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DEDICATION

In the name of Allah, the Most Gracious, the Most Merciful.

I dedicate this accomplishment to my beloved family, whose love and unflinching support have been my guiding light. Your confidence in me has inspired me to persevere, and I will always be appreciative of having you in my life.

And to everyone who has ever wanted to give up, always keep in mind that every obstacle presents an opportunity for development. Remain resilient, never give up, and have faith in your abilities. You have the potential to achieve extraordinary things.

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تطور تدهور النظام البيئي للغابات في منطقة تلمسان: حالة بلدية أولاد ميمون (شمال غرب الجزا)

خلاصة

تستكشف هذه الدراسة تطور تدهور النظام البيئي للغابات في منطقة أولاد ميمون في تلمسان، الجزائر. تشمل منطقة الدراسة غابات زرديب وسيدي حمزة الواقعة في الشمال الغربي من الجزائر والتي تتميز بمناخ البحر الأبيض المتوسط. تم إجراء أخذ عينات ميدانية لوصف خصائص الغطاء الحرجي وتقييم أسباب الاضطراب. تم اختيار ما مجموعه ثلاثين نقطة للتصنيف والتحقق من الصحة، خمسة عشر نقطة لكل غابة، وتوثيق الإحداثيات الجغرافية. تم استخدام تقنيات الاستشعار عن بعد، وتحديداً صور القمر الصناعي لاندسات واكتشاف التغيير بعد التصنيف، لتحليل تغيرات الغطاء الحرجي خلال فترة الدراسة. كشف تحليل قياس الكثافة الشجرية عن انخفاض كثافة الأشجار في كلتا الغابتين، حيث أظهرت غابة زردب مساحة قاعدية إجمالية أكبر من غابة سيدي حمزة. أظهر اختبار مان ويتني عدم وجود فروق ذات دلالة إحصائية في محيط الشجرة (ع > 0.09) والارتفاع (ع > 0.21784) بين الغابتين، مما يشير إلى تشابه هياكل الوقوف على الرغم من اختلاف مساحاتها القاعدية الإجمالية. علاوة على ذلك، أظهرت غابة سيدي حمزة استقرارا ملحوظا في الغطاء النباتي، حيث بقي 76.91% من الغطاء النباتي مستقرا مقارنة بـ 58% في زرديب. وتؤكد هذه المرونة قدرة سيدي حمزة على الحفاظ على استقرار الغطاء النباتي وسط التغيرات الديناميكية في الغطاء الحرجي

وتشير النتائج إلى وجود تأثير كبير للتدهور على المناظر الطبيعية للغابات، مما يهدد التنوع البيولوجي المتوطن. وتسلط الدراسة الضوء على أهمية معالجة قضايا التجديد، لا سيما في سياق الضغوط والاضطرابات البيئية المتزايدة.

الكلمات المفتاحية: النظم البيئية الغابوية، تطور التدهور، التشجير، إزالة الغابات، الكشف عن بعد، أولاد ميمون (شمال غرب الجزائر).

Evolution of Forest Ecosystem Degradation in Tlemcen area: case of Ouled Mimoun Municipality (North-West Algeria)

Abstract

This study explores the evolution of forest ecosystem degradation in the Ouled Mimoun region of Tlemcen, Algeria. The study area includes the Zerdeb and Sidi Hamza forests, situated in the northwest of Algeria, characterized by a Mediterranean climate. Field sampling was conducted to describe forest cover characteristics and assess disturbance causes. A total of thirty points were chosen for classification and validation, fifteen for each forest, documenting geographical coordinates. Remote sensing techniques, specifically Landsat satellite imagery and post-classification change detection, were employed to analyze forest cover changes over the study period. Dendrometry analysis revealed low tree densities in both forests, with Zerdeb Forest exhibiting a larger total basal area than Sidi Hamza Forest. The Mann-Whitney test showed no significant differences in tree circumference ($p > 0.09$) and height ($p > 0.21784$) between the two forests, indicating similar stand structures despite their different total basal areas. Furthermore, Sidi Hamza Forest demonstrated notably higher stability in vegetation cover, with 76.91% of its vegetation remaining stable compared to 58% in Zerdeb. This resilience underscores Sidi Hamza's ability to maintain vegetation stability amidst dynamic forest cover changes

The findings indicate a significant impact of degradation on the forest landscape, threatening endemic biodiversity. The study highlights the importance of addressing regeneration issues, particularly in the context of increasing environmental stresses and disturbances.

Keywords: Forest Ecosystems, Evolution of degradation, Afforestation, Deforestation, Tele detection, Ouled Mimoun (Nord-west Algeria).

Evolution de la dégradation des écosystèmes forestiers dans la région de Tlemcen : cas de la commune d'Ouled Mimoun (Nord-Ouest Algérien)

Résumé

Cette étude explore l'évolution de la dégradation des écosystèmes forestiers dans la région d'Ouled Mimoun (Tlemcen, Nord-Ouest Algérien). La zone d'étude comprend les forêts de Zerdeb et de Sidi Hamza, caractérisées par un climat méditerranéen. Un échantillonnage sur le terrain a été effectué pour décrire les caractéristiques du couvert forestier et évaluer les causes des perturbations. Au total, trente placettes ont été choisies, quinze pour chaque forêt, documentant les coordonnées géographiques et leur description. Des techniques de télédétection, en particulier l'imagerie satellitaire Landsat et la détection des changements post-classification, ont été utilisées pour analyser les changements du couvert forestier. L'analyse dendrométrie a révélé de faibles densités d'arbres dans les deux forêts, la forêt de Zerdeb présentant une surface terrière totale plus grande que la forêt de Sidi Hamza. Le test de Mann-Whitney n'a montré aucune différence significative pour la circonférence des arbres ($p > 0,09$) et la hauteur ($p > 0,21784$) entre les deux forêts, indiquant des structures de peuplement similaires malgré leurs surfaces terrières totales différentes.

De plus, la forêt de Sidi Hamza a montré une stabilité notablement plus élevée dans la couverture végétale, avec 76,91% de sa végétation restant stable, contre 58% pour Zerdeb. Cette résilience souligne la capacité de Sidi Hamza à maintenir la stabilité de la végétation face aux changements dynamiques de la couverture forestière.

Les résultats indiquent un impact significatif de la dégradation sur le paysage forestier, menaçant la biodiversité endémique. L'étude souligne l'importance de résoudre les problèmes de régénération, en particulier dans le contexte de stress et de perturbations environnementaux croissants.

Mots clés : Ecosystèmes forestiers, Evolution de la dégradation, Afforestation, Déforestation, Télédétection, Ouled Mimoun (Nord-Ouest Algérien).

Abbreviations

Mha: Million hectares

NDVI: Normalized difference vegetation index

GIS: Geographic information system

SDGs: Sustainable development goals

MDGs: Millennium development goals

ES: Eco-system services

FAO: Food and Agriculture Organization

DGF: Directorate general of forests

Ha: Hectares

CFT: Conservation of forest in the wilaya of Tlemcen

Mm: Millimeters

°C: Degree Celsius

T: Temperature

ArcGIS: Aeronautical Reconnaissance Coverage Geographic Information System

Landsat: Land satellite

GEE: Google earth engine

UTM: Universal transverse Mercator

WGS84: World Geodetic System 1984

Km^2: Kilometer square

Cm: Centimeter

LULC: Land use and land cover

WWF: Worldwide life fund

Fra: Forest resources assessment

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INTRODUCTION

Introduction

Forests are vital to life on Earth. They purify the air we breathe, filter the water we drink, prevent erosion, and act as an important buffer against climate change (WWF, 2022). In addition to being the lungs of the atmosphere, forests are critical for economic growth and livelihood sustenance for traditional rural populations, particularly those living in forest edge areas (Kindermann et al., 2008; Ullah et al., 2022). Forests provide a diverse range of services and livelihood support to nearly half of the world's population, including employment, food, water conservation, fuel wood and wood for construction, grazing grounds, medicinal herbs, and contributions to local and national economies, with over 1 billion people directly reliant on forests (Khan & Khan, 2009; Nazir et al., 2019; Schusser, 2013; Shen et al., 2006). Forests have an important role in soil conservation by providing organic content and avoiding erosion (Hayat et al., 2021). Furthermore, forests are critical for biodiversity conservation since they house 80% of amphibian species, 75% of bird species, and 68% of mammal species, as well as breeding places for fish and shellfish (FAO, 2020).

Africa's forest cover, or tree cover, has been rapidly declining during the last two decades. Forest cover, or tree cover, as defined by (Hansen et al. 2013), is all vegetation taller than 5 meters in height. The consequences include a decrease in species richness, alterations in the water cycle, and the loss of forest carbon stock.

Algeria's woods occupy roughly 4.1 million hectares (Mha), with 44% in the East, 27% in the Center, and 29% in the West. These woods are classified into four types: light shrublands (52%), thick shrubs (18%), light wooded regions (18%), and dense forested areas (11%). Forests are historically significant in Algeria's economy due to their vast biodiversity and high-quality lumber (cedars, holm oak), furniture wood (cedar), and cork (Zeng et al., 2018).

Algerian woodlands supported many rural livelihoods at the turn of the nineteenth century, providing pastureland, agriculture, firewood, food, and craft supplies. Despite Algeria's forest wealth, the country has the issue of fulfilling expanding demands with susceptible and deteriorating natural resources (DGF, 2022). Deforestation has a massive impact not only on the biophysical environment but also on the socioeconomic conditions of the people living in wooded areas (Ahmad et al., 2018; Haq et al., 2019; Hayat et al., 2019; Irshad et al., 2015; Mujahid & Minhaj, 2020; Nazir & Ahmad, 2016).

Deforestation has resulted in drastic changes over the last three to four decades, including ecosystem destruction, damage to natural habitats, soil erosion, increased intensity and frequency of flash floods, severe and persistent dry weather, soil erosion, a tremendous decline in water resources, abandonment of traditional mixed mountain agriculture, and outmigration (Hayat et al., 2021; Hussain et al., 2018; Zeb et al., 2019). For example, from 2001 to 2023, Algeria lost 227-kilometer square (km^2) of tree cover, a 19% decline from 2000 (Global Forest Watch, 2024). The causes of this significant loss of forest cover are numerous (clearing land for agriculture, construction, grazing, illegal logging, etc.) and are worsened by degradation factors such as forest fires, desertification, resource overexploitation, climate change, pests and diseases, etc.

There are several choices for identifying areas that are evaluated to quantify the amount of area deforested, measured at present, thanks to a suitable and trustworthy monitoring framework for deforestation through the interpretation of satellite imagery (Lorena et al., 2015). In this regard, markers of vegetation dynamics generated from satellite data are essential for identifying processes of environmental change, like land degradation. These indicators, which are linked to the photosynthetic capacity of vegetation canopies, are often derived from spectral vegetation indices seen in satellite photography. For example, the Normalized Difference Vegetation Index (NDVI) time series accurately depicts changes in photosynthetic activity resulting from both natural disturbances like deforestation and human-caused ones like phenological cycles (Kuenzer et al., 2015; Sankaran et al., 2008). Thus, knowing the detrimental effects of forest loss on the forest ecosystem and its role in contributing to greenhouse gas emissions requires an understanding of the spatial-temporal extent and patterns of the drivers of forest loss in Africa.

Problem Statement

Over the millennia, a variety of biogeographical forces and human pressures have caused regressive changes in the pre-forest and forest ecosystems of the Mediterranean region. In actuality, anthropo-zoogenic and edapho-climatic factors—specifically, clearing, overgrazing, cutting, etc.—are to blame for the current state of Mediterranean forest ecosystems (Aouadj et al., 2020). Similar to other Mediterranean countries, Algeria is experiencing severe human pressure and overexploitation of its forests and marshes, far beyond their capacity for regrowth. This has resulted in the almost complete extinction of woody plants, or dematoralization and deforestation, which are being replaced by annual and perennial herbs, respectively, and steppization and therophytization (Aouadj et al., 2021). Natural rules apply equally to the Tlemcen region. Various sections of this area have a major role as an essential reservoir of plant biodiversity, as shown by numerous research programs and worldwide publications (Benabadji et al., 2010). According to (Borsali et al., 2019), various factors such as climatic conditions (summer drought, irregular rainfall, torrential downpours), and human actions like deforestation and overgrazing have led to a substantial and recent decline in the forest heritage of the Tlemcen region.

The Tlemcen region's biodiversity is greatly preserved by the Tlemcen mountains, which include places like Zariffet, Aïn Fezza, and other sites. All the same, over time, human activity has had a major impact on these environments. The Ouled Mimoun region's woodlands, home to distinctive plant species like oak and mixed stands of zeen oak, cork oak, holm oak, wild olive, and juniper, are in danger due to practices like overgrazing and deforestation. The forests in the area offer vital ecosystem services that sustain local way of life and promote environmental sustainability in the area. These benefits include soil protection, carbon sequestration, biodiversity preservation, timber and cork production, and recreational activities. However important these ecological services are, human activities like fires, grazing, and expanding agriculture pose a serious threat to the woods. The natural equilibrium of the forest is being harmed by these forces, which are also leading to deforestation and biodiversity loss. Comprehending the spatiotemporal forest cover changes unique to the Zerdeb and Sidi Hamza Forest is necessary for addressing these difficulties. Scarcely many studies have been conducted to counteract the deforestation of the forests in Tlemcen. To my knowledge, none of these studies have, however, particularly examined the spatiotemporal shifts in forest cover changes and their projected futures in the forest of the Ouled Mimoun region.

Objectives;

Main Objective

To understand the evolution of forest ecosystem degradation in the Tlemcen Wilaya

Specific Objectives:

1. To assess the forest composition and stand structure in the Ouled Mimoun forests, specifically in the Zerdeb and Sidi Hamza forests.
2. To use remote sensing methods to assess how quickly the forest cover has changed between 1990 and 2023

Research Questions

This study seeks to answer the following question: How can we understand the evolution of forest ecosystem degradation and its drivers, considering the case of the Ouled Mimoun Region? The sub-research questions are as follows:

1. What is the current composition and stand structure of the forest ecosystem in the Ouled Mimoun forests, particularly in Zerdeb and Sidi Hamza forests?
2. How has the forest cover in the Ouled Mimoun forests changed from 1990 to 2023?

Scope of the study

This research was carried out in the Ouled Mimoun District (Municipality), one of the districts in the Tlemcen Wilaya of Algeria. Specifically, Zerdeb and Sidi Hamza forests were selected as case studies for the study. By context, the intention of this research was to understand the dynamics of forest cover change over 30 years, from 1990 to 2023, with a focus on the Zerdeb and Sidi Hamza Forest in Tlemcen, Algeria. Plot measurement and field observations were used to assess the forest composition and stand structure of the two forests whereas the Normalized Difference Vegetation Index (NDVI) vegetation indices were used for the forest cover and deforestation mapping in an ArcGIS environment. The content of the study covered aspects that include characterization of the two forests, forest cover classification, and deforestation and afforestation change mapping as well as the development of informed policy recommendations that will serve as a decision-making tool for promoting healthy forest ecosystems in the Ouled Mimoun District.

Significance

This study employs a combination of remote sensing techniques, including satellite imagery analysis and geographic information systems (GIS) mapping, to quantify and analyze forest cover change. By comparing historical and current satellite images, the study assesses the extent and patterns of deforestation, afforestation, and natural forest dynamics in the study area.

One of the key aspects of the study is its ability to generate accurate and up-to-date information on forest cover change, which is crucial for understanding the drivers of deforestation and devising effective forest conservation strategies. The digital land cover maps produced as part of this study can be used to monitor changes in forest cover over time and assess the impact of land use practices on forest ecosystems. Furthermore, the study provides valuable insights into the socio-economic and environmental factors influencing forest cover change. This information can be used by policymakers, land managers, and conservationists to develop and implement sustainable forest management practices that balance the needs of local communities with the conservation of forest resources. This study could also assist policymakers in designing sustainable land use policies and deforestation risk emergency programs for the district. In addition, the findings of this study can serve as a baseline for comparative studies related to deforestation.

CHAPTER 1: LITERATURE REVIEW

1.1.Overview of forest ecosystems

Forests are a major source of income for many people, particularly in developing countries, and they provide many direct and indirect benefits to human beings. The forestry sector is one of the main pivots on which the well-being of the nation rests. For example, it serves as a resource base for many forestry industries, which are one of the most important sectors for generating income and employment. Furthermore, forestry also plays an important role in poverty reduction in the broadest sense, in terms of capacity, empowerment and rights. The importance of forests to humanity cannot be overstated (Tropek et al., 2014). Over half of the world's surface area is covered by forests, accounting for 31% of total land area. Of these, over a third are naturally regenerated native forests, or primary forests, showing no obvious evidence of disturbance. Around 4.06 billion hectares of forest cover the planet, and a great diversity of terrestrial plant and animal species find homes in this ecosystem (FAO, 2020).

Concepts and terminologies related to forests have an impact on how we evaluate and interpret forest transitions, which are the shifts in the relative amounts of forest gain and loss across time in a given region, where gain and loss are expressed in terms of forest cover. According to (Chazdon, 2014), forest gain and forest loss are not the same thing:

- A series of satellite photos or aerial photos can be used to clearly record the majority of cases when forest loss is concentrated and abrupt.

- Contrarily, forest increase is a highly variable, distributed, and protracted process that is challenging to record and track using widely accepted forestry criteria and methods.

The forest or non-forest ecosystems that are replaced by fresh tree cover have very different functional, structural, and compositional characteristics (Brown and Zarin 2013; Tropek et al., 2014). There are various ways to create new tree cover, such as monospecific plantations of non-native plants or spontaneous natural regeneration (Vinceti et al., 2020). It is also challenging to identify and keep track of the localized forest disturbances and regrowth that come with tree removal and silvicultural management (Juliev et al., 2019). It is far more difficult to distinguish between these various types of tree cover gain than it is to locate regions where forest cover has been lost (Long et al., 2016). When evaluating rates of forest conversion to non-forest land uses, commonly accepted definitions of forests have been shown to be ineffective for evaluating rates of forest regeneration and restoration (Adila et al., 2021).

(Ghazoul et al., 2015) emphasize that forests can be viewed from a variety of viewpoints. They supply wood products, support varied ecosystems, serve as dwellings for indigenous peoples, store carbon, and provide a variety of ecosystem functions. They are also constituents of socioeconomic systems. Forests are legally defined as such, regardless of their existing vegetation, from a "land use" standpoint. This means that even if a forest is currently devoid of trees, it can be officially recognized. (Van Khuc et al., 2018) argues that there is no single description that encompasses all of these elements.

Forests provide a wide range of ecosystem services, including socio-cultural benefits, nature experiences, and climate management. Unfortunately, these pristine natural resources are under severe threat from both natural and man-made stressors (Ghazoul et al., 2015). Conventional forest management has concentrated on utilizing forests' potential for timber production or recreation, targeting only a minor subset of the advantages they provide (Puettmann et al., 2015; Felipe-Lucia et al., 2018). These interventions have had a direct or indirect impact on the structure and composition of many of today's forest systems. Over time, there has been a growing recognition that forests provide services that extend far beyond their traditional uses, and that they need to be studied from various viewpoints to realize their full potential. The fact that forests are the most practical solution for combating climate change is among its most significant advantages (Juliev et al., 2019).

In addition to acting as the primary terrestrial sink by retaining more than twice as much carbon as the atmosphere, forests also "remove about 3 giga tonnes of carbon that is emitted into the atmosphere each year by anthropogenic activities," these two ways of regulating the global climate are significant. A difficult scenario arises from an inverted assessment of the influence of climate on forests and their consequent consequences on the carbon cycle, despite the fact that the importance of forests in mitigating climate change is undeniable (Canadell et al. 2018).

Therefore, it may not be adequate to evaluate the cause-and-effect link between trees and climate based only on carbon stocks and sequestration capability (Hakim et al., 2023).

Forest ecosystem is a terrestrial system in which living things such as trees, insects, animals and people interact. It is a smaller classification of the ecosystem as a whole, which is the largest functional unit including all geographical features and living organisms on Earth (Shenet al., 2015). Forests are the most resilient ecosystem, as they are not significantly altered by weather, natural forces or human activity. There are many types of forest ecosystems, classified according to local climate, including amount of precipitation and temperature (Getzner et al., 2020). According to (Canadell et al., 2018), these include (Fig.1.1):

• Tropical evergreen forest: Only a small percentage of tropical forests are rainforests, where rainfall averages 80 to 400mm per year. These forests are characterized by dense, deep vegetation made up of large trees reaching different levels."

• Tropical deciduous rainforest: The main characteristic of tropical deciduous rainforest is the presence of broad-leaved trees, dense bushes, shrubs and so on. Two main seasons - summer and winter - are clearly visible. This type of forest is found in many parts of the world. They are home to a wide variety of flora and fauna.

• Temperate evergreen forest: The temperate evergreen forest is a type of forest characterized by a reduced number of trees but a sufficient number of ferns and mosses.

• Temperate deciduous forest: Temperate deciduous forests are made up of develop in humid temperate regions where there is sufficient rainfall and where winter and summer are clearly defined, so that the trees lose their leaves in winter. The dominant species in these forests are maple, oak and beech.

• Taiga/Boreal: situated just south of the tundra, the taiga is characterized by evergreen conifers. The average temperature is below freezing for almost half the year.

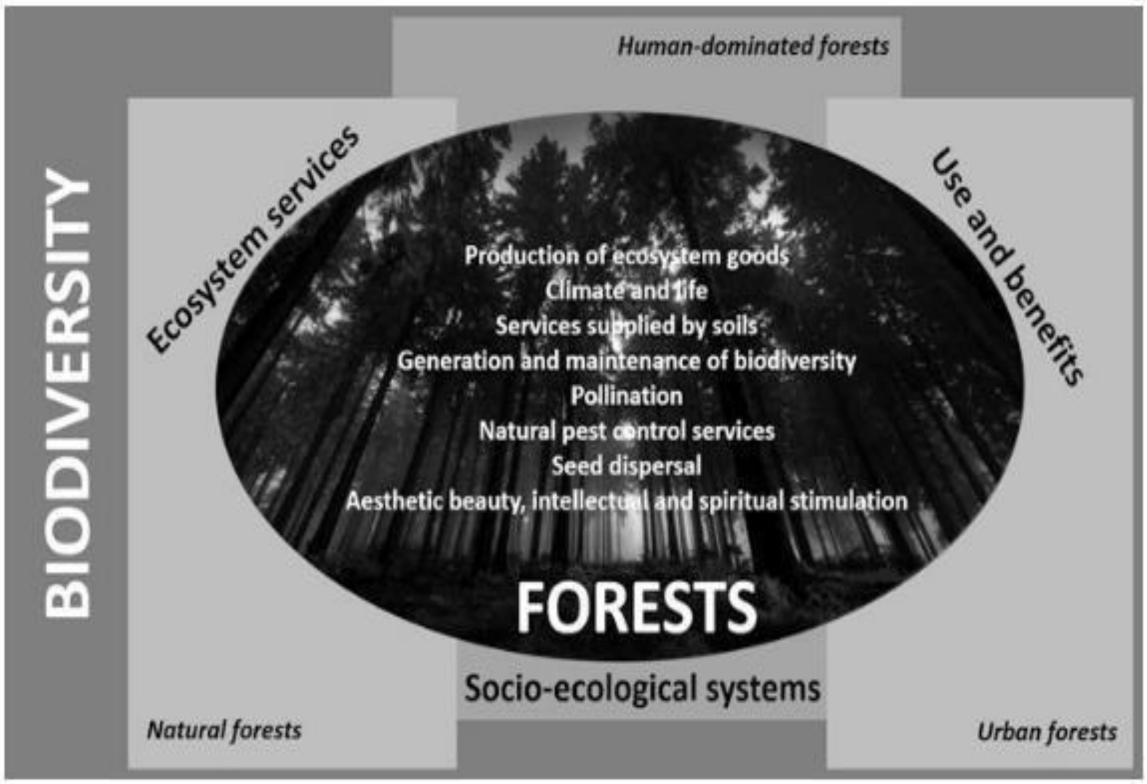

Figure 1.1 Importance of forest eco-system services (Martínez Pastur et al., 2016)

In conclusion, the forest ecosystem plays a crucial role in mitigating global warming by absorbing water from the soil through plant roots, releasing excess water into the atmosphere to promote rainfall, preventing soil erosion and maintaining soil fertility.

1.2.Forest Ecosystem and the Millennium Development Goals

For the maintenance of human well-being, forest ecosystems are crucial because they offer services like soil retention, carbon sequestration, oxygen release, air purification, water source conversion, forest product production, biodiversity support, forest recreation, and many more (Getzner et al., 2020; Liu et al., 2021). Furthermore, human well-being and the ecosystem services that support it are the primary goals and objectives of sustainable development (Costanza et al., 2014; Summer et al., 2014; Wang et al., 2014).

The term "sustainable development" was defined in 1987 by the World Committee on Environment and Development in their study "Our Common Future". Meeting current requirements without sacrificing the capacity of future generations to meet their own needs is known as sustainable development (Lomazzi et al., 2014).

As the importance of sustainable development increases, the idea is always changing and getting clearer.

With the combined efforts of nations all across the world, humanity has achieved significant progress in addressing issues like hunger, poverty, and environmental quality. Nonetheless, considerable obstacles to development still exist (Cuenca-García et al., 2019; Lomazzi et al., 2014). After the completion of the Millennium Development Goals, the United Nations responded by introducing the 2030 Agenda for Sustainable Development in September 2015. To steer global sustainable development and solve developing concerns, this agenda sets 17 Sustainable Development Goals (SDGs) and 169 targets.

In order to safeguard human well-being and protect, restore, and enhance the ecosystem, the SDGs are applicable to all spheres of society, the economy, and the environment (United Nations, 2021). The SDGs cannot be achieved without forest ecosystems, as they constitute the backbone of terrestrial ecosystems. Improvement of the services provided by the forest ecosystem and sustainable forestry development are mandated by the SDGs. One Millenium Development Goals (MDG) that specifically concerns forestry is MDG 15, "Life on Earth," which states that the goal is to "protect, restore, and promote the sustainable use of terrestrial ecosystems; sustainably manage forests; combat desertification; halt and reverse land degradation; and halt biodiversity loss." Forest ecosystems also have the ability to save water, which is a function closely related to MDG 6 (clean water and sanitation) (Ferraz et al., 2013; Caglayan et al., 2021). Forests' ability to absorb and store carbon helps people adapt to and mitigate the effects of climate change, which helps achieve SDG 13 (climate action) (Lin et al., 2019). Furthermore, the material products that forests provide—such as food, wood, biofuels, and other items—can help achieve SDG 1 (end poverty) (Angelsen et al., 2014), SDG 2 (zero hunger) through promoting food security, and SDG 7 (affordable and clean energy) through enabling sustainable and modern energy alternatives. MDG 8 (decent work and economic growth) is partially supported by the job opportunities provided by forest production and forest-based tourism. The connections amongst the several SDGs are intricate, though. Individual SDG modifications can have a positive or negative feedback effect on other pertinent SDGs. For instance, when demand for food or bioenergy from forests rises, pressure on forest ecosystems also rises (Angelsen et al., 2014).

1.3.Relationship between Man and Environment

Man's impact on the environment is increasing with the growth of the world's population. It is astonishing to see the extent to which our species has been able to use natural resources to meet its needs. However, even as we exert greater control over the environment, the increasing scale of human activity is disrupting long-established ecological balances (Cauley, et al., 2012) (Fig. 1.2). According to (Miller et al. 2005), for example, the substantial changes in vegetation and the extinction of megafauna in Australia between 50,000 and 40,000 years ago were very probably caused by human use of fire. (Crutzen, 2002), on the other hand, defines the 'human-dominated' Anthropocene period in terms of the date, around 300 years ago, when global human activity began to significantly alter the world's climate, as indicated by increasing concentrations of greenhouse gases in ice cores. Although they apply the idea of human domination of terrestrial processes to very different spatial scales, both formulations are legitimate, convincing and useful.

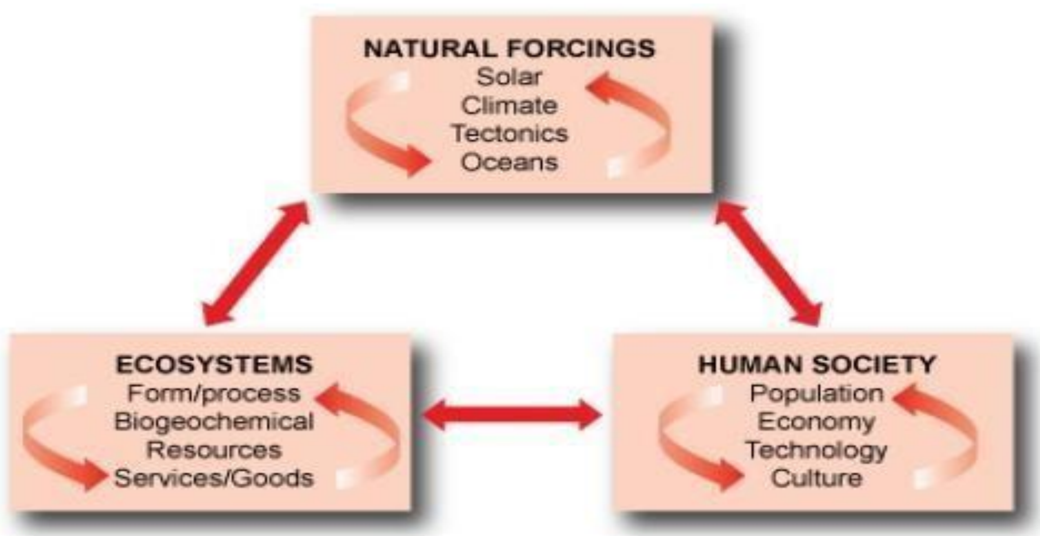

Figure 1.2: Conceptual diagram showing how human society, ecosystems and natural forces can be linked in Earth systems. Each box has circular arrows representing internal dynamic processes (Dearing, 2006).

1.4.Notions of Disturbance / Degradation / Deforestation

1.4.1. Understanding the terms

1.4.1.1. Disturbance

Forest ecosystems, in particular, provide essential ecosystem services (ES) for humanity (FAO 2010) and are home to most of the world's terrestrial biodiversity (Gustafsson et al., 2012).

According to (Veyret et al., 2007), a disturbance is characterized as an event in the environment, often temporary, which modifies (or deteriorates) the functioning of the ecosystem and affects elements such as the soil, fauna, climate, etc. In contrast, (White et al.,2001) define disturbance, in the absolute sense, as an event relatively distinct in time which modifies the resource, substrate availability or physical environment while disrupting the ecosystem.

The deterioration of a natural habitat (or disturbance) is a physical degradation that appears proportionally easy to measure (for example by assessing the reduction in surface area, change in the characteristics of a habitat or loss of the ecological structures and specific functions necessary for the long-term maintenance of this habitat).

(Simula, 2009) summarizes all these definitions, saying that disturbances can be caused by human activity, such as unsustainable logging, excessive collection of firewood, shifting cultivation, excessive hunting, overgrazing, etc.; or by natural causes, such as fires, storms, droughts, snow, pests, diseases, atmospheric pollution and temperature changes.

1.4.1.2. Degradation

Despite significant advancements in scientific techniques and technology utilized in forestry studies, researchers have faced decades of difficulty in obtaining practical definitions of ecosystem degradation (Messier et al., 2013). (Lanly et al., 2013) say that "The situation regarding forest degradation is unsatisfactory, not least because of the imprecision and multiple, and very often subjective, interpretations of the term." Lund (2019) successfully identified over 50 definitions of forest degradation, demonstrating the concept's imprecision and contradictions.

Most scientists concur that disturbances varying in magnitude, intensity, character, source, and frequency are what lead to forest degradation (FAO, 2006; Schoene et al., 2007; Bogaert et al., 2013).

Forest degradation is a process in which the biological diversity of a forest area is permanently diminished by one factor or a combination of factors. "This does not imply a reduction in forest area, but rather a reduction in its quality. The forest is still there, but with fewer trees, or fewer species of trees, plants or animals, or some of them affected by disease. This degradation makes the forest less rich and diverse and can lead to deforestation. Forest degradation is one type of the more general problem of ecosystem degradation. Deforestation and forest degradation continue to occur at an alarming rate, contributing significantly to the ongoing loss of biodiversity (FAO and UNEP, 2020). Forest degradation can occur without being immediately observable (visible).

The notion of "permanence" also poses some difficulties: a forest affected by a mild seasonal drought may suffer a loss of biological diversity, but if it is seasonally converted, then this is not considered degradation. Conversely, a severe and prolonged drought can seriously degrade (deteriorate) a forest and make human intervention opportune or even necessary to limit the damage. Since 1990, an estimated 420 million hectares of forest have been lost to land use change for other purposes (agriculture, urbanization, etc.), although the rate of deforestation has fallen over the last three decades. Between 2015 and 2020, the rate of deforestation has been estimated at 10 million hectares per year, compared with 16 million hectares per year in the 1990s. The world's primary forest area has shrunk by more than 80 million hectares since 1990. More than 100 million hectares of forest are affected by forest fires, pests, diseases, invasive species, drought and extreme weather events (FAO and UNEP, 2020).

1.4.1.3. Deforestation

Deforestation is much worse than forest degradation, but it is clear and visible, unlike forest degradation. Deforestation raises concerns because of its negative consequences, for example climate change, biodiversity loss, soil degradation and reduced wood supply, flooding and siltation. It is therefore a complex process with both environmental and economic impacts (Van Khuc et al., 2018).

According to the Food and Agriculture Organization (FAO), Deforestation is defined as the continuous conversion of forest to other land uses, whether or not it is human-induced; or the sustained decline of vegetation cover below the threshold of 10% (Lanly, 2003; Giri, 2007; FAO, 2012; Romijn et al., 2013; WWF, 2019).

According to (Kamungandu, 2009), deforestation is not an instantaneous process; rather, it is the consequence of a series of degradation stages that culminate in deforestation that is obvious and perceptible on satellite imagery.

Deforestation is therefore essentially a change in land use, not a change in tree cover. So, to define deforestation, we need to define forest, which, according to the Assessment, combines physical criteria (minimum thresholds of 10 per cent forest cover, 0.5 hectare surface area and 5 meters tree height) and a principle of predominant land use, which excludes treed areas with a predominantly agricultural or urban vocation; this definition therefore excludes tree plantations (oil palm plantations and orchards, for example) and city parks, but includes various types of planted forest (FAO, 2018). However, many technical and scientific studies do not use the FAO definition and equate deforestation with the loss of tree cover without taking into account the land use criterion. This more approximate definition is used in methodologies based on remote sensing for two reasons: it takes into account all tree cover (including treed areas that do not correspond to the FAO definition of a forest); and it counts as deforestation cases of non-permanent loss of tree cover (for example, clear-cutting of a natural or planted forest that will regrow later, or the temporary consequences of a forest fire). Therefore, when interpreting deforestation figures, users should pay attention to the definitions and tools used in the different studies (FAO, 2018).

Numerous attempts have been made in recent decades to assess the underlying causes of deforestation. A dynamic process that varies from place to place, deforestation is caused by the interaction of proximate and underlying variables. These include demographic, institutional, political and economic aspects (Geist and Lambin, 2002; Lambin et al., 2003; Rudel et al., 2005). Despite a number of contributing factors, scientists and policy-makers agree that the expansion of agriculture - in particular commercial food production - is the main immediate cause of deforestation worldwide (Fearnside, 2001; McMorrow and Talip, 2001; Miyamoto, 2006; Zak et al., 2008; Motel et al., 2009; DeFries and Rosenzweig, 2010).

1.4.2. Types of disturbance

There are two main forms of disturbance affecting forests: natural disturbance and disturbance caused by man.

1.4.2.1. Natural disturbances

Events such as windthrow, epidemics, climate, forest fires and droughts are examples of natural disturbances. According to (Mézard et al., 2018), these disturbances are a necessary component of the life cycle of forests and contribute to their natural regeneration.

1.4.2.1.1. Climate change

The structure and function of forest ecosystems are influenced by a disturbance regime that can be modified by climate change (Fig.1.3). When disturbances exceed their normal range of variation, forest structure and function are disrupted. Climate change represents a significant and growing global risk to ecosystems and biodiversity. The structure and function of ecosystems, as well as the goods and services that natural systems provide to society, are being altered by the effects of climate change on individual species and the way they interact with other creatures and their habitats (Díaz et al., 2019).

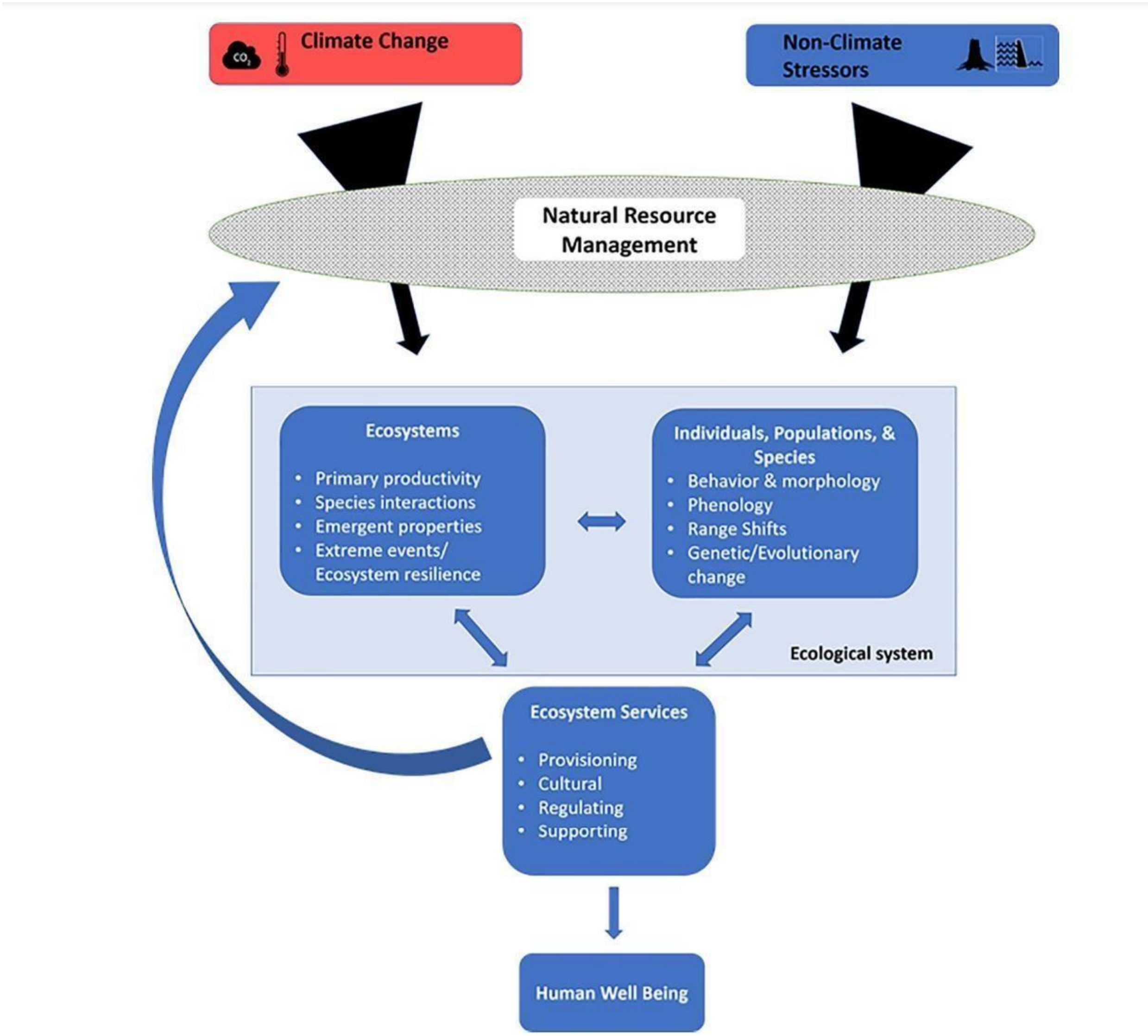

Figure 1.3: Millennium Ecosystem Assessment, 2005 (Díaz et al., 2019)

1.4.2.1.2. Forest fires

Disturbance of wildlife habitat, acceleration of nutrient cycling and mortality of individual trees are some of the effects of fire on the forest ecosystem. In addition to the structure and content of the forest, other factors influence the frequency, severity, size and seasonality of fires, including the frequency and amount of rainfall. According to (Rice ,2010), the power of a forest's carbon sinks is diminished by fire, which is a primary regulator of the carbon balance in forests. Forest fires deplete the majority of soil nutrients, which affects the quantities of macronutrients available.

1.4.2.2. Anthropogenic disturbances

Anthropogenic disturbance, as defined by (Mézard, 2018), is defined as deliberate or involuntary human behavior that negatively affects biodiversity. Anthropisation is therefore the term used to describe all changes made to the environment as a result of human activities, whether conscious or unconscious (Betsch et al., 1998). The effects of these activities are identical to those of natural disturbances function of ecosystems, as well as the goods and services that natural systems provide to society, are being altered by the effects of climate change on individual species and the way they interact with other creatures and their habitats (Díaz et al., 2019).

1.4.2.2.2. Deforestation

Deforestation has been having a detrimental effect on forests; it decreases the richness, forest species abundant and diversity primarily those that are unique and endemic to a region—are typically the result of clearing forest regions, which also affects species habitats (Adeoye et al., 2011). After reaching 16 million hectares annually in the 1990s, the rate of deforestation is predicted to drop to 10 million hectares annually between 2015 and 2020. Many species exhibit a variety of, frequently erratic, reactions to environmental factors (Barlow et al., 2007).

Soil erosion, sporadic flooding, and unpredictable rainfall are all being caused by widespread deforestation and the degradation of forest areas and woodlands in the Himalayan region (Mekasha et al., 2020).

According to (Liu et al., 2021) the rural and tribal populations in the region fear that, in the future, the expensive of food will be lower than the fuel that will be needed to cook it

1.4.2.2.3. Overexploitation

The desire to meet the demands of a populous population has been leading to hasty loss of forest ecosystems globally. Forest ecosystems are extensively used for industrial and commercial purposes, mostly for the extraction of commodities like gum, resins, and lumber. Forest ecosystems, especially those related to timber, are being destroyed as a result of industrial demand exceeding supply. Local and global extinction has resulted from overexploitation of a particular class or group of animals. The overuse of forest plants has resulted in soil erosion in addition to the extinction and loss of species (Giam, 2017).

1.4.2.2.4. Overgrazing and livestock farming

Large areas of forest ecosystems have been used extensively for cattle and sheep husbandry as pastureland all throughout the world. Large tracts of woodland are turned into pasture for domesticated animals as a result of overgrazing. Because cattle farming involves trampling the earth and removing plant species that can no longer flourish, it has severely harmed forest ecosystems. Alpine landscapes are being extensively grazed due to the massive global population of sheep and cattle. Consequently, the soil deteriorates quickly, causing significant erosion of the topsoil of the forest (Karnieli et al., 2014).

1.4.2.2.5. Fragmentation

According to (Garcia et al. 2014), one of the primary causes of forest loss is the fragmentation of the forest cover. (Douglas et al. 2000) claim that fragmentation results in a decrease in the number of species or individuals within each species because it makes it harder to get the resources needed in each fragment. In a forest setting, it is the outcome of an alteration in the original forest landscape's composition and spatial configuration, usually brought about by human activity, splitting results from deforestation (Broadbent et al., 2008).

1.5.Deforestation in the Africa region

1.5.1. Forest loss

The globe is losing 10 million hectares of forest annually, an area the size of Iceland, despite the importance of forests, according to the FAO's most recent Global Forest Resources Assessment (FRA). The African continent is not spared much of this loss. It is concerning to note that, although the global trend in deforestation seems to be progressively declining, the tendency is rising in Africa, where there has been a net loss of forest of 3.94 million hectares annually over the 2010–2020 decade (as opposed to 3.4 million hectares annually over the preceding decade)

Between 2015 and 2020, 4.41 million hectares of forest will be lost annually due to deforestation (FAO, 2020).

1.5.2. Forest growth

As stated by the (FAO,2020) the Africa region has 625.25 million hectares of regenerating forests, with 11.39 million hectares planted every twelve months. Between 2011 and 2019, agroforestry, woodlots, and lumber plantations have made significant additions to sub-Saharan Africa's growth with just 19% of African nations stated an addition in the rate of forest cover from the year 2010 and 2020. In 1990 to 2020, Reunion steadily increased the ratio of forest cover, while Eswatini's growth was steady. Over the following 20 years, Algeria and Burundi improved after first declining. From 1990 until 2000, Cabo Verde had rapid expansion; after that, it increased more slowly. Also, Forest cover in Djibouti was rising swiftly and not till a swiftly increase transpired between 2010 and 2020. Amidst this, Ghana lost a lot as well till 2010, to which an increasement happened again. Morocco and Mauritius displayed erratic trends, with recent slight rises. Tunisia's growth rate was slowing, but it was still growing every ten years.

1.6.Algeria - Forest - Eco system

Algeria's future depends largely on its forests. Public interest in preserving the environment and the country's forest heritage is reflected in the many associations currently working to mobilize civil society in favor of environmental conservation. Algeria's 4.1 million hectares of forest and woodland are made up of 1 902 00 hectares of scrub and undergrowth, which account for 46% of the total area. Responsibility for the protection, conservation and sustainable management of forests and wooded areas for the benefit of present and future generations lies with the Forestry Administration, also known as the Directorate-General of Forests (DGF). The forest is mainly made up of conifers such as Aleppo pine (*Pinus halepensis*), Atlas cedar (*Cedrus atlantica*), maritime pine (*Pinus pinaster*), cedar (*Tetraclinis*) and juniper (*Juniperus*). There are also deciduous trees such as cork oak (*Quercus suber*), holm oak (*Quercus ilex*), zeen oak (*Quercus faginea*) and afares oak (Quercus afares), as well as various species of eucalyptus and ash (*Fraxinus*), among others.

According to several authors (Boundy, 1955; Madani et al., 2001), the current Algerian forest is characterized by the following fundamental qualities:

- It is essentially an open, irregular forest with open stands of deciduous or coniferous trees of various sizes and ages, often in an irregular mixture (FAO, 2000).
- With extensive grazing (particularly in cork oak forests) and the encroachment of adjacent communities on woodland areas.
- A dense undergrowth composed of numerous secondary species that limits visibility and accessibility and encourages the spread of fires.

1.6.1. Data and information on Algerian forests

- Some 1,492,000 hectares, or 0.6% of Algeria's land area, are covered by forest, according to the FAO. There were 404,000 hectares of planted forests in Algeria.
- Change in forest cover: Algeria experienced an average annual loss of 8,750 hectares, or 0.52%, between 1990 and 2010. Overall, 10.5% of Algeria's forest cover, or around 175,000 hectares, was lost between 1990 and 2010.
- Biodiversity and protected areas: Data from the World Conservation Monitoring Centre indicates that there are around 582 recognized species of birds, mammals, reptiles and amphibians in Algeria. 4.5% of species are threatened and 1% are endemic, meaning that they only exist in this country (Tab1.1), (FAO, 2010):

Table 1.1. Algeria: Forest cover, 2010

Total surface area (1000 ha)	238174
Total forest area (1000 ha)	1492
Percentage of forest cover	1
Primary forest cover	0
Primary forest, % of forest	0

Other wooded land (1000 ha)	2685
Percentage of other wooded land	1

Unfortunately, Algeria's forest cover has declined due to deforestation, climate change and unsustainable land use practices. Algeria lost 8,750 ha, or 0.52%, of its forest cover as an annual average between 1990 and 2010, representing a total loss of 10.5%.

1.6.2. Forest area and distribution

1.6.2.1. Geographical breakdown

Algeria is first and foremost a country of desert and high plateau, with a few mountains and a narrow, sporadically distributed coastal plain at 3,003 meters, is the highest point in the country, and Chott Melrhir, at around -40m below sea level, is the lowest (Ouelmouhoub, 2005). According to the same author, the Algerian forest is made up of a wide range of species of Mediterranean flora, and temperature has a major influence on the way these species thrive. The north and south of the country present different forest landscapes as you move away from the coast. Two main and clearly distinct areas can be identified:

- The coast, in particular the coastal regions in the east of the country, notably El Milia, El Kala, Béjaïa, Jijel and Grande Kabylie. It is in these well-watered regions that we find the densest and most exquisite forests. Two major species, the cork oak and the zebra oak, are found in this region.
- The steppe areas between the coastal ranges and the Saharan Atlas represent the driest upper continental plains. Large stands of Aleppo pine and Holm oak (Aurès, Djelfa and Saïda) can be found in the mountainous sections of these regions.

1.6.2.2. Surface area of the main tree species

As a result of the disappearance of the forests, maquis and shrubland have spread over 1,662,000 hectares. In addition to these forested areas, there are 2.7 million hectares of alfa grassland.

The surface areas of the main tree species are compiled in the table below, which is based on extensive research by (Boudy, 1955); (Seigue, 1985); (Ghazi et al., 1997); and (DGE, 2007).

1.6.2.3. Role and importance of the Algerian forest

Forests provide a wide variety of social and economic benefits, ranging from the easily quantifiable economic values associated with forest products to less tangible services and contributions to society (Long et al., 2016). In order to measure progress achieved in the implementation of sustainable forest management, it is necessary to monitor changes in the outcomes provided by forest management in the social and economic, as well as environmental dimensions (Puettmann et al., 2015).

Forests in Algeria serve social, economic and environmental objectives in addition to scientific ones. Most of the forests classified or created in the 1980s were intended for social and conservation purposes. Their surface area is considered stable since then, as it has not changed significantly. The (World Bank report, 2020) highlights several key areas for action for:

- Strengthen the sustainability and climatic resilience of Algeria's forests, including financial resources and sustainable investment in the forestry sector,
- Putting sustainable forest management and fire risk analysis at the heart of our operations,
- Improve governance by clarifying the legal and organizational framework for forest and forest fire management,
- Improving information management by strengthening inter-institutional collaboration,
- And strengthen the sector's technical capabilities to ensure effective forest and fire management.

Sustainable forest management in Algeria can bring a number of potential economic benefits, including:

- Carbon storage: Algeria's forests contain around 70 million tonnes of carbon in living forest biomass.

- Job and income creation: Forestry activities can provide sustainable jobs and income for local communities.
- Leisure and tourism: Forests can contribute to the country's tourism industry, offering opportunities for outdoor activities and panoramic views.
- Soil and water conservation: Forests help to protect soil and water resources, which are essential for agriculture and other human activities.

1.6.2.4. Biodiversity in Algeria

Algeria is home to a wide variety of plants and animals, each with its own environment, scattered throughout the country. Habitat loss caused by agriculture and urbanization, pollution, infrastructure development, tourism, hunting, poaching and climate change are all threats to the country's biodiversity. A total of 121 Algerian species are on the CITES list, 75 of which are threatened or endangered. These include 11 bird species, 14 mammal species and 23 fish species. Wild ungulates (gazelles, antelopes, Barbary sheep and Barbary deer), cheetahs, monk seals and Barbary macaques are among the most threatened animal species. Black pine, thuriferous juniper and Tassili cypress are among the most threatened plant species (World Bank, 2020).

1.7.Contribution of remote sensing and GIS to monitoring forest ecosystems

Geographic Information Systems (GIS) and remote sensing have become indispensable tools for monitoring forest ecosystems, providing accurate and rapid data on forest composition, cover and disposition. The way ecologists and foresters' approach strategic and tactical planning has been completely transformed by these technologies, which enable them to create more accurate records of the state of forests.

Sustainable forest management techniques rely on remote sensing techniques, such as satellite imagery and aerial sensors, to identify and monitor forest disturbances over vast areas. For more than 30 years, land cover mapping and forest monitoring have been carried out using Earth observation satellites. Research carried out by (Angelsen, 2001; and Kaimowitz et al., 2003) showed that even when land cover appears to be the same, Landsat data can be used to identify specific human activities taking place in different areas of the terrain.

As indicated by (Saatchi et al., 2011) and (Mayes et al., 2015), remote sensing, GIS and fieldwork can be used to determine the two most obvious variables for correlation (actual and previous size), which are needed to monitor and assess changes in land cover. Based on an examination of remote sensing data, (Temudo et al., 2011) conducted interviews with farmers and found that Africa's changing agricultural practices are complex. They noted that: "Change has occurred at different times and in different ways, but at parallel rates. Deforestation in tropical regions is therefore best explained by a variety of factors and motivations rather than by a single cause. Their research also demonstrated the advantage of merging remote sensing and ethno-agronomic information in the study of land use and land cover adjustments.

In another study using satellite photos, (JunJie et al., 2013) showed how many socio-economic phenomena can be taken into account in the analysis of land use and land cover. For example, suburbanization, urban redevelopment, urban sprawl and economic division are closely linked to the extent of forest cover displacement.

According to (Dahdou-Guebas 2005), the application of GIS in social science research, particularly in human geography, has become incredibly important. In addition, (Hamzah 2001) noted that GIS is becoming increasingly accepted in the administration of forest resources. Therefore, in addition to remote sensing, GIS has become an essential scientific tool for land cover and land use investigations at local, regional and global scales (Saatchi et al., 2011; Mayes et al., 2015). In recent decades, GIS has often been used in combination with remote sensing, particularly in pest surveys, ecological modelling, agricultural intensification and disease, forest fire and drought monitoring, and forest and wetland conservation.

In addition, the integration of remote sensing and GIS has facilitated the assessment of biodiversity in forest ecosystems, enabling continuous observation of the overall state of forests. Until the 1930s, when aerial photographs became available, forest managers relied solely on data acquired in the field concerning available resources. The development of aerial photography proved to be an invaluable tool, making it easier to gather the necessary knowledge (Saatchi et al., 2013).

CHAPTER 2

PRESENTATION OF THE STUDY AREA

2.1.Overview of the wilaya of Tlemcen

The wilaya of Tlemcen is located in the northwest of Algeria, on the border with Morocco, between the coordinates 34°30′N and 1°30′W. It represents an important crossroads of international and national exchange between the South and the North, the East and the West. It is delimited by:

- The Kingdom of Morocco, in the West
- The Mediterranean Sea in the North
- The wilaya of Ain Temouchent at the North-East
- The Sidi-Bel-Abbes wilaya in the East,
- The Naâma wilaya in the South

It covers an area of approximately 9,061 square kilometers (km^2) and currently brings together 20 daïras and 53 communes, the wilaya capital of which is Tlemcen (Fig. 2.1). The territory of the wilaya of Tlemcen is made up of a succession of roughly parallel natural environments. The Traras mountain range is visible from North to South, the plains and plateaus are limited to the South by the Tlemcen mountains and finally the steppe zone extends to the borders with the wilaya of Naâma (Bensaolaf et al., 2012).

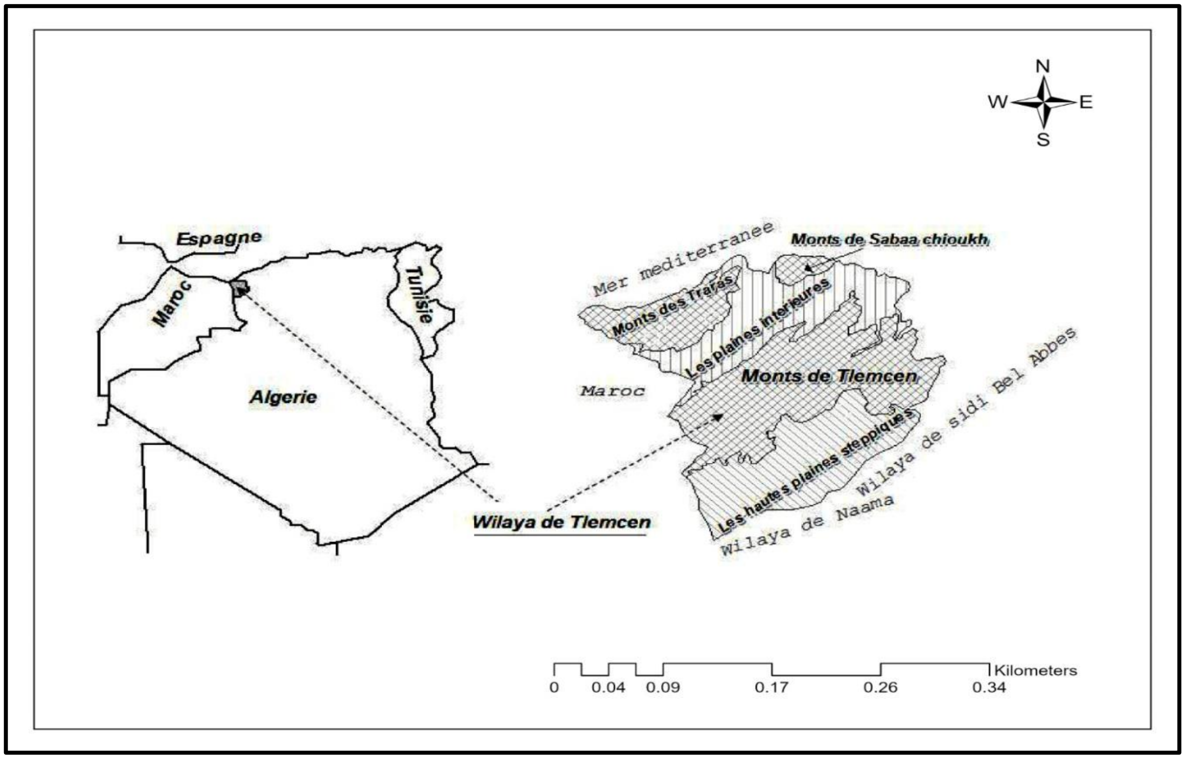

Figure 2.1: Geographic Situation of Tlemcen (Bensaolaf et al., 2012) (Modified)

The forests of Tlemcen Province play a crucial role in the region's ecosystem, providing numerous benefits to the local population. These forests are a major source of livelihoods, providing resources such as timber and non-timber forest products and supporting some forest industries. In addition, the forests of Tlemcen contribute to climate regulation, soil conservation and the conservation of biodiversity.

Upper Jurassic carbonate rocks, Tertiary sandstones and recent underground deposits define the Tlemcen region. Thus, (BENEST, 1985) classified the following categories of geological formations:

- Boumédiène sandstone.
- Zariefet limestone.
- Dolomites of Tlemcen.
- Raouraï marl-limestone.
- Dolomites of Terny.

Covering 238,820 hectares (ha), Tlemcen province is home to an abundant variety of flora and animals, including unique and endangered species. This region contains a significant Stipa Tenacissima (Alfa) steppe covering 154,000 ha in addition to a range of forest types including scrub, scrub and woodland. This total area of forested land corresponds to a forested land rate of 26% for the province. The tree stratum of this environment, made up of reforested regions and natural woods, covers 28,856 ha, or 12% of the total wooded area. 19,829 ha (8% of the total area) are covered by reforestation zones, compared to 9,027 ha (4% of the total area) of natural forests (BNEDR, 2008).

In addition, more than 80% of the potential forest area is concentrated in the Tlemcen mountains. The region's vegetation is shaped by its sub-humid and semi-arid climate and is mainly composed of Mediterranean plant species.

The forests of the Province of Tlemcen are:

- Entirely artificial forests,
- Completely natural forests,
- Mixed forests (natural and replanted), either inhabited by two or more species, as in the national forests of Hafir and Zariefet (Cork oak, Zeen oak and Holm oak), or by a single species, like the forest of Tlemcen (Aleppo pine) (BNEDR, 2008).

2.2.Description of the study area

2.2.1. Historical and geographical location

The Daira of Ouled Mimoun is a Daira of Algeria located in the eastern center of the wilaya of Tlemcen and whose capital is the eponymous town of Ouled Mimoun. It is made up of three municipalities: Ouled Mimoun, Oued Lakhdar and Beni Semiel (36,355 inhabitants in 2008) and between the geographical coordinates 34°54'16" North and 1°02'05" West.

The commune of Ouled Mimoun is located to the east of the wilaya of Tlemcen. It was the seat of many historical events. The ancient Roman city of Altava was built on the right bank of Isser, ISARIS of the Romans, on a plateau crossed by Oued Khalfoun to the East.

In 1869, during colonization, the town was named Lamoricière in honor of General Lamoricière and became part of the department of Oran. In 1958, the commune became part of the Tlemcen department. After independence, it took the name of Ouled Mimoun.

The Sidi Hamza area is named thus in honor of Sidi Hamza, who was preparing an attack in 1868 from October 7 to 8 to obtain herds and seeds from the settlers' farms. And to defend Ouled Mimoun, the French administration of Tlemcen sent a column of 600 to 700 French soldiers.

In 1984, the commune of Ouled Mimoun was made up of the following localities:

- Ouled Mimoun Center
- Sidi Zouaoui
- Sidi Sufi
- Tahmoumine
- Kheneg

Covering the "douars" of Ouled Mimoun and Beni Smiel, the commune of Ouled Mimoun owns the national forest of Zerdeb, divided into three cantons (North Zerdeb, South Zerdeb and Miez) and governed by the conservation of the forests of the wilaya of Tlemcen.

The state land designation of January 15, 1968, which authorized the delimitation and distribution procedures carried out within the framework of the realization of the Senatorus Consults within the Ouled Mimoun tribe, applies to the part of the forest located within 'Ouled Mimoun. Whereas, the government decree of November 2, 1892, which sanctioned the operations carried out in execution of the Senatorus Consults in the Beni Smiel tribe, classified the part of the territory located in the Beni Smiel as state land subject to forestry regulations (CFT, 2013).[1]

For the forest of Sidi Hamza, property of the commune of Ouled Mimoun also, covers the "douars" of Ouled Mimoun and Oued Lakhdar. It is also governed by the Forest Conservation of the wilaya of Tlemcen. This forest, which is part of the State domain, is subject to the forestry regime by the government decree of August 19, 1898, approving the delimitation and

[1] https://www.facebook.com/photo/?fbid=126195512369580&set=a.114644600191338,

distribution operations carried out in execution at the Senatorus Consults in the Ahl-El Oued tribe. The origin of the property is the public domain of the State.

These two forests are bordered by the municipalities of:

- Sidi Abdelli at North,
- Beni Smiel in the South,
- Ain Tellout to the Est,
- Chouly, at the West.

According to the 1/50,000 scale map of Ouled Mimoun, type 1922, sheet no. 271, and that of Beni Smiel, type 1922, sheet no. 301, the Zerdeb national forest is located in the Northwest of Algeria, in the Gourari mountains south of the commune of Ouled Mimoun and 33 km Southeast of Tlemcen. The (Fig 2.2) shows the geographical location of the Zerdeb national forest and Sidi Hamza Forest according to the geographical coordinates of the CFT (2024) (Latitude: 34.8386°N; Longitude: -1.1189°W) and using Google Earth and ArcGIS.

Table 2.1: Cartesian coordinates of Zerdeb (CFT, 2020)

x_1: **156km,**	y_1: **181km**
x_2: 162.5km,	y_2: 186km

While the forest of Sidi Hamza, according to Sheet No.: 301 and Scale 1/50,000, is located between the following coordinates (CFT, 2020) (Tab.2.2):

Table 2.2: Cartesian coordinates of Sidi Hamza (CFT, 2020)

x_1: ***150km,***	y_1: **175km**
x_2: 153km,	y_2: 181km

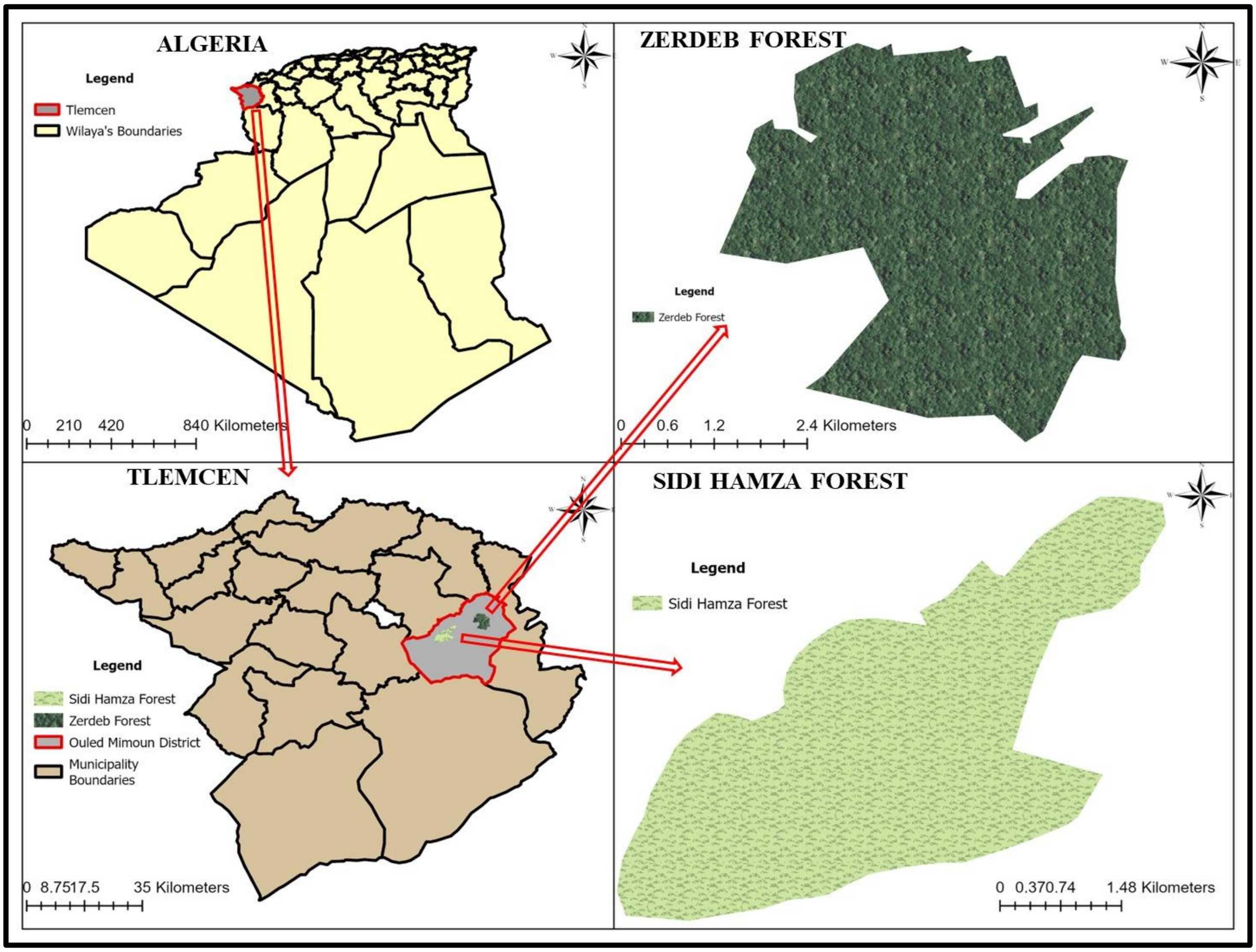

Figure 2.2: Geographic Location of Zerdeb and Sidi Hamza Forests (Original)

2.2.2. Geomorphology

Located between 818 m and 1,010 m above sea level, Zerdeb has a slightly rugged terrain, characterized by a mixture of gentle slopes and steeper terrain (Tab. 2.3). The majority of the area (60%) consists of slopes between 3 and 12.5%, indicating gently sloping or rolling terrain.

Table 2.3: Distribution of slopes of Zerdeb Forest (%)

Proportion	Percentage
0 to 3% slope	10%

3 to 12.5%	60%
12.5 to 25%	20%
More, by 25%	10%

In the case of the Sidi Hamza Forest, which is between 900m and 1239m above sea level, its relief is described as hilly terrain, with rounded hills and gentle slopes (Tab.2.4). Most of the area (70%) is composed of slopes ranging from 3 to 12.5%, suggesting a predominance of gentle slopes and hills.

Table 2.4: Distribution of slopes of Sidi Hamza Forest (%)

Proportion	Percentage
0 to 3% slope	10%
3 to 12.5%	70%
12.5 to 25%	70%
More, by 25%	10%

Both areas also have northwest exposure, which influences factors such as sunlight, wind patterns and precipitation.

2.2.3. Pedology

Soil is a complex and dynamic entity, formed by the process of pedogenesis, which transforms the parent rock into a rich and fertile layer. It is characterized by its loose nature and relative surface stability, incorporating elements of plant life. Composed of decomposed organic matter and minerals, soil derives its essential properties from its mineral composition. The soil in this region is brown, of a thin forest brown type, with a limestone surface layer. It has rock and rock formations, of indeterminate texture, and the humus is medium and localized.

According to research by (Mazour, 2004); (Hezlaoui et al., 2018), the soils of this region are formed from limestone rocks. They resemble red fersialitiques soils.

2.2.4. Geology

Certain sections of the national forest of Zerdeb and Sidi Hamza would have been covered with marl and clay rocks. Two different types of geological formations are identified according to (Ainad, 1996) as existing in the Ouled Mimoun region, namely:

- The Marly Limestone marks the transition from the Jurassic to the Cretaceous. It is created near the top of the Upper Jurassic carbonate group. Its upper limit is indicated by the roof of a limestone cornice, while its lower limit is located at the level of the Merchich sandstone wall.
- Clays: They represent the Lower Cretaceous, with a predominance of clay-sandstone and a clearly limestone summit. The upper limit of the marly limestone of Ouled Mimoun is less obvious than the lower limit; it appears at the first sandy or dolomitic bench of the "Berthlot" sandstone formation, which has a sandy to dolomitic history. While the lower limit is located at the roof level of the last limestone layer of the marly limestone.

2.2.5. Hydrology

In the context of the hydrographic network, the region is full of "chabaats", with the exception of Oued Isser which flows along its eastern border and divides into two smaller rivers. (CFT, 2020), lists among them four low-flow sources.

- The Source of Ain Flou
- The Source Hassi Mediaza
- Source Tighighette
- The Boudjamhour Spring

2.2.6. Fauna and Flora

The Zerdeb forest contains a diverse tree formation, including holm oak, Aleppo pine, juniper, Mediterranean cypress and eucalyptus. In the shrubby formation, we find mastic, cistus and kermes oak typical of the Maquis. The herbaceous formation is characterized by rosemary, diss, doum and broom.

In terms of stand composition, Aleppo pine is the dominant species with an occupancy rate of 50%, coming from a natural stand with a density of 800/ha, with an age of more than 50 years and a coverage rate of 60%. Secondary species include holm oak, cork oak and eucalyptus, with an occupancy rate of 45%, coming from a natural stand with a density of 200/ha, with an age of more than 50 years and a coverage rate of 40%.

The distribution of areas by type of population reveals that there are 750ha of seedlings, 800ha of undergrowth dominated by cork oak and eucalyptus and 830ha of holm oak and mastic.

In the case of Sidi Hamza, the forest consists of a variety of tree formations, including cork oak, holm oak, mastic, cypress and cedar. The shrubby formation is characterized by diss and Alfas, typical of the maquis. Herbaceous plants such as roman, broom and doum also contribute to the vegetation. In terms of composition of the stands, the dominant species are cork oak, holm oak and cedar, with an occupancy rate of 30%, originating from a natural stand, of moderate density and age greater than 50 years. The coverage rate for these species is 40%. Secondary species include Aleppo pine and cypress, with an occupancy rate of 10%. The distribution of areas by type of settlement reveals that there are 20ha of young plants, 50ha of undergrowth dominated by Aleppo pine, 65ha of young plants including cypress and olive green, juniper, 280ha of posts, 140ha of young stands, 210ha of old stands and 340ha of neat appearance, mainly cypress.

In terms of importance, the current fauna of the commune of Ouled Mimoun is composed of partridges, wood pigeons, hedgehogs, wild boars, jackals and sedentary game.

[2]

[2] The information and figures are inspired by the archives of the C.F.T., Ouled Mimoun 2024.

2.2.8. Climate

Changes in temperature and precipitation can also disrupt the delicate balance of the forest ecosystem, which can impact plant growth, soil quality and water availability. These changes could lead to changes in species composition, a decline in biodiversity and increased vulnerability to pests and invasive species, which could compromise ecosystem resilience in the Ouled Mimoun forests (Tab.2.5)

Table 2.5: Climatic characteristics of the Forest of Zerdeb and Sidi Hamza

Features	Zerdeb Forest	Sidi Hamza Forest
Annual precipitation (mm/year)	200 to 300	300 to 350
Maximum temperature (°C)	40°C	40°C
Minimum temperature (°C)	05°C	05°C
Prevailing winds	South West	North and West Wind
Bioclimatique stage : Semi-aride	Semi-aride	Semi-aride
Sirocco (number of occurrences per year): 02 times in July and August	02 times in July and August	01 to 02 times per month

The Table highlights the differences in precipitation, prevailing winds and sirocco occurrences between the two forests. Zerdeb experiences lower annual precipitation and has southwesterly winds, while Hamza receives slightly higher precipitation and is influenced by northerly and westerly winds. In addition, the sirocco wind affects Zerdeb twice in July and August, while Sidi Hamza experiences it once or twice a month.

3

The information and figures are inspired by the archives of the C.F.T., Ouled Mimoun district, 2024.

2.2.8.1. Temperature

Temperature plays a crucial role in the survival, evolution and spread of organisms in various environments. Studies have highlighted the importance of temperature variations in Mediterranean forests. Thus, the impact of temperature on the biological activities of the earth cannot be overestimated.

The distribution of the annual temperature of the Ouled Mimoun station for the period 1992 - 2022 is presented in (Fig 2.3). Examining annual trends in these temperatures provides insight into climate patterns and variations.

- Periods of high temperatures: Several years, such as 1999, 2005, 2021 and 2012, stand out for their higher annual temperatures. For example, in 2012, the annual temperature reached a peak of 44.98°C. These years may be linked to specific climatic phenomena, such as heat waves or El Niño events, which can lead to high temperatures.
- Cooler years: Conversely, some years, including 1995, 1997 and 2018, had lower annual temperatures, with 1997 standing out with a peak of 36.69°C.

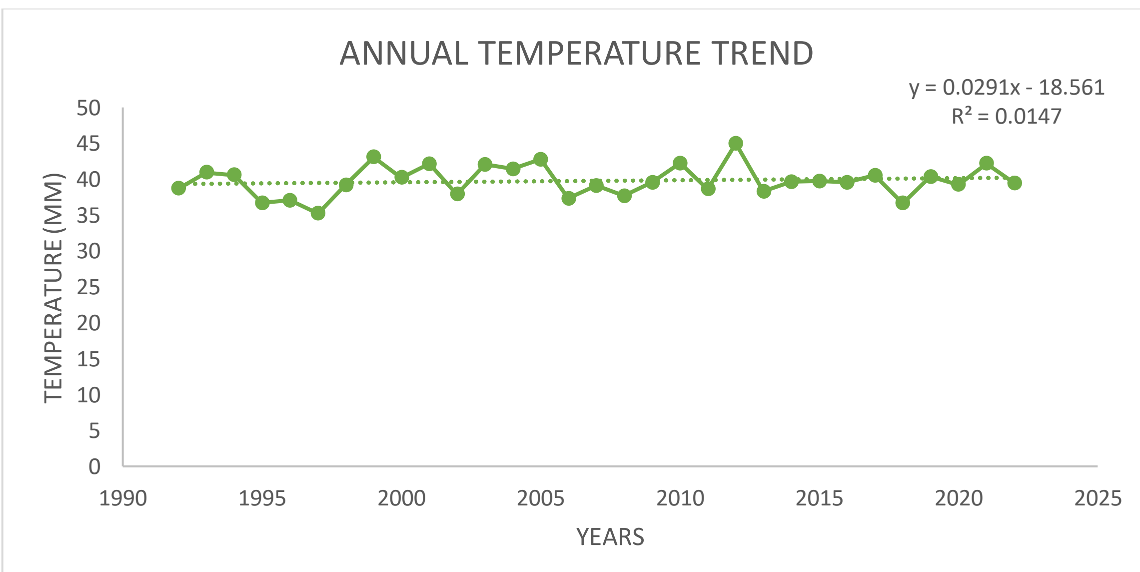

Figure 2.3: Annual temperatures of the Ouled Mimoun station for the period 1992-2022 (NASA/POWER CERES/MERRA2 Native resolution, accessed May 14, 2024)

Overall, these data provide a snapshot of annual temperature trends for this location over three decades, showing how temperatures have fluctuated over time.

2.2.8.2. Precipitation

The most important weather factor affecting the likelihood of fires is rain. It is the speed with which fires appear, and not the amount of water that falls, that prevents them from occurring (Trabaud,1991). The distribution and amount of precipitation directly impacts a number of forest characteristics, such as plant growth, soil moisture content and overall biodiversity. Plants can experience water stress from insufficient or erratic precipitation, which can hinder their ability to grow and survive, and low precipitation levels can lead to drought conditions, which can increase the risk of wildfires. forest by making dry vegetation more flammable. Additionally, variations in precipitation patterns can affect the amount of water available to flora and fauna, which can lead to changes in ecosystem dynamics and species composition.

Precipitation data from 1992 to 2022 demonstrate variations in precipitation in the study area:

- Highest precipitation years: The years 2003, 2008, 2012 and especially 2018 stand out for their higher annual precipitation with 2018 marking the peak at 632.81 mm.
- Driest years: Conversely, the years 1997, 1998, 2002 and 2020, notably 1998 which recorded the lowest annual fall with 221.48 mm, represent significantly drier periods.

Trends:

The data show significant variability in precipitation from year to year, indicating a lack of clear long-term trends in increasing or decreasing precipitation (Fig.2.4). This variability suggests the influence of various climatic factors and highlights the complexity of precipitation regimes in the region.

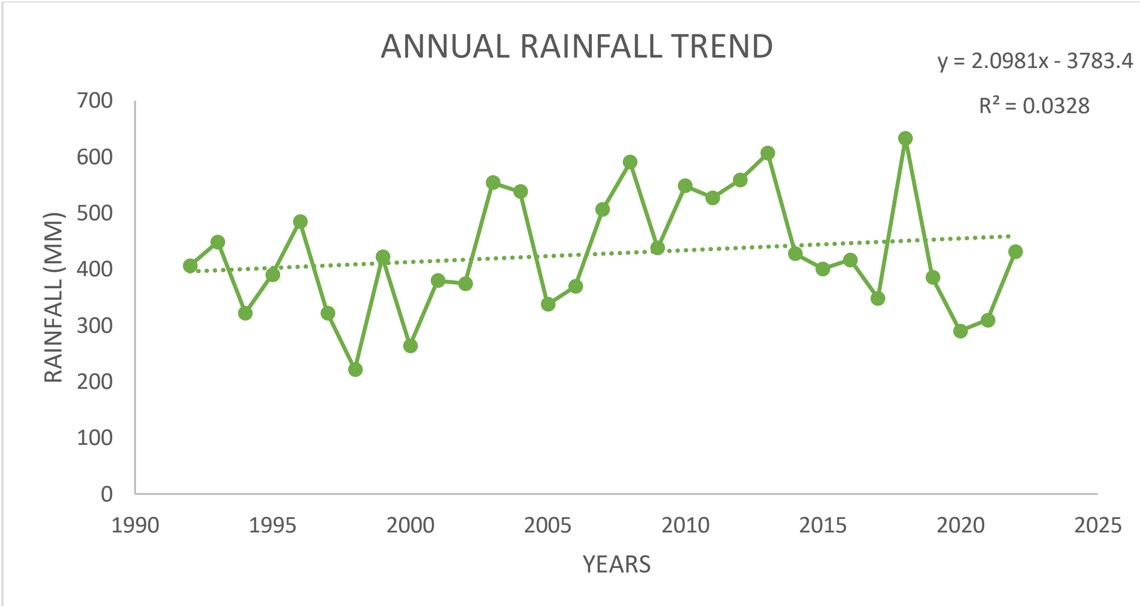

Figure 2.4: Annual precipitation from the Mimoun station. Data source: NASA/POWER CERES/MERRA2 Native resolution.

These trends highlight the variability in precipitation patterns over the years, with periods of drought followed by periods of increased precipitation.

2.2.8.3. Seasonal Pattern

The method involves grouping months by quarter so that the first month of each quarter or season contains either a solstice (summer or winter) or an equinox (spring or fall), resulting in four average seasonal precipitation totals. Then, these four seasons are classified in descending order of precipitation, and the first letters of the seasons thus classified form what is called the "seasonal indicator" (HALIMI, 1980). The summer season is determined by the 3 consecutive months of low precipitation.

Step 1: Group the months by quarter, with each season beginning at a solstice or equinox. This corresponds to the traditional weather seasons:

- Winter: December, January, February
- Spring: March, April, May
- Summer: June, July, August (identified as the season with the lowest precipitation)

- Fall: September, October, November

2nd step: Calculate the average seasonal precipitation for each of these quarters from the data provided.

Step 3: Rank the seasons in descending order of their precipitation averages to obtain the seasonal indicator.

Result: Seasonal indicator

Table 2.6: The seasons from highest to lowest average rainfall

Spring	**43.94mm**
Autumn	38.34mm
Winter	36.91mm
Summer	21.10mm

The seasonal indicator, based on the HALIMI method (1980), would be "PAWS" (PAHE) representing seasons from highest to lowest average precipitation.

2.2.8.4. Climate synthesis

2.1.8.4.1. The De Martonne aridity index

The De Martonne aridity index, first described in 1923, is the product of mean annual temperature and mean annual precipitation. It's a number intended to indicate how dry the weather is in a given location.

Formula: $I = P/(T + 10)$

Where;

P: average annual precipitation (mm).

T: average annual temperature (°C).

I: Martonne index.

This index can be used for activities such as agriculture and livestock, as well as a climate classification factor (Tab.2.7). (De Martonne, 1923) proposes the following classification:

Table 2.7: Climate classification according to De Martonne (1923)

Hyperaride climate	**I < 5**
Desert climate	5 < I < 10
Semi-aride climate	10 < I < 20
Humide climate	I > 20

Based on these indices, our station falls into the semi-arid climatic category, with indices of 16.88 mm.

2.2.8.4.2. Mediterranean vegetation phases

The following classification makes it possible to identify the stages of Mediterranean vegetation: the average annual temperature (T°C) plus the average temperature of the coldest month "m".

- Thermo-Mediterranean: T > 16°C; m > +3°C (warmer variation).
- Meso-Mediterranean: 0 < m < +3°C; 12 < T < 16°C (Cold variation).
- Sub-Mediterranean: 8°C < T < 12°C; -3 < m < 0°C (Cold variation). (Daget, 1977).

During classification, we found that all years in the dataset fell into the "Thermo-Mediterranean" category, as they all had T values above 16°C and m values above +3°C. This classification indicates that the climate of these years and regions exhibited characteristics typically associated with Mediterranean vegetation.

2.2.9. Socio-economic factor

For grazing and entertainment, local people frequently travel to Zerdeb and Sidi Hamza throughout the year. The main livelihood activities of the local population are animal husbandry and grain cultivation, underscoring their dependence on agriculture and animal husbandry. Regarding forest products, the annual consumption of the population is expected to consist mainly of wood, necessary for heating and other purposes. The animal herd, which has a significant impact on the region, is made up respectively of 200 heads of cattle for Zerdeb, 400 heads of sheep for Sidi Hamza, 1,000 heads of sheep for Zerdeb and 200 and 300 heads of goats. Additionally, a variety of wildlife species, such as hares, rabbits, jackals, sedentary game and wild boars, can be found in the area. These species are important in terms of presence and influence (CFT, 2024).

2.3.Methodology

This chapter describes the methods that was used to investigate the evolution of forest ecosystem degradation in Ouled Mimoun forests, Tlemcen, Algeria. The objectives of the study were to assess the forest composition and stand structure, analyze the rate of change in forest cover from 1990 to 2023 and suggest possible recommendations to mitigate the impacts of forest cover change. To achieve these objectives, the study used remote sensing techniques to analyze the changes in forest cover over the study period. Specifically, Landsat satellite imagery was used to assess forest cover change using post-classification change detection techniques. The study area, Zerdeb and Sidi Hamza forests, is located in the North-West of Algeria. The area is characterized by a Mediterranean climate, with hot, dry summers and mild, wet winters. The forest cover in the study area is primarily composed of evergreen oak, cork oak, and Aleppo pine.

The data analysis involved two steps. First, field work was carried out to choose the selected plots for the description of the place. Second, the satellite imagery was processed and analyzed using ArcGIS software to extract the forest cover information. The forest cover change was analyzed using post-classification change detection techniques.

2.3.1. Field Work

2.3.1.1. Field Sampling

Prospective visits to all the two forests of studies carried out by the director of the thesis and the forester Mr. Zair A. This preceded our sampling and allowed us to identify the different squares.

After targeting the stands, in April and May 2024, we opted for systematic sampling and the establishment of 100 m² (10 m x 10 m) plots. Indeed, according to (Assefa et al., 2013), square plots include a higher intra-plot variance than circular plots. Thirty squares were established, fifteen for each of the two forests (Zerdeb and Sidi Hamza). Five visits were made to obtain all the parameters. The study documented the geographical coordinates (latitude and longitude), forest cover, the most common life forms, and disturbances such as encroachment, land use conversion, and fires on the selected sites.

From the first tree spotted, the rest of the trees were chosen by the method of the nearest neighbor (Mueller-Dembois et al., 1974), but they must be representative as much as possible of all the trees in the square. When the stem is composed of several strands of tailings, we have retained only the largest strand, and if they are of the same size, a strand is chosen at random. We avoided inventorying stands recently burned or undergoing very strong anthropogenic action (roadside, firewalls, urbanized areas).

2.3.1.2. Description of the squares and trees

The positions of the squares were identified with the GPS (Geographic Positioning System). And to better characterize them, we carried out the measurement, analysis, description and observation of several parameters, some are related to squares (30) and others to trees (203). Ecological and forest characteristics are basic information for defining study sites. They specify stationary descriptors (geography, topography, altitude, slope, exposure, etc.); edaphic descriptors and other descriptors that are always necessary to describe and analyze stand from a forestry point of view, human attendance, regeneration, layouts, etc. The thickness of the litter layer was determined on the ground.

Dendrometry descriptors estimate the growth of trees. They have the total height of the trees (at Blum-Leiss) and the circumference at 1.30 m from the ground (with a tape measure).

2.3.2. Image Processing

Vegetation Cover Map and Its Classifications using NDVI Analysis

An analysis with satellite data extending over 33 years was examined to better understand the trend of forest cover in the studied area (1990 to 2023). The vegetation within every satellite image was identified using the Normalized Difference Vegetation Index (NDVI), which was also used to analysis changes in forest cover throughout the course of the study. Researchers from all over the world have utilized NDVI since it is one of the greatest methods for examining changes in forest cover (Chu et al., 2019; Gao et al., 2021; Haq et al., 2021; Liang et al., 2018; Mane et al., 2022; Othman et al., 2018). This index distinguishes between the amount of photosynthetic activity present in the landscape on a dimensionless, radiometric basis. This index is computed in each pixel by dividing the difference between the near-infrared and red electromagnetic bands' surface reflectivity values with the sum of both (Jensen, 2015). The NDVI index is symbolized by the equation:

$$NDVI = \frac{(NIR - RED)}{(NIR + RED)}$$

Where;

NDVI: Normalized Difference Vegetation Index

NIR: Near-Infrared

RED: Red

Band 5: Near-Infrared Band (specific to Landsat imagery)

Band 4: Red Band (specific to Landsat imagery).

As a result, NDVI values ranges gradually from - 1 to + 1 (non-vegetation to most vegetation). A higher value represents the increase of biomass and vegetation cover. A negative NDVI value means the water coverage, built-up, non-vegetated area, etc. A low NDVI value means low biomass and vegetation density. A high NDVI value shows high biomass and vegetation density (Hartoyo et al., 2021).

The 32-day Tier 1 Landsat NDVI image collections were utilized in this work (Fig.2.5) to ascertain the vegetation cover dynamics of the study area. The photographs were obtained between 1990 (Landsat 5) and 2023 (Landsat 8) via the Google Earth Engine (GEE) platform. The final NDVI images were produced by taking the mean of all the photographs for each period. GEE is used to obtain the annual median value in order to prevent seasonal effects on vegetation cover and redundancy. Moreover, deciduousness in a dry and wet season is eliminated by each year's median value. Moreover, Landsat pictures from path 151 and rows 35 and 36 cover the study site. Any scenes having more than 10% cloud cover were eliminated

from the study. The removal of scenes with more than 10% cloud instead of atmospheric correction was opted to reduce distortions caused by obscured data. The Shapefile for Ouled Mimoun was collected from the Diva GIS portal and that of Zerdeb and Sidi Hamza were extracted from open street map. The data were re-projected to a Universal Transverse Mercator (UTM) coordinate system and data WGS84. The vegetation index was analyzed by using NDVI, specifically band 4 and band 5 in Landsat 8.

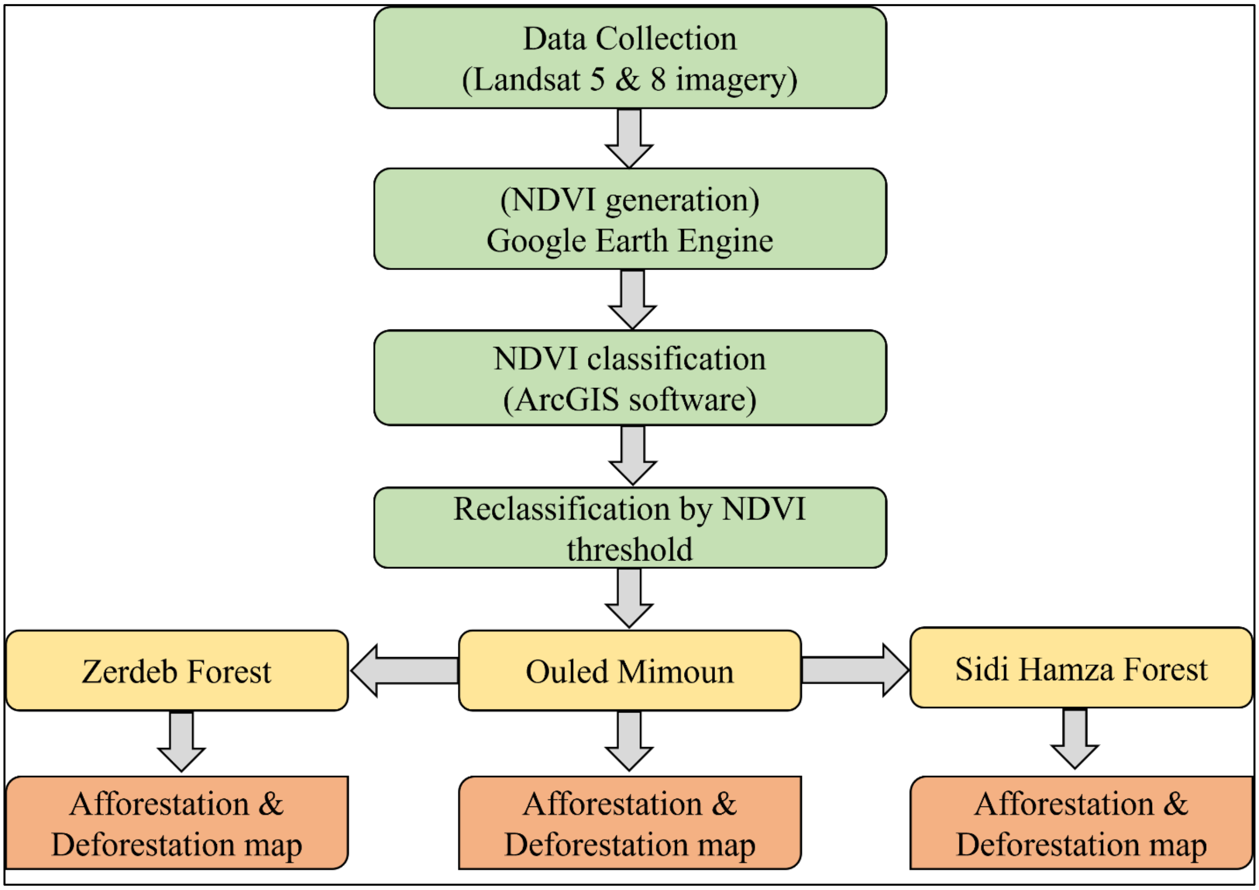

Figure 2.5:Methodological framework for the afforestation and deforestation mapping (Original).

2.3.3. Image analysis

2.3.3.1. Image Classification

Both temperate and tropical forest regions have found success with the widespread and well-proven use of satellite data for forest classification (Hildebrandt, 1996). Creating spatially explicit generalizations that display specific classes chosen to represent various land organization scales is the goal of this process. Either supervised or unsupervised classification can be used to extract land cover information from digital remotely sensed data. Using a combination of fieldwork, maps, and firsthand knowledge, the study employed supervised categorization to determine the identity and location of particular land cover classes. In order to do this, specific locations that serve as uniform instances of these recognized land cover types were identified using remotely sensed data. Thus, the research area's land cover is characterized by six kinds of land cover (Tab. 2.8).

Table 2.8: Category classification of the study area Source (Hashim et al., 2019)

Class	NDVI Range
Water Body	-0.28 – 0.015
Built up Area	0.015 – 0.14
Barren Land	0.14 – 0.18
Shrub and Grassland	0.18 – 0.27
Sparse Vegetation	0.27 – 0.36
Dense Vegetation	0.36 – 0.74

2.3.4. Comparing remote sensing and ground surveys to estimate forest cover

Satellite images should come from the same year and date in order to reduce inaccuracy in measuring the area of change. The use of remotely sensed imagery, as (Mike, 1998) noted, makes it possible to map vast areas quickly and digitally, enabling precise assessment and integration with geographic information systems. One restriction of ground surveys is their reliance on samples, which makes it impossible to cover the entire area in terms of vegetation. Another drawback is their difficulty in providing information at any time or location, particularly in restricted areas with complex topography. This research was carried out using ground survey techniques and data from remote sensing. Based on a ground survey, the study's results provided accurate and detailed information regarding a variety of topics, including the number of stems per hectare, species share, regeneration, and biological diversity. The primary information gleaned from remote sensing data is the kind of land cover. On this point, (Malingreau, 1992) concurred. Remote sensing can measure three key categories of metrics associated with deforestation: vegetation types, changes in forest cover and usage, and specific surface biophysical properties.

According to (Kleinn, 2002), field observations or measurements must bolster any estimation of forest resources derived from remote sensing, there should ideally be a minimum of a specified number of field plots for every picture. This means that, as a supplementary tool for forest inventory, ground surveys are still required. Requirements today include the effective integration of remote sensing among other information sources. For a broad variety of variables that cannot be observed with an acceptable degree of accuracy using remote sensing technology, field work is especially essential. (Kline, 2002) also states that for mapping and landscape-level analysis, remote sensing in conjunction with ground control points is the preferred method

2.3.5. Statistical Analysis

Because of the unique features of our field data, we used the Mann-Whitney U test for statistical analysis in this work. Our data did not match the assumptions of parametric tests like ANOVA, which depend on a normal distribution and equal variances. Because of this, the non-parametric Mann-Whitney U test was the better option. The Mann-Whitney U test is a useful tool for comparing two independent groups in situations where the data do not have to have equal variances or conform to a normal distribution.

Our statistical analysis was carried out using Past 4.13 software, which is known for its capacity to run non-parametric tests such as the Mann-Whitney U test.

CHAPTER 3

RESULT AND DISCUSSION

3.1.Description of the plot

Different trends in plant species distribution can be seen throughout the research region in the sampled plots. The plot map, representing both Zerdeb and Sidi Hamza Forests, provides a visual overview of these trend (Fig. 3.1.) and (Fig. 3.2.).

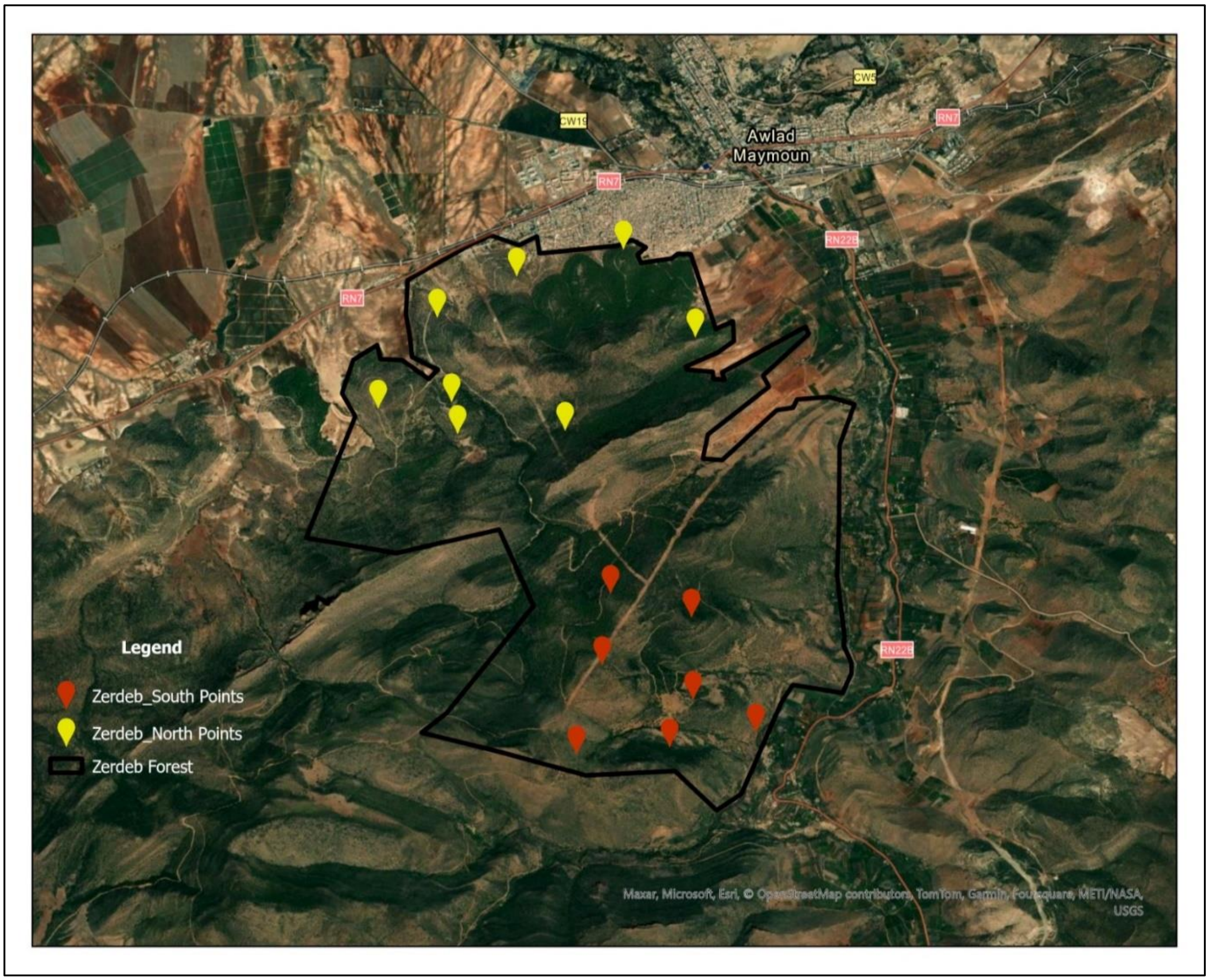

Figure 3.1: The distribution of Plant Species in Zerdeb Forests derived from Open Street Map (Original)

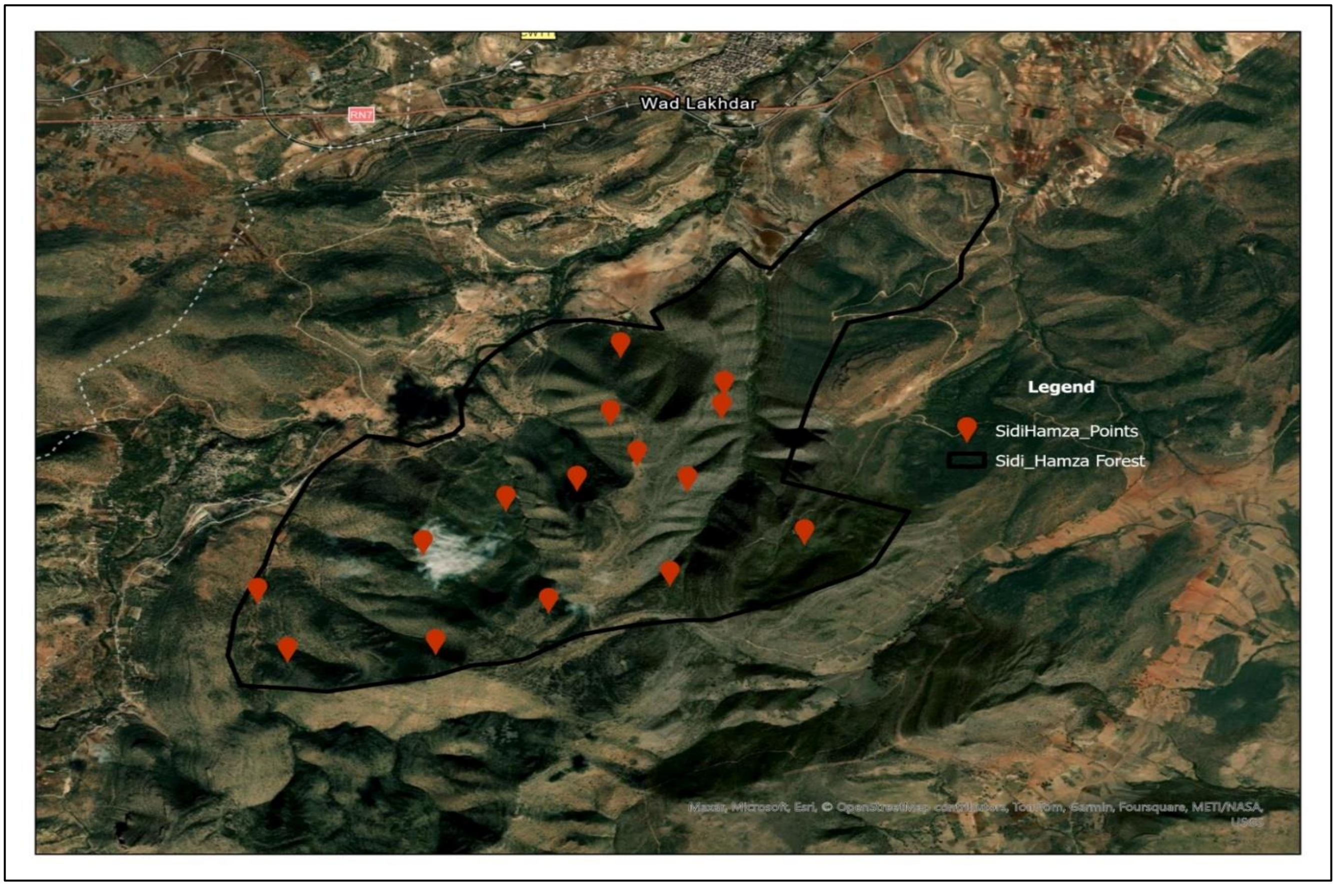

Figure 3.2: The distribution of Plant Species in Sidi Hamza Forests derived from Open Street Map (Original)

Genêt, which is sporadic, appearing in several plots but not consistently. The isolated patches that are indicative of the localized distribution of Pistachier lentisque (*Pistacia lentiscus*) are observed. There are many plots where doum (*Chamaerops humilis L.)* is present (Fig.3.3). In comparison to Diss (*Ampelodesmos mauritanicus*) and Chêne kermès (*Quercus coccifera*), which are common across the plots, oléastre (*Olea europea*) is present but less plentiful.

The interesting absence of Pistachier térébinthe (*Pistacia terebinthus*) from the sampled plots points to a possible environmental restriction or different distribution pattern. There is a spotty distribution of asparagus (*Asparagus plumosus*), with some plots having it and others not. While Lavande (*Lavandula dentata*) exhibits a more restricted distribution, Chêne vert (*Quercus ilex*) is rather ubiquitous, observed in numerous plots.

 A. Diss (*Ampelodesmos mauritanicus*)	 B. Chene kermes (*Quercus coccifera*)
 C. Arbousier (*Arbutus unedo*)	 D. Genet *SP.*

Figure 3.3: Some original photos of the floral diversity found in the region (Original)

This section presents a visual exploration of the floral diversity found in the Zerdeb and Sidi Hamza forests. The following photos provide a glimpse into the unique ecosystems (Fig.3.4.).

A. Zerdeb Forest

B. Sidi Hamza Forest

Figure 3.4: General over-view of the two forests (Original)

3.2.Forest composition and stand structure

This section covers the results and discussion of the study. The number of trees recorded in Zerdeb forest (101) was less than the number of trees recorded in Sidi Hamza Forest (102). The circumference class distribution for Zerdeb forest was grouped into 11 classes:

The circumference class 50-70cm had the highest number of individuals, it recorded (33 trees), followed by the class 70-90cm with (25 trees). The circumference class 170-190cm and 210-230cm recorded the lowest number of individuals, with 2 and 3 trees respectively. Overall, majority of the trees were recorded in the middle classes (Fig.3.5). Based on this distribution, it appears that the forest is primarily middle-aged and is growing under ideal conditions, which encourage rapid expansion in these size classes. Larger trees may have been scarcer historically due to selective logging, but they are also rare due to natural loss from storms, pests, and disease. Furthermore, the anthropogenic disturbances like fire, overgrazing, and illegal logging account for the rarity of larger trees and the abundance of trees in the moderate diameter class. The growth of middle-sized trees has been favored by the fight for resources, and the smallest size classes may not yet represent recent patterns of regeneration.

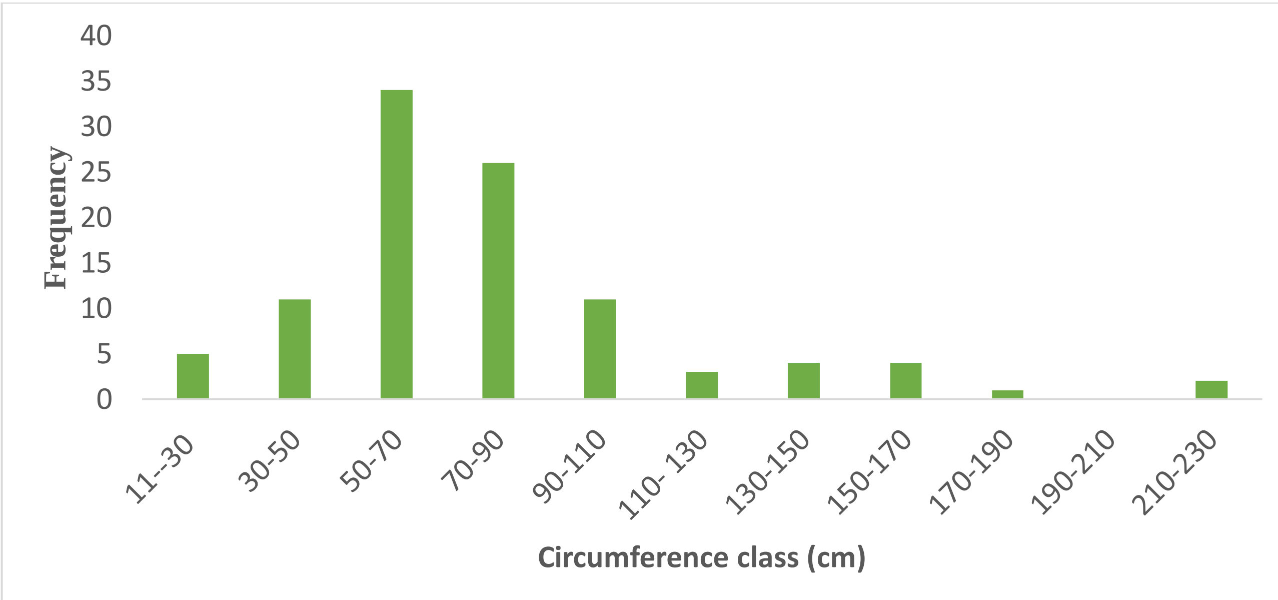

Figure 3.5: Tree circumference class distribution of Zerdeb forest (Original).

The tree height distribution in Zerdeb forest was grouped into 8 classes.

The class 6-9m had the highest number of individuals (45 trees), followed by the class 3-6m with (20 trees). The height classes with the least number of individuals were the class 18-21m and 21-23m with 1 tree each for them. Similar to the tree circumference class distribution, the number of individuals in the height classes decreased with increasing height classes (Fig.3.6). The reason for the relatively smaller number of tree individuals in the upper height class can be attributed to the limited number of species that naturally grow up to these heights.

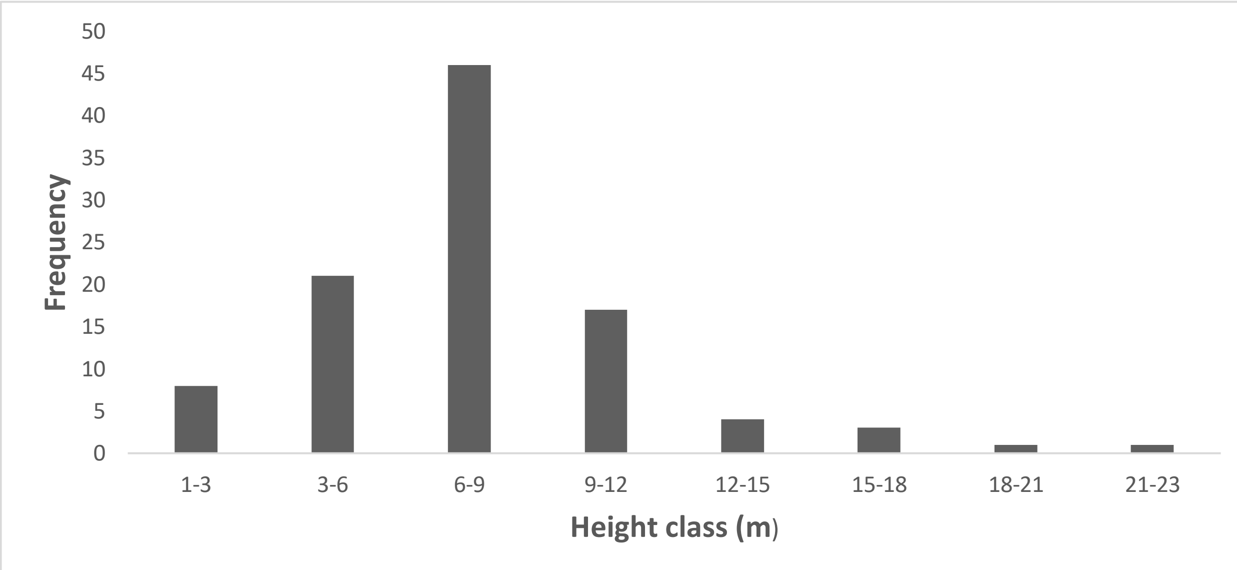

Figure 3.6: Tree height class distribution of Zerdeb Forest (Original)

In the case of Sidi Hamza Forest, the circumference distribution was grouped into seven classes.

The class 70-90cm recorded the highest number of individuals with (30 trees), followed by the class 50-70cm with (27 trees). The circumference classes with lowest number of individuals were the 110-130cm and 130-150cm with 4 and 2 trees respectively (Fig.3.7). This pattern could have a few different causes. First, diseases, pests, wind damage, and competition are some of the reasons why larger, older trees are more likely to die. The likelihood of trees dying from these stresses rises with age and size. There might be a high mortality rate in the greatest size classes if there are few extremely huge trees. Secondly, fewer young trees may be maturing into the bigger size classes if there has been little recruitment of new trees into the population in recent decades. Uneven distribution of size classes may result from factors such as changes in land usage, drought, or other disturbances that hinder tree regeneration.

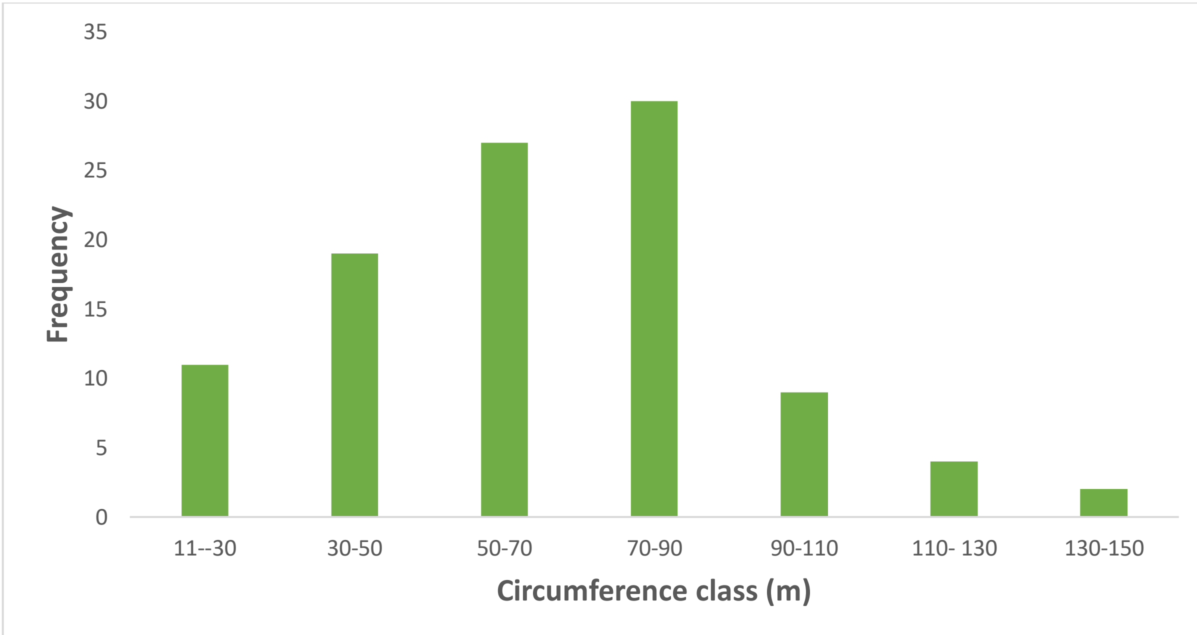

Figure 3.7: Tree circumference class distribution of Sidi Hamza Forest (Original)

In terms of the height class distribution at Sidi Hamza Forest, it was grouped into 5 classes:

The class 6-9m had the highest number with (34 trees), followed by 3-6m class with (33 trees). The height class with the lowest number of individuals were the class 1-3cm and 12-15m with (11 trees) and (3 trees) respectively. Similar to the tree circumference class distribution, the number of individuals in the height classes decreased with increasing height classes (Fig.3.8). The reason for the relatively smaller number of tree individuals in the upper height class can be attributed to the limited number of species that naturally grow up to these heights.

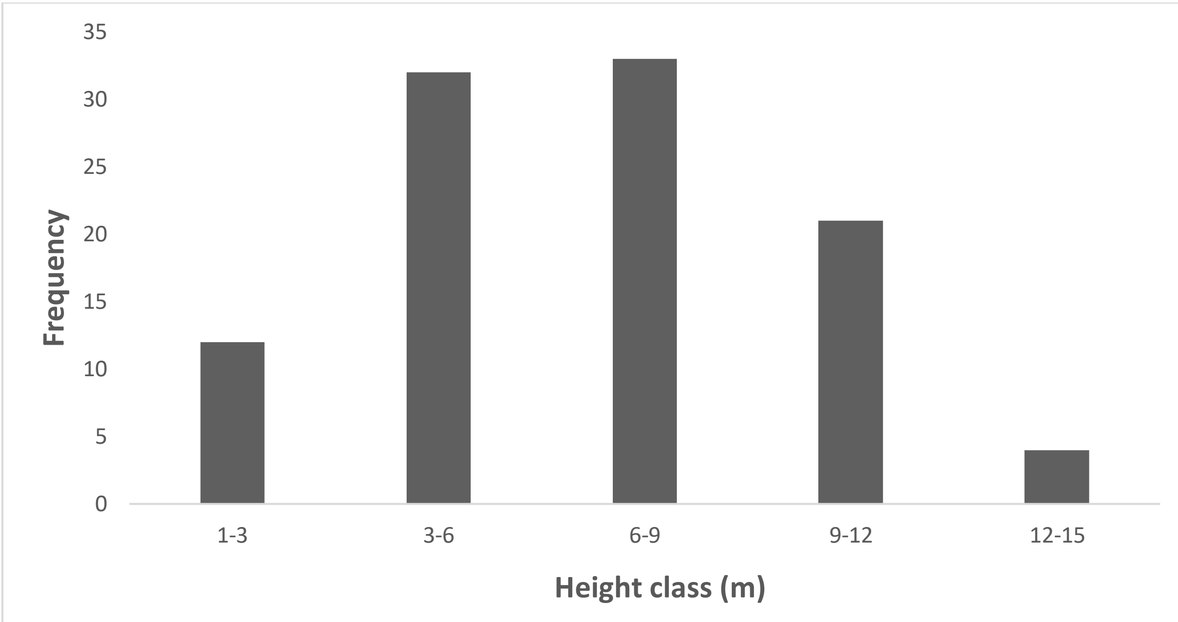

Figure 3.8: Tree height class distribution of Sidi Hamza Forest (Original)

The findings of the current study are consistent with previous research indicating that prior to the drought, the magnitude of stress experienced by individual trees in a forest typically already spans the entire spectrum from little or no stress to chronically high stress, the latter usually resulting from some combination of competition, poor local site conditions (such as shallow or nutrient-poor soils), past physical damage, the effects of previous droughts, ongoing attack This is consistent with research by (Pedersen 1998), ;(Suarez et al. 2004), (Kane et al.,2014), and (Gaylord et al. 2015), who discovered that chronically stressed trees, as indicated by persistent slow growth prior to drought, frequently have higher average mortality rates during drought than their less stressed, rapidly growing neighbors. In addition, (Cailleret et al. 2015) underlined the significance of comprehending the techniques and gaps in knowledge that exist in the quantification of drought-induced tree death.

3.3.Tree density and Basal area

This study helps estimate the volume of trees in the forest and understand the density of stands, as well as the competition and the space occupied by each forest. The tree density was slightly lower in Zerdeb forest (101) trees than in Sidi Hamza Forest (102 trees) (Fig. 3.9). In general, both forests had low tree density. The low tree density in both forests can be related to the poor regeneration and sapling recruitment. (Bessaid et al. 2020), also recorded low tree density in Zariffet forest. The total basal area for Sidi Hamza Forest (422.28 m2/ha) was lower than the one recorded for Zerdeb forest (616.18 m2/ha) (fig.3.8). A possible reason for the low basal area in Sidi Hamza Forest could be due to the presence of young trees compared to Zerdeb forest. Comparing Zerdeb Forest to Sidi Hamza Forest, it may be inferred that the former has more mature trees, which may indicate superior growing circumstances or less past disturbance.

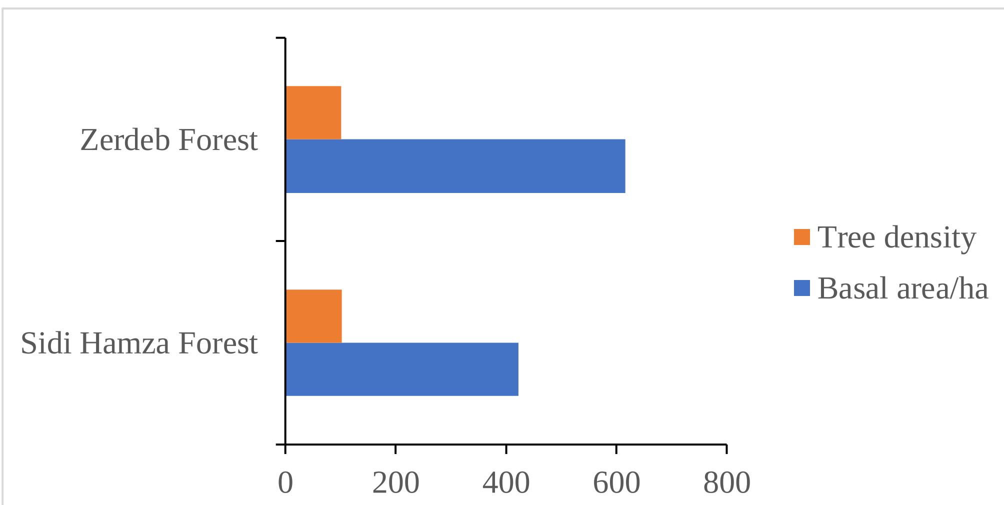

Figure 3.9: Tree Density and Basal Area

3.4.Comparative Dendrometry Analysis of Sidi Hamza and Zerdeb Forests Using Mann-Whitney U Test

Since tree circumference and height data might not be regularly distributed, the need to use the Mann-Whitney U test, a non-parametric test, in other words, a test that does not assume a specific distribution for the data, arises to see if there is a significant difference between the medians of two independent groups (circumference and height) among the two forests.

Where:

N: Number of observations

Z: Represent the z-score which is a measure of how many standard deviations an item is from the mean. It is used in hypothesis testing and indicates the significance of the difference between two groups.

P: The p-value for the same median hypothesis test is p (same median). It is the probability of obtaining the observed results, provided that the null hypothesis is true (i.e., there is no difference between groups) (Tab, 3.5.).

Table 3.1: Circumference Analysis of the two forests with Mann-Whitney Test

Mann-Whitney test for "equal medians"	
Sidi Hamza Forest	Zerdeb Forest
N: 102	N: 101
Mean rank: 47.759	Mean rank: 54.241
Mann-Whitn U: 4442	
z: 1.6933 p (same med.): 0.090405	
Monte Carlo permutation: p (same med.): 0.0887	

Compared to Sidi Hamza Forest (47.759), Zerdeb Forest had a mean rank for tree circumference (54.241), which indicates that trees in this forest typically have a larger diameter. The p-value for the Mann-Whitney U statistic of 4442 is 0.090405, equivalent to a z value of 1.6933. The null hypothesis, according to which the medians of the two groups are equal, is not rejected because the p-value is higher than the standard significance level of 0.05. This suggests that, at the 5% significance level, there is no statistically significant difference in the tree circumferences between the two forests.

The p-value, however, marginally drops to 0.0887 when the Monte Carlo permutation test is used. This result is still over the 0.05 threshold but shows a trend in the direction of significance.

This extra test yields a more reliable analysis, indicating that bigger sample sizes and additional research may be necessary to validate these results.

Overall, based on our current sample size and analysis, the results show a trend towards larger tree circumferences in Zerdeb Forest compared to Sidi Hamza Forest, but the difference is not statistically significant.

Zerdeb Forest has a higher mean rank (53.276) for tree height data than Sidi Hamza Forest (48.724), suggesting that trees in Zerdeb Forest frequently have higher values for the measured attribute. Nevertheless, the Mann-Whitney U test yielded a p-value of 0.21784, which is greater than the customary significance level of 0.05 (Tab.3.9).

Table 3.2: Height analysis of the two forests with the Mann-Whitney test

Mann-Whitney test for "equal medians"	
Sidi Hamza Forest	Zerdeb Forest
N: 102	N: 101
Mean rank: 48.724	Mean rank: 53.276
Mann-Whitn U: 4638	
z: 1.2323 p (same med.): 0.21784	
Monte Carlo permutation: p (same med.): 0.2146	

This implies that there is no statistically significant difference between the two groups. Therefore, the study failed to reject the null hypothesis that their medians are equal.

Similarly, the Monte Carlo permutation test produced a p-value of 0.2146, validating the conclusion that there is no statistically significant difference between the medians of Zerdeb Forest and Sidi Hamza Forest.

3.5.Temporal Analysis of Vegetation Cover in Ouled Mimoun Region from 1990- 2023

This section presents the findings derived from remote sensing analysis of vegetation cover carried out in 1990 and 2023 in the Ouled Mimoun region, which included estimates of the forest cover, changes in that cover, and the dynamics of those changes. The areas of each class were combined with their respective frequencies compared to other classes in the results. Using NDVI image categorization, cover maps displaying five land use and land cover are presented in (Fig 3.10).

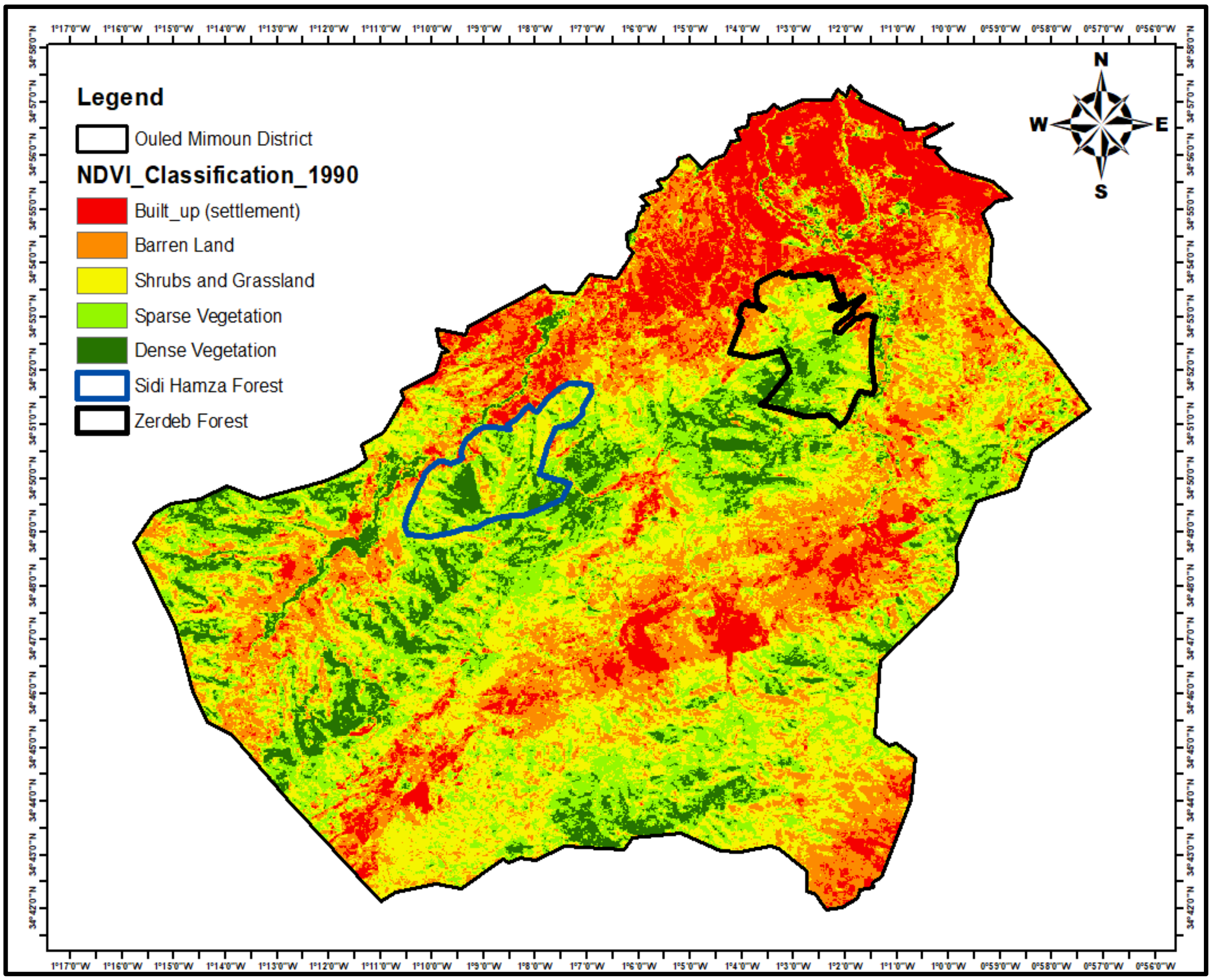

Figure 3.10a: 1990 NDVI Classification of Ouled Mimoun (Original)

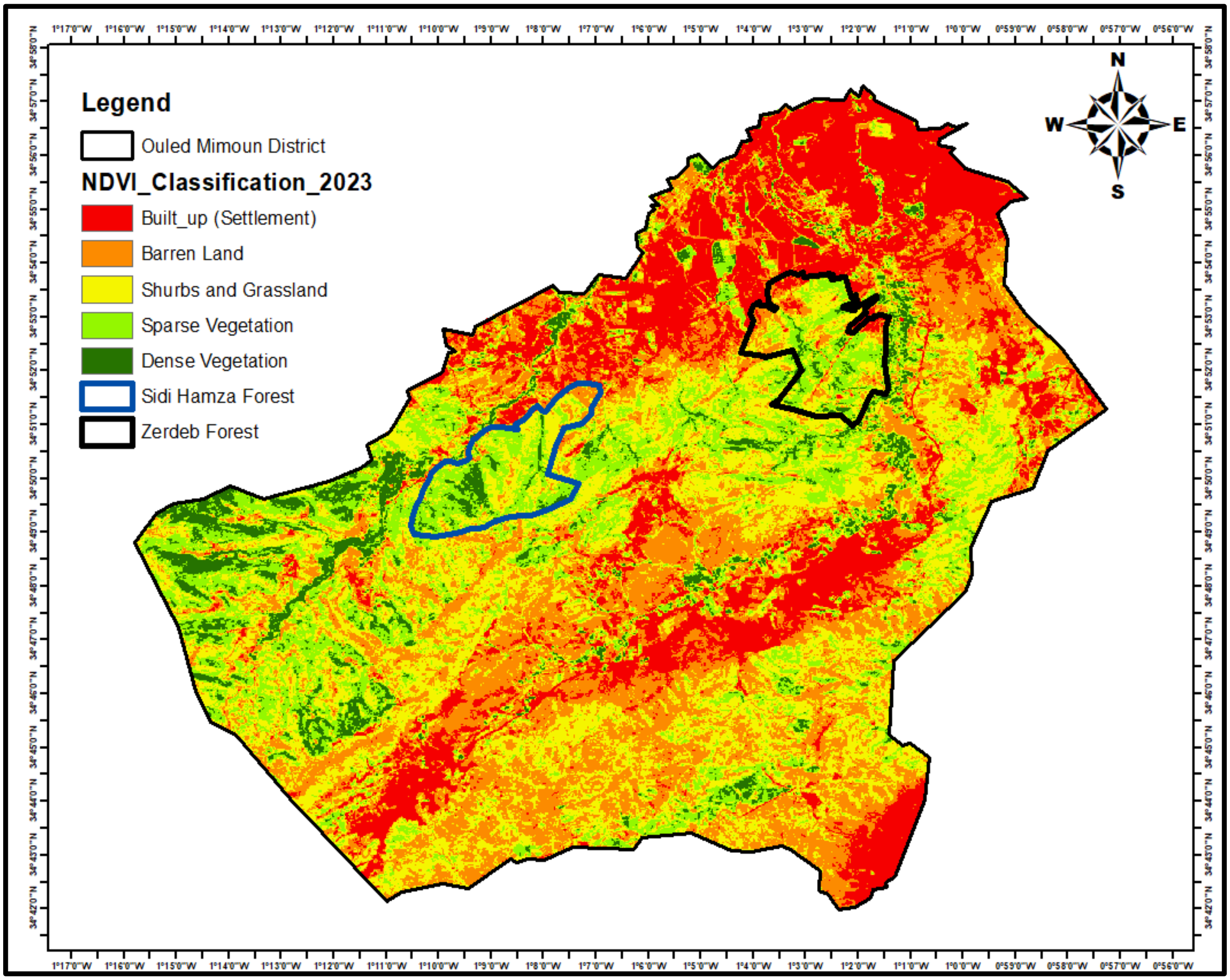

Figure 3.10b: 2023 NDVI Classification of Ouled Mimoun (Original)

The majority of the forest cover was found in the East and West. The sparse vegetation was mostly found in the center of the research area while Agriculture dominated the Northeast stretching to the Southeast. The assessment provides a comprehensive summary of the various land covers found in the inventoried area according to remote sensing analysis conducted in the Ouled Mimoun from 1990 to 2023. The figure categorizes the land cover into several distinct types, each representing different states of vegetation and forest cover.

Comparing the vegetation cover data between 1990 and 2023 the (Fig.3.11) reveals a notable transformation in the region. In 1990, non-vegetated land covered 232.6 km², slightly higher than the vegetated area at 221.6 km². By 2023, the non-vegetated land significantly increased to

273.7 km², while the vegetated area decreased to 180.5 km². This shift indicates a 17.7% increase in non-vegetated land and an 18.5% decrease in vegetated land over the 33-year period, corresponding to a total loss of approximately 41.1 km² of vegetated land.

This shows that, during the course of the 33 years, there has been a noticeable change away from vegetated areas and toward more non-vegetated land, which most likely represents pressures from development and human activity on the ecosystem.

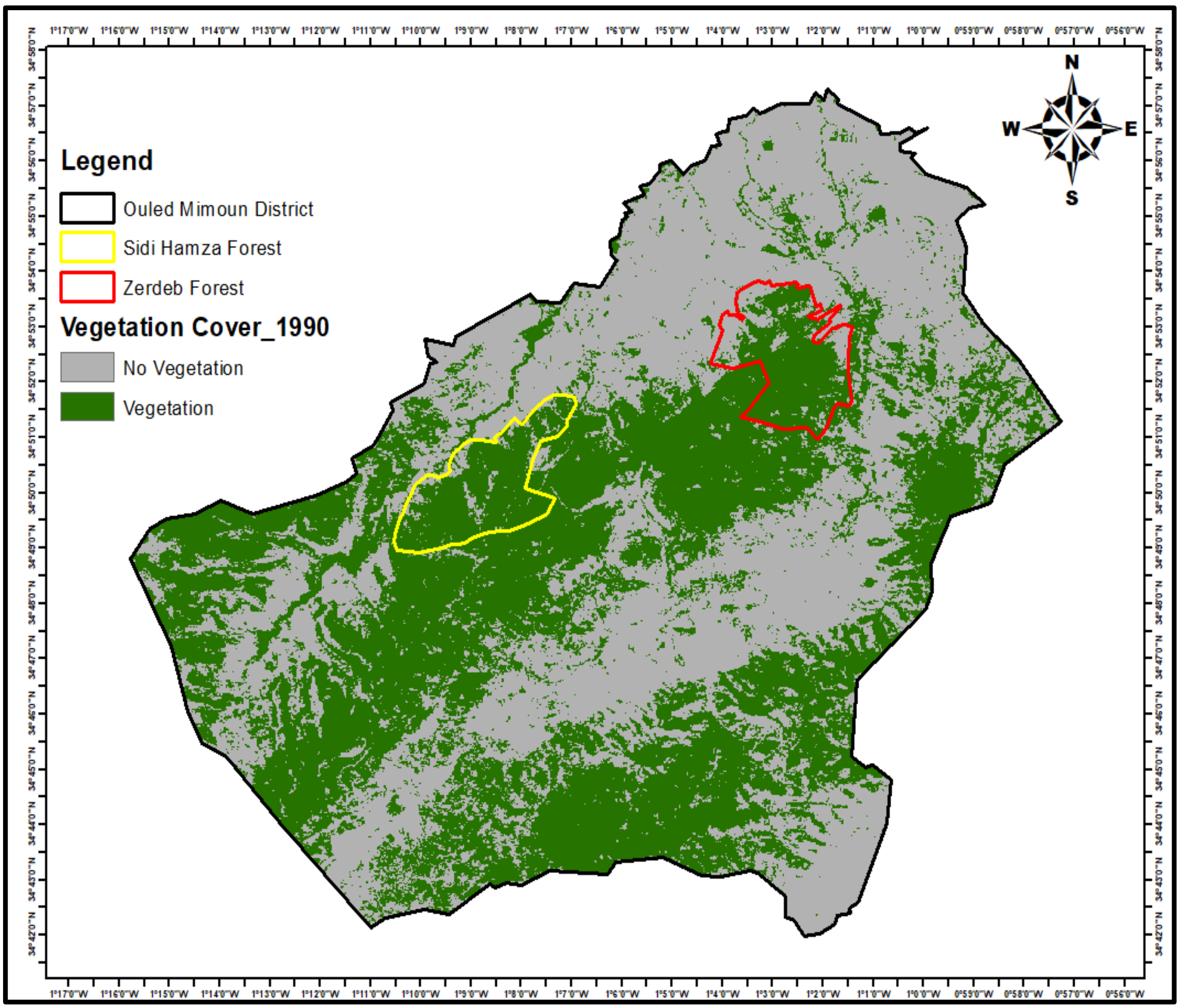

Figure 3.11: Evolution of Vegetation and Non-vegetation Land in the Ouled Mimoun (1990) (Original)

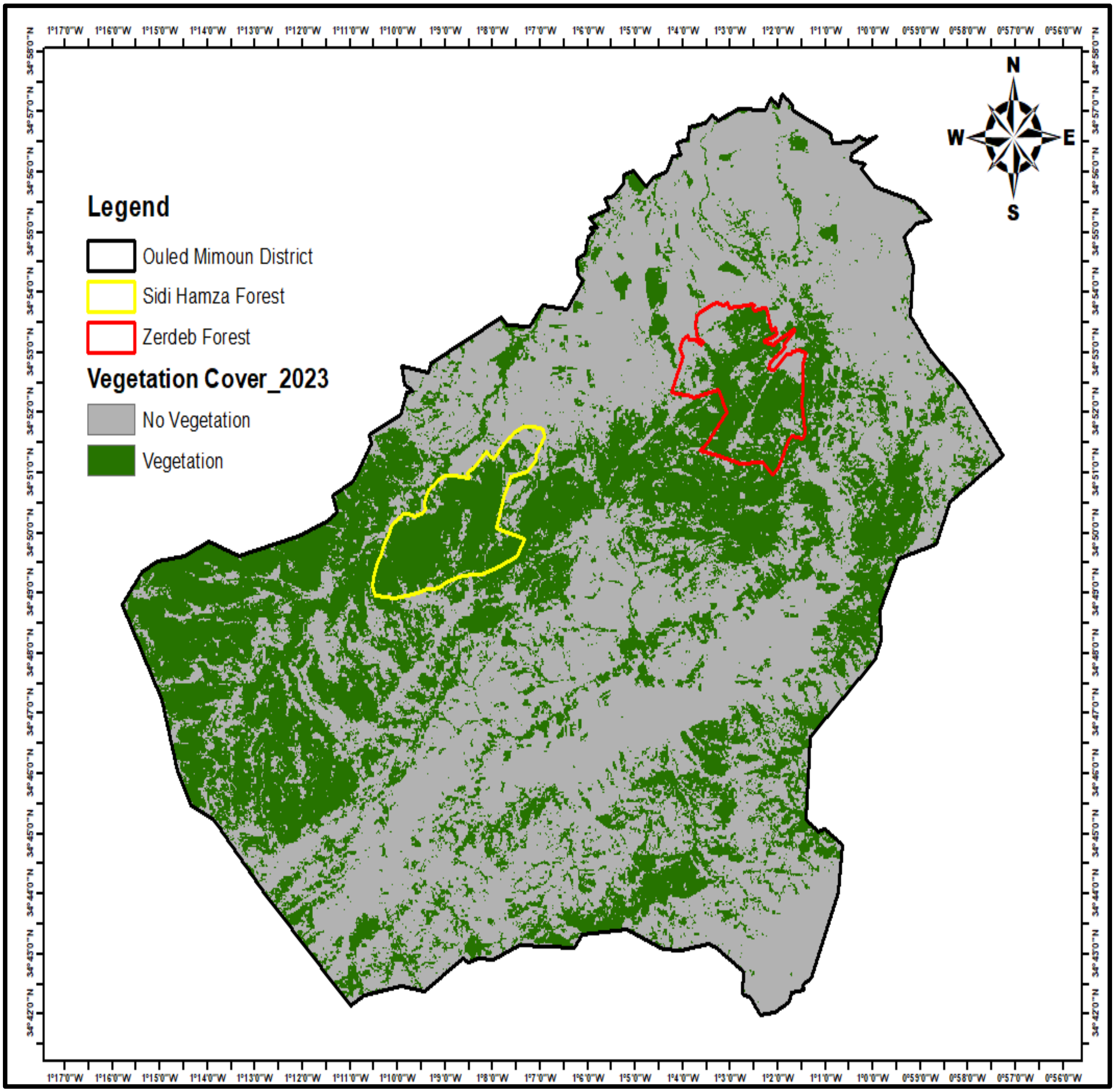

Figure 3.11b: Evolution of Vegetation and Non-vegetation Land in the Ouled Mimoun (2023) (Original)

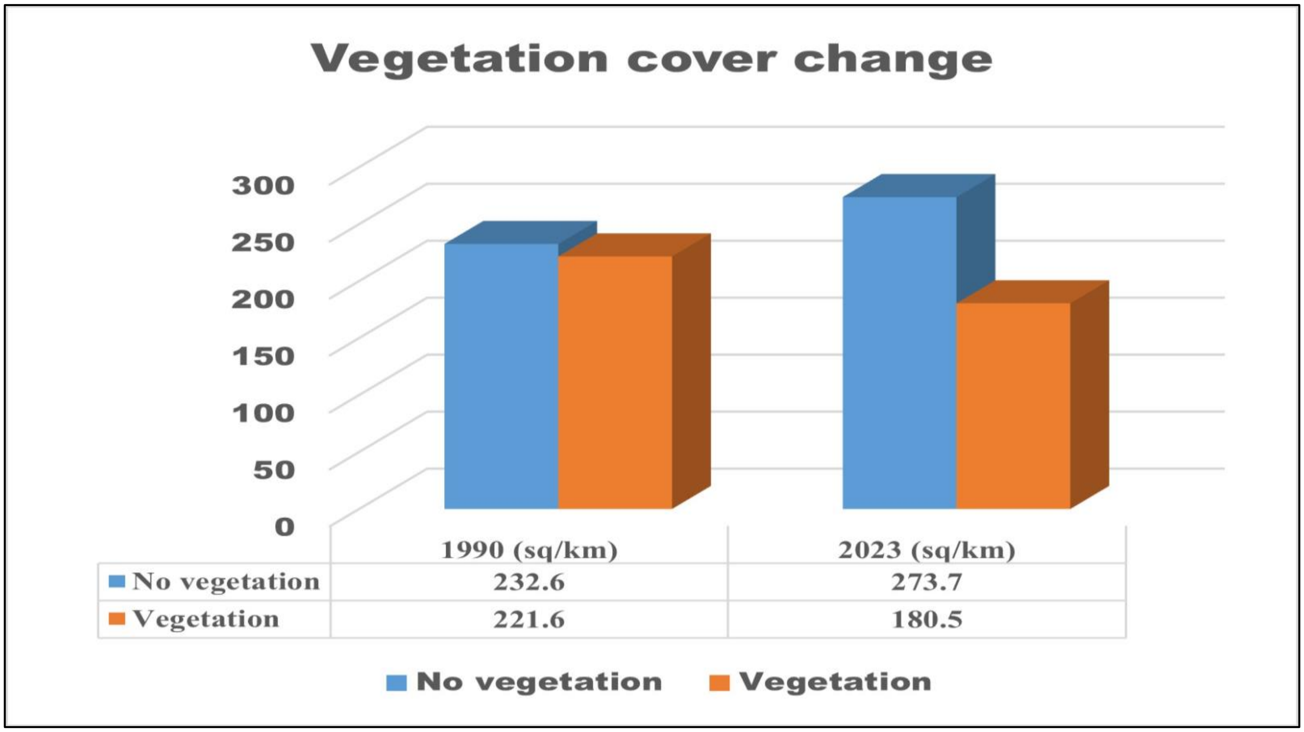

Figure 3.11c: Evolution of Vegetation and Non-vegetation Land in the Ouled Mimoun (1990-2023) (Original)

3.5.1. Forest cover change in Ouled Mimoun Region

The dynamics of forest cover changes during a thirty-three-year period, from 1990 to 2023, are depicted in (Fig 3.12). In 1990, the forest cover was 454.08km^2, about 141.17 km^2 of this forest area stayed unaltered on the same land in 2023. But a large amount, about 193.28km^2, had been degraded to become sporadic bushes and trees. Selective logging techniques may have contributed to the deterioration of forest into scattered trees and shrubs by decreasing crown closure and changing the land cover classification from forest to scattered vegetation. It is significant to remember that because of its poor crown closure and changed ecological features, the category of dispersed trees and plants is not regarded as a forest. In addition, deforestation resulted in the loss of 80.37 km^2 of forest area. In this context, the term "deforestation" refers to the transformation of wooded lands into land uses other than forests, including agriculture or bare ground. Positively, during the same time period, some 39.26 km^2 of land were converted to afforestation. The process of establishing new woods on previously unforested land is known as afforestation. The conversion of sporadic areas of trees and bushes into agricultural land or barren land, however, also resulted in deforestation and must be taken into account when analyzing the overall deforestation process seen in the study area.

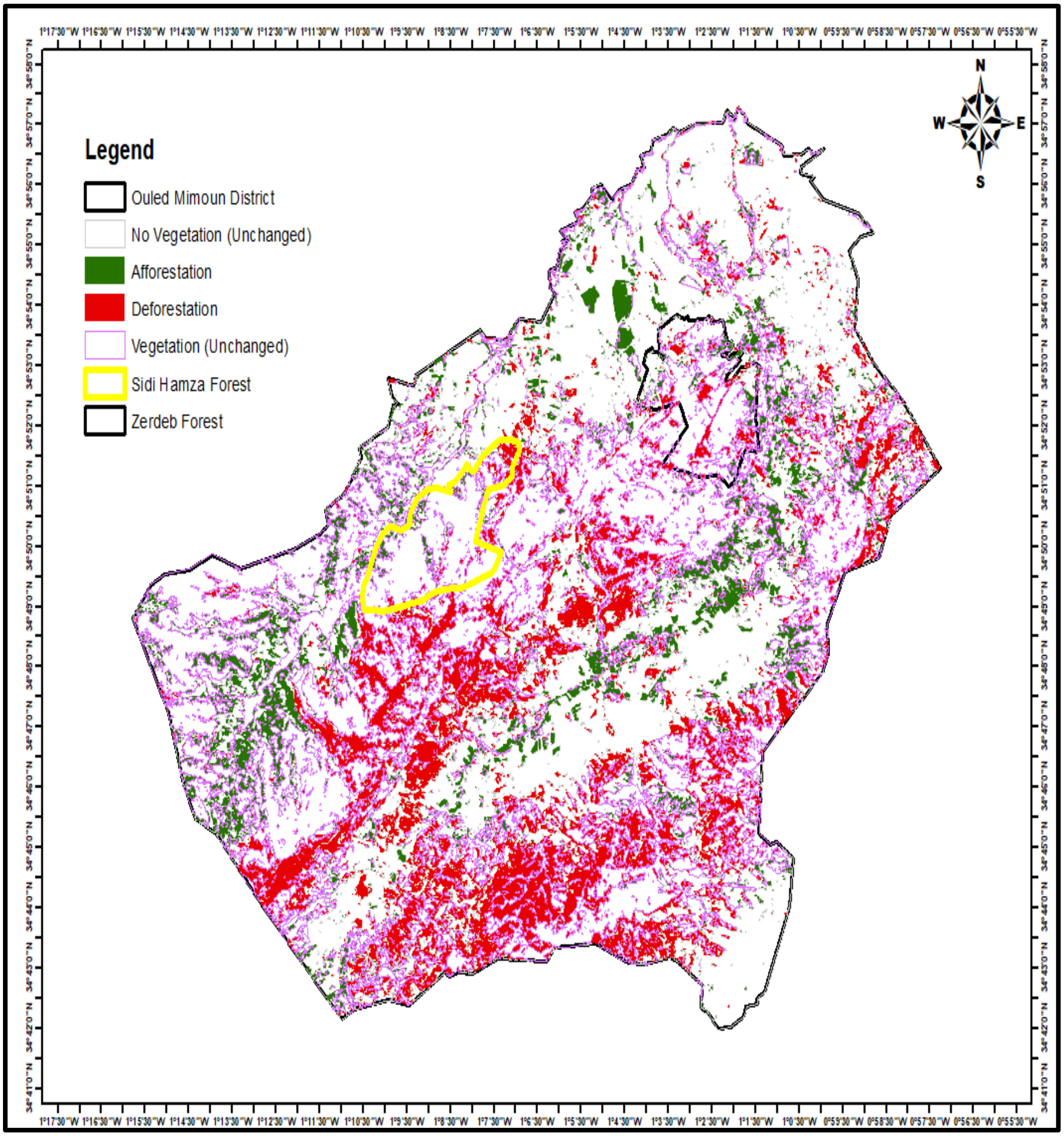

Figure 3.12a: Dynamic of the forest cover between the two period 1990-2023 (Original)

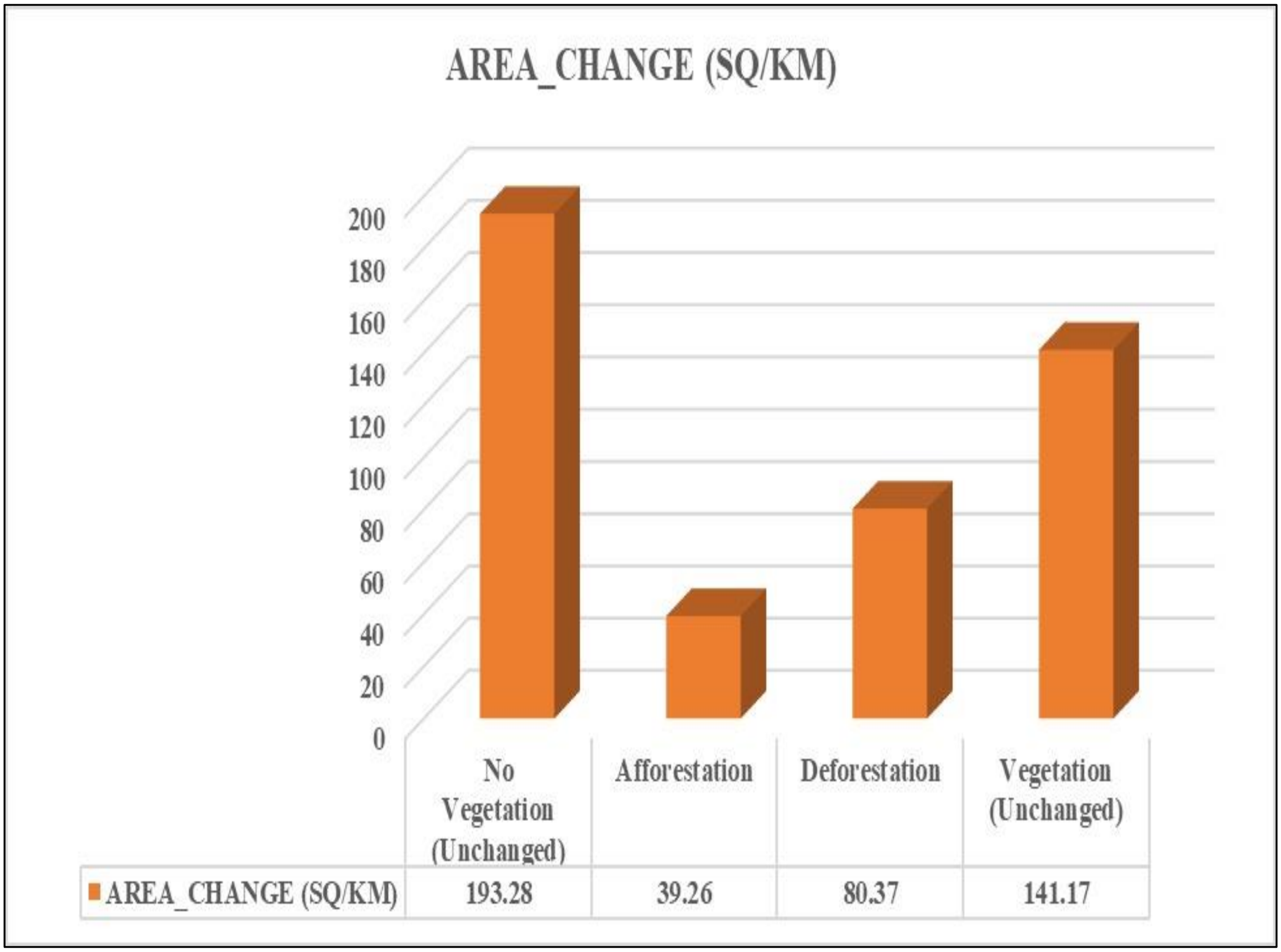

Figure 3.12b: Dynamic of the forest cover between the two period 1990-2023 (Original)

During the study period, settlements and land cover conversions, such as conversion to agricultural land, changed the forest cover of the Mimoun Forest. In general, the amount of forest cover in Tlemcen is decreasing in a few locations due to the city's rapid population expansion and rising demand for open space for agriculture, as it has been reported by other researchers (Abdelkader et al., 2021). Anthropogenic pressures and climate disruptions might be responsible for the significant loss of forest cover that occurred during the interval (1990–2023) of the research period.

3.5.2. Forest cover change in Zerdeb forest from 1990- 2023

Unchanged Vegetation: This category represents the largest portion of the study area, accounting for 58%. These are areas where the forest cover has remained stable and unchanged over the years, maintaining their original tree density, species composition, and overall forest structure.

No Vegetation: The second largest category is land with no vegetation, representing 22% of the study area (Fig.3.13). This includes barren land, rocky areas, and regions where vegetation has been completely removed due to various factors such as urbanization or environmental degradation.

Other Cover: This category encompasses changes in forest cover, including deforestation and afforestation, which together represent 20% of the study area. Specifically:

- Deforestation: This account counts for 14% of the area. These are regions where forests have been cleared, often for purposes such as logging, agriculture, or infrastructure development.

- Afforestation: Represents 6% of the area. These are areas where new forests have been planted on lands that previously did not have forest cover, indicating efforts to restore and increase forested areas.

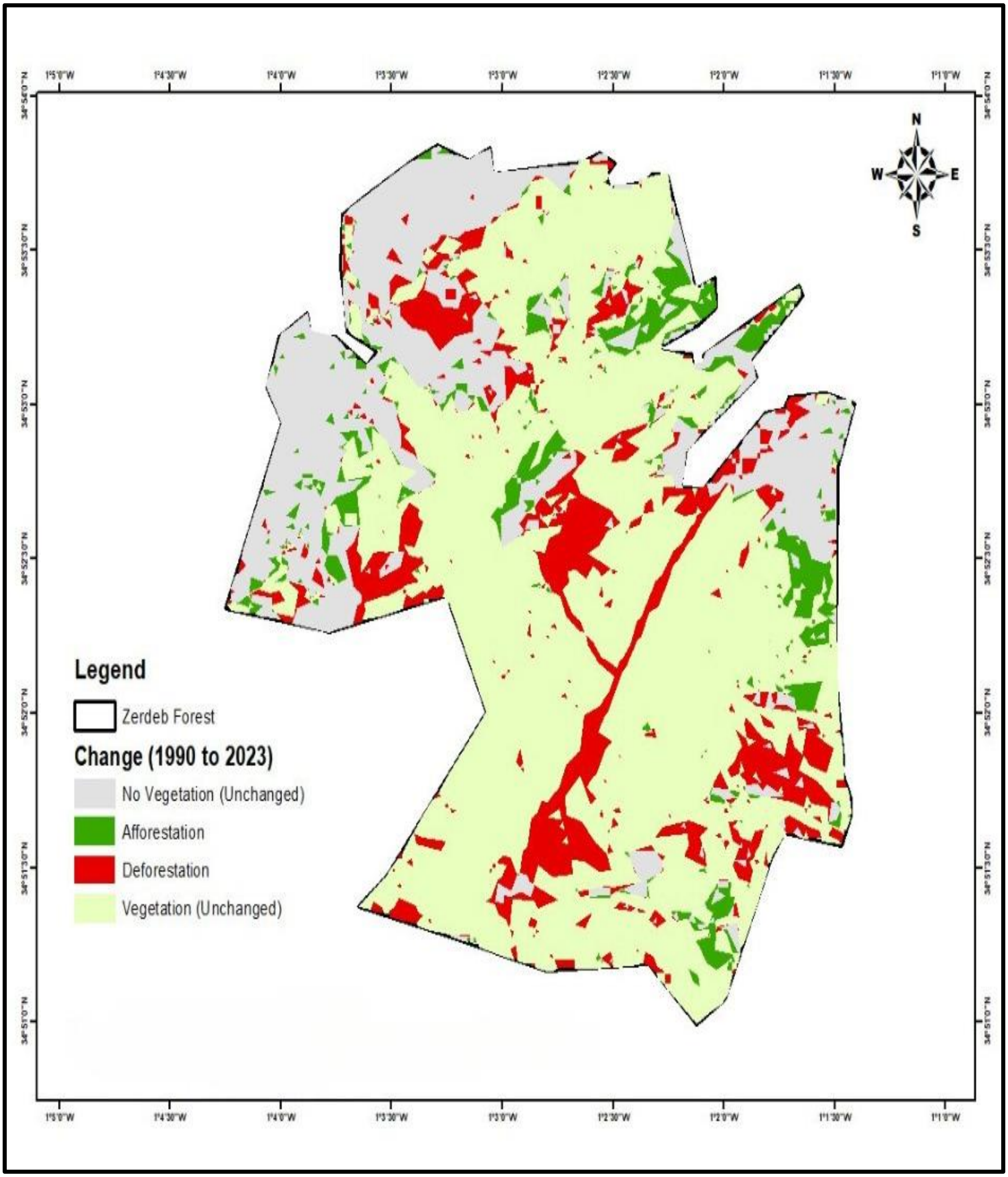

Figure 3.13a: Forest Cover Map of Zerdeb 1990-2023 (Original)

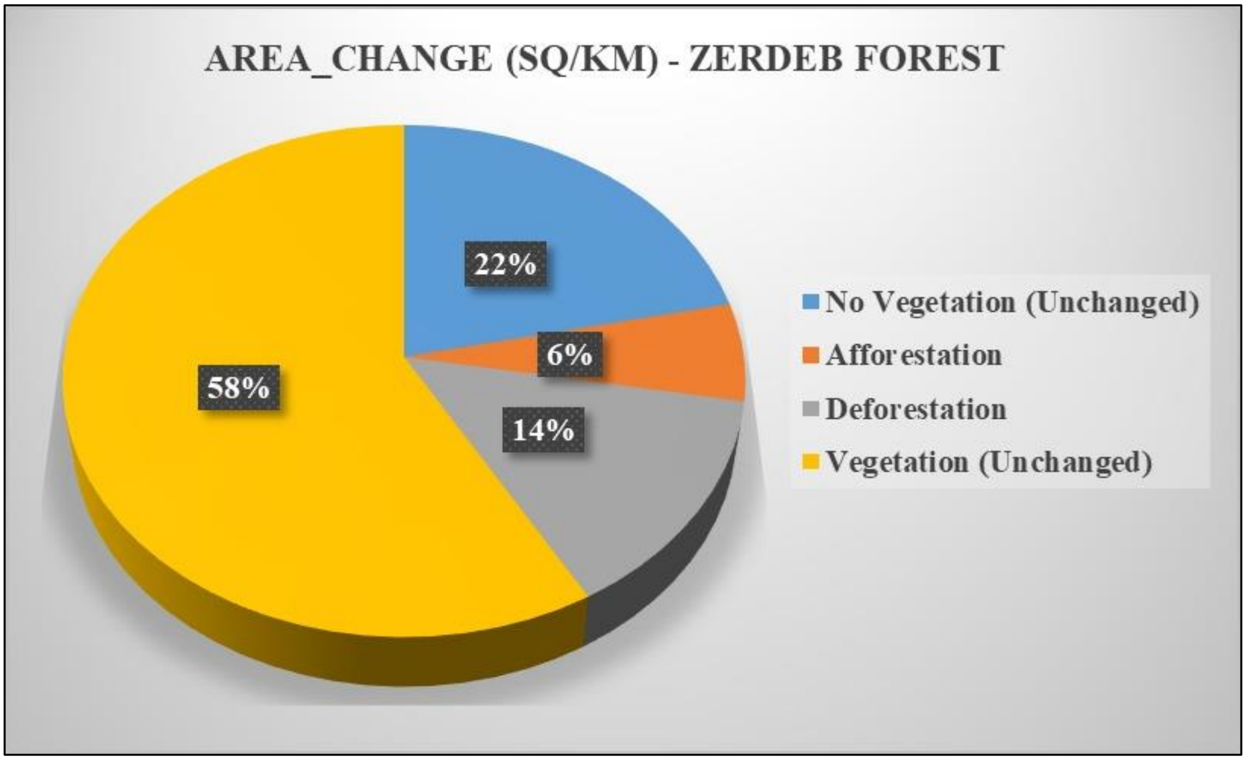

Figure 3.13b: Dynamic of Zerdeb Forest cover maps 1990 - 2023 (Original)

3.5.3. Forest cover change in Sidi Hamza Forest from 1990- 2023

The land cover categories in the Sidi Hamza region from 1990 to 2023 are shown in (Fig. 3.13). According to the results, 76.91% of the vegetation cover had not been altered over time, indicating places where the vegetation has stayed consistent. This is a 18.91% rise from Zerdeb forest. Furthermore, the results show that 7.29% of the region is categorized as having no vegetation, a noteworthy drop of 14.71% from the Zerdeb forest. Additionally, the data shows that 8.30% of the region has had deforestation, which is 5.7% less than what was found in the Zerdeb survey. Finally, the (Fig.14) indicates that afforestation (the process of establishing new forests) has taken place in 7.49% of the region.

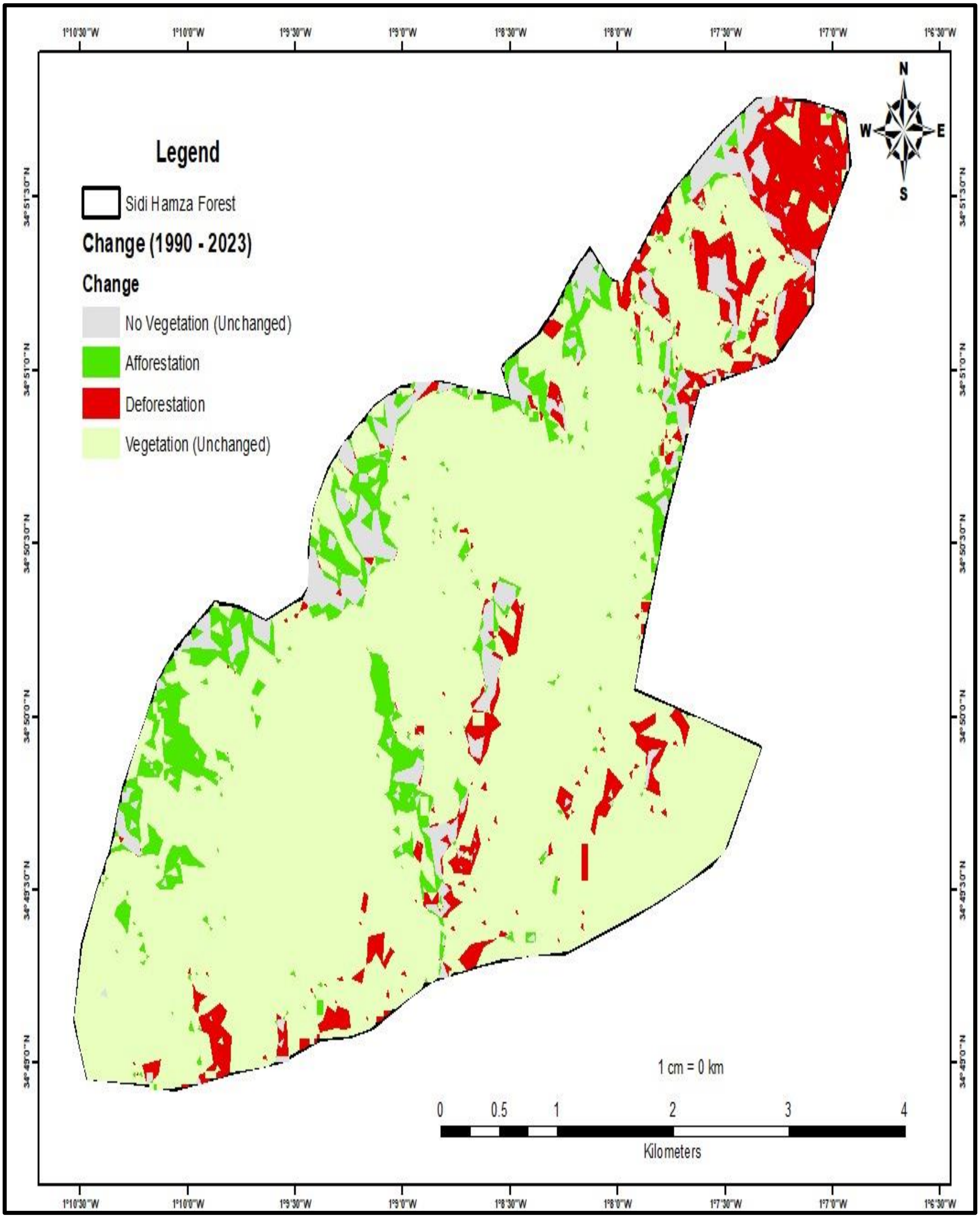

Figure 3.14a: Forest Cover Map of Sidi Hamza 1990-2023 (Original)

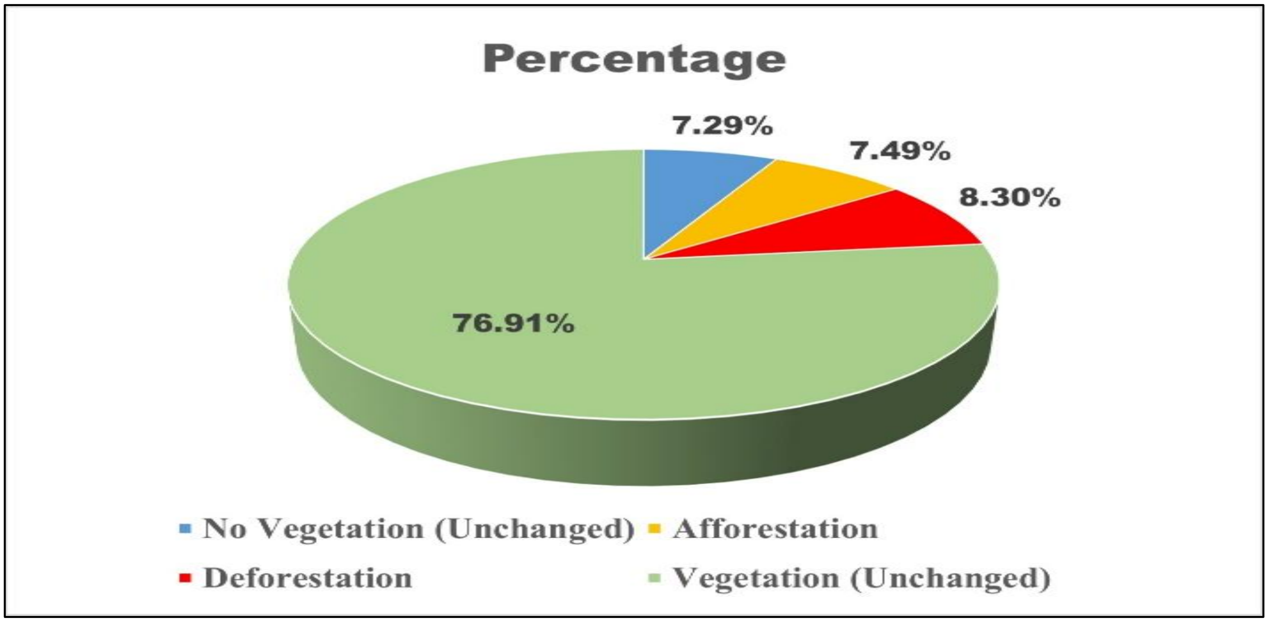

Figure 3.14b: Dynamic of Sidi Hamza Forest cover maps 1990 - 2023 (Original)

3.6.Forest degradation in Ouled Mimoun region

The remote sensing analysis shows that the Ouled Mimoun Forest's cover has changed significantly for the 33-year period. A possible reason for the change in the forest cover could have been due to anthropogenic activities and the changing climate. (Bencherif, 2010), also attested that the Tlemcen region has witnessed a rising temperature and a declining precipitation, which has led to changes in the local climate, making it more suitable for certain plant species and less suitable for others.

Furthermore, Drought could be another possible cause of the loss in the covers in the Ouled Mimoun region. In the Mediterranean Basin, prolonged drought is a common occurrence (Seguí et al., 2016). Growing trees and forest productivity are severely impacted by these droughts. The Mediterranean region's forest dieback has reportedly increased three to four times in the past 30 years, according to (Allen et al. 2010). In addition, the decline of forest cover in the region could have been due to frequent fires.

These results align with earlier studies that found that, "from 1987 to 2017, the region of Tlemcen experienced considerable variations in burnt areas, with fluctuations from one year to another, with the year 1994 being the most catastrophic in terms of burnt area and number of fires, due to the unstable conditions the country experienced that year. Also, despite efforts to regenerate forests in Algeria, these initiatives have not been very successful, there is an annual fire-fighting campaign that runs from June to September, but the extended drought in western Algeria causes fires to begin in May and persist beyond September. The limited resources of the forestry services make it challenging to extend the fire-fighting efforts beyond the summer months (Bardadi et al., 2021).

3.7.Causes of forest degradation in Ouled Mimoun region

The Algerian civil war is one other potential reason for forest loss. Research has indicated that a state's ability to enforce stringent regulations over its possessions, such forests, is compromised during hostilities, leading to conditions of unrestricted access. (Peckarsky, 2013) reports that between 150,000 and 200,000 people died during the catastrophic civil war that started in 1991.

Wood demand could also be a major factor driving deforestation (Fig.3.15). Local communities rely on logging for firewood, furniture, and construction materials as a common source of income.

Another cause of the deforestation in the area could also be as result of infrastructural development and urbanization. This validates (Claire's, 2021) assertion that urbanization is a contributing factor to deforestation. According to the researcher for an urbanization coefficient, there is a long-term of 0.31% increase in deforestation for every 1% rise in urbanization. In addition, the findings of this study are similar with the research conducted by (Natheniel et al., 2019), which revealed that urbanization has detrimental effects on environmental quality in both the short and long run.

Figure 3.15: Human activities in the region (Original)

3.8.Regeneration in Ouled Mimoun region

The findings indicate low regeneration taking place in the region. This is probably due to grazing pressure and the clearing of forest land for agriculture. The amount of land used for grazing and agriculture has increased over the past few decades, which has decreased the amount of forest cover and the amount of regrowth in arid regions. According to (Miller, 1999) noted that a number of conditions, including fire, grazing, and intense agriculture, have caused the seed banks of numerous species to collapse.

CONCLUSION, RECOMMENDATION AND LIMITATION OF STUDY

Conclusion

The Ouled Mimoun area woodlands, located in Tlemcen, illustrate how common species infiltrate due to stand degradation and sparseness. The Zerdeb and Sidi Hamza Forest's special location close to the semi-arid natural border of the cork oak's range emphasizes the necessity of resolving regeneration issues there. This thesis examined how the Zerdeb and Sidi Hamza Forests, which are located in the Ouled Mimoun region of Tlemcen, Algeria, have changed in terms of ecological degradation over time. The study provides evidence that deterioration plays a significant role in shaping the forest landscape. The tremendously endemic biodiversity of the forest environment is threatened by frequent degradations such fire, drought, and deforestation.

The following findings are reached based on the answers to the study's objectives:

Regarding the 30 plots assessed, three main species were consistently found. Genêt (*Cytisus scoparius*) was dominant in 28 out of 30 plots, followed by Doum (*Chamaerops humilis L.*) in 29 plots. Le Pistachier térébinthe (*Pistacia terebinthus*) and La Férule commune (*Ferula communis*) were less abundant, each appearing in only one plot, suggesting localized distributions. Diss (*Ampelodesmos mauritanicus*) was present in all plots, indicating its pervasive influence on overall vegetation. Additionally, Chêne kermès (*Quercus coccifera*) and Chêne vert (*Quercus ilex*) were widely distributed, highlighting their ecological significance.

Compared to the Sidi Hamza Forest (102), the Zerdeb Forest had a slightly lower total of trees (101) noted. There was a concentration of middle-aged trees in Zerdeb Forest, as seen by the circumference class distribution, especially in the 50–70 cm range. Following a similar pattern, the majority of the trees in the height class distribution fell between 6 and 9 meters. Given the previous logging, natural losses, and human disruptions like fire and illegal logging, these patterns indicate that Zerdeb Forest is growing healthily under favorable conditions, even though larger trees are rare. On the other hand, the distribution was somewhat different in Sidi Hamza Forest. The height class of 6-9 m and the circumference class of 70-90 cm had the greatest number of participants. Due to environmental stresses and disturbances, there may have been less recruitment of new trees into the population in recent decades, as indicated by this distribution pattern, which also shows a greater mortality rate among larger trees.

The analysis also revealed that the two woods had low tree densities, with Zerdeb Forest having a larger total basal area (616.18 m^2/ha) than Sidi Hamza Forest (422.28 m^2/ha). This suggests the Zerdeb Forest might have a higher proportion of older trees, better growth conditions, or less historical disturbance.

Since the dendrometry data from the two forests was not normal overall, the Mann-Whitney test was used in the study to see whether there were any significant differences between the two forests. Based on data on tree circumference, the results indicate that there was no significant difference ($p > 0.09$) between the two forests. In the same way, there was no discernible variation in tree height between the Sidi Hamza and Zerdeb forests ($p > 0.21784$).

Over the 30-year study period (1990–2023), the region experienced shifts in forest cover according to land use and land cover change analysis. The area exhibited extremely low biodiversity, lacked large trees, and showed signs of immature forests. Human activities, including deforestation for valuable wood, and woody fuel harvesting like charcoal and firewood, significantly degraded the region. Forest land conversion to agriculture, pastures, and urban development also contributed to deforestation. Ground surveys conducted in 1990 and 2023 provided insights into forest cover dynamics over time, with NDVI image analysis showing concentrated forest cover in the East and West, contrasting with agriculture-dominated North-East and South-East areas.

In the Sidi Hamza Forest, vegetation has remained more stable compared to the Zerdeb forest. Specifically, 76.91% of Sidi Hamza's vegetation remained unchanged over the years, significantly higher than Zerdeb's 58%. Conversely, Zerdeb experienced more deforestation, with 14% of its area cleared, compared to only 8.30% in Sidi Hamza. Additionally, Zerdeb had a higher percentage of land with no vegetation at 22%, in contrast to Sidi Hamza's 7.29%. This data indicates that while Sidi Hamza maintained greater vegetation stability, Zerdeb faced more extensive deforestation and barren land areas. Both forests exhibited afforestation and deforestation, reflecting the dynamic changes in forest cover over the study period.

Recommendations

- Launch focused afforestation and replanting initiatives to encourage cork oak woodlands natural regeneration, especially in regions where it is currently lacking.
- To promote biodiversity and resilience, introduce species that are well suited to the regional environment.
- Create and implement land use regulations that support sustainable farming methods and urban development while reducing deforestation and land degradation.
- Promote agroforestry techniques that increase agricultural productivity and forest cover by combining crop production with tree planting.
- To stop illicit logging and stop forest fires.
- Look for partnerships and funds to have access to Sentinel-2 and other better resolution satellite imagery for more accurate monitoring of changes in the forest cover.
- Inform and empower the community about the value of sustainable land use and forest conservation.
- In order to preserve accountability and transparency in conservation efforts, findings should be published on a regular basis.

Limitations of the study

The data and procedures utilized in this study have limitations.

The obligation to use Landsat images rather than Sentinel-2 data to assess changes in forest cover in the Ouled Mimoun region significantly constrained this study. The primary driving force for this choice was the absence of Sentinel-2 data throughout the entirety of the inquiry. Due to its superior spatial resolution (10 m), Sentinel-2 would have been a better choice for detecting minute changes in forest cover. However, due to restricted access to data, Landsat images with a coarser spatial resolution (30 m) was used.

However, due to logistical and time constraints, the questionnaire could not be implemented as originally intended. This limited the study's understanding of local perspectives on changes in forest cover, which could have provided valuable context and validation for the remote sensing analysis. Moreover, there were not enough people living in the forest area to participate in the questionnaire. The study aimed to survey up to 100 people in order to gather a comprehensive range of opinions and perspectives on the degradation of the forested areas. Because of these factors, the human element was deemed essential because it would provide insights into local perceptions, knowledge, and perspectives on changes in forest cover changes, which could then be compared and confirmed with the remote sensing data.

Despite the limitations of not being able to implement the questionnaire and the limited number of people in the forest area, efforts were made to ensure the robustness of the remote sensing analysis.

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APPENDIX

Appendix 3.1: Tree Circumference class category of Zerdeb forest

Number of Classes	Circumference Classes (cm)
1	11-30
2	31-50
3	51-70
4	71-90
5	91-110
6	111-130
7	131-150
8	151-170
9	171-190
10	191-210
11	211-230

Appendix 3.2: Tree height class category of Zerdeb forest

Number of Classes	Height Classes (m)
1	1-3
2	4-6
3	7-9
4	10-12
5	13-15

6	16-18
7	19-21
8	22-23

Appendix 3.4: Tree circumference class category of Sidi Hamza Forest

Number of Classes	Circumference Classes (cm)
1	11-30
2	31-50
3	51-70
4	71-90
5	91-110
6	111-130
7	131-150

Appendix 3.4: Tree height class category of Sidi Hamza Forest

Number of Classes	Height Classes (m)
1	1-3
2	4-6
3	7-9
4	10-12
5	13-15