Dedication

This work is dedicated to my dear mother for her love, care and continuous support through my whole life , to the soul of my father, to my brother Adel for his continuous support and encouragement ,to my wife for her patience and caring the kids during my study and all my brothers, sister and my kids Mohammed, Rawaa ,Rawanag and Mohand.

Acknowledgements

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Abstract

This Study used remote Sensing and Geographic information Systems (GIS) through MODIS data 8 day surface reflectance to document the history of fire and produce maps of burned areas in the Southeastern part of Gedaref state for the period between 2000 to 2013 with main aim to investigate fire regime (wildfire extend, frequency and seasonality) in the area and hence contribute in preparation of integrated fire management program. The methodology applied in order to achieve this goal was an analysis of the images obtained by the MODIS sensor to map the burned areas. Collection of 27 images on every season is processed (351 image for 13 seasons) and analyzed to extract the burned area using MODIS images each season. Envi 4.7 and Arc Map 9.3 software were used for image processing and maps production. The study revealed that the fire season started at the beginning of the dry season in the mid of September and continue until ends of the April with the peak of burned areas in November and February. The study also showed that there was two peaks of burnt area within the fire seasons this was appear in the season of 2000-2001 and the season of 2008-2009. The frequency map showed that the higher frequency burned area was located in the southern and eastern part of the study area and the least frequency burned area was located in the northern part of the study while the medium frequency burned area dominated in the middle part of the study area. The study recommended development of integrated fire management plan, and investigating the relation between dispute and outbreak of fire in the study and the various causes of wildfire.

ملخص عربي

هذه الدراسة نحو استخدام فى الاستشعار عن بعد ونظم المعلومات الجغرافية من خلال القمر الصناعي MODIS بالمواصفات250 متر دقة مكانية, منتج ثمانية ايام لتوثيق الحرائق وإنتاج خرائط للمناطق المحروقة في الجزء الجنوب الشرقي من ولاية القضارف للفترةمن 2000 الي 2013 مع الهدف الرئيسي لفهم نظام الحرائق (المساحة– التردد– وموسمية) في المنطقة، وبالتالي المساهمة في تجهيزر خطة متكاملة لإدارة الحرائق. وكانت المنهجية المطبقة من أجل تحقيق هذا الهدف تحليلا للصور التي حصل عليها نظام استشعار MODIS لتعيين المناطق المحروقة. تمت معالجة عددد 27 صورة في كل موسم (351 صورة في فترة 13 مواسم) وتحليلها لاستخراج المنطقة المحروقة. واستخدم برنامج 9.3 Arc map, ENVI 4.7 لمعالجة الصور و لإنتاج الخرائط. وكشفت الدراسة أن موسم الحرائق يبدأ مع بداية موسم الجفاف في منتصف سبتمبر ويستمر حتى ينتهي في أبريل مع ذروة المساحات المحروقة في نوفمبر وفبراير. وأظهرت الدراسة أيضا أن هناك قمتين للمساحات المحروقة بين مواسم الحرائق كان هذا في موسم 2000،20001 وموسم 2008،2009. وأظهرت خريطة التردد أن المساحة المحروقة ذات التكرار العالي تقع في الجزء الجنوب الشرقي من منطقة الدراسة ,المساحة المحروقة ذات التكرار الاقل في الجزء الشمالي منمنطقة الدراسة في حين أن المساحة المحروقة ذات التكرار المتوسط كانت في الجزء الأوسط من منطقة الدراسة.أوصت هذه الدراسة بتجهيز خطة متكاملة لادارة الحرائق ,التحقيق في العلاقة بين النزاعات واندلاع الحرائق في منطقة الدراسة والتحقيق في اسباب الحرائق المختلفة في منطقة الدراسة.

Contents

Acronyms & Abbreviation

AADS	level Atmospheric Archive and Distribution System
AVHRR	Advanced Very High Resolution Radiometer
CAD	Computer Aid Design
DN	Digital Number
ENVI	Environmental For Visualize Image
EME	Electromagnetic Energy
EDC	EROS Data Center
EVI	Enhanced Vegetation Index
FAO	Food and Agriculture Organization
FNC	Forests National Corporation
GIS	Geographical Information System
LPDAAC	Land Processes Distributed Active Archive Center
MODIS	Moderate Resolution Imaging Spectroradiometer
NASA	National Aeronautics and Space Administration
NDVI	Normalized Difference Vegetation Index
NIR	Near Infrared
NOAA	National Oceanic and Atmospheric Administration

CHAPTER ONE

1. INTRODCTION

Fire is an important and widely used tool to meet land management goals and maintain the functioning of ecological processes. However, every year wildfires destroy large area of forest, woodland and other vegetation, causing loss of many human and animal lives and economic damage. There are also impacts on society and the environment –for example, damage of human health, loss of biological diversity, release of carbon dioxide and other greenhouse gases, damage of recreational and amenity values (FAO, 2007). The fire regime is an objective measurement of fire’s historic natural occurrence in the landscape, which is not necessarily the current condition or appearance. The fire regime includes the seasonality, frequency, intensity, and spatial distribution of fires (Hardy, 2001) and (Hann, 2001). Despite the severe social, economic and environmental impacts of fires, reliable current information on extent and causes impact and costs is insufficient .Yet such information is essential to the development of policies, legislation and plan for prevention and suppression (FAO,2007). The Southeastern part of Gedaref State is suffering from wildland fire, but there is lack of information and the fire regime is not well yet .There is non-existence of neither integrated fire management plan nor specialized fire management organization. The dry season start two to three weeks after rainy season from September to May/June and the fire danger increase with grass dry out and the existence of human activities (Bayoumi 2001).

1-2 Research Problems

- The Southeastern part of Gedaref State suffering from wildland fire, but there is inadequate of information and the fire regime is not well yet investigated
- There is non-existence of neither integrated fire management plan nor specialized fire management organization.
- The ecological effect of wildfires frequency on vegetation structure and composition is un known due to non- existence of wildfire frequency map

1.3 Research Objectives

1.3.1 General Objectives

To investigated the fire regime (wildfire extend, frequency and seasonality) in the Southeastern part of Gedaref state.

1.3.2 Specific Objectives

- To produce maps of burned areas at the Southeastern part of Gedaref state for the period 2000 to 2013, in order to document the history of fire data.
- To produce fire frequency map at the Southeastern part of Gedaref state.
- To contribute in elaboration of integrated fire management plans.

1.4 Research Justification

- There is lack of reliable records about fire incidence and its spatial distribution and the fire regime was not properly investigated.
- To provide information needed to develop integrated fire management plan.
- To provide the ecologist with the information needed to study the relationship between the structure, composition of the vegetation cover and wildland fire frequency.

1.5 Research Questions

1. How much is the burned areas in the Southeastern part of Gedaref state each year?
2. How many times fire repeated in deferent part of Southeastern part of Gedaref state during the period of the study?
3. When fires start and end in Southeastern part of Gedaref state

CHAPTER TWO

2. LITERATURE REVIEW

2.1 Remote Sensing

Remote sensing can be defined as the study of something without making actual contact with the object of study. It can be known as: Remote Sensing" is the science and art of obtaining information (spectral, spatial, temporal) about material objects, area, or phenomenon, without coming into physical contact with the objects, or area, or phenomenon under investigation.(Lillesand *et al.,*1994). According to (compell, 1987). Remote sensing systems consist of seven components: The first one is Energy Source, the second is Radiation with the energy, the third one is interaction with the Target this which is depend on the properties of both the target and the radiation. The fourth component is the Sensor which Record the back reflected or scattered Energy from the target. The fifth component is the process of Transmission, Reception, and then the data are processed into an image (hardcopy and/or digital). The component number six is Interpretation and Analysis by which we means that the processed image is interpreted, visually and/or digitally to extract information about the target and the seven component is application which means to benefit from the information we have been able to extract from the imagery about the target in order to better understand it, reveal some new information, or assist in solving a particular problem (Campbell. 1987).

2.2 Moderate Resolution Imaging Spectroradiometer (MODIS)

MODIS is the Moderate Resolution Imaging Spectroradiometer. The MODIS instrument is a polar orbiting, high temporal, moderate spatial resolution sensor that acquires remote sensing data for monitoring the Earth's land, ocean and atmosphere. The MODIS instrument is currently on board two NASA EOS satellites – Terra, launched in December 1999, and Aqua, launched in May 2002. Each MODIS sensor has a wide field of view (2,330 kilometers) that allows the sensor to image the Earth on a daily basis at latitudes greater than 30 degrees and every 1 to 2 days at latitudes less than 30 degrees. MODIS image data are acquired in 36 co-registered spectral bands at moderate spatial resolutions (250, 500, and 1,000 meters). Thermal information is collected at 1,000-meter spatial resolution and is collected twice daily by each sensor (one daytime and one nighttime observation) in the mid to high latitudes. MODIS images are different processing levels. Level 0 products are raw digital number images. Level 1 product includes calibrated radiance values. Level 2 and 3 products have more processing and are derived from lower level products MODIS products are available from several sources and usually free to the public (Kaurivi *et al* .,2003).

2-3Vegetation Indices

Vegetation indices used widely to distinguish between the different features in satellites image such as vegetation, soil and water in one hand, while on the other hand can be used to generate information about vegetation characteristics such as vigor, health and maturity status. Vegetation index is a quantitative measure used to measure biomass or vegetative activity , usually formed from a combination of several spectral bands , added , divided , or doubled in order to yield a value of one indicates the amount of force or vegetation values . The simplest form of vegetation index is the ratio between reflectance of the near infrared and the red reflectance. For healthy vegetation this percentage will be high because of the inverse relationship between brightness vegetation in red and infrared region of the spectrum.

Normalized Difference Vegetation Index (NDVI) is one of the most important and widely used vegetation indices it depends on the visible and near-infrared light reflected by vegetation. Healthy vegetation tends to absorbs most of the visible light that hits it, and reflects a large portion of the near-infrared light, while unhealthy or sparse vegetation reflects more visible light and less near-infrared light. (Nearly all satellite Vegetation Indices employs this difference formula to quantify the density of plant growth on the Earth: — near-infrared radiation minus visible red radiation divided by near-infrared radiation plus visible red radiation. The result of this formula is called the Normalized Difference Vegetation Index (NDVI). Illustrated mathematically with the following NDVI formula.

NDVI = (NIR - R) / (NIR + R)

Calculations of NDVI for a given pixel always result in a number that ranges from minus one to plus one; however, no green leaves gives a value close to zero. A zero means no vegetation and close to +1 (0.8 - 0.9) indicates the highest possible density of green leaves. (Tucker, 1979) and (Crippen, 1990).

2-4 MODIS Vegetation Index product

MODIS vegetation indices produced on 16-day intervals and at multiple spatial resolutions, provide consistent spatial and temporal comparisons of vegetation canopy greenness, a composite property of leaf area, chlorophyll and canopy structure. Two vegetation indices are derived from atmospherically-corrected reflectance in the red, near-infrared, and blue bands; the Normalized Difference Vegetation Index (NDVI), which provides continuity with NOAA's AVHRR NDVI time series record for historical and climate applications, and the Enhanced Vegetation Index (EVI), which minimizes canopy-soil variations and improves sensitivity over dense vegetation conditions. The two products more effectively characterize the global range of vegetation states and processes.(Xiang Gao *et al.*,2011) .

2-5Use of remote sensing in forestry

Remote sensing is used at large scale in various forestry aspects such as forest cover discrimination, changes in forest cover, agro forestry mapping, forest management process like clear cut mapping and regeneration assessment, other process like reconnaissance and inventories for assessing forest cover can be carried by means of remote sensing. Also remote sensing aids in Burned areas delineation, biomass estimation, deforestation and Forest health and vigor assessment studies among many other usages (Noam Levin, 2003).

2.5.1 Remote Sensing product for fire management

Remote sensing data can assist fire management at three stages relative to fire occurrence:

- Before the fire**:** estimation of fuel load and assessment of vegetation status (e.g. moisture content) and rainfall.
- During the fire**:** near real-time location of active fires.
- After the fire: assessment of burned areas (Goldammer *et al*., 2004).

2.5.1.1 Burned Area Product Principles

Burned areas are detected from remotely sensed Data based on three main changes in surface properties following fire: Vegetation is removed, Combustion residues are deposited and the day, the burned surface is hotter than surrounding Vegetation, with a maximum contrast in temperature occurring around mid - day.

The main downsides are that, at present, burned area detection methods are generally less automated than active fire-based methods. (Goldammer *et al*., 2004).

2.5.1.2Burned Area Products in Fire Management

Integrated into a Fire Management Information System, burned area Products are useful at all stages of the fire management (Goldammer *et al*.,2004).Burned area products can provide important baseline information on fire regimes (frequency, seasonality and intensity). Fire frequency maps are obtained by superimposing burned area maps for successive years. Seasonal fire maps are produced using several successive burned area products. Burned areas are characterized by deposits of charcoal and ash, removal of vegetation, and alteration of the vegetation structure (Roy, 1999). It detects the approximate date of burning at 500 m by locating the occurrence of rapid changes in daily surface reflectance time series data. The algorithm maps the spatial extent of recent fires and not of fires that occurred in previous seasons (Goldammer *et al*., 2004).

2.6 Geographic Information System (GIS)

2. 6.1Definition and component

GIS is a system of hardware and software used for information storage, retrieval, mapping, and analysis of geographic data. It is also the GIS practitioners they include total operating personnel and the data that go into the system. Spatial features are stored in the system of coordinates (Latitude / Longitude, State Plane, UTM, etc.), which references a particular place on Earth. And associated descriptive attributes in the form of a table with spatial features. Spatial data and related attributes in the same coordinate system can then be layered together for mapping and analysis. It can use GIS for scientific investigations, resource management and development planning. GIS differs from CAD and other graphical computer applications in that all spatial data geographically referenced to the map projection coordinates system in the ground. For the most part and spatial data can be " re- projected " from one coordinate system to another the data from different sources can be brought together into a common database and integrated using GIS software . Border of spatial features should “register" or aligned correctly the same coordinate system. Other property from a database of geographic information system is that it has “topology”, which determines the spatial relationships between features. The basic components of spatial data in GIS are points, lines (arcs) and polygons. When there are topographical relationships, you can perform analyzes such as modeling the flow through connecting lines in the network, combining adjacent polygons that have similar characteristics] and overlaying geographic features (Swanson, 2003) and (Aronoft, 1991).

2.6.2data representation Models

GIS data represents real objects (such as roads, land use, elevation, trees, waterways, etc.) with digital data to determine the mix or merge. Real objects can be divided into two abstractions: discrete objects (for example, the House of Representatives) and continuous fields (such as rainfall amount, or heights). Traditionally, there are two methods broad used to store data in a GIS for both types of abstractions mapping references.

- A raster data type is essence any type of digital image represented in grids. Raster data is stored in various formats; from a standard file –based structure of TIF, JPEG, etc.

- A simple vector map, using each of the vector elements: points for wells, lines for rivers, and a polygon for the lake. (Swanson, 2003) and (Aronoft, 1991).

2.7 Wildland fire

Wildfire is any uncontrolled and rapidly spreading fire that occurs in the countryside or a wilderness area. Other names such as brush fire, bushfire, forest fire, grass fire, hill fire, peat fire, vegetation fire, and wildland fire may be used to describe the same phenomenon depending on the kinds of vegetation being burned. A wildfire differs from other fires by its extensive size, the speed at which it can spread out from its original source, and its ability to change direction unexpectedly and to jump gaps, such as roads, rivers and fire breaks. Wildfires are characterized in terms of the cause of ignition, their physical properties such as speed of propagation, the combustible material present, and the effect of weather on the fire (FAO, 2007)

2.7.1 Causes of wildfires

- Land owners, farmers and the rural population In most countries, agriculture burning, such as shifting cultivation, Grazing, and fires to control vermin and insects, together with the many variations of rubbish and debars burning are major causes of wildfires.
- Slash and burn farming it's a common practice for agriculture which refers to the cutting and burning of forests and vegetation to clear land. Often, the results of the practice slash-and-burn in the disastrous forest fires.
- Lightning Wildfires Forest fires caused by lightning occur at a frequency of three to five per year. Since rain is usually associated with lightning such as fire does not spread over large areas.
- Drought, wind and changing weather conditions Extreme hot temperatures lead to dryness of the vegetation in this area, and can worsen wildfire through fueling all that and Moreover, it can actually ignite the fire spread across great distances with the wind as a medium.
- Underground coal fires are slow and flameless forms combustion, below the earth's surface. These fires continue to burn for many years, leading to the release of toxic fumes, the destruction of vegetation and human property.
- They are controlled fires to eliminate elements that can exacerbate wildfire or forest fires. Often, they are a part of the wildland. Management Sometimes these - prescribed fires are also not channelized properly and lead to a catastrophic infernos(FAO,2007)

2.7.2 Fire regime

The fire regime includes the seasonality, frequency, intensity, and spatial distribution and major ignition source. Ecosystems and main habitat types can generally be classified as relationship to one of three wide fire regime types. These types are fire-dependent, fire-sensitive and fire independent ecosystems. Experts classified 46% of the global area of main habitat types as fire-dependent/influenced; 36% as fire-sensitive; and 18% as fire-independent (The Nature Conservancy, 2004).

2.8 Fire Management Plan

A strategic plan that defines a program to manage Wildland fire and Prescribed fire and documents the Fire Management Program in the approved land use plan. The plan is supplemented by operational procedures such as Preparedness plans, preplanned dispatch plans (Fire wise, 1998).

2. 9 Forest fires and impact factor

Afire is a chemical reaction that needs heat, oxygen and fuel to start and carry on, as it is established in the fire fundamentals triangle (pyne, 1996). When an uncontrolled fire starts in or spreads to natural vegetation it converts to forest fire .therefore , the probability of occurrence of it depend on the ignition causes and environmental preconditions (Bachmann,2000).Among these are the fuels quality , distribution , the weather , topography and human factors (Grimm,1984)and (whelman , 1995).

2.9.1 Classification of forest fires

There are two forms of wildland fire classification depend on its origin, or on the affected layer of fuel. Each classification is useful for development of preventive or enforcement measures in the integrated fire management plan forest. To design a plan for prevention it is important to know the origin of fire. On the other hand, defines the affected layer of the fuel reflect behavior and intensity of fire. As a result, can adopt measures to control an active fire. The main characteristics of each classification: Can be classified by origin fire started either naturally or by human beings. Usually led to a natural fire is light. But can also be natural causes: extreme heat. The sparks generated by the friction of falling rocks or volcanic eruption. Another classification focuses on the affected layer of fuel .Afire that spreads horizontally above terrain and consumes the leaves, twig fallen trees, grasses and other plants (Bond, 1996). If shooting up to fire the crown of the tree under the influence of wind and slope, and then be transferred to crown fire (Jhonson1996) . These types of fires are very destructive and difficult to be controlled (COFOM, 2007). On the other hand, ground fires are those that have spread below ground burning of organic material such as dead leaves and roots (Bond, 1996).

2.9.2 Impacted wildland fires

Wildland fire causes significant biological changes. Some are the direct consequence of the fire, like singe or disintegration of the tissue. However, there is another indirect effect that remains after fire has been put out(Shy, 2001)and(Ellingoson, 2000) such increased light and soil Temperature (Whelan, 2005) and (shy, 2001) and increasing wind speed as a consequence of removing vegetation (Wright 1982). Because of these changes, soil erosion processes are expected to take place immediately after fire (Mallick, 1986). Unless the ecosystem is adapted to fire, repeated fires reduce the and alter the biodiversity of species and vertical structure (FAO, 2007), (Schwik, 1997)and (Collins, 1992). There also could be a great social and economic impact such as wood burning and damage of house that are built from grass and wooden materials. In short, among the damage of forest fires the following can be found:

- wood destruction,

- increase the erosion of land
- and the destruction of habitat, plants and animals lose,
- tree weakness and disease, and increased
- pollutants,
- low scenic beauty(Roy,2004).
- Changing species composition of the forest toward the fire resistant species, for example (***Ziziphus spina christi*** and ***Acacia seyal***).Afire-free environment will provide niches for species (both flora and fauna) sensitive to a fire environment (Goldammer, 1991).

2.10 Wildland Fire Management Situation in Sudan

2.10.1 Climate and ecological role of forests fires

The dry season starts two to three weeks after the rains end in northern Sudan, November to April/May. Tall and short grasses are increasingly desiccated during the dry season. Increased wildfire hazard is associated with low humidity, high fuel loads and the presence of moving grazers. Annual wildfires are common and spread speedily due to northeast winds and flat terrain. This is the case in central, and western Sudan. Repeated fires occur if the hot dry weather continues, i.e. late rains. ((Bayoumi2001) Fires have reduced yields of ***Acacia Senegal*** gum up to 50%. which is a great economic loss. In the average year fires affect about 70 per cent of the open grasslands. Fires have also encouraged the spread of some species, such as ***Acacia mellifera place*** in central Sudan in clay soil where the Acacia-grassland cycle" takes place. The occurrence of Acacia alternate with tall grasses. Acacia take if fire danger low and Herbs become dominant with increasing quantities of fuel and high-intensity fires (Bayoumi, 2001). Fire statistics is lacking in Sudan except for limited areas. Fire management organizations not exist in Sudan.

2.10.6 Forest policy and Act concerning fires

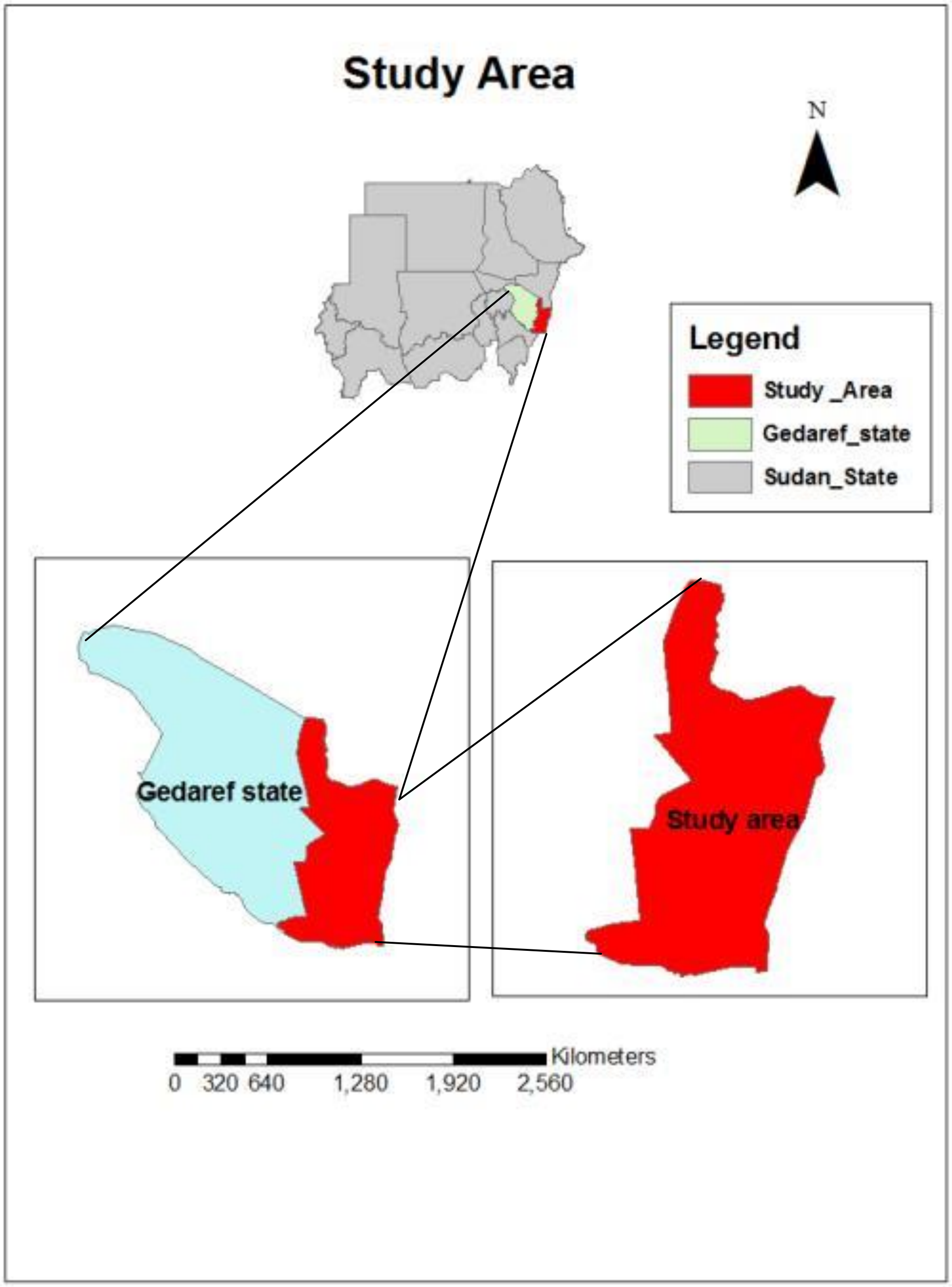
Forest Policy of 1986 emphasizes the protection of forests from fires. Forest Act of 1989 prohibits trespassing of people and their animals in the reserved forests and prohibits carrying material ignited in the forest, making fires for cooking or for other purposes in or near forests and obliges people to help in extinguishing forest fires. The reductions of fires certainly maintain the natural resources of the country, and will improve the growth of many trees species (Bayoumi, 2001).

CHAPTER THREE

3. The STUDY AREA

3.1 location

The study area located in the Southeastern part of Gedaref state between latitude 13.236° and14.5037°N and longitude 35.5536° and 36.2021°E (Fig 3.1). It portrays different land cover and land use types including agriculture, forests and range areas. Agriculture forms are small holdings, mechanized and characterized by fertile agricultural soils, and is considered one of the largest areas of agricultural production in Sudan, the biggest producing areas, sorghum and sesame in world. On the eastern part bounded by state of Kassala, borders of Sudan and Ethiopia and on the southern part bounded by the state of Sennar. The Study area includes Elrahd, West Galabat, East Galabat and Elfashqa localities ,the study area is (17716.34) $km^{2.}$


Study Area
N
Legend
Study _Area
Gedaref_state
Sudan_State
Gedaref state
Study area
Kilometers
0 320 640 1,280 1,920 2,560

Fig(3-1)

3.2 Demographics

The total population of the state in 1993 is estimated 1,148,262 people, according to census results in 1993 and annual growth rate is 3.7%, this is considered as high rates when compared with the overall growth rate of the country, which has a 2.8% in the year. The high rate of population growth is attributed to many factors, including internal migration from other states to Gedaref areas as agricultural areas attractive to residents, as well as seasonal migration in addition to high rates of natural increase and the flow of refugees and displaced persons and the security stability in different parts of the state. If we look to the installation of the state's population by life style, we find that the proportion of urban and rural and nomadic to the total population of the state in 1983 was 22.7% - 73.6% - 3.7% respectively, while this ratio becoming in 1993 as 25% 73.7% 1.3% . As observed there is a rise in proportion of the urban population and a decrease in the percentage of Arab nomads, which indicates that there is a migration from the countryside of the state to the cities as Gedaref. Total population of Gedaref State 1.348.378 people in 2008 (www.gadarifstate.gov).

3.4Climate

Climate in Gedaref state range between two feature the northern and North-Western areas in semi-arid and characterized by a summer rainy season (April-October) a relatively short which the Eastern and southern areas are located within the wet climate. Precipitation ranges from 500 -900 mm of rain. The average minimum temperature 17 ° c (in January) and the maximum temperature of 47° c (in April and May), while the average wind speed is10 km/h. (Economic planning, Gedaref State) and (www.gadarifstate.gov).

3.5 Topography

Generally characterized by mud-state land interspersed with some higher elevations, the topography of the state can be divided into three main units:

1. Highland region (High lands) and are concentrated in the South-Eastern State with the international border with Ethiopia, as well as some isolated mountains.
2. Plains region, which is the dominant unit in the state and is characterized by the existence of the mud flat or simple regression.
3. Valleys area includes sedimentary ground around the seasonal rivers (the Atbara River, Setit, Rahad and baeslam(www.gadarifstate.gov).

3.6 soil

Clay soils are prevalent in the State with a high proportion of Clay Granules ranging between 45-80%, high fertility and high water retention, studies indicate that it can increase the productivity of crops grown on these soils by increasing its content of organic materials and improving cultivation method. (www.gadarifstate.gov)

3.7 Water Resources

Pass through the territory of the state are several rivers and valleys on their way towards the Nile, they are important water resources. These rivers are Atbara River and baeslam, Setit and Rahad. The Rahad has several branches in the Faw area. Despite the abundance of seasonality rains in the state that annual average of rainfall is less than 300 mm in the far north of the State to the more than of 900 mm in the South East and the availability of rivers and valleys in the state, but large parts of the state are suffering from water shortages during the dry seasons due to the nature of the geological composition of the jurisdiction where the basal rocks (Basement complex) non-bearing groundwater. The study pointed out that the average daily per capita consumption of 9 liters water, a rate about 50% lower than the rate recommended by the World Health Organization (WHO) is 20 liters per day (www.gadarifstate.gov).

3.8 Agriculture

State characterized by vast land suitable for agriculture, and the largest projects for rainfed agriculture in Sudan, namely mechanized farming which are used in various stages of production. It is also a big market for crops, especially semsame, sorghum. Strategically important center for food security in Sudan, so agriculture is the economic activity is mostly dependent on rainfed, as well as services related to agriculture and trade, including border trade with Ethiopia and Eritrea. Agriculture expanded in 1945 with the introduction of the machine and attracted capital and investors and the total area of state (71.621.33) kilometers, of which 5,000,000 Fadden are grown sorghum, Sesame, cotton and other crops. . (www.gadarifstate.gov).

3.9 Forest

There are eleven reserved forests dominated by acacia trees (***Acacia Seyal***). Forest area is 2,376,563 feddan.), a product of lower quality gum Arabic gum of acacia trees of the product ***(Acacia Senegal***). In addition there are thirty-one of the forest are reserved, where the acacia trees which are utilized in the timber for many purposes, the areas of these forests ranging between (100-800) feddan. There is potential for expansion in forest area in the state and planting more trees. Forests are an essential resource for gum Arabic - honey - fruits - medicinal Plants in addition to forests of nomadic grazing of animals, residents, and also wildlife (www.gadarifstate.gov).

3.10 livestock

Gedaref State is characterized by the existence of considerable numbers of livestock, estimated at five 5 million heads of various factions, and this number increases to seven million head in the autumn season as a result of the movement of animals from neighboring states to Gedaref state. The sector contributes about 30% of the total domestic income (www.gadarif state).

CHAPTER FOUR

MATERIAL AND METHODS

4.1. Materials

The following materials were used:

4.1.1 MODIS images

MODIS is stand for Moderate Resolution Imaging Spectroradiometer. Images acquisition of MODIS, 8 days surface reflectance product 250 m spatial resolution ordered and free by http://reverb.echo.nasa.gov.

4.1.2 Software

4.1.2.1 ENVI

ENVI (which is an acronym for "Environment for Visualizing Images") is a software application currently marketed by ITT Visual Information Solutions used to process and analyze geospatial imagery .

4.1.2.2 Arc GIS

ArcGIS is a suite consisting of a group of geographic information system (GIS) software products produced by Esri Arc map software 9.3.

4.1.2.3 Other System

Microsoft office word 2007. Microsoft Windows xp professional Service Pack 2

4.1.3 Hardware

Computer: Pentium ® Dual-Core CPUT4200@2.00GHz 2.00 GHz, 2G MB of RAM

4.2 Methods

4.2 Methodology of the burned area mapping

The methodology adopted in burnt area mapping was combination of visual and digital interpretations to identify the burnt areas scars from MODIS image. This study was directed towards using remote sensing and geographic information Systems (GIS) through MODIS data to document the history of fire and produce maps of burned areas in western southern part of Gadaref state for season (2000-2001) to (2012-2013). Following are the steps carried out:

4.2.1 Study Area Subset

Shape file for the study area was prepared using Arc GIS 9.3 software, the same shape file is used to subset out the original images using ENVI software 4.5, and the typical subset frame of the same area been saved then used for sub setting rest of the images. to include Elrahd, West Galabat, East Galabat and Elfashqa localities.

4.2.2 Normalized Difference vegetation Index Calculation (NDVI)

With ENVI band math facilities Normalized Difference Vegetation Index (NDVI) was computed for all the images by applying the following NDVI formula:

(Float (B2) -float (B1)) / (float (B2) + float (B1))

Where: B1=Band1 (Red)   B2=Band2 (Near infrared)

4.2.3 Change detection

In order to detect the burned areas within 8 days each previous NDVI image was subtracted from earlier ones and, hence change was detected.

4. 2.4 Density slicing

Color density slide was created by selecting pixels of the lowest change detection value and the one with the highest value within the burned area

4.2.5 Region of Interest Generation and Mask Building

Region of interest covering the real burned area was used to build mask in order to eliminate noise. Regions of interest were created for each Change detection image in order to mask out noises. Then unburned areas that contain values of NDVI variation similar to that of burned areas are removed (masked out) to create a new noise free image. In order To eliminate overlap occurred during burned area mapping, each pixel having DN more than one in the final image is rendered to one.

4.2.6 Monthly Burned Area Image Generation

The monthly burned area for each season was created by collecting all the burned areas detected between all successive images in the same month.

4.2.7 Total Burned Area Image Generation

The total burned area image was generated by using ENVI to add all burned areas detected among all successive images in the same season.

4.2.8 Raster to Vector

Resulting seasonal total burned area images were transferred from raster to vector (shape file) for use in ARC Map software 9.3 to calculate all the burned area polygons and facilitate the preparation of the final burned area maps after that calculating burned area and then generating burned area frequency map.

4.2.9 Fire Frequency Map

To perform this task all burned area maps of each season is summed by giving burned area a value from 1-13 and unburned area take zero value to obtain the fire frequency or number of times that each part of the study area were burned during the study period.

CHAPTER FIVE

RESULT AND DISCUSSION

5-1 Results and discussion

5-1-1 quantification of Burned Areas

The total burnt areas maps were produced as shown in figures (5-3) (5-4)(5-5) (5-6). The monthly burnt areas in km^2 is shown in figures (5-7)(5-8)(5-9)(5-10). The study revealed that the fire season started with beginning of the dry season in the mid of September and continue until the ends of the April with the peak of burned areas in November and February, this coincide with the fact that the grasses in the area are dry during this time of the year. As showed in figure (5-1). The study also shows that there is two peaks of burnt area within the fire seasons this was appear in the season of 2000-20001 and the season of 2008-2009 may be attributed to high rainfall in these years, which increased the fuel loads. As showed in figure (5-2)

5-1-2 Fire extent

Using detailed information from satellite images can help to quantify the extent of wildland fires in Southeastern part of Gedaref state and elsewhere in Sudan. This study generates historical background for the Southeastern part of Gedaref state using MODIS imagery. The study indicated that wildland fires occur annually over large areas. Two factors that influence the extent of burned area every year; these are the total amount of rainfall and the extent of burned area in the previous year. High rainfall increases the development of grasses, which considered as the main fuel available for fire. Fire reduces seed bank inside the burned area so the amount of grasses are expected to be lesser in the years where burned area was at large extend in the previous year.

5-1-3 Fire Season

The analysis of the fire information over the period 2000 to 2013 resulted in an investigation of the fire regime in the study area. The fire season started few weeks after rainy season and usually extend from September to April, because the remaining high biomass of vegetation is senescent and the weather extremely dry. During that period large uncontrolled wild fires can be very devastating. The spatial and temporal distribution is generally variable. The study indicated this variability and clearly indicated peak fire activity in November and February during the year 2000-2013 showed figure (5-1). Could be the Slash and burn agriculture that practiced in the South-East of the study area causes an increase in

fire activity at the end of the dry season in February, which is corresponding to the preparation of the field for the next crop season. Also the peak fire activity in November is due to existence of high biomass and vegetation is senescent and weather very dry. Fire activity occurred in the centre, south, south-East and middle of study area but very few in north of study area see (figure (5-13) Most of the fire activity took place in study area because the possibility, of their continuous herbaceous cover combined with human activities such as honey and gum collection, hunting and charcoal production. In the north and north- west of the study area the lower biomass maybe is usually used by the cattle and fire activity is consequently very low, also this area is mechanized farms. The fire season start in about month later just after the ends of the rainy season. In the mid of September where the grass start to go drier and continue up to the ends of April.

Table (5-1) showed the starting and ends date with the total burnt area for each season and the percentage of total burnt area

Season	Start Date	End Date	Burnt Area km^2	the percentage of total burnt area
2000-2001	21.Sep.2000	23.Apr.2001	2383.27	13.45
2001-2002	6.Sep.2001	30.Mar.2002	1751.26	9.89
2002-2003	14.Sep.2002	23.Apr.2003	1781.97	10.06
2003-2004	14.Sep.3003	22.Apr.2004	1601.57	9.04
2004-2005	13.Sep.2004	23.Apr.2005	1533.40	8.66
2005-2006	14.Sep.2005	23.Apr.2006	2012.81	11.36
2006-2007	14.Sep.2006	23.Apr.2007	1865.44	10.53
2007-2008	14.Sep.2007	6.Apr.2008	1874.41	10.58
2008-2009	21.sep.2008	23.Apr.2009	2910.27	16.43
2009-2010	14.Sep.2009	23.Apr.2010	1904.67	10.75
2010-2011	14.Sep.2010	30.Apr.2011	1342.68	7.58
2011-2012	13.Sep.2011	30.Apr.2012	820.18	4.63
2012-2013	21.Sep.2012	30.Apr.2013	1478.99	8.35

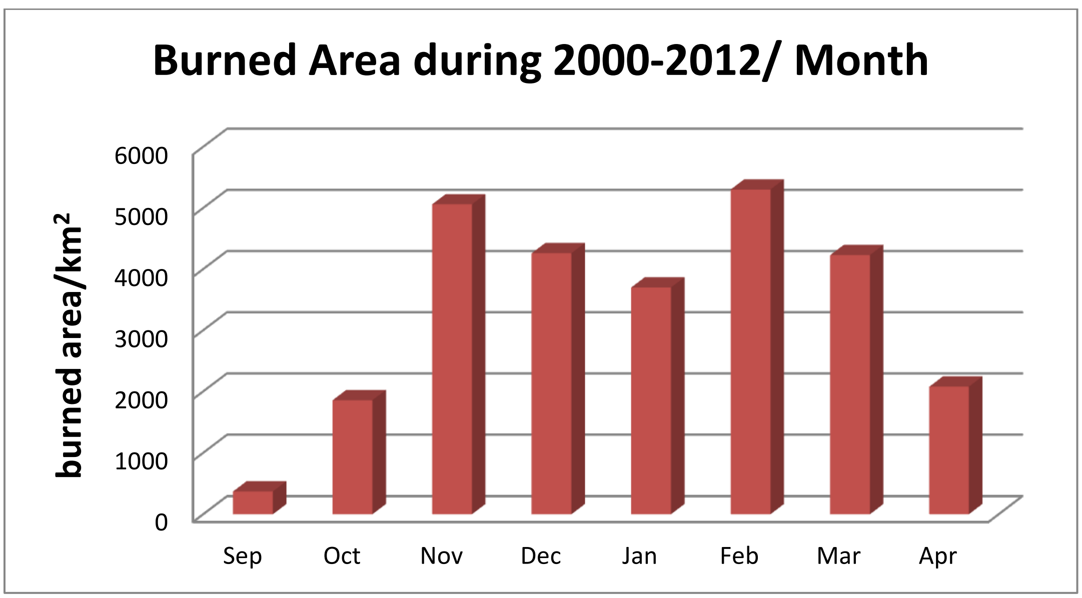


Figure (5.1): Burned area during 2000-2013/Month

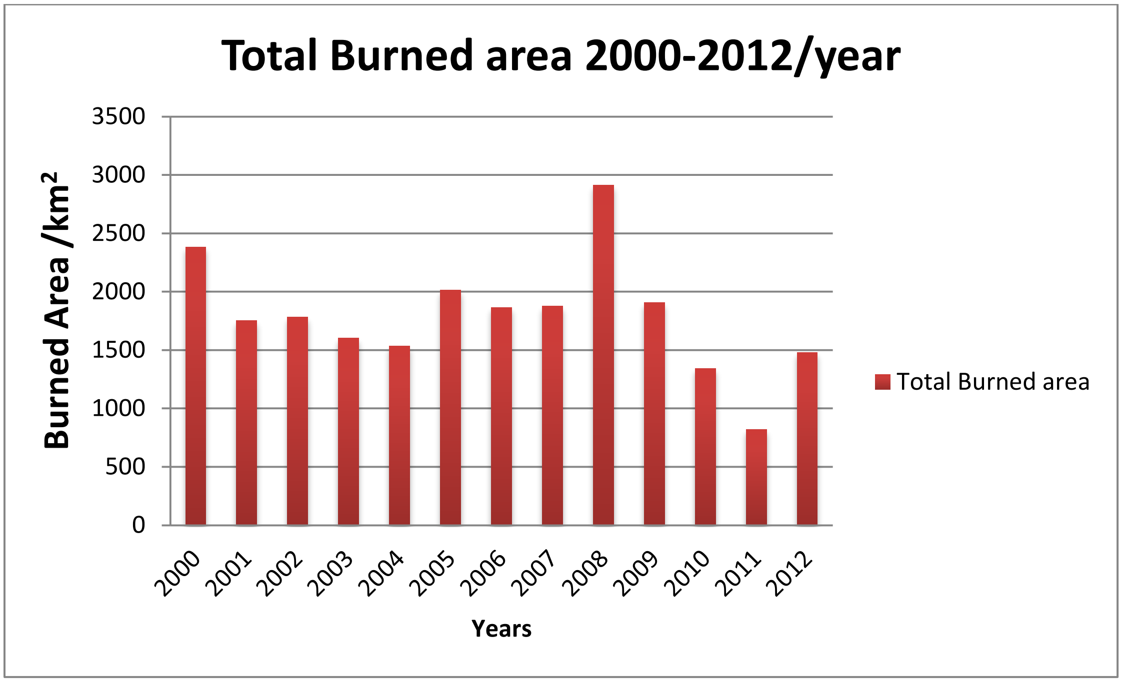


Figure (5-2) all seasons burned area in km^2

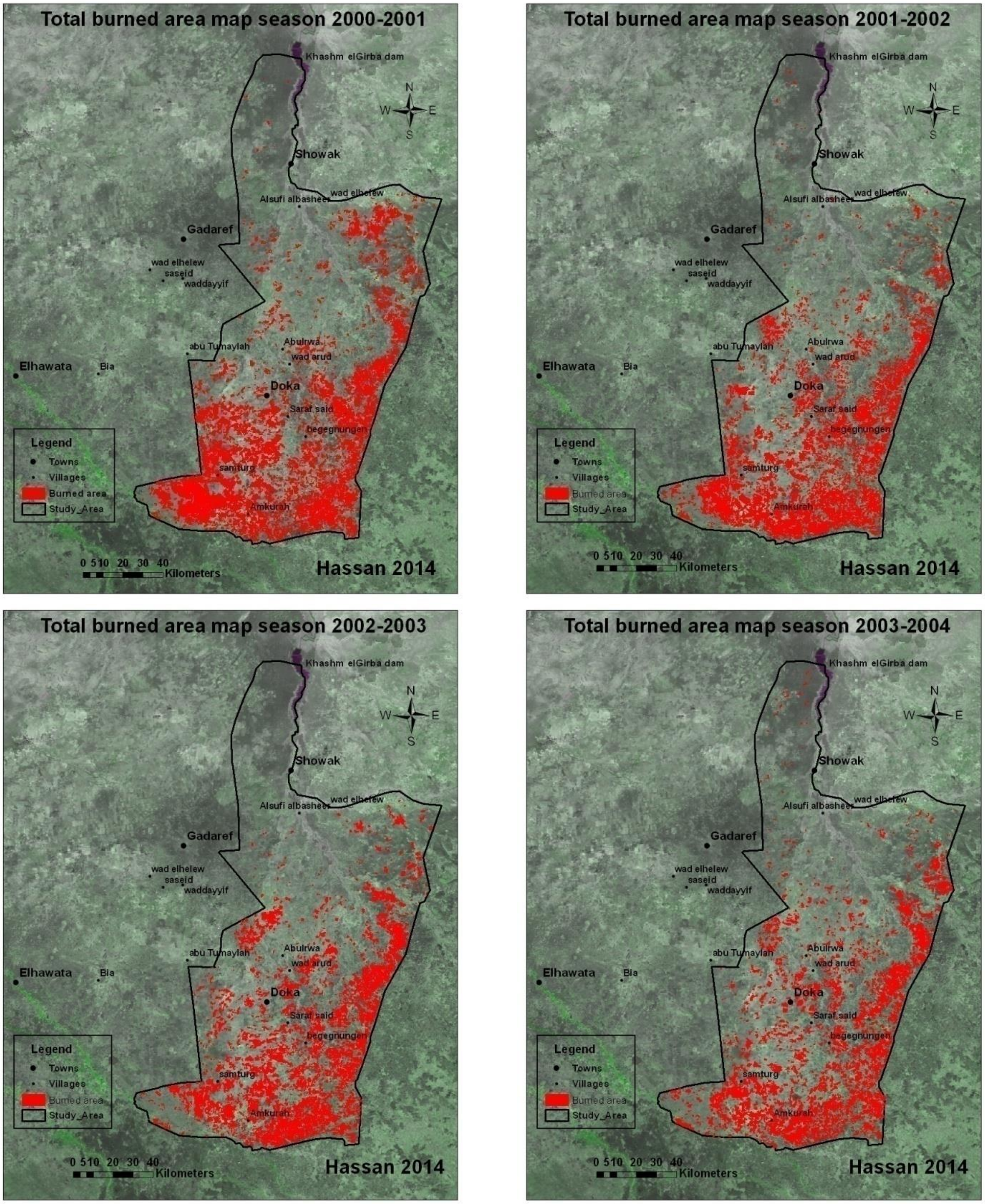


Figure (5-3) Maps of total burned area seasons 2000-2001, 2001-2002, 2002-2003 and 2003-2004

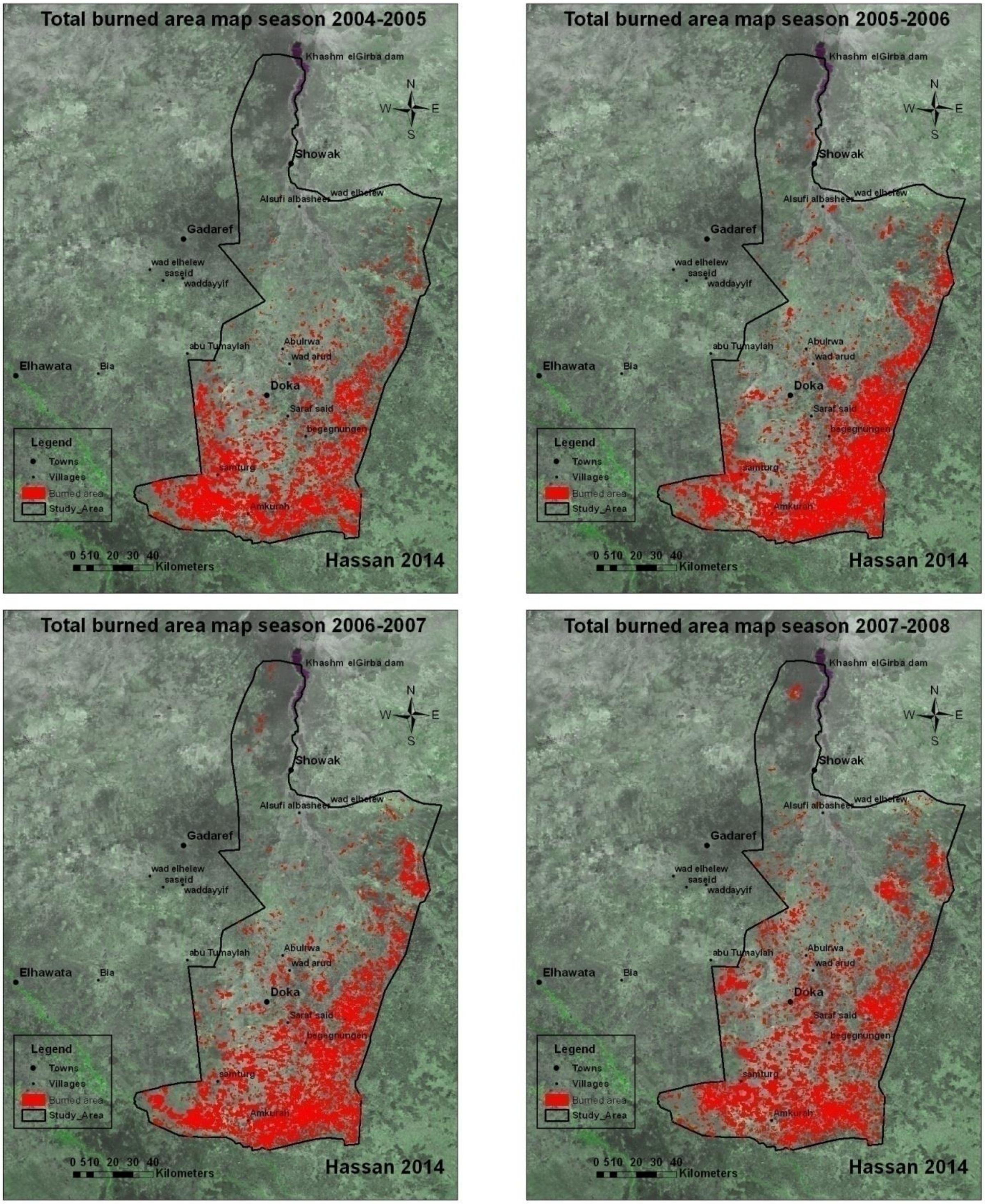


Figure (5-4) Maps of total burned area seasons 2004-2005, 2005-2006, 2006-2007 and 2007-2008

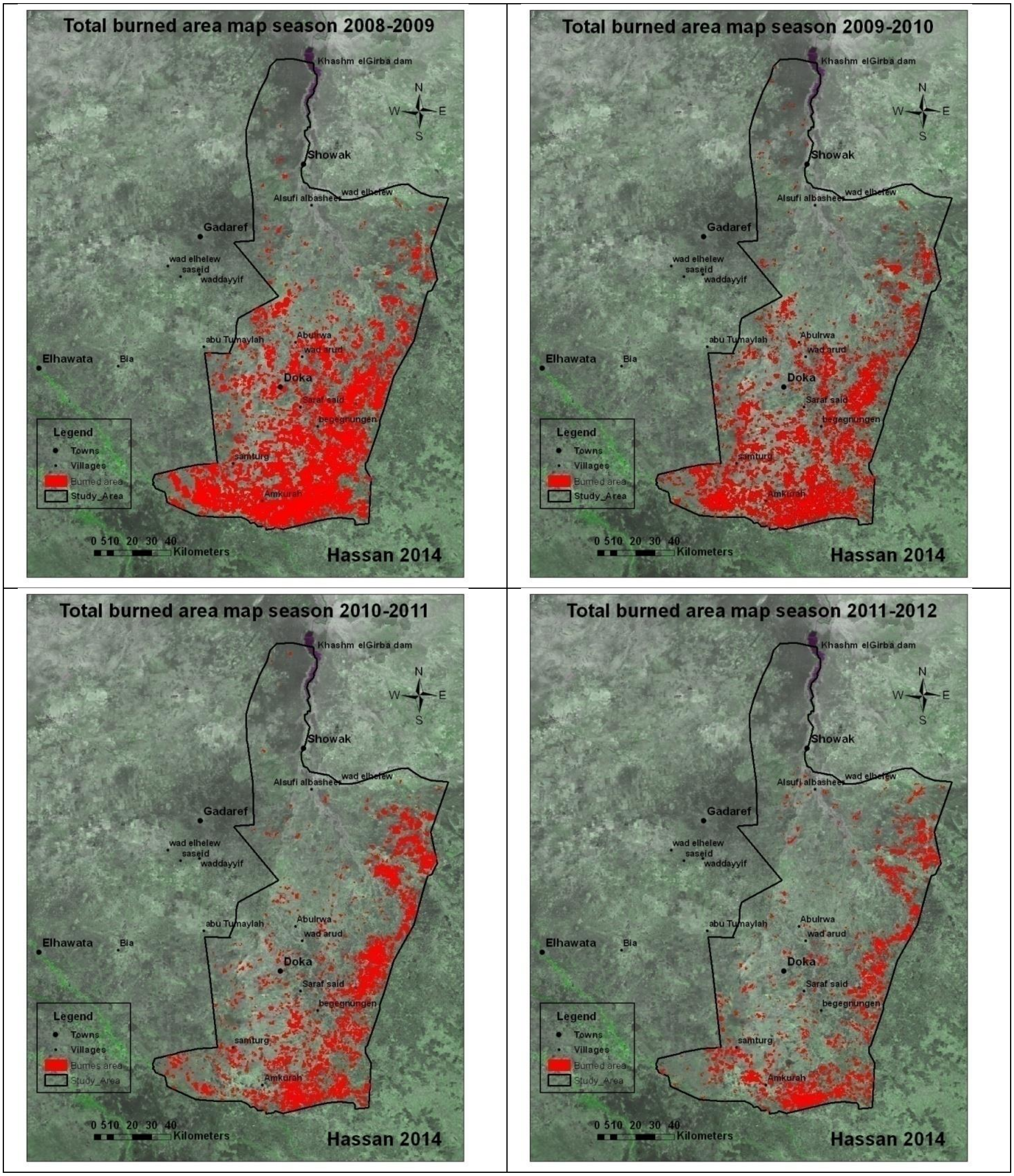


Figure (5-5) Maps of total burned area seasons 2008-2009, 2009-2010, 2010-2011 and 2011-2012

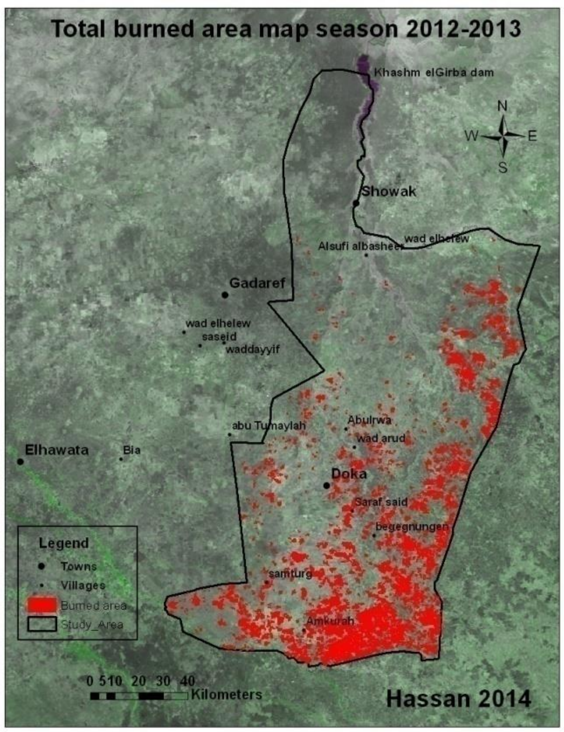


Figure (5-6) Map of total burned area season 2012-2013

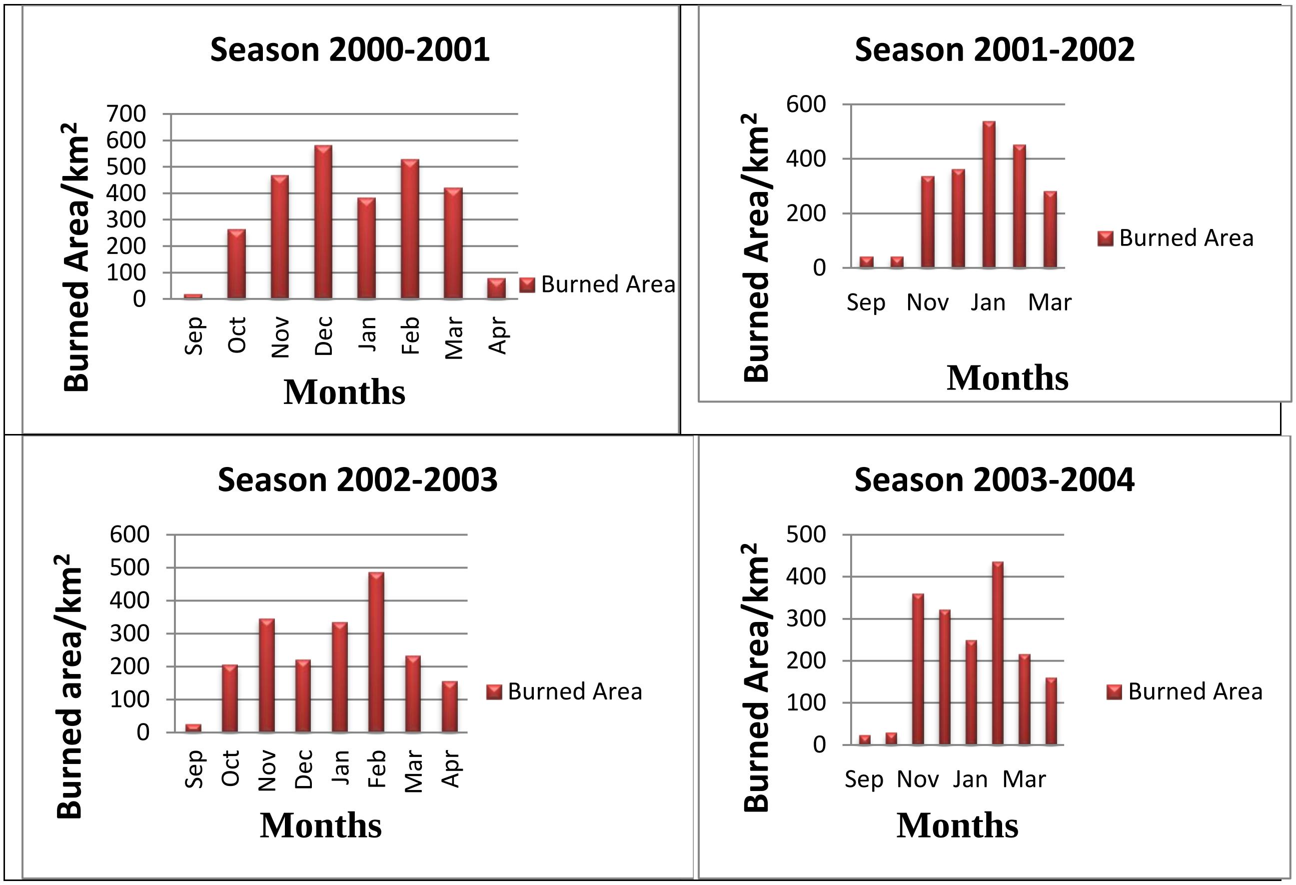
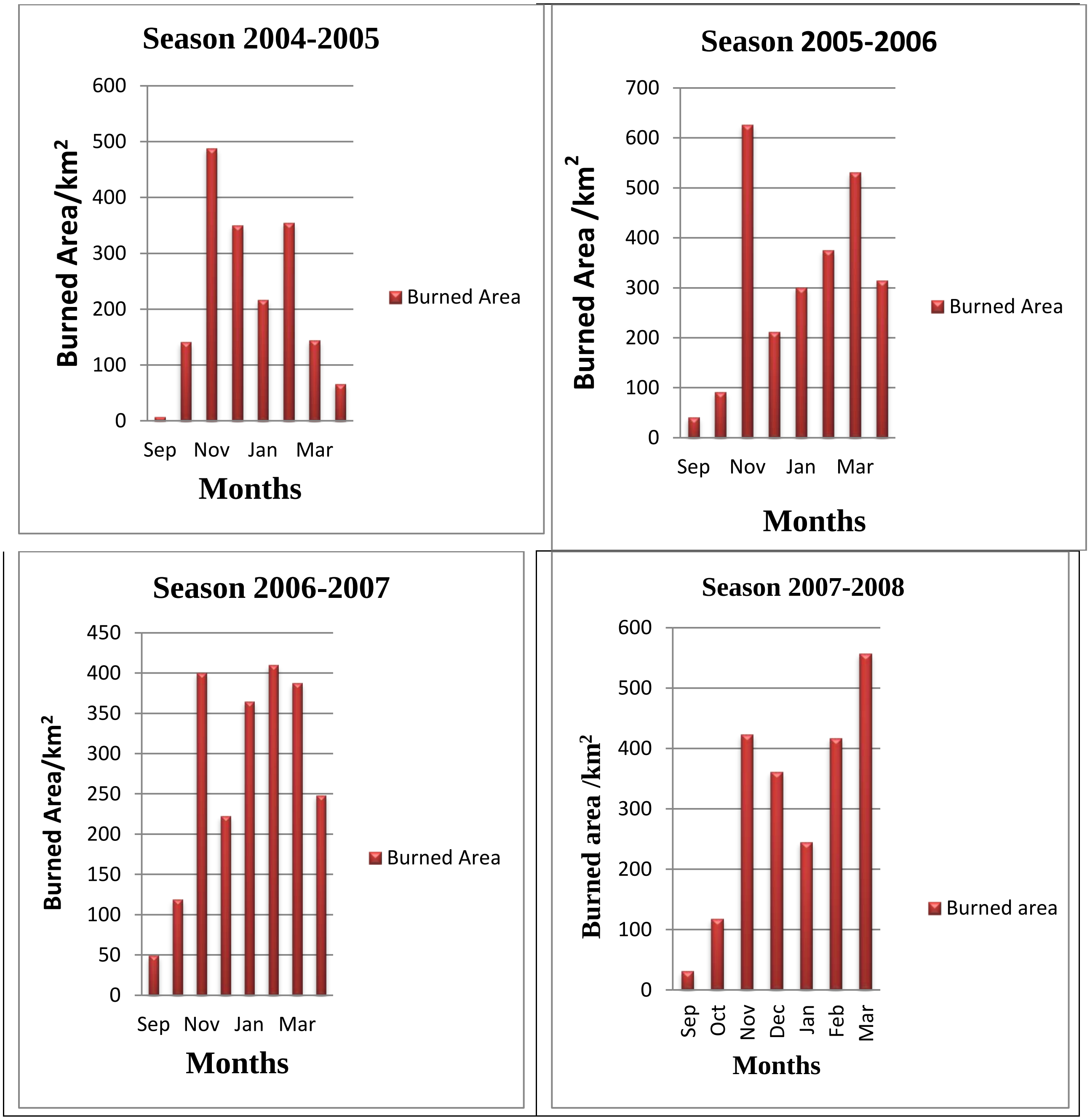
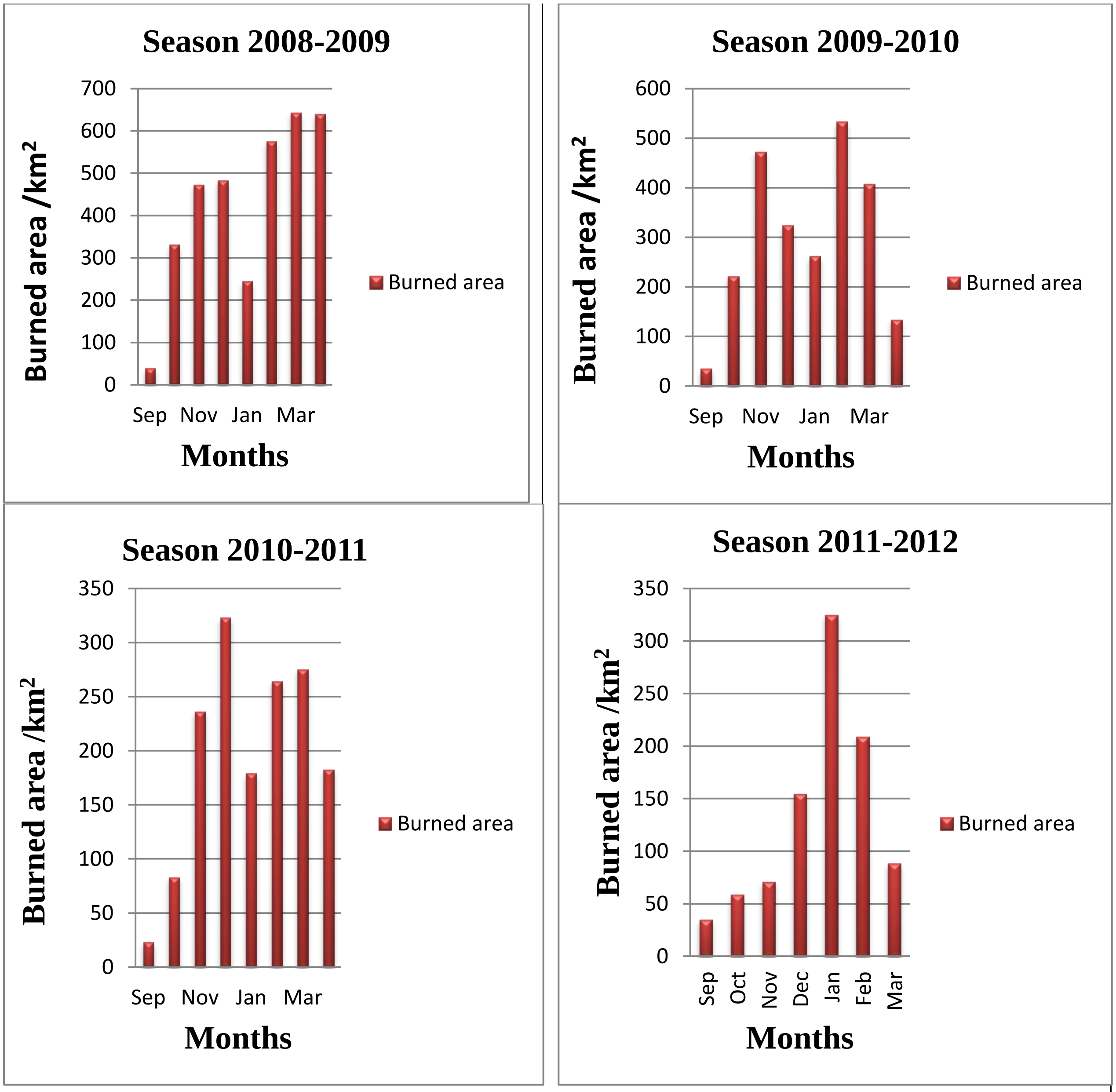


Figure (5-7) Monthly burned areas in km^2 seasons 2000-2001, 2001-2002-2002-2003 and 2003-3004



Figure(5-8)Monthly burned areas in km^2 seasons 2004-2005, 2005-2006. 2006-2007 and 2007-2008



Figure(5-9) Monthly burned areas in km^2 seasons 2008-20009,2009-2010,2010-2011 and 2011-2012

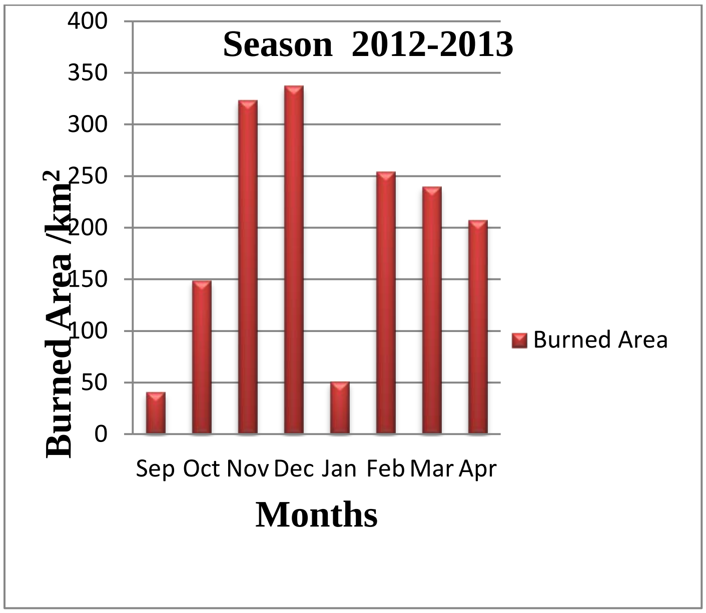


Figure (5-10) Monthly burned area season (2012-2013)

5-1-4 Fire Frequency

In order to come out with fire frequency map all maps of the burnt area from season 2000-2001 to 2012-20103 were summed to produce new map in which the burnt area takes value from 1-13 and unburned area take zero value to obtain the fire frequency or number of times that each part of the study area were burnt. Table (5-2) shows the total burnt area and percentage per fire frequency or number of times burnt. Figures (5-30) and (5-31) are map and diagram show the fire frequency. It is clear from the frequency map that the higher frequency burnt area was located in the southern , southern east and southern west part of the study area and the least frequency burnt area was located in the north part of the study whereas the medium frequency burnt area located in the middle part of the study area.

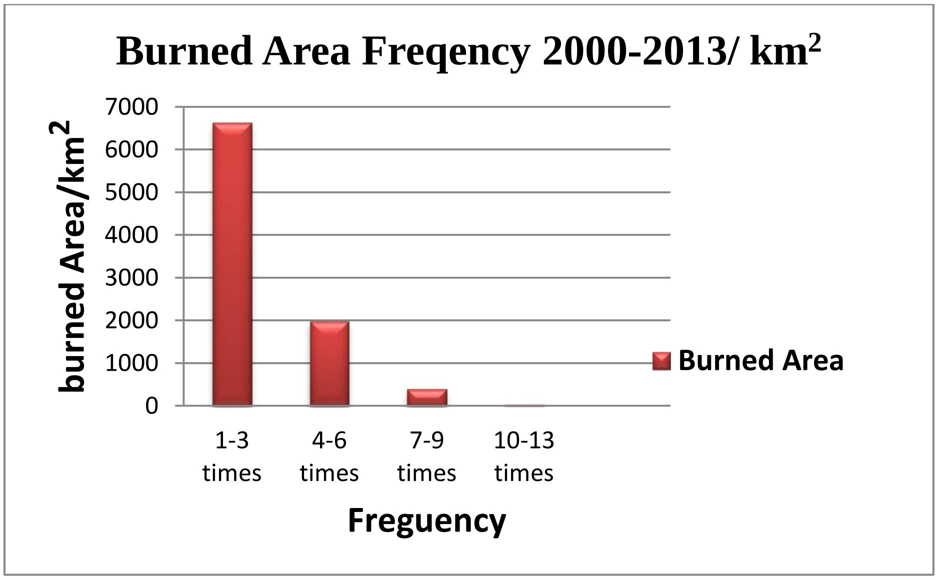


Figure (5-11) Diagram of burned area per fire frequency

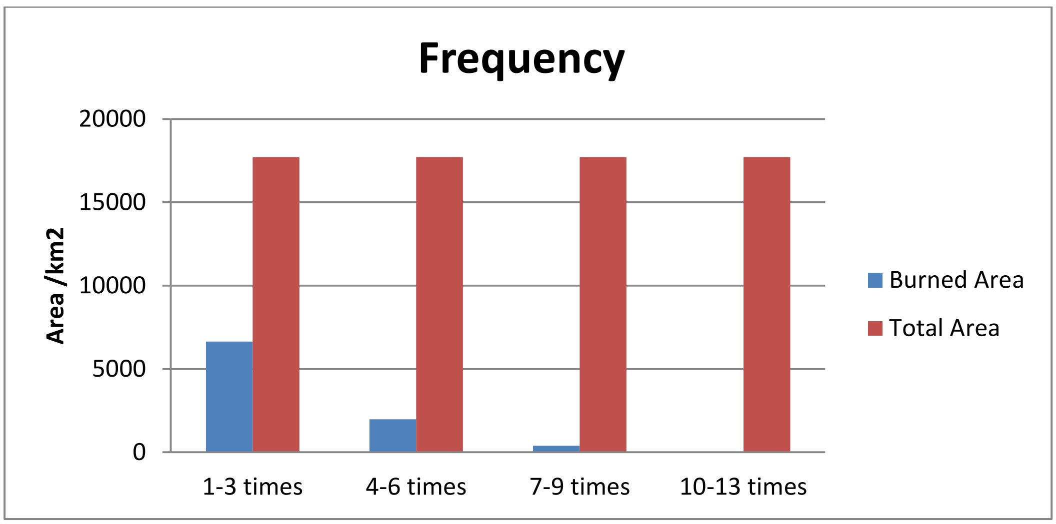


Figure (5-12) Diagram shows the fire frequency compare to the total area

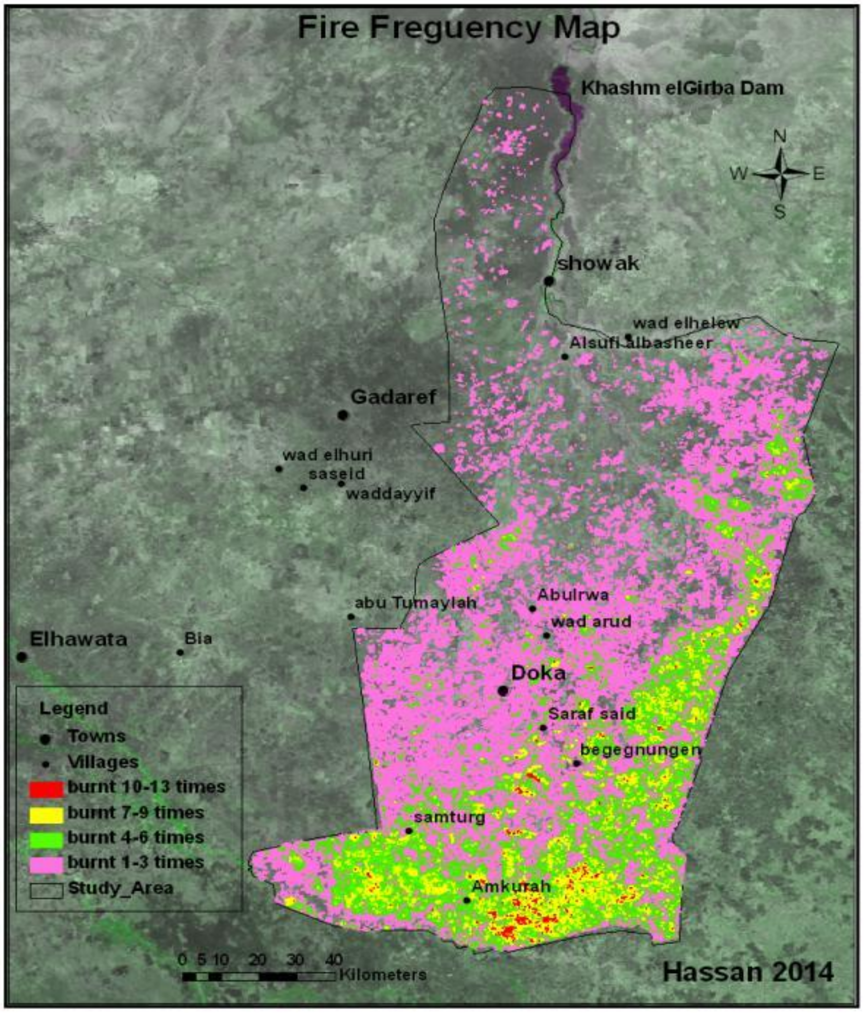


Figure (5-13) Map of fire frequency

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

Conclusion

1. 1-Wildfire is largely extend in some parts of the study area during the period of the study 2000-2013
2. The fire season started usually in middle of September and lasted towards the ends of April.
3. Burned area was occurred in the southern and middle parts of the study area, while rarely were burned in the northern part.
4. MODIS images used for burned area mapping proved to be efficient.
5. It is clear from the frequency map that the higher frequency burned area is located in the southern and east part of the study area and the least frequency burned area is located in the north part of the study whereas the medium frequency burned area located in the middle part of the study area.

Recommendations

The following issues should be considered for more investigation in the future:

- In addition to the adopted technique of visual and digital interpretation other technique like pixel analysis can be adopted
- Field validation studies are essential
- The various causes of wildfire.
- The social impacts of wildfire.
- The positive and negative impacts of wildfire on flora and fauna.
- The relation between dispute and outbreak of fire in the study area.
- The noise caused by non burned areas that have the same change detection value as in the burned areas.
- Development of integrated fire management plan.

7 Reference

- **Agee, James K**. 1993. Fire Ecology of Pacific Northwest Forests. Washington, D.C.: Island Press. 490 p
- **Aronoft S.(**1991) Geographic Information SystemManagement perspective. WDL Publication Canada
- **Averill**, R.D., L. Larson, J. Save land, P. Wargo, J. Williams, M. Bellinger. 1995. Disturbance processes and ecosystem management A paper chartered by the Directors of Forest Fire and Atmospheric Sciences
- Research, Fire and Aviation Management, Forest Pest Management, and Forest Insect and Disease Research
- **Bachmann,A.,$ Allgower**. B. 2000. The need for aconsistent wildfire risk terminology . Paper presented at the proceeding from the joint fire science conference and workshop : Crossing the millennium : integrating spatial technologies and principles for anew age in fire management . Boise.ID.
- Bayoumi, A., 2001. Fire Situation in Sudan. International Forest Fire News No. 25, 115-117
- **Bond ,W.,J., $ Wilgen** , B.W.V. 1996. Fire and plants (population and community biology series 14)london: Chapman $Hall
- **Campbell,** J.B. (1987) Introduction to Remote Sensing. The Guilford Press, New York
- **Eva, H. and E.F. Lambin**. 1998. Burnt area mapping in Central Africa using ATSR data. Int. 1. Remote Sensing 19, 3473-3497.
- **Chelan Ranger** District, US Forest Service. 2003. Environmental Assessment,Antilon to Alta Ecosystem Restoration. Chelan Ranger District, Okanogan-

  Crippen, R.E. (1990) 'Calculating the vegetation index faster,' Remote Sensing of Environment, 34, 71-73 Wenatchee National Forests, USDA-FS.

- **Collins, S,** I, 1992.Fire frequency and community heterogeneity in tall grass prairie vegetation.Ecology73:2001-2006.
- **Encyclopedia state** economic planning , Gedaref State - Ministry of Finance and Economy - Gedaref 2007
- **Ellingoson ,L,J .,** Kauffman ,J,B,Cummings, D.L., Sanford ,R .L .,$ Jaramillo. V.J. (2000).soil N dynamics associated with deforestation ,biomass burning and pasture conversion in amexican tropical dry forest . Forest Ecology and management .
- **FAO,2007**. Fire management- Global assessment 2006. FAO forestry paper no. 151. Ro
- **Fire wise**. 1998. Wildfire News and Notes. Wildland Fire Management Terminology. Vol. 12, No. 1, pp. 10. March, 1998.
- Noam Levin 2003,Fundamentals of Remote Sensing book.
- **Goldammer,** J. G. 1991 Integrated fire management, Jebel Marra Forest Circle (Sudan). Report for GTZ P. N. 86. 2595.6-01.100
- **Grimm, E.C**. 1984 . Fire and other factors controlling the big woods vegetation of Minnesota in mid-nineteen century. Ecological Monographs, 54:291-311/.
- **Hann, W.J**., and D.L. Bunnell. 2001. “Fire and Land Management Planning and Implementation Across Multiple Scales.”Int. J. Wildland Fire 10: Pp. 389–403.
- **Hardy, K.M.,** C.C. Schmidt, J.M. Menakis, and N.R. Samson. 2001. “Spatial Data for National Fire Planning and FuelManagement.” International Journal of Wildland Fire 10: Pp. 353
- **Jhonson , E** .1992 .Fire and vegetation Dynamics : Studies from the North American Borel Forest : Cambridge university press .

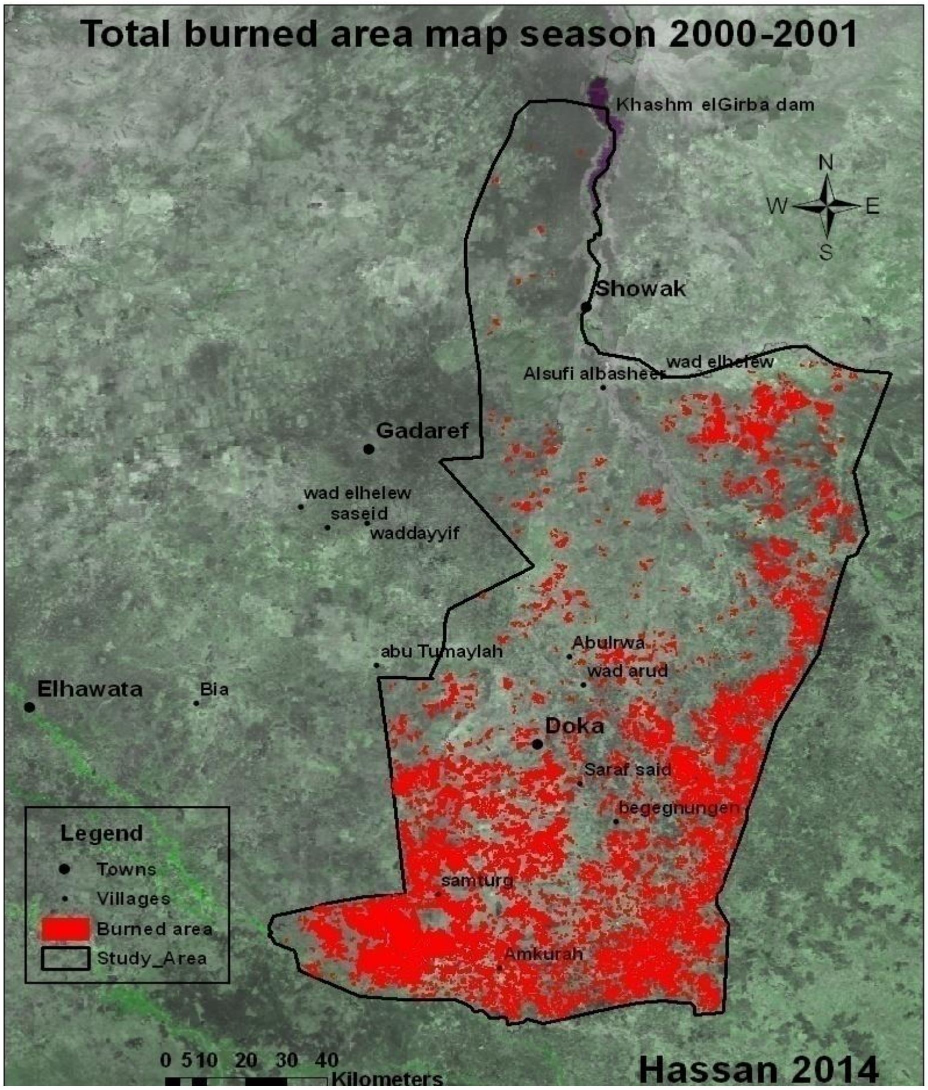
- **Shy ,J., Kunce** , D., $ D., B., 2001. Short term effects of fire frequency on vegetation composition and biomass in mixed prarie in south western Manitoba .plant Ecology, 155:157-167
- **Kaurivi, Jorry** Z. U., Alfredo R. Huete, Kamel Didan (2003) Multitemporal MODIS-EVI relationships with precipitation and temperature at the Santa Rita Experimental Range,
- **Lillesand**, Thomas M. and Ralph W. Kiefer. 1994. Remote Sensing and Image Interpretation. John Wiley and Sons, Inc.
- **Mallick** ,A, U.1986.Near –ground micro- climate of burned and un burned calluna heath land . Journal of Environment al Management,
- **Pyne, s,Andrews ,**p,L,$ laven ,R.D. (1996), Introduction to wildland fire .NewYork:John wiley $Sons.
- **Roy, D.P.,** Lewis, P.E., Justice, C.O., 2002, Burned area mapping using multi Temporal moderate spatial resolution data a bi-directional- reflectance model based Expectation approach. Remote sensing of the environment 83: 263-286.
- **Roy,** P. S. 2004, Forest fire and degradation assessment using satellite remote sensing and geographic information system. In M. S. Roy, K. harmesen & S. K. Saha (Eds),Satellite Remote Sensing and GIS applications in Agricultural Meteorology
- **Schwilk,**D,W,K.,KeelymJ,F.,&Bond,W,J.1997,The intermediate disturbance hypothesis does not explain fire and diversity pattern in fynbon. Plant Ecology,132:77-48.
- **S. W. Running,** C. O. Justice, V. V. Salomonson, D. Hall, J. Barker, Y. J. Kaufmann, A. H. Strahler, A. R. Huete, J.-P. Muller, V. Vanderbilt, Z. M. Wan, P. Teillet, and D. Carneggie, “Terrestrial remote sensing science

and algorithms planned for EOS/MODIS," Int. J. Remote Sensing15, pp. 3587–3620, 1994.

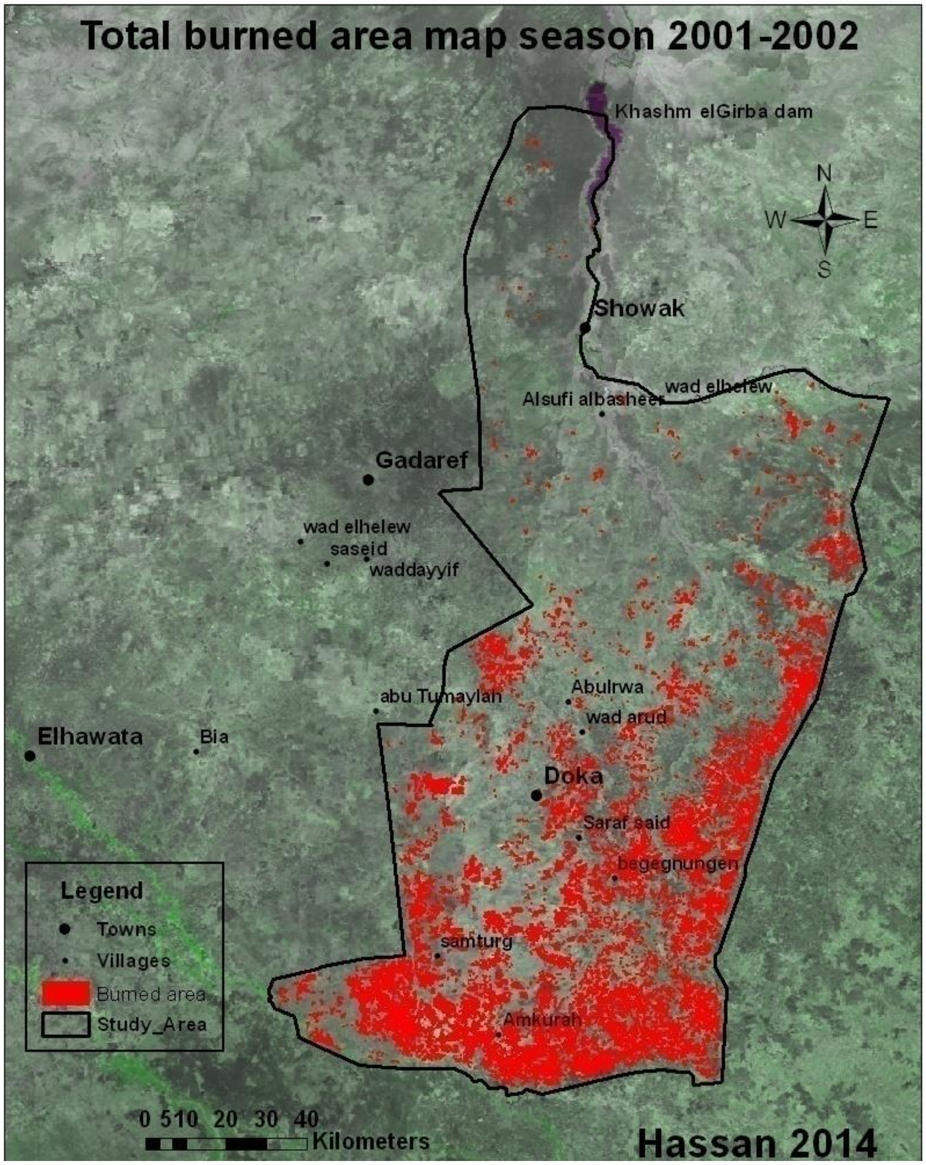
- , **The Nature Conservancy** wildfires/fire_ecosystems_and_people.Threat and Strategiesfor Global Biodiversity Conservation2004.
- **Tucker** , C. J. (1979): Red and Photogra phic Infrared Linear Combinations for Monitoring Vegetation Remote Sensing of the Environment. 8:127-150.
- **Whelan** , R.J.(2005) .The ecology of fire , Cambridge : cambirdge university press.
- **Wright ,** H., A., $ Bailey , A.W. 1982. Fire ecology unitsd states and southern Canada.New York Wley –Interscience.
- **World Health** Organization1992 studies in sudan
- **Swanson**,**E**(2008).Geographic Information System(GIS) Information Enhanced Land Use Planning,Michigan Center for Geographic Information Department of Information Technology, April 2008.
- (**Johann G Goldammer** & Cornelis de Ronde ,Wildland Fire Management Handbook for Sub-Sahara Africa_2004)
- **Xiang Gao**, Alfredo R. Huete, and Kamel DidanTitle: Multisensor comparisons and validation of MODIS vegetation indices at the semiarid Jornada Experimental Range.Source: IEEE Transactions on Geoscience & Remote Sensing, 41(2011):2368-2381
- **http://www.gadarifstat**e.gov.sd/2010
- **www.modis-land**.gsfc.nasa.gov 2015
- **Threat and Strategies for Global** Biodiversity Conservation, the Nature Conservancy wildfires/fire_ecosystems_and_people2004

8. APPENDICES

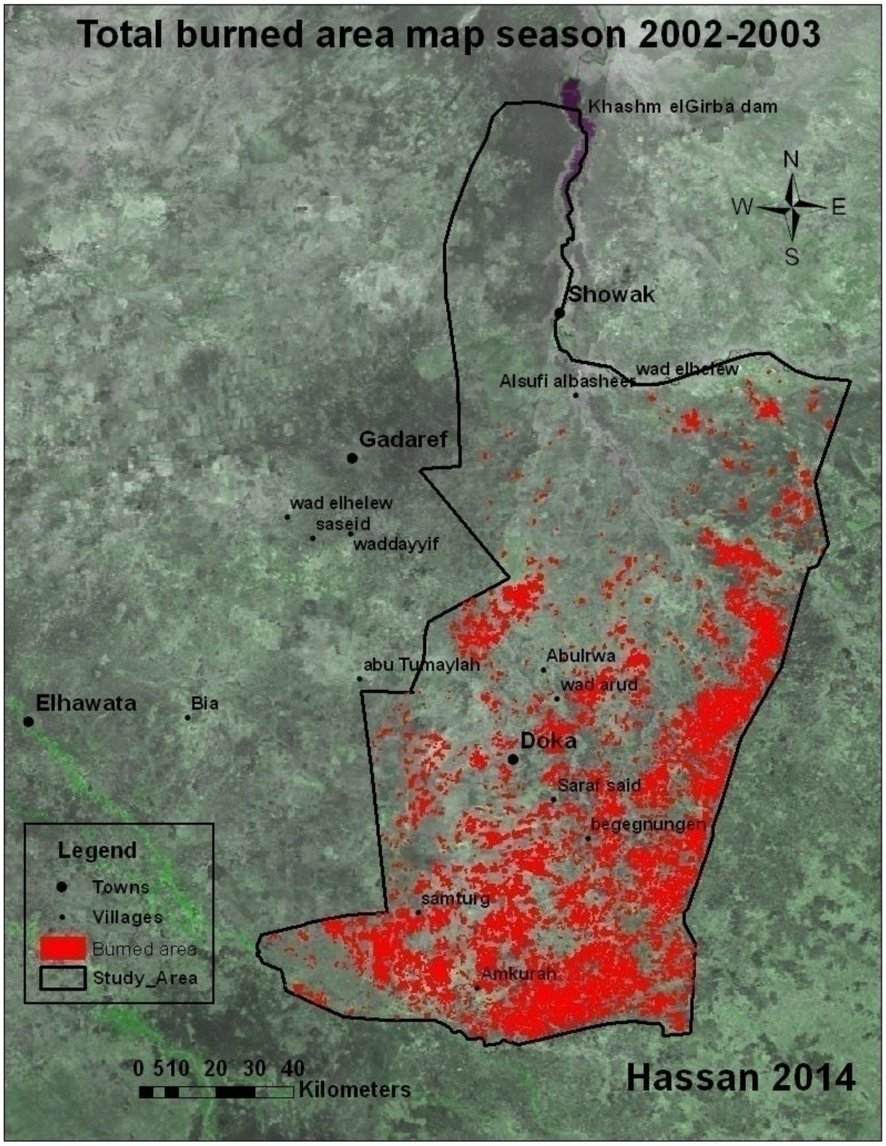
Appendices-1 Map of total burned area season 2000-2001



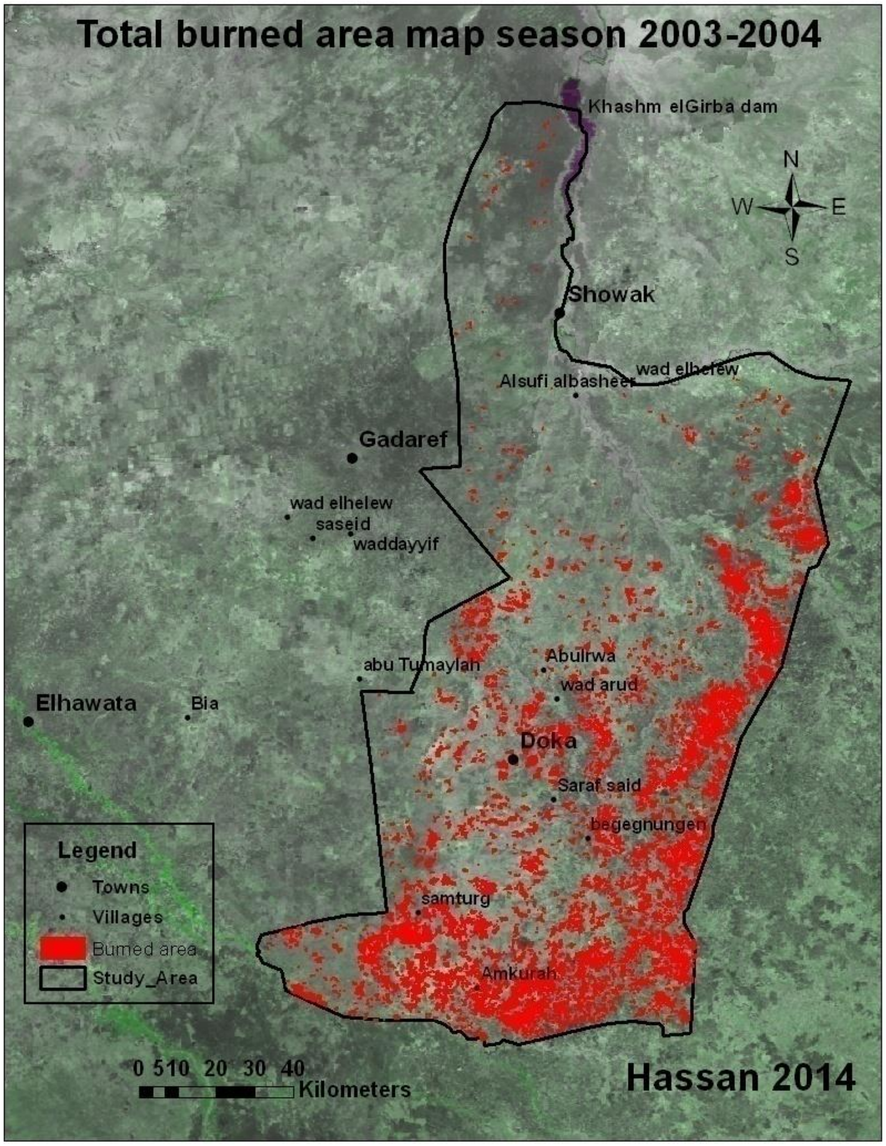
Appendices-2 Map of total burned area season 2001-2002



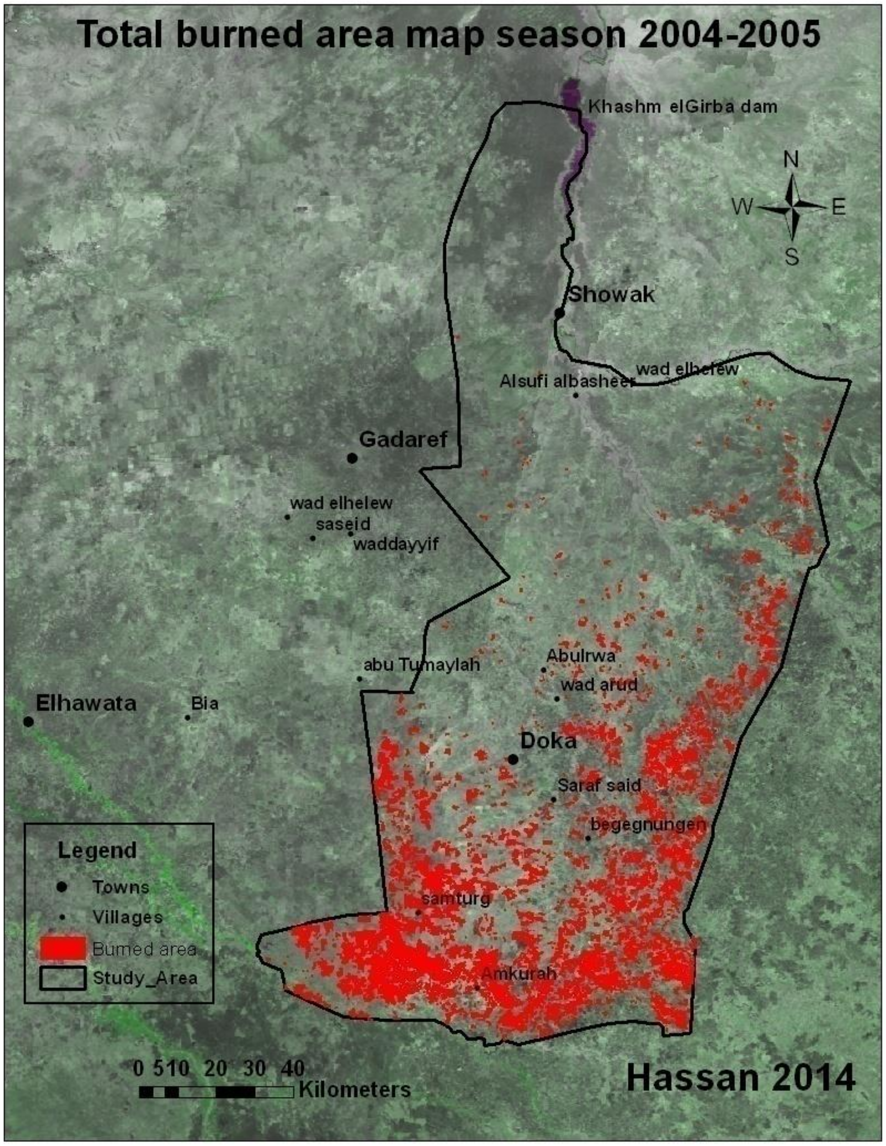
Appendices-3 Map of total burned area season 2002-2003



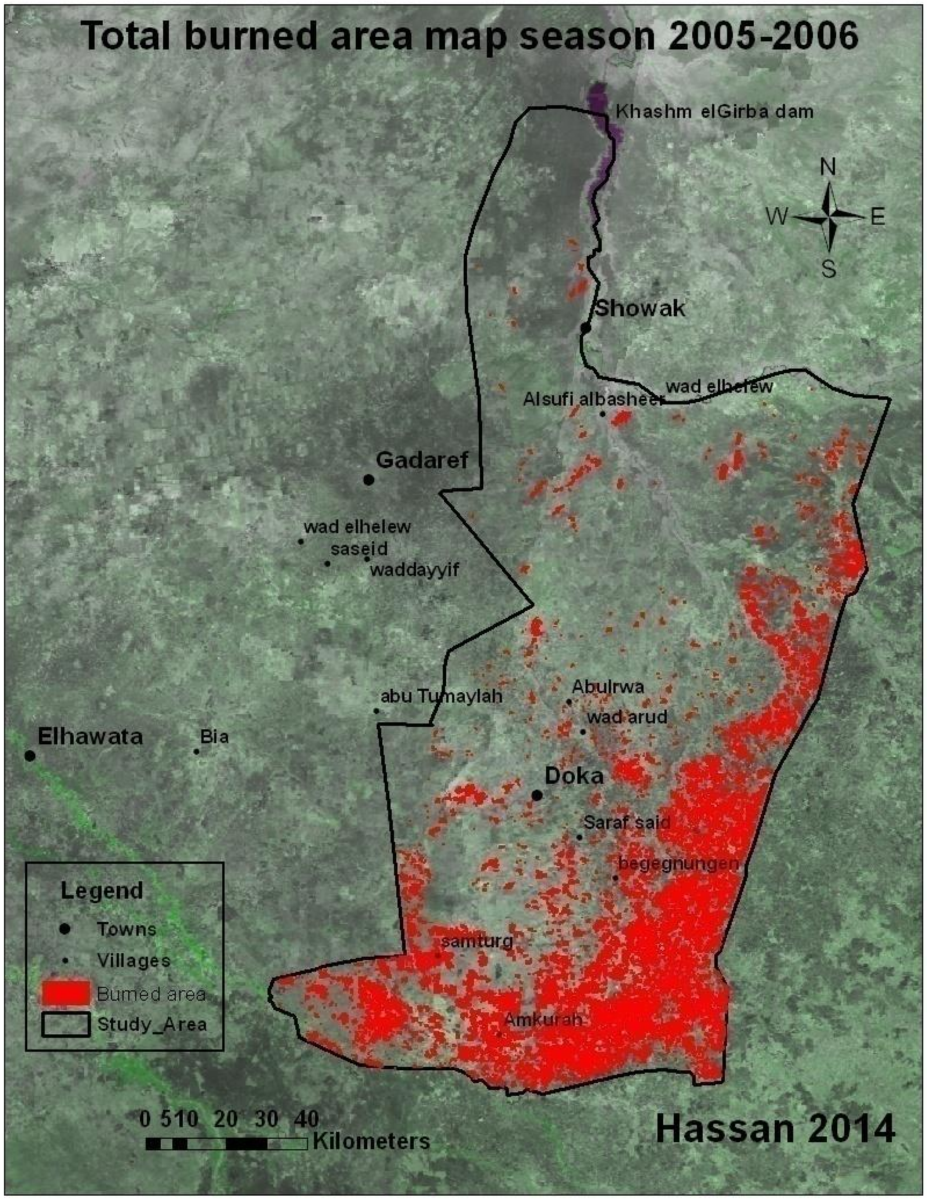
Appendices-4 Map of total burned area season 2003-2004



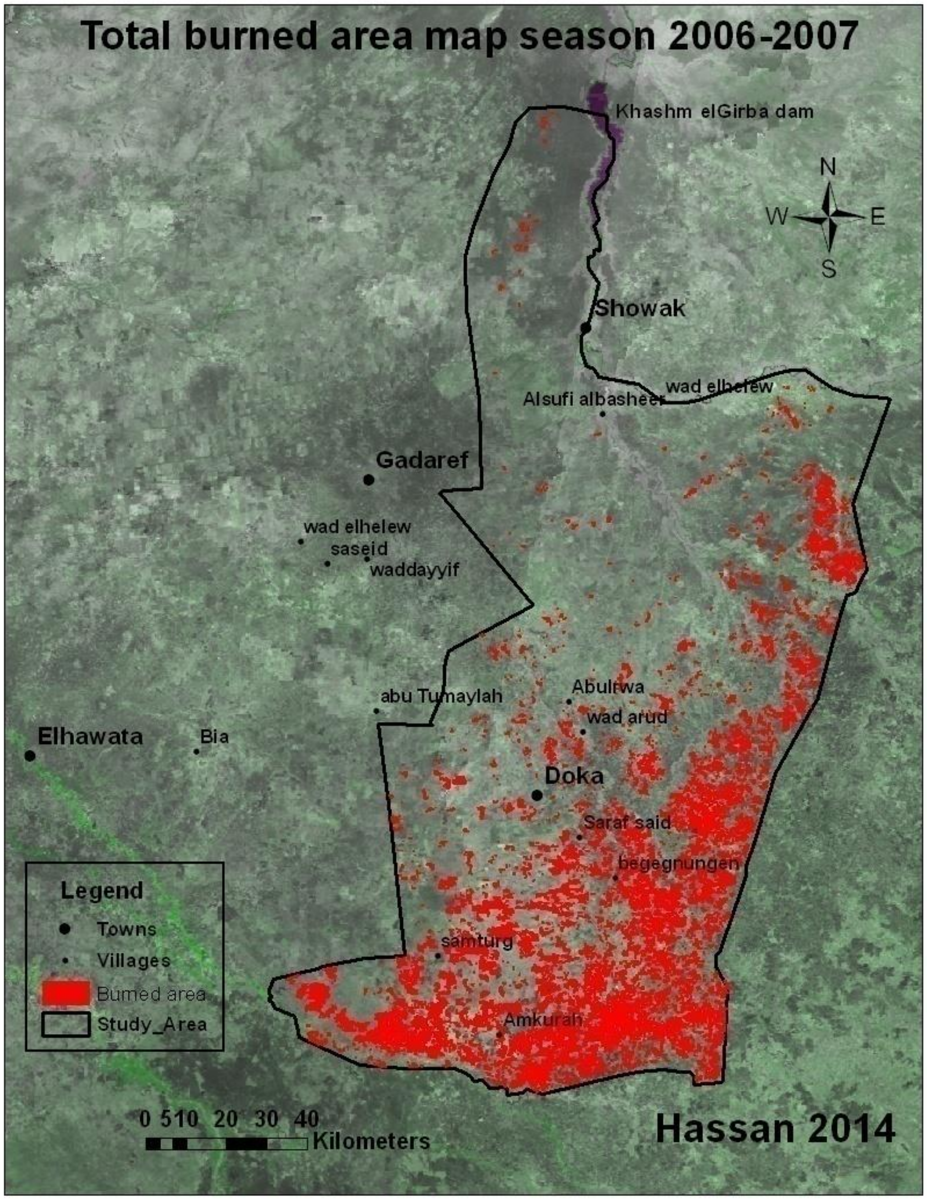
Appendices-5 Map of total burned area season 2004-2005



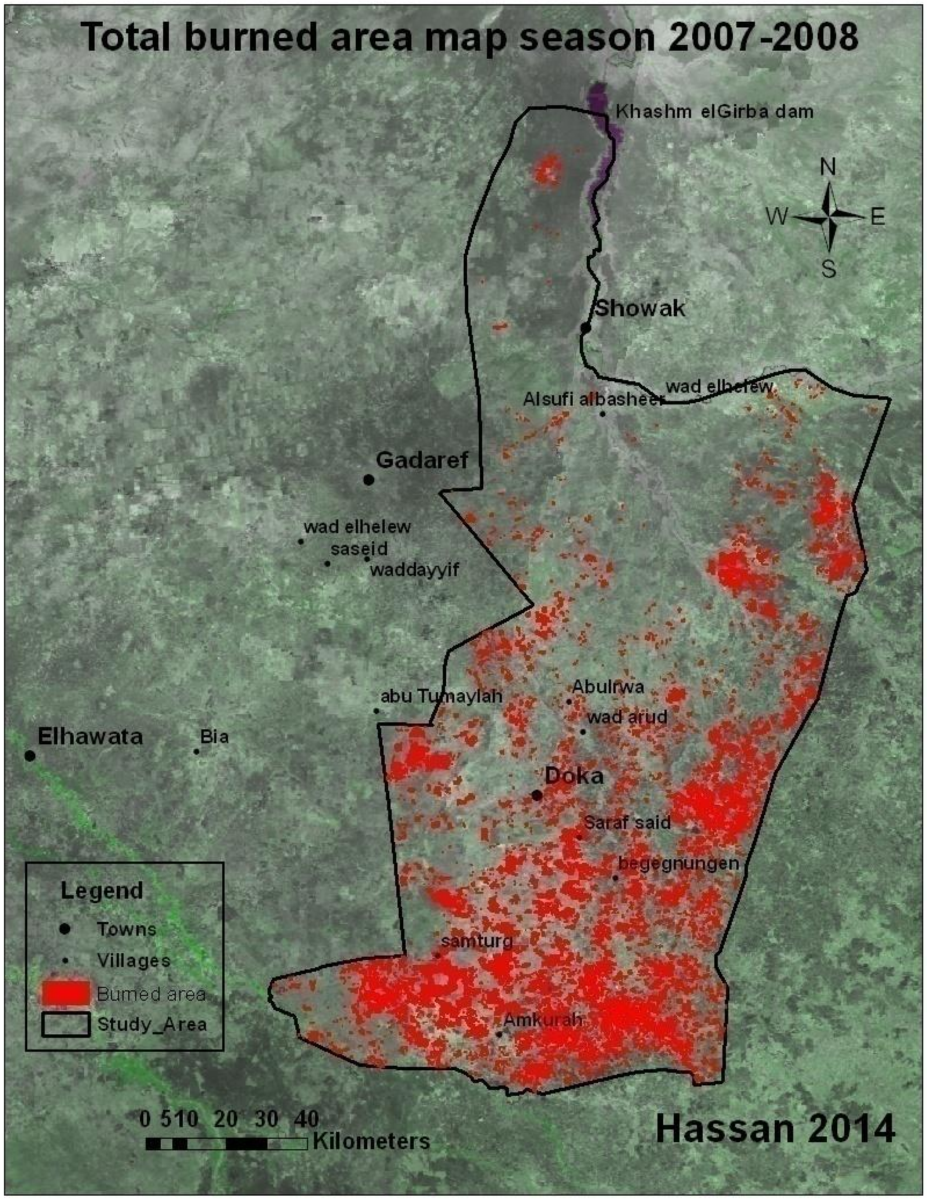
Appendices-6 Map of total burned area season 2005-2006



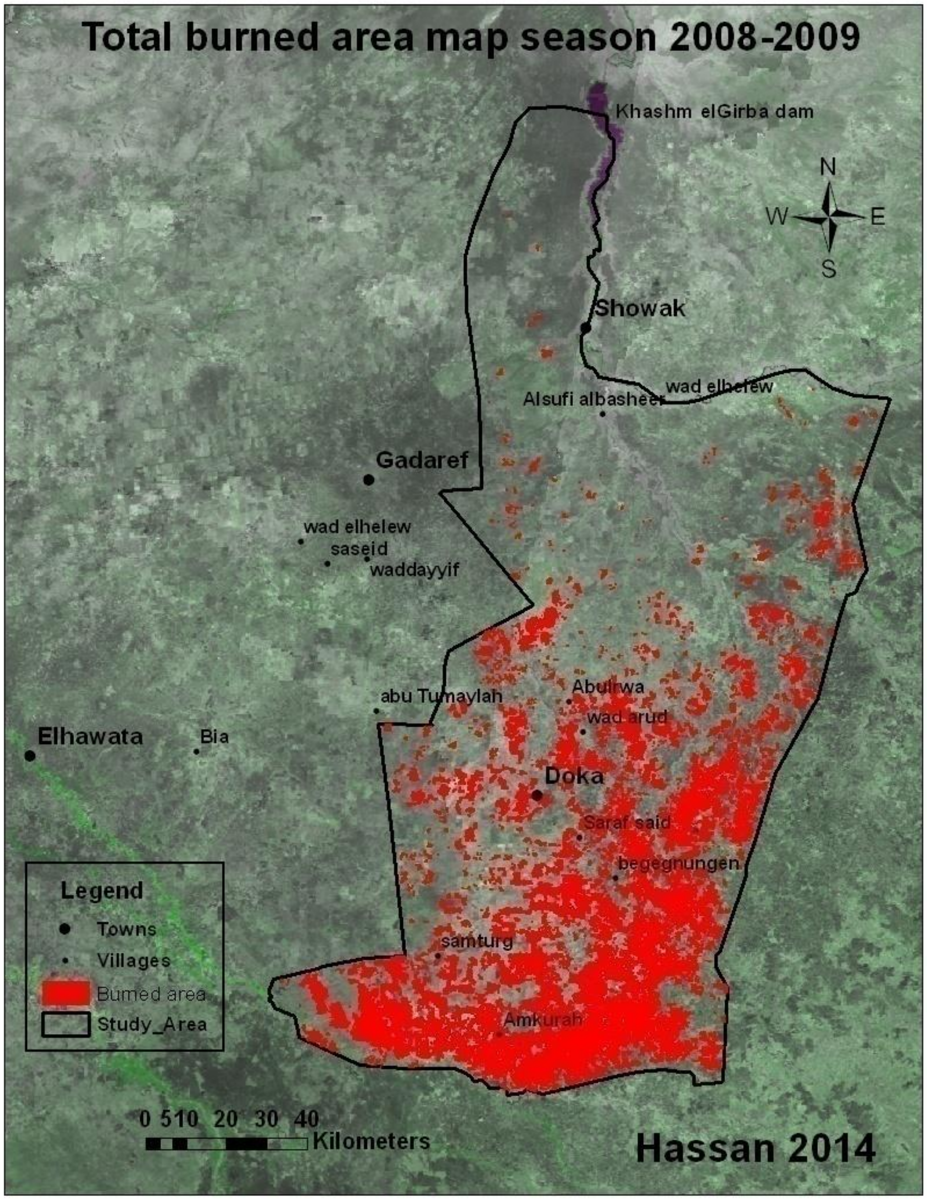
Appendices-7 Map of total burned area season 2006-2007



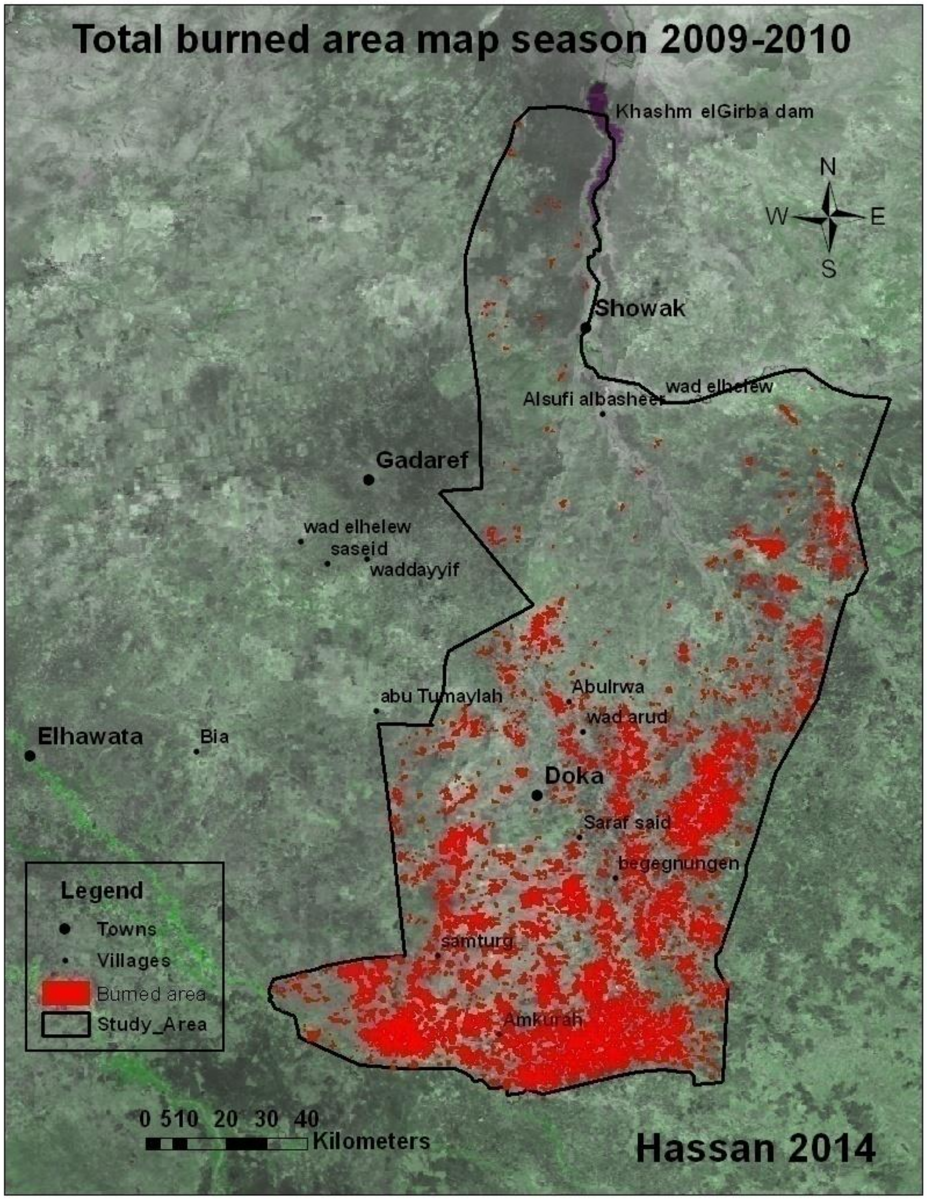
Appendices-8 Map of total burned area season 2007-2008



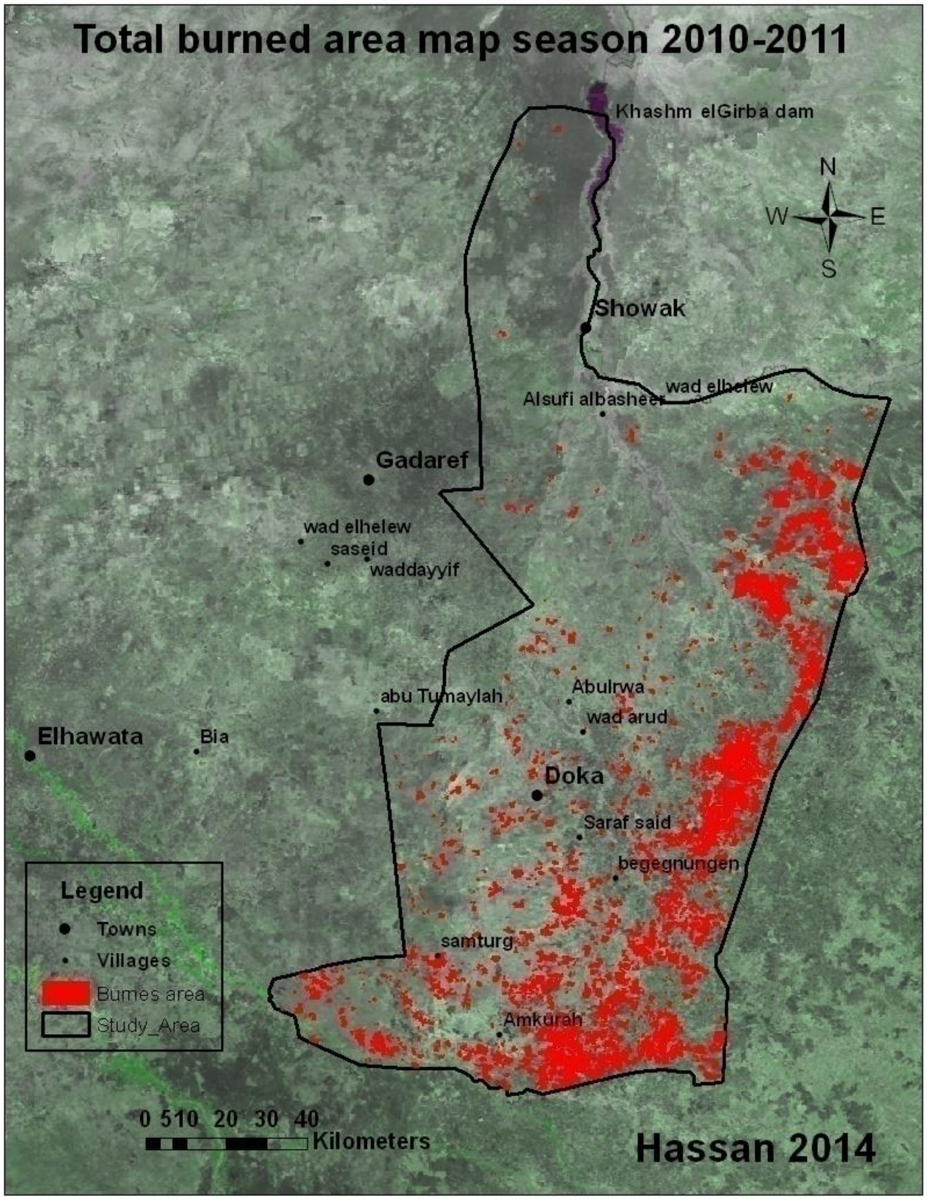
Appendices-9 Map of total burned area season 20082009



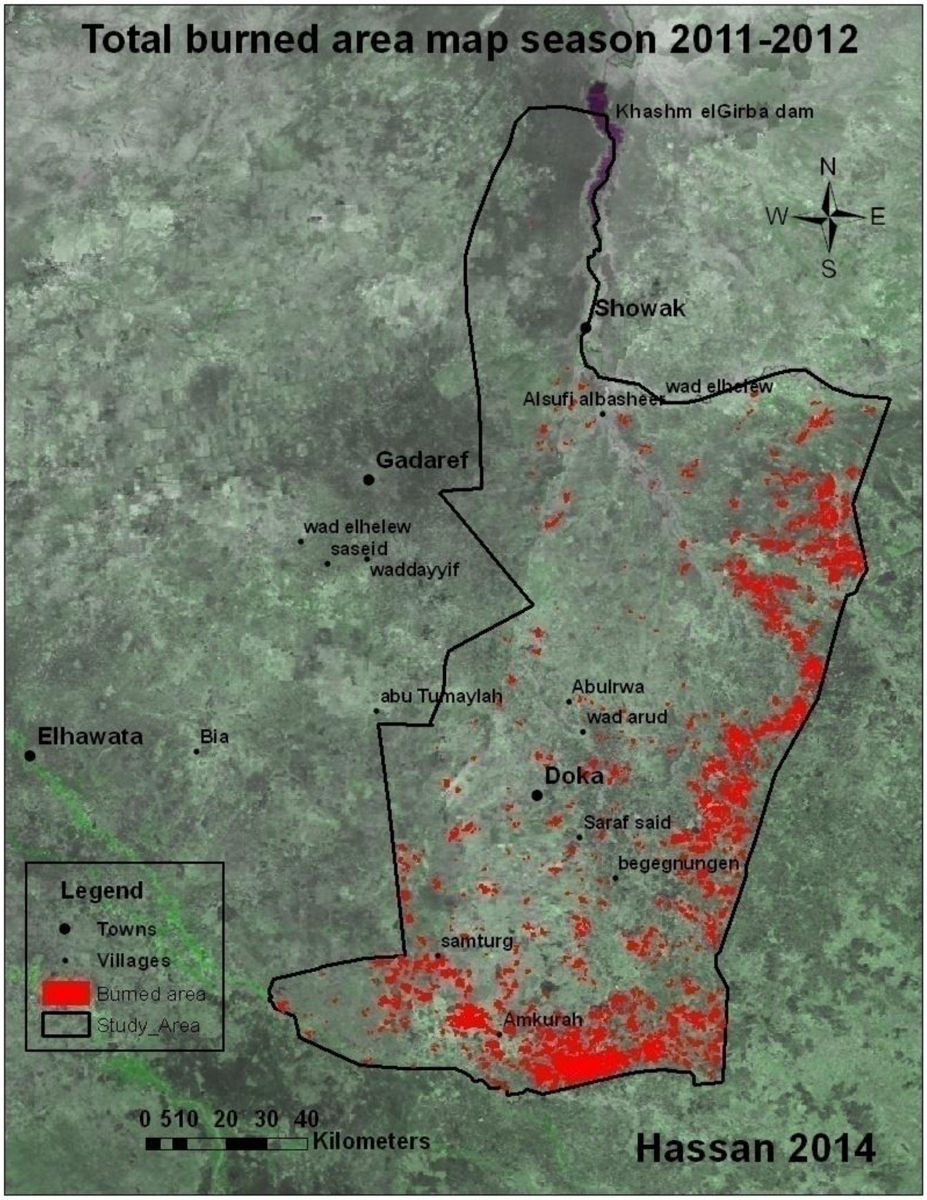
Appendices-10 Map of total burned area season 2009-2010



Appendices-11 Map of total burned area season 2010-2011



Appendices-12 Map of total burned area season 2011-2012



Appendices-13 Map of total burned area season 2012-2013