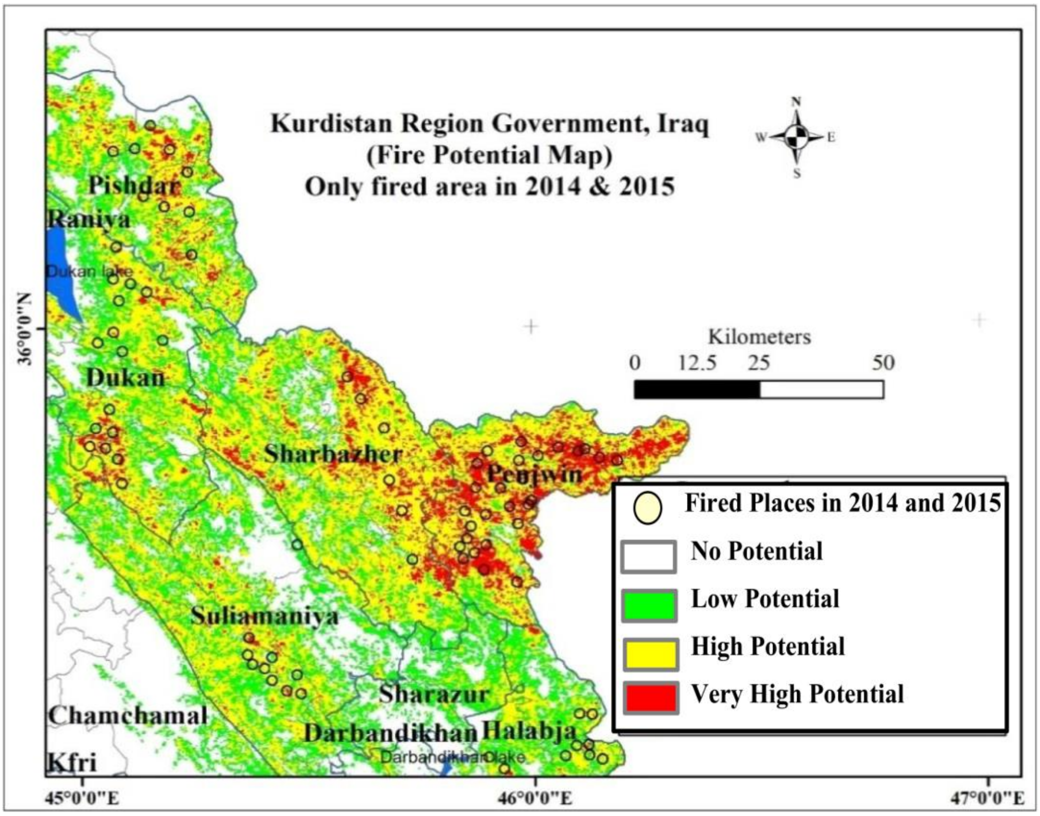


**Fig. 6:** More details on Penjwen, and Sharbazher, the western part of the study area. [Researchers]

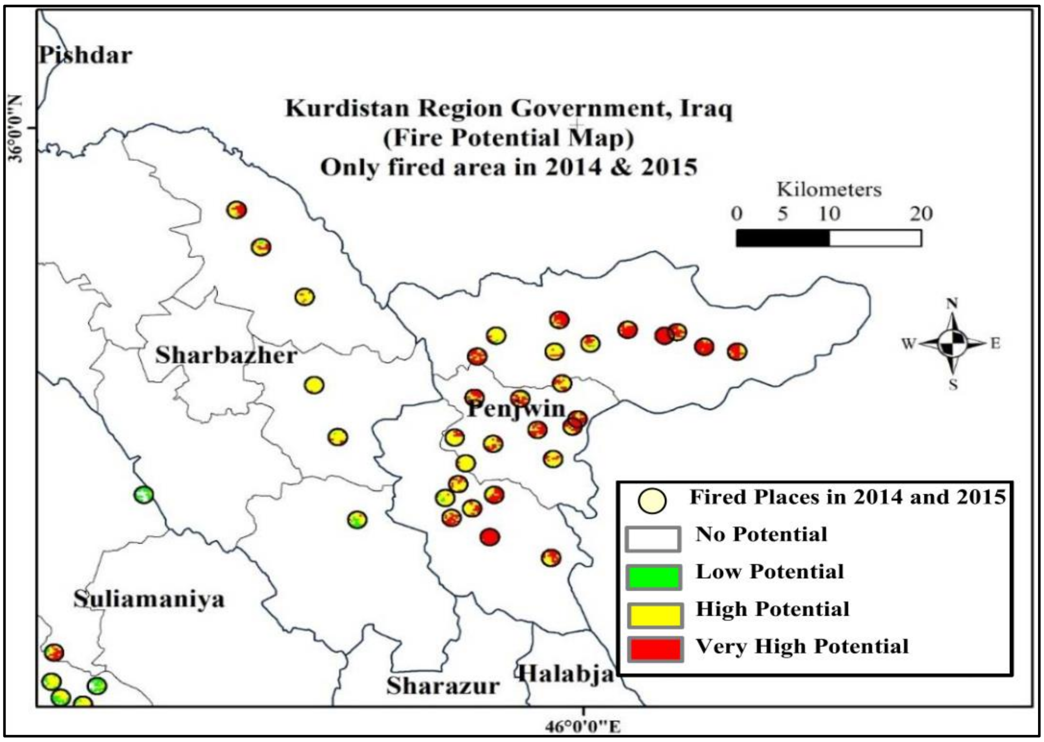


**Fig. 7**: Inside of circles (buffers) is mostly red and yellow. It means that the fire danger map developed based on 2010's data has predicted the areas that have experienced fire in 2014 and 2015 [Researchers]

DOI: http://dx.doi.org/10.25098/6.2.31

## Discussion

There are numerous studies at the global, regional, and local scales focusing on the application of remote sensing on environmental issues (e.g., wildfires). There are, also, a number of systematic models for forest fire monitoring and fire prediction by use of (RS). Among them, the McArthur Forest Fire Hazard Classification System and the McArthur Grassland Fire Hazard Classification System are widely used in Australia. In addition, North American models the National Fire Hazard Classification System (NFDRS), Fire Behavior (BEHAVE), Fire Area Simulator (FARSITE), and the National Fire Management Analysis System (NFMAS) [49, 50]. Furthermore, the Canadian bushfire hazard classification system which is mostly used in Canada [51, 52]. The Russians have also developed the Russian Federal Forest Agency (SMIS-Rosleshoz) Forest Fire Monitoring Information System [48, 51]. Despite all the invaluable researches conducted all over the world in forest fire monitoring using (RS), in Iraq, and especially in the (KR), the application of (RS/GIS) in environmental investigations is rarely taken into account. This study did not aim to develop an innovative technique and method, but it aimed to create a wildfire potential map for northern Iraq, which can be considered as new research in this study area.

## Conclusion and Recommendation

This study reveals that (RS/GIS) can play a critical role in environmental management, such as forest fires, such as natural resource monitoring. (RS) helps us produce a thematic map at different scales. The occurrence of fire is closely related to the state of vegetation, including fuel temperature (FT), and fuel moisture content (FMC) at a given time and place. Several studies have suggested the use of (NDVI) variations in order to assess the inclination of vegetation to fire. Since pasture and forage (grassland species) have less heat tolerance, so they have the most firepower. The (NDVI) index can play a critical role in the study of these types of fires because the (NDVI) index can give a reliable and traceable insight into the health and density of vegetation, as well as its growth in this region. Moreover, access to more detailed field data as well as the use of other multispectral and hyper-spectral satellite images, combined with other satellite-based indicators, may lead to more reliable and accurate maps. It is highly recommended to do some research on the study of water stress (WS) among Kurdistan forests, as well as (FMC) and (FT) among different species during different seasons. Careful research on mapping the type of vegetation in the study area will be very useful for the venue to estimate fire hazards and fire potential.


DOI: http://dx.doi.org/10.25098/6.2.31

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