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Collage of Graduate Studies

Assessment of El-Rawashda Reserved Forest Resources Using Selected Climate Change Indicators - Gedaref State - Sudan

تقييم موارد غابة الرواشدة المحجوزة بإستخدام مؤشرات مختارة لتغير المناخ - ولاية القضارف - السودان

A thesis Submitted For Fulfillment of the Requirements of M.Sc. in Forestry Science

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قال تعالى:

بسم الله الرحمن الرحيم

(ظَهَرَ الْفَسَادُ فِي الْبَرِّ وَالْبَحْرِ بِمَا كَسَبَتْ أَيْدِي النَّاسِ لِيُذِيقَهُم بَعْضَ الَّذِي عَمِلُوا لَعَلَّهُمْ يَرْجِعُونَ).

صدق الله العظيم

الروم، الآية (41)

Dedication

To my big family that supported me

My mother, father and brothers

and

To my small family that was the source of my inspiration

My wife, son and daughter

To my supervisors

Dr. Mahgoub, Prof. Abdelaziz and Prof. Sabit

To my closely friend

Dr. Mohammed Abdelmanan Hassan

And to everyone who helped to bring this work out

Acknowledgement

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I must record our great and special thanks to

Dr. Mohammed Abdelmanan Hassan

Staff of Cankiri Karatekin University

and staff of FNC – Gedaref State

Abstract

This study was carried out in El-Rawashda Natural Reserved Forest. It is located in the Eastern part of Sudan at latitude 14.2˚ N and longitude 35.6˚ E. The aim of this study is to assess and monitor forest cover change at El-Rawashda Natural Reserved Forest using Remote Sensing Imagery and selected indicators related to climate change (rainfall, temperature, soil quality, aridity index, and floral and faunal species). Remotely sensed data for the years 1988, 1998, 2007 and 2018, were used to achieve this objective, In addition, a stratified random sample with 5% sample size from the target group (100) questionnaires were designed and distributed among the respondents of El-Rawashda, Darelzain and Wadelnair villages. Moreover, ten soil samples for surface layer (0 – 30 cm) were taken by augur and using directed random sampling. The remote sensing data were possessed and analyzed by using Arc map and Envi software's, Statistical Package for Social Science (SPSS)were used to analyzed data obtained by questionnaires, and Soil samples were analyzed using laboratory equipment, followed by Statistical Analysis Software (SAS) to find the relationship between different sites. The results revealed that there were remarkable changes from the satellite remotely sensed images showed in El-Rawashda Natural Reserved Forest cover. Local community also confirmed that a huge change occurred between 1988 and 2018 and this change was attributed to climatic variability and human induced activates. In addition, El-Rawashda Natural Reserved Forest played a considerable role by providing a wide range of benefits, contributing significantly to people's livelihoods and environmental services. For that reason the basic needs of the local community around the forest should be taken into consideration by FNC, beside activating protection and increasing the number and facilities for guards and monitoring forests using modern techniques.

الملخص

أجريت هذه الدراسة في غابة الرواشدة الطبيعية المحجوزة، التي تقع في الجزء الشرقي من السودان على خط عرض 14.2 درجة شمالاً وخط طول 35.6 درجة شرقًا. تهدف هذه الدراسة إلى تقييم ورصد التغير في غطاء غابة الرواشدة المحجوزة الطبيعية بإستخدام صور الإستشعار عن بعد ومؤشرات مختارة متعلقة بتغير المناخ (هطول الأمطار ودرجة الحرارة ونوعية التربة ومؤشر الجفاف والأنواع النباتية والحيوانية). تم إستخدام بيانات أقمار لاندسات للأعوام 1988 ، 1998 ، 2007 و 2018 على التوالي لتحقيق هذا الهدف ، بالإضافة إلى ذلك ، تم تصميم إستبانات بإتباع طريقة العينة العشوائية الطبقية لحجم عينة 5٪ من مجتمع البحث (100 إستبانة) وتوزيعها على المجيبين في قرى الرواشدة، دار الزين و ودالناير. وعلاوة على ذلك، أخذت عشرة عينات للتربة السطحية (0 – 30 سم) بواسطة الأوقر و بإستخدام طريقة العينات العشوائية الموجهة. تمت معالجة وتحليل بيانات الإستشعار عن بعد باستخدام برنامج Arc. Map وبرنامج Envi ، تم إستخدام الحزمة الإحصائية للعلوم الإجتماعية (SPSS) لتحليل البيانات التي تم الحصول عليها من خلال الإستبيانات ، وتم تحليل عينات التربة بإستخدام المعدات المعملية ثم تبع ذلك إستخدام برنامج التحليل الإحصائي (SAS) للحصول على العلاقة بين المواقع المختلفة. كشفت النتائج أن هناك تغييرات ملحوظة من صور الأقمار الصناعية في غطاء غابة الرواشدة المحجوزة، أيضاً المجتمعات المحلية أكدت على حدوث لك التغير الكبير من 1988 وحتى 2018 ، هذه التغييرات ترجع إلى التقلبات المناخية وتدخلات الأنشطة البشرية. إضافة إلى ذلك تلعب غابة الرواشدة الطبيعية المحمية دورًا كبيرًا من خلال توفير مجموعة واسعة من الفوائد ، حيث تساهم بشكل كبير في سبل عيش الناس والخدمات البيئية. لذلك الإحتياجات الأساسية للمجتمعات المحلية حول الغابة يجب أن توضع في الإعتبار من قبل إدارة الغابات ، مع تفعيل الحماية عبر زيادة عدد الحراس ومعينات الحراسة ومراقبة الغابات باستخدام التقنيات الحديثة.

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List of Abbreviations

FNC	Forest National Corporation
NDVI	Normalize Difference Vegetation Index
RS	Remote Sensing
GIS	Geographical Information System
FRA	Forest Resource Assessment
FAO	Food and Agriculture Organization of United Nation
LULC	Land Use Land Cover Change
IPCC	International Panel of Climate Change
UNFCCC	United Nation Framework Convention on Climate Change
IUCN	International Union for Conservation of Nature
UNEP	United Nations Environment Programme
GRA	Global Research Assessment
UNESCO	United Nations Educational, Scientific and Cultural Organization
JICA	Japan International Cooperation Agency
USDA	United States Department of Agriculture
NAPA	National Automotive Parts Association
USGS	United States Geological Survey
SPSS	Statistical Package for Social Sciences
SAS	Statistical Analysis System
CFA	Carbon Farmers of Australia

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CHAPTER ONE
INTRODUCTION

1.1 Background

Sudan is the third largest country in Africa, located in northeast part of Africa with an area of 1882000 km^2 (Fashir, 2014). This area extended over various ecological zones; among them is the semi-arid zone. According to FRA (2015) stated that, forests cover in Sudan is 21,826,163.27 hectares and that estimated to be approximately 12% from the total country area.

Forests are an important natural resource and they play a considerable role in our daily life. It provides a wide range of benefits and contributing significantly to people's livelihoods through provision of environmental services such as biodiversity, recreation, wildlife habitat, clean air and water, as well as main source of income for almost all rural population. However, these benefits should be conserved through sustainable forest management that has become an essential component in current strategies of managing natural resources and monitoring environmental changes.

According to FAO (2009), forests support the livelihoods of more than a billion people who are living in extreme poverty and provide paid employment for over 100 million people, homes to more than 80% of people worldwide. In addition, biodiversity, and help to protect watersheds that are considered to be a critical source of clean water supply for all most all humanity.

In this century, the climate change concept has become a hot issue debated at various level and scales due to its severe impacts in ecosystem and human welfare. During past several decades, forest are being altered and modified due to extreme

climatic variations in semi-arid areas, including unreliable precipitation and high air temperature. Forests resource also has been affected negatively by climate change that resulted in forest deterioration and environmental degradation as well as increasing the rate of deforestation and desertification.

Therefore, to support decision making processes, there is an urgent need for better understanding of spatio-temporal measurements of environmental changes and associated impacts on forest in this sensitive environment. On the other hand, sustainable forest management strategy related to climate change is another part that could have a positive contribution to climate change mitigation and adaptation, while failure to do it might lead to more risk and barriers to sustainable forest management. For example, predominant clearing of forest, overgrazing, and rain-fed agriculture expansion could increase when decision-makers disregard the needs of local people to sustain their livelihoods.

Adaptation of sustainability and sustainable forest management concepts by analyzing and improving some indicators to expresses the current forests situation in order to provide accurate spatial information for a sustainable forest plans are the main objective of this study.

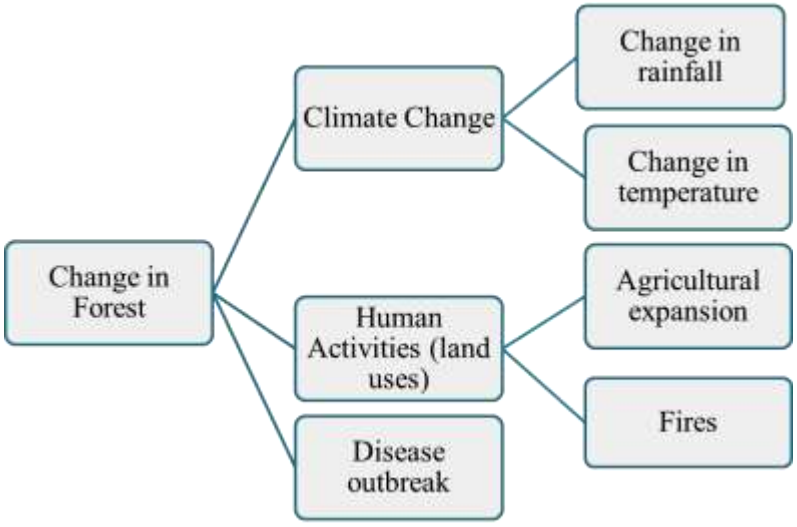
Remote sensing (RS) tools integrated with Geographical Information System (GIS), recently become an indispensable and cost-less means for assessing aspects such as vegetation cover degradation and more generally for most types of Land Use Land Cover (LULC) changes by giving timely and spatial information about forest resources in the past, current status, and to predict their future (Solaimani, *et al*, 2010).

1.2 Problem Statement:

The scientific evidence showed that earth's climate is changing clearly in the last century (IPCC, 2017), and that change in climate will create a direct impact on both natural and man-made forests. During the past decades, forests in semi-arid areas has been exposed to severe degradation such as species changes, loss of biodiversity, and change in spatial coverage due to various disturbances ranged from human induced to climatic variability (Kirilenko *et al*, 2007).

In fact, 80% of rural population in Sudan is heavily dependent on forest resources; therefore, deterioration of these resources can give rise to increases poverty, environmental refugees and even conflict.

In addition, there is a lack of scientific information related to climate change indicators (Betts, 2017), thus an urgent need to assess the forest cover change using remote sensing data and some climatic indicators to locate the area at risk as well as to suggest some recommendation for improving and implementing sustainable forest management in El-Rawashda forest.



Source: Designed by researcher

Figure 1. Problem guidelines

1.3 Objectives:

Main objective:

The main objective of this study is to assess and monitor the forest cover change at El-Rawashda Natural Reserved Forest using remote sensing imagery and some indicators related to climate change (rainfall, temperature, soil, aridity index and floral and faunal species).

Specific objectives

The following specific objectives will pursued in order to achieve the overall objective above:

1. To identify and detect changes in forest cover.
2. To find out the suitable indicators that express climate change.
3. To figure out at what extent impact of climate in El-Rawashda Forest.

1.4 Hypotheses

- EL-Rawashda Forests cover is changed due to climate and natural factors.
- The selected indicators are easy and acquired to assess and monitor forests changes.

1.5 Research questions

- What are the changes in El-Rawashda forest cover?
- What factors are driving the forest changes?

- At what rate does the forest change progress and when did start?
- How the forests cover being transformed and how such information can be used for effective sustainable forest management?

CHAPTER TWO
LITERATURE REVIEW

2.1. Introduction:

Forest cover change has significant climate impacts in arid and semi-arid areas with added complexity of occurring within the context of a warming climate. These changes are expected to have major impacts on environmental, social, economic, and political aspects of human society. The environmental impacts include changes to biodiversity, productivity, migration and sustainability. Climate change also called global warming, refers to the rise in average surface temperature of the earth. Climate change could be a development trappings greenhouse gases which CO_2, Methane, within the atmosphere and to not outflow resulting in an increase of surface temperature is understood as warming or the greenhouse gases (Ammar *et al*, 2015).

Lindsey et al, 2012 reported that the air temperature of earth's surface has increased by approximately 0.8° C which equal to 1.4° F over the past century. The raise of earth surface has a great impact on all forms of life on earth in the near future. Changing in climatic factors (temperature and precipitation) patterns and increasing concentrations of atmospheric carbon dioxide are likely to drive significant modifications in natural resources (Andrei *et al*, 2007).

The Forests resources is one of the natural resources that are affected positively or negatively by climate change, and its affected by the absorption of greenhouse gases and carbon dioxide which reduces its effects on the ground. Recently forest degradation due to changing natural environments alongside deforestation is a major threat to forests.

Based on the importance benefits of forests, it is important to find ways to manage forests sustainably and to develop indicators capable of monitoring and assessing forest vulnerability. Moreover, due to climate change and use of modern technology, the amounts of information that address the issues are needed.

Definitions of key terminologies:

2.2.1 Forest:

Forest defined as Land spanning more than 0.5 hectares with trees higher than 5 meters and a canopy cover of more than 10% or trees able to reach these thresholds in situ. It does not include land that is predominantly under agricultural or urban land use (FRA, 2015).

2.2.2 Remote sensing:

Obtaining information about objects or areas at the earth's surface without being in direct contact with the object or area (Shefali, 2004)

2.2.3 Climate change:

Climate change in IPCC usage refers to a change in the state of the climate that can be identified (e.g. using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer (UNFCCC, 2011).

It is long-term continuous change (increase or decrease) to average weather conditions or the range of weather (Keely, 2008).

2.2.4 Climate variability:

The way climate fluctuates yearly above or below a long-term average value (Keely, 2008).

2.2.5 Indicators:

An indicator is any variable or component of the forest ecosystem or the relevant management systems used to infer attributes of the sustainability of the resource and its utilization (FAO, 2002).

2.2.6 Forest management:

Forest management means giving the forest proper care, so it stays healthy and vigorous and provides the products and values the land owner desires.

2.3 Forests resources:

Forests play a vital role for economic, social and environment, and they provide super benefits at different levels. These benefits include the importance of forests for water catchment protection, and mitigate soil erosion and improvement the micro climate, medicinal benefits, employment, carbon fixation, biodiversity (FAO, 2007).

According to IUCN (2015) identified that forests regulate ecosystems and play main part in the carbon cycle and supply goods and services beside them its other role in livelihoods income of 1.6 billion people depend on forests worldwide by submitting goods and services. Furthermore, the forests are considered as home of almost 80% of the world's terrestrial biodiversity.

According to state of the world's forests report 2018 confirmed that 284 million people in Africa found in or around tropical forest and savannah areas and classified as forests population, 50% of them living under poverty line and they depend entirely on forests.

UNEP identified seven type of forests in Sudan that include desert and semi-desert trees and shrubs, riverine forests, low rainfall woodland savannah, high rainfall woodland savannah, mountain an d gallery forest, tropical forest and plantations (FAO, 2017).

2.4 Forests biodiversity:

Biological diversity is a term that suggests the variability among living organisms from all sources together with, inter alia, terrestrial, marine and alternative aquatic ecosystems and therefore the ecological complexes of that they're part; this includes diversity inside species, among species and of ecosystems (FRA, 2015).

Forests resources are one of the richest habitats of diverseness on Earth, beginning from the microorganism under the forests surfaces to bird at the crown of trees (UNCCD *et al*, 2007).

According to UNCCD (2007) indicated that, forests provide various habitats for plants, animals, micro-organisms and biodiversity. It is the base for goods and services. Losing forest diversity encourages missing for medicines, food, raw materials and employment opportunities.

The variability of forest trees and shrubs play a big role inside the existence of rural communities in many areas. Because forest is the major sources of wood and non-wood product, contribute to soil conservation, repositories of aesthetic, ethical,

cultural and religious values. Forest provides forage for animals, also is measured as big unit offering nutrition and game to many people. Its play a vital role in ecology, such as fertilization, seed predation, spreading and germination, and predation on potential tormenter species.

Forests provide quite 10% of the gross domestic product in many of the poorest countries and supply with food and other products. Also it's contributing 78% of the national energy balance and (FAO, 2007). All the same such a relevant role in world economy, progress towards proper forest management remains restricted, and there is continued loss and degradation of forests in many developing countries.

2.5 Forests management:

Forest Management is the way that forests and the trees are protected and used to provide forest products and other services (CFA, 2012).

According to Elbashir (2007) quoted that forest management arrange interprets national forest policies and low into a thoughtfully ready and well co-ordinated operational program for a forest and for regulation biological science activities for amount of time, and therefore the term forest management is applied in things where associate integrated co-ordinate of series of actions in area unit taken direct towards the action of specific objectives. In broadest sense forest management is also a way that effectively integrates the biological, social and economic factors that influence the alternatives leading towards the implementation of one or further specific objectives.

According to FAO (2006) Sudan forest management began in earlier since 1902 with the established the Forests and Woodlands Service and issued regulative acts in 1908 and 1917 appurtenant to the adopted policies of conservational nature and also the initial formal national forest policy was declared in 1932.

El-Rawashda forest was one of forest previously managed to achieve some goals such as to protect environmental stability and provide forest products like fuel wood, poles and fodder for national, regional and local demand (FAO, 1989).

2.6 Sustainable Forests Management:

Deforestation and forest degradation are the second leading human explanation for carbon dioxide emissions conducive to heating and it's estimated that deforestation and forest degradation account for roughly 17% of global greenhouse emission emissions, Therefore, there was an accord on the necessity for international cooperation to combat climate change to increase attention to the role of forests in carbon storage and also the great deal of carbon dioxide emissions that would be avoided if deforestation stopped (Morrison *et al*, 2016).

Historically, forest management and inventories were primarily for timber management and targeted on capturing area and volume by species. Within the past decade, forest management responsibilities have broadened. As a result, inventory information needs have dilated to include measures of non-harvest connected characteristics such as forest structure, wildlife environment, biodiversity, and forest hydrology.

For that, sustainable forest management needs that landscape ecological characteristics involving environment and biodiversity are included in forest inventory and certification procedures (Michael *et al*, 2005).

El-Rawashda forest has since ancient time seen the future and sustain vision in their management by effort of FAO which was represented in protection, regeneration and felling. A rotation of around twenty years, financial analysis at different productivity levels and considering fire line opining and determination of amount for grazing and sale of charcoal and poles. In order to implementing those objective forest was divided in five working circle are fuel wood circle at 68% of total area, village working circle at 13%, *Acacia senegal* locally known (Hashab) working circle at 5%, fodder working circle at 2% and protection working circle at 12%.

2.7 Role of modern technique's in forests management:

Remote sensing may be a powerful tool that can't be ignored due to its data potential, lack of effort and therefore the time it takes to work, and conjointly of a great deal of accuracy.

In recent years, computer aided process of satellite images and aerial photographs became powerful tool once applied to geographical issues. Various methods are developed to analyze multi-level special data that as sometimes summarized under the term Geographical information system.

The advent of technologies in mapping and natural resources management provided scientists with automated tools for extracting and evaluating special data. RS and GIS are such examples of technologies which permit the extraction, manipulation, analysis and generation of tabular and graphical representations of information of data of knowledge concerning the earth surface even without undertaking actual field surveys to gather data. Field surveys are undertaken just for group verification functions.

2.8 Applications of RS in forest management:

RS and GIS are important complementary technologies that, improved observation and management of forest resources when it used. The use of RS by forest managers has steadily increased, promoted in wide part by higher integration of images with GIS technology and databases, also as implementations of the technology that better suit the knowledge wants of forest managers. The most important forest data obtained from remotely sensed data are often broadly in forest inventory and observation of forest health and natural disturbances like fire, insects and disease, additionally its role in assessment of forest structure in support of sustainable forest management (Michael *et al*, 2005).

2.9 Impacts of climate change in the forests resources:

Global warming refers to the worldwide average increase in temperature above a long-term average, and therefore the global average temperature rose by concerning 0.85 degrees between 1880 and 2012, and also the rate of warming has accelerated over the past fifty years, and the global warming doesn't increase at a constant rate from year to year and therefore the average of temperature will increase or decrease, but over decades the warming trend is clear (UNESCO, 2013).

The change in temperature, rainfall produce a powerful direct impact on natural and artificial forests, and therefore the frequently change in the other events, such as sturdy winds, winter storms, drought, etc. might end in heavy losses in forests particularly in the productive forests (Andrei *et al*, 2007).

Global warming has become a world issue. Attention is additionally focused on the adverse impact of deforestation on the environment. Clearing forests in to field's leads to releasing greenhouse gas that was previously absorbed by the forest (JICA, 2016).

According to Chemmuttut (2016) stated that climate change additionally leads to impacts on forest growth rates, the distribution of tree species, the speed of ecosystem processes and the ability to hold out forest operations with increased severity of impacts experienced by forest-dependent communities, and therefore the impacts observed until now include droughts and severe flooding.

Climate change and its impacts on the environment additionally create a further challenge to achieving the objectives of sustainable forest management because the main economic sectors in Africa depend principally on natural resources, including forests, which is able to be vulnerable to climate change and will be exacerbated by existing development challenges like poverty; Ecosystems and conflicts (Chemmuttut, 2016).

According to UNESCO (2013) stated that One billion Africans are within the way of harm due to instability within the rains, large-scale diseases, sea-level rise and flooding. This makes them in internal conflicts, and one amongst the impacts of climate change is that the frequent search for water and land.

Sudan is one of the most areas affected by climate change ratio environmental regime fragile, weak environmental infrastructure and economic, the vast majority of the territory of Sudan is sensitive to changes in temperature and precipitation as food security determines the speed of rainfall. Over 70% of Sudan's population

depends directly on the resources sensitive to the climate in livelihood. And there are some none climatically factors increase the vulnerability in Sudan such as Poor soil fertility, desertification, and conflict over natural resources lack of awareness (Bashir *et al*, 2015).

2.10 Indicators related to climate change in the forests sector:

For the great importance of the forests resources and their role in the protection of the environment and earth planet, many efforts have been made globally to developing a system of indicators that monitor and assess the extent of change and impact on the resource due to climate and other factors affecting it from natural factors or as a result of human intervention. The National Advisory Committee on Climate Assessment and Development of the United States of America is one of those that has sought to develop a system of indicators of the impact of climate change on the forest sector, and in those effort, it focused on indicators directly related to forest ecological systems, and associated social and economic systems as they relate to climate change detection, mitigation and adaptation and The extent to which some indicators are related to climate change, and as a result of intensive efforts, eleven indicators were recommended in three five categories (USDA, 2015).

2.11 Recommended indicators of climate impacts for forests:

Those indicators divided in groups according to the phenomenon monitored by and it’s including forest and human domain.

2.11.1 Extent: the indicator title for this group is forest land area and extent and its view with land use or land cover.

2.11.2 Structure and function: the indicator title for this group is Forest biomass density and its monitor by calculated the forest inventory data.

Also there is another indicator title for this group is Forest growth or productivity these are obtained by calculated the field data and moderate satellite imaging.

2.11.3 Ecosystem services: the indicator title for this group is diversity or abundance of forest-associated floral and faunal species and it's gained from assessing the change on forest diversity.

2.11.4 Disturbance: The indicators titles for this group are wildfire effects, Forest insect and disease damage these are obtained by estimated burned or affected area.

2.11.5 Biophysical: The indicators titles for this group are Water balance deficit an indicator of "plant-relevant" drought by estimated from surface climate observations and vegetation data.

2.11.6 Extent / Socioeconomic: The indicator title for this group is wild land urban interface.

2.11.7 Climate impacts on the human domain via forest: The indicator title for this group is a Cost to mitigate wild fire risk.

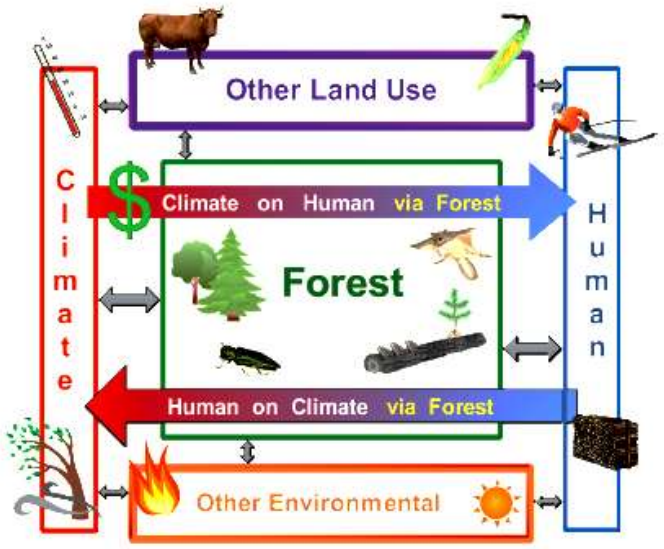
2.11.8 Human Domain influences on the Climate Domain via Forest: The indicator title for this group is Energy produced from forest-based biomass.

2.11.9 Socioeconomic/Ecosystem services: The indicator title for this group is recreation.

2.11.10 Physical climate indicators: This is kind of indicators divided to three main type of indicators are temperature, Precipitation and wind and added to them the Drought.

2.11.11 Health impacts related to forests: In this part, respiratory diseases related to water shortage issues, which are strongly associated with forests.

2.11.12 Phenology: In this section we relied on indicators such as Senescence and Budburst.



Source: Indicators of Climate Impacts for Forests: Recommendations for the U.S. National Climate Assessment Indicators System, 2015

Figure 2. The relation between Assessment indicator categories

2.12 Example of some efforts in climate change sector in Sudan:

In Sudan there are some greet efforts of projects worked to release the impacts of climate change when the global warming is be fact. One of those efforts that project were done in the river Nile state to improving sustainable agricultural practices under increasing heat stress , these project was done in the desert zone to adapted people of that zone to reduce the increase in temperature during both winter and summer seasons and also suffer from high wind speed and shifting sand dunes that negatively affect the cultivated lands and animals, by introduction of heat resistant plant varieties and new economic crops, improvement of irrigation system, establishment of rocky barriers to reduce wind speed and intensification of trees planting, digging of water pools (hafirs) and wells for domestic and animal uses and capacity building (HCENR, 2007).

According to HCENR, (2007) there are some efforts done too in semi desert zone by the project of environmental conservation and biodiversity restoration in Northern Kordofan State as a coping mechanism for rangeland protection under conditions of increasing climate variability to help people who inhabit the area is anticipated to increase as they lose productive lands, vegetation cover and eventually face desertification by rehabilitation of vegetation cover and restoration of biological diversity through awareness rising of the local people, Achievement of sustainability of livelihoods, development of animal wealth sectors, fixation of sand dunes and combating desertification

In addition to the project of enhancing resilience to increasing rainfall variability through rangeland rehabilitation and water harvesting in the Butana area of Gedaref State, for adapting pastoralists in savannah zone to reduce the

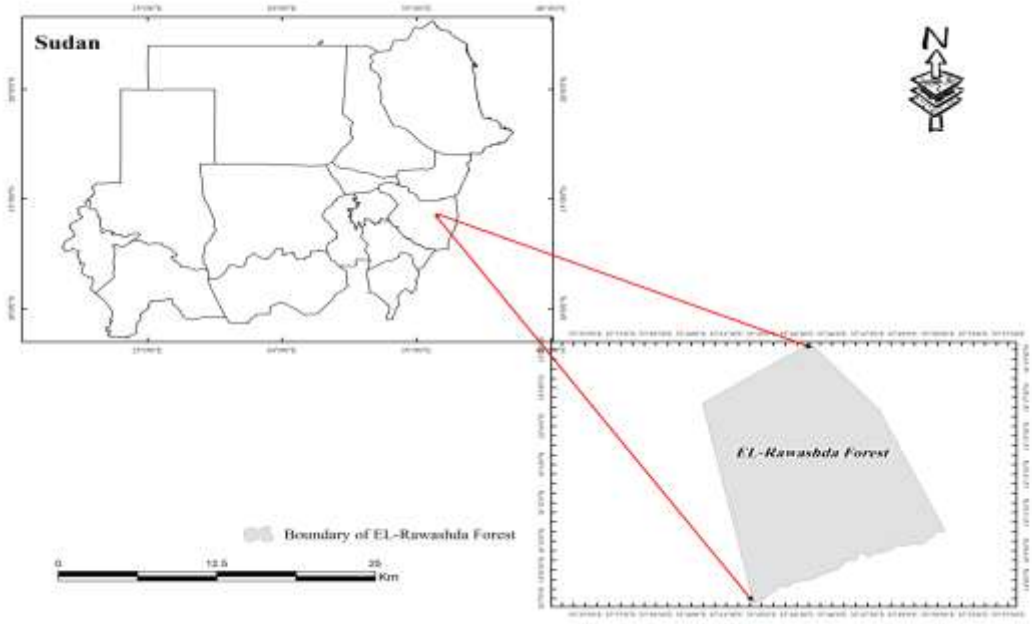
deterioration of both the productivity and biological diversity of the Butana rangelands by introduction of new fodder rotation and management schemes, improve household income diversity through provide alternative income sources during periods of low rainfall, identify optimal water harvesting, storage and spreading techniques relative to climate change and reduce pressure on rangelands resources through building awareness (NAPA, 2007).

CHAPTER THREE
THE STUDY AREA

3.1 Location

This study has been conducted in El-Rawashda Natural Reserved Forest. It locates in Eastern part of Sudan at Gedaref State, geographically lies about 45 km Eastern Gedaref at latitudes 14.2˚ N and longitudes 35.6˚ E.

El-Rawashda Natural Forest is one of the reserved forests, administratively is part of El-Fashagah Forest Circ1e. Legally the forest was reserved and gazetted in 1960 as a Central Forest Reserves under 1932 Control Forest Ordinance to safeguard the charcoal supplies for Khartoum. It covers an area of about 25290 hectares (Babiker, 2003).



Source: Designed by the researcher

Figure 3. Location of the Study area

3.2 Population

The total population of Gedaref State according to 2008 census was estimated to be 1,348,378 person, most of them are settled in local areas and their major activities includes agriculture, fishing and forest-related activities. While the employees, mining, industry, transport, trade and services are the main activities of urban population.

3.3 Soil

The soil of Gedaref State is deep dark cracking and heavy clay soil. It is classified as verity soils and generally intensively cracked (Ministry of Agriculture, 1973).

The soil clay fraction varies from 61% to 73%, and it tends to extend southeastward, coinciding with increase in rainfall. The origin of the soil material was believed to be from Ethiopian high lands. Yet, extensive areas of cracking clay were derived from decomposition of rocks in suit (Babiker, 2003).

3.4 Geology

The Gedaref area consists of clay mantle overlying basaltic rock, no bed rock occurs at the surface but it's found within 250 cm depth. In addition, to Gedaref and its surroundings are located on a high plateau forming watershed between Atbara to the East and River Rahad to the West (Ministry of Agriculture, 1973).

According to Babiker (2003), Gedaref district consists of basement complex, Nubian series, volcanic rocks and superficial deposits, and the basaltic rock fragments are scattered on the surface in varying density.

3.5 Climate

UNEP (2007) reported that the dominant characteristic of Sudan's climate is a geographical variation in rainfall and temperature in different part of the country.

El-Rawashda Natural Reserved Forest located in semi-arid zone; the rainy season starts in August and continues up to mid of October, the rainfall pattern ranging from 400 to 800mm with an annual average of 600 mm. However, the year is divided in to two distinct seasons dry warm Winter (October - March) and hot dry Summer from April to June with average temperature equal to 29˚C (Musa, 2017).

3.6 Vegetation cover

According to Musa (2017) the vegetation cover is largely dependent on the rate of rainfall and soil types. The vegetation cover is composed of great diversity of trees, shrubs and grasses. The type of trees and shrubs are *Acacia seyal var. seyal* (Talih), *Acacia seyal var. fistula* (Sufar Abyad), in groups and stands especially in South West part of the forest and *Acacia senegal* (Hashab), mainly planted some naturally mixed in Talih stand, *Acacia mellifera* (Kitr), large shrubs, incident al throughout, more frequent and dominant on the slopes of the major valley locally known as Khors draining towards Atbara River. *Acacia orefota* (Laot), incidental as a small shrub, some pockets in North part of the forest, and *Banalities aegyptiaca* (Heglig), small to large dominant trees scattered throughout the reserve.

According to FNC the type of grasses are *Ocimum spp*. (Rehan), *Senna obtusifolia* (Kawal), *Xenthium brasilicum* (Ramtouk), *Aristida spp*. (Gaw), *pennisetum* spp. (Um farw) and *cymbopogon mervatus* (Naal).

3.7 Land use:

Gedaref State considered one of important State for food security in Sudan's strategic center, and it is considering the largest projects for rain-fed mechanized agriculture (Idris, 2017).

According to FAO (1989) stated that agriculture was and still the dominant economic activity in Gedaref State followed by livestock raising, gum and forests products collecting and trading charcoal.

The types of crops grown in Gedaref State are sorghum and sesame as main crops in the State. Other crops like millet, cotton, peanut and sunflower were also cultivated (Adam *et al*, 2008).

CHAPTER FOUR
MATERIALS AND METHODS

The general objective of this study is to assess the forest cover change in El-Rawashda Natural Reserved Forest by using remotely sensed data and selected indicators related to climate change. Also this chapter highlighted the various data used and method of analysis.

To achieve objective of this study data were divided to two main categories which are remote sensing data and ancillary data. Ancillary data includes the field observations, socio-economic data and meteorology data. While other section included the land sat images that obtained from land sat 5, land sat 7 and land sat 8, these images downloaded free from USGS websites and pre-processed from radiometric and atmospheric problems moreover filled gaps in land sat 7 image, after that digitizing the study area and process images to produced NDVI Maps and classified to five classes and compare it with the ground observation results of the study area to validate accuracy. Then in conclusion was produced the linear trend map for the study area for years 1988, 1998, 2007 and 2018.

Which has been done in methodology can be seen through the chart below:

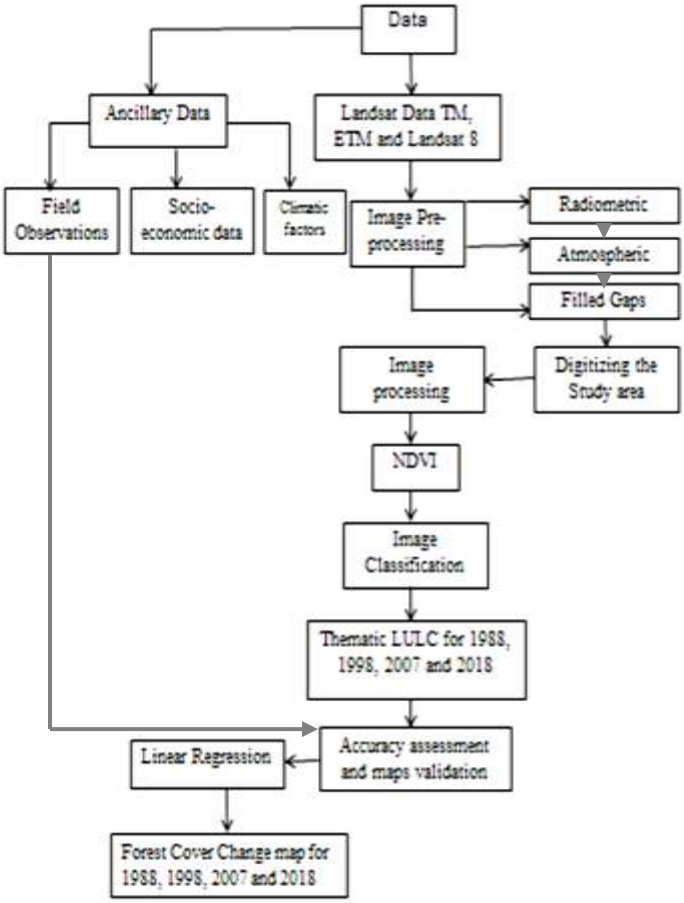


Figure 4. Methodology guidelines

However, two methods of data collection have been followed as below:

1- Secondary data

2- Primary data collection

Secondary data:

The secondary data were collected from various sources which include published and unpublished works, text books, internet, official government documents and reports of literature related to the study.

The primary data collection includes:

I. Remotely sensing data

Remote sensing data have become indispensable tools in natural resources related studies. Landsat satellite data for the years 1988, 1998, 2007 and 2018 were used in this study. All images were downloaded free of cost from the United State Geological Survey websites: (USGS) http://glovis.usgs.gov/ and https://earthexplorer.usgs.gov/. All images acquired from the period between November and December as it is the best time for acquisition and the sky is almost clear from the cloud. Table (1) shows the characteristics of remote sensing data used in this study area.

Table 1. Characteristics of remote sensing data used in study area

Year	Sensor	Spatial resolution	Spectral band	Swath	Format
1988	Landsat 5	30 m	7	185	GeoTiff
1998	Landsat 5	30 m	7	185	GeoTiff
2007	Landsat 7	30 m	8	185	GeoTiff
2018	Landsat 8	30 m	11	185	GeoTiff

Remote sensing data pre-processing:

All downloaded images were geometric, radiometric and atmospherically corrected to enhance the image and increase the amount of information extracted. The missed pixel values of Landsat 7 images were filled.

NDVI calculation:

The Normalize Deference Vegetation Index (NDVI) is a numerical indicator that uses visible band (Red) and Near-infrared bands of the electromagnetic spectrum to analyze remote sensing measurements and assess whether the target being observed contains live green vegetation or not, for that NDVI used in the study to assess the change in El-Rawashda Natural Forest cover.

For calculating NDVI the following formula according to Mohamedain (2009) was used:

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

Where:

NIR: Near infrared

R: Red

Linear Trend (Slope):

Linear regression trend analysis was performed using ArcGIS10.3 to simulate trends in point that reflect spatial trend of vegetation cover characteristics by using the following formula:

$$\theta\ slope\ = \frac{\mathrm{n} \times \sum_{i=1}^{n} \mathrm{i} \times \mathrm{NDVI}_i - \sum_{i=1}^{n} \sum_{i=1}^{n} \mathrm{NDVI}_i}{\mathrm{n} \times \sum_{i=1}^{n} i^2 - \left(\sum_{i=1}^{n} i\right)^n}$$

Where:

i: The annual number of image

n: monitoring period (the cumulative number of years)

NDVI: NDVI mean value of the i year

Slope = pixel NDVI trends of the slope, if, indicating that the pixel NDVI value in *n* years is increasing, otherwise it is decreasing.

Slope study is categorized into: a significant increase, slight increase, essentially the same, slightly reduction and a significant reduction within the study lifespan (1988-2018).

Correlation:

Correlation between geographical elements was applied to explain the closeness of the relationship between geographic features and closely related elements, mainly through the correlation coefficient calculation (Yagoub *et al*, 2017).

This study detect the relation between NDVI and average annual precipitation by point spatial correlation, the correlation coefficient used to reflect the sequence of climatic factors and NDVI values.

II. Socio-economic data

Based on the study objective, the target community of this study consisted of villagers and nomads around El-Rawashda natural Forest. Due to the large number of research community stratified random sampling with 5% sample size and 95% level of confidence, questionnaires were administrated and distributed to (100) household. In addition, local community leaders and forest officers were also interviewed to get detailed information concerning forest cover change and the drivers behind it.

III. Field observation and ground truth points

The observation was done according to Roger M. McCoy (2005) in his guide book of field methods in remote sensing (appendix no.7).

IV. Soil samples

Soil samples were taken with augur tool by directed random sampling technique in depth from 0 – 30 cm to detect soil pH and calculate the organic carbon and organic matter. Also statistical analysis done to soil sample result to detect the correlation between sites.

V. Aridity index

Calculating aridity index for the study area by using the following formula of UNEP as cited in Trabucco (2018):

Global-Aridity_ET0 (AI_ET0) = MA-Pr / MA-ET0

Where:

MA-Pr = Mean Annual Precipitation

MA-ET0 = Mean Annual Reference Evapo-Transpiration

VI. Data processing and Analysis:

- Satellite imagery was processed using ENVI 5.1 and ArcGIS 10.3 software's.
- Socio-economic data analyzed using Statistical Package for Social Sciences (SPSS) version 24 and the results presented and discussed.

- Soil samples analyzed by pH meter and Laboratory tools in National Center for Research. Then after, Statistical Analysis Software (SAS) version 6.12 was used to separate the mean.

CHAPTER FIVE
RESULTS AND DISCUSSION

5.1. General

El-Rawashda Natural Reserved Forest was considered as one of the important forest in Gedaref State. It is provide the basic needs for local people around the forest such as; fire wood, gum arabic, fruits, and fodder, charcoal, building pols beside the other indirect benefits like hunting and recreational as well as ecosystem services. The present study aims to assess the forest cover change using remotely sensed data and selected indicators related to climate change, besides the impact of human induced and attitudes towards conservation and management of the natural forest sustainably.

5.2. Remote sensing data

The classified images for the years 1988, 1998, 2007 and 2018 produced thematic maps of El-Rawashda Natural Reserved Forest with five forest cover classes includes: Bare Land (BL), Grassland with scattered trees (GLT), High Density shrubs (HDS), High Density Trees (HDT) and Agriculture land (AG).

5.2.1. Forest covers classes of EL-Rawashda Natural Reserved forest

The NDVI results used to categorize the forest cover. The variation between those classes refers to their greenness and NIR reflectance.

5.2.2. El-Rawashda Forest covers analysis

5.2.2.1. El-Rawashda Forest Cover in 1988

The spatial extent of 1988 forest cover map generated by NDVI had yielded five forest cover classes: BL, GLT, HDS, HDT and AG. The HDS occupying highest spatial coverage with almost (23899 Fed) followed by GLT with high area coverage (21440 Fed) and then HDT with an area coverage (10333 Fed) followed by BL with cover of (7637 Fed) and in the last the AG in the south margin of forest with coverage (845.8 Fed).

From image of 1988 the GLT, HDS and HDT coverage 86.3% and HDS and HDT with 53% of total area of El-Rawashda forest.

BL

GLT

HDS

HDT

AG (inside forest)

AG (at forest boundary)

Figure 5. El-Rawashda Forest classes

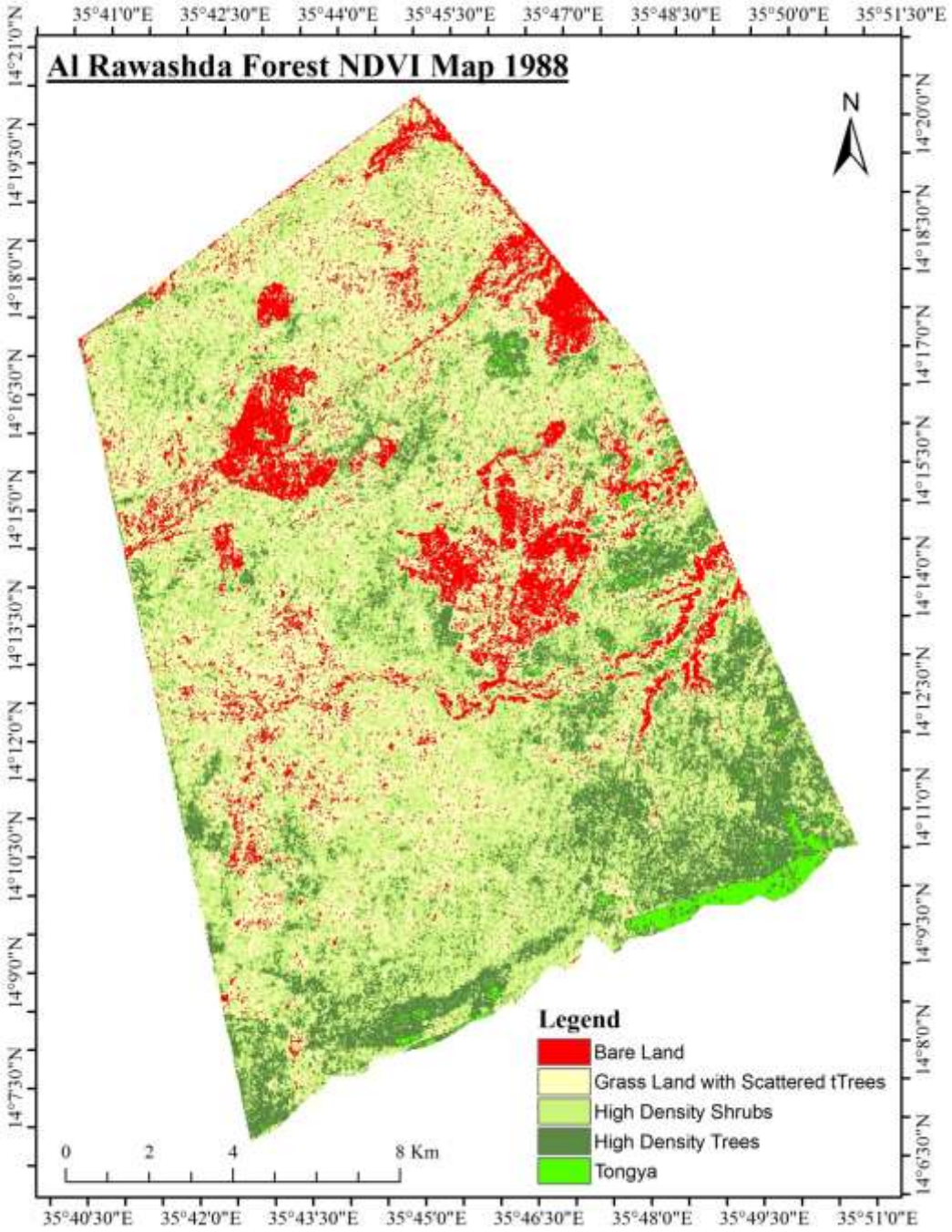


Figure 6. Forests Cover Map of El-Rawashda in 1988

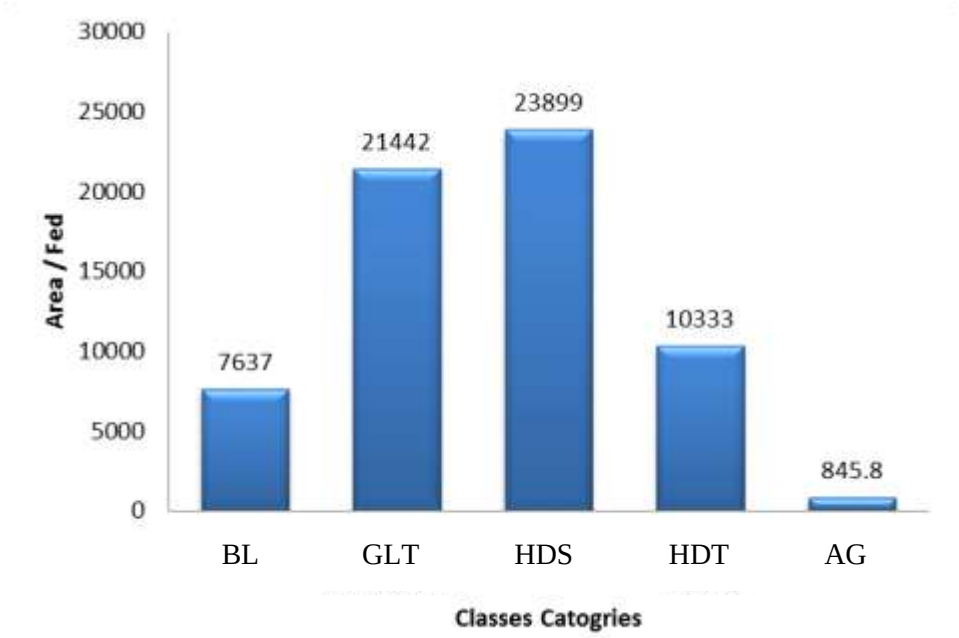


Figure 7. Differences in forest cover classes in 1988

5.2.2.2. El-Rawashda Forest Cover in 1998

The NDVI image of 1998 produced forest cover categories with highest areal coverage for GLT of (27052 Fed) flowed by HDS (16516 Fed), BL (12807 Fed), HDT (6399 Fed) and AG with cover area (845.8 Fed), respectively.

Form 1998 NDVI map the GLT increased rapidly compared to 1988.The AG also increased and extended inside forest center while HDS was decreased over the half.

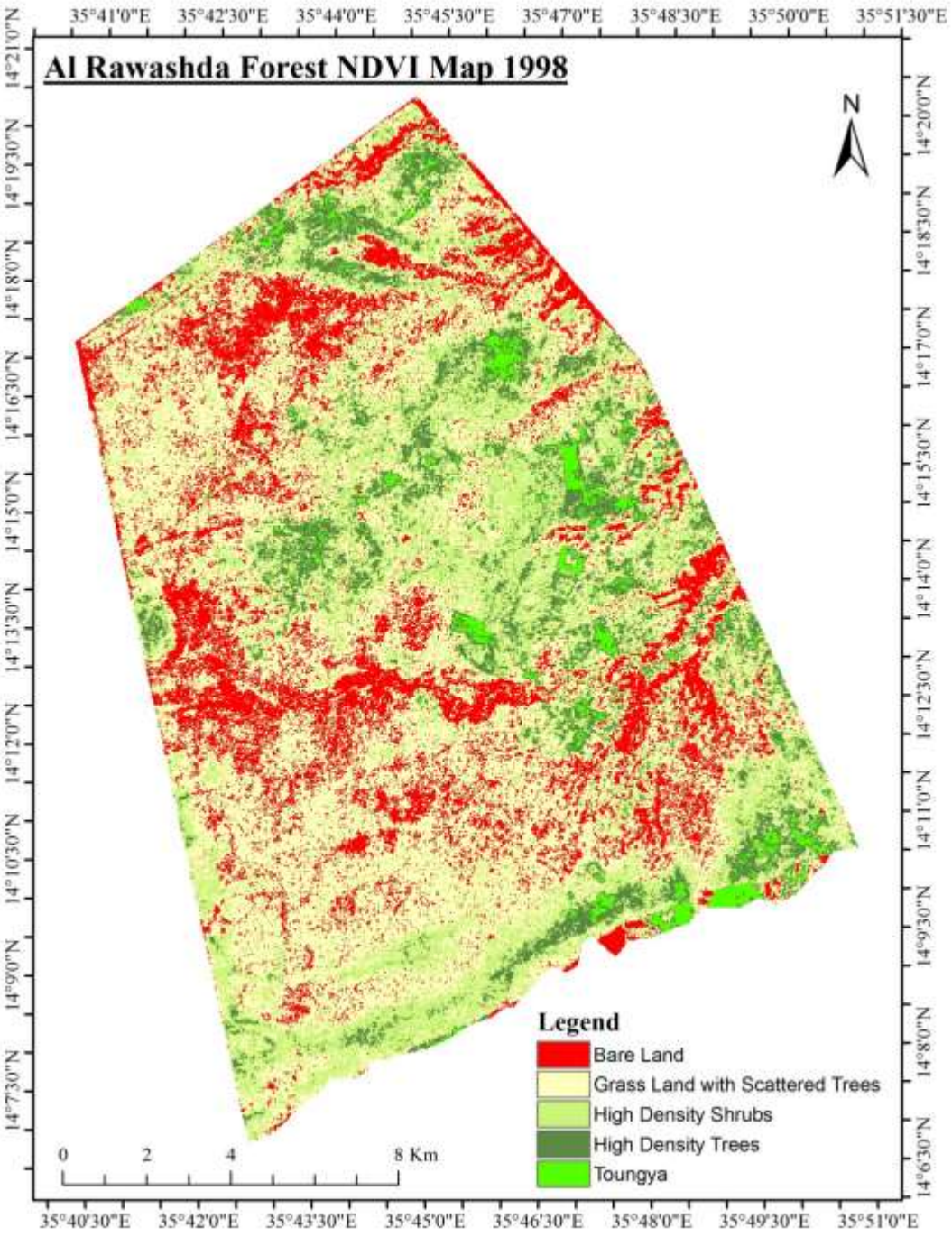


Figure 8. Forests Cover Map of El-Rawashda Forest in 1998

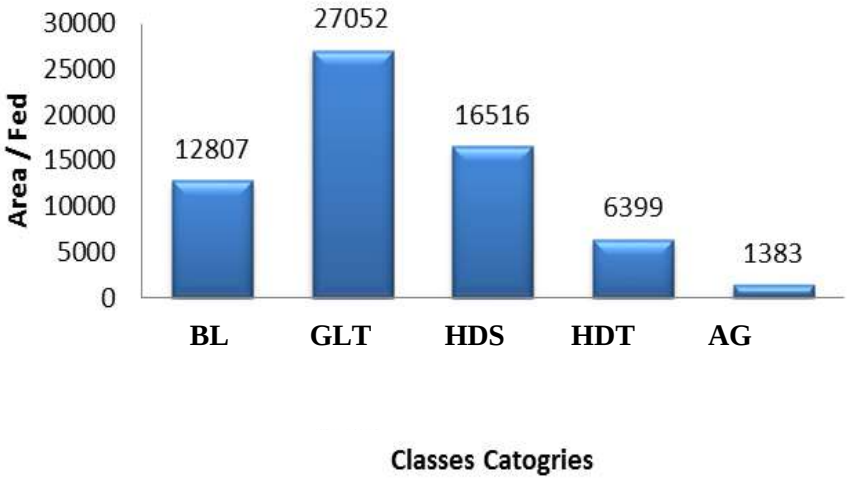


Figure 9. Differences in forest cover classes in 1998

5.2.2.3. Forest cover classification in 2007

In 2007 the HDS cover the highest area (26365.9 Fed) followed by GLS with an area coverage (16860.4 Fed) and then HDT with area coverage (12359.3 Fed) followed by BL with cover of (5059.1 Fed) and in the last AG with coverage (3511.7 Fed).

NDVI map 2007 showed that a clear decrease in NDVI values and increase in agricultural land compared with previous map of 1998 and that might be attributed to locusts attack in 2007 according to FAO annual report for the general situation of the desert locust and prediction 2007 in addition to fire effects.

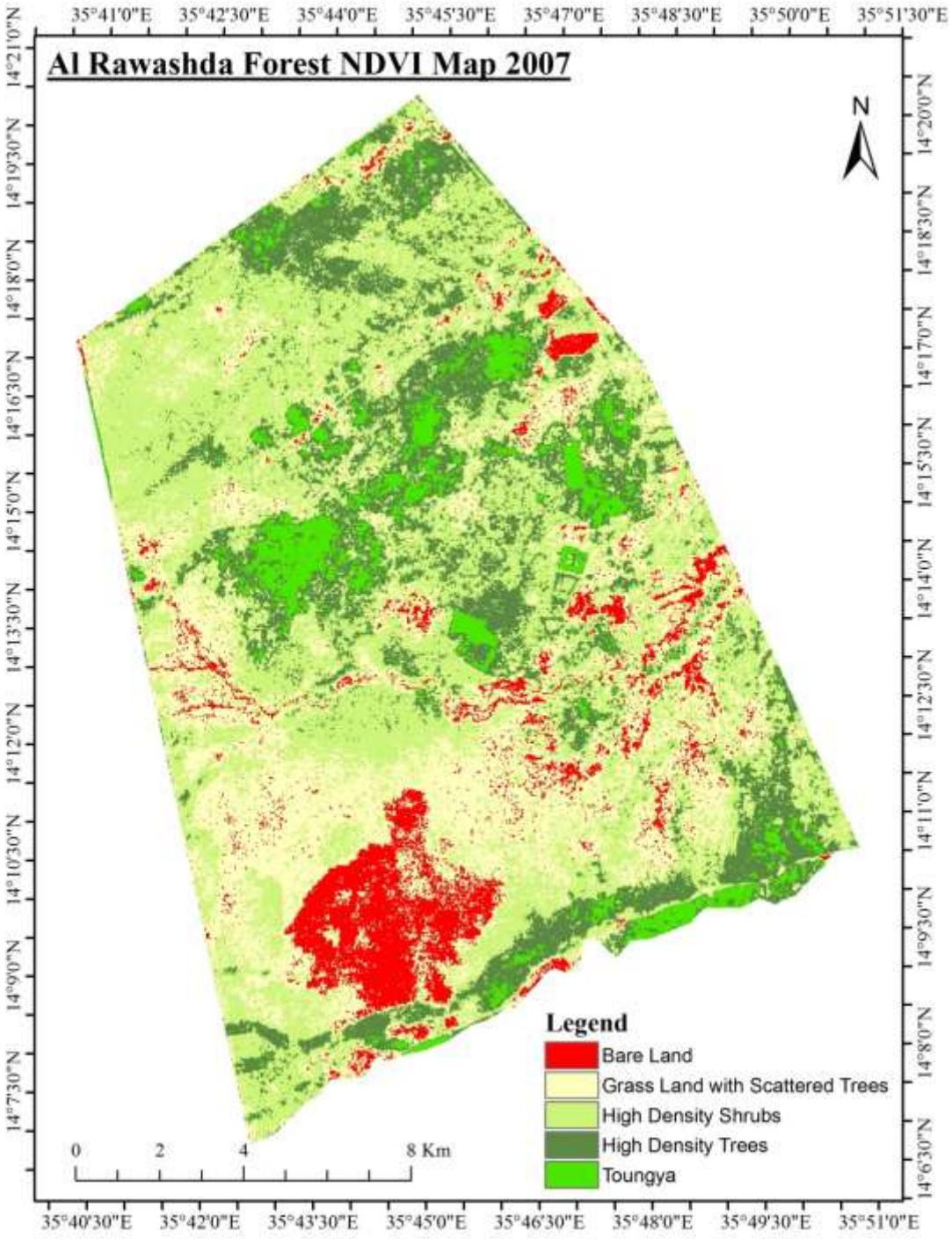


Figure 10. Forests Cover Map of El-Rawashda Forest in 2007

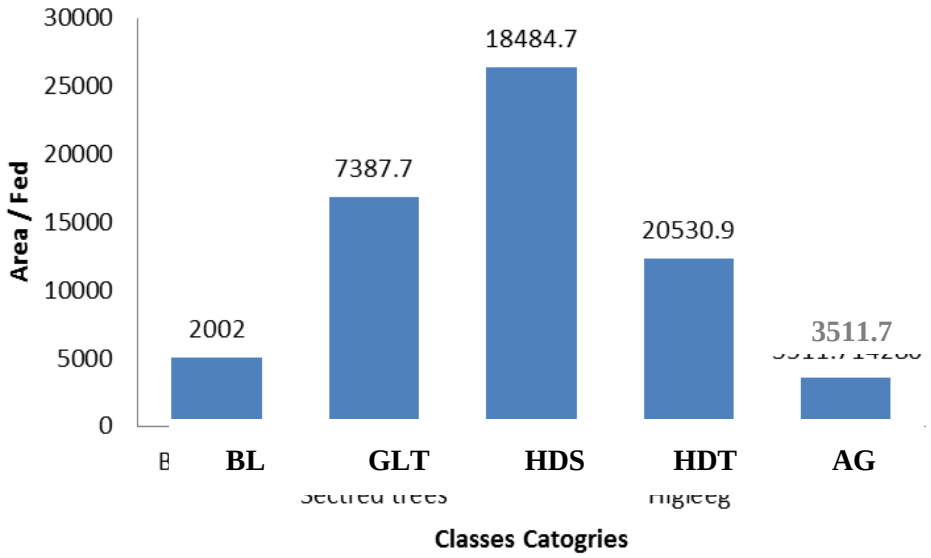


Figure 11. Differences in forest cover classes in 2007

5.2.2.4. Forest cover classification in 2018:

In 2018 forest cover map produced by NDVI map showed the highest coverage occupied by GLT (20520.8 Fed) followed by HDS with coverage (16399.3 Fed), HDT with area of (12559 Fed) flowed by AG with coverage (7514 Fed) and in the last BL with cover area (7163 Fed), respectively.

The forest cover map of 2018 showed that a clear change occurred in El-Rawashda forest compared with previous periods of 1988, 1998 and 2007. For example, agricultural activities have expansion inside forest under Toungya system and increase of the grassland. Also during the period a remarkable decrease of trees cover have been noticed at El-Rawashda forest. These changes in the forest could be attributed mainly to FNC management plan strategy.

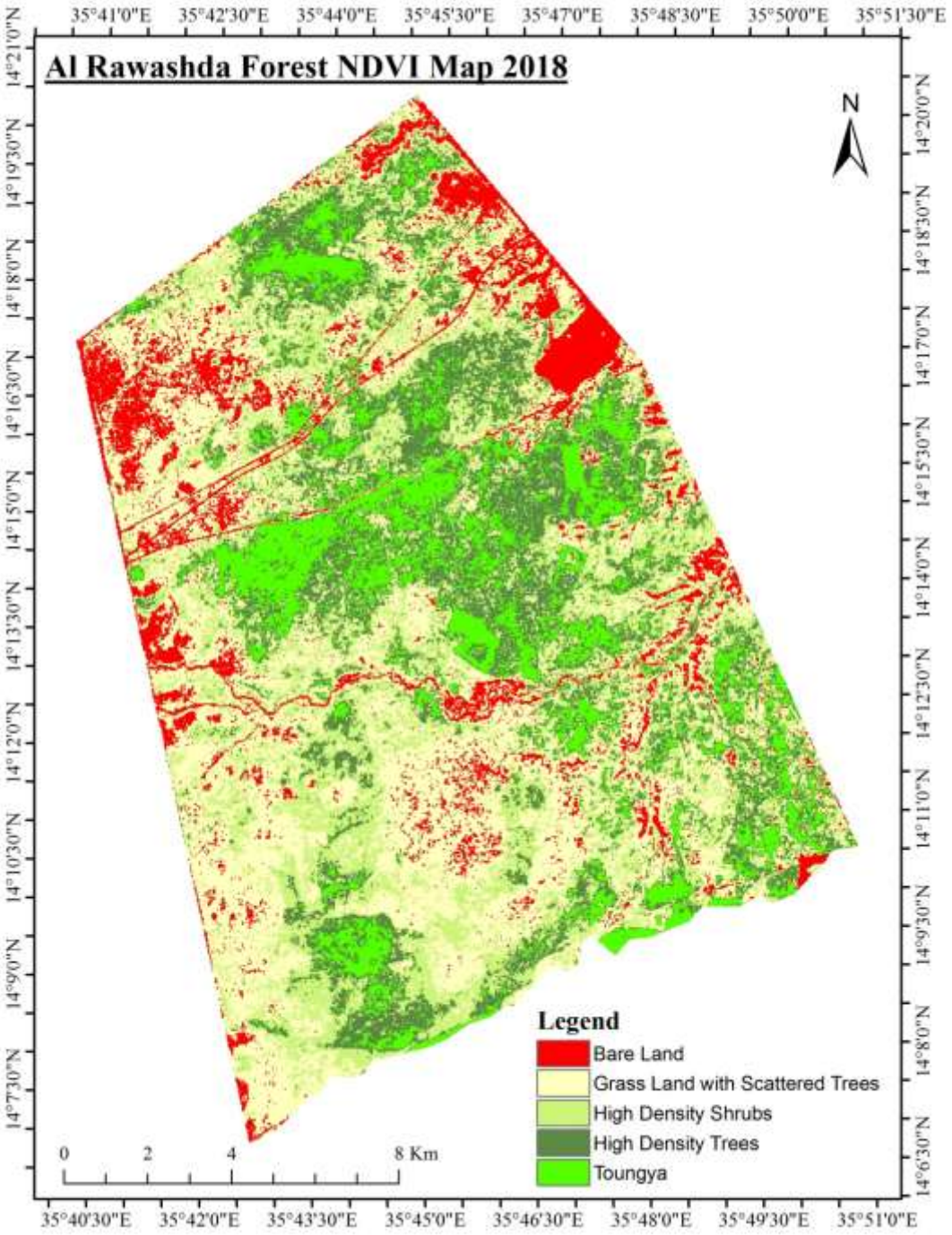


Figure 12. Forests Cover Map of El-Rawashda Forest in 2018

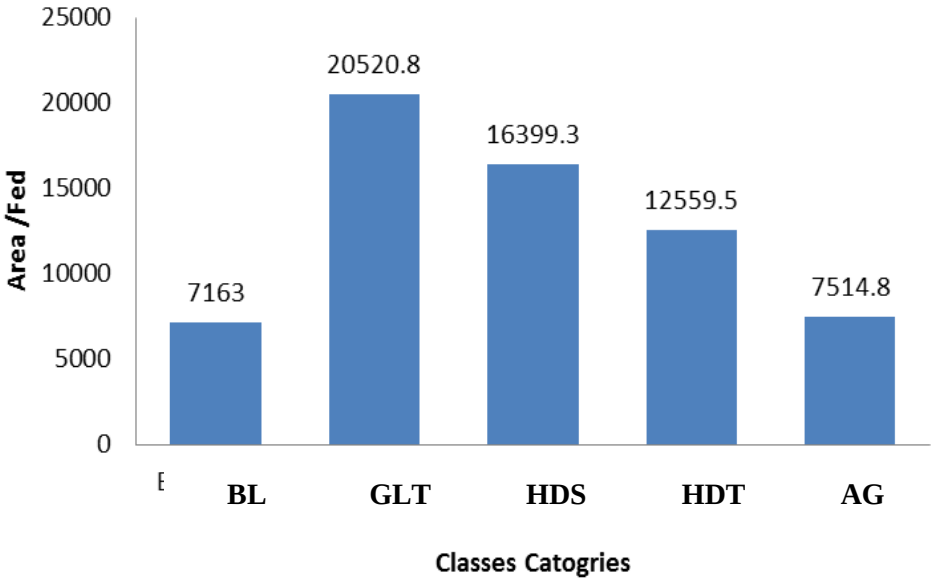


Figure 13. Differences in forest cover classes in 2018

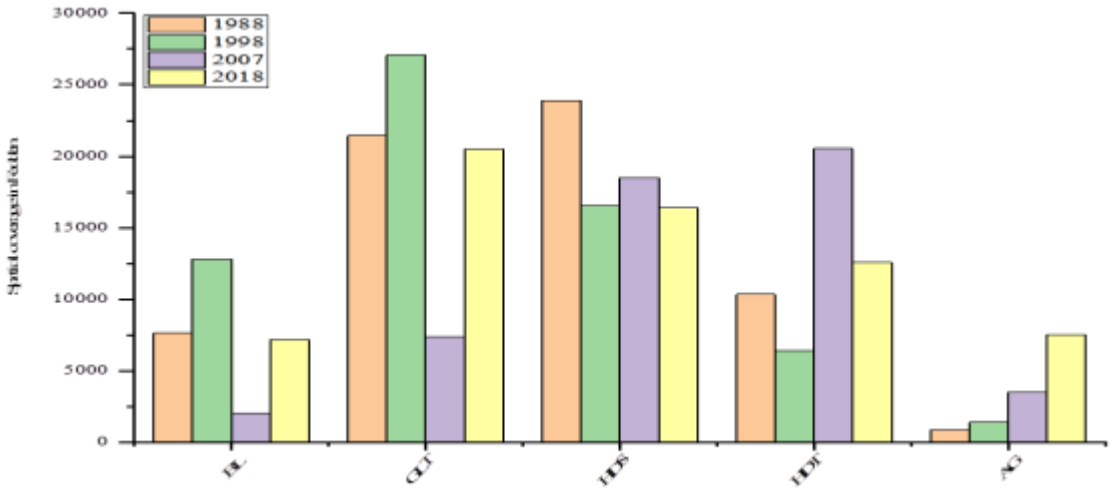


Figure 14. Classes Area of El-Rawashda Forest between 1988 and 2008

5.2.3. Annual linear regression:

Based on annual linear regression analysis principle (θ) *slope* value between -1 and 1 of mean annual-NDVI in EL-Rawashda forest during the period of 1988 - 2018 was conducted using Arc-Gis software. The images were reclassified from low to high value into seven categories according to Yagoub (2017) Which includes: significant degradation, moderate degradation, mild degradation, no change, mild improvement, moderate improvement and significant improvement.

Figure 15 and table 2. Showed there was generally improved of vegetation cover in center and northern part of El-Rawashda forest, while in eastern, southern part and some margin were under degradation. The spatial variation of vegetation cover in order are: significant degradation with spatial coverage of 244.5 fed which equal to 0.38 % of the total area; moderate degradation cover an area totaling 382.3 fed(2.1 %); mild degradation with an area of 1367.6 fed that account 2.13 %; no change occupying a total of 28737.4 (44.79 %) of the total forest area; mild improvement which cover an area of approximately 8841.9 fed account 13.78 % of the total area; moderate improvement with an area of 6700.1fed account 10.44 % whereas significant improvement extended over an area of 17883.9 fed account 27.87 % of the total El-Rawashda Natural Forest.

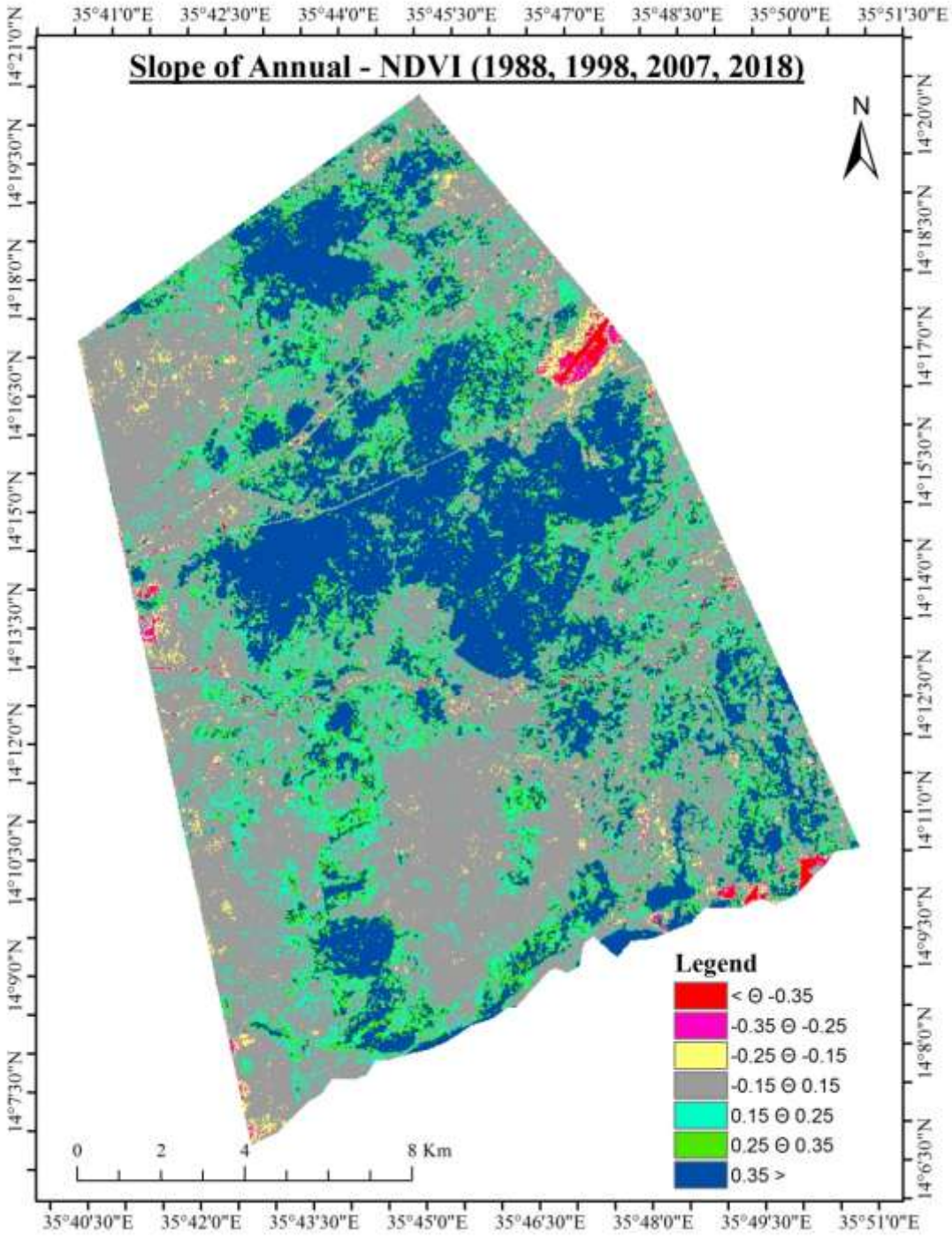


Figure 15. Slope of annual NDVI Map for the years 1988, 1998, 2007 and 2018

Table 2. Statistical Result of trend of mean annual-NDVI change simulated in El-Rawashda Natural Forest during 1988 – 2018

No.	Category	Θ Slope Range	Mean NDVI	
			Area / Fed	% of total area
1	Significant degradation	$\theta < -0.035$	244.5	0.38
2	Moderate degradation	$-0.035 < \theta > -0.025$	382.3	0.60
3	Mild degradation	$-0.025 < \theta > -0.015$	1367.6	2.13
4	No change	$-0.015 < \theta > 0.015$	28737.4	44.79
5	Mild improvement	$0.015 < \theta > 0.025$	8841.9	13.78
6	Moderate improvement	$0.025 < \theta > 0.035$	6700.1	10.44
7	Significant improvement	$\theta > 0.03$	17883.9	27.87

5.2.4. Relationship between vegetation cover and climate factors:

SPSS Program used to calculate the correlation coefficients between NDVI and spatial variation of climate factors in El-Rawashda forest during 1988 to 2018.

From SPSS result no significance between the factors and that refer to scarcity of comparative data (4 points), but in the figure 16 below we can seek a relation between greenness and rainfall. A sharp decline in greenness rate for 2007 year is due to locust attacks and fire on the Southwest side of the forest.

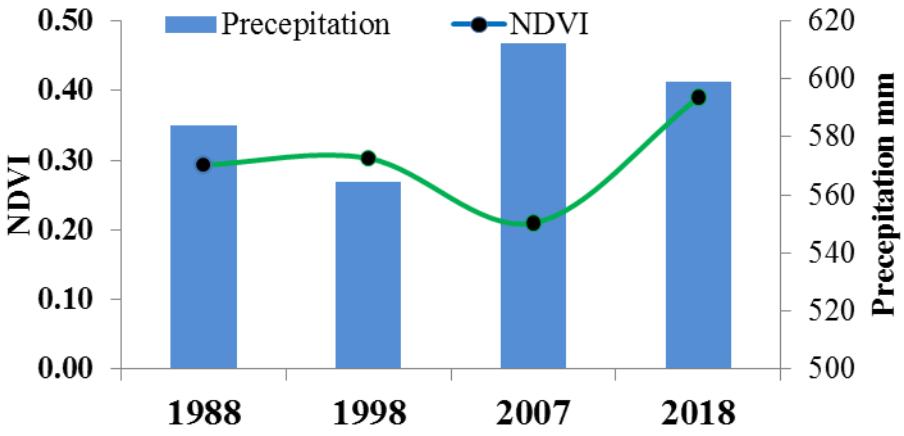


Figure 16. Relation between NDVI and rainfall

5.3. Socio-economic characteristic of respondents

5.3.1. Respondents Age group:

According to the results in table (3), the highest percentage was recorded for the age over than 30 years (61%). The respondents whose age ranged in this category are knowledgeable, more experiences and settled in the area for longtime. Therefore, they can explain significantly with their opinions and views about the drives behind forest cover change.

Table 3. The percentage of Respondents Age Group:

Categories	Frequency	Percent%
18 – 25	14	14
26 – 35	25	25
36 – 50	31	31
50 and above	30	30
Total	**100**	**100**
Sign	*****	

NS = Not Significant (p>0.5). * = significant (p<0.01). ** = high significant (p<0.001). *** = highly significant (p<0.0001).

5.3.2. Respondents Education level:

Table (4) indicates that majority of the households their education level were primary schooling with percentage of 35% followed by the secondary school education 25% and illiterate 21%.

This result consistent with the result of Adam *et al* (2008), which found that the majority of the population had a basic education.

Table 4. The percentage of respondents education level:

Categories	Frequency	%
Illiterate	21	21
Khalwah	7	7
primary education	35	35
Secondary education	25	25
University	12	12
Total	**100**	**100**
Sign	***	

5.3.3. Respondents marital status:

There was highly significant difference between the numbers of the respondents investigated in term of marital status, the result in table (5) showed that majority of them were married about 83%. These indicated future population growth projections, which required meeting the basic needs from the forest, therefore, in turn forest resources should be managed sustainably and maintain from deteriorating.

Table 5. Respondents marital status:

Categories	Frequency	Percent%
Single	15	15
Married	83	83
Widow	1	1
Divorce	1	1
Total	**100**	**100.0**
Sign	***	

5.3.4. Main activities practices by respondents:

According to the results in table (6) more than 49% of respondent practice farming as the main activity around and inside the forest by the name (Taungia system)

and outside forest in the rain-fed scheme and other respondents have another source of generating income such as trade and herd.

Agriculture is the most dominant land use activities in Gedaref State, which is considered the largest scheme of rain-fed mechanized farming in Sudan.

Table 6. Main activities in area:

Categories	Frequency	Percent%
Farmer	49	49
Herder	7	7
Trader	1	1
Employer	2	2
Labour	21	21
House keeper	20	20
Total	100	100
Sign	****	

5.3.5. Direct benefits gain from El-Rawashda Forest:

According to the results in table (7) the majority of people who lives in villages around the El-Rawashda forest are mainly dependent on firewood with high percentage of 93%, flowed by collecting resins 67% and forest fruits 63%. Also there is some other direct benefits gained from the forest like charcoal, building materials, source of traditional medicine, fodder and forage for animals and the environmental services and hunting.

In addition to the respondent reported that with percentage 88% there is indirect benefits gain from El-Rawashda forest represented in its environmental role on purify air from dust and improve the microclimate.

Table 7. Benefits gain from forest:

Answer	Fire wood		Charcoal		Building poles		Fruits		Resin	
	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%
benefits	93	93	41	41	31	31	63	63	67	67
No benefits	7	7	59	59	69	69	37	37	33	33
Total	100	100	100	100	100	100	100	100	100	100

Answer	Drugs		Recreation		Hunting		Fodder		Other	
	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%
Benefits	11	11	24	24	29	29	63	63	28	28
No benefits	89	89	76	76	71	71	37	37	72	72
Total	100	100	100	100	100	100	100	100	100	100

5.3.6. The changes of El-Rawashda forest:

Table (8) indicates that the highest percentage of respondent 97% have said there is change occurred in El-Rawashda forest and the majority of respondents (89%) believed that the type of change that occurred in forest is worse.

There results in agreement with result reported by Yagoub *et al*. (2015), which indicated the trees cover were decreased due to expansion of agriculture and bare land.

Table 8. The changes of Al Rawashda forest:

Answer	Frequency	Percent
Changed	97	97.0
Not changed	3	3.0
Total	100	100.0
Sign	***	

5.3.7. The change in the beginning and end of rainfall season

The results showed in figure (17&18) that the majority of people with high percentage (72%) agreed with the information that revealed about the change in beginning and end of rainy season. Whereas the rainy season is currently starting in July and continues until October, in previous years, people confirmed that the rainy season starts in June and end up to late October. Almost 52% of respondents claimed that the rain was an inadequate compared with same seasons of previous years.

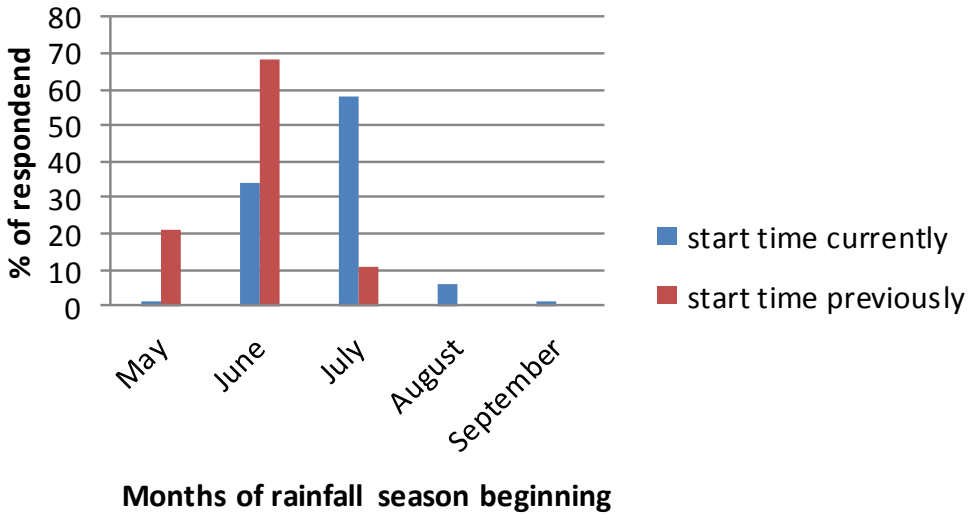


Figure 17. The change in the beginning of rainfall season

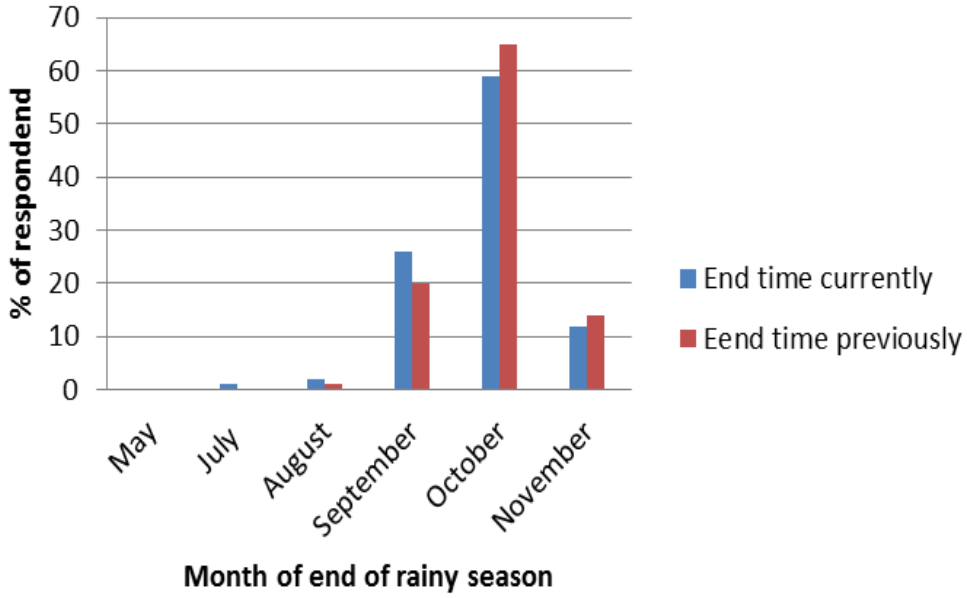


Figure 18. the change in the end of rainfall season

5.3.8. The difference in temperature

According to the results in table (9), about ninety percent of respondents around the forest said that there is change in temperature in area compared with previously years, and describe that change as increase in temperature degree and heating during the day time. However, this result is in line with meteorological data that showed fluctuation in maximum and minimum temperatures during the year.

Table 9. The difference in temperature:

Categories	Frequency	Percent
There is difference	90	90
No difference	10	10
Total	100	100
Sign	***	

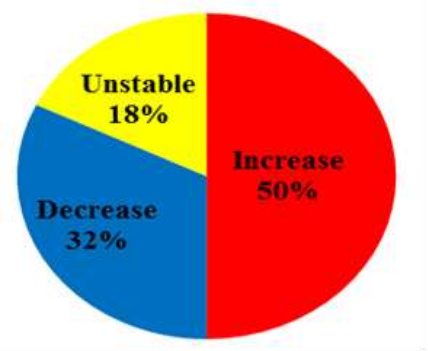


Figure 19. Type of change in temperature

5.3.9. Species of plants in El-Rawashda forest:

The result in table (10) showed that the dominant vegetation covers in the forest are *Acacia seyal, Acacia mellifra, Acacia senegal, Acacia oerfota, Balanites aegyptiaca, Ziziphus spina cresti*. According to FNC officer there are few of *Combretum ssp., Prosopis spp*. and *Dichrostashys ceineria*. The types of grasses and herbs inside El-Rawashda forest are *Cassia obtusifolia, Xanthium prazilucum, pennisetum sp, Osmium sp., Arstida sp., symbopogon nervatus*. From local community observation with highly significance (85%) and according to FNC record all types of plant species are present in forest now compared with the previous years and there was a difference in dominant species whereas *Acacia mellifra* shrubs and *Acacia oerfota* are the dominant species compared to the previous years, which was dominated by trees of *Acacia seyal, Acacia senegal* and *Balanites aegyptiaca* and they have explained that difference to over-cutting and selective clearance of tree species .

Table 10. The plant species existed in past and now disappeared

	Acacia seyal		*Acacia mellifra*		*Acacia Senegal*		*Acacia oerfota*		*Balanites aegyptiaca*		*Ziziphus spina cristi*	
	Freq.	**%**	**Freq.**	**%**	**Freq.**	**%**	**Freq.**	**%**	**Freq.**	**%**	**Freq.**	**%**
Existed	84	84	82	82	72	72	65	65	48	48	44	44
Not ex.	16	16	18	18	28	28	35	35	52	52	56	56
Total	100	100	100	100	100	100	100	100	100	100	100	100

5.3.10. Wild life living in El-Rawashda Forest:

The respondents were agreed with percentage of 75% there are some wild animals inside El-Rawashda forest include Foxes, Rabbits, Snakes, Hystrix and birds. And compared with past the respondents with highly significance (85%) said there are types of animals disappeared including Elephants, Gazelles, Hyenas, Lions and leopard.

5.3.11. Types of insects affected forest trees

The result in table (11) demonstrated that there were some types of insects affecting the forest trees include Borer Beetles, Dura Bug, Locusts and Bark Larva's. Respondents with highly significance (85%) agreed with the severe damage and impact of locusts during rainy season and winter.

Table 11. Types of insects affected forest trees:

Categories	**Borer Beetles**		**Dura Bug**		**Locusts**		**Bark Larva's**	
	Freq.	**%**	**Freq.**	**%**	**Freq.**	**%**	**Freq.**	**%**
Yes	12	12	13	13	77	77	13	13
No	88	88	87	87	23	23	87	87
Total	100	100	100	100	100	100	100	100

5.3.12. Fire incident in the forest:

It's clear from the figure (20) that (61%) of respondents reported that there is not any large fires occurred inside the forest. While some fires incidents very rarely made damage to the trees and shrubs.

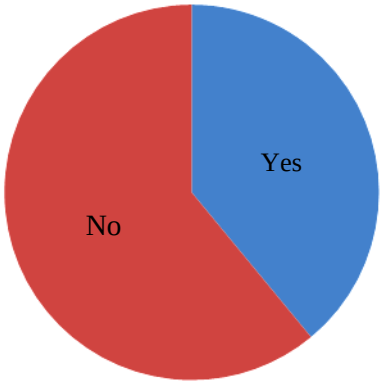


Figure20. Fire happen inside the forest:

5.3.13. Agriculture Practice inside the forest

Table (12) showed that, the majority of respondents (99%) answered that there is agricultural practice inside El-Rawashda forest under Toungia system to rehabilitate the forest besides the cultivated crops. Usually, the crops that growing are Sorghum sp., Sesamum sp. and Panicum sp.

Table 12. Agricultural practices inside the forest:

Answer	Frequency	Percent
Practiced	99	99
Not Practiced	1	1
Total	100	100
Sign	***	

5.3.14. Grazing or browsing inside forest:

According the result in table (13), most of respondent (97%) said that, there is grazing activities practiced inside El-Rawashda forest and the types of animals are camels, sheep's, goats and cows. According to respondent pastoralist in past grazed inside the forest at most months of year except the rainy season. But right now the pastoralist and their animals were practicing grazing inside the forest intensively during June, July and November and outside these period animals are grazing in Butana area or in agricultural schemes.

Table 13. Grazing or browsing inside forest:

Answer	Frequency	Percent
Practiced	97	97
Not practiced	3	3
Total	100	100
Sign	***	

5.3.15. Forest as a source of fodder in scarcity period:

It's clear from the table (14) respondents agree with percentage of 88% on the role of El-Rawashda forest as providing fodder especially during scarcity period, and

this result is consistent with FAO (2017) noted that forest trees contribute around 30% of animal feed per annum and over 70% in dry seasons.

Table 14. Forest as a source of fodder in scarcity period:

Answer	Frequency	Percent
Yes	88	88.0
No	12	12.0
Total	100	100.0
Sign	***	

5.3.16. Prevalence of grazing inside or outside the forest:

The result from table (15) showed the respondent with percentage of 65% prefer the grazing inside forest for plenty of shade and free of cost.

Table 15. Prevalence of grazing inside or outside the forest

Categories	Frequency	Percent
Inside	65	65.0
Outside	35	35.0
Total	100	100.0
Sign	**	

5.3.17. Knowledge about climate change

According the result in table (16), the most of respondents with percentage of 64% don't heard about climate change word, and that could be due to lack of awareness that should introduced by extension department of FNC.

Table 16. Knowledge about climate change

Categories	Frequency	Percent
Yes	64	64.0
No	36	36.0
Total	100	100.0
Sign.	**	

5.3.18. Role of FNC in awareness improvement

Table (17) the lack of awareness programs provided by FNC in the villages surrounded the forest and at that area where the 66% of respondents said there are no extension program provided by forests office to local community around the forest.

Table 17. Role of FNC in awareness improvement

Categories	Frequency	Percent
Active	34	34.0
Not active	66	66.0
Total	100	100.0
Sign.	**	

5.3.19. Legislations prevent cutting and organize entering into the forest

Table (18) showed that, the significance percentage of respondent (77%) answered that legislations and law of forest organize the entering and benefits could be gained out of El-Rawashda forest.

Table 18. Legislations prevent cutting and organize enter to forest

Categories	Frequency	Percent
Yes	77	77.0
No	23	23.0
Total	100	100.0
Sign.	***	

5.4 The variations between sites in soil factors

It's known that the surface soil layer is most affected by climatic factors and land use in the specific area. As a result, soil samples were taken for different sites in El-Rawashda Forest to determine the difference in organic matter and acidity and alkalinity of the soil which may affect the pattern of land uses beside the soil type.

The result of the analysis of soil samples in table (19) showed that there is no difference in pH of the soil in different locations and the acidity ranged from 8.05 to 8.46, while the organic matter result showed significance deference between the BL and AG sites.

Table 19. Analysis of soil in study area

Categories	pH	Organic Carbon	Organic Matter
Bare Land	8.05 a	0.89 a	1.54 a
Grass Land	8.27 a	0.72 ab	1.24 ab
Shrubs	8.46 a	0.76 ab	1.31 ab
Trees	8.30 a	0.74 ab	1.27 ab
Taungya	8.40 a	0.55 b	0.94 b

Means with the same letter are not significantly different at alpha= 0.05

Table 20. Analysis of variance to organic carbon and organic

matter:

Source	D.F	Mean sq.		F. value		P>F	
		O.C	O.M	O.C	O.M	O.C ns	O.M
Sample	4	0.03	0.091	2.86	3.07	0.16 ns	0.15 ns
Rep.	1	0.02	0.057	1.28	1.93	0.24 ns	0.23 ns

ns: no significant differences at alpha =0.05

5.5. Aridity index in El-Rawashda Forest:

Aridity index is term that used globally to measure dryness of the climate at a given location and its using six subtypes of arid lands or dry lands to classify the location which: hyper-arid, arid, semi-arid, dry sub humid and humid.

We used the annual precipitation and potential evapotranspiration for 2018 season in El-Rawashda forest to calculate the aridity index where the rainfall for the year 2018 is 599.1 mm and the amount of evaporation in the region according to the global aridity index for the central region of Sudan 2500 and above 0.24. This figure in the standard aridity index table within the range of semi-arid land (0.2 – 0.5). This is in line with Musa (2018) that Gedaref is located in semi-arid region which requires more special adaptations to the environment in the light of fluctuating rainfall and high temperatures.

CHAPTER SIX
CONCLUSIONS AND RECOMMENDATIONS

6.1. Conclusion

The study was concluded that remarkable change from the satellite remotely sensed images showed in El-Rawashda Natural Reserved Forest cover as well slope calculation indicates that forest change is equals to 56% that distributed between degradation and development. Almost 97% of local people confirmed that there was a big change occurred in from 1988 and 2018 and this change was attributed to climate factors and human induced. In addition, majority of people living around El-Rawashda Reserved Forest are mainly dependent on goods and services provided by forest with 93% such as firewood, charcoal, fodder and forage, building materials and traditional medicine.

6.2. Recommendation:

Due to high complexity of different factors that responsible of forest cover change the study recommends that:

- Monitoring forests using modern techniques and indicators related to climate change.

- The basic needs of local community especially around the forest should be taken into consideration by FNC.

- More attention should be paid by FNC regarding agricultural practices (Taungya) in order rehabilitate and mange forest on sustainable manner.

- Activate protection and increasing the number and facilities of guards.

- Reactivate the role of extension programs in community awareness.

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APPENDIXES

Appendix 1. Accuracy assessment matrix

Error matrix

Categories	Class types determined from reference source					
Class types determined from classified map	Plots	BL	GLT	HDS	HDT	AG	Total
	BL	14	1	0	0	0	15
	GLT	0	13	0	1	1	15
	HDS	0	2	12	0	1	15
	HDT	0	0	0	15	0	15
	AG	0	0	0	0	15	15
	Total	14	16	12	16	17	75

Quantifying accuracy

Total Accuracy = Number of correct plots / total number of plots

$$= \frac{14+13+12+15+15}{75} \times 100\%$$

= 92 %

User's Accuracy = Number correctly identified in a given map class /

Number claimed to be in that map class

Accuracy users BL = $\frac{14}{15} \times 100\%$ = 93.3%

Accuracy users GLT = $\frac{13}{15} \times 100\%$ = 86.6%

Accuracy users HDS = $\frac{12}{15} \times 100\%$ = 80%

Accuracy users HDT = $\frac{15}{15} \times 100\%$ = 100%

Accuracy users AG = $\frac{15}{15} \times 100\%$ = 100%

Producer's Accuracy = Number correctly identified in ref. plots of a given class / Number actually in that reference class

Accuracy producers BL = $\frac{14}{14} \times 100\%$ = 100%

Accuracy producers GLT = $\frac{13}{16} \times 100\%$ = 81.25%

Accuracy producers HDS = $\frac{12}{12} \times 100\%$ = 100%

Accuracy producers HDT = $\frac{15}{16} \times 100\%$ = 93.75%

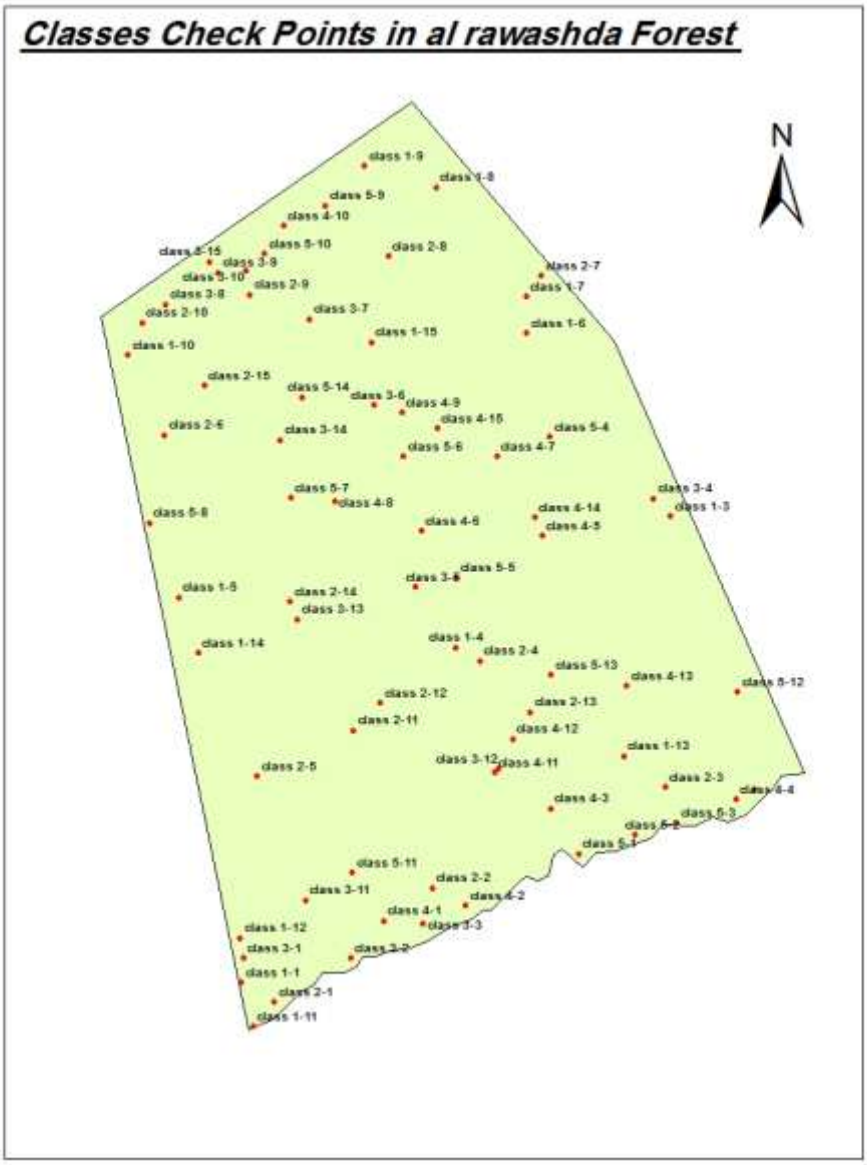
Accuracy producers AG = $\frac{15}{17} \times 100\%$ = 88.23%

Accuracy Assessment Summary

Categories	Class types determined from reference source						Total	User's Accuracy
Class types determined from classified map	Plots	BL	GLT	HDS	HDT	AG		
	BL	14	1	0	0	0	15	93.33%
	GLT	0	13	0	1	1	15	86.66%
	HDS	0	2	12	0	1	15	80%
	HDT	0	0	0	15	0	15	100%
	AG	0	0	0	0	15	15	100%

	Total	14	16	12	16	17	75	Total 92%
Producer's Accuracy		100%	81.25%	100%	93.75%	88.23%		

Appendix 2. Accuracy point distribution:



Appendix 3. Observation form:

FIELD DATA
GENERAL PURPOSE

Project Name _____ Date/Time _____/_____

Site ID/Photo Reference _____/_____ Observer _____

GPS Grid _____ Coordinates X: _____ Y: _____

LAND USE _____

TOPOGRAPHIC INFORMATION

Slope angle _____ Slope Aspect _____

SOILS INFORMATION

Texture: sandy _____ silt _____ clay _____ loam _____

stony _____ soil absent _____ parent material _____

Moisture: dry _____ moist _____ saturated _____

signs of seasonally waterlogged soil _____

Color: _____

VEGETATION INFORMATION

Physiognomic Type _____

		Dominant Species	% Cover
Top Layer	1	_____	_____
	2	_____	_____
Intermediate	1	_____	_____
	2	_____	_____
Ground Layer	1	_____	_____
	2	_____	_____

COMMENTS

_____

Adapted from Joyce (1978).

Appendix 4. Questionnaire sample:

Household Questionnaire

Title: ***Assessment of Forests Resources Using Some Selected Indicators Related to Climate Change - Case study of Al Rawashda forest GEDAREF STATE / SUDAN***

NOTE: *All responses are confidential and will be used for this study only*

Firstly, just so that I can compare the views of different people's, please could you tell me about yourself?

(A) General Information:

1- Sex: ☐ le F☐ le

2- Age: ……..

3- The education level?

Illiterate ☐ alwah ☐ primary education ☐ econdary education ☐

University ☐ other, please write ……

4- Marital status: ☐ le m☐ ed v☐ w ☐ rs

5- Occupation: ☐ er animal h☐ er ☐ er em☐ yer

Other, please write ……

6- How many years you are been in al Rawashda area? Less ☐ 5 5☐ 10 1☐ - 30 ☐ 30 - 50 ☐ e than 50

(B) The benefits provided by the forest:

7- what is types of benefits provided to you by al Rawashda forest :

Fire wood ☐ charcoal ☐ Belding poles ☐ fruits ☐ resin ☐ drugs ☐ recreation ☐ hunting ☐ fodder ☐ other ……

8- How you gain the benefits from forest? .....

…….

9- Are there some other benefits gains from al Rawashda forest?

Yes ☐ No ☐

If your answer (yes) please nominates those benefits: ……..

…….

(C) The impacts of rainfall and temperature on al Rawashda forest:

10- Do you think there are changes in the forest throughout your stay in the area?

Yes ☐ No ☐

If your answers (yes) please describe the types of changes and its place:

…….

11- Do you think the changes in forest was gone to better or worse?

To better ☐ to worse ☐

The reasons: …….

12- In your opinion, are there any change in the beginning and end of rainfall season compared with the previous years (15 year and ove)? Yes ☐ No

	Months											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Currently												
Previously (15 >)												

13- Is the amount of rainfall in recent years enough compared to previous years (15year and above)? ☐equate U☐equate

If your answer (yes), please explain: ……..

14- Is there a difference in temperature compared to previous years (15year and above)?

Yes ☐ No ☐

If your answer (yes), please explain the type of deference: Increase Decrease Unstable ☐ ☐

15- Please, mention the species of plants in Al Rawashda forest at now dates?

……

……

……

16- Are there some plants that existed in past and have no disappeared? ☐s ☐No

If your answer (yes), describes the species and the reason for their disappearance:

……

……

17- Are you seen wild life and birds living in the forest? Yes No

If your answer (yes), describes the species: ……☐……☐……

……..

18- Are you heard or know some wild animals and birds that existed in past and have right now disappeared? ☐ ☐

If your answer (yes), describes the species: ……

……..

(D) <u>The impacts of other factors on Al Rawashda forest:</u>

19- Please, can you tell us if there any types of insects of diseases affected forest trees, and its types? ……

……

20- Are there any types of insects in forest? ☐es ☐No

If your answer (Yes), Please named it and the months when the insect is many: ….

……
……

21- Is there a fire happening inside the forest? ☐es ☐No

If your answer (Yes), please list the years, months and the reasons of fire: ……..

……
……

(E) <u>The impacts of land use on Al Rawashda forest:</u>

22- Are there any types of agriculture inside the forest? ☐s ☐o

If yes, list the agricultural system used and the species: ……...

……

23- Are there any types of grazing or browsing inside forest? ☐s ☐o

If yes, please named the type of animals: ……....

……

24- What are the periods when the pastoralists are being inside the forest?

	Months											
	1	2	3	4	5	6	7	8	9	10	11	12

Currently												
Previously (15 >)												

25- Is the forest a source of fodder in scarcity period? ☐ Yes ☐ No

26- Are there any other grazing places outside forest? ☐ Yes ☐ No

27- Is the pastoralists' preferred grazing inside or outside the forest? Inside ☐ outside ☐

……..……

(F) **The role of forests office and related entities in awareness on climate change:**

28- Are you heard about climate change word? ☐ Yes ☐ No

If yes, explain when you heard it: ……

29- Does the forests office organize sessions to improve local community awareness?

Yes ☐ No ☐

30- Are there any roles or legislations prevent cutting and organize enter to forest?

Yes ☐ No ☐

31- Please give us your suggestion about forest for forest office:

……..…

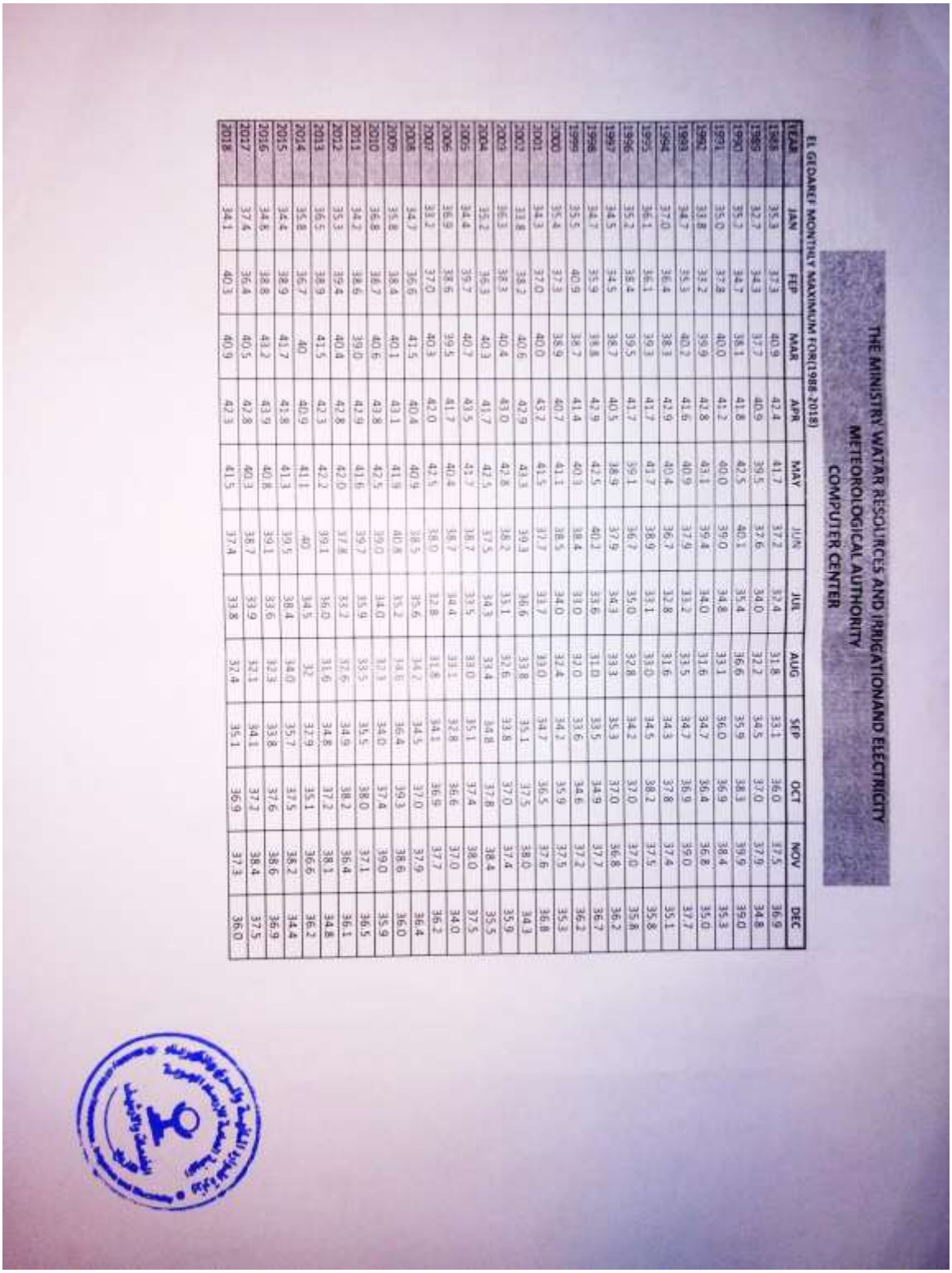
……..

……

……...

Thank you for your valuable information & time

Appendix 5. Metrological data:



THE MINISTRY WATAR RESOURCES AND IRRIGATIONAND ELECTRICITY
METEOROLOGICAL AUTHORITY
COMPUTER CENTER

EL GEDAREF MONTHLY MAXIMUM FOR(1988-2018)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1988	35.3	37.3	40.9	42.4	41.7	37.2	32.4	31.8	33.1	36.0	37.5	36.9
1989	32.7	34.3	37.7	40.9	39.5	37.6	34.0	32.2	34.5	37.0	37.9	34.8
1990	35.2	34.7	38.1	41.8	42.5	40.1	35.4	33.6	35.9	38.3	39.9	39.0
1991	35.0	37.8	40.0	41.2	40.0	39.0	34.8	33.1	36.0	36.9	38.4	35.3
1992	33.8	33.2	39.9	42.8	43.1	39.4	34.0	31.6	34.7	36.4	36.8	35.0
1993	34.7	35.3	40.2	41.6	40.9	37.9	33.2	33.5	34.7	36.9	39.0	37.7
1994	37.0	36.4	38.3	42.9	40.4	36.7	32.8	31.6	34.3	37.8	37.4	35.1
1995	36.1	36.1	39.3	41.7	41.7	38.9	33.1	33.0	34.5	38.2	37.5	35.8
1996	35.2	38.4	39.5	41.7	39.1	36.7	35.0	32.8	34.2	37.0	37.0	35.8
1997	34.5	34.5	38.7	40.5	38.9	37.9	34.3	33.3	35.3	37.0	36.8	36.2
1998	34.7	35.9	38.8	42.9	42.5	40.3	33.6	31.0	33.5	34.9	37.7	36.7
1999	35.5	40.9	38.7	41.4	40.3	38.4	33.0	32.0	33.6	34.6	37.2	36.2
2000	35.4	37.3	38.9	40.7	41.1	38.5	34.0	32.4	34.7	35.9	37.5	35.3
2001	34.3	37.0	40.0	43.2	41.5	37.7	33.7	33.0	34.7	36.5	37.6	36.8
2002	33.8	38.2	40.6	42.9	43.3	39.3	36.6	33.8	35.1	37.5	38.0	34.3
2003	36.3	38.3	40.4	43.0	42.8	38.2	33.1	32.6	33.8	37.0	37.4	35.9
2004	35.2	36.3	40.3	41.7	42.5	37.5	34.3	33.4	34.8	37.8	38.4	35.5
2005	34.4	35.7	40.7	43.5	42.7	38.7	33.5	33.0	35.1	37.4	38.0	37.5
2006	36.9	38.6	39.5	41.7	40.4	38.7	34.4	33.1	32.8	36.6	37.0	34.0
2007	33.2	37.0	40.3	42.0	42.5	38.0	32.8	31.8	34.1	36.9	37.7	36.2
2008	34.7	36.6	41.5	40.4	40.9	38.5	35.6	34.7	34.5	37.0	37.9	36.4
2009	35.8	38.4	40.1	43.1	41.9	40.8	35.2	34.6	36.4	39.3	38.6	36.0
2010	36.8	36.7	40.6	43.8	42.5	39.0	34.0	32.3	34.0	37.4	39.0	35.9
2011	34.2	38.6	39.0	42.9	41.6	39.7	35.9	33.5	35.5	38.0	37.1	36.5
2012	35.3	39.4	40.4	42.8	42.0	37.8	33.2	32.6	34.9	38.2	36.4	36.1
2013	36.5	38.9	41.5	42.3	42.2	39.1	36.0	31.6	34.8	37.2	38.1	34.8
2014	35.8	36.7	40	40.9	41.1	40	34.5	32	32.9	35.1	36.6	36.2
2015	34.4	38.9	41.7	42.8	41.3	39.5	38.4	34.0	35.7	37.5	38.2	34.4
2016	34.8	38.8	43.2	43.9	40.8	39.1	33.6	32.3	33.8	37.6	38.6	36.9
2017	37.4	36.4	40.5	42.8	40.3	38.7	33.9	32.1	34.1	37.7	38.4	37.5
2018	34.1	40.3	40.9	42.3	41.5	37.4	33.8	32.4	35.1	36.9	37.3	36.0

EL GEDAREF MONTHLY MINIMUM FOR (1988-2018)

YEAR	JAN	FEP	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1988	17.1	18.1	22.0	23.9	26.9	23.2	21.8	21.7	21.6	22.3	20.8	19.3
1989	14.0	15.7	20.1	23.3	25.5	23.0	21.8	21.5	22.2	22.4	22.3	17.8
1990	17.3	17.4	20.1	23.8	26.3	25.6	22.2	21.8	22.4	23.7	22.9	21.0
1991	17.8	18.7	21.0	26.3	24.8	24.8	22.8	22.1	23.3	23.2	21.8	17.7
1992	15.4	14.9	20.7	25.1	26.3	24.4	21.7	21.3	22.1	22.7	21.3	17.3
1993	16.5	16.7	21.8	24.6	25.4	23.7	21.8	21.4	22.1	22.7	22.8	20.3
1994	19.7	18.5	19.6	25.7	26.2	23.0	21.8	21.1	22.1	22.9	21.7	18.0
1995	18.7	18.7	21.4	24.1	25.3	22.8	20.9	20.8	21.4	22.7	21.6	19.0
1996	17.7	17.5	22.0	24.7	24.5	22.3	22.4	21.6	22.3	23.0	21.5	20.1
1997	17.9	17.0	21.8	24.7	26.0	23.5	22.5	21.5	22.7	22.9	21.9	19.5
1998	17.3	18.3	21.4	25.2	26.8	24.9	22.7	21.4	21.9	22.7	22.7	20.5
1999	18.8	22.7	20.9	24.3	25.4	23.5	21.6	21.0	21.2	21.7	21.4	19.9
2000	18.0	19.7	21.1	25.2	26.7	24.3	21.8	21.6	21.6	21.9	21.3	18.4
2001	16.8	18.9	23.3	26.3	26.2	23.6	21.7	21.5	22.3	23.0	22.3	21.1
2002	16.4	20.4	22.5	25.7	25.7	24.7	22.8	21.5	22.0	23.3	23.4	18.1
2003	18.7	20.2	22.1	25.4	27.2	23.7	21.7	21.5	21.9	22.9	22.0	19.3
2004	18.4	18.8	22.7	25.5	26.6	23.6	22.0	21.7	22.4	22.7	22.9	18.5
2005	16.8	21.1	22.5	26.1	25.3	24.5	22.0	21.7	22.4	23.2	22.2	20.7
2006	19.7	20.4	22.0	25.1	25.6	23.7	22.4	21.7	21.5	22.9	20.9	17.4
2007	16.0	18.8	21.7	25.1	27.7	27.7	22.0	21.3	22.0	22.8	22.7	20.2
2008	18.8	19.2	23.6	25.7	24.7	23.9	22.2	21.7	22.3	22.7	22.2	20.1
2009	19.0	21.7	22.2	26.6	27.4	25.1	22.0	22.2	23.1	23.7	22.2	19.3
2010	20.1	21.6	23.6	27.0	27.0	24.3	22.9	22.0	22.2	23.4	23.4	20.1
2011	17.7	20.6	21.5	25.8	26.2	25.7	23.5	22.0	22.9	23.4	20.5	19.3
2012	17.6	20.6	21.4	24.5	27.1	24.1	22.1	21.7	22.4	23.1	22.1	19.8
2013	19.5	21.3	23.2	24.5	27.2	25.4	23.6	21.7	22.5	23.2	22.8	20.3
2014	19.3	19.9	23.5	25.7	26.1	25.1	22.7	21.7	22.1	23.2	22.2	20.9
2015	17.7	21.5	25.0	25.0	27.3	25.2	24.5	22.4	23.6	24.0	23.3	18.3
2016	17.5	20.4	25.5	26.2	27.0	24.6	22.5	22.3	23.0	24.0	22.9	19.3
2017	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	22.6	ND
2018	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	21.9	ND

GEDAREF MONTHLY RAIN FALL (MM) FOR (1988-2018)

YEAR	JAN	FEP	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1988	0.0	0.0	0.0	0.0	10.8	99.9	151.4	228.8	92.0	1.1	0.0	0.0	584.0
1989	0.0	0.0	0.0	1.0	14.1	132.2	158.3	354.2	90.1	10.0	1.4	0.0	761.3
1990	0.0	0.0	0.0	0.0	6.2	36.7	116.7	72.7	136.1	3.5	0.0	0.0	371.9
1991	0.0	0.0	0.0	16.8	66.8	17.5	115.7	147.9	29.9	23.5	0.7	0.0	418.8
1992	0.0	0.0	4.0	0.0	6.8	20.8	229.2	196.1	61.3	55.9	0.0	0.0	574.1
1993	0.0	0.0	0.0	13.5	44.2	81.4	201.2	301.3	133.1	2.3	0.0	0.0	777.0
1994	0.0	0.0	0.0	0.2	24.8	63.6	278.6	189.4	75.4	3.4	0.0	0.0	635.4
1995	0.0	0.0	0.0	5.9	5.4	80.8	198.8	142.9	96.2	0.0	0.0	0.0	530.0
1996	0.0	0.0	17.1	2.0	115.4	81.9	87.7	337.2	89.2	8.0	0.0	0.0	738.5
1997	0.0	0.0	0.0	3.6	21.0	72.9	183.2	222.0	55.8	14.4	1.4	0.0	574.3
1998	0.0	0.0	0.0	2.2	5.0	23.3	107.7	290.0	112.2	23.9	0.0	0.0	564.3
1999	0.0	0.0	0.0	0.0	59.5	114.9	210.8	343.1	94.7	48.4	1.2	0.0	872.6
2000	0.0	0.0	0.0	6.7	8.9	100.5	230.4	180.6	76.8	40.2	0.0	0.0	644.1
2001	0.0	0.0	0.0	0.0	29.8	54.4	93.4	127.4	114.3	86.6	1.2	0.0	507.1
2002	0.0	0.0	9.2	4.4	2.2	95.7	200.5	290.7	107.9	43.7	0.0	0.0	754.3
2003	0.0	0.0	0.0	0.0	0.0	5.0	118.2	424.9	172.6	115.0	11.0	0.0	846.7
2004	0.0	0.0	0.0	9.9	5.9	140.2	146.9	161.9	70.8	25.3	0.0	0.0	560.9
2005	0.0	0.0	0.0	0.0	42.0	48.0	158.1	258.0	43.7	8.7	0.0	0.0	558.5
2006	0.0	0.0	0.0	0.7	42.6	76.7	222.5	207.4	109.6	9.9	0.0	0.0	669.4
2007	0.0	0.0	1.5	7.8	1.3	77.4	200.5	246.0	59.7	18.0	0.0	0.0	612.2
2008	0.0	0.0	0.0	56.1	33.2	57.0	143.5	250.7	88.6	0.0	0.0	0.0	629.1
2009	0.0	0.0	0.0	6.5	9.4	39.2	197.1	127.7	152.7	0.1	0.0	0.0	532.7
2010	0.0	0.0	0.0	3.4	14.9	76.4	168.4	208.8	94.4	35.2	0.0	0.0	601.5
2011	0.0	0.0	0.0	0.0	39.4	71.8	101.9	132.1	91.6	30.9	0.0	0.0	469.7
2012	0.0	0.0	0.0	0.0	55.1	59.0	215.2	208.9	21.6	4.3	0.0	0.0	564.1
2013	0.0	0.0	0.0	0.0	7.3	23.4	80.6	231.8	82.7	10.5	0.0	0.0	436.3
2014	0.0	0.0	25.3	45.7	4.1	61.6	236.5	220.1	190.1	81.7	0.0	0.0	865.1
2015	0.0	0.0	0.0	0.0	70.0	7.8	60.7	268.7	62.5	20.8	0.0	0.0	490.5
2016	0.0	0.0	0.0	6.7	40.4	60.9	58.0	199.3	116.0	18.4	0.0	0.0	499.7
2017	0.0	0.0	0.0	3.0	70.1	186.7	171.9	196.5	66.0	3.4	0.0	0.0	697.6
2018	0.0	0.0	0.0	0.0	30.1	82.0	127.4	241.7	78.5	34.2	5.2	0.0	599.1

Appendix 6. soil analysis result:

Sample	pH	Organic Carbon%	Organic Matter%
1	7.91	0.740	1.276
2	8.20	1.050	1.810
3	8.28	0.671	1.157
4	8.26	0.774	1.334
5	8.65	0.706	1.217
6	8.27	0.809	1.395
7	8.25	0.740	1.276
8	8.36	0.739	1.274
9	8.39	0.585	1.008
10	8.41	0.516	0.889
11	8.50	0.516	0.889