DOCTOR OF PHILOSOPHY

Deforestation in Jefara Plain, Libya: Socio-economic and Policy Drivers (Algarabulli District case study)

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Award date:
2016

Awarding institution:
Bangor University

Deforestation in Jefara Plain, Libya: Socio-economic and Policy Drivers (Algarabulli District case study)

A thesis submitted for the degree of Doctor of Philosophy

to Bangor University

by

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May 2016

Dedication

This thesis is dedicated to my beloved parents for their invaluable contribution towards my success. Also to my beloved wife for her encouragement, understanding, patience, moral and material support and willingness to share difficulties which I encountered during the tenure of my study. Additionally it is dedicated to my daughters Razan and Rawan. Thank you all very much and Allah bless us all.

Acknowledgements

First and above all, I praise Allah, the almighty for providing me this opportunity and granting me the capability to proceed successfully. This thesis appears in its current form due to the assistance and guidance of several people. I would therefore like to offer my sincere thanks to all of them.

I take this opportunity to express my deep gratitude in particular to Dr. Robert M. Brook, my main research supervisor, for his scholastic guidance, advise, constructive criticism, support, encouraging insight, and friendship throughout the course of this research. His informed knowledgeable opinions and advice guided me forward step by step. I do not have enough words with which to express my feeling of gratitude to him. I am also indebted to Dr Neal Hockley for informed comment and constructive advice whenever it was required, also with resolving the effects of political influences affecting my progress along my chosen path of study.

I owe a sincere thanks to Ian Harris and Andrew Packwood at Bangor University for their help and support with the technological aspects of GIS and RS; to my committee members specially Prof. Morag McDonald for her constructive comments and advice during my annual committee meeting; to Dr Amin Kamete who was my original co-supervisor from 2010-2011 prior to moving to Glasgow University; to my friend Yasir Edowid.

I owe a big thanks to the Agronomist and Forestry expert in the Ministry of Agriculture, Libya, Mr Faraj Idris who has facilitated my studies from my initial proposals when I was in Libya to the culmination of my studies here in Bangor.

I would like also to thank the varied individuals in the Ministry of Agriculture who contributed to my research and thesis in Libya - Adnan Jebriel; Dr Bashir Nwer; Mr Adnan Sbeita and the forestry expert Khalifa Khatabi who was the administrator of Sand-dune fixation and afforestation campaigns in Algarabulli District from 1955 to 1973; to Dr Khaled Ben-Mahmoud.

I wish to register my gratitude to Forest Department staff in Algarabulli District for their invaluable support during my fieldwork, in Libya.

I am very much grateful to all respondents who shared their views and spared their valuable time in discussing to have their perception of forest and deforestation.

Last, but not least, to Mohammed Idris who helped me in any way he could from my home country of Libya. It is sad that he did not survive to see the fruits of his efforts and my labour.

Abstract

Deforestation has many negative effects on the environment. In North Africa the most dramatic are a loss of habitat for wildlife, desertification, soil erosion, and climate change.

In the Jefara plain, Libya, tree planting was undertaken to combat desertification and stabilize sand dunes and by 1984, 248,000 ha had been planted. However, these forest now suffer from severe deforestation, leading to serious encroachment of sand dunes, which now puts at risk those areas converted to agriculture.

The major objective of this thesis was to understand the real causes of deforestation focussing mainly on socio-economic and policy drivers in Algarabulli District.

Interviewed respondents stated that deforestation commenced in 1986, the major direct causes being agricultural expansion, building and road construction, and land trading. However, the major indirect cause contributing to deforestation was reported to be the change of forest governance in 1986; this led to an increase in corruption and a decrease in law enforcement, resulting in many land allocation contracts being issued to officers and government officials who then cleared forestland for themselves and later by local people. They reported that deforestation increased dramatically in the study zone after the fall of the Gaddafi regime in 2011, due to the total breakdown in governance.

Interviews were also conducted with 20 government officials (in the Ministry of Agriculture and legal experts of in administrative and real estate law) Legislation, Forest Department records and policies were also reviewed. These findings agreed with those from research with local residents. Officials added that the former regime contributed to destruction of the forests indirectly by: giving orders to abolish the Ministry of Agriculture several times, encouraging burning of the Land Registry Centres, and distributing forest land to officials, all of which led to an increase the corruption and lack of law enforcement. This was despite the *de jure* adequacy of forest protection legislation.

Remote sensing, using SPOT imagery was used to estimate the rate of land cover change. The results of supervised classification and ground truething showed a remarkable degree of agreement with other two methods (local residents' estimates and Forest Department records): 27% of total forest area was cleared between 1986 and 2010, but after the fall of the Gaddafi regime another 35% was cleared between 2011 and 2013. Currently only 36% of the originally planted forest remains.

Finally, a survey was conducted with 43 forest clearers. The results showed that population growth and density had not contributed to deforestation. Analysis of the characteristics of forest clearers found that 93% of respondents were educated, 100% were employed and their income was slightly higher than respondents who had not cleared forests. The main purpose of clearing forest after the 2011 uprising was to sell the land illegally, due to a tenfold increase in land prices, which incentivised land speculation and forest clearance as a means of money laundering.

If deforestation continues at the current rate, all forests will be lost within three years. Due to the total breakdown in governance, deforestation in Libya nowadays is one of the biggest environmental challenges.

Table of Contents

Contents

List of Tables

List of Figures

List of Abbreviations and Acronyms

ACSAD	Arab Centre for the Studies of Arid Zones and Dry Lands
AOI	Areas of interest
ASA	Arid and semi-arid lands
AVHRR	Advanced Very High Resolution Radiometer
BRSC	Biruni Remote Sensing Centre
BSC	Bureau of Statistics and Census
CAD	Council of Agriculture Development
ESRI	Environmental Systems Research Institute
ETM+	Enhanced Thematic Mapper plus
FAO	Food and Agricultural Organization of the United Nations.
Fig	Figure
FRA	Global Forest Resources Assessment
GCP	Ground Control Points
GEA	General Environmental Authority
GMMR	Great Man- Made River
GPS	Global Positioning System
ha	Hectare
HRV	High Resolution Visible
ICARDA	International Centre for Agricultural Research in the Dry Areas
IR	Infrared
ITTO	The International Tropical Timber Organization
km^2	Square Kilometre
LCC	Land Cover Change
LCRSSS	Libyan Centre for Remote Sensing and Space Science
LD	Libyan Dinar.
LNMC	Libya National Meteorology Centre
LULC	Land Use Land Cover
m^3	Cubic metres

MLC	Maximum Likelihood Classifier
NGO	Non Governmental Organization
RS	Remote Sensing
SD	Standard Deviation
SPOT	Satellite Pour L'Observation de la Terre (Satellite for the Observation of the Earth)
TM	Thematic Mapper
UNCCD	United Nations Convention to Combat Desertification
UNEP	United Nations Environmental Programme
UNFCCC	United National Framework for Climate Change Convention
USGS	United Sates Geological Service
WCMC	World Conservation Monitoring Centre

1 General Introduction

1.1 Background

The world's total forest area in 2010 was estimated to be over 4 billion ha and occupies more than a quarter of the world's land area corresponding to an average of 0.6 ha of forest per capita (FAO, 2010). About 93% of the total forest cover is natural and 7% is planted forest. However, the forest area is unevenly distributed with just under half the world's forests in the tropics (45% of total forest area), about one third in boreal zones (31%) and smaller amounts in temperate (16%) and subtropical (8%) domains (Lebedys and Yanshu, 2014). Global forest plantations cover 264 million ha with Asia accounting for 62% of the total, Europe, 17%, North and Central America, 9%; South America, 6%; Africa, 4%; and Oceania less than 2% (FAO, 2012). These plantations are classified based on their function into productive (40%) and protective forest (60%) (Fenning, 2014). Industrial plantations are established partly or completely for the production of wood for industry use, whereas non-industrial plantations are established partly or wholly for production of ecosystem services (FAO, 2012). The FAO (2000) reported that in Africa, the majority of forest plantations have been established in South Africa (1.4 million ha) and in the Mediterranean countries of North Africa (1.7 million ha or 55% of all forest plantation in Africa).

Forests provide many essential goods, such as timber, fuelwood, bush-meat and paper. They also supply essential services that include: water filtration, erosion control, soil protection, nutrient storage, carbon sequestration, habitats for numerous animal species and space for recreation (Emily, 2012).

Deforestation is the conversion of forest to an alternative permanent non-forested land use such as agriculture, grazing or urban development (Chakravarty, 2012). Deforestation has been especially serious in the last three decades in developing countries (Miah *et al.*, 2011) with an estimated deforestation rate of 14.6 Mha per year during the period of 1990 to 2000, mainly due to conversion to agricultural land (Lindquist *et al.*, 2012). Also, Grinand *et al.* (2013) estimated global net loss of forest area has decreased at the rate 5.2 Mha per year between 2000 and 2010, during which about 130 million ha was lost from the world's forests (FAO, 2012). The rate of deforestation however, varies from region to region.

In Africa, forests currently cover about 23% of the land and it was reported that 75 million ha of forest land (10% of the total forest area) was converted to other uses between 1990 and 2010 (FAO, 2012).

Deforestation is a complex process that is driven by the interplay of sets of proximate and underlying factors that can vary from region to region. These factors include demographic, economic, political, and institutional drivers (Geist and Lambin, 2002; Lambin *et al.*, 2003 and Rudel *et al.,* 2005). However, researchers and policy makers agree that agricultural expansion is the major proximate cause of deforestation globally, particularly the production of commercial commodities (Fearnside, 2001; McMorrow and Talip, 2001; Miyamoto, 2006 ; Zak *et al.*, 2008; Motel *et al.,* 2009 and DeFries and Rosenzweig 2010). It is estimated to be the proximate driver for around 80% of deforestation worldwide followed by infrastructure development at 72% and wood extraction at 67% (Geist and Lambin, 2002). The underlying causes of deforestation are not fully understood, and the influence of various factors has been extensively debated. These include population growth (Jha and Bawa, 2006), poverty (Sunderlin *et al.,* 2008), economic development (Rudel *et al.,* 2005), insecure land tenure (Robinson *et al.,* 2014), and weak law enforcement and corruption (Gaveau *et al.,* 2009). In many African countries, widespread corruption related to weak governance of forest management is the main, underlying, cause of deforestation (Indufor, 2013). Land-use change is driven by a combination of synergistic factors: pressures on resources, opportunities created by markets, policy intervention, vulnerability, and social organization (Lambin *et al.*, 2003).

In Libya, the main forest type is the natural forest, which was estimated to comprise about 500,000 ha in 1950; by 1988, 35% of this land had been converted to agricultural land (Al-Idrissi *et al*., 1996). BRSC (2007) in their research, used remote-sensing to study deforestation around the city of Tripoli during a 10-year-period from 1990 to 2000 and found out that 40% of the plantation forest had been converted to urban and agricultural land. The underlying causes of deforestation in these areas were concluded to be population growth and government mismanagement.

Deforestation has had many negative effects on the environment in Libya. The most dramatic impact are a loss of habitat for wildlife of species, desertification, soil erosion, and climate change. In North Africa, climate change and decreasing rainfall are related to deforestation. The deforestation on the Africa continent is probably a major cause for increased aridity (Zaimeche, 1994).

Research studies of Ben-Mahmoud *et al*. (2000); Oune (2006); Saad *et al.* (2011); El-Tantawi (2005); Ibrahim (2010); El-Aswed (2009); Saager and Alwahishe (2005) found that deforestation and natural vegetation degradation is one of the main causes and drivers of desertification. Therefore, this present study outlines the proximate and underling causes of deforestation in Algarabulli district, Libya, with a focus mainly on the socio-economic and policy drivers. The study also illustrates the dynamics of land cover changes and assesses the magnitude and rate of deforestation.

1.2 Outline of the study

1.2.1 Context of the research

The period of the research was actually five and a half years, during which the following events took place.

When I started my PhD, Gadhafi was still in power, but after 7 months the uprising started in Libya and as I could not go to Libya and I was thinking to do something rather different.

The reason for choosing this topic was that I found during the first visit to Libya just after the fall of the Gaddafi regime while the topic of my study was about desertification causes, I found that most of local people of my area (Algarabulli district) were very concerned about the issue of deforestation. Accordingly, I decided to conduct research on the causes of deforestation (socioeconomic and policy drivers). The area of Algarabulli, Eastern Jefara Plain, was selected, because in the security context, local knowledge and local familiarity are paramount considerations, and also this zone is representative in terms of deforestation of the whole area. Also I am from this area and it was easy for me to deal with local people in light the of lack of security.

The field work of this research took seven months and was conducted in two stages: the first being between December 2012 and February 2013, and the second stage was between December 2013 and April 2014, in Algarabulli district (See fig 2.1) under severe security constraints.

1.2.2 Thesis research questions

The major objective of this thesis was to understand the true causes of deforestation focussing mainly on socio-economic and policy drivers in Algarabulli District.

Specific aims of the research focus on providing answers and (approaches utilized given in brackets) to the following questions:

1- What are the local people's perceptions of the causes and consequences of deforestation in Algarabulli district? (Semi-structured interview survey with local people who had not cleared forest; Chapter 4).

2- Which human activities are contributing to deforestation and to what extent? (Applying remote sensing and field work observation to detect and quantify the extent of deforestation and evaluate the dynamics of land cover changes that are taking place, using SPOT 5&6 imagery; Chapter 5).

3- How have policy factors in Libya contributed to deforestation in this area? (Reviewing policy, forest laws and forest management and using semi-structured interviews with government officials in the Ministry of Agriculture and Land Registry Centre; Chapter 6).

4- What are the drivers of deforestation? (Using data on population censuses and deforestation, and surveys with forest clearers to identify their characteristics and attitudes towards forests; Chapter 7).

1.3 Thesis Structure

Chapter two describes the study area: human and biophysical context, including the location, physical setting, population, sand dune stabilization and afforestation.

Chapter three presents a review of deforestation concepts and literature, describing the general causes and consequences.

Chapter four describes causes and consequences of deforestation specifically in Algarabulli district. It presents the local people's (non-forest clearers) perceptions about the causes and the effects of deforestation.

Chapter five assesses land use change using remote sensing, SPOT imagery data, and estimates deforestation rate.

Chapter six explains the contribution of Libyan forest policy and management to forest cover change.

Chapter seven explains the socio-economic drivers of deforestation. It focusses on this in two ways: firstly to determine whether there is a link between population growth, density and deforestation; and secondly to understand the characteristics, attitudes and knowledge about forests and deforestation.

Chapter eight is a general discussion, which includes a summary of the study, major limitations, future challenges, conclusions, and recommendations.

2 Biophysical and Human context

This chapter is presented in three sections. The first section sets out the physical setting of the study area, describing location, geology, topography, climate, soil and water. The second section describes land cover and land use and population in Libya. The third section describes the stage of forest plantation in the Jefara Plain.

2.1 Physical setting of study

2.1.1 Location and Geography

Libya is located in North Africa and bounded on the north by the Mediterranean sea (1900 km coastline), to the east by Egypt (1150 km border) to the west by Tunisia (459 km) and Algeria (982 km) and to the south by Sudan (383 km), Chad (1055 km) and Niger (354 km). Its area is approximately 1,676.000 km^2 of which more than 95% is desert, and it located between longitudes 9° 50 E- 25° E and latitudes 18° 45 N 33° N (Almahdawi, 1998).

The Jefara Plain which is one of five major physical identified regions, is the largest and most important plain and is located in the northwest part of Libya. It forms a triangle between the Mediterranean Sea and the northern mountain belt of ex-Tripolitania. Its vertex occurs at En-Neggheza near Ras Elmsan; west of Khoms in the east and its base in parallel with the Libyan Tunisian border in the west (about 260 km), with a total area of approximately 18,000 km^2. It comprises about half of a natural semi-circular plain (about 37.000 km^2) which extends into Tunisian territory (Al-Hajjaji, 1989).

Due to its more favourable location and high population, the region is of great significance to the economy of Libya. Since the fall of the Roman Empire, the dominating element in the economy has been the soil and the primitive agriculture it can sustain. The Jefara plain is the most prosperous part of the whole country. This plain contains 50% of the total irrigated land in Libya, produces 60% of all of the agricultural output, and also contains 60% of the population (El Jadida, 1986).

Algarabulli district (the study area) is located in the eastern part of Jefara plain and bounded on the north by the Mediterranean sea (29 km), to the east by Wadi Turghat (25 km) to the west by Wadi R'mel (35 km) and to the south by Series Nafusah Mountains (37 km).

Its area is approximately 415 km^2. which represents 2.1% of the area of Jefara plain and 0.02% of the area of Libya. It located between longitudes 13°.31.44 E- 13°.49.26 E and latitudes 23° 43.38 N-32°.48.7 N.

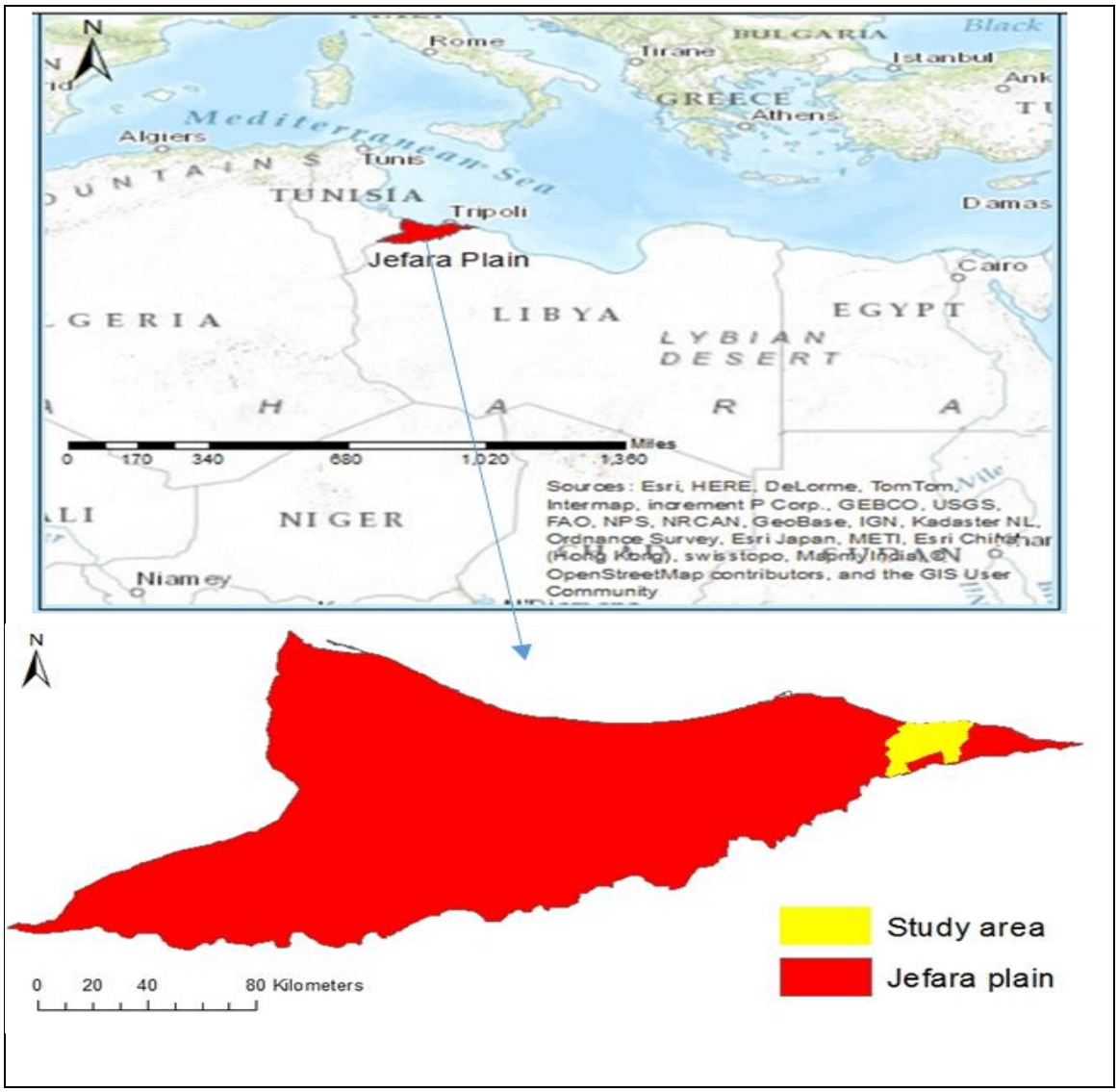

Figure 2.1: Location of study area from Libya and the Jefara plain.

2.1.2 Geology

Structurally Libya is part of the Mediterranean foreland formed by the North African shield, and has a sedimentary section that has been subjected to transgressions and regressions since the early Paleozoic. The result is a mix of sheets of non-marine sediments (shale and sandstone) and other shallow marine carbonates that have been deposited all over platforms formed in local cratonic basins (Imbarek, 2008).

Anketell and Mriheel (2000) divided Libya into several important structural zones. These are: (1) southeastern Libya, which includes the Precambrian basement, and the Al-Kufra Basin; (2) southwestern Libya, which encompasses the Murzuq Basin, and Al-Qarqaf Arch; (3) western Libya, which comprises the Ghadames Basin, and Naffusah Uplift; (4) central Libya, which occupies the most significant oil area in the North African plate represented by the Sirt Basin (5) northeastern Libya including the Cyrenaica Basin and the Al-Jabal Al-Akhdar Uplift; and (6) northwestern offshore Libya including the Tarabulus Basin, located on the North African continental shelf (Hallett, 2002).

The Jefara Plain comprises Late Tertiary to Quaternary strata and the deposits of Quaternary represent the main sediments that covering the Jefara Plain with occurrences of some limestone outcrops of the Azizia formation. The foot hills strip which represents the southern part overlaps with the mountain belt, forming the transitional region between the two, and coarser fluvial sediments have been found. The consolidated aeolian deposits mixed with brownish silts are the main deposits that occurred in the central part of the Plain. The northern part which represents the coastal strip is formed of calcarenites underneath the coastal sandstones (Sadeg and Karahanolu, 2001).

The geology of Algarabulli district is covered by Quaternary deposits as illustrated in (Figure 2.2 and table 2.1) and formation from aeolian deposits, Jefara Formation and Fiuvio-eolian representing 90% of all formation.

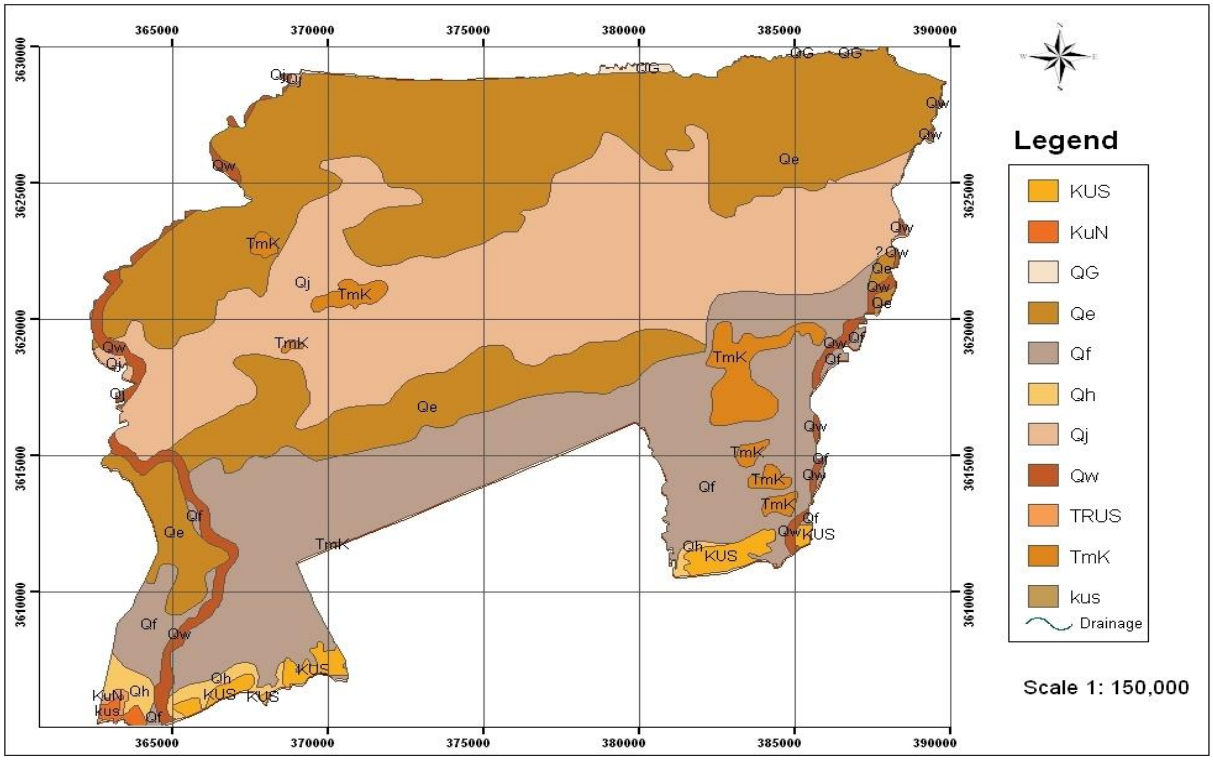

Figure 2.2: Geological map of Algarabulli district (Source: Industrial Research Centre, Tripoli, Libya, 1975, updated 2008).

Table 2.1: Formation Suites of Geological map of Algarabulli district.

Code	Formation Suites	Period (Age)	Lithology
Qw	Recent Wadi deposits	Holocene	gravel, sand and Loam
Qe	Eolian deposits		sand dunes, sand sheets and sandy loess
Qf	Fiuvio-eolian sediments		silt and fine sand with occasional caliche bands
QG	Gargaresh Formation	Pleistocene	calcarenite with occasional silt lenses
QJ	Jefara Formation		silt, sand and conglomerate with occasional gypseous and calcareous crust
Qh	Qasr al Haj formation		mostly proluvial cemented and noncemented gravels with calcareous crust
Tmk	Al Khums formation	Miocene	limestone, algal limestone, lumachelle, calcilutite calcarenite and clay
KuN	Nalut formation	Upper Cretaceous	Limestone, dolomitic limestone to dolomite, with chert bands and concretions
Kus & KUS	Sid ass Sid Formation		upper part : marly Yafrin Member: lower part ; limestone, dolomitic to dolomite with occasional quartzite and quartz sand intercalations –Ayn Tobi Member
TRuS	Abu Shaybah Formation	Upper Triassic	sandstone and clay with minor calcareous intercalations

Source: Geological map of Libya, sheet Al-Khums, NI 33-14, (IRC), Tripoli, Libya, 1975.

2.1.3 Topography

Landforms of Libya generally consist of barren plains in the north against plateaus and depressions in the south; the coast land of the Mediterranean Sea and the Sahara desert are the most prominent natural features. Though there are several highlands, no true mountain ranges exist except in the southern desert near the Chad border where the Tibesti Massif rises to over 3,000 m. Elsewhere a barren wasteland of rocky plateaus and sand occur which only allow minimal human habitation and agriculture is possible in a few scattered oases (McMorris, 1979). In Libya the highest point is Bikku Bitti (2,267 m above sea-level) and the lowest point is Sebkhat Ghuzayil (47 m below sea- level) (El-Tantawi, 2005).

The Jefara Plain is usually described as being flat, but this is a misconception. Actually, this plain, for the most part and especially in its southern portion, is broad and undulating, for it contains many hills and sand dunes which rise to considerable heights in relation to the general level of the area. The number of fixed sand dunes increase southward up to the escarpment of Jabal Nafusah. The Jefara plain can be divided into three different area; the coastal area, the central area and the foot of Jabal Nafusah in the south mountain area with area an altitude of between 450 and 1000 m.

The study area, which is shown in Figure 2.1 is part of the Jefara Plain and comprises an almost flat area. The gradient of the plain increases from north to south. It starts a very few metres above sea level, then, after rising about 15 km inland, it is elevated to about 50 m, in the south, in the foothills of the mountain chain of Tarhunah (Jabal Nafusah), the plain rises to about 200 m, a downhill gradient of about 0.8% (Salem and Talha,1984).

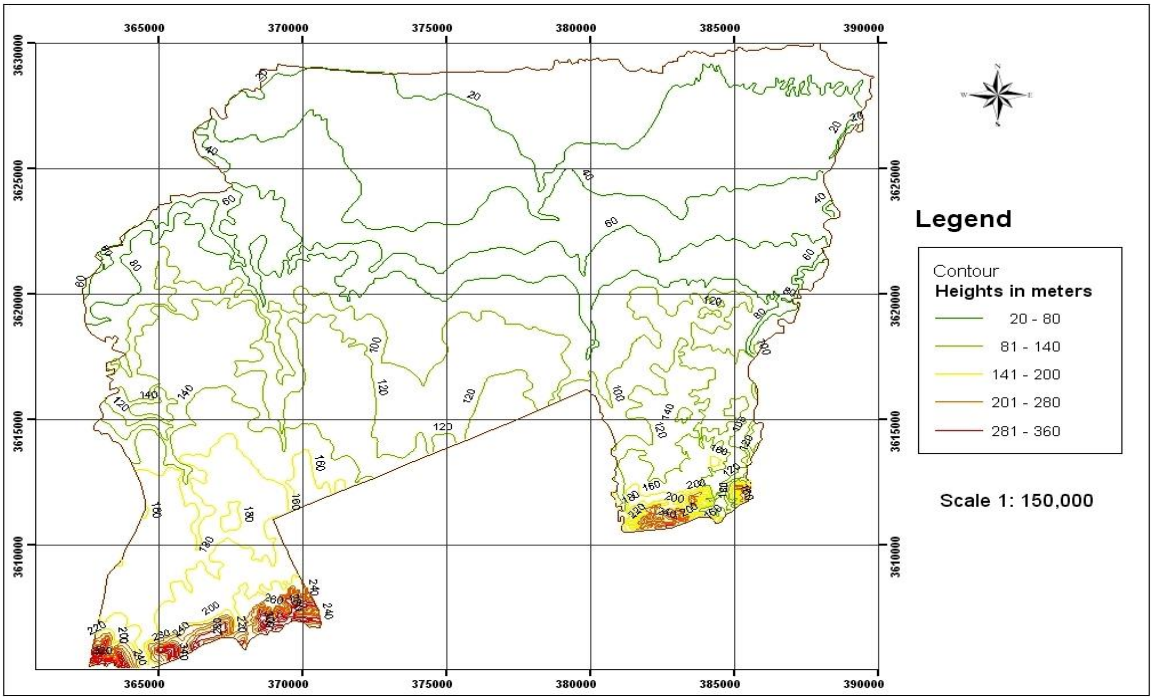

Figure 2.3: Topographic map of Algarabulli district (Source: ICR, Tripoli, Libya, 1974).

2.1.4 Climate

As many as five different climatic zones have been recognized in Libya, but the dominant climatic influences are Mediterranean and Saharan. In coastal lowlands, where 80 percent of the population lives, the climate is Mediterranean, with warm summers and the winter rainfall is scanty, and the dry climate results in a year-round 98 percent visibility (Al-Hajjaji 1989).

Chapin (2010) stated that, "The weather is cooler in the highlands and frosts occur at maximum elevations. In the desert interior the climate has very hot summers and extreme diurnal temperature ranges."

Ham (2002) stated that "Around 2500 years ago, the historian Herodotus claimed that "in the upper parts of Libya, it is always summer." and yet, in winter the weather can be cool and rainy on the coast between October and March…"

The climate is generally described as arid to semi-arid, with hot and dry summers and moderate winters with erratic rainfall (Ben-Mahmoud, 2013). The mean annual temperature varies given the fact that the north of the study area corresponding to the Mediterranean Sea is milder (16.9°C in Shahat) compared to the south (22.8°C in El Kufra), which is located in the extremely arid Sahara (Table 2.2) .

Table 2.2: Libyan land area according to the annual rate of rainfall

Type of land	Average precipitation (mm per year)	Area of land (ha/thousands)	Percentage of Libya total area (%)
Very dry	Less than 50	1515	90.4
Arid	50-200	130	7.8
Semi-arid	200-400	26	1.5
Semi-humid	More than 400	5	0.3
Total		1676	100

Source: Committee of agriculture policies study, 2003.

The Jefara plain has a Mediterranean climate with moderate temperatures, the average temperature ranges between 30°C in summer and 10°C in winter. Having said that, hot, very dry and sand-laden scorching wind (El Ghibli) can raise the temperature up to 40°C; this plain recorded the highest temperature on Earth (57.8°C) on September 1922 at Al-Azizia City, which is about 50 km west of the study area. The mean annual relative humidity ranges between 68% and 73% (LNMC, 2012).

The average annual rainfall in the plain, which falls mainly in winter, varies from 370 mm close to the Mediterranean coastline to less than 100 mm on the southern slope of Jabal Nafusah (Figure 2.4). Rain usually falls during a short winter period due to the vulnerability of Libya in this season to the prevailing northern and north-western winds that bring rainstorms (Figure 2.6).

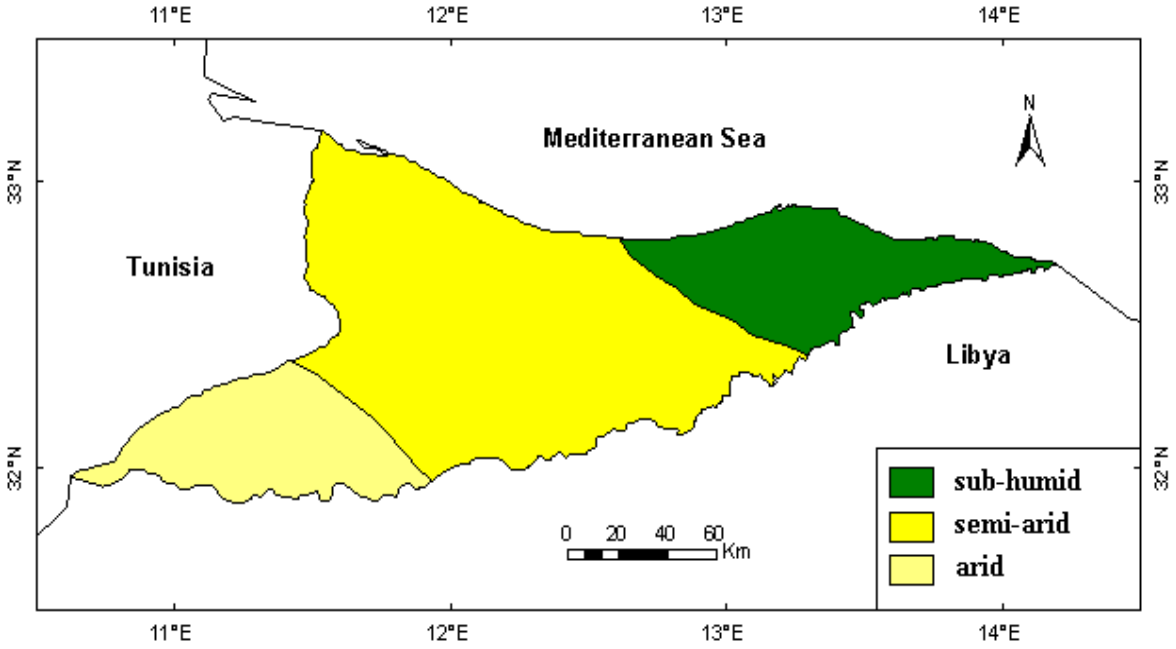

Figure 2.4: Climate regions in Jefara Plain according to De Martonne climate classification (Source: LNMC, 2012 Tripoli).

To examine the elements of the climate in the study area, data gathered from the meteorological station of Qasr Khiyar District, which is located 15 kilometres west of Algarabulli City, were used, because the study area contains no meteorological station other than a rain gauge.

Temperature is affected by several factors, including: geographic location and proximity or distance from the sea, and the terrain, and the presence of the area on the coast of the sea. The sea has a great effect on the heat during the seasons of the year and plays a major role in moderating the temperature. The highest temperatures occur from June to August with maximum temperatures over 35°C in August (Figure 2.5).

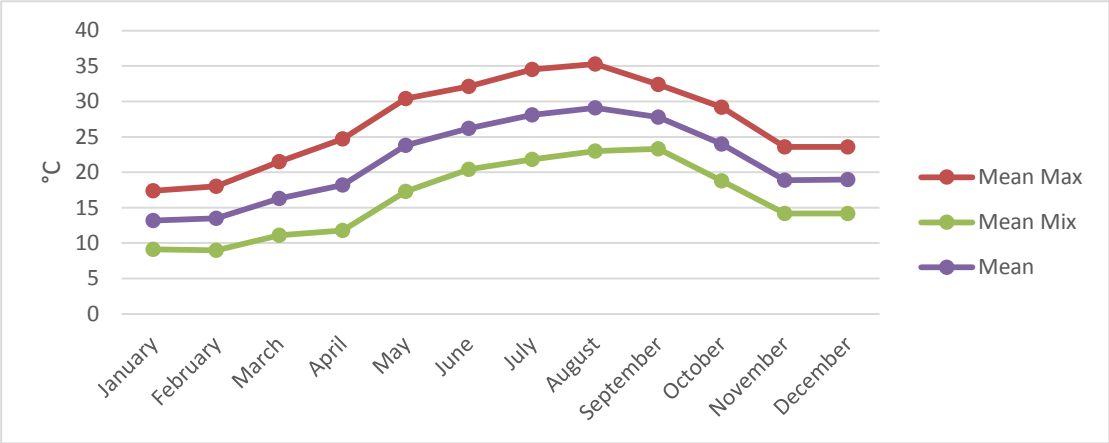

Figure 2.5: Average temperature, maximum and minimum range in Algarabulli District of 1990-2010 (Source: LNMC, Tripoli 2013).

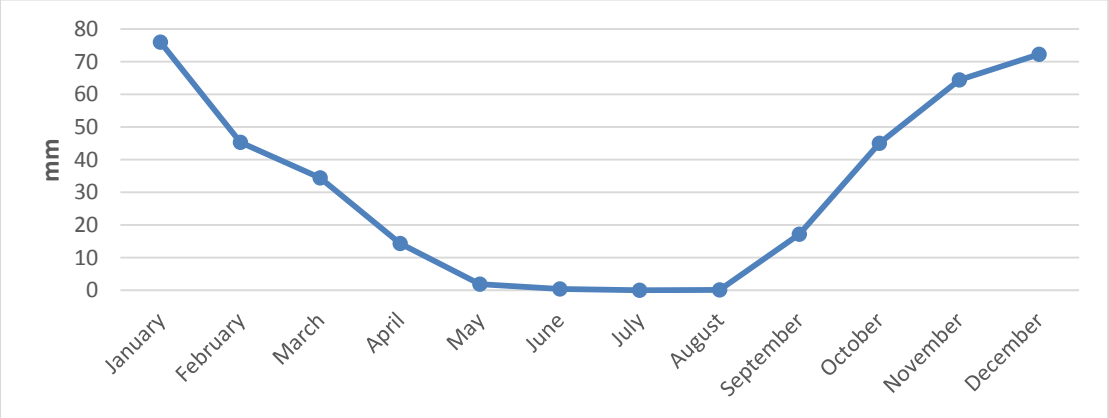

Figure 2.6: Monthly Average Rainfall from in Algarabulli District (mm) from 1965-2010 (Source: LNMC, Tripoli 2013).

Air relative humidity is generally high, particularly in the area closest to the coastline, and tends to reduce toward the south. Mean annual relative humidity is 66.7%.

In general, based on the climatological data, the climate of this area can be defined according to the method of classification of the Mediterranean climate.

2.1.5 Soil Resources

Over the last four decades, foreign companies have carried out extensive soil studies (250 studies) in Libya. These studies have focused on the northern part of Libya and small, scattered areas in the southern desert. The most recent soil survey reports and maps differ in terms of content, map type, scale of the mapping classification systems used, method of soil analysis, and the criteria with which the data have been interpreted. The soil classification systems used in these reports are the USA Soil Taxonomy, the modern soil classification of Russia, the French soil classification, and the FAO/UNESCO system (Ben-Mahmoud, 2013).

The main types of soil in Libya are Aridisols, Entisols, Mollisols, Alfisols, Inceptisols and Vertisols. Aside from the Al-Jabal Al-Akdar and some Jabal Nafusah soils, most are Entisols and Aridisols (Ben-Mahmoud, 1995). The main categories of Libyan soil are shown in table 2.3.

Table 2.3: The main orders of soil in Libya.

Soil orders (US Soil Taxonomy)	**Russian Classification**	**FAO and UNSCO Classification**
Entisols	Reddish Brown Arid	Regosols
Aridisols	Serozems, Desert Soils	Luvisols
Alfisols	Red Ferrisiallitic Typical	Chromic Luvisoils Calcic Chromic Luvisols
Mollisols (Rendolls)	Rendzinas Dark Red Rendzinas	Rendzins Leptosols
Inceptisols	Siallitic Cinnamonic	Cambisols

Source: Nwer, 2005.

The soils of the Jefara plain include: Entisols and Inceptisols (49.1%), Aridisols (11.5%), Salorthids (10.7%) and sandy soils 3%. Sandy soils bear more developed vegetation with more regular and greater primary productivity than finer textured soils (Figure 2.7).

Most of the soils in the study area are located within the soil of reddish brown arid category, which is usually sandy soils, the content of organic matter for these soils is a poor.

Secondly, the continental sand soil which is mostly found in the northern region near the Mediterranean Sea, has a weak texture mixed with low content of organic material (Table 2.4).

Commercially cultivated rain-fed olive orchards are grown profitably on deep sandy soils under as little precipitation as 200 mm/year in the Tripoli area, while this is not possible without an additional runoff complement on silt soils (El-Tantawi, 2005).

Irrigated soil is prone to salinization and alkalization. These phenomena are common on the northwestern Jefara Plain, where soils are converted to saline soils due to the high levels of salt in the groundwater used for irrigation, subpar development schemes such as using salty water on heavy soils or insufficient drainage (El-Tantawi 2005).

The major soil-related issues in Libya are erosion and salinity. Soil erosion is a major factor limiting the amount of arable land in Libya, on both the Mediterranean coast and in the southern desert (Nwer, 2005).

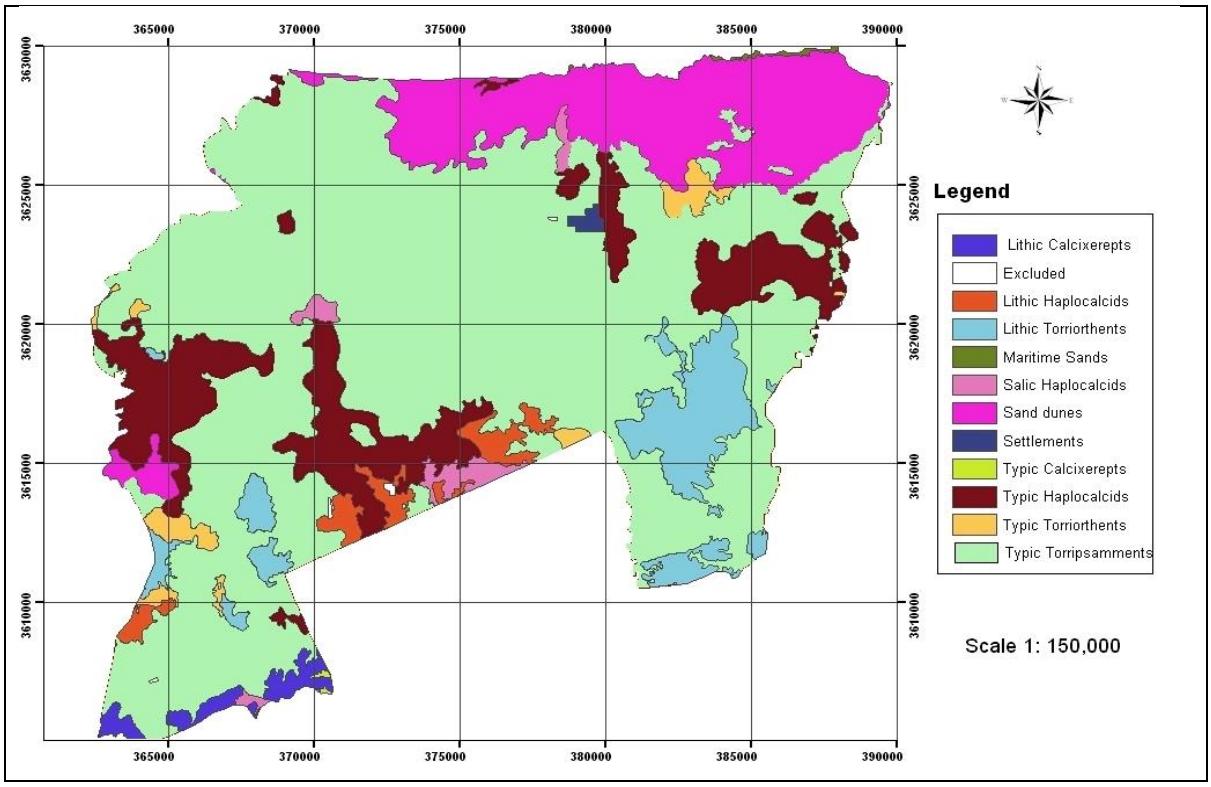

Figure 2.7: Soil Map of Algarabulli district (Source: The Ministry of Agriculture, Department of mapping 2010.

With regard the soil fertility as shown in figure 2.8 where most of the soil types are moderate, poor and very poor. Very poor soil represents sand soil or sand dunes.

Table 2.4: Mechanical chemical analysis of the soil in study area

Soil	Sandy soil	Loam soil	Clay soil and organic materials	Calcium carbonate Soil
Percentage	82.6	13.8	3.4	0.2

Source: Commission of studying the coastal road, 1979.

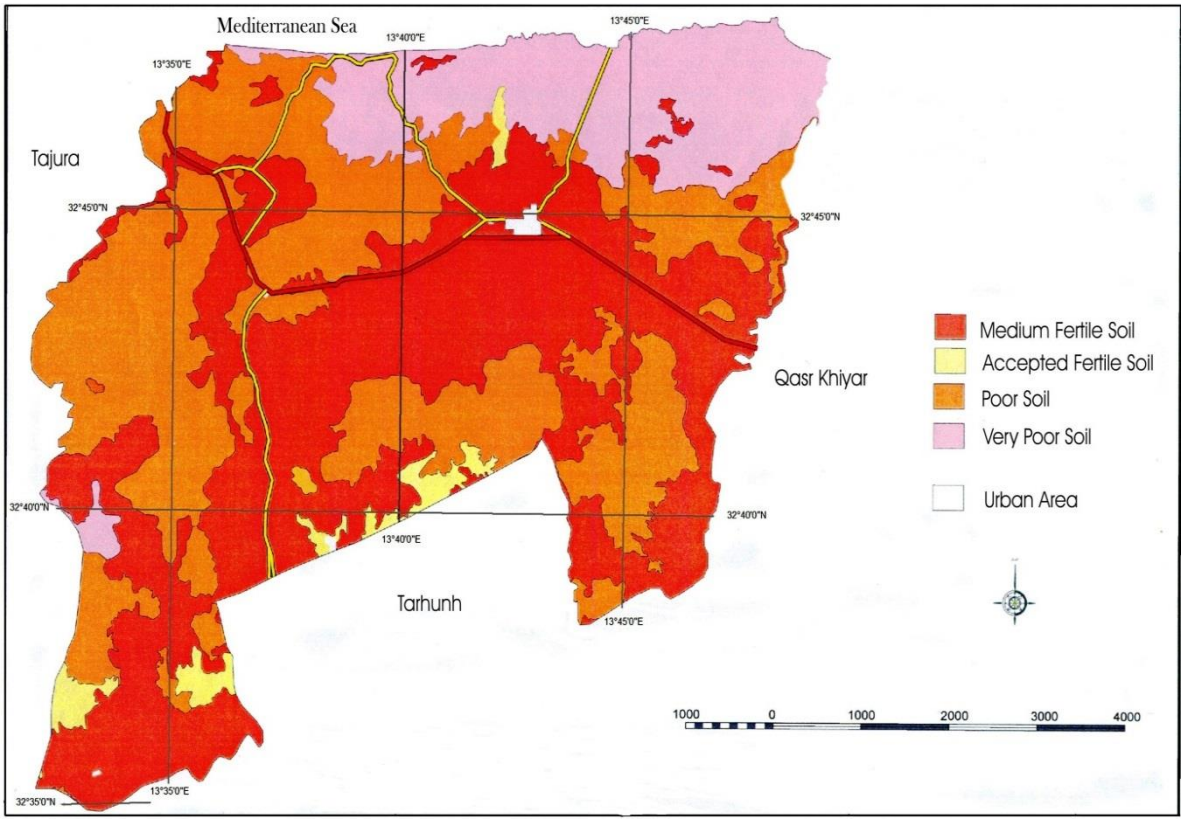

Figure 2.8: Soil fertility of Algarabulli district (Source: The Ministry of Agriculture, Department of mapping 2010**.**

2.1.6 Water Resources

Libya is an arid country with an average annual rainfall of less than 100 mm, which falls over 93% of its surface area. There is important potential for groundwater development, but whereas most of the population, and consequently the water demand, is concentrated within a narrow strip along the Mediterranean coast, most of the groundwater potential is located to the south in the desert areas (Pallas, 1980). The discussion below divides water resources into surface and groundwater components.

2.1.6.1 Surface water

According to reports from the Ministry of Agriculture, surface water is very limited, contributing negligibly to overall water consumption. Surface run-off from the seasonal water stores at Jabal Nafusah, Al-Jabal Al-Akdar and the central region valleys, is estimated to be about 285 million m^3 of water per annum.

Each year, about 60 million m^3 additional of water are dammed. Rain water is collected in underground cisterns and reservoirs constructed in relatively high-rainfall areas. Libya has more than 450 springs, though these generally contain little water. At most of these springs, the level of production does not exceed 1 litre/second. The exceptions are: Tawargha, Kaam, Zayana, Dabussia, and Derna springs. Some of these springs are used for agricultural and drinking purposes, while plans are currently underway to utilize the rest (Public Authority for Water, 2008). There are several wadis within study area deeply cut into the escarpment, ranging to 100 m deep in the Jabal and to 15 m in the plain. All the wadis courses are directed towards the north and they are flowing as far as the sea. However there are no dams on these wadis to harvest the water which outflows into the sea. There are some remnants of dams in Wadi Rmel which indicated that the Roman used these dams for the agriculture activity in this area before.

Table 2.5: Hydrographic characteristics of the valleys of Algarabulli District

Valley	Drainage basin area km^2	Along the course of valley	Average surface runoff (mm^3)
Ramel	400	85	1.95
Turghat	258	40	3.30
Al-Masida	172	37	2.80

Source: Public Authority for Water. Libya, 2008.

2.1.6.2 Groundwater

Groundwater is the main source of freshwater in Libya as it represents 95% of water resources, providing a vital supplement to surface water sources. Groundwater availability and quality are; however, vulnerable both to climate change and over-abstraction, and in regions where the water table has lowered there has been a consequent impact on agricultural activities (El-Aswed, 2009).

The coastal aquifers are the only stores replenished by rainfall, but the need for groundwater from these aquifers exceeds the annual replenishment. This has caused a severe decline in water levels and seawater encroachment, which makes the coastal groundwater resources almost unusable because of their high salinity. Of the total water withdrawal of 4,268 million m^3, about 83% is used for agricultural purposes, 14% for domestic use and 3% for industrial use (Ben-Mahmoud, 2013).

In the Jefara plain which represents more than 80% of the irrigated area in the country, the early Cretaceous/Triassic formation contains aquifers with varying degrees of discharge and depth. Water quality ranges from good to saline.

The study of the Public Authority for Water (2008) confirmed that the amount of groundwater withdrawals exceeded the annual natural renewal ability of the groundwater reservoirs, which were estimated at 270 million m^3 per year. Further, the amount of withdrawals per year is increasing (shown in table 2.6) and, during the period of 1962–2005, the annual rate of the decline in the water level was estimated in Jefara Plain as between 0.5 to 2.3 metres (Public Authority for Water, 2008).

In the study area, people depend mainly on groundwater, which is mainly used from Quaternary-Miocene aquifers through excavated wells, excavated-drilled wells and drilled wells (Council For Agricultural Development, 1974). This study examined the rates of withdrawal of groundwater in the Jefara Plain during 1962–2005 (million cubic metres per year).

Table 2.6: The rate of withdrawal of groundwater in the plain of Jefara between 1962-2005 (Mm^3)

Use/ years	1956-1962	1972	1975	1978	1980	1993	2005
Agriculture use	195	313	475	461	483	802	940
Drinking and industrial use	15	65	92	94	91	200	109*
Total	210	378	567	555	574	1002	1049

Source: Public Authority for Water. Libya, 2008.

* Decrease in the rate of consumption due to supplying the city of Tripoli by the Man-Made River water since 1996.

2.1.7 Land use land cover in Libya

According to the 2005 Libyan land cover map shown in figure 2.9 which used visual interpretation and analysis of satellite images (GEOVIS), almost 90% of the total area of Libya is covered by desert of sand dunes and marsh and the rest is used for agriculture, rangelands, forestry, natural vegetation lands and urban area. The following figure illustrates Libyan land use classification according to a land cover classification system (LCCS).

This study which was conducted by the FAO. UNDP with the cooperation on the BRSC, of the Libyan Centre for Remote Sensing and Space Sciences and a team of National Experts in Agriculture, Rangeland and Forestry in the Ministry of Agriculture, illustrates that approximately 9% of the land is covered with vegetation (grasses and bushes), pastoral areas and natural and man-made forest (Figure 2.9).

2.1.7.1 Agricultural Lands

Agricultural production depends mainly on the private sector, and private farms owned by individuals are producing the biggest part of the agriculture products. Some government production projects were established under irrigation in the desert, mainly for cereal and forage production (Al-Idrissi *et al.*, 1996).

Before the discovery and exporting of oil, the most important economic activity of the population in Libya consisted of farming and herding. However, in no case did the area planted with stable agriculture exceed 1% of the total area of the country, and up to 1960, 93% of the income of Libya came from agricultural production and about 87% of the workforce was engaged in agricultural activity (Al-Hajjaji 1989). Now, however, 98% of the income comes from oil (BSCL, 2006 b).

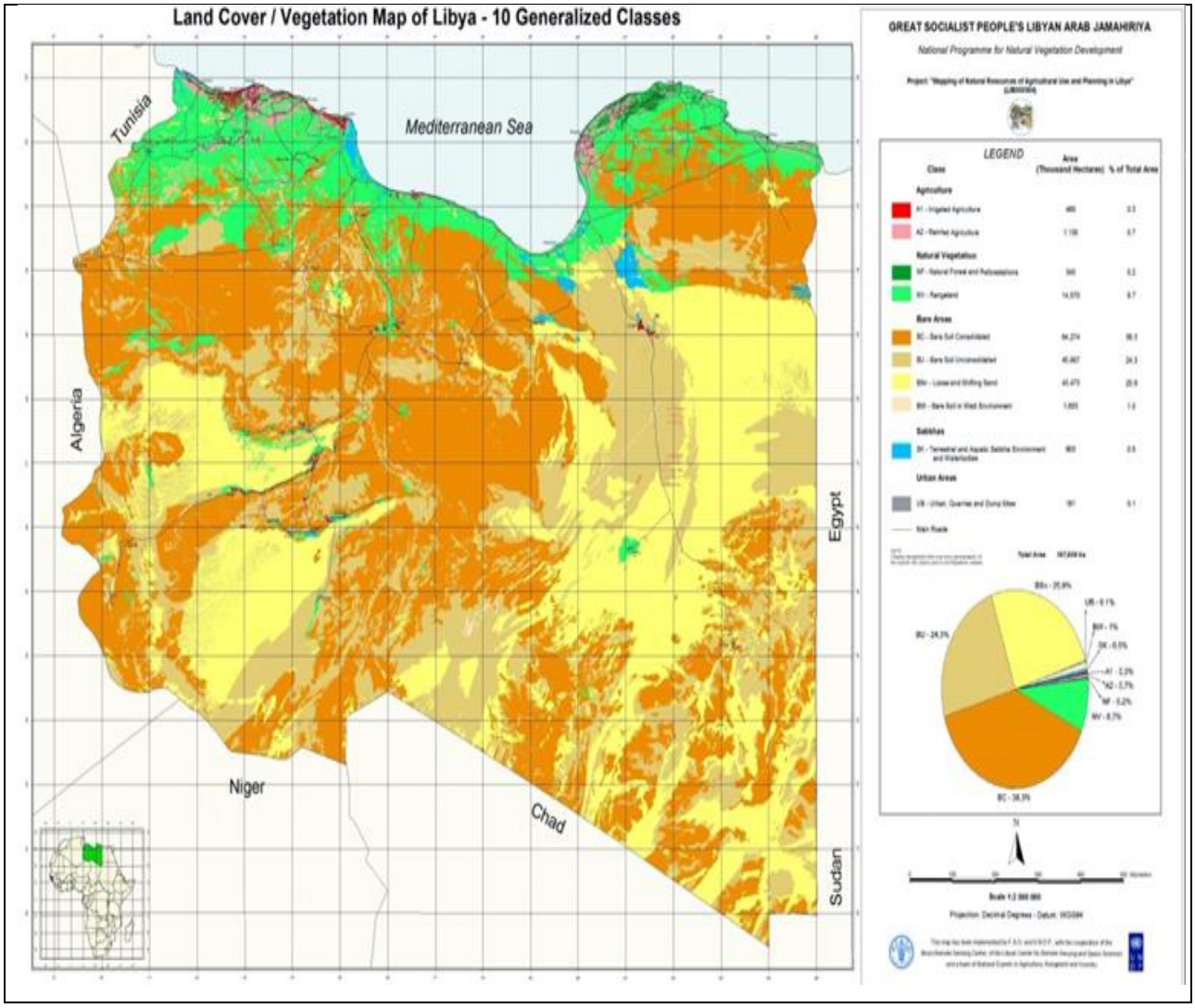

Figure 2.9: Libya land cover 2005 (Source: FAO and UNDP, 2005).

According to a 1960 agricultural census, agricultural lands were estimated at 1.4 million ha. However, during the 1970s and 1980s, as a consequence of plans made for social transformation and economic growth, the share of the agricultural sector in the country exceeded 17% of total public expenditure and as of 1984 resulted in the addition of about 2.6 million ha under cultivation.

These included cereal crops (865,000 ha), vegetables (39,000 ha), fodder crops (37,000 ha) and fruit trees (400,000 ha), while some references show that the expansion of fruits and olives was from 170,000 to 400,000 ha. According to the 1995 agricultural census, agricultural land area covered 3.3 million ha, which in comparison with 1960 had increased three times.

In particular, the area under irrigation increased from 468,000 to 1.3 million ha due to the establishment of some agricultural projects after the Great Man-made River was constructed which is a network of pipes that supplies water from the Sahara Desert in the south of Libya, to the coastline in the north. This project is aimed at the delivery of more than 6 million m^3 of water per day. It is the world's largest irrigation project.

In Libya, about 90% of the fruits and vegetables, and more than 60% of grain productions, are obtained under a variety of irrigation schemes. Because of the prevailing sandy soils in most of the arable land, sprinkler irrigation is practiced on nearly all the irrigated plots in Libya. About 99% of irrigation uses groundwater, while the remaining 1% is irrigated by surface water and treated wastewater (Figure 2.10).

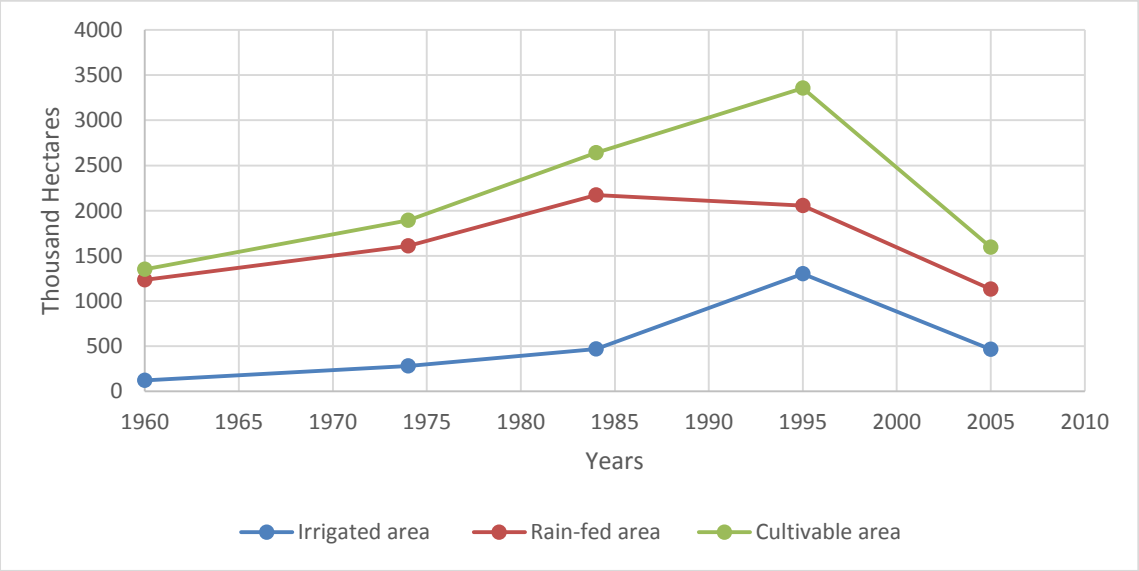

Figure 2.10: Cultivable area in Libya in (1960, 1974, 1984, 1995 and 2005) (Source: Bin Kayal, 1995; Almahdawi, 1998; BSCL, 1984; BSCL, 1995; FAO and UNDP, 2005)

The main crops produced in the country are barley, wheat, maize and millet as cereal crops; potatoes as roots; dry beans, broad bean, peas, chickpeas and groundnuts as pulses; tomatoes, cabbage, cauliflower, pumpkin, squash, cucumber, eggplant, onions, garlic, green peas, carrots, watermelons, cantaloupes, muskmelons as vegetables; and grapes, dates, olives, apples, pears, peaches, plums, oranges, lemons, apricots, almonds and tobacco as fruits and industrial crops. Wheat and barley are the two of the most important cereal crops in Libya and the public and private sectors play an important role in their production.

The public sector produce them in public projects located in the heart of the desert under permanent irrigation, while private sector individuals produce these grains under rainfed conditions.

Therefore, the figure 2.10 shows that the area of wheat under rainfed production has decreased from 104,000/ha in 1985 to 35,000/ha in 2002, due to socio-economic causes and climate changes, with resultant decreasing rainfall. However, the area of barley under cultivation remained more stable (The Ministry of Agriculture, 2003) (Figure 2.11).

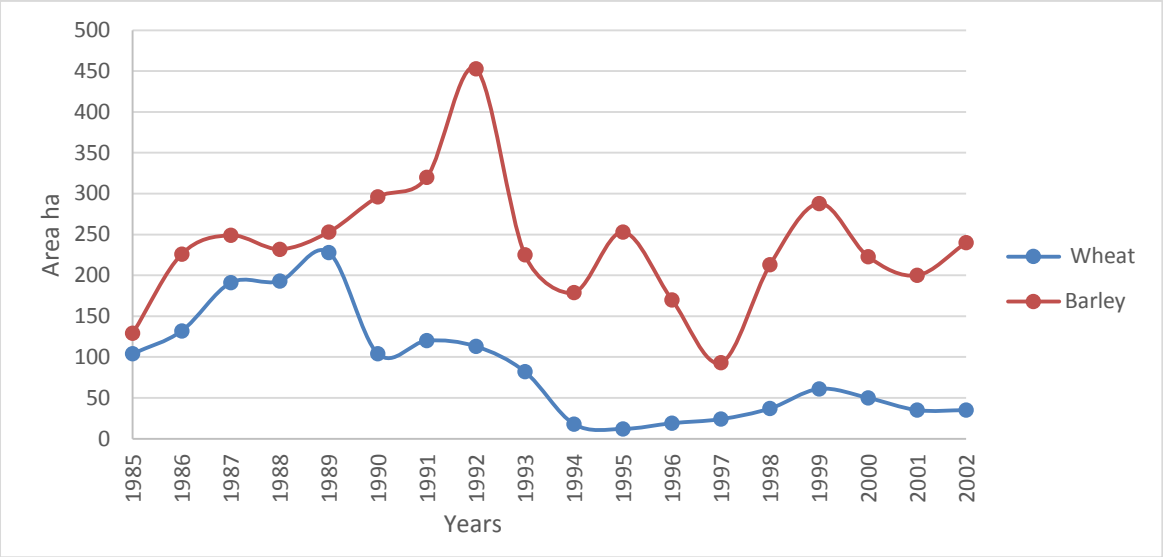

Figure 2.11: Area of Wheat and Barley in Libya in ha (1985-2002) (Source: The Ministry of Agriculture report, 2003).

According to the agriculture census of 2001, the number of farmers in the country was 176,658. Of these, 33.7% (59,566 farmers) practiced only farming work, while the other 66.3% did not work fully in agriculture and had other businesses (BSCL, 2001).

According to satellite imagery results in 2005, agricultural lands are estimated to be 1.5 million/ha (1% of total area), of which the rainfed area was estimated at 1.13 million ha (71%) or 0.7% of Libya's total area, and irrigated was estimated at 466,000 ha (29%) or 0.3% of Libya's total area, with most agricultural lands being located along the coastline of Libya in the Jefara Plain. This showed that a significant decrease in agricultural area was found from 3.3 million/ha in 1995 to 902,000/ha in 2006. It could be argued that some references indicated that the agricultural census depended on estimating, which is rather less accurate than using satellite imagery, which has a very high degree of accuracy.

However, most of the references indicated that most of the agricultural area has decreased dramatically due to some environmental issues such as ground water shortage, salinity and soil degradation.

2.1.7.2 Range Land

Especially in rural areas in Libya, grazing is one of the most important livelihoods, and in 1969 the area of rangeland was estimated at 11 million/ha, which is about 6.7% of Libya's total area. Since the early seventies, rangelands have been under heavy investment and remarkable activities of development; about 23 grazing projects on 2.5 million ha were established and 70 million seedlings of shrubs planted, which, as of 1974, led to increasing the area of rangeland to 14 million ha, which lie along isohyet lines of between 50 mm and 200 mm/yr (Sbeit, 1998). Later, the area of rangeland in Libya decreased from this level to 11.7 million ha in 2001, due to a ten-fold increase in the number of livestock flocks within half a century. In 1952, this was estimated at about 700,000 head and in 2002 had reached to 8.2 million head of sheep, goats and camels. The decrease in rangeland was also due to agricultural expansion, land degradation and desertification, as well as the continuing deterioration in the ability of pasture productivity for reasons of repeated droughts, inappropriate exploitation and overgrazing.

Total production of rangelands was estimated to be about 516 million feed units, which provides 20% of the total feed requirement of animals (sheep, goats, cows and camels). In some areas rangelands are private to certain individuals or to the tribes, but in general all rangelands are subjected to the same situation of overgrazing and deterioration of the plant cover.

The number of animals is very high in rangelands compared to its grazing capacity; sometime this reaches up to five times in the middle region of Libya (Almahdawi, 1998). Encroachment of rangelands with cultivation of barley became practiced on a large scale under rainfed conditions, especially with good opening rain in some seasons, and with the use of machinery.

The new paved roads helped people to reach all the remote places of rangelands and facilitated the transfer of machinery, allowing the concentration of feeds and water to animals in any part of the rangelands.

However, according to the land cover map of Libya in 2005 (Figure 2.9), the rangeland area was increasing and was estimated at about 14.570 million/ha, which is 8.7% of Libya's total area. Further, some reports have stated that in recent years the government has played a great role in the enlargement of rangeland area (Figure 2.12).

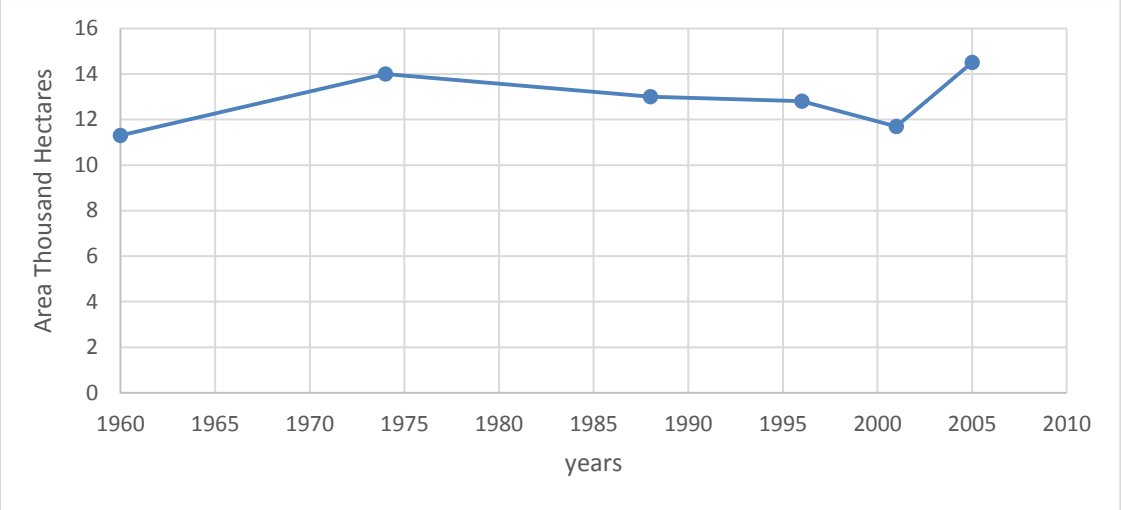

Figure 2.12: Rangeland area in Libya in (1960, 1974, 1988, 1996, 2001 and 2005) (Source: Bin Kayal, 1995; Almahdawi, 1998; FAO and UNDP, 2005).

2.1.7.3 Forests

In Libya, the forests have been divided into natural and man-made types of forests, as follows:-

1- Natural forests and vegetation

Natural forest occurs only in the Al-Jabal Al-Akdar region in eastern Libya; 90% of the country's natural forest occurs in this region. Al-Jabal Al-Akdar forest is the only natural forest in North Africa between Lebanon in the east and Tunisia in the west. Specialists consider these forests to be remnants of a forest that stretched across North Africa when the climate was more suitable for the growth of forests and covered an area that is now known as the Libyan Desert (Al-Zeni and Bayoumi, 2006).

A number of studies have been conducted on Libya's natural vegetation. These studies began in 1703 when Lemaire examined archaeological remains in the Cyrenaica region (eastern Libya) and outlined his vision for the *silphium* plant, which was later given the name *Selfione* (Environment Public Authority 2010).

Although this plant does not currently exist, it was made famous in Al-Jabal Al-Akdar (in the Cyrenaica region) by ancient civilizations, and was economically important to the country at that time (Al-Jabal Al-Akdar, Study in Geography 1960). In 1817, Della-Cella collected 260 plant species from Tripoli to the borders of Egypt along the coastline, and this work marked the beginning of the study of modern plants in Libya (Environment Public Authority, 2010).

In 1821, Lyon introduced a list of plants that were cultivated in the Fezzan region (south western Libya), and backed it with some information on the natural vegetation of the area. Dickson had also collected several plants during his stay in Tripoli from 1818 to 1847 (Environment Public Authority, 2010).

Important work in this area was carried out by Rholf in 1871 and it was more accurate and up to date than the information that had come before it. This work included a study of the vegetation in Tripoli, Cyrenaica and Fezzan, and also included a list of local plants (Environment Public Authority, 2010).

In addition to the studies carried out above, many Italian plant experts (such as Bequinot, Borzi, Corti, Ttotter and Pampanini) have studied Libyan plants from 1910–1942 (Al-Zawam 1995).

The most thorough studies on flora in Libya were conducted by British botanist Keith in 1965. Although he did not contain full descriptions, they did contain taxonomic information and information on the use of certain plants and their local names, which are used as references for Libyan plant experts today.

From 1969–1979, Scholz published a number of research studies on the vegetation in Libya and described many plants that had not been mentioned previously. From 1976 to 1986, many experts (both foreign and Libyan) contributed to the Libyan Encyclopaedia of Plants.

Based on previous studies on natural plants, most have indicated that there are 1,750 species in 744 genera of which 118 are endemic species. Also, 75% of these plants grow on the coastal strip of Libya, which represents only 5.5% of Libya's area (93,000 km^2). This is also the most fertile area, with rain falling at a rate of 150 to 600 mm per year (Environment Public Authority, 2010). Fifty per cent of all plant species in Libya grow on the Al-Jabal Al-Akdar, and juniper trees represent 90% of all the trees in this area. In a study done at Omar AlMukhtar University (2005), it was found that 75 types of these plants grow only in Libya, on Al-Jabal Al-Akdar area, which represents 4% of all the plants in Libya (Ben-Mahmoud, 2013).

According to the first national report on the state of the environment (2002), the main regions in Libya about natural plants are as follows:

1 – The western regions of Libya, which includes Jefara plain, Jabal Nafusah and parts of El-Hammada Elhamra to the north of the 50-mm isohyet. The most common plants in this region include shrubs derived from forest plants that used to cover Jabal Nafusah such as*: Juniperus phoenicea, Rhantherium* spp*, Pistacia khinijuk suaveoters, Cupressus semperucrens, Calicotome villosa, Stipogrostis pungens, Zizyphus spina-christi, Haloxylon shveinfurthii, Artemisia tridentate, Stipa fernaccssions, Retamo raetam, Acacia gummifira,* and *Artemisisia campestris.*

2 – The central region includes areas extending along the Gulf of Sirt and to the north of the 50-mm rainfall line. The coastal area receives little rainfall and is covered by marshes and saline soil. The main plants are: *Retamo raetam, Acacia gummifira, Suaeda vermiculata, Artemisia campestris, Asphodelas microcurpus, Orginea scilla* and *Stipa tenacissima (esparto). Lygeum spartum* is found less frequently.

3 – The eastern region covers the area of northeast Libya, including Al-Jabal Al-Akdar, which is the only naturally forested area in Libya. The Al-Jabal Al-Akdar region constitutes only 1% of the total area of Libya but hosts biodiversity accounting for more than 50% of all plant species in the entire country. Approximately 1100 of the 1,750 plant species in Libya are found in this region. Approximately 75 species of plants grow only in this region of the world, however, is that encompassing the foothills and plateau to the south of Al-Jabal Al-Akdar. Here there is a transition from coastal plants and marshes to forest trees and shrubs; dry-land plants become more common to the south of on Al-Jabl Alakdar area. This region is considered the richest in terms of plant diversity. The current regional data show 44 endemic species representing 28 families and 41 genera (El-Darier and El-Mogaspi, 2009).

The most common plants are: *Juniperus phoenicea, Pitacia khinijuk, Calicotome villosa, Cupressus semperucrens, Quercus coccifera, Artemisia tridentata, Arbutus pavary, Pinus ralepensis, Thymus capitatus, Oleaceae rosmarinus officienalis, Ceratonia siliqua* and certain species used for medicinal purposes.

4 – The only type of plant in the Libyan Desert is grass in wadi bottoms, basins (oases), playas and marshes. The desert is practically devoid of perennial plants because water is so scarce. Such a region, of course, has no grazing value whatsoever. However, it is not unusual to find seeds of rapidly growing annual xerophilic vegetation in sandy or rocky areas.

However, over the ages these forests have been subjected to the widespread destruction of trees through the cutting of large sizes for shipbuilding and the use of wood in construction and special roofs. Al-Jabal Al-Akdar forest was estimated as originally comprising 1 million ha. while the total area of the forest was about 500,000 ha in 1950, in 1988, 35% of this land was converted to grow crops. Thus the actual area of this natural forest was about 320,000 ha in 1988 (Ben-Mahmoud , K 2013) Patches of natural forest also remain in Jabal Nafusah in the southwest portion of Jefara Plain.

Some reports have indicated that natural vegetation was exposed to deterioration during the Second World War as well as during the War of Italian occupation in Libya (The Ministry of Agriculture, 2004). Recent studies using satellite images have found that the area of natural vegetation cover, specifically on the Al-Jabal Al-Akdar area, was 320,000 ha in 1980 and decreased to 200,000 ha by 2005 (Omar Al Mukhtar University, 2005). All of the natural plants in Libya is degraded in terms of quality and density as a result of human activity and climate change (Ben-Mahmoud, 2013).

Therefore, many plants have become extinct or are on the verge of extinction, left to be replaced by plants that are more resistant to environmental conditions and overgrazing (The Ministry of Agriculture, 2004). The density of plants is also decreasing sharply in all regions, and in many areas it is decreasing at a rate of 10%–15%, so neither the soil nor the land can be protected (Al-Zawam, 1995). Therefore, erosion (particularly soil erosion) is a natural phenomenon in most areas, decreasing soil depth and fertility, and leading to plant deterioration (Ben-Mahmoud, 2013).

Table 2.7: Vegetation cover density in Libya 2005

Vegetation cover density	Areas (thousand/ha)	%
Very high density (more than 65%)	91	0.6
High density (40- more 60%)	276	1.9
Moderate density (15-40%)	4573	31.4
Low density (15-40%)	5760	39.5
Very low density (1-4%)	3870	26.6
Total area	14570	100

Source :Ben-Mahmoud, 2013.

2- Planted forests

The manmade forest in the western coastal area comprised 248,000 ha as of 1984, which were planted to combat desertification and stop the movement of sand dunes. But as of 2005 this forest's area was estimated at 60,000 ha.

However, according to Mapping of Natural Resources for Agricultural Use and Planning (2005) planted forests area was estimated at 60,000 ha and both types of natural forest and planted forests areas were estimated at 340,000 ha, which is 0.2% of Libya's total area. Figure 2.13 presents forest area in different periods, including natural forest and reforestation, which were available and estimated in 2010 at 210,000 ha .

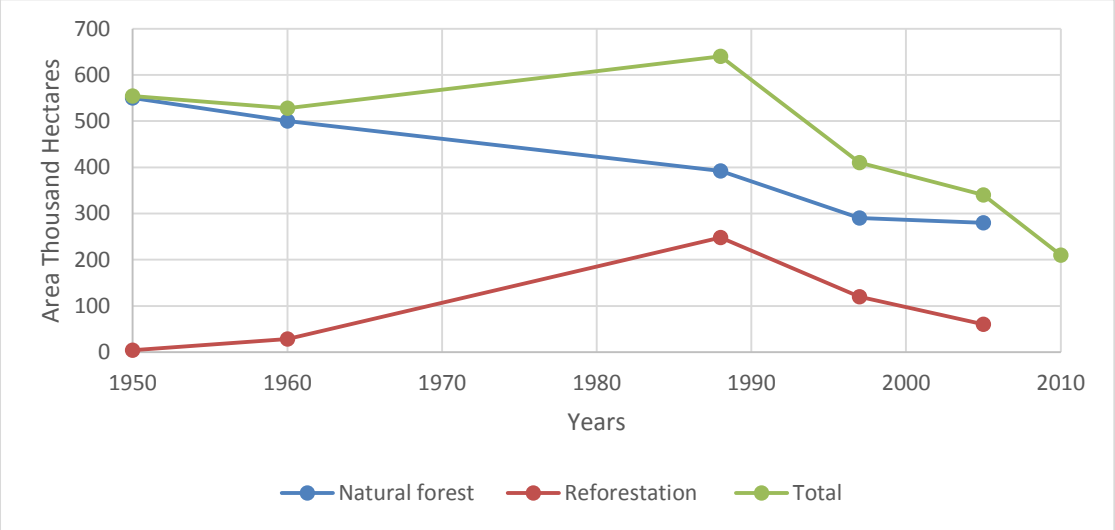

Figure 2.13: Natural and Man made forest cover in Libya in (1950, 1960, 1988, 1997, 2005 and 2010) *No date has been published to classify forest type in 2010 (Source Bin Kayal, 1995; Almahdawi, 1998; FAO and UNDP, 2005; FAO 2010 b).

2.1.7.4 Urban area

Urban areas increased from 10,000 ha in 1966 to 40,000 ha in 1980, then to 95,000 ha in 1994, an increase of 850% for the period between 1966 and 1994, which represents an annual increase of 30% and is due to population growth and improved level of income after oil exports in Libya. In 2005 urban areas was estimated as 181.000 ha which represents 0.1% of Libya total area, as shown in Figure 2.14.

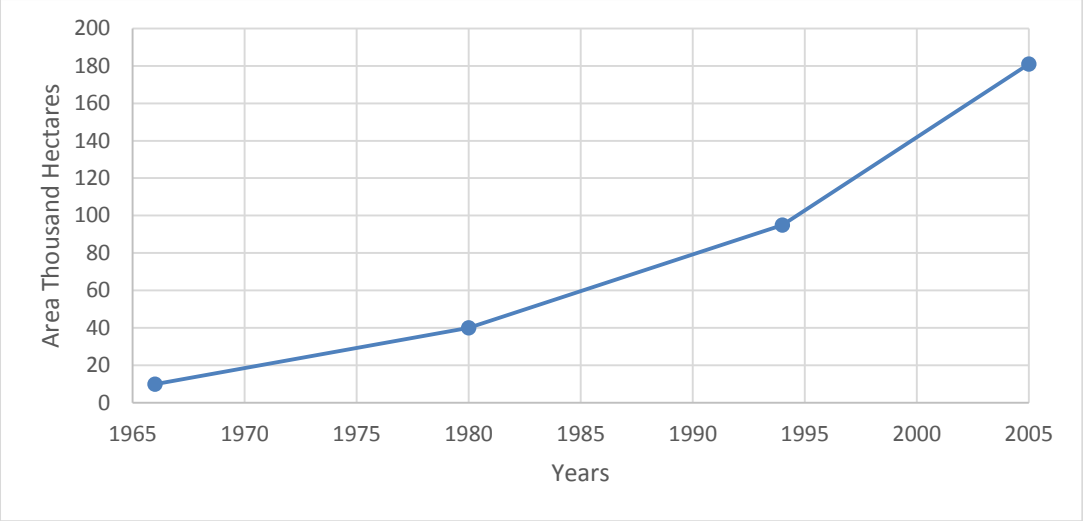

Figure 2.14: Urban area in Libya (Thousand ha) for the years of 1966, 1980, 1994 and 2000 (Source: Bin Kayal, 1995; Almahdawi, 1998; FAO and UNDP, 2005).

2.1.7.5 Bare Land and Marshes

Libyan Desert areas constitute the highest percentage of land cover, which is about 15,001,700 ha or 89.5% of the total area, which represents all kinds of bare land, as shown in table 2.8.

Table 2.8: Bare Land and Marshes in Libya 2005

Bare area type	Area	% form of bare land	% total area
Bare soil consolidated	64,274	42.8	38.3
Bare soil unconsolidated	40,667	27.1	24.3
Loose and shifting sand	43,473	29	25.9
Bare soil in Wadi Environment	1,603	1.1	1.0
Total	150,017	100	89.5
Marshes	905	.	0.5

Source: FAO and UNDP, 2005.

2.2 Sand Dunes Stabilization in Jefara Plain

Due to the serious problems caused by sand dunes movements or shifting sand dunes, for example, effects on cities' urban and rural areas, agricultural lands and irrigation land, it is very important and very necessary to combat sand dunes movement (Fadhil, 2002). Stabilization of sand sheets and sand dunes is achieved by different means (mechanical, chemical, physical and biological methods) (Hegazi *et al*., 2005). Also, it is designed to prevent the movement of sand long enough to enable either natural or planted vegetation to become established (FAO, 1985). Activities of sand dune movement control is achieved through maintenance and improvement of shrub by vegetation cover natural or artificial revegetation.

Sand dunes cover vast areas of Libya, but the largest area of dunes is located within the sprawling desert areas. However in this study our focus will be on those sand dunes which are located near the coastline of the Libyan-Tunisian border, to the west to Misratah. These are mostly located on the Jefara plain which is estimated to be 250,000 ha (Aljduaa, 1970).

2.2.1 Sand dune types in Jefara Plain

On the coastline of Jefara plain there are two types of sand dunes which are:-

2.2.1.1 Maritime Dunes

Maritime dunes are caused by tidal factors. They stretch along the coast, made up of rough white to pale grey sand, with high calcium carbonate content (ranging from 60-89%) and very low organic matter content. The ability of this sand to retain moisture is low, and it has impacted negatively on the adjoining agricultural land onto which it encroaches due to the north-west winds blowing in winter. Encroaching sand dunes have already covered several residential houses and surrounding trees. This type of dune makes up 40% of the sand dune area (Khatabi, 1981).

2.2.1.2 Continental dunes

Continental dunes are found towards the interior of the African continent (Moomen and Barney, 1981). They are characterized by soft sand with a colour that tends towards orange. These dunes are fast moving, from south to north, due to the Gibli winds which blow in the spring and autumn. This sand contains a high proportion of nutrients compared with the maritime sand, with the proportion of carbonates being only between 5-9%.

Furthermore, the ability of this sand to retain moisture is high compared to the maritime sand. These dunes have also covered vast areas of previously cultivated land (Khatabi, 1974).

2.2.2 Sand dunes stabilization methods

Since the early 1960s, serious measures have been taken to combat desertification in Jefara plain, Libya (Bbn-mahmoud *et al.,* 2000). However some reports (Jibril, 1999) state that sand dune stabilization in Libya began at the beginning of the twentieth century, during the second Ottoman reign, when Rajab Pasha contributed greatly to the process of sand dune stabilization in an attempt to stop sand movement and to combat desertification, particularly in the suburbs of Tripoli. At first these efforts were not accepted by the local people, because they thought that it was impossible to stop the movement of the sand dunes, going so far as to say Rajab Pasha was crazy to try to resist the sand and wind. However, he was successful in stabilizing a small area of the dunes, estimated to be 2000 ha, over a period of 6 years. According to some sources, the method used to stabilize sand at this time was by "thatching", using palm fronds and dead trees to cover the dunes (Al-Tillisi, 1972).

2.2.2.1 Successful methods

2.2.2.1.1 The traditional method of surface stabilization (dry plant materials).

Mechanical fixation appears to be effective, widely used and has successfully been applied in most Saharan countries, for instance, Libya (Messines, 1952), Egypt (Ibrahim, 1969) Sudan (Rapp *et al., 1976)* Mauritania (Ben Salim, 1991), Niger and Senegal (Grainger, 1990).

In Tunisia, this traditional method used in Tunisia since 1886 to stabilize continental dunes, dunes stabilization is carried out through establishing vegetation between the dune and the area to be protected (Swearingen and Bencherifa, 1996).

In Libya, the accepted method of stabilization, until recently, has been to erect low barriers, or palisades of cut vegetation (Moomen and Barney,1981). This method was first applied in Libya during the Italian occupation in 1916. After independence, Libya continued to use this method on a wide scale using local expertise (Ajaj, 1982). The plants used to erect the barriers are the *Imperata cylindrica* and *Aristida pungens* (Khatabi, 1981) see fig 2.16, however in other dry countries different kinds of plant materials are used (FOA, 1985; Han, 2007; Hegazi *et al.,* 2005; Fadhil, 2002).

Two sets of narrow, approximately parallel, trenches are laid out at right angles to each other to form a grid of square, or rectangular, enclosures. The trenches are due to a depth of about 20-30 cm while the sand is still moist following rain. The trenches are about 2 m apart at the top of the dunes, 3 m apart on the slopes, and 4 m apart at the base of the dunes.

Stems of the cut plants (at least 50 cm long) are set upright in the trenches which are then filled (Khatabi, 1981). The quality of the stems is very important: old or decaying stems cannot be used. The thickness and height of the barriers, and the length of the fixation period, will vary with local conditions (Moomen and Barney, 1981) as shown in figures 2.15, 2.16 and 2.17.

Figure 2.15: Sand dunes stabilization using dry plant materials first: Illustration of the process of sand dunes stabilization using *Imperata cylindrica* and *Aristida pungens* , Al- Atayah village in Algarabulli district in 1966 (Ajaj, 1982).

Figure 2.16: Sand dunes stabilization by dry plant materials in second stage: Illustration of sand dune after stabilized dry plant materials in Al Atayah village in Algarabulli district by *Imperata cylindrica* and *Aristida pungens* 1968 (Ajaj, 1982).

Figure 2.17: Sand dunes stabilization by dry plant materials third stage: Tree growth within squares which was stabilized by dry plant materials and planted in Al Atayah village in Algarabulli district 1969 (Ajaj, 1982).

2.2.2.1.2 The modern method of stabilization (using crude oil)

In countries where labour is in short supply the method can prove costly. Moomen and Barney (1981) reported that rising costs of erecting barriers and heavy use of plant material that also threaten to denude and accelerate erosion in other areas prompted the search for other methods of dune stabilization .In 1964, a technique was developed in Libya for the stabilization of dunes through the use of a bitumen spray (Moomen and Barney, 1981). This is faster and more economical than the older vegetation method. The first experiment using bitumen in Libya was conducted in 1961 and 1962. The success of this experiment was such that it was officially applied on a large scale in 1964, achieving great success, and leading Libya to become known internationally due to its experience in stabilizing sand dunes. It was subsequently applied in some other countries, such as Iran and Saudi Arabia (Khatabi, 1981). In Libya a bitumen mulch is sprayed on some areas before planting (Goor and Barney, 1976). The bitumen is heated to about to 80°C and then sprayed onto the sand. This is done as soon as possible after good rainfall in order to reduce evaporation losses, and before trees are planted. The bitumen not only binds the sand particles and keeps them from moving (Moomen and Barney, 1981), but also acts as moisture-conserving mulch that helps with the establishment of planted trees. The bitumen also provides better protection against wind erosion than the grid-type barrier does (Abo-Khchim, 1995).

The equipment used in applying the bitumen mulch is quite simple. It consists of a large cubical tank, on which are mounted four double-nozzle aerial sprayers. The tank capacity is thirteen m^3 of bitumen, which is enough to cover an area of about 4-5 ha (Khatabi, 1981). The equipment is mounted on a smooth, toboggan-like base so that it can be easily pulled over the dunes by a bulldozer. A pump provides a pressure of about 7.03 to 8.45kg cm^{-2} (Moomen and Barney, 1981).

Figure 2.18: Sand dunes stabilization by using crude oil: The process of sand dunes stabilization by bitumen spray by a bulldozer which pulled the tank over the dunes ,in Al Atayah village in Algarabulli district in 1971 (Khatabi, 1981).

Figure 2.19: Planting *Eucalyptus gomphocephala* trees: Reforestation campaign which comes after sand dunes by stabilized bitumen spray , in Al Atayah village in Algarabulli district in 1971(Khatabi, 1981).

In the beginning concerns were expressed about using crude oil to stabilize the dunes, in that it forms a black layer once sprayed onto the surface of the sand, which potentially causes oil pollution of both water and soil. However, these concerns dissipated completely after four years by which time the thin black layer of bitumen had disintegrated and was replaced by biological stabilization of plantation forests and natural plantings of annuals and perennials that had invaded the area after the oil was sprayed on. With regard to the water pollution, in the areas that had been sprayed the groundwater was found to be safe, as it was not close to the soil surface, and the probability of oil leaking into the soil was very low, because of the density of the bitumen, and the fact that it contains a waxy substance that prevents leakage.

The conclusion was that there were no side effects causing pollution of the environment, and so the results of these experiments were that this method is considered to be the best of what has been achieved so far in the field of materials technology designed to stabilize sands (Khatabi, 1981). Sand dunes stabilized since 1952 to 1979 were estimated to cover 75,988 ha in Jefara plain using both above methods (Khatabi, 1981) (Figure 2.20).

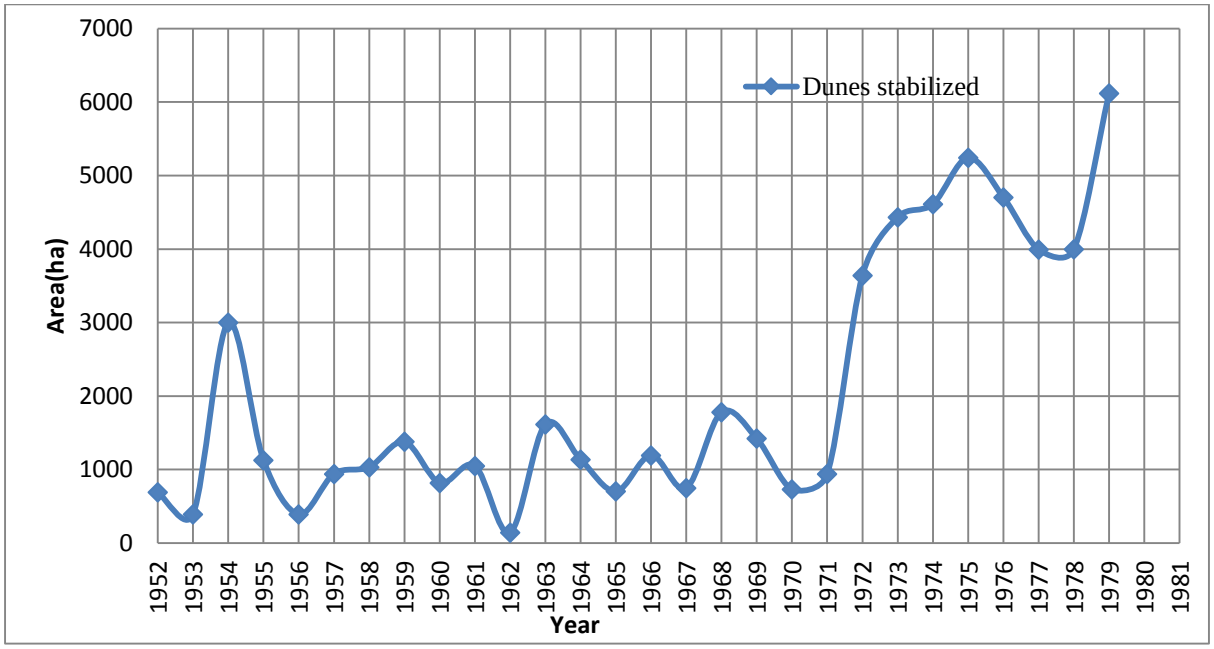

Figure 2.20: Sand dune stabilized in Jefara plain, Libya of 1952-1979: Sand dunes stabilized since 1952 to 1979 were estimated to cover 75,988 ha in Jefara plain using dry plant materials and bitumen spray methods (Khatabi, 1981).

2.2.2.2 Failed methods tested

2.2.2.2.1 Chemical Stabilization Method

Chemical mulching is a method for the stabilization of the surface layer of sand dunes, especially when a large area needs to be stabilized in a short period (Ahmed, 1990). Where vegetation is ultimately to stabilize the surface, the chemicals must not restrict plant growth by toxic effects or prevent water penetration (Ahmed, 1990).

As early as 1963, the chemical dune stabilization method was tested by British scientists in some areas such as in the desert areas of Israel and Australia. Later this was conducted in other countries, including Libya, Iran, Saudi Arabia, Algeria, Iraq and China (Han, 2007).

A chemical method was experimented with in 1967 in Algarabulli district, Libya by an Austrian company, AGRARFLUG-GLUG, when bentonite powder was sprayed from a small aircraft in order to preserve moisture after preparing the ground with the seeds of grasses and shrubs. (Figure 2.21). However, the weather conditions did not help the process. Because the sandy surface was so dry the intended cover supplied by the bentonite only assisted the wind erosion. For this reason this method was not suitable in Libya (Khatabi, 1981). However in China this method was successfully applied with very good results and also different kind of chemicals were developed (Han, 2007).

Figure 2.21: Spraying of chemicals from the air in an attempt to sand stabilisation: This figure illustrates an attempt of sand dunes stabilization by spraying of chemicals from a small aircraft, in Al Gawea village in Algarabulli district in 1968 (Khatabi, 1981).

2.2.2.2.2 Synthetic rubber (Latex) method

An experiment using synthetic rubber to stabilize the dunes was carried out in 1970/1971. This involved spraying a mixed emulsion of latex from the rubber industry with mineral oil, where water made up 96% and the mixture 4%. This mixture was sprayed on the sand, and experience in the areas of Zahra and Alhacha, North West of the city of Tripoli, showed only a fair level of success for the method, due to the large amounts of water that would be required for making wider use of the method in the dry sandy areas (Ajaj, 1982).

Recently, according to the Annual Report of the National Committee for Combatting Desertification for the period January to December 2009, many experiments were conducted aimed at sand dune stabilization. Several new methods for stabilizing sand dunes were conducted in cooperation with Chinese experts within a framework of local capacity building. This process is still under investigation and there have been no reports to indicate the extent of any success. One of these methods is the environmentally friendly Eco-mat, which is embedded in the soil and aims to protect the soil from erosion and dune encroachment. This method is being applied to the south of Jefara (National Committee to Combat Desertification, 2009).

2.3 Plantation Forest in Jefara plain

Some thousands of years ago, much of the coastal lowland areas of Libya were favourable for the growth of trees and supported open woodlands of *Zizyphus lotus*, *Acacia tortilis*, etc. The mountainous areas carried a Mediterranean type of forest, consisting of *Pinus halepensis*, *Juniperus phoenicea*, *Cupressus sempervirens*, *Pistacia atlantica*, *Quercus calliprinus*, *Quercus ilex*, and possibly *Tetraclinis articulata* and other species. Many of these species can only be found in the forests of Al-Jabal Al-Akdar, in the east of Libya (FAO, 1972).

The Greek historian Herodotus, in the fifteenth century BC, wrote that the mountainous belt of the Jefara plain was covered with evergreen forests, providing shelter and shade for the wild animals that were living there (Manaa, 1969) Herodotus spoke of visiting the Al-Jufrah district in central Libya, and said it had a high density of woodlands (Manaa, 1969). However, by 1852, it is recorded that residents of this district had migrated as a result of sand dune encroachment, with the advance of the dunes during the second Ottoman reign (Ataiwar, 1991).

The plain was crossed by dry valleys which during the rainy winter season, channel water runoff from to the mountains the Mediterranean Sea. Serious destruction of the forests and woodlands of Libya probably coincided with the advent of the Phoenicians and Romans, and such forests as survived the onslaughts of those early colonizers have, in the course of centuries, largely disappeared due to uncontrolled exploitation, shifting cultivation and overgrazing (FAO, 1972).

2.3.1 Turkish occupation

A period of agricultural revival and urbanization occurred during the Ottoman Period, at the beginning of the reign of Sultan Mahmud (1808-1839). This flourished even more strongly during the era of his successors, and at this time thousands of seedlings of willow trees were imported into to Libya from the Turkish city of Izmir in order to plant them right across the country. This happened particularly in the Jefara plain, which by now was mostly covered with sand dunes, due to the cutting down of timber for construction purposes, and to supply poles for telegraph lines, which were expensive to purchase (Ataiwar, 1991). Besides planting willow trees, the Turkish government planted *Eucalyptus camaldulenis* trees, which in August 1909 were described by the Ministry of Agriculture and Minerals in Istanbul as of great benefit in providing deodorization, and providing timber for various industries.

The Ottomans were the first to introduce the eucalyptus tree into Libya (Khatabi, 1981). During the second Ottoman rule, afforestation was seen as of increasing importance, both for the provision of timber and poles for telephone lines, and also as protection from disease. The planting of forest trees also aimed at protecting the environment through soil stabilization and protection from erosion. In March 1910, the Ministry of Agriculture and Forestry in Istanbul issued a declaration regarding the importance of afforestation in the city of Tripoli, and in the surrounding valleys and mountains, in order to avoid the damage caused by floods.

Turkish officials emphasized the importance of Tripoli increasing its afforestation programs, and forced employees and officials to plant a certain number of trees each year, depending on the individual's income. If they did not, they would be deprived of their jobs in administrative and military institutions (Ataiwar, 1991).

2.3.2 Italian occupation

In 1911, when the Italians first occupied the coastal zone of Tripoli, some eight or ten Eucalyptus trees, species not recorded, where found growing near the city walls (FAO, 1972). During this period, many thousands of Eucalyptus trees were planted as windbreaks, as roadside trees along the major roads of Tripoli, and near to outlying towns and villages. These plantations consisted mainly of Eucalyptus and Acacia, and the following species of Eucalyptus were introduced into Libya during this period: *Eucalyptus camaldulensis, E. cornuta, E. gomphocephala, E.diversicolor, E.redunca, E.melliodora, E. polyanthemos, E. sideroxglon , E. cladocalyx , E. viminalis, E. saligna and E. citriodora*, among others (FAO, 1972). Other reports indicated that more than 70 species were planted (Khatabi, 1974). However these species grew with varying levels of success, the most successful being the *Eucalyptus camaldulensis* and *E. gomphocephala* (FAO, 1972).

During this period the area under planted forest was estimated at about 4000 ha, but most of this area was later destroyed during the Second World War, because of cutting firewood due to the exploitation of the available fuel for the Axis soldiers and also by the local population (Aljduaa, 1970). By the end of the war reports estimated that the remaining forest covered just 2000 ha (Ajaj, 1973).

2.3.3 British administration

An afforestation programme was started again in 1946 by the British Military administration in an attempt to remove the sand dunes along the main roads and adjacent to agricultural lands. The species used were the *Eucalyptus* spp and *Acacia cyanophylla* (FAO, 1972). The reports available from this period indicate that the British administration contributed to afforestation in small areas of Libya, which were estimated to be 300 ha. However, they also contributed to the protection of the rest of the forest (Khatabi, 1981).

2.3.4 After independence 1951 up to recent time.

In 1952, after the independence of Libya, and the return of trained forest officers from their two-years training at the Cyprus Forestry College, the Libyan Forestry Department began afforestation on a fairly large scale.

The area planted amounted to about 3,000 ha per annum. The two species used were those found to be the best suited to the climatic conditions, as well as being fast growing species, *Eucalyptus camaldulenis* and *Eucalyptus gomphocephala* (Aljduaa, 1970).

Some reports estimate that by 1961 the forest area was 43,763 ha. After the discovery of oil and the start of its export in 1963, five-year plans for afforestation were drawn up to plant forests on the coastal strip of the Jefara plain. The whole plan consisted of six five year phases, and was supposed to finish in 1993, with the first five-year plan being 1963-1968 (Aljduaa, 1970). The first five year plan was implemented successfully by the State, with the planting of about 26824 ha of forests (Aljduaa, 1970). The second plan, for the years 1968-1973 was also carried out successfully, despite afforestation stopping for four months in 1969 due to the military coup against the monarchy at that time.

The second plan was then resumed, and most of the coastal area of the Jefara plain was planted under forest, so that there was no need for an afforestation program after 1973 in the Algarabulli district (Khatabi, 1981). Some reports stated that the afforestation programs of the former administration continued in Libya until 1984, but these were not in the form indicated in the original plan. Between 1952 and 1983 248,104 ha were planted with 220,427,740 seedling trees (Khatabi, 1981) (Figure 2.23 and 2.24).

From this examination the following conclusions can be drawn: As to the stability of various large groups of dunes, Khatabi (1981) reported that no overall movement was observed during the period of 1953 and 1973 and as to the stability of the southern dune group, the rolling dunes of 1953 were covered in thick forest.

Figure 2.22: Government officials supervise the process of sand dunes stabilization (02/02/ 1972).

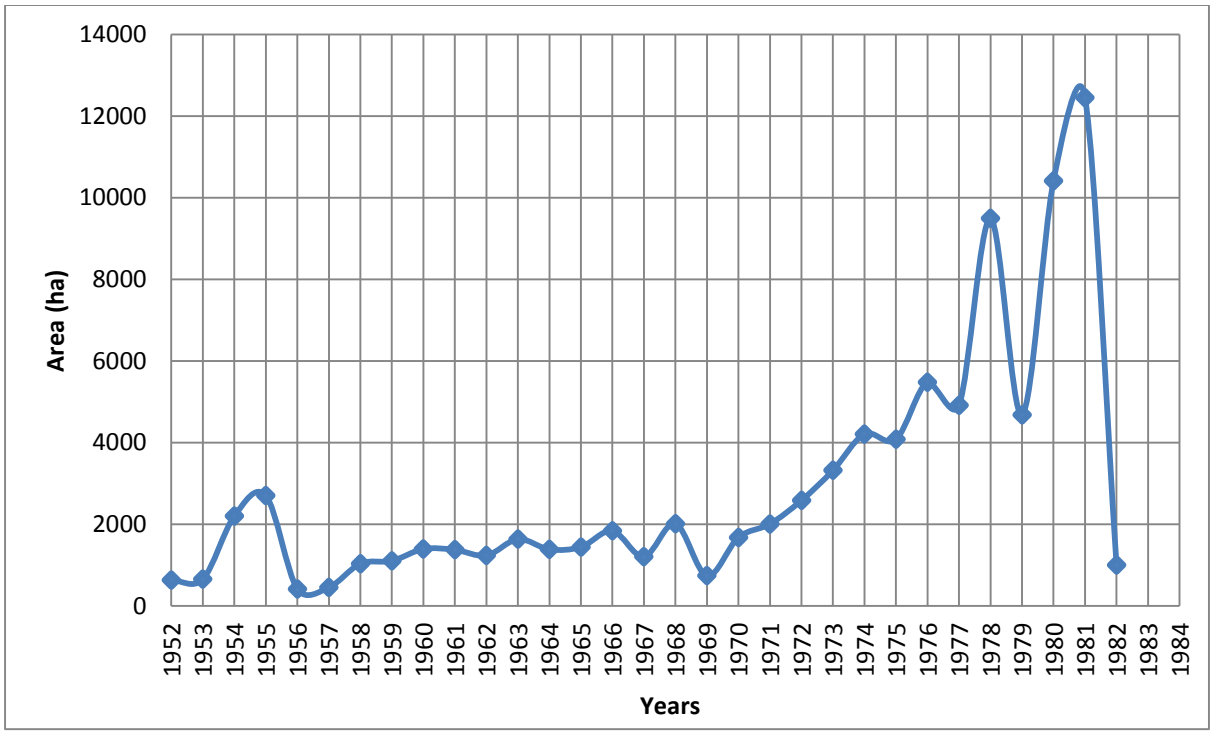

Figure 2.23: Area of sand dunes planted in Jefara Plain from (1952-1982): Sand dunes planted after stabilized since 1952 to 1982 were estimated to cover 82,744 ha in Jefara plain, Libya (Khatabi, 1985).

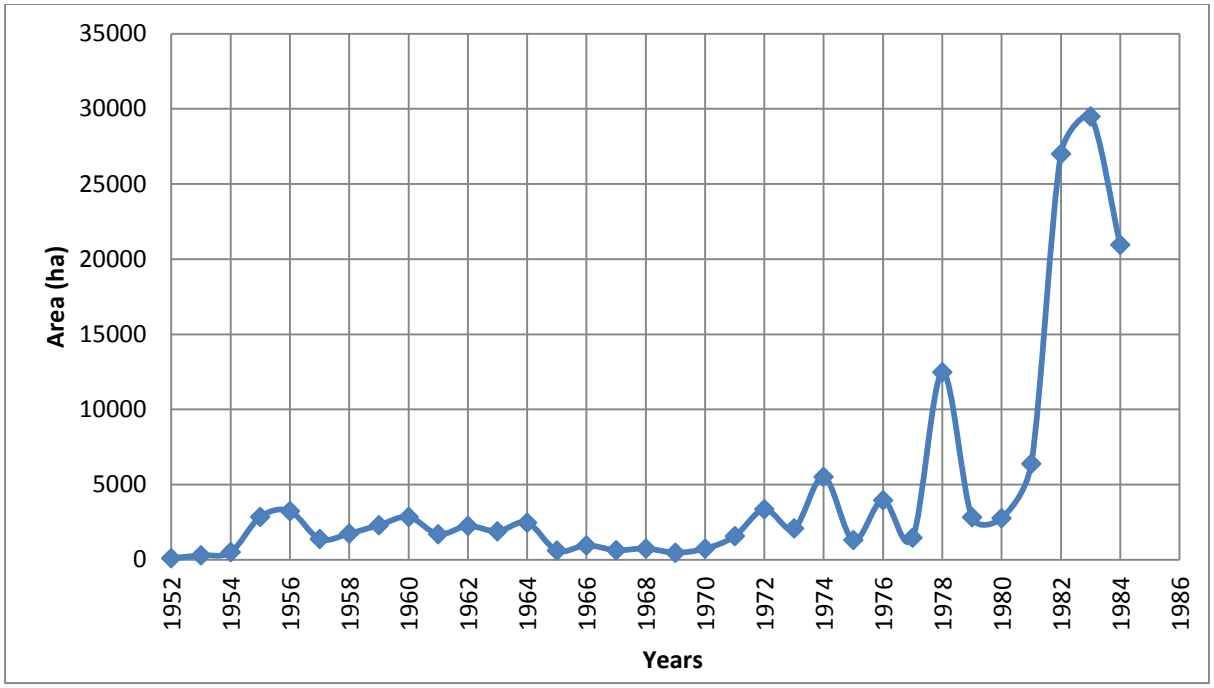

Figure 2.24: Barren land planted in Jefara plain/ha from 1952 – 1984: Barren land planted in Jefara plain since 1952 to 1984 were estimated to cover 148,868 ha in Jefara plain, Libya (Khatabi, 1985).

2.3.5 The choice of tree species

The choice of tree species for afforestation is perhaps the most important decision which must be taken before starting afforestation. The choice of tree species depends on the purpose of plantation. Three quarters were grown for productive purposes (production of wood. fibre, fuel or non-wood forest production) and one quarter for protective purposes (mainly rehabilitation of degradation lands, combating desertification or protection of soil and water (Kollert, 2010). In Libya, plantation forest for productive purposes, tree species were introduced to Libya, but very few species were planted successfully due to the environmental conditions (GEFLI, 1973).

2.3.5.1 Acacia:

The acacias used in Libya are native to Australian and several Australian acacia species have become highly invasive in a number of ecologically sensitive areas of Africa (Impson *et al*., 2004). In Africa generally Acacia is covering 4.3% of all planted areasd. In Libya, Acacia spp are the most widely planted covering 55% of all these planted in Jefara plain. Only two Acacia species were introduced into Libya (Khatabi, 1981).

- ***Acacia cyanophylla***

Acacia cyanophylla, which also known as A*cacia saligna*, was introduced to North Africa from Australia and was planted in 1870 in Algeria, then used extensively in Libya after 1916 for sand dune fixation and for the same purpose after 1930 in Tunisa (Tiedeman and Johnson 1992) and as a windbreak to protect cropland. It also provides fuelwood and increases soil nitrogen by fixation (Tiedeman and Johnson, 1992).

Furthermore, the leaves can be used as animal fodder during the dry period. *Acacia cyanophylla* grows in association with *Eucalyptus gomphocephala* and *Acacia cyclops* (Goor and Barney, 1976).

It is a tall shrub, up to 7 m in height, which grows on sandy loam on drained and calcareous soils, and it grows well in plantation in areas where the annual rainfall is less than 300 mm (Goor and Barney, 1976).

- ***Acacia cyclops***

Acacia cyclops was introduced into Libya in 1954 (Khatabi, 1981) and was widely planted in the stabilization of the maritime dunes, where it is a very useful species for binding coastal dunes and planting on difficult sites (Goor and Barney, 1976). It can cope with salt and exposure to onshore winds and sea spray, which have a detrimental effect on most plants, but it does not grow under rainfall conditions of less than 150 mm (Khatabi, 1974).

A shrub, up to 3 m, it grows where the annual rainfall ranges from 150-750 mm (Goor and Barney, 1976). *Acacia cyclops* originated in south-western Australia and became invasive after it was introduced into South Africa in the early 1800s (Kotzé *et al.*, 2010), primarily for stabilisation of sand dunes (Mokotjomela and Hoffmann, 2013).

2.3.5.2 Eucalyptus

Eucalyptus is one of the world's most important and most widely planted genera (Giamakis *et al.*, 2001). There are over 600 species of eucalypts, almost all of which are native to Australia and New Guinea, and which dominate about 95 per cent of the forest area of Australia. These species of eucalyptus grow in a wide variety of climates and soils, from the hot desert to the cold mountain slopes (Goor and Barney, 1976).

Over 100 different species of eucalyptus have been tried in experimental plantings in different countries in various savannah types (Laurie, 1974) .

In Libya, it was mentioned previously that more than 12 species of eucalyptus were introduced during the Italian occupation, however only two species of eucalyptus have successfully established which are *Eucalyptus gomphocephala* and *Eucalyptus camaldulenis*, particularly on the continental dunes, while in some areas a mixture of eucalyptus and acacia have been used to obtain some economic advantages. In Africa eucalyptus is the most widely planted genus covering 22.4% of all these planted, but in Jefara plain eucalyptus (*Eucalyptus camaldulenis* and *Eucalyptus gomphocephala*), account for 40% of all planted forest (Khatabi, 1981).

- ***Eucalyptus gomphocephala***

A tall, evergreen tree, up to 42 m, and grow on sandy loams and coastal dunes where this species is frequently used in arid zone afforestation, especially in the southern Mediterranean Basin (Goor and Barney, 1976). *E. gomphocephala* is often planted in zones with less than 250 mm rainfall and is a fast-growing species (Kaul, 1970).

This species of *eucalyptus* was introduced into Algarabulli district in early 1920s by Italian occupation as windbreaks for their farms (Khatabi, 1981) then used later widely, distributed in the whole area except coastline, because it cannot grow in soils that contain a high percentage of salinity.

- ***Eucalyptus camaldulenis***

A tall, evergreen tree, reaching a height of 40 m, growing in regions where rainfall ranges from 200 to 600 mm with up eight dry months (Goor and Barney, 1976) it is fast-growing in favourable sites. This species has been extensively planted with great success in many semiarid zones of the world. This species of eucalyptus was introduced into Algarabulli district in early 1950s.

2.3.5.3 Pine

Pines are very valuable introductions to certain arid zones, where pines do not require a high level of soil fertility (Laurie, 1974). In Africa *Pinus* is a widely planted genus covering 20.5% of all planted areas, but in the Jefara plain, pines account for 5% of planted forest. Many of these species can be found naturally in the forests of the Al-Jabal Al-Akdar in Cyrenaica, eastern Libya. There are two species of pines, *Pinus halepensis* and *Pinus pinea*, used in the study area as a forest plantation:

- ***Pinus halepensis***

An evergreen tree, up to 25 m high but usually under 18m and widely distributed in the semiarid zones of the Mediterranean Basin, from Spain and Morocco to Greece, Libya, and Jordan (Goor and Barney, 1976). During the twenty century extensive programs in the Mediterranean Basin have mainly relied on plantations of *Pinus halepensis*, which now cover thousands of ha. It is one of the most important tree species in this region.

The main goal behind vast afforestation programs of *Pinus halepensis* was in many cases socioeconomic, and implemented for protecting soils, controlling catchment hydrology and fostering forest productivity. As it is very drought-resistant and grows in area with 250-800 mm of rainfall and seven or eight rainless months (Goor and Barney, 1976). *Pinus halepensis* was preferentially chosen due to low-technical requirements for nursery production, high-resistance to adverse climatic and soil conditions, and because it was considered part of the climax community, as in extensive areas in Tunisia, Algeria, and Greece (Maestre and Cortina, 2004).

This type of pine is extensively cultivated at higher elevation (Laurie, 1974) . In Algarabulli district, this species represent only 4 per cent of all planted forest, particularly in clay soil.

- ***Pinus pinea***

A large evergreen tree, up to 24m high requiring an average rainfall between 400 to 800 mm, it grows on a wide range of soils; best growth is on fixed dunes and sandy loams (Goor and Barney, 1976). It is one of the most appreciated species in the northern Mediterranean basin due to the multiple products and functions. It was introduced to Lebanon in the sixteenth century to prevent the coastal dunes from encroaching on Beirut (Goor and Barney, 1976). In Tunis, *Pinus pinea* has been planted since 1907 in reforestation programs, being the most important specie after *Pinus halepensis*, occupying about 20,000 ha (Piqué *et al.*, 2013). However in Libya, this is the least important species that has been planted in Jefara plain where it represented 1 per cent of all planted forest (Khatabi, 1981).

2.3.6 Plant nurseries

Nine plant nurseries were established in Libya by the Forestry Department to serve the afforestation programs, and until the year 1971 these produced about 13 million seedlings per year.

The most important of these nurseries is the Aljedayeda nursery in the city of Tripoli, which was established in 1935, and produced 400,000 seedlings annually at that time; by 1971 it was able to produce about 5.5 million seedlings per year (Khatabi, 1985). It is now able to produce 8 million seedlings a year, of various species, and it is the largest nursery in Libya and in the Middle East. Also falling within the study area is a plant nursery which was established in 1967 and was then producing about 1,500,000 seedlings per year but is now able to produce 2.5 million per year. However, most of the original nurseries have not functioned for many years (Khatabi, 1974).

2.4 Human context

2.4.1 Population

In 2006, Libya's total population was 5.2 million and non-nationals were estimated at 359,540. In 1995, the Libyan population was 4.3 million with an annual growth rate of 2.8%, a birth rate of 25.15/1,000/year and a death rate of 3.37/1,000/year (BSCL, 2006a) . Of the total population, 88% is urban.

Overall, the population of Libya is not great, but it is growing at a rapid rate. However, the period of 1954–1964 was rather low due to the poor state of the country's economy before the discovery of oil. Also, during the period of 1984–1995, the population growth rate experienced a decrease due to the passing of the Nationality Law and the abolition of some of the facilities under which individuals could obtain Libyan nationality (El-Kikhia 1994). However, during 1973–1984, the growth rate increased due to the positive impact of immigration, while during 1984–1995 the growth rate fell significantly as the country had reached the stage of maturity and stability of the population. When compared to the global average as a whole, the population growth rate in Libya was one of the highest in the world, standing at 1.67% and then gradually decreasing (Abo-Ayana 1980).

According to Libya's population census of 2012, which was conducted one year after the uprising in Libya, Libya's population and growth rate were seen to be decreasing. About 831 households were missing and unaccounted for in the census (BSCL, 2012). This is because they were not found in their houses or cities when censuses were conducted. However, some of the cities in Libya were abandoned as the occupants became refugees in other countries or somewhere in Libyan camps, where the census was not permitted to take place (BSCL, 2012).

Because the population is growing rapidly, the amount of arable land is decreasing. In 1973, the urban population in Libya was 57.5% of the total population; in 2006, this figure had increased to 86%. Almost 95% of the population lives in the coastal region in the north, and the rest in widely scattered oases in mid- and southern Libya.

According to the population distribution in Libya based on a 2006 estimation, people concentrate in two centres, the first, in the northwest (Jefara Plain), where about 60% of all Libyans live. This includes Tripoli City – the capital of Libya – where more than one million people live, and the second centres on north-eastern Libya (Ben-Ghazi Plain). The main reasons for this concentration are fertile soils and seasonable, moderate climatic conditions.

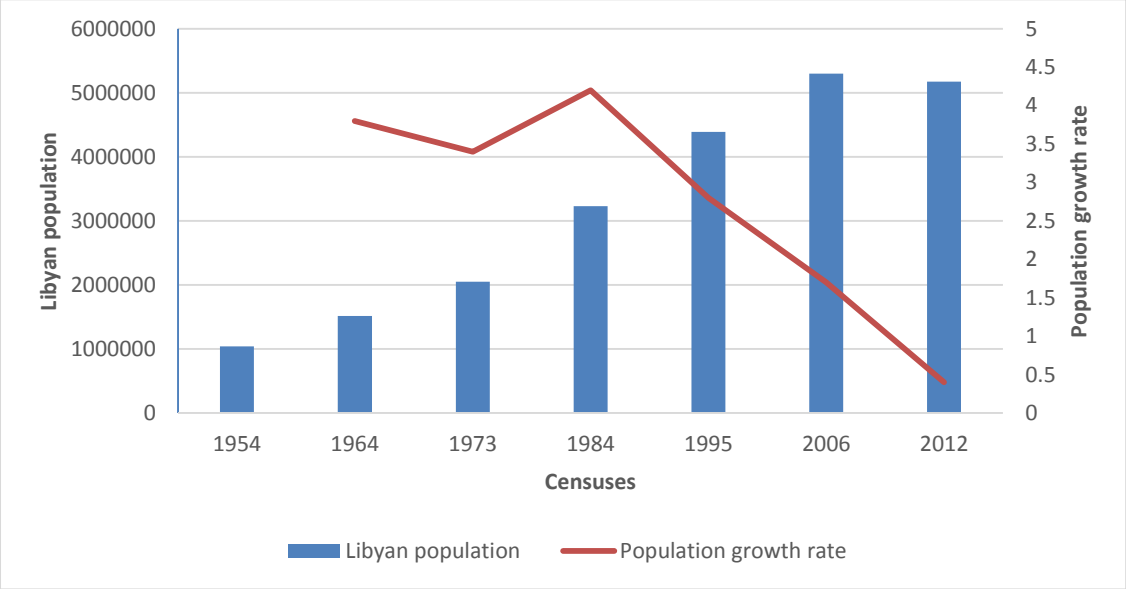

Figure 2.25: Libyan population and growth rate in censuses of (1954, 1964, 1973, 1984, 1995, 2006 and 2012). **Source**: Bureau of Statistics and Census Libya, the final results of General Census of 2012.

2.4.2 Gender in Libya

Libyan culture is structured around an Arab Berber tribal system of society. Tribes (qabila) further consist of sections (bayt), which are then subdivided into larger families that branch into a number of smaller family groups. Libya has an estimated 140 tribes, only about 30 of which are viewed as having any real significance (Sehib *et al.*, 2013)

The vast majority of the Libyan population is Sunni Muslim and "religion permeates all facets of life" (Attir and Al-Azzabi, 2004). In the first half of the 20th century, women in urban Libya were largely confined to their homes and would not venture out without wearing the veil. According to tradition, men brought home the greatest proportion of the household income,

with the contributions of women being difficult to establish. Today, these practices are relaxing (Attir and Al-Azzabi, 2004).

Libya's constitution is one of the minority of Arab nations that grants women equal rights to employment, yet women's participation in the labour force remains low (Sehib *et al.*, 2013). To further illustrate this point, in 2008 women accounted for only 22% of the workforce, a figure unchanged from 1996 (Attir and Al-Azzabi, 2004). Currently, the vast majority of working women in Libya (87%) are employed in the public sector, particularly in health and education (Sehib et al., 2013). Previously, most posts held by women were poorly paid and rarely within the "professional" sector. Yet, today, women may work in hospitals, some administrative office posts, and more so in schools and universities, particularly in the cities. In the countryside however, the strongly traditional views and customs prevail, which includes the forestry industry that is male dominated (Attir and Al-Azzabi, 2004).

Most national legislation in Libya supports equal rights for men and women, but many legal provisions that would ensure equality have yet to be effectively enforced. Traditionally, women have been excluded from the social and political worlds regarded as men's territory. The social position of Libyan women is inferior to that of men, and deeply rooted patriarchal values and traditions still persist. It can be observed, however, that the level of freedom and equality women experience increases in relation to the social class to which they belong (Sehib et al., 2013).

Despite the equality between the sexes in law in Libya, *de facto* inequality persists. Although this occurs more often in rural areas, there remain practical roadblocks, such as women and men meeting individually, even for the purpose of conducting interviews. A male is more at liberty to conduct an interview with an employed woman in her place of work (Attir and Al-Azzabi, 2004).

Birke (2011) notes that a lack of democratic institutions and freedom of assembly and expression in Libya continues to limit Libyan women's abilities to lobby for change. This is mirrored by their comparatively low representation within the work force. Moreover, traditional and current attitudes and living patterns continue to exist in parallel in Libya, forming barriers to women's participation into the political, economic, and social facets of Libyan life (Attir and Al-Azzabi, 2004). Yet, over time, this situation has seen some changes due to the views and influence of the younger, educated sector of society.

However, one consequence of the demise of Gadhafi's rule has been further restrictions on women's rights by the Libyan regime "in power," as the extremist Islamic sector views equality of the sexes as a negative Western influence. Emerging ruling tribes also continue to hold traditional patriarchal views. Although women currently living in Libya have access to education and medicine (Samia and Sahar, 2015), and working women are treated equally, they also carry the additional burden of homemakers expected to clean and cook for the entire family and care for any children.

2.4.3 Economics and political context

With regard to the Libyan income and occupation, in a FAO report on Libya's economy in 1952, the country was an excellent example of extreme poverty, under which most citizens lived in destitution and without energy and mineral resources; additionally, the harsh climate conditions in the region prevented agricultural expansion. The lack of capital, skilled labour and basic infrastructure exacerbated the already adverse situation (Al-Hajjaji, 1989).

At the time, Libya was regarded by the UN as one of the poorest countries in the world; its average annual per capita income was US$30, and the national income was about US$45 million, which came from international aid (Abolghemh and Alkazery, 1995).

After Libya acquired independence, the UN extended aid amounting to US$30 million for the purpose of executing the country's development plan from 1952 to 1958. The funds were intended for the development of farmlands and the improvement of the conditions of farmers (Abolghemh and Alkazery, 1995). Some of the goals realised during this period were the exploration of arable land, the search for water, the stabilisation of sand dunes, the establishment of plantation forests and the extension of agriculture and provision of agricultural services (Abolghemh and Alkazery, 1995).

Before the discovery of oil, agriculture and grazing were key sectors in the Libyan economy. Amongst the population, 80% lived in rural areas; 70% of the total number of workers were employed in agriculture, producing 60% of the gross national product of the country (Al-Hajjaji, 1989).

After the discovery of oil and oil export in the 1960s, revenue from oil production became the primary source of national income. This development increased the average per capita income in the country, stabilised the conditions in the region and facilitated the implementation of development programmes for the agricultural, industrial and residential sectors.

These programmes included stabilising sand dunes, establishing forest plantations and fostering awareness of the importance of forests. The discovery of oil and oil exportation encouraged numerous Libyans to forgo agriculture as a profession and assume posts in the administrative, service and industrial sectors. These individuals hired Arab or foreign labour to work on their farms and compensated them through wages or shares in farm production.

In 1954, the service sector in Libya was of a limited scale, with only 16.3% of the total workforce working in this industry. The country's expansion initiative, which included improvements to health, education and administrative services, began attracting a substantial proportion of the Libyan labour force, thereby rapidly increasing the employment rate to 32% in 1964, 53% in 1973, 55% in 1984, 60% in 1995 and 63% in 2006. 90% of Libyan labour force work in the public sector (BSCL, 2010). Figure 2.26 shows the GDP per capita of Libya in comparison with those of Egypt and Tunisia.

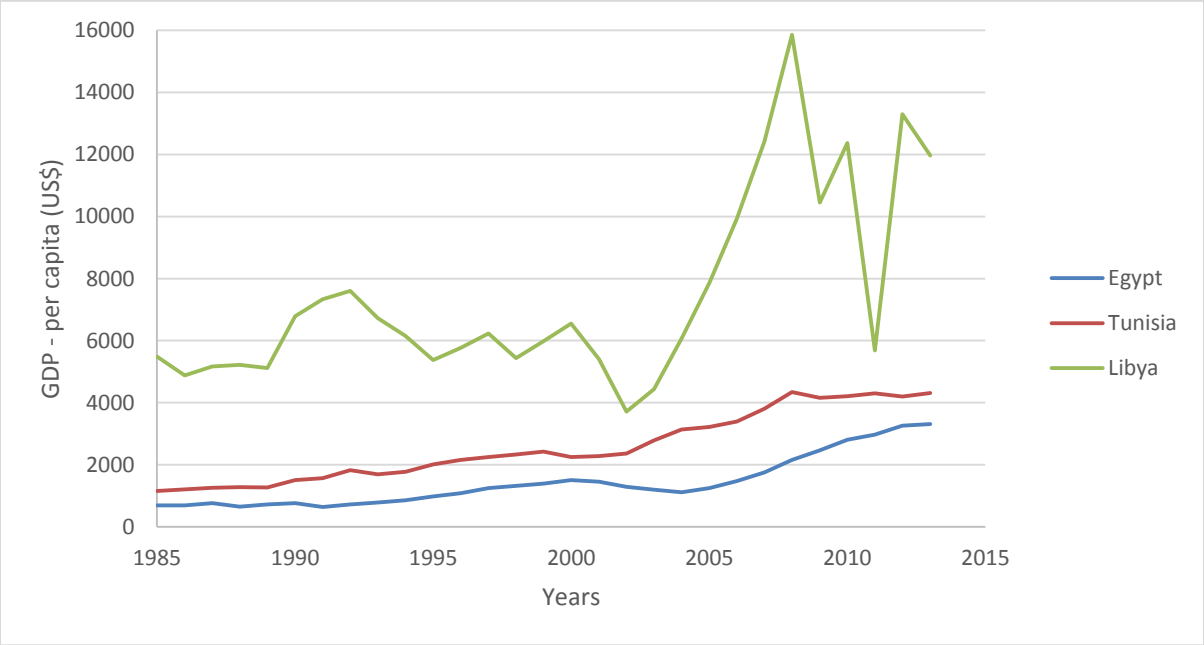

Figure 2.25: GDP per capita of Libya, Egypt and Tunisia (Source: The World Bank, 2015).

Like many countries in Africa, Libya suffers from a "resource curse," defined by Doraisamy (2013) as a phenomenon that occurs when countries that have large amounts of natural resources also have a high poverty rate. The country itself contains the largest oil reserves in Africa and the ninth largest in the world, but according to the CIA World Factbook, about one-third of Libyans live beneath the poverty line.

By African standards, Libya has a high GDP, which was equivalent to approximately $10 000 per person in the mid-2000s. High oil revenues in the past decades helped boost incomes. However, Libya's economy is underdeveloped compared to the oil exporting states of the Middle East. The sentiment that Libyans had failed to benefit sufficiently from the country's energy resources under the Gaddafi regime significantly contributed to the popular uprising (Sehib et al., 2013).

The spread of the phenomenon of poverty in Libya after the culmination of the continued failure of the policies and practices under Gaddafi also confirmed the inability of the regime to achieve any form of social justice. This phenomenon, as we see it today in Libya, describes the dialectical relationship between corruption and poverty: increased corruption and looting led to an increase in the number of poor people in Libya (Sehib et al., 2013).

Following the demise of the Gaddafi regime in 2011, a number of factors continue to stand in the way of eradicating poverty in the new Libya. Yet, while Libya's new government faces political challenges of ideology, unification, and extremism, it also has greater opportunities than ever to collaborate with aid agencies and foreign investors to address these major problems and begin to eradicate poverty in such a resource-rich country (Samia and Sahar, 2015). It is thus crucial to realize that the economic prospects depend on the political and security climates in the country.

Garikai (2015) describes Libya as a failed state and considers its economy to be in shambles. As control slips through the government's fingers and into the hands of militia fighters, oil production has all but stopped. The militias, variously local, tribal, regional, Islamist, or criminal, which have plagued Libya since NATO's intervention, have recently assembled into two warring factions. At the time of writing (March 2016), Libya has two governments, both with their own Prime Minister, parliament, and army. On one side, in the West of the country, Islamist-allied militias took control over the capital Tripoli and other cities, setting up their own government and chasing away a parliament that was elected over the summer of 2013. On the other side, in the East of the Country, the "legitimate" government, dominated by anti-Islamist politicians and exiled 1,200 kilometres away in Tobruk, no longer governs anything.

The fall of Gaddafi's administration has created all of the country's worst-case scenarios: Western embassies have all left, the South of the country has become a haven for terrorists, and the Northern coast a centre of migrant trafficking. Egypt, Algeria, and Tunisia have all closed their borders with Libya. This all occurs amidst a backdrop of widespread rape,

assassinations, and torture that complete the picture of a state that is botched to the bone. It comes as no shock then that most of the Libyan people see NATO's 2011 intervention in Libya as an opportunity to loot its material rather than to protect its citizens (Garikai, 2015).

3 Deforestation: Review of Concepts and literature [1]

This chapter reviews the concept and literature of deforestation including the direct and indirect cause of deforestation. Also reviews the pros and cons of deforestation particularly in arid areas.

3.1 Concepts

3.1.1 Arid and semi-arid areas definition

Drylands zones cover more than 60% of the earth surface (Sunil *et al.,* 2013) and 61% of the African continent (Edmund, 2014). Drylands are classified climatically as hyper-arid, semi-arid and dry sub-humid (Jon, 2015) and have the most severe edapho-climate conditions (Sunil *et al.,* 2013). FAO defined arid and semi-arid areas as areas falling within the rainfall zones of 0-300 mm and 300-600 mm, respectively (FAO, 1987). Arid zones account for 19% of the land area of the world with Africa having about 46%, and Asia 36% (Fowler, 1986). These areas have rainfall patterns that are unpredictable and are subject to great fluctuations making them unsuitable for cultivation (Flagg *et al.,* 2014).

3.1.2 Forest

A recent study of the various definitions of forests (Lund 2008) found that more than 800 different definitions for forests and wooded areas were in use worldwide. However, three major categories of forest definitions are commonly used: administrative or legal, land use and land cover.

Watson et al. (2000) observed that the administrative definition of the term forest may be based primarily upon the legal requirements of the land and does not consider the presence or absence of vegetation on the land. In this case, any land that is designated as a forest may be defined as a forest even in the absence of vegetative cover.

Another set of definitions defines forests in terms of land use. This definition is based upon the primary use to which the land is put. This may include an area managed for the production of timber or other forest products or maintained as woody vegetation for such indirect benefits as protection of catchment areas or recreation. Under such a Land Use definition, cleared roads

[1] This literature review is based on search of web science (Science Direct and forests), google scholar and libraries, which includes all information that i need in this study.

or infrastructure within an area used for forestry, or areas within the region that have been cleared by harvesting, disease or fire may still be considered as forests even if they contain no trees (Watson et al., 2000).

The third category defines a forest in terms of vegetative land cover. Such definitions typically define a forest as an area growing trees above some threshold. These thresholds are typically the number of trees per area (density), the area of ground under the tree canopy (canopy cover) or the section of land that is occupied by the cross-section of tree trunks (basal area) Watson et al. (2000).

FAO's definition states that forest is a 'vegetal formation or ecosystem with a minimum of only 10 per cent crown cover trees'. According to the Clean Development Mechanism (CDM) of the Kyoto Protocol, a 'forest' is an area of more than 0.5–1.0 ha with a minimum tree crown cover of 10–30%, with 'tree' defined as a plant with the capability of growing to be more than 2–5 m tall. To date, most countries define forests as having a minimum crown cover of 30% (DeFries et al., 2007; Sasaki and Puta, 2009).

Under land use definitions, there is considerable variation on where the cut-off points are between a forest, woodland, and savanna. Under some definitions, forests require very high levels of tree canopy cover, from 60% to 100% (Mathys, Lukas), excluding savannas and woodlands in which trees have a lower canopy cover. Other definitions consider savannas to be a type of forest, and include all areas with tree canopies over 10%. (MacDicken, 2013).

3.1.3 Deforestation

To summarise, most definitions characterize deforestation as the long term (>10 years) or permanent conversion of land from forest use to other non-forest uses. Under the current United Nations Framework Convention on Climate Change (UNFCCC) definition, deforestation is the direct, human induced conversion of forested land to non-forested land (Olander *et al.,* 2008).

The United Nations Research Institute for Social Development (UNRISD) uses a broad definition of deforestation, which includes not only conversion to non-forest, but also degradation that reduces forest quality -i.e. the density and structure of the trees, the ecological services supplied, the biomass of plants and animals, the species diversity and the genetic diversity, However, FAO uses a narrow definition: the permanent conversion of forest to another land use or the long-term reduction of tree canopy cover below the 10% threshold (Giri, 2007; Romijn *et al.*, 2013). All definitions can also be grouped into those which refer to changes in land cover and those which refer to changes in land use. Land cover measurements

often use a percentage of cover to determine deforestation. Land use definitions measure deforestation by a change in land use.

3.1.4 Forest degradation

Perceptions of forest degradation are many and varied, depending on the driver of degradation and the goods or services of most interest. In a recent survey, Lund (2009) found more than 50 definitions of forest degradation, formulated for various purposes. FAO (2009) shows that many such definitions are either very general or their focus is on the reduction of productivity, biomass or biological diversity.

However, the generic definition of the Second Expert Meeting on Harmonizing Forest-related Definitions for Use by Various Stakeholders (FAO, 2002b), provides a common framework for all the international definitions and is also compatible with the ecosystem-services approach, defines forest degradation as the reduction of the capacity of a forest to provide goods and services.

Forest degradation has been characterized by a significant reduction in either tree density or in the proportion of forest cover from closed forests to open or fragmented forests (Karjalainen *et al.,* 2003; Achard *et al.,* 2004; DeFries *et al.,* 2007).

According to FAO (2011,b) forest degradation is the changes within the forest class which affect the forest stand, quality or site negatively. Reduction of the tree canopy above the original threshold of 10% is classified as forest degradation (FAO, 2010). In a more general sense, forest degradation is the long-term reduction of the overall potential supply of derivatives from the forest, which includes wood, biodiversity and any other product or service (Giri, 2007).

CBD (2001, 2005) defined degraded forest as a secondary forest that has lost, through human activities, the structure, function, species composition or productivity normally associated with a natural forest type, expected on that site. Hence, a degraded forest delivers a reduced supply of goods and services from the given site and maintains only limited biological diversity.

IPCC (2003a) defined forest degradation as a direct human-induced long-term loss (persisting for X years or more) of at least Y% of forest carbon stocks (and forest values) since time T and not qualifying as deforestation or an elected activity under Article 3.4 of the Kyoto Protocol.

IUFRO (Nieuwenhuis, 2000) defined forest degradation as damage to the chemical, biological and/or physical structure of a soil (soil degradation) and to the forest itself (forest degradation), due to incorrect use or management, and which, if not ameliorated, will reduce or destroy the production potential of a forest ecosystem (in perpetuity). Explanatory note: external factors, e.g. air pollution, can also contribute.

In the light of the above definitions, it is pertinent to observe that forest degradation has been described using variables such as changes in canopy and understory tree density, plant or animal species richness, and/ or carbon stocks as measured against a baseline from apparently undisturbed conditions (Lambin 1999, Devi and Behera 2003, Harrison 2011).

Furthermore, societal choices largely determine what is considered to be degraded. For example, a manager who replaces a primary forest with a tree plantation to supply a sustained yield of wood is unlikely to perceive that forest as degraded. The same plantation, however, is less capable of providing other goods and services supplied in primary forests because of reduced biodiversity (e.g., Brockerhoff et al. 2008, Thompson et al. 2009).

3.1.5 Afforestation and Reforestation

Afforestation is the conversion from other land uses into forest, or the increase of the canopy cover to above the 10% threshold (Giri, 2007).

Terms such as "human made forest" or "artificial forest" were considered synonyms for forest plantations as defined by The Forest Resources Assessment (FRA, 2000) which are defined as those forest stands established by planting or/and seeding in the process of afforestation or reforestation. They are either of introduced or indigenous species which meet a minimum area requirement of 0.5 ha; tree crown cover of at least 10% of the land cover and average height of adult trees above 5 m (FAO, 2000; Fenning, 2014).

However, reforestation is the re-establishment of forest formations after a temporary condition of less than 10% canopy cover due to human-induced or natural perturbations (FAO, 2000), i.e. Artificial establishment of forest on lands which was occupied by forest earlier.

3.2 Current Rates of Deforestation

Forests provide many important goods, such as timber and paper. They also supply essential services for example; they filter water, control water runoff, protect soil, regulate climate, cycle and store nutrients, and provide habitat for countless animal species and space for recreation (Emily, 2012). The world's total forest area in 2010 was estimated to be over 4 billion ha, about 93% of the total forest cover is natural forest and 7% is planted forest, covering 31% of the world's land surface. This corresponds to an average of 0.6 ha of forest per capita (FAO 2010). However, the area of forest is unevenly distributed with just under half the world's forests in the tropics (45% of total forest area), about one third in boreal zones (31%) and smaller amounts in temperate (16%) and subtropical (8%) domains (Arvydas and Yanshu, 2014).

Brown and Pearce (1994) stated that many deforestation estimates are based on ground surveys for determining forest area, which in recent years utilize remote sensing techniques. Remote sensing combined with ground measurements plays a key role in determining loss of forest cover (Montes *et al.*, 2000; Drake *et al.*, 2002; DeFries *et al*., 2007).

According to estimations from the FAO, deforestation was at its highest rate in the 1990s, when each year the world lost on average 16 million ha of forest. At the same time, forest area expanded in some places, either through planting or natural processes, bringing the global net loss of forest to 8.3 million ha per year. In the first decade of this century, the rate of deforestation was slightly lower, 13 million ha were destroyed annually. As forest expansion remained stable, the global net forest loss between 2000 and 2010 was 5.2 million ha per year, nearly four times the size of Italy (Emily, 2012).

While deforestation has slowed down in the industrialized countries in recent times, it has accelerated in the developing economies (Boahene, 1998) and most of the losses of forest happen in countries in the tropical region (FAO, 2010). The world lost 3% of its total forested area between 1990 and 2005 (Deng *et al.*, 2011).

Forest in Africa lost 34 million ha from 2000 to 2010 with a rate exceeding 1% per year (Emily, 2012). In the period between 2005 and 2010 Comoros and Togo suffered the highest rate of deforestation in Africa at 9.71% and 5.75% per year, respectively (Indufor, 2013).

The current forest cover in Africa is about 23%, although African countries reported that 75 million ha of forest land (10% of the total forest area) was converted to other uses between 1990 and 2010 (FAO, 2012).

In comparing the trend in the Libyan city of Tripoli between 1986 and 1993, it can be obseved that the forests of this city have been subjected to severe deforestation in Al-Hadba Alkhadra (almost complete loss) and Ein Zara (40% lost) as a result of building construction and other urban expansion. In the El-Witia area in south-western Jefara Plain, vegetation cover was reduced by 52% between 1986 and 1996 (Ben-Mahmoud et al., 2000). Moderate destruction at Elhashan Elgharby (33% remaining) and Tlil (25%) was observed, while the 30% remaining forests did not experience reductions from 1986–1993 (El-Tantawi, 2005).

3.3 Forest plantations

In term of global forest plantation distribution, Asia accounts for 62% of the total forest plantations , Europe, 17%, North and Central America, 9%; South America, 6%; Africa, 4%; and Oceania, less than 2% (FAO, 2000).

The annual rates of forest plantation establishment in tropical and subtropical countries are reported to be slightly more than 4 million ha per annum (Christopher, 2000). The ownership of forest plantation is 27% public, private 24%, other 20% and not specified 29% (FAO, 2000).

Forest plantations covered 187 million ha in 2000 (FAO, 2012), which represents 5% of global forest cover. 48% of forest plantations are industrial, 26% non-industrial and 26% unspecified. The forest plantation area represents a significant increase from the 1980 estimate of 17.8 million ha to 43.6 million ha in 1990, with an annual planting rate 3 million ha per and increased to an estimated 124 million ha as of 1995 (FAO, 2012).

In China, which is the country with the highest planted forest area and has the greatest annual increase in planted forest area in the world, plantations cover 61.7 million ha, representing 31.6% china’s forest area or 23.4% of the world’s planted forest area (Fenning, 2014). This plantation is classified into 40% productive and 60% protective forest, according to their function (Fenning, 2014).

The FAO (2000) reported that in Africa, the majority of forest plantations have been established in South Africa (1.4 million ha) and in the Mediterranean countries of North Africa. In North Africa the countries with the largest area of forest plantations are: Algeria (0.6 million ha); Morocco (0.6 million ha); Tunisia (0.3 million ha); and Libya (0.2 million ha). Collectively these North Africa countries account for 55% of all forest plantations in Africa. Forest plantations are, nonetheless, widely distributed amongst other countries in Africa, with another 16 countries having more than 0.1 million ha of plantations. The country with the largest

industrial forest plantations in Africa (productive plantation) is the Republic of South Africa, which accounts for 79% of all industrial forest plantations in Africa (FAO, 2000)

The plantations of North Africa tend to utilise xeric, slow growing species, well suited to arid and semi-arid conditions. A considerable amount of planting has been carried out in dune stabilisation projects in an attempt to halt desertification (Christopher, 2000).

Africa has the highest proportion (36%) of non-industrial plantations to total plantations of all the geographical regions and probably the highest proportion of forest plantations used for wood fuel production. In particular, Sudan, Ethiopia and Rwanda, are countries with relatively large areas of forest plantations used for wood fuel, which are mostly planted with Eucalyptus or Acacia species (Christopher,2000). Other common forest plantation species used in North African countries include: *Pinus halepensis; Pinus brutia; Eucalyptus camaldulensis; Eucalyptus globulus; Eucalyptus gomphocephala;* and many species of Acacia.

3.4 Causes of Deforestation

According to the DPSIR framework of deforestation around the word, there is a chain of causal links starting with '*driving forces*' leading the way through '*pressures*' to '*states*' and ending on '*impacts*' which all transmits to the '*responses*'. Figure 3.1 shows the diagram of DPSIR framework of deforestation describing these relationship (Jianhua *et al.*, 2014; Hengaju, 2015).

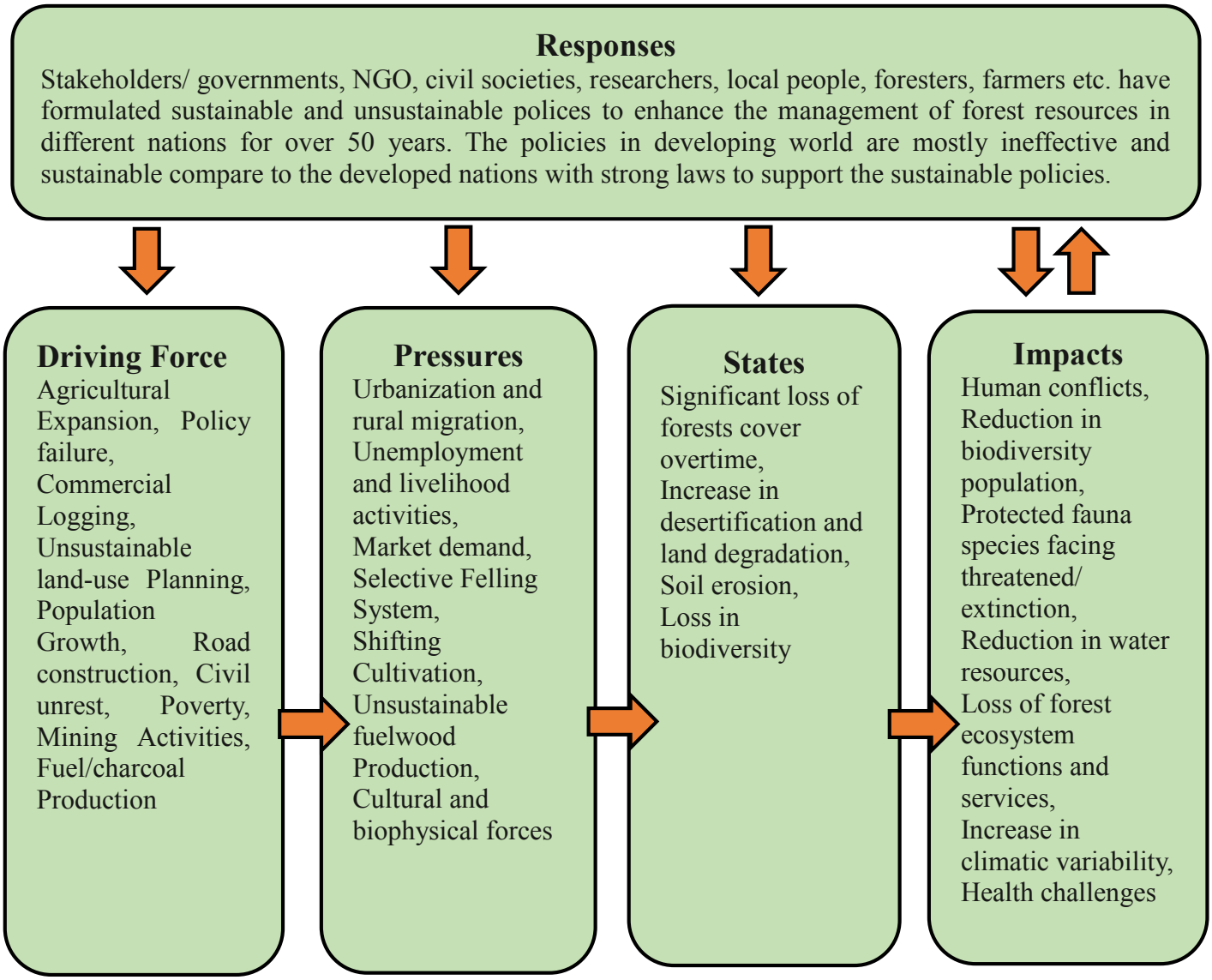

Figure 3.1: DPSIR Analytical framework on the causes of deforestation.

In scientific literature, there is a common separation of proximate/direct and underlying/ indirect causes of deforestation (Hosonuma *et al.*, 2012). Sands (2005) suggested that the direct causes are easy to identify but the indirect causes are not so easily understood. Figure 3.2 illustrates the proximate drivers of deforestation and degradation as mentioned in Geist and lambin (2002).

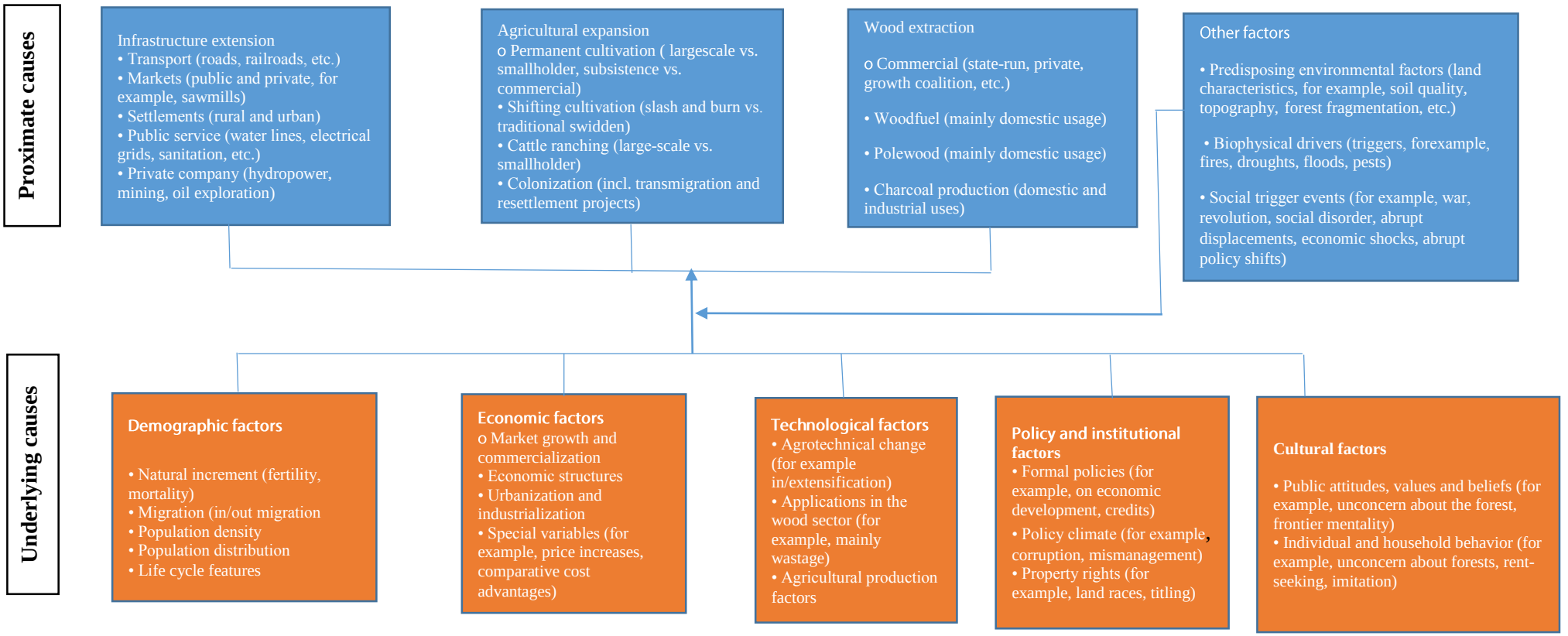

Figure 3.2: Framework for analysing proximate and underlying causes deforestation (Turner *et al.*, 1990).

3.4.1 Direct Causes of Deforestation

3.4.1.1 Shifting Agriculture and Permanent Crops

Research has identified agricultural land use as the major proximate driver of deforestation (Pirard and Belna, 2012; Sophia, 2015). Kissinger and Herold (2012) estimated agricultural activities to be the driver for around 80% of deforestation worldwide. Of this conversion for agriculture, commercial agriculture (which includes permanent crops) is the most prevalent deforestation driver, accounting for 40% of deforestation while local/subsistence agriculture contributes 33% deforestation. Other drivers include urban expansion, fire, excessive logging to mention a few (Gibbs *et al*., 2010) reported that in the 1980s and 1990s, about 60% of new agricultural land in Africa came through clearing intact forests and the land was mostly converted to small-scale subsistence farming. Brown and Schreckenberg (1998) stated that the impacts on forest cover and composition of shifting agricultural systems at varying points on the landscapes are very different. Thrupp et al. (1997) refers to shifting agriculture as being any temporally and spatially cyclical agricultural system that involves clearing of land - usually with the assistance of fire - followed by phases of cultivation and fallow periods Shifting agriculture is estimated to support the livelihoods of some 300-500 million people worldwide (Brady, 1996). The food crop production system (in most parts of Africa) is based on the practice of slash-and-burn farming, which, due to population pressure and reduced fallow cycle, is no longer sustainable (Duguma *et al.*, 2001). Ickowitz (2006) found that not only do practices differ in shifting agriculture, but the same practices will have different environmental impacts depending upon: soil type, soil quality, pH level, land use history and vegetation. Also, according to Kleinman *et al.* (1995), 'Inherent soil characteristics define the magnitude and quality of degradation that may occur as well as the potential productivity of low-input agro-ecosystems. In Libya, Al-Idrissi's *et al.* (1996) study found that by 1988, 35% of about 320,000 ha natural forest land in El Jabl–El-Akhdar region was converted to grow crops.

3.4.1.2 Logging and Fuelwood

ITTO (2003) reported that about 70% of log and fuelwood imports are from non-tropical sources, though fuelwood is the main timber product extracted from the forests of savannahs and semi-arid lands where deforestation is at its peak. Sands (2005) and Hosonuma *et al.* (2012) affirmed that more than 80% of energy consumption in developing regions of Africa is from fuelwood extraction and logging activities are causing more degradation than deforestation.

Fuelwood gathering is more concentrated in tropical dry forests and degraded forest areas (Repetto, 1989 and 1990; Rowe *et al.*, 1992). In the semi-arid and arid regions of North Africa, fuelwood gathering can be a major cause of deforestation and degradation (Chakravarty, 2012). However, Merlo and Croitoru (2005) reported that the trend of removal of wood from forests in semi-arid lands declined from 1.5Mm^3 in 1991 to less than 0.25Mm^3 in the following years. This is because import of fuelwood was not significant compared to timber wood imports at 25,000 m^3, or 31.2% of the total timber consumption. The development an impact on deforestation rate in arid region in recent times.

3.4.1.3 Fire

Brooks (1999) claimed that fire was historically rare in semi-arid and arid lands, but over the years, this has changed, primarily due to the invasion of exotic annual grasses onto dry rangelands.

Exotic grasses can form a near-continuous cover in the normally open spaces between shrubs, and can become highly flammable as standing dead cover builds up during the arid months of high air temperatures and low relative humidity (Rogers and Vint, 1987). Desert fires fuelled by these exotic grasses can be intense and cause widespread mortality of native vegetation.

In Libya, the main forest type is the natural forest occurring in Al-Jabal Al-Akdar. These forests have been exposed to significant damage mainly through the fires (Eldiabani *et al.*, 2014). The Joint Research Centre (2014) reported that in 2013 seven minor fires were mapped in Libya. However, the year before, Libya suffered 34 fires, destroying 3,400ha. Practically all the damage occurred in May and included a single very large fire of 3,308 ha in the province of Al-Jabal Al-Akdar.

Americo and Mendes (2005) reported that in 2001, over 800 forests fires occurred in Portugal of which 95% were discovered to be as result of human interference through negligence such as bush burning, cigarettes and social outings. Others were accidental ignition of machinery in the forest areas, conflicts and arson. Cochrane *et al*. (1999) determined that in the preceding few years, fire had affected approximately 50% of the standing forests in the Amazons basins. He went on to suggest that accidental fire-induced deforestation increased by 129% between 1993 and 1995 in the Amazon. If left unchecked, the current fire regime, regardless of the high or low estimate of the fire cycle, would result in an inevitable transition of the entire area of the Amazons to either scrub or grassland.

The effects from deforestation caused by fire on climate, biodiversity and the local economy are likely to be extreme. Unless changes are made in current land management practices, the entire forest remaining on the globe will be lost (*Cochrane et al.*, 1999; Sands, 2005).

3.4.1.4 Mining and Dam Construction

Although mining in Libya only on a small scale, Mather (1990) and Sands (2005) described mining to be very intensive and very destructive. The area of land involved is quite small and it is not seen as a major cause of primary deforestation. Mining is a profitable activity promoting livelihood improvements which may cause a population increase with consequences for deforestation (Chakravarty, 2012). Staff (2010) explained that the deforestation rate due to mining activities in Guyana from 2000 to 2008 increased 2.77 times according to an assessment by the World Wildlife Fund-Guianas. Sands (2005) explained that the creation of dams for water supply and electricity generation could flood forestlands. Often dam construction faced resistance from foresters and individuals or groups that had an interest in ecosystem services in the tropics and arid lands. Any development claims from mining and dam construction should be considered in conjunction with environmental consequences, particularly deforestation, especially during the hydroelectricity power generation that include clearing of forests for power transmission lines.

3.4.1.5 Urbanisation and Transportation

Urbanisation and road expansion cause significant losses to forest, both in the exploration of construction materials and as a source of land. While urbanization may reduce direct pressures on forests by the migration of rural residents to population centres, urban and suburban sprawl may be damaging when they occur in frontier settlements (Butler, 2012). The construction of roads, railways and airports and the expansion of cities and towns require land to establish infrastructure necessary to support growing populations (Sands, 2005).

Although urbanisation and road expansion are very critical for national development with the population upsurge, they have a very significant effect on the rate of deforestation in the Amazon and arid areas as they give more access to forests for clearing, construction and exploitation (Portnov and Safriel, 2004).

Utting (1993) considered that the major factor that led to the loss of forest resources in El Salvador was that the country had more road and bridge construction than other regions such as Brazil.

Nedjahi and Zamoum (2005) in valuing the forest resources of Algeria, which is mostly arid vegetation, stated that deforestation has, as a result of urbanisation, during the last 50 years reduced the forest area by 37%, if only natural forests are considered, and by less than 10% if both natural and plantation forests are included.

3.4.2 Indirect Cause of Deforestation

3.4.2.1 Population growth

Sands (2005) described population's role in deforestation as a very contentious issue. This is because other factors that lead to deforestation are not necessarily directly linked to population increase in recent years (Colchester and Lohmann, 1993; Kaimowitz and Angelsen 1998; Cacho *et al.*, 2014). However, the impact of population growth on deforestation as a result of road construction and rapid urbanisation is increasing across developing nations in the last four decades (Palo *et al.,* 2000). In Sub-Saharan Africa, shifting cultivation, subsistence farming excessive exploitation of fuelwood and poor government policies relating to population increase and subsistence needs have contributed seriously to deforestation (Kaimowitz and Angelsen, 1998; Angelsen and Kaimowitz, 2001; Wehkamp *et al.*, 2015). Recent researches have encouraged the need to focus on country-specific analyses of the costs and relative mitigation potential of addressing institutional and policy drivers of deforestation after it was realised that the deforestation drivers include poor policy implementation and corruption (Karsenty and Ongolo, 2012; Wehkamp *et al.*, 2015).

3.4.2.2 Inequitable land distribution

Omran (2000) stated that 53% of the total forest area in Egypt is publicly owned and serves several purposes while the remaining 47% is privately owned and serves more as windbreaks. The legal land owner in Egypt is the tree owner in the ownership and tenure of forest plantation. Downing *et al.* (1992); Croitoru and Merlo (2005) reported that farmers at the forest areas do not have legal ownership over the land in North African countries and are often displaced by privileged minorities who have political influence thereby pushing the subsistence farmers to clear new forests for cultivation since they have very poor or no access to loans. This was further confirmed by Sands (2005) that in most regions of Central America in the 1970's land holding size per ha was decreasing among rural families and led to further clearing of the tropical forests for more agricultural land in the regions.

3.4.2.3 Development Policies

Forestry policy is a subsidiary of the agricultural policy in most countries of North Africa and the law and institutions to enforce its implementation are usually very weak (Croitoru and Merlo, 2005). Daly-Hassen and Ben Mansoura (2005) explained the role of forest policy in Tunisia to include protective ways of banning clearing and cultivation, reforestation programmes and ensuring the management and use of all forest products must abide by all forest laws and regulations either private or public. However, policy change as a result of political influence and corruption has made the laws and forest codes in most African countries very ineffective (Sands, 2005).

Globalisation has affected the forestry sector and there is a call for more awareness on impacts on deforestation on livelihoods (UNFF, 2001) to demonstrate the need for international collaboration and the need for effective policy making as it relates benefits and costs in forestry sector of African continent (Cacho *et al*., 2014; Wehkamp *et al.*, 2015). Arvydas and Yanshu (2014) reported that globally in 2011, the forestry sector employed about 0.4% of the labour force, contributed about 1.0 percent to GDP and accounted for about 2.4% of global economy. However, the contribution of the forestry sector to the total economy has steadily declined in recent years, due to faster growth in other sectors.

3.4.2.4 Corruption

Several researchers have discussed corruption and mismanagement as the problems of most African countries in the last four decades (Kaimowitz and Angelsen, 1998; Croitoru and Merlo, 2005; Cacho *et al.*, 2014). Frequently, donor funds meant for development of forestry sectors are not judiciously utilised. Forest plantations are illegally cleared and given to influential government officials without due process. In addition, unlawful logging is not controlled (Angelsen and Kaimowitz, 2001; Sands, 2005; Cacho *et al.*, 2014). Ellatifi (2005) estimated that about 40,000 hunters are found in Moroccan forests. This large number is as a result of corruption and mismanagement among the forest authorities. Corruption has been reported to permeate every sector of Libya's society and institutions, including natural resources management before and after the Gadaffi regime which, contributed immensely to the deforestation process in the recent times (Mzioudet, 2014).

3.4.2.5 Forest governance and post conflict

The declines of forest area and degradation of forested land across the globe led to significant changes in governance and management of forest resources around the world (Mersudin, 2012). At first, the world was more focused on forest lands sustainable management as a solution to deforestation and degradation. However, in recent times, debates have recognized the socio-economic value of forests expanded to include ecological, cultural, recreational, and spiritual aspects to benefit humanity (Mohanty and Sahu, 2012).

Political mobilization of interest groups and individuals in combination with climate change drivers that led to forest loss and extreme poverty coupled with civil unrest, especially in the developing world, have resulted in the malfunction in forest management around the world (RCDC 2004; World Bank, 2009).

In the last 20 years, new forms of forest governance for multifunctional sustainable forest management evolved around the world (Mersudin, 2012; World Bank, 2009). However, Pascal (2009) discussed the challenges that results in poor quality of forest governance in Africa from the power tussle between forest communities and forest administrators to gaps and contradictions within the legislation, and weak forest administration with inadequate manpower, and outdated ideas on forest governance. Others are corruption of the forest administrative staff and sometimes, the NGOs.

Beevers (2015) and Autesserre (2010) discussed that forest governance solutions had a significant impact on shaping and influencing the direction of forest governance in post-conflict Liberia and Congo. The peacemakers through political and administrative reforms promoted better policies and practices that included all the stakeholders (companies, communities, governments NGOs) in the recovery and reconstruction processes (Beevers, 2015).

3.5 Pros of deforestation

Although deforestation is often thought of negatively, there are some advantages of the practice; otherwise, it would not be happening. Here are some of the advantages of deforestation;

3.5.1 Provides Products and Services to the People

Deforestation provides local communities with products and services (Sinare and Gordon, 2015). For instance, consider the ecosystem that is destroyed in the process. Useful resources like wood-fuel, seeds, and bush-meat can be sold, and used when obtained from the forest (Sinare and Gordon, 2015). For individuals struggling to stay alive in developing countries, deforestation is rather a necessity for continued survival as resources acquired are sometimes used in farming and other local technologies (Adesina and Chianu, 2002). In addition, deforestation also provided services to the communities including improved transportation systems and expansion of housing units for the growing population to stimulate small scale businesses and grow the economy (Sinare and Gordon, 2015).

3.5.2 Provides Locals With Jobs In Struggling Economies

There are many factors that caused deforestation around the world (Ryan et al., 2014). However, the drivers of deforestation include the people, who create jobs. For struggling economies, to feed and take care of a family is a difficult task for the locals, destroying the ecosystem seems to be less relevant to day-to-day survival. As a result, the short-term gains outweigh the long-term goals of sustaining the forests, even if it is ultimately more beneficial for the community not take part in deforestation. The individuals affected have no option than to rely on the deforestation as a means of survival thereby creating employment (Ryan et al 2014; Pfaff et al., 2013).

3.5.3 Provides Export to Struggling Governments.

Deforestation also provides resources to a struggling economy in developing countries as the products of deforestation are exported to other countries to earn foreign exchange (Runyan et al., 2015). Although, in timber exporting countries where selective logging is carried out, it causes more forest degradation than deforestation (Mya et al., 2012). The export of timber and non-timber products significantly provides useful services to the people, improves the economy and political stability and sometimes results in good policies on forest management and sustainability making excessive deforestation unnecessary (Eckert et al., 2011).

3.6 The Consequences of Deforestation in Semi-arid lands

There are many Cons of deforestation. Here the focus is mainly on disadvantages in arid and semi-arid lands:

3.6.1 Socio-economic issues

Nagothu (2001) explained that fuelwood was still the major source of household energy in the arid lands of India, and close to 55%, the national average for India. This is similar to earlier reports from other semi-arid hilly areas in India where fuelwood is the dominant fuel. Unsurprisingly there is an inverse relationship between fuelwood extraction and distance from the forest sites (Qureshi and Kumar, 1996). Barnes (1990) reported that the consequences of deforestation can be ascertained using two main variables; the size of human population and the area of the remaining forests felled per annum. The collection frequency depends to some extent the size of the population, the income of the people and proximity to the source of wood. It would take a longer time to collect with greater distances, and hence people reallocate the collection time to biomass production on their own farms. This is mostly the case of households with larger land holdings where biomass production is possible.

3.6.2 Grazing and fodder extraction patterns

Grazing patterns of animals and the relationship between the predator and prey in the forest, has a significant role in the deforestation rate. This is because the pattern in the system, if grazing herbivores are not moved on and kept to a sustainable number by predators, they can damage current forests and eradicate natural regeneration (Struhsaker, 1997; Agyei, 1998). Nagothu (2001) agreed that the reasons attributed for higher density of herbivores were the constraints such as limited irrigation sources, shifting agriculture, traditional modes of livelihoods based on livestock, demand for milk and meat in the nearby market and availability of grazing land. Ellatifi (2005) discussed maintenance of more buffaloes by large farmers in arid areas in their herds when compared to the small and marginal farmers and landless kept small ruminants, helped in sustaining the grasslands and the environment.

3.6.3 Environmental issues

The environmental hazards of deforestation in an arid area are mainly desertification and climate change. Though distinct, these two phenomena generate positive feedback loops, and

these feedback loops can interact and reinforce each other. Consequently have similar implications and solutions (Williams, 2003).

3.6.3.1 Desertification

Sutton and Zaimeche (1996) defined desertification as the impoverishment of terrestrial ecosystems under the impact of man. A UNEP (1992) report considered desertification as a consequence of deforestation as a result of land degradation over time in arid, semi-arid, and dry humid areas which was ascribed to various factors such as human activities and climate change. Benabid (1996) reported that in North African countries including Libya, the ultimate stage of deforestation and forest degradation is desertification. Deforestation and desertification involve a drastic change in microclimates. Examples can be linked to felling of shrubs and trees, exposing the shaded soil to direct sunlight and heat thereby becoming warmer and drier, and organisms living on or in the soil will change environment by migration or dying as a result leading to desertification and deforestation. The above ground biomass - dead leaves, twigs and branches, will be quickly oxidized, the carbon dioxide being carried away (Pachauri and Kanetkar, 1993). Croitoru and Merlo (2005) reported that over 300,000 ha of forest land was lost to desertification in Algeria and the value of the affected area in its role of watershed management was up to €10 per ha. The desertification trend in North Africa has a great economic effect on the ecosystem services of the region as it adversely affects agricultural productivity, the health of humans as well as of livestock, and economic activities such as eco-tourism (Bellot *et al.*, 2001).

3.6.3.2 Climate Change

Climate change decreases water availability and water quality, increases droughts, floods and salinity leading to a decrease in soil fertility and loss of vegetation threatening food security (Saad *et al*., 2011). The consequences of climate change are very difficult to quantify based on the environmental and financial impacts (Tobin *et al.,* 2014). The tremendous changes in biodiversity directly involves increase in the cost of management for sustainability (Kiritani, 2007). In other studies, Hamilton *et al.* (2005) and Merlo and Coitoru (2005) explained the consequences of climate change to be more complex across the trophic levels on its role in carbon sequestration leading to more loss of biodiversity and decrease in availability of nutritional quality of forest products. On the other hand, Grace *et al.* (2014) confirmed that fire management is a major concern as climate change can often lead to local decreases of

precipitation which in turn increases the chances of wild fire due to the warm climate and an extension of the fire season in semi-arid and Mediterranean regions.

Studies have found that high intensity loss of forests leading to desertification were primarily caused by small-scale agriculture and urbanisation (Geist and Lambin, 2002; Ryan *et al.*, 2014) and that low intensity losses were caused by a wide range of activities, including illegal logging and poor management. Efforts to reduce deforestation and forest degradation in this area will require a broader approach that considers multiple land use management such as agricultural development alongside forest management such as landscape approaches to REDD+ (DeFries and Rosenzweig, 2010; Murray *et al.*, 2015).

Climate change and deforestation remain inextricably linked through feedbacks between forest degradation and variabilities of edaphic factors. Climate change might exacerbate deforestation and desertification through alteration of trends and patterns in temperature, precipitation, solar insolation, and winds in arid regions. Conversely, deforestation induces climate change through the release of CO^2 from cleared and dead vegetation and reduction of the carbon sequestration potential of arid lands (McCarthy, 2001; Druyan, 2005).

In the following chapter, deforestation causes and consequences specifically in Algarabulli district are described. It attempts to give the local people's (non-forest clearers) perception about the causes and the effect of deforestation.

4 Deforestation: Causes and Consequences in Algarabulli District

4.1 Introduction

Forests occupy more than a quarter of the world's land area and are of three broad types: Tropical moist and dry, temperate, and degraded. Forests are also one of the most significant components of the Earth's biosphere (Lambin *et al*., 2006). They play a critical role in regulating the Earth's surface temperature and precipitation, preserving soil nutrients, protecting soil from erosion, minimizing flooding and fixing carbon. In addition to serving as a valuable habitat for wildlife. In spite of these functions, however, forest resources around the world are being depleted for many reasons. Forest depletion or deforestation is a process of removal of a forest (Megan, 2012).

According to Johnson and Chenje (2008), deforestation occurs when a once-forested area is removed for agriculture, pastures, urban development, logging, or wasteland. Forest clearance has been driven mainly by the expansion of agriculture to meet the needs of a growing global population (Sands, 2005). Logging for timber, mining and other industrial activities has also caused substantial deforestation. Underlying drivers of deforestation include poor governance and lack of secure tenure (Ghazoul, 2013). This conversion from forest to non-forest covers has contributed to environmental degradation, increased flooding, exacerbated soil erosion and reduced biodiversity as well as socio-economic problems throughout the world (Megan, 2012).

In addition, conversion of forests in arid and semi-arid lands for agricultural crops and pasture land are the main cause of the increasing desertification (Malagnoux *et al.*, 2007); Sutton and Zaimeche, 1996). Also deforestation has been especially serious in the last several decades in developing countries (Pahari and Murai, 1999).

In Libya, the study of Omar Al Mukhtar University on natural forest in Al-Jabal Al-Akdar region in 2005 indicated that the main cause of forest degradation and deforestation in eastern Libya is human activity, including fires, indiscriminate cutting, overgrazing, administrative problems and the absence of a forest management plan. As a consequence, some of the natural forest was destroyed (Omar Al Mukhtar University, 2005).

The deforestation is affecting people in many ways; for example, it accelerates soil erosion, followed by degradation, which is reducing food productivity. Various reports mentioned that

deforestation led to changes in the local climate in Jefara Plain, such as an increase in temperatures and sharp reduction in precipitation (Ben-Mahmoud *et al*., 2000).

Studies conducted practically on deforestation of planted forest in Libya have been very scanty and researchers in that part of the world have prioritised the need to take some action in near future on deforestation drivers such as land resources degradation (forest), overgrazing, misuse of water resource, poor land management practices due to lack of adequate knowledge and information (Ben-Mahmoud, 1995).

The research question for this chapter was; what are the local people's perceptions of the causes and consequences of desertification in Algarabulli district? To address this issue, this chapter analyses the causes and consequences of deforestation in Algarabulli district and identifies local people's opinions and attitudes about how and why the forest is being cleared, as well as the consequences using a semi structured interview survey with local people who had not cleared forest.

4. 2 Methods

Many techniques and methods for data collection can be used during field research, such as a survey. A survey is used to collect systematic data on people's actions, thoughts and behaviour by asking direct questions in natural settings (Angelsen, 2011). Field research is often necessary to fill an information void related to the problems to be investigated (appendix 1).

Interview

Interviews are one of the most commonly employed methods of data collection in qualitative research (Bloom and Crabtree, 2006). This is because talking with people is an excellent way of gathering information (Clifford, 2010). In addition, this method is used when there is very little or no existing information concerning to be investigated in a given place of topic (Angelsen, 2011). Therefore, this chapter uses interviews as the chosen form of qualitative research.

Types of research interview

The first issue to consider is the type of research interview to use to obtain useful information about this issue. There are many different types of interviews such as structured, unstructured and semi-structured interviews.

Semi-structured interviews were chosen as the means of data collection. Many researchers prefer this method because questions can be prepared ahead of time to allow the interviewer to be prepared and to appear competent during the interview (Barriball, 1994). Also, this method allows a degree of freedom to explain their thoughts, to highlight issues of particular interest and expertise regarding complex and sometimes sensitive issues and to provide reliable, comparable qualitative data (Barriball, 1994).

The semi-structured interview is a verbal interchange or a method of data collection where the interviewer attempts to elicit information from the respondents by asking questions (Clifford, 2010). They are useful for when the researcher knows something about a topic but want to give respondents an opportunity to raise new issues and when the researchers are working with a complex issue because the interviewer can use probes and spontaneous questions to explore, deepen understanding and clarify answers to questions (Wilson, 2014).

Interview methods and techniques

The semi-structured interviews were one-on-one, which the most common form of semi-structured or unstructured interview; involving a meeting between one researcher and one informant (Denscombe, 2003). These types of interviews are popular because they are easy to arrange. In this type of method, validity and reliability depend on conveying equivalence of meaning. This equivalence of meaning helps to standardize the semi-structured interview and facilitate comparability. Also, this method has the potential to overcome the poor response rates of a questionnaire survey due to using the personal interview (Barriball, 1994). Semi-structured interviews were used to obtain, detailed responses during the three month period from December, 2012 to February, 2013. The responses obtained were used to design a questionnaire survey for forest clearers in the second stage of field work survey. In addition, semi-structured interviews were conducted with some local officials. Audio recorders, note-taking and video cameras are the most common methods of recording interview data (Rubin and Rubin, 2012). All interviews in this research were audio-recorded and transcribed verbatim for descriptive analysis.

Samples were divided or stratified into five groups based on their locations, as the study site has five villages. A sample from each group (i.e. village) was then selected based on their willingness to participate in the interview. Heads of household were interviewed for this survey. During the interview, several questions were explained in order to gain an accurate

answer with the interview time of the consultation with the head of household set and based on their available free time.

In addition, semi-structured interviews were conducted with some local officials. These included the Minister of Agriculture in 2013, the Deputy Minister of Agriculture in 2013, the mayor of Algarabulli District, the Director of Forestry Department in Algarabulli District, the Director of Agriculture sector in Algarabulli District, the Director of Land Registry in Algarabulli District, The Director of Transport sector, the Police Chief of Agriculture in Algarabulli District, ex-government officials in the Forestry Department (1965–1986) to obtain their opinion about the problem of deforestation in this area.

One positive aspect of the interview is that the researcher could communicate in the local language as he is one of them; those questioned felt more comfortable answering the questions of trying to find solutions after identifying the real causes.

Types of Questions

Interviews can reveal information or surprising answers that the researcher does not know. Open-ended questions were used in the semi-structured interview to avoid-loaded questions, double-barrelled questions, leading questions, and (usually) presuming questions (Leech, 2002).

Sample size

The researcher's design includes the information required to answer the research question and how these information should be collected. Sampling determines from whom information needs to be obtained. Simple random sampling was chosen in this study. A group of 50 respondent households were selected at random from all villages, as shown in table 4.1.

Table 4.1: Distribution of local residents sample within the localities of Algarabulli district

Locality	Household No*	Selected sample
AL-Karawa	2796	17
Al- Ataya	1882	11
Al- Gaweaa	1135	8
Al- Rawajih	1031	7
Al- Kawaleg	720	7
Total	7564	50

*According to population census of 2010.

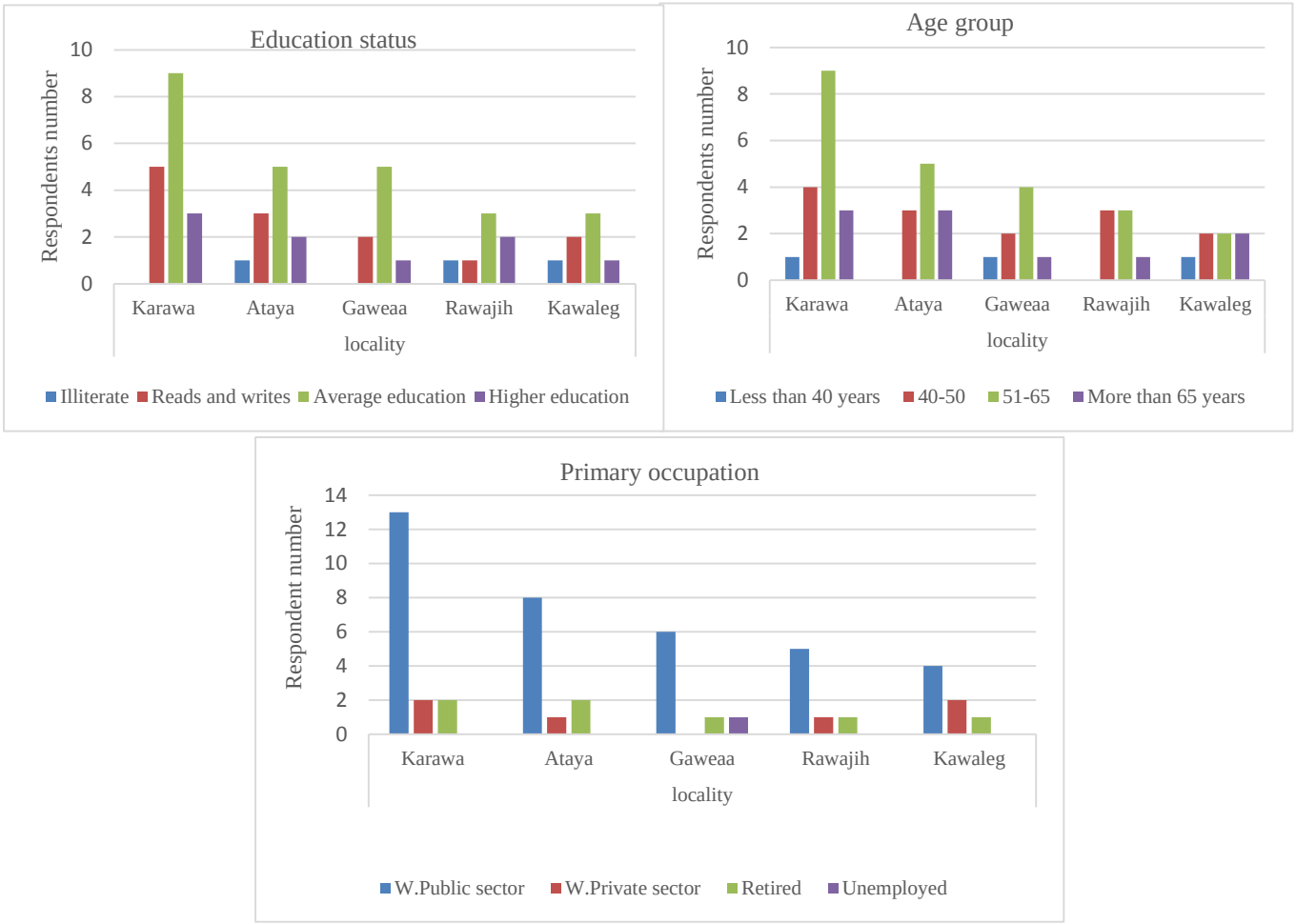

Figure 4.1 Respondents' characteristics (N=50)

Sample (gender issues).

This aspect needs to be considered in light of research contributors and the individuals interviewed during this investigation as it can be considered to reflect on the results obtained. The results and relevant contributory information were exclusively obtained from the male sector of the Libyan population. No females were interviewed as none were encountered working in this sector (forestry) and at the locations visited during the fieldwork undertaken for this research. The reasons for lack of contributions from the female sector of the population is now explained together with the problems women face. As a consequence it was not possible to disaggregate data by gender.

Issues carrying out research involving women in Libya:

Women wishing to carry out research in Libya would find the following barriers inhibiting them from working in this area:

1) Currently in Libya, there is a civil war between two different factions. Consequently, it would be very dangerous for a female student to work alone in remote war torn areas where there was no possibility of organisational, statutory agencies (police) or family support.
2) A female researcher could also currently find herself in danger when interviewing or collecting field data such as photographs in this area from those illegally clearing trees and levelling sand dunes with bulldozers. Similarly, this would apply to male researchers, who were advised by local residents, workers and officials. An example is, the requirement of taking aerial photographs of the area and withdrawing immediately when any hostile reaction was perceived such as coming under gunfire or hearing aggressive shouting.
3) In addition, not all the population have an enlightened view of female researchers. They would question the accuracy, validity and integrity of any research conducted by a woman. These individuals would also probably present a hostile non-cooperative attitude and be very reticent or refuse to cooperate with a female researcher not providing her with the data requested and essential for the research.
4) Some cultures also are not comfortable with females conducting research involving strangers, particularly if they are males, on religious grounds. Some hold the extreme viewpoint that women should not undertake work including "research" and their place is in the home.

Problems of interviewing women

1) The first is based on females' previously traditional roles, nature of the education of most women and the jobs they secure. Currently, women in Libya are not considered to be aware of environmental issues and currently do not hold key positions of interest to the researcher and were not encountered during this work.
2) Culturally, it is not accepted, on religious grounds for a "strange" male to approach a female "stranger" without an intermediary or chaperone to ensure her integrity.
3) It would be acceptable for this male researcher to interview a professional female at her place of work but completely unacceptable to approach her privately e.g. at her home. However, none were encountered in a professional role in Forestry in Libya whilst conducting this research.

Difficulties for women conducting interviews

1) Women have no inherent problems in conducting interviews and are as proficient as any male. The problems arise when the context, culture and location of these particular interviews in Libya are considered, as stated above.
2) It is logistically difficult for women researchers to carry out interviews with a lone male or men as she will need one of her relative with her during the interview as chaperone.
3) Due to lack of security, especially after the uprising 2011, the danger to her personal safety is very real. Therefore, most women researchers focus on social problems, which deal with the family or women but not with environmental issues or within male dominated industries.

4.3 Results and discussion

4.3.1 Causes of deforestation in Algarabulli district

The causes of deforestation have been reported to be divided into two namely; direct or proximate causes and indirect or underlying causes (drivers). This will be explained in the following results. However, to identify what is the most serious environmental problem in Algarabulli district, respondents were asked a general (open) question to determine to what extent is it a serious concern. It was found that deforestation emerged as topmost of the major concerns of the community as significant environmental impacts are attributed to it.

The results of the multiple responses shown that 84% of the respondents said deforestation is the most serious environmental issue in Algarabulli district at present, and 50% of respondents said groundwater shortage. 44% of the respondents agreed to decrease of crop productivity, while 30% and 26% of the respondents said degradation of orchard (fruit trees) and the degradation of natural vegetation respectively.

4.3.1.1 Direct causes of deforestation in Algarabulli district:

The respondents mentioned a combination of direct causes of deforestation in their responses as shown in figure 4.2 below:

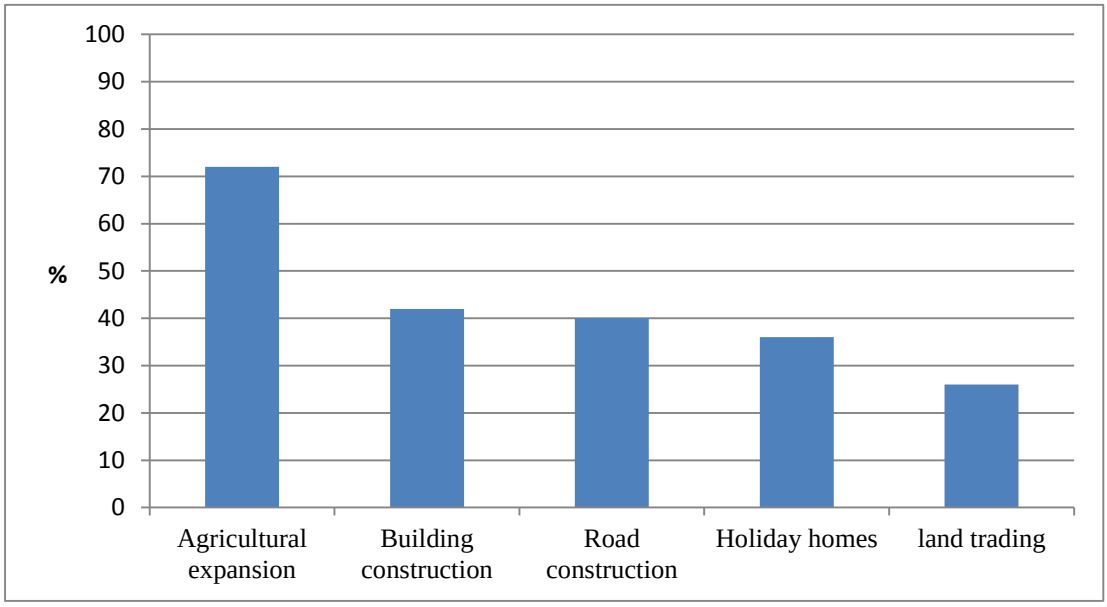

Figure 4.2: Direct causes of deforestation in Algarabulli district (N= 50)

4.3.1.1.1 Agricultural expansion

Agriculture expansion is one of the main drivers of deforestation, where 72% of the respondents indicated that population growth and the increasing demand for agricultural products led to high prices of land, which led some of them to go into commercial agriculture because of the high income. However, the Director of Forest Department in Al-Garabulli district [2] pointed out that agricultural expansion in this area is not due to population growth or increasing demand, but poor implementation of Libya forest laws by the authorities especially as it concerns cutting of trees and residents wanted to acquire more lands and were not aware of the risk of clearing the forest and risks desertification and sand dunes. This is because the soil is sandy which has, typically have very low water-holding capacities and extremely low in all essential nutrients making it very limited for agricultural productivity (Ben-Mahmoud, 1995). In addition, the Director of Agriculture sector[3] in this district also confirmed that the most of the agricultural practices in these areas which were converted from forest to farm land failed due to poor soils for growing crops.

The Al Biruni Remote Sensing Centre (BRSC) (Tripoli, 2008) confirms that clearing forest in Jefara plain is mainly led by expansion of agricultural activities, thus caused land degradation in that region.

Barraclough et al. (2000) and Pirard and Belna (2012) also reported that, in most parts of semi-arid regions of Sub-Saharan Africa, the expansion of agriculture activities into forestland is, to a great extent, the consequence of poverty, limited alternative employment and inadequate technology, combination of poor soil management and population growth, and leading to migration towards forests with richer soils.

4.3.1.1.2 Building Construction

Building construction includes indiscriminate construction of illegal and urban sprawl and this factor was indicated by 42% of the respondents. The Director of Land Registry in Algarabulli District[4] confirmed that 90% of the buildings were built without building permits which is also a serious cause of deforestation; one of the unofficial respondents said that buying a plot of land for building in forest land is cheaper compared with other not forest area which is documented in Land Registry Centre. However, Libyan building law does not permit clearing forest to construct buildings. Also one of the official respondents said that some people were

2 Interview Date 01.01.2013, in the field
3 Interview Date 02.01.2013, in the field
4 Interview Date 15.01.2013, in his office in Algarabulli District ,Libya

cutting shade trees meant for travellers during higher temperatures, in order to build shops along the road (Figure 4.3).

This conforms with the findings that reported the necessity of clearing forest to construct settlements can be traced to the growth in urban population of the Province that rose sharply mainly due to migration and the expansion of human settlement has precipitated deforestation in many parts of the world (Gao and Liu, 2012; Entwisle *et al.*, 2008).

A similar study in Tripoli found that about 40% of forest area was cleared within seven years between 1986-1993 as a result of building construction or urbanisation (El-Tantawi, 2005).

Figure 4.3: Cutting windbreaks for building shops along the main road in study area (Source: Picture taken on 05.01.2013 by the researcher).

4.3.1.1.3 Road Construction

40% of the respondents stated that roads contributed to destroying forests and responded that road construction provides easier access to forest land for conversion and settlement. Road construction also made the construction of railway lines and man-made rivers easier. The Director of Transport sector[5] in this district said that approximately 70 kilometres of roads were established in forest interiors which now contributed to providing easy access to forests, opening up of large areas to deforestation. The Director reported that there is a relationship between establishment roads and deforestation by building a home as first stage and then the second stage is the spread of agriculture into forests. Many studies agreed that building and upgrading roads increases pressure on forests (Deng *et al.*, 2011). Also El-Tantawi (2005)

[5] Interview Date 12.01.2013, in his office in Algarabulli District.

reported that due to Urban expansion out of Tripoli, the roads have contributed access to forest and cleared them for building houses. However, logging activities also contributed to deforestation, beginning with the construction of roads to gain access to forests for timber (De Koninck and International Development Research Centre, 1999).

Figure 4.4 A,B: The same road within two year period (2011-2013), in comparison shows how roads inside forest have contributed to deforestation thereby leading to sand dunes encroachments, in Alataya village, Al-Garabulli District, picture (a) taken by the researcher on 20.01.2011, picture (b) was taken by the researcher on 20.01.2013.

4.3.1.1.4 Holiday Homes and Resorts

24% of the respondents stated that the construction of holiday homes was the first and the main causes of deforestation in the district when some officers and officials in the Gaddafi regime obtained forest land illegally. The Director of Forestry Department in Algarabulli District [6] affirmed that local people were prompted to clear forest after seeing officers destroy the forests for the purpose of building holiday homes not for an urgent housing need, a phenomenon which was not seen in other areas.

Forests along the beach in this region have been cleared for resorts since year 2000. The Director of Planning sector in this district explained that Algrabuil district is known one of the best area in Jefara plain and has one of the best beaches in Libya. For this reason, most tourists come from Tripoli and other regions, this in turn at the district level led to clearing of more forests by the locals who are close the beaches to establish more resorts (Figure 4.5) exploiting the forests area for profit in light of the absence of stringent regulations and government control.

Figure 4.5: Illustrates some resorts in Alataya village, Al-Garabulli district (Source: Picture taken on 05.01.2013 by the researcher).

6 Interview Date 05.01.2013, in the field

4.3.1.1.5 Land Trading

22% of respondents stated that people cleared forest for illegal land trading. The land is sold to buyers by the locals without official documents to support such transaction. There is further discussion on this factor in chapter 7 where this factor became one of the main direct causes of deforestation after the fall of the Gaddafi regime in 2011.

4.3.1.2 Indirect causes of deforestation

Figure 4.6 shows the very many and complex factors affecting indirect causes of deforestation in Libya. All of the respondents agreed that land allocation was the foremost driver in deforestation of Libyan forest. Though other factors such as change of forest governance and corruption on the part of government officials also contributed significantly as shown below.

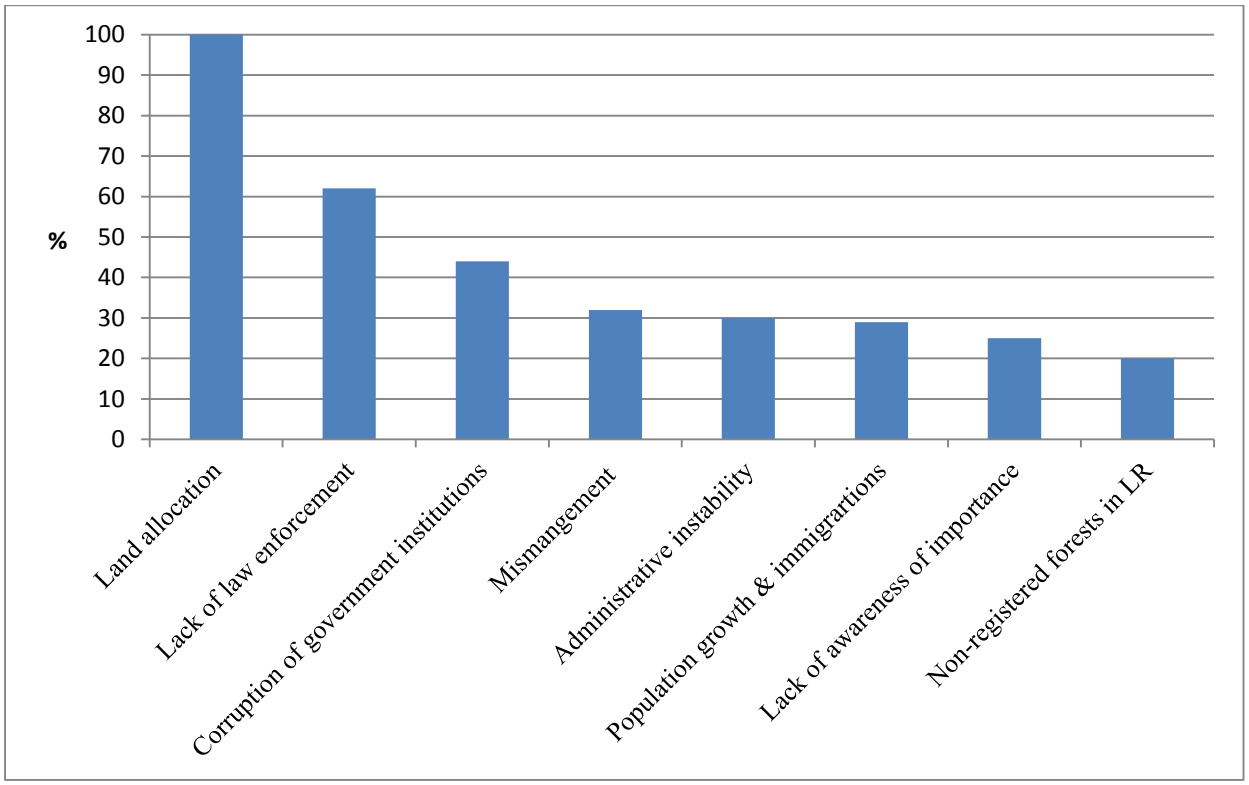

Figure 4.6: The main Indirect causes of deforestation (N=50)

4.3.1.2.1 Land allocation or Usufruct contracts (illegal permits):

There was complete agreement among all questionnaire respondents that land allocation was one of the main indirect causes of deforestation. Where respondents said that this is the process of allocating forest land to certain people in the first years of giving land allocation (1986-1990), particularly to some officers and officials from outside the district and in 1990-1991

some of the locals also obtained land allocations letters. In addition, official respondents reported that there is a relationship between land allocation which is a policy factor and forest which is an indirect cause of deforestation. Official and unofficial respondents stated that issuing land allocations affected some socioeconomic factors as reported below:-

- **Increase forest encroachment**

Respondents explained that issuing land allocation encouraged local people to encroach on forests, thus becoming a concern in terms of obtaining land, whether from forest neighbours or people with power in the government at that time. Some respondents reported that land allocation influenced local people's behaviour toward the forests due to greed and the collapse of moral values. In addition, land allocation led to lack of appreciation of the value of the forest and implementation of laws and regulations governing forests was very weak, even among the officials. All these factors led to more forest encroachment for selling land and other purposes.

Figure 4.7: Forest encroachment in Alataya locality, Al-Garabulli district (Source: Picture taken on 05.01.2013 by the researcher).

- **Conflicts over land ownership**

Conflicts between people and between tribes over land ownership occurred as a result of illegal issuing of land allocations, resulting in many parties to claiming land ownership, respondents stated. These respondents further explained that no one claimed ownership of the protected forest land before 1986. However, the Director of Forestry Department in Algarabulli District [7] confirmed that there was no formal proof of land certificates that the land belonged to whoever was clearing forest areas claimed by the land occupants. It was found that land ownership issue is as a result of bad governance and corruption. Also, an elderly respondent, 95 years old, said that whoever claims the ownership of part of forest land is not being truthful, because it was sand dunes area before afforestation replaced it. This is because the traditional custom gives certain lands to certain families or tribes except sand dunes due to their non-arable or grazing land characteristics. One non-official respondents indicated that the wealthy locals, powerful or aggressive/potentially violent families were taking the land forcefully. The Director of Forestry Department in Algarabulli District indicated that cases of killings were recorded in which the purpose was to acquire forest land.

- **Land title fraud**

Respondents indicated that some of those who encroached upon the forest forged land ownership certificates, which became widespread in the region apparently.

In this context, the Director of Land Registry in Algarabulli District [8] stated that in the last few years of the Turkish occupation of Libya which ended in 1911, private land and public lands in Libya were registered and documented. Libyan courts still accepted the customary titles which were made during Ottoman rule in Libya as proof of ownership of the land. The Director of Land Registry in Algarabulli District confirmed that in recent years they had found land ownership title fraud and confirmed that land tenure and property rights is the biggest issue now affecting land allocation which leads to more deforestation. Some other respondents blame the fact that the Libyan government still recognize and accept the Turkish titles.

The Director of Forestry Department in Algarabulli District [9]confirmed that the local people, in the beginning, rejected the allocation of some of the forest land in the region to officers who

[7] Interview Date 05.01.2013, in the field

[8] Interview Date 15.01.2013, in his office in Algarabulli District ,Libya

[9] Interview Date 05.01.2013, in the field

were from outside the region. As some of the officers used brick construction for the purpose of building holiday homes, the local people stole the bricks at night.

Also, some people could not gain access to land they wished to acquire, so they had to resort to other methods to get access to the forest land. Officers employed some of the local people's sons in government institutions, for maintaining local schools and building some new roads. By using this approach of patronage and nepotism, they were able to gain otherwise unobtainable permission to enter the forest, and they became important people in the area. Further discussion about land allocation or usufruct contracts how and why they were issued from legal point of view, is presented in chapter 6.

4.3.1.2.2 The lack of law enforcement:

62% of respondents stated that the lack of law enforcement with regard to the forests was one of the main causes that contributed to deforestation in this area. The Minister of Agriculture[10] confirmed that the laws existed, and that they are the most appropriate for protecting forests and pastures. However, the problem was applying the law properly, as it was only applied to some people.

In this context, the Police Chief of Agriculture in Algarabulli District[11] confirmed that when they arrest an offender and were taken to prison, the following day they would find them released. They were often not punished for their infringements because a higher authority prevented implementation of the law in a improper way, thus encouraging deforestation and discouraging law enforcement officers as reported by some officials. It was reported that there was strong law enforcement from 1952 up to the middle period of 1980s and forestry officials confirmed that there were no recorded breaches. After then, law enforcement was weakened resulting in law enforcement being affected by corruption and connivance which led to more forest loss. Therefore the enforcement of the Forest Act is rarely carried out by the Forest Department and Police of Agriculture and when it is, their attempts were at times frustrated by higher legal authorities.

In contrast to this, in some forest area in the world, strong law enforcement efforts were found to reduce deforestation; however, law enforcement efforts were weak in remote areas around

[10] Interview Date 24.01.2013, in the Ministry of Agriculture Tripoli ,Libya

[11] Interview Date 09.01.2013, in the field

the world thereby achieving social, economic and environmental sustainability (Heeswijk and Turnhout, 2013; Gaveau *et al.,* 2009).

4.3.1.2.3 Corruption of government institutions

Corruption can be defined as "the unlawful use of public office by politicians or civil servants for private gain (Koyunen and Yilmaz, 2009) According to this definition, corrupt acts are illegal acts that are committed intentionally and furtively for private gain, and involve public officials, property and power. In most of literature corruption is particularly related with the forest sector (Jawad *et al*., 2005). Many illegal activities in the forest sector are associated with corruption. Corruption is a complex political, social and economic phenomenon. It involves the use of one's position for illegitimate private gains. The FAO has identified forest crime and corruption as one of the main causes of deforestation in its 2001 report and warned that immediate attention has to be given to illegal activities (illegalities) and corruption in the world's forests in many countries (Koyunen and Yilmaz, 2009). Thus, besides the previous factors identified in deforestation literature, corruption may also play important role in explanation of deforestation.

44% of the respondents indicated that the corruption of government institutions is one of the main cause of deforestation in this area either by forestry department or other authorities. In this context, one of the ex-government officials in the Forestry Department (1965–1986)[12] confirmed that although Forestry Department is the key actor in the care and management of forest land in Libya, this department was abolished then reinstated many times due to corruption. In Libya corruption is related to many sectors and many authorities as it was confirmed that mis-using authority. Corruption, particularly, in forest management, is widespread in developing countries (Jawad *et al.,* 2005). It was found in similar case that corruption in forestry undermines and weakens broader governance systems in countries where it occurs and may be a potential driver of illegal logging and poor forest management. However, corruption in the forestry sector also has broader implications for governance as it requires the complicity of different sectors to be carried out successfully (Contreras-Hermosilla, 2002).

4.3.1.2.4 Mismanagement by officials

32% of respondents stated that there was a clear change in forest management particular in the last three decades. This finding was supported by one of the ex-government officials in the

[12] Interview Date 08.01.2013, in his house

Forestry Department (1965–1986) the importance of this factor for deforestation in Libya, he also said that many officers in important positions in the Ministry of Agriculture were unqualified, and they brought staffs who had no experience with forests or agriculture.

In fact, some of the experts would not work with them in the decision-making process. This led some of the experts to resign or retire from work, while others searched for new jobs. He explained that due to mismanagement by officials.

Forestry Department who was only the key actor in the care and management of forest land in Libya was formerly administered in a good way by forestry experts in Libya between 1952 to the late 1980s; however, now the management was poor because there are many actors in forest also this is linked with widespread of the forms of corruption among officials and employees in governmental institutions; however, these forms, particularly with regard to relatives and friends who break the law, all these form of corruption did not exist before in the last three decades also it was linked with the governance from good to bad.

In addition, the Minister of Agriculture indicated the weakness of the Ministry of Agriculture compared to some of the ministries supported by the former regime, such as the Ministry of Defence, as well as the overlapping of authority between ministries in certain areas. For instance, if the Ministry of Defence planned to build a camp in a forest area, they did not need to have permission from the Ministry of Agriculture because they had more power and authority. On the other hand, in 1975 the Ministry of Transport took ten years to get permission from the Forestry Department in Libya to extend the road between Tripoli city to the airport which about 35 kilometre. The mismanagement represented as the Deputy Minister of Agriculture[13] stated that the national afforestation program in Algarabulli district was stopped in 1974, even though there were programs of afforestation in other regions. Even these programs, however, have not achieved the desired success because of mismanagement by officials and corruption.

In this context, the Director of Forest Department in Al-Garabulli district[14] stated that some of the officer of previous administration contributed to the destruction of the forests, as they decided to clear forests because the role of forests was no longer considered vital, and the forests must be changed to other types of land use.

[13] Interview Date 09.02.2013, in the Ministry of Agriculture Tripoli ,Libya

[14] Interview Date 08.02.2013, in his house ,Tripoli ,Libya

4.3.1.2.5 Administrative instability

30% of respondents stated that administrative instability was a factor in deforestation, and according to their point of view, the permanent state of change in the Ministry of Agriculture was a part of this. For instance, the name of the Ministry of Agriculture changed many times from the Ministry of Agriculture, to the Ministry of Agriculture and Livestock, to the Ministry of Agriculture and Livestock and Marine Wealth and this indicates a constant separation and amalgamation of ministries.

Respondents who indicated this category said that there were changes in the administrative subordination of this region, from the capital to three other regions, within a 15 year period. One of the official respondents stated that this region was transferred (administratively) from the capital to another region which are as remote region and had less awareness about forest management and was more corrupt.

Also one of official respondents said that administrative corruption was less in the capital than in remote areas and one of the serious problems which appeared due to this administration changes, Sheikhs of a tribe became authorities on the issuance of letters of Land Ownership, where some of these the remote region dealt with customs more than with the law.

In this context, the Deputy of the Ministry of Agriculture[15] confirmed that administrative instability contributed to deforestation also led to a loss of Ministry archives, and specifically maps of forests, and he also indicated that these actions were intended to destroy the Ministry archives.

4.3.1.2.6 Population growth and immigration

29% of the respondents stated that population growth and immigration played a significant role in reducing the forest area in the region. However it could be argued that this result is not accurate in this area. Some officials stated increasing immigration as the reason behind it. While the mayor[16]attributes it to the high cost of housing and rent in Tripoli leading to land acquisition in this area due to its proximity to the capital.

In this context, the mayor of Algarabulli District [17]confirmed that there was no correlation between the population growth and deforestation of the region through acquiring more plots of

15 Interview Date 09.02.2013, in the Ministry of Agriculture Tripoli ,Libya
16 Interview Date 24.01.2013, in his office in Algarabulli District ,Libya
17 Interview Date 24.01.2013, in his office in Algarabulli District ,Libya

land, because they knew that this land was forest land. However, people from outside the region were not aware of the former land use, nor of the illegality of buying or selling this land. Also, the local people are aware of the issue of land fraud.

However, it has been reported by the respondents in the study that immigration is the most significant factor in global deforestation. It should be understood that demographic growth, economic growth; an increasing demand for wood are not tied exclusively to population growth, whether local or global; for instance, it is quite evident that the expansion in the cultivation of having lands (de Koninck and International Development Research Centre, 1999). More discussions in this matter, chapter 7 investigates deeply whether there is any link between population growth and deforestation.

4.3.1.2.7 Lack of public awareness of the importance of forests

25% of the respondents stated that the lack of awareness about the importance of forests was a result of the negligence of the state in educating people through the media, schools and mosques. According to the elders of the region perception of deforestation, they said were collecting the timber from some natural plants from long distance for cooking and building huts, however the period of 1950s, afforestation campaigns were started and we had no idea about it, some people tried to remove the plants which just were planted, however the government issued acts to protect forest and did awareness campaigns in this district during 1960s for the importance of forests and became as responsible to protect forest "we supported the government to plant more forest". However, when the government by military regime in an indirect way contributed to clearance of forest in 1980s the moral awareness collapsed and there was a change in people's behaviour, from positive to negative where now the first concern for some people is to make money, where some of clearers want to flaunt or to display the size of land ostentatiously also to sell some plots of the land when needed.

One of the official respondents said that in the 1960s and 1970s there were celebrations of World Tree Day to educate students about the importance of trees. However, since that period, there has been no mention of this practice.

4.3.1.2.8 Non-registration of forests

20% of respondents (practically the officials) said this factor is not known among them until now, while the Minister of Agriculture[18]confirmed that the forests in question had not been gazetted as state forests, and therefore had not have protection from squatters. In fact, after the

18 Interview Date 24.01.2013, in the Ministry of Agriculture Tripoli ,Libya

reforestation project in 1979, the Forestry Department contracted the French National Geographic Institute (IGN) to create a map of the forest and to document the forest on behalf of the State in the Land Registry to be able to register all of Libya's forest. However, for unknown reasons, the state in 1986 rejected the idea of registering the forest after the forest had been mapped and documented for forest demarcation, which causes many problems in land ownership where the presiding judge of the agricultural crimes court in Algarabulli District confirmed that there was no legal basis for state ownership of the forests, and he has helped some people win lawsuits filed against the state due to a lack of evidence that the forests belongs to the state and the state of the forest as question.

4.3.1.3 The underlying causes of deforestation after the uprising (2011-2013)

As respondents reported earlier that the rate of deforestation is higher after 2011 comparing with the period before, to identify why, 50 respondents were questioned what reasons were responsible for increased deforestation after 2011 and they mentioned the reasons as shown in figure 4.10.

4.3.1.3.1 Total breakdown in governance

80% of the respondents said that the absence of government led to increased deforestation after the fall of the former regime. In Libya, in August 2011, a new government appeared in Tripoli but this government is weak in terms of the presence of arms, and so the focus was on establishing security and collecting weapons from the people.

In the meantime, some people began to encroach on the forest because of the absence of regulatory agencies and the policing of agriculture.

Figure 4.8: Reasons behind recent increase in the deforestation after 2011

In this context, the Minister of Agriculture[19] indicated that the Ministry was unable to stop the forest encroachment, and he was fearful of exposing police officers to risk in light of the proliferation of weapons among the people. This means that there was a violation of the laws for forest protection and the policing of agriculture could not apply the laws in earnest.

4.3.1.3.2 Large increase in land prices

60% of the respondents indicated the dramatic increase in land prices in recent years due to population growth and immigration. One of the respondents said that the price per ha of land in 2013 has risen ten-fold from what it was in 2005. Whereas one of the official respondent said that increasing land price in non-forested areas which were documented led people to buy lands of forest where it cheaper rather than other land which undocumented.

4.3.1.3.3 Criminal activity to earn money by selling the land

40% of the respondents indicated that some people were clearing forests and established roads and then subdividing the land to sell plots. The problem is that people from outside the region were buying these plots of land, which is undocumented.

[19] Interview Date 24.01.2013, in the Ministry of Agriculture ,Tripoli ,Libya

Figure 4.9: Offering the land for sale (Land trading): Offering the land which was cleared for sale which was an illegal action, Sign on electricity pylon says, 'One hectare for sale' and the phone number (but the sign poster does not own the land), In Alataya village, Al-Garabulli district, Libya. Picture taken, by the researcher on 05.01.2013.

4.3.1.3.4 Lack of housing projects for youths

According to the questionnaire results, 25% of the respondents pointed out that the lack of housing for youths played a role in deforestation. In this context, The Director of Forestry Department in Algarabulli District[20] indicated that most of people encroaching on the forest after the 2011 uprising are from the youth category, which is those less than 40 years old, because this category has weapons. In the past, those who encroached on the forests were typically from 40–60 years old. The mayor of Algarabulli District [21] mentioned that the lack of housing projects for youths caused many social problems, such as the delayed age of marriage.

4.3.1.3.5 Lack of trust between the citizens and the state

15% of the respondents indicated that the state, before the uprising, contributed directly or indirectly to deforestation by allocating land to officials and officers, and that this issue created feelings of inequality in other citizens. In turn, some of these citizens then exploited the absence of government to clear forest.

[20] Interview Date 05.01.2013, in the field
[21] Interview Date 24.01.2013, in his office in Algarabulli District ,Libya

4.3.2 History of forest clearing in the region

The status of the forest clearance in the study area was divided by respondents into three phases; Before 1986, 1986–2011 and 2011–2013;

4.3.2.1 The status of the forests before 1986:

Respondents indicated that the forests were flourishing and in good condition due to good governance and good management. In addition, forest encroachment had not been noted in this region prior to 1986 and forestry officials confirmed that there were no recorded breaches.

With regard to forest protection in this period, respondents were questioned about why forests were protected before 1986, and they indicated that there were several factors, such as fear of the law and punishment, respect for the laws, lands were cheap.

In this context, the respondents indicated that it was not possible to cut tree nor clear forest and there was no nepotism and patronage in the application of the law. Also the Director of then Forestry Department in Libya[22] indicated that the laws and legislation were applied in a good way. Agricultural police patrols roamed the forest areas at all times and forest encroachment had not been recorded in this region prior to 1986.

4.3.2.2 The period from 1986–2011.

90% of the respondents and officials confirmed that the beginning of deforestation began in 1986. In terms of the reason why deforestation began in 1986 specifically, 82% of all respondents indicated the issuance of land allocations, which is the main cause of deforestation and known by local people as the Forest Disaster (النكبة) .Also, 10% of the respondents indicated the abolition of the Ministry of Agriculture in 1986. The last reason indicated by the 8% of respondents was the burning of the land registry centres.

In this context, the Deputy Minister of Agriculture[23] confirmed that in 1986 some things happened in Libya that contributed to the destruction of the forests. The Ministry of Agriculture was abolished, and its authority was transferred to the Directors of Agriculture sectors in Libya regions. Some of the officials in Forestry Department and the Ministry of Agriculture in Libya

[22] Interview Date 02.01.2013, in the Ministry of Agriculture Tripoli ,Libya
[23] Interview Date 09.02.2013, in the Ministry of Agriculture Tripoli ,Libya

refused to issue land allocations in forest area as they believed that this procedure would destroy the efforts of many years of planting trees.

Also, instructions of the previous regime were adopted, such as that land does not belong to anyone, and for this reason the land registry centres were burnt in Libya by the previous regime. Due to many problems on land rights and land tenure between tribes in Libya, in 1991 the land registry centres reopened and reported that is why it was not possible to register forests in the land registry in 1986.

The extent of deforestation between 1986 and 2013 is shown in figure 4.10. Respondents estimated that 32% of total forest area was cleared between 1986 and 2010, but the rate of deforestation has increased dramatically after the fall of the Gaddafi regime where another 44% was cleared between 2011 and 2013 and currently only 24% of the originally planted forest remains which is also suffering from severe degradation.

4.3.2.3 The period from 2011– 2013

The deforestation index in the last two years is higher than the period before the uprising, which covers 25 years due to a range of factors such as a total breakdown in governance and a tenfold increase in land prices. Nevertheless, the respondents expected that deforestation rate will stabilize after the uprising in Libya because they believe that the policy of the former regime indirectly destroyed the forest cover.

In addition, respondents stated that people clearing forest before the uprising were some of government officials, officers and forest neighbours, but with regard to recent clearing of forest, the respondents indicated three types of people who were doing this: people who claim ownership of the land including forest neighbours, local non- forest neighbours and armed gangs.

As shown in figure 4.10 that the most serious deforestation before 2011 occurred in Ataya forest block (locality). So it is important to understand why the rates of deforestation in these blocks are different. In order to diagnose the causes behind the higher rate in Ataya, respondents stated that:

1-The government constructed an official paved road across this forest in 1986, encouraging more forest encroachment. Later, an unofficial unpaved network of roads was built to link with this road (see Fig 5.10). Roads usually have a major impact on deforestation (Barber *et al.*, 2014). Since Libya's revolution, the rate of deforestation has increased and forest encroachment has reached the forests located near the major roads.

The construction of paved roads has grown rapidly recently, as are illegal or unofficial roads. However, major roads (the Tripoli–Benghazi road) are to the south of Ataya forest block, and the forest here was unaffected by deforestation before the uprising because these forests are located in front of official and unofficial eyes, but recently, even these forests are deforested with no care from the official people.

2-The Al-Ataya population allowed officials from outside their village to obtain usufruct contracts for this block of forest in the late 1980s, before some of the local people obtained the usufruct contracts as well. In addition, it allowed the village inhabitants to sell land to people from outside the region. In contrast, the population of the Al-Karawa locality refused to accept any usufruct contracts from outside the village. It also refused to sell forest land to foreign interests.

3-All respondents stated that administrative corruption exists in all the villages. However, administrative corruption in this village is the highest, and the highest number of administrative certificates stating a right to land ownership of forest area were given by the sheikhs of this village. In addition to the corruption, forest supervisors and inspectors of this block of forest cover up forest encroachments and in return for bribes or forest land.

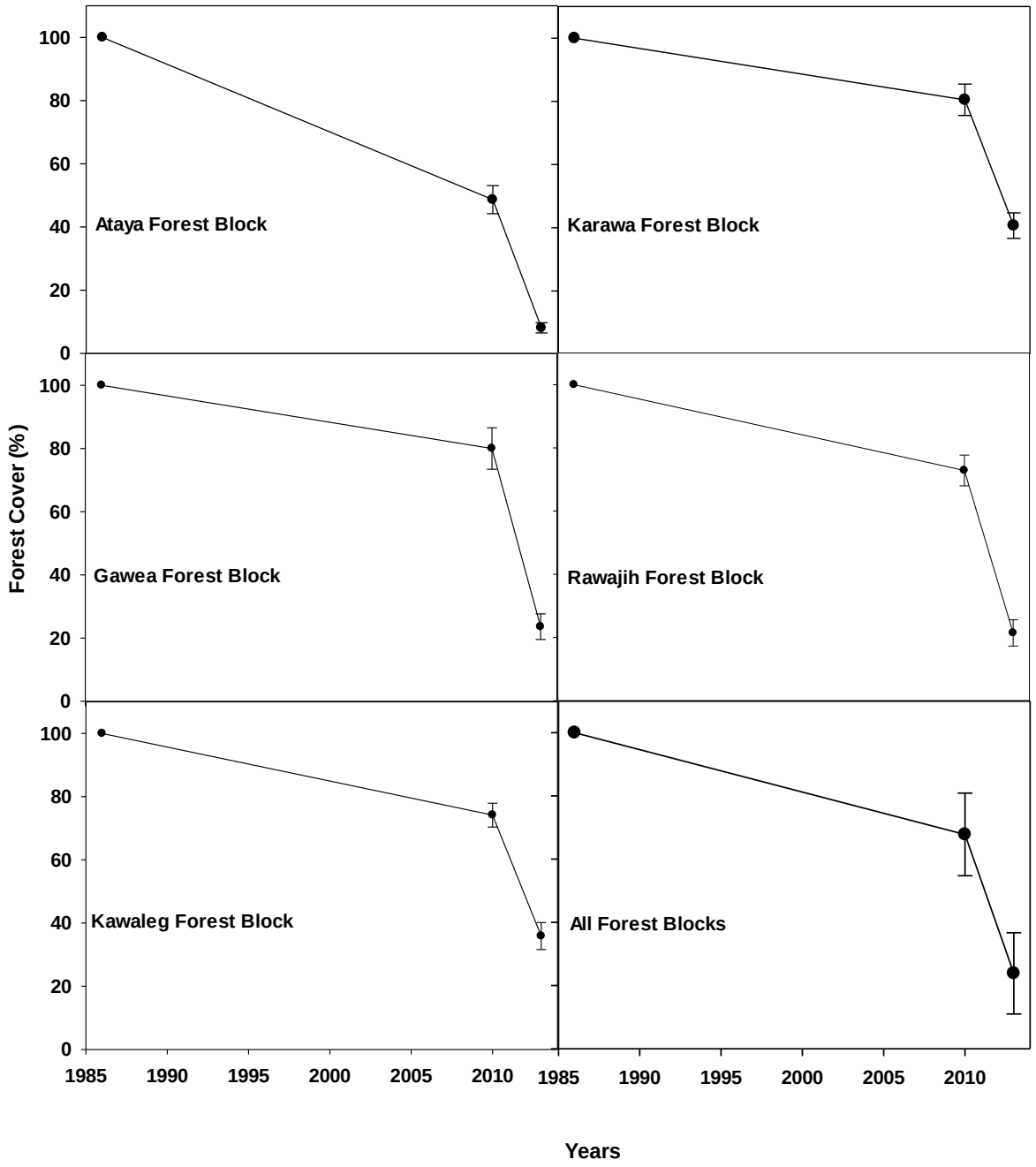

Figure 4.10: Index of Forest Cover (respondents' estimates): 1985–2013 in percentages (standard deviation in brackets) over the whole study and in each forest block.[24]

4.3.3 Consequences of deforestation:

As deforestation proceeds, its short-term consequences could be disastrous for the state. Effects of deforestation are compounding and becoming complex. To identify the consequences of

[24] Respondents estimates were based on the Remote Sensing data of 1985 (See appendix 7 for more information and how this figure was analysed)

deforestation 50 respondents were asked which consequences that have been experienced so far. The responses are as indicated in the figure 4.11 below.

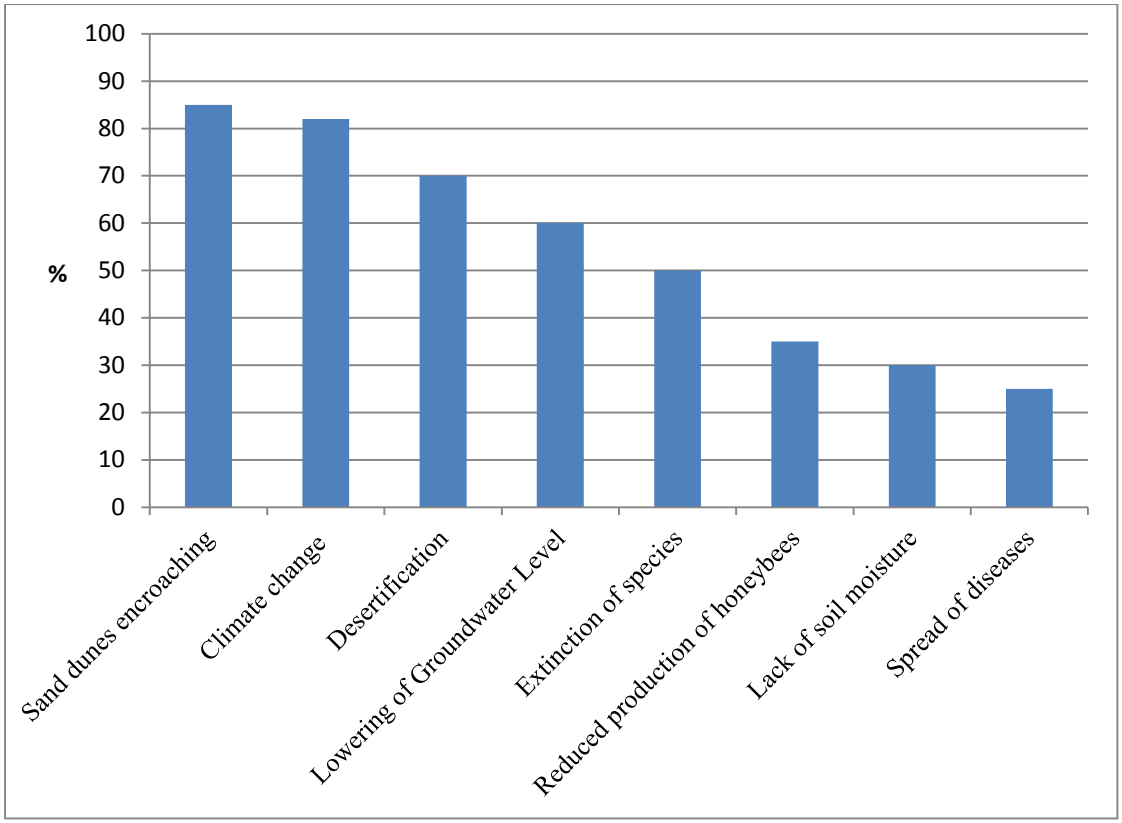

Figure 4.1: Consequences of deforestation in Algarabulli District

4.3.3.1 Sand dunes encroaching

Jefara Plain experienced vegetation deterioration, settlement expansions and sand dunes encroachment with over 33,500 ha Jefara plain area been affected by creeping sand dunes (El-Tantawi, 2005). The mobility of the sand presents a constant menace, affecting Jefara plain, particularly the areas south and east of Tripoli. A monitoring study on El-Witia area showed an increase of 227% in sand dunes formation during 10-years from 1986-1996 (Ben-Mahmoud, el at., 2000).

Of the respondents, 85% indicated encroachment by sand dunes was a serious a problem affecting farm land and houses as a result of cleared forest in this region. In particular, one of the respondents indicated that sand dunes appeared when deforestation began and its effects are clear to all. However, this respondent indicated that people would not stop clearing forests.

Also this respondent said that although people were aware of problems caused by deforestation, but this is their greed overtook their concern about this issue.

Another respondent, who was affected by the encroaching sand dunes, noted that it is not possible currently to cultivate the land due to the movement of sand dunes. Additionally, this respondent said that he built a wall around his farm to prevent sand movement, as shown in figure 4.12.

Figure 4.2: A wall built to prevent sand dunes encroaching, Alkarawh village, Al-Garabulli district (Source: Picture taken on 05.01.2013 by the researcher).

4.3.3.2 Climate change

Approximately 82% of respondents indicated climate change which includes as explained by respondents; wind speed increases and air pollution from dust, lack of and erratic rain and increases in the temperature. They stated that forest was providing a moderation of wind velocity, regulation of atmospheric temperature, enhancing precipitation, Maintenance of humidity and provide places for recreation. They also explained that whenever the rate of deforestation is increased, the wind speed and air pollution from dust become higher. This was almost as prominent as encroaching of sand dunes.

The wind moves faster due to clearance of the forests and a lack of trees acting as windbreaks. The wind carries grains of sand over long distances. The respondents indicated that when the winds pick up, they must close their windows until the wind stops. Some respondents reported

that the dust leads to a poor psychological state, as it stays in the air for a long time. Sometimes, it also becomes very difficult to drive. One elderly man indicated that this took him back to 60 years, prior to when forests were planted.

Strong wind is considered a dangerous meteorological phenomenon; it can cause a significant damage, particularly for natural resources, as it is blowing dust accompanied by erosion of soils. Wind is a more frequent phenomenon in arid and semi- arid lands leading to degradation and a high degree of strong air pollution (El-Tantawi, 2005).

In spring and autumn, strong southerly winds - Gibli - blow from the desert, filling the air with sand and dust and raising the temperature to about 50 °C in some parts. This distractive wind is one of the major erosion factors in the Jefara Plain transporting the eroded soils from one place to another. The dust transported from Sahara to Europe from Saharan was estimated at 80–120 mill.t/ year (El-Tantawi, 2005). Plantations suffer greatly from a prolonged subjection to southerly winds because of the greatly reduced relative humidity, leaves are withering and crops are destroyed (El-Tantawi, 2005).

Figure 4.3: The impact of desert dust transport from Libya across the Mediterranean Sea (Source: El-Tantawi, 2005 from NASA, 2003).

In this context respondents also indicated a change in the local weather pertaining to rain. They noted that there was a lack of rain and that the rain that did occur was erratic. They also noted that within 2011-2013, the change was clearly experienced. In total, only three days of rain were experienced during 2012-2013.

This was not noted before. Also they had experienced temperature increase recently due to forest clearance. This result agrees with observation of El-Tantawi (2005) and Tinker *et al*. (1996) that change in land use, particularly deforestation, is a direct cause of climate change. With changes in evapotranspiration, runoff and local climate. The regional effects of deforestation will be to lower the rainfall volume due to reductions in evapotranspiration as the vegetation changes from a forest to others land use convective rainfall circulation is reduced (Neal *et al.*, 1992). However it could be argued that this change in local weather namely lack of precipitation or increase temperature as a result of deforestation in this area is not accurate as meteorologists stated that it is difficult to link change with deforestation only where forests in this area are small but the results are related with long time of deterioration in vegetation including deforestation in Jefara plain which impact on agriculture activities.

4.3.3.3 Desertification

In total, 70% of the respondents indicated that deforestation contributes to the accelerated process of desertification, which is becoming clear in this area. Also it has been noted that not many people know about desertification in meaning and in processes. It was found many studies have been conducted in Libya because it is experiencing a serious problem of land degradation and desertification due to human activity and extreme climate variations (Saad *et al.*, 2011; El-Tantawi, 2005) where deforestation and removal of vegetation is one of the main anthropogenic factor causing degradation in Libya (Saad *et al.*, 2011). As the main causes of desertification in Libya are many and vary by regions (Al Farrah *et al.*, 2011).

The plain has experienced a stress on its natural resources (water, soil and vegetation) in recent decades as a result of heavy population growth and increasing food demand (El-Tantawi, 2005). Another study found that west of the plain has been significantly degraded in quantity and quality of vegetation where vegetation destruction took place by overgrazing and over cultivation, both activities being driven by the needs of a rapidly growing population. Clearing forest which was planted to combat desertification and soil erosion during fifty years led to desertification phenomena again (Ben-Mahmoud, 2013).

According to remote sensing data 1982 to 2007 estimating vegetation cover change in Arab countries. The rate of deterioration of vegetation in Libya reached 58% and another estimation was 24% in irrigated land, 35% in rainfed land, 80% in rangeland (Ben-Mahmoud, 2013). Deforestation results in a variety of negative environmental, economic and social impact directly or indirectly (Saad *et al.*, 2011) .

4.3.3.4 Lowering of Groundwater Level

Of the respondents, 60% indicated a lack of an appropriate groundwater level. However, there was a lack of agreement among respondents about this issue. Some of the 30% respondents agreed that the decrease in the groundwater level was due to deforestation, but others respondents did not agree. They indicated that it was due to other causes. However, all respondents agreed that seawater intrusion as result of deforestation was problematic. In this context, one of water expert in Algarabulli District indicated that deforestation depletes aquifers and that deforestation inhibits water recycling. Deforestation or land conversion is responsible and will affect the climate system, including its impact on local and regional hydrology (Tinker *et al.*, 1996).

4.3.3.5 Loss of flora and fauna

50% of the respondents said that extinction of natural vegetation which grows naturally among forest trees and animal species due to the continuous depletion of forests. However, prior to the afforestation, it was sand dunes and no species living in these dunes, but after afforestation the species came and adapted to living in the forests over three decades. Some of the respondents noted that some of the natural plant species, such as *Retama retama* had appeared in the forest, which is now extinct. With respect to animal species, foxes and wolves were reported by respondents to have become extinct.

4.3.3.6 Reduced production of honeybees

35% of respondents indicated that the forest is a habitat for hives in this region. In this context, the president of the beekeepers' association in the region confirmed that this region was the best region in North Libya for producing honey. However, it has been noticed that bees disappeared following the massive forest clearance. One of the respondents, a beekeeper, indicated that beekeeping was a source of income and mentioned that beekeepers are most affected by deforestation.

4.3.3.7 Lack of soil moisture

In total, 30% of the respondents indicated that the soil lacked moisture and destruction of the forest has been accelerating soil erosion, once steep slopes are left to face the violent monsoon downpour without any protective vegetation (Neal *et al.*, 1992). One of the soil scientist in Algarabulli District [25]noted that the massive clearance of the forest made the land barren and

[25] Interview Date 20.01.2013, in the field

exposed the soil to erosion. Additionally, exposing the soil to direct sunlight with increased temperatures has led to decreased soil moisture through transpiration. In this context, one of forestry experts in Algarabulli District[26] indicated that the decline in soil moisture would be a significant problem in the future if the government plans to plant trees. In Jefara Plain increasing loss of topsoil are mainly due to removal of protective vegetation cover and forest by overgrazing and poor management practices on agricultural fields. Terrain deformation plays a smaller role in degraded soils on a large scale; however, it is dominant in some of the more vegetated regions showing a significant amount of soil degradation (Ben-Mahmoud *et al.*, 2001).

In Tropical forest, cutting trees can be for the purpose of traditional shifting cultivation, after which forest is regenerates (Tinker *et al.*, 1996). However, these practices in semi-arid area practically plantation forest in Libya, it is quite difficult for natural regeneration to occur due to lack of soil moisture.

4.3.3.8 Spread of diseases

25% of respondents indicated that after forest was cleared, some diseases such as asthma emerged. As stated earlier that the forests has been decreasing significantly during recent year, thus consequences of deforestation are reaching and affecting every of human life in this district, it could be argued that urgently Algarabulli needs more forests with better managements and good law enforcement, if its people are to survive.

[26] Interview Date 20.01.2013, in the field

4.4 Conclusions

The results of the semi-structured interview used in this chapter have shown that deforestation has direct and indirect causes. Many respondents stated direct causes of deforestation. Agriculture has been identified has the most important reason for clearing forests; agriculture is common throughout the world, but in the period of 1986-1990, clearing forests was for building a holiday home which not common throughout the world.

Many indirect causes contributed significantly to the destruction of forests or increased the forest encroachments in Libya in general and in the study area specifically. The results shows underlying causes. They include poor administration, issued land allocation (illegal permits), the lack of law enforcement, corruption, mismanagement, poor management and land tenure. Because these indirect causes or factors are very complex, the results of chapter four describe how these factors led to deforestation. Other social and economic factors were also mentioned as causes of deforestation. Therefore, chapter five describes the extent to which these factors led to deforestation.

The respondents in this chapter mentioned the specific time that deforestation commenced 1986. They also estimated forest clearance, showing that the deforestation rate increased dramatically after the 2011uprising in Libya; 32% of the total forest area was cleared from 1986 to 2010, 41% of the total forest area was cleared between 2011 and 2013. In this context, chapter five describes the deforestation rate using satellite imagery to check for consistency with the responses.

This increase in deforestation recently is due to many reasons, which are completely different from the reasons stated for 1986-2011, such as total breakdown in governance and the spread of weapons. The government is unable to stop people from clearing forests in light of increased demand for the purchase of land without official documents.

Government officials and forest neighbours cleared the forest before the uprising. After the uprising, however, armed militias and other people who claimed ownership of forest land (forest neighbours and others that did not stay near the forest) began clearing the forest.

The consequences of deforestation in this area has many environmental consequences. As was stated in the background chapter, the sandy soil was very low in organic matter; originally, the soil was sand dunes and unsuitable for cropping. Sand dunes appeared again, causing increased movements of heavy dunes over time, only slight change in the climate elements (rain,

temperature and winds), extinction of species and desertification. Therefore, studies illustrated that desertification took place in most regions of the Jefara plain.

Based on these findings, the following chapter (chapter 5) focused on land cover change and for which type of land cover forests were converted into and to determine the extent of deforestation rate to compare that with the rate of the respondent's estimates in this chapter with using remote sensing.

5 A remote sensing assessment of land use change

5.1 Introduction

Within Land-Use/Land-Cover Change (LULCC) research, dynamics of land-cover (e.g., the biophysical attributes of the land surface) and land-use (e.g., the anthropogenic influences on the land) changes are considered two of the main driving forces of global environmental change. They have, therefore, received increasing attention from scientists and decision makers. LULCC expresses social, environmental, institutional and economic processes (Mas *et al.,* 2014).

Traditionally, LULCC studies have focused on the processes of negative land-cover change (LCC), primarily deforestation, because examples of positive LCC are uncommon (Calvo-Alvarado *et al.,* 2009). Landscape managers and policy makers must understand the underlying relationships of both LCC and deforestation processes in order to design nature conservation and sustainable management strategies (Brinkmann *et al.,* 2014). The FAO reviewed global forest clearance and found that between 1990 and 2000, forest loss averaged a rate of 16.1 million ha per year. Of this, 14.6 million ha was lost through deforestation (Lindenmayer and Burgman, 2005).

According to current estimates (FAO, 2013) 0.38% of the world's forests were converted to other land uses (i.e. deforested) every year during the 1990s. The main drivers encouraging the deforestation and the fragmentation of the remaining forests included large- and small-scale agriculture, cattle ranching, logging and urban growth (Wyman and Stein, 2010).

In Libya, the main forest type is the natural forest, which was estimated to comprise about 500,000 ha in 1950; by 1988, 35% of this land had been converted to agricultural land (Al-Idrissi *et al.,* 1996). BRSC (2007) used remote-sensing to study deforestation around the city of Tripoli during the 10-year-period from 1990 to 2000 and found that 40% of the plantation forest had been converted to urban and agricultural land.

The research question of this chapter was; which human activities are contributing to deforestation rate and to what extent? Therefore, to address this, remote sensing was applied and field work observation to detect and quantify the extent of deforestation and evaluate the dynamics of land cover changes that are taking place, using Landsat for the whole area land cover change and using SPOT 5&6 imagery for forest area.

This chapter will focus on the processes of LULCC in two stages: Stage one will examine the whole area using Landsat satellite imagery to identify positive LCC (from sand dunes cover to forest cover), and stage two will use SPOT 5amd SPOT 6 imagery to examine the ways in which forested areas have changed, as well as to discuss their rates of deforestation.

5.2 Material and methods

Remote-sensing (RS) technologies and methods have evolved dramatically within the last three decades to include a suite of sensors operating at a wide range of imaging scales with potential interest and importance to planners and land managers (Rogan and Chen, 2004). RS technologies are important in acquiring useful data on the earth or its surface. They also provide the broad scope and the ability to collect sequential imagery to estimate the trends and the patterns of LUCC, deforestation rates or other phenomena (Zheng et al., 2014). This chapter focuses on the processes of LULCC in two stages:

- Stage one will examine the whole area using Landsat satellite imagery to identify positive LCC (from sand dunes' to forest cover).
- Stage two will use SPOT 5& 6 imagery to examine the ways in which forested areas have changed, as well as discussing their rates of deforestation, addressing the research question.

5.2.1 Satellite imagery data

Today, satellite images provide a key source of information about the environment and play an important role in generating accurate and reliable information about forest cover, vegetation type and land-use changes (Portillo-Quintero *et al.*, 2012). In this study, two different kinds of satellite imageries and diverse ancillary data were collected in order to identify historical and recent land cover/land use. Several strategies and techniques allowed the processing of these input data to efficiently express the desired results.

5.2.1.1 Landsat imagery

The Landsat series of missions, first launched on July 23, 1972, carried on board instruments to examine the earth's surface. Since then Landsat missions have provided enormous amounts of data at different spatial, spectral and temporal resolutions.

This study used five types of Landsat imagery (Table 5.1), including from the Landsat1 Multispectral Scanner (MSS) 1972, the Landsat5 Thematic Mapper (TM) 1986, the Landsat5 (TM) 1990, the Landsat7 Enhanced Thematic Mapper (ETM) 2002, and the Landsat8 Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS) 2013.

All imagery used was from dry season in Libya (from May to October) with cloud-free (0% cloud cover) surface reflectance data in in order to differentiate between LCLUC with a spatial resolution of 30 m. This Landsat imagery data enabled the study of the landscape's dynamic changes and trends to create a time series of LUCC covering 41 years from 1972 to 2013. ERDAS software was used for the digital image processing techniques of classification and ratio indices, for the whole Algarabulli District, whether positive or negative for LUCC.

The Landsat images used in this study were provided by Bangor University, Geographical Information Systems Manager from the United States Geological Service (USGS) at a single level of processing known as systematic correction (Level 4).

Table 5.1:Properties of different Landsat satellite imagery data used during this research

Platform	Sensor	Date of acquisition	Path/Row	Pixel/Ground resolution (m)	Spectral resolution (Bands)
Landsat 1	MSS	04/05/1972	202/37	57	4
Landsat 5	TM	16/10/1986	188/37	30	7
Landsat 4	TM	15/07/1990	188/37	30	7
Landsat 7	ETM	24/06/2002	188/37	30	7
Landsat 8	OLI/TIRS	07/08/2013	188/37	30	11

5.2.1.2 SPOT imagery data

The Satellite Pour L'Observation de la Terre (SPOT) is a commercial high-resolution satellite system operated by a French consortium since 1985; the SPOT 1, launched February 22, 1986, has since been withdrawn. The SPOT images used in this study include SPOT 5 (2010), which was launched on May 4, 2002, and has two high-resolution geometrical (HRG) instruments that were derived from the High Resolution Visible IR (HRVIR) of SPOT4. The SPOT 5 image from 2010 was provided by the BRSC. SPOT 6 (2013), also used in this study, was launched September 9, 2012. This imagery was provided by the Libyan Centre for Remote Sensing and Space Science (LCRSSS).

Table 5.2: Properties of different SPOT imagery data used during this research

Satellite (platform)	Sensor	Date of acquisition	Path/Row	Spatial resolution	Spectral resolution (Bands)
SPOT 5	HRGs	05/06/2010	284/71	2.6 m	3
SPOT 6	PSLV-CA	15/02/2013	284/71	1.5 m	3

The purpose of using SPOT imagery is to study the LUCC in forested areas and estimate the deforestation rate. In Chapter 4, respondents stated that Libya's deforestation started in 1986, and they estimated that the deforestation rate rose after the country's 2011 uprising. It was difficult to use Landsat imagery to investigate this matter because not all Landsat images from 2009 and 2010 focusing on the area of study were of good quality—some images contained banding, making it impossible to identify the 2010 forested areas. As a result, a forest map from 1983, created before deforestation was believed to have started in Libya, the SPOT imagery existed, was used to measure the deforestation rate in two different periods, as well as the processes of negative LCC change. The image processing tools used in this chapter include ERDAS IMAGINE 2013 and ArcMap 10.2 software; therefore, the methods used in obtaining multispectral classifications were taken from ERDAS software.

5.2.2 Map topography

A series of digital and paper maps were also obtained, as detailed below:

- A digital topography map was obtained from the BRSC with a scale of 1:50,000. It was projected under the geodetic datum 'WGS84' and map projection NUTM 33, and the units are in metres.
- A map of land cover with a scale of 1:50,000, prepared by the Army Map Service, Corps of Engineers, U.S. Army, 1962, was obtained from the LCRSSS. In 1979, it was updated by POLSERVICE-GEOKART, POLAND from 1976 aerial photographs taken at a scale of 1:20,000.
- A forest map (nine sheets covering the study area) was obtained from the Department of Mapping of the Libyan Ministry of Agriculture, with a scale of 1:10,000. It was prepared by the IGN Paris in 1983 from aerial photographs taken by the KLM in 1980 at a scale of 1:20,000, under the supervision of the surveying department of the SPLAJ.

5.2.3 Ground truth survey

The decision about where to collect ground sample data is an important step in remote-sensing ground verification (Muzein, 2006). After completing the preliminary image supervisor clarification of Landsat 8, 2013 with 100 points in the whole Algarabulli district and SPOT 6, 2013 with 50 points for only the forest and deforested area. Random sampling techniques were applied and information was collected from the sample plots. Each point was registered using GPS technology to allow for further integration with spatial data in a geographic information system (GIS).

5.2.4 Image pre-processing

The image pre-processing of remotely sensed data is essential for image classification. Because of the direct linkage between the data and biophysical phenomena and features, it requires several processing steps for better identification of the image features (Akhter, 2006) and improving the ability to qualitatively and quantitatively interpret image components (Shahabi *et al.*, 2012). These steps include radiometric, atmospheric and geometric correction.

5.2.4.1 Radiometric and atmospheric correction

It is important to calibrate raw sensor data to meaningful physical units prior to a postclassification change detection. Radiometric calibration helps to ensure that detected changes can be taken for real instead of as errors caused by differences in sensor calibration and sun angles (Coppin *et al.*, 2004).

Atmospheric and radiometric correction applications were essential to the current study for two reasons. First, the study compared the relationship between field-based data and spectral information in a time series of the imagery. Second, the imagery was acquired during dates with different atmospheric conditions and was collected by different types of sensor. Removing atmospheric effects involves calibration and atmospheric correction. Calibration adjusts the image by converting raw radiance values of each pixel to top-of-atmosphere absolute (radiance) or relative (reflectance) values. Atmospheric correction then adjusts these values to ground radiance or reflectance at each pixel based on sun-ground-sensor geometry and atmospheric composition (Zakaria, 2010). Radiometric resolution also refers to the ability of a remote-sensing system to distinguish the subtle disparity in the intensity of the radiant energy from a target at the sensor.

5.2.4.2 Geometric processing

Geometric correction is the process of warping the image to fit a planimetric grid or map projection (Zakaria, 2010). Additionally, it attempts to address the effects of image distortion owing to image acquisition, such as sensor movement and topographic variation, and to convert the raw image coordinate system to a particular coordinate model projection. Researchers commonly use two geometric correction methods: 1) image-to-map rectification, 2) image-to-image registration. Image-to-map rectification is used when accurate measurements from images are required, while image-to-image rectification is usually used when it is unnecessary to assign each pixel to a unique *x, y* coordinate in a map projection. In order to determine accurate measurements from images, this study used the image-to-map rectification method. For which a set of Ground Control Points (GCPs) is required.

5.2.4.3 Ground control points selection

To transform satellite imagery geometrically to a local map-coordinate system, a set of ground control points (GCPs) is required. Accordingly, the images of MSS, TM, ETM and OLI/TIRS were geometrically coregistered to the rectified OLI/TIRS 2013 data (UTM, Zone, 33 projection, WGS84 Datum) and SPOT 6. Georeferencing was provided by grid selecting and applying GCPs.

Image enhancement techniques include histogram stretching and filtering, for example. These steps are used to alter the appearance of the data to potentially increase the information content visible in the image(Mather and Magaly, 2011) .Any pre-processing stage might include all techniques to prepare the data or just some of them, depending on the level of data acquired and the application for which it will be used.

Image enhancement involves the mathematical combination of imagery from different dates, including the subtraction of bands, image regression, principal components analysis, and image ratioing. Image ratioing is one of the conceptually easier to understand change-detection methods because the data are ratioed on a pixel-by-pixel basis (Coppin *et al.*, 2004). Data that have no change will yield a value of one, but pixels from areas that have changed will have a value of either higher or lower than one.

Image enhancement is valuable for detecting and defining LULC information classes because they have different spectral characteristics. A proper image enhancement includes multispectral transformation, false colour composites and vegetation indices, which are important to achieve information of the area and spectral knowledge. Therefore, image-

enhancement techniques were applied in this study in order to improve visual interpretation and to map land cover and its changes within the research area.

5.2.4.4 Selection of bands used

It is important to use appropriate spectral bands for land-cover classification. The bands used should achieve the maximum spectral discrimination between different land-cover types, especially those with similar spectral properties. Previous studies of optical remote sensing showed that for agricultural studies, broadband sensors such as AVHRR, Landsat MSS, Landsat TM and SPOT HRV XS and panchromatic data have good spatial resolution, and it is often possible to visually interpret land cover using textural information (Ghodieh, 2000).

Spectral resolution bands refer to the ability of a remote-sensing system to separate the subtle differences in reflectance of the same ground object at different wavelengths (Schowengerdt, 2007). The use of more spectral bands is conducive to achieving a higher degree of classification accuracy, to a certain extent.

Table 5.3: Landsat spectral bands and their applications

Bands No	Spectral light	Principal application
1	Blue	Distinction of soil, water andvegetation
2	Green	Distinction of vegetation
3	Red	Distinction of vegetation and soils
4	Near infrared	Biomass and urban areas
5	Shortwave infrared	Distinction of vegetation androcks
6	Thermal infrared	Measuring of temperature
7	Shortwave infrared	Amount of water in vegetationand soils
8	Panchromatic	Distinction of areas

Bands 1,2,3,4 and 5 were selected as false colour composite RGB from TM 5 and 7, with the exception of band 6 as a thermal band, were based on the optimum index factor (OIF). The OIF was used in this study to achieve the optimum spectral discrimination between different land-cover types, especially those with similar spectral properties.

5.2.4.5 Image classification

Digital-image classification is a remote-sensing technique intended to categorize all pixels in a digital image into one of several land-cover classes, or 'themes' (Jensen, 2005). This categorized data may then be used to produce thematic maps of the land cover present in an image. Normally, multispectral data are used to perform the classification. Image classification is perhaps the most important part of digital-image analysis (Zakaria, 2010).

Traditional methods of classification encompass two approaches used for agricultural land-cover mapping, namely unsupervised and supervised classification, which are often called hard classification (Zakaria, 2010).

Unsupervised classification involves algorithms that examine the unknown pixels in images and aggregate them into a number of classes based on the natural groupings or clusters present in the image values (Elhag, 2006). This classification can be applied when the analyst has no prior knowledge of the study area and has carried out no field-data collection program.

This technique's advantage, compared to the supervised method, is that it does not require fieldwork and can be accomplished quickly (Ghodieh, 2000). Supervised classification, however, does require prior knowledge of the ground cover in the study area and is, therefore, a more intuitive method for LCC mapping (Rogan and Chen, 2004).

In the supervised approach, calibration pixels are selected for LCC and associated statistics are generated for the classes of interest (Rogan and Chen, 2004). This classification is preferred by most researchers because it generally provides more accurate class definitions than unsupervised approaches (Zakaria, 2010). Therefore, this study used the supervised classification method to characterise changes in the LCC.

5.2.4.6 Supervised classification

Supervised classification consists of three basic steps; 1) In the training stage, the analyst identifies representative training areas and develops a numerical description of the spectral attributes of each land-cover type of interest in the scene; 2) in the classification stage, each pixel in the image data set is categorized into the land-cover class it most closely resembles. If the pixel is insufficiently similar to any training data set, it is usually labelled 'unknown'. The category label assigned to each pixel in this process is then recorded in the corresponding cell of an interpreted data set as an output image. Thus, the multidimensional image matrix is used to develop a corresponding matrix of interpreted land-cover category types; 3) after the entire data set has been categorized, the results are presented in the output stage (Elhag, 2006). In a supervised classification, three statistical classifiers are generally used: the parallelepiped

method, the minimum distance classifier and the maximum likelihood algorithm (Zakaria, 2010).

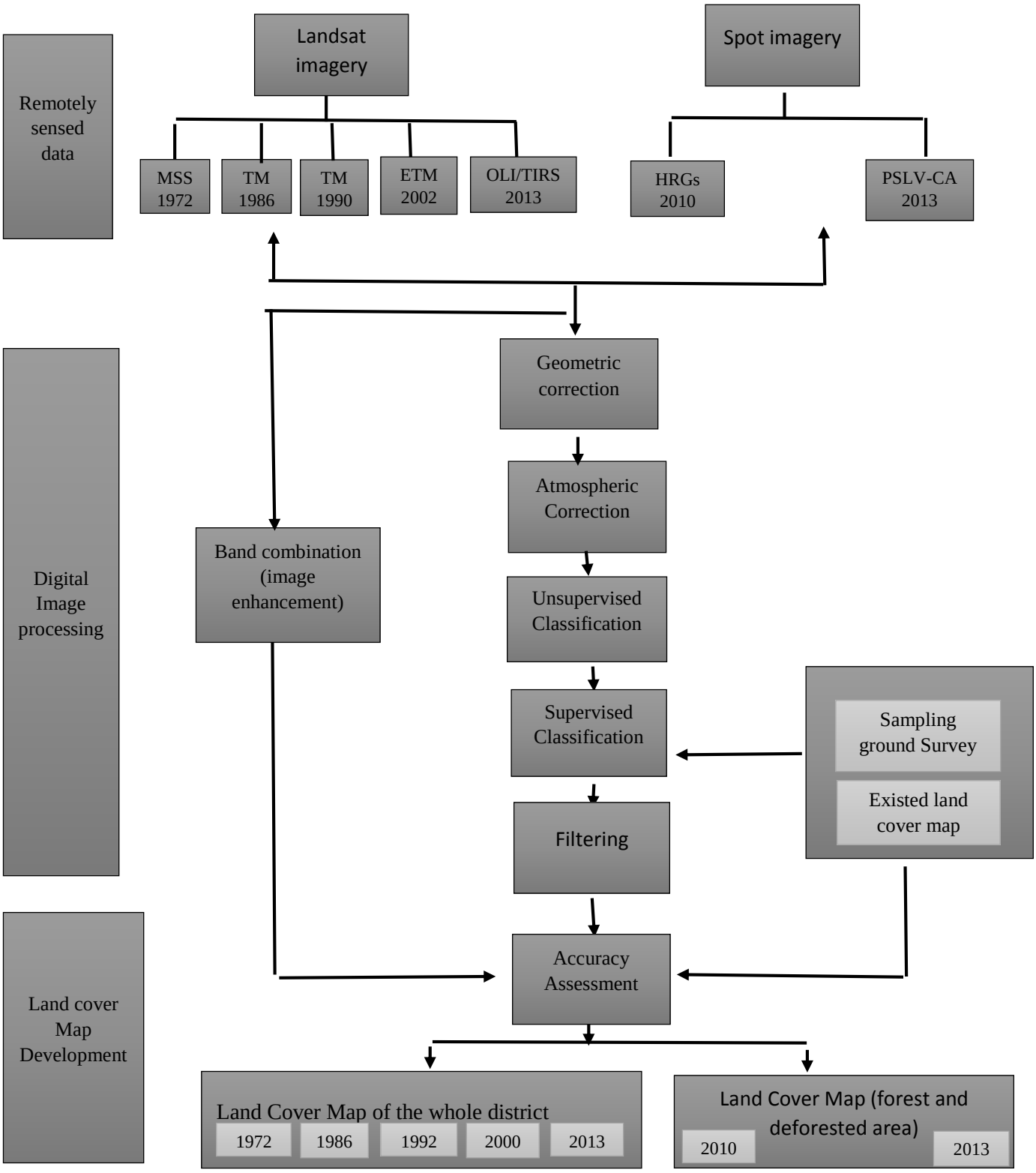

Figure 5.1: Flow-diagram processing steps of (SOPT& Landsat) images classification carried out for derivation of land-cover information from remote-sensed data.

This study used maximum likelihood classifier in the image analysis. It is commonly used as a hard classifier because each pixel is treated as statistically independent and allocated only to a single class. This is one of the traditional parametric approaches widely applied to the supervised classification of remotely sensed data (McIver and Friedl, 2002). Samples of pixels are selected based on available ground truth information to represent each class; these steps are called training areas.

The process in this study began by selecting training areas that are representative and homogeneous examples of each information category used in the classification stage. The training areas for the classes were selected, topographic maps and information collected on-site.

These training areas were chosen by the visual interpretation of Landsat and SPOT and by locating them in the area. The colour was changed to contrasting combinations to differentiate and enhance classes. A total of six classes were determined from Landsat 1972, 1986, 1992, 2002 and 2013, as well as SPOT 5 for 2010 and 2013.

5.2.5 Fieldwork

Fieldwork, the process of observing and collecting data about people, cultures and natural environments, is important for most applications of remote sensing. Lillesand *et al.* (2004) pointed out that field-survey data serve three purposes. First, field data can be used to verify, to evaluate, or to assess the results of remote-sensing investigations. Second, field data can reliably guide the analytical process, for example, by creating training fields to support supervised classification. Third, field data can provide information to model the spectral behaviour of specific landscape features, allowing for a better understanding of the spectral signatures of various types of land use and land-cover change in the area of study.

In the fieldwork which was conducted during the period between December 2013 and April 2014 in order to examine the patterns of land cover in the study area in different years, a very good opportunity arose to take video and aerial photographs from the sky by helicopter, because it was difficult and dangerous to enter some forest patches on foot. For the purposes of this study, the helicopter obtained video camera and photos of the ground with permission from the Ministry of Defence on February 21, 2012 (see Appendix 6) in order to show how people had cleared forest land using bulldozers and weapons after the uprising in Libya in 2011.

5.2.6 Image classification accuracy

The classification accuracy assessment of derived land use/land cover maps from remotely sensed data is the procedure to quantify the reliability of a classified image, which is important to identify the sources of errors (Ghodieh, 2000). A classification is incomplete until its accuracy has been assessed (Zakaria, 2010).

Accuracy assessment presented by a confusion error matrix by Kappa coefficient is a common and typical method (Congalton and Green, 1999). The Kappa coefficient (K) is calculated as follows:

$$K = \frac{N\sum_{i=1}^{r} Xii - \sum_{i=1}^{r} X_i + X_{+i}}{N^2 - \sum_{i=1}^{r} X_i + X_{+i}}$$

Where:

r = Number of rows/columns in the confusion matrix

Xii = Number of observations in the major diagonal in row *i* and column *i*

X+i = Total number of row *i*

X+I = Total number of column *i*

N = Number of observations

The Kappa statistic provides a statistically valid assessment of the quality of classification (Tottrup and Rasmussen, 2004); therefore, it was used in this study to assess overall class of agreement or accuracy. A Kappa value higher than 0.5 is considered satisfactory for modeling land-use change (Pontius, 2000). Characterized agreements for the Kappa coefficients are as follows: values greater than 0.79 are excellent, values between 0.6 and 0.79 are substantial and values of 0.59 or less indicate moderate or poor agreement (Landis and Koch, 1977).

The overall classification accuracy is the percentage of correctly classified samples of an error matrix. It is computed by dividing the total number of correctly classified samples by the total number of reference samples. It can be expressed by:

$$Overall\ accuracy\ (a) = \frac{1}{N}\sum_{k=1}^{n} a_{kk}$$

Where:

A = Individual cell values

k+a = Row total

ka+= Column total

n= Total number of classes

N = Total number of samples

5.2.6.1 Landsat accuracy

Accuracy assessment was applied to all land-cover maps produced from satellite imagery by comparison with aerial photography and through Kappa coefficient calculation. After using the methods mentioned previously, the accuracy result for each land-cover map was obtained and summarized in table 5.4. Post-classification analysis, judged to be the most accurate procedure, also had the advantage of indicating the nature of the changes that had occurred.

For instance, the classification accuracy obtained from Landsat 8 2013 image classification was 86%. Classification results were assessed by using the known land-use information obtained from the field during the training stage and the field-sampling survey.

Table 5.4: Classes and points collected for accuracy in the study area of forest land

Classes	Forest	Irrigated land	Rain-fed land	Sand dunes	Settlements	Total
Forest	50	0	6	0	2	58
Irrigated	0	40	2	0	1	43
Rain-fed land	3	0	30	1	0	34
Sand dunes	0	0	1	40	3	44
Settlements	1	0	0	2	18	21
total	54	40	39	43	24	200

Overall Classification Accuracy = (50+40+30+40+18) / 202 = 178 / 200 = 0.89

Expected Classification Accuracy = 8574 / 40000 = 0. 21

Kappa Statistic = (0.89 – 0.21} / {1 – 0.21) = 0.86 = 86%

5.2.6.2 SPOT imagery accuracy

After the fieldwork, including ground truthing, was successfully finished using Landsat time series data to map LC for the whole area of Algarabulli district, a good opportunity was presented to use SPOT imagery which are very high resolution for the years 2010 and 2013, Based on the forest map in 1985, forest maps (nine sheets covering the study area) were used in this study, The first step was to mosaic these maps into one map with georeferencing, then digitize the maps as polygons by selecting forested area only, where these area polygons were projected on SPOT 5 imagery 2010 and SPOT 6 2013 for image classification.

In order to achieve a very good accuracy, SPOT imagery used for forest land and how LCC took place and evaluated how and for what purpose forest land was cleared and made it possible to estimate the rate of deforestation.

An accuracy assessment for SPOT 2013 was conducted by using 291 points, which included five classes: forest high density, forest low density, irrigated land, sand dunes and settlements to develop land-cover maps for the years 2010 and 2013 based on the forest map in 1985.The Kappa coefficient took a value of 0.89 and an overall accuracy of 92.1%.

In addition, to estimate annual deforestation rates, this study adopted the method proposed by the FAO (Souza *et al.*, 2013). The area of forest lost to deforestation is assumed to decrease over time at an exponential rate, given by:

$$r_{(t-1,t)} = \left(\frac{1}{t2 - t1}\right) \times ln\left(\frac{A_{t2}}{A_{t1}}\right)$$

$$D_t = A_{t-1} \times (1 - e^{r_{t-1,t}})$$

For instance, for t = 2001 and t−1 = 200, the annual deforestation rate in the above equation is obtained by:

$$D_{2001} = A_{2000} \times (1 - e^{r_{2000,2001}})$$

5.3 Results and discussion

5.3.1 Land cover (Landsat imagery)

The result of Landsat imagery processing techniques used to produce the land-cover maps for the five classes of land-cover types was clearly visible and occurred from five Landsat (MSS, TM, ETM and OLI/TIRS) images from 1972 to 2013. The change in land-cover classes was not uniform across all classes.

The overall accuracies result of the Landsat classifications of 1972, 1986, 1992, 2002 and 2013 were 82%, 83%, 84%,83% and 86% respectively, with corresponding Kappa statistics of 0.64, 0.65, 0.68, 0.65 and 0.70 respectively. The overall accuracy for each land-cover map was comparatively high; all of them reached more than 80%. The classification accuracy above 73% is often accepted as mentioned in the remote-sensing literature (Lillesand *et al*., 2004).

Land-cover classes used in this study, defined from ground-truthing field surveys, included rain-fed agriculture, irrigated agriculture, sand dunes, forest and settlement (Table 5.5). Positive and negative changes in land cover were found in these areas, particularly in the forest area and the sand dunes.

Table 5.5: Area (ha) of each land-cover class and their percentage from 1972 to 2013

Class	1972		1985		1992		2002		2013	
	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%
Rain-fed	23,014	59.8	15,556	40.4	12,458	32.3	14,160	36.8	17,190	44.6
Irrigated	218	0.6	11,924	31.0	11,212	29.1	10,580	27.5	9,621	25.0
Sand dunes	10,620	27.6	30	0.1	4,360	11.3	5,505	14.3	7,350	19.1
Forest	4,510	11.7	10,530	27.3	9,950	26.0	7,605	19.7	3,350	8.7
Settlement	138	0.3	460	1.2	520	1.3	650	1.7	989	2.6

5.3.1.1 Rain-fed agriculture

In this class, rain-fed lands include areas characterised by natural and semi-natural vegetation; shrubs; fruits such as olives, almonds and figs; and wheat and barley, which depend on rain. This type of land cover comprised 44% of Algarabulli's total area in 2013.

5.3.1.2 Irrigated agriculture

These areas depend on groundwater for crop vegetables and for fruits such as citrus. The area of irrigation was estimated to be 218 ha in 1972; however, it increased dramatically to 15,556 ha in 1985 due to agricultural development projects and the government's support of farmers by supplying equipment and well drilling. However, the area of irrigation then decreased gradually due to water shortages and seawater intrusion. poor enforcement of groundwater abstraction regulations during the last three decades allowed people to drill wells and cultivate any kind of crop they wished, including those that consume a great deal of water, such as watermelons and potatoes.

5.3.1.3 Sand dunes

Sand dunes which include marine and continental dunes, were estimated to encompass 10,620 ha in 1972. However, due to great efforts by the government to stop sand-dune movement, an estimated 50 ha of dunes were converted to forest land. However, dunes appeared again in 1992 due to deforestation.

5.3.1.4 Forest

Forest includes both high- and low-density forest. As stated in chapter two, the plantation forest project started in 1952 in this area and ended in 1974. Planted forests were an estimated 4,510 ha in 1972 and increased to 10,530 ha in 1985 before decreasing gradually due to deforestation (see further information in section 5.3.2).

5.3.1.5 Settlement

Settlement areas represent the urban areas and buildings distributed in the rural area, which have increased from 0.3% of total area in 1972 to 2.6% in 2013.

5.3.2 Land cover change (SPOT imagery)

Land-cover conversions constitute the replacement of one cover type by another as in the case of agricultural expansion, deforestation or changes in the urban extent (Lambin *et al.*, 2006).

The result of the processing techniques used on the SPOT imagery, focused mainly on forests cover and how forests were converted to other type of land cover and to produce the land-cover maps for the five classes of land-cover types was clearly visible.

An accuracy assessment for SPOT 2013 was conducted by using 291 points, which included five classes: forest high density, forest low density, irrigated land, sand dunes and settlements to develop land-cover maps for the years 2010 and 2013 based on the forest map in 1985.The Kappa coefficient took a value of 0.89 and an overall accuracy of 92.1%.

Table 5.6: Area (ha) of each land-cover class in each image and their percentage for 1985, 2010 and 2013

Class	1985		2010		2013	
	Area (ha)	%	Area (ha)	%	Area (ha)	%
Forest	11011	100	7991	72.5	4108	37.3
Rain-fed area	0	0	1580	14.4	3858	35.0
Sand dunes	0	0	1011	9.2	2145	19.5
Irrigated area	0	0	297	2.7	615	5.6
Settlement	0	0	132	1.2	285	2.6
Total	11011	100	11011	100	11011	100

Results indicated that forest cover has been drastically reduced by a conversion to other land use as a result of agriculture, sand dunes and urban expansion.

In the arid and semi-arid areas, the conversion of desert to productive land has become a worldwide issue. In Egypt, agriculture is the core goal for any development strategies and sustainable development planning (Shalaby and Ali, 2010).

It is generally agreed in some region that the world's extensive forested areas are rapidly being converted to agricultural and pastoral use, and that agriculture remains the main direct cause of such deforestation due to an increase in the global food demand (Casse *et al.*, 2004). Comparing the supervised classifications shown in figure 5.2 helped to determine for which land use forest was converted. From the period of 1986 to 2010, 28% of the total area of forest land was converted to another land use, and almost 17.1% was converted to agricultural land (with an irrigated area of 2.7% and a rain-fed area of 14.4%) 9.2% converted to sand dunes and 1.2% was converted to settlements.

Between 2010 and 2013, more forest was cleared for agricultural land: agricultural land represented 40.6% (5.6% irrigated land and 35% rain-fed land) of total cleared area.

An increase in sand dunes occurred that was not seen in 1985, increased from 9.2% in 2010 to 19.5% of the total area in 2013.

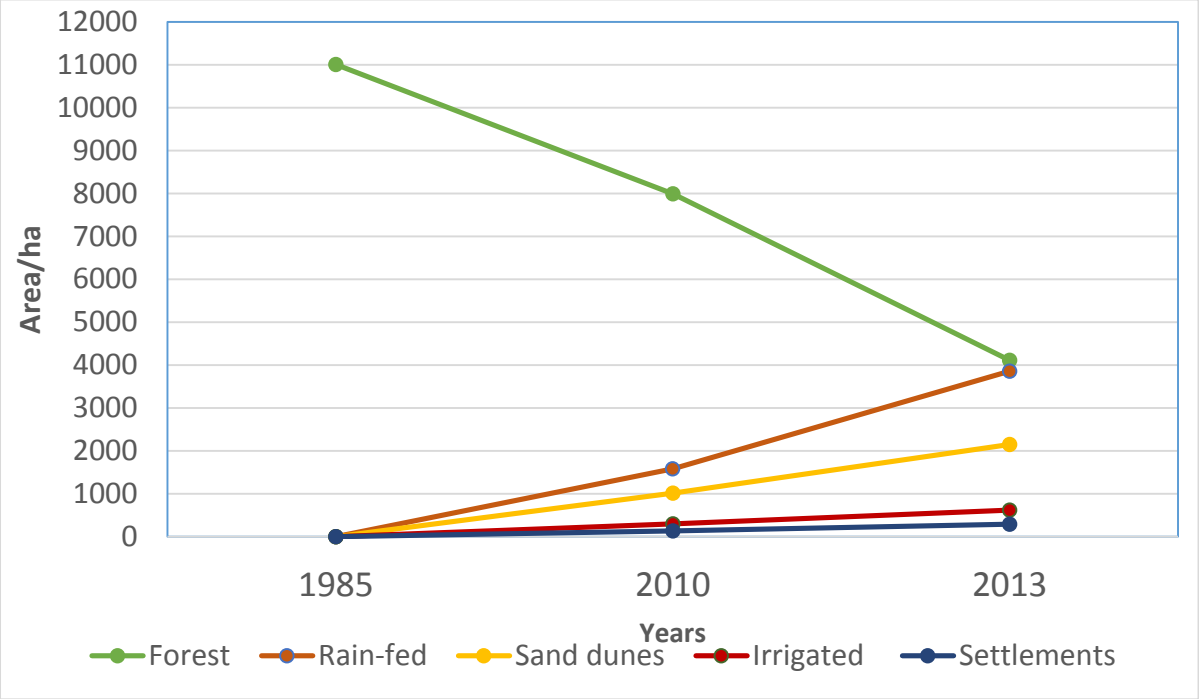

Figure 5.2: Area (ha) of each land-cover class change in the years 1985, 2010 and 2013

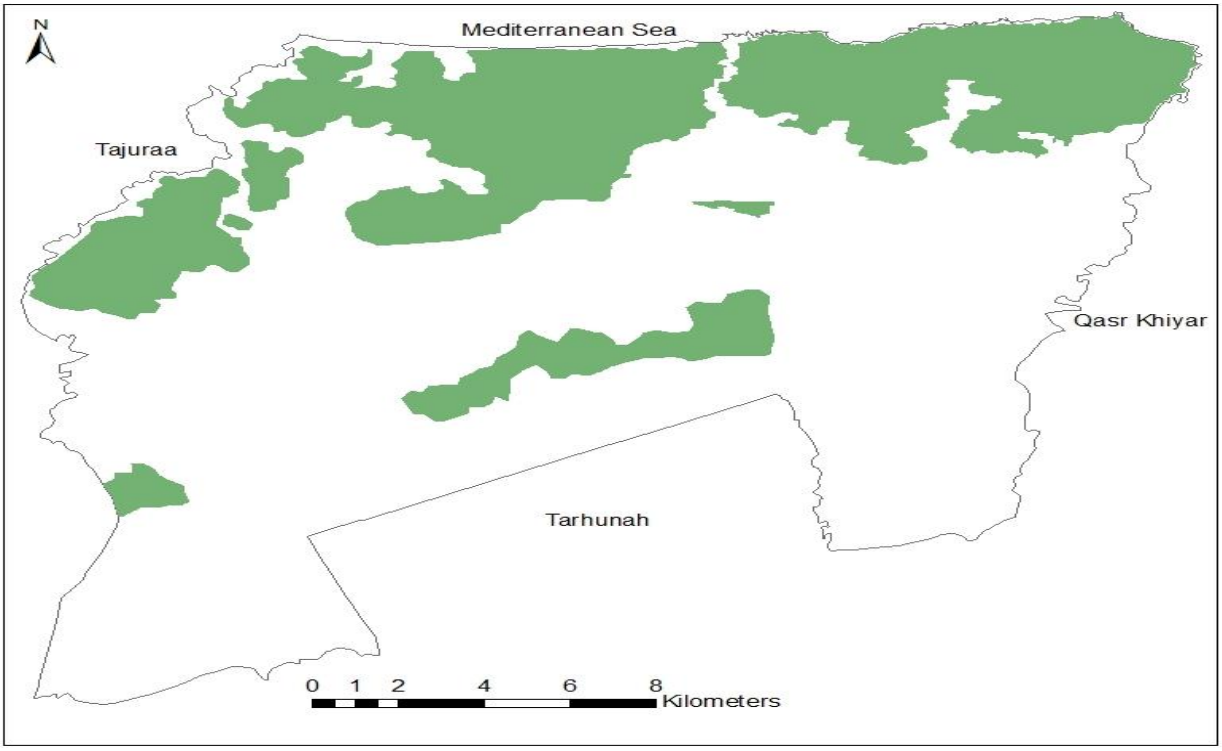

Figure 5.3: Forest cover in the Algarabulli district in 1985 (based on Libya forest map)

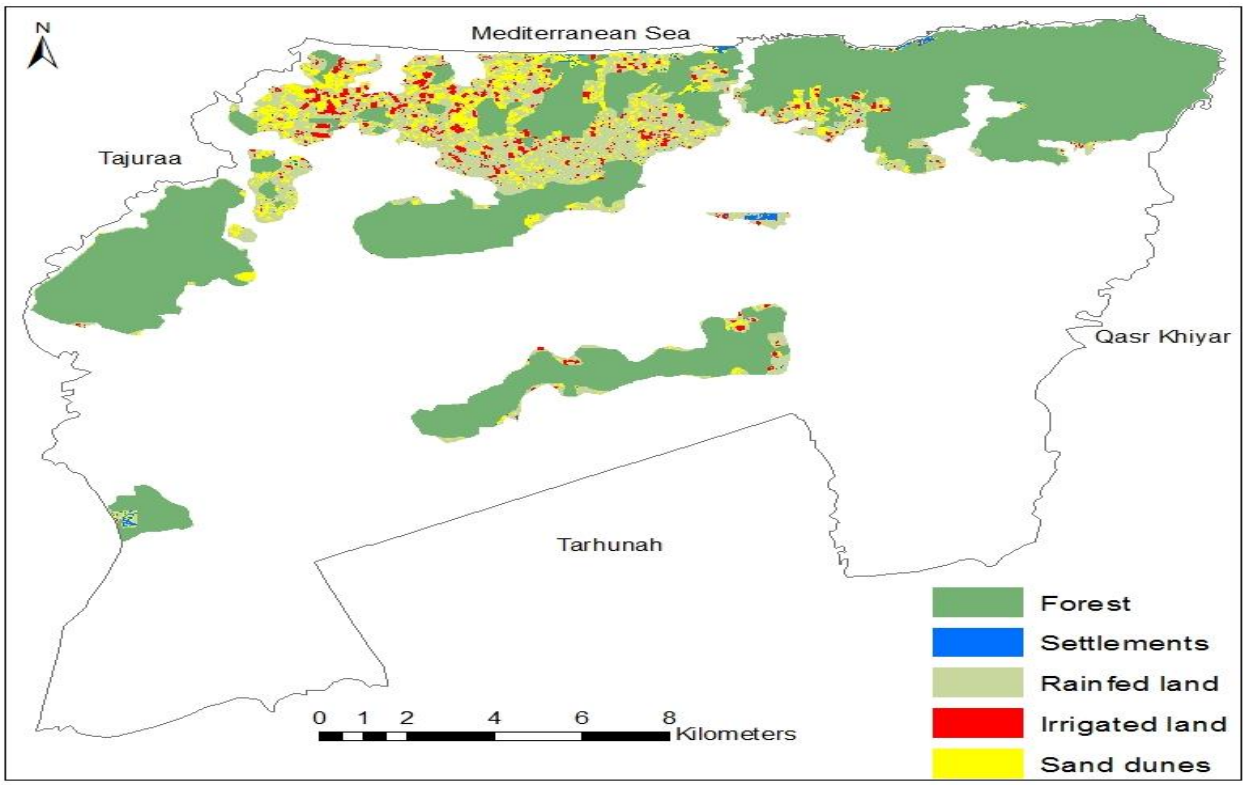

Figure 5.4: Land cover and land use classification in the Algarabulli district in 2010

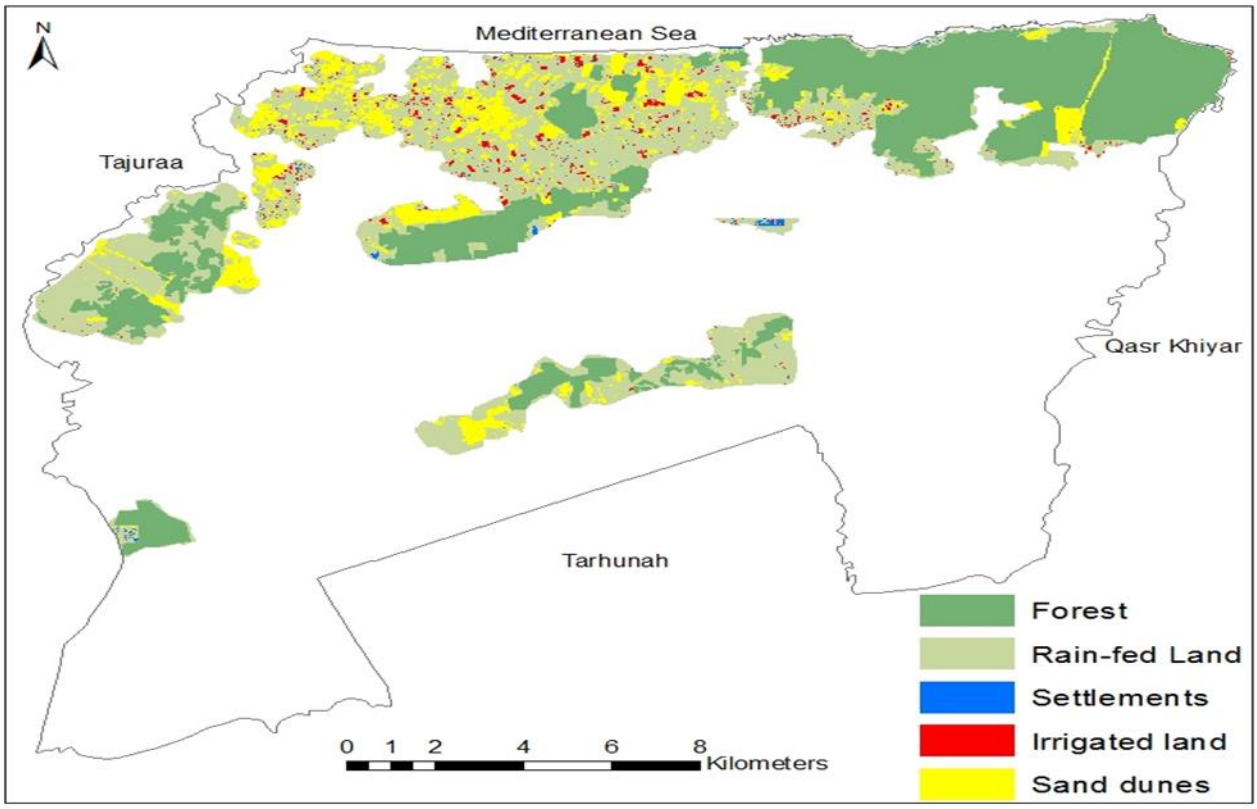

Figure 5.5: Land cover and land use in the Algarabulli district in 2013

5.3.3 Deforestation rate

As a result of supervised classifications in this study, the annual deforestation rate was compared among three different periods (1985–2010 and 2011–2013), which allowed the annual rate of deforestation within 24 years and 3 years to be determined (see table 5.7).

Table 5.7: Annual rate of forest loss in study zone (ha/year) for 1985, 2010 and 2013

Year	Forest area (ha)	Forest as % of total area	Annual forest loss (ha/year)	Annual percentage rate of deforestation (ha/year)	Percent of forest cover remaining	Percent of forest loss
1986	11011	26.5	-----		--------	----
2010	7991	19.2	142	1.3%	71%	27%
2013	4108	9.8	1295	19.8%	36%	35%

Forest area was estimated to be 11,011 ha in 1985 and was estimated to be 7,991 ha in 2010 (after 24 years). As a result of SPOT imagery classification, the annual rate of forest loss was estimated to be 142 ha per year (1.3% per year). Therefore, 27% of forest cover was lost by this time .

In contrast, forests around Tripoli in the northern Jefara Plain were estimated at 14,705 ha in 1986 and were estimated once again at 7,039 ha in 1993 (Kresegh, 2002). The annual rate of deforestation in this period is estimated to be 1,100 ha per year (7.5% ha per year). Because these forests surround Tripoli, they were cleared for urban expansion (El-Tantawi, 2005).

The second period compared 2010 and 2013, covering the period of the uprising. Forest cover was estimated in 2013 at 4,108 ha; as a result, the annual deforestation in this period was very high— 1295 ha per year (19.8%), by 35% of the forest cover was lost.

Comparing the rate of deforestation in 2013 in the study area, which was estimated to be 1295 ha per year, with the deforestation rate in the whole country of Tunis in 2013, which was 2,050 ha, found that the deforestation rate in this area was higher than the deforestation rate in Tunis despite the fact that Tunisia witnessed a revolution in 2011, as Libya did.

If the current rate of deforestation (1295 ha per year or 19.8% year) continues, the area could lose its remaining forest cover by 2016.

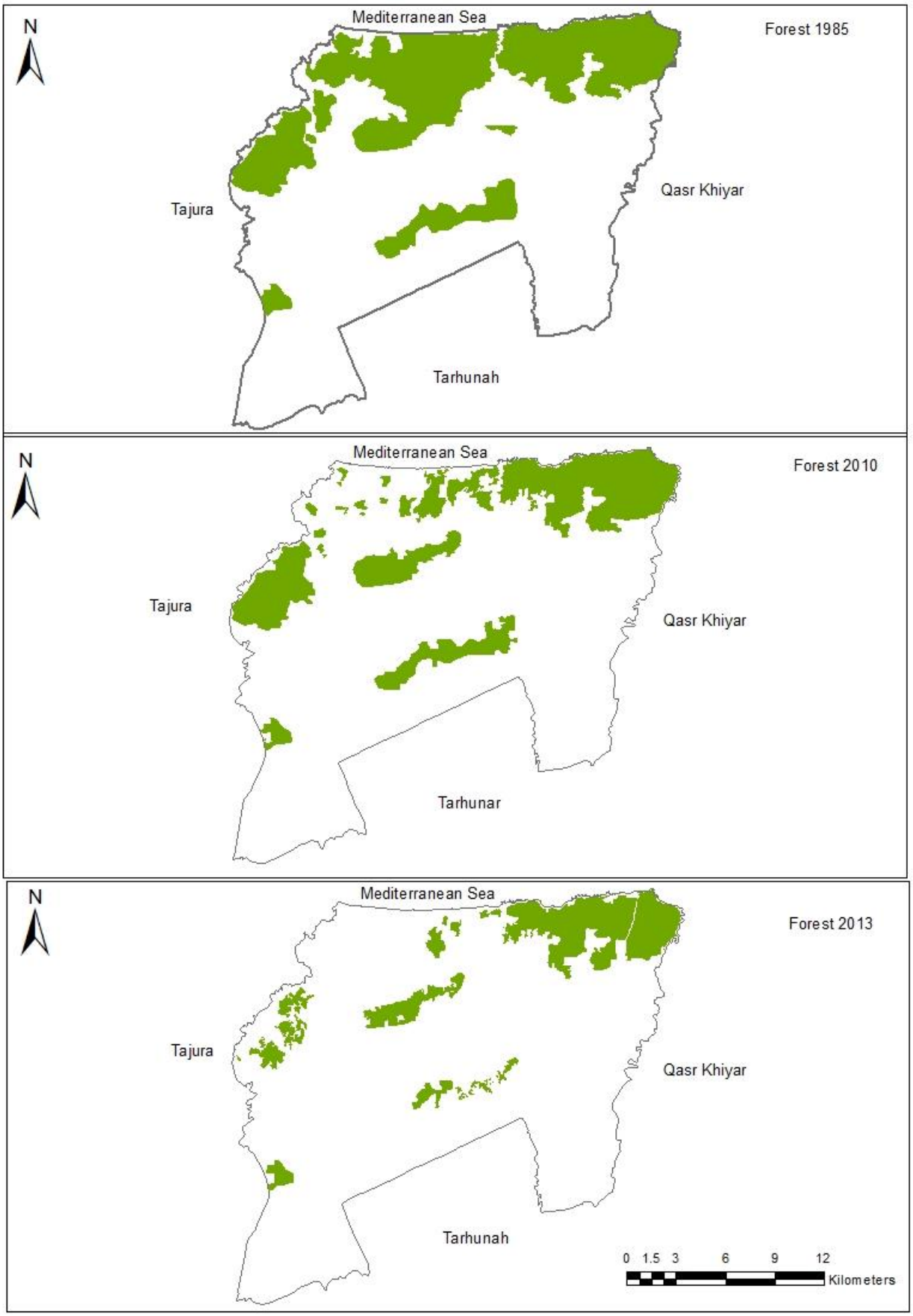

Figure 5.6: Forest cover in Algarabulli District in 1985, 2010 and 2013

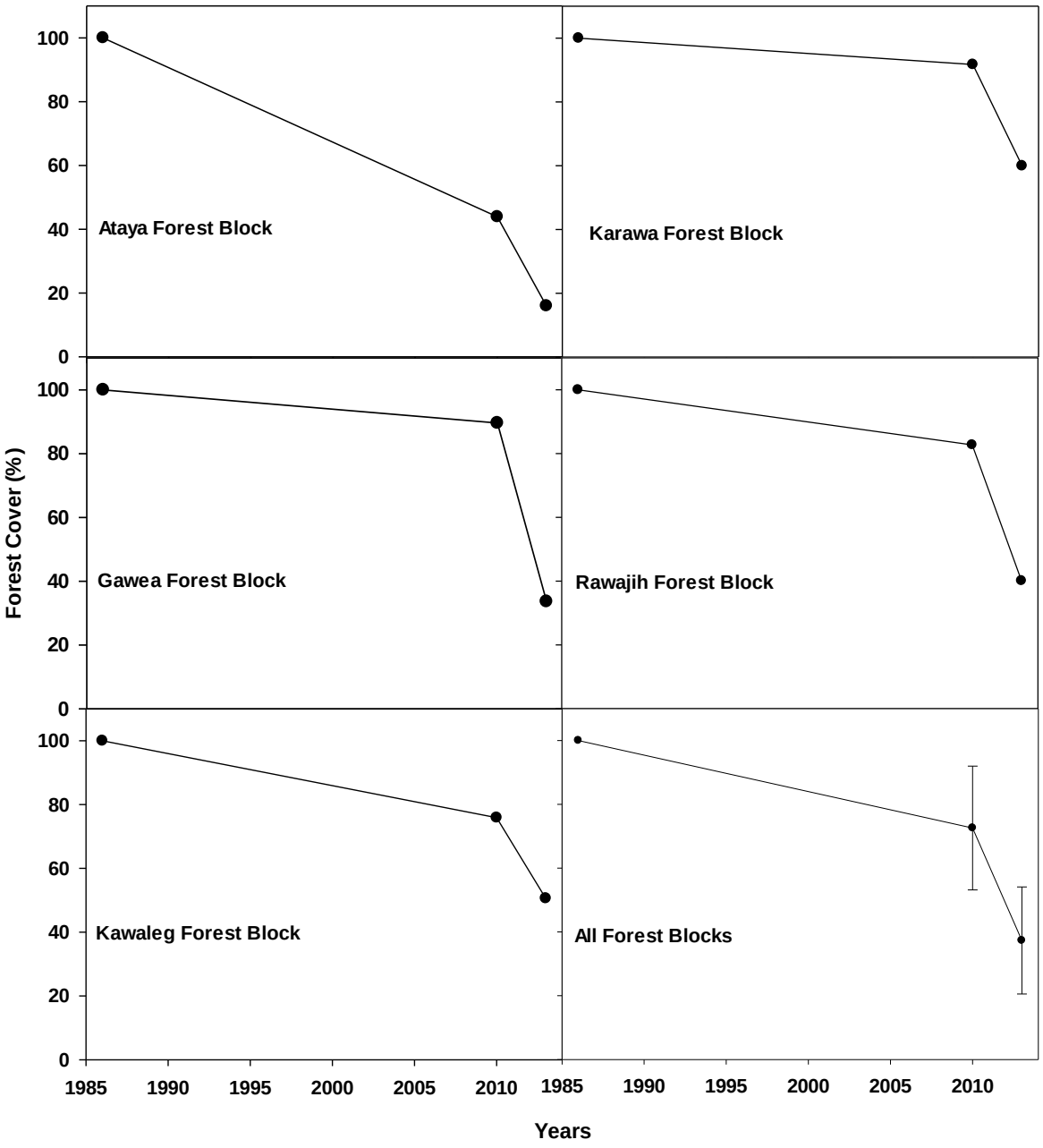

Figure 5.7: Remote sensing (SPOT imagery) estimates of the rate of deforestation in percent between (2010-2013) in all forest blocks: the index of forest clearance in percentage in and the standard deviation the whole area in below figure and forest clearance in percentage in each forest block in figures above.

In addition, the results of the supervised classification map show a clear difference in deforestation rates between the forest blocks in the study area. The rate of deforestation varies from one block to another where each block is located in a different village with a different administration.

When compared to the above satellite image, results of the percent of forest lost in two different periods (before the fall of Gaddafi regime and after) agree with results from the interviews reported chapter three.

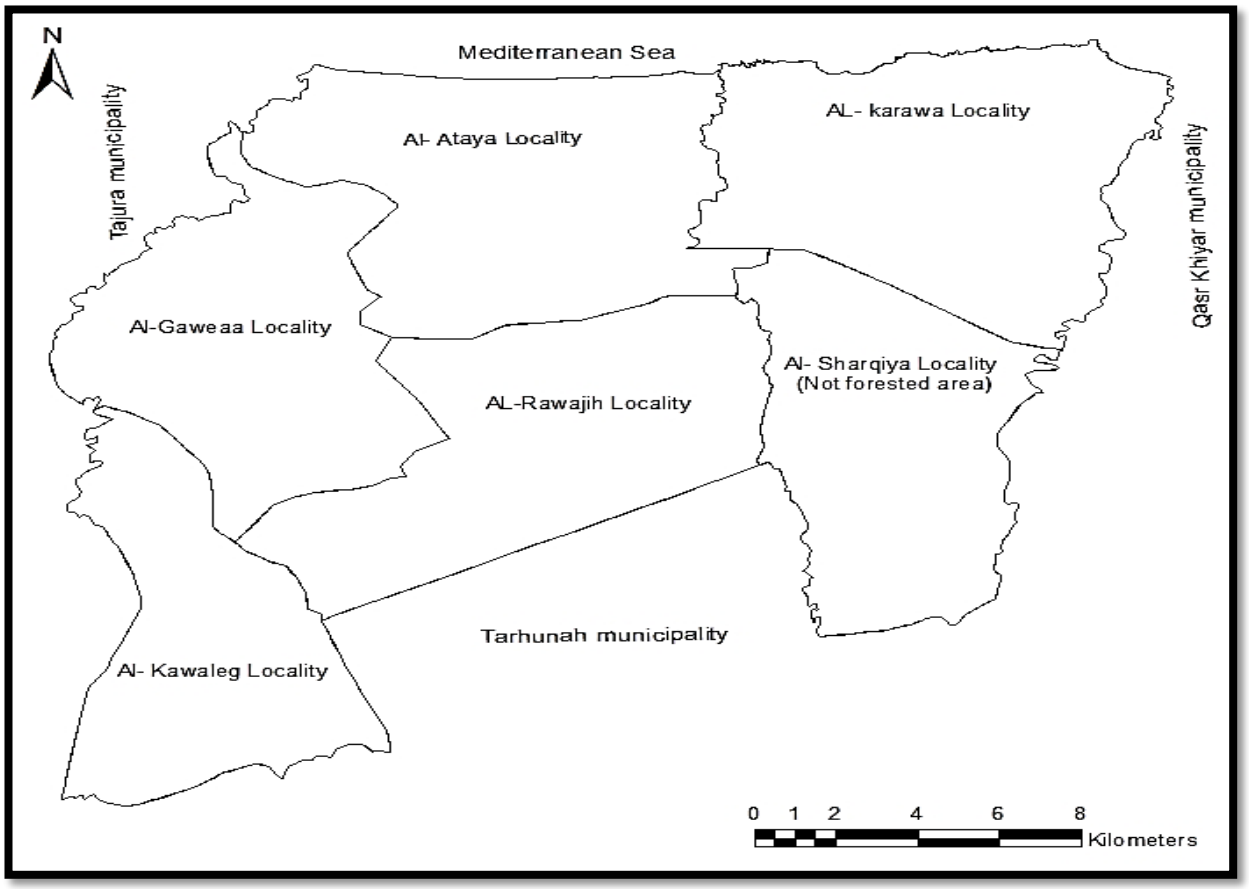

Figure 5.8: Location of the localities within the study area.

The deforestation rate varied from block to block during these two different periods. In the first period between 1986 and 2010, the rate of deforestation was higher in the Al-Ataya than the blocks. It was the biggest block of forest in the study area in 1985, estimated at 4,020 ha, but decreased to 1,766 ha in 2010, with 2,254 ha lost by this time and with an annual deforestation rate at 94 ha per year over this period and 643ha in 2013 with an annual deforestation rate at 374 ha per year between 2010 and 2013.

In other blocks of forest the annual deforestation rate in the period of 2010 was in Alkarawa, Algawea, Alrawajh and Alkawalig forest block at 12, 7, 8 and 3 ha per year respectively, but in 2013 the annual deforestation rate was 398, 327, 173 and 22 ha per year respectively.

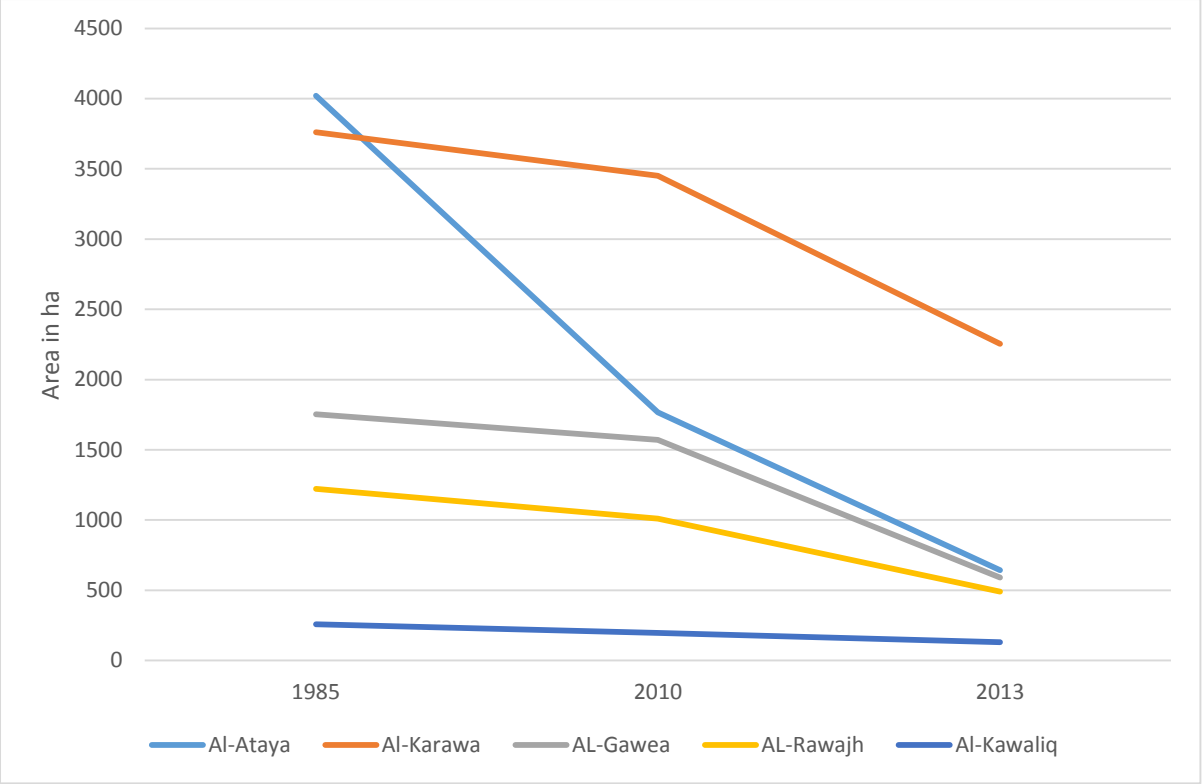

Figure 5.9: Forest area in each forest block for the years of 1985, 2010 and 2013

In addition, figure 5.10 shows the development of road networks in the Algarabulli district between 1985 and 2010, and how the establishing roads have contributed to more deforestation particularly in Ataya forest, as discussed in chapter three.

More maps on forest cover, forest density and land use change in Algarabulli District's localities are presented in Appendices 4 and 5.

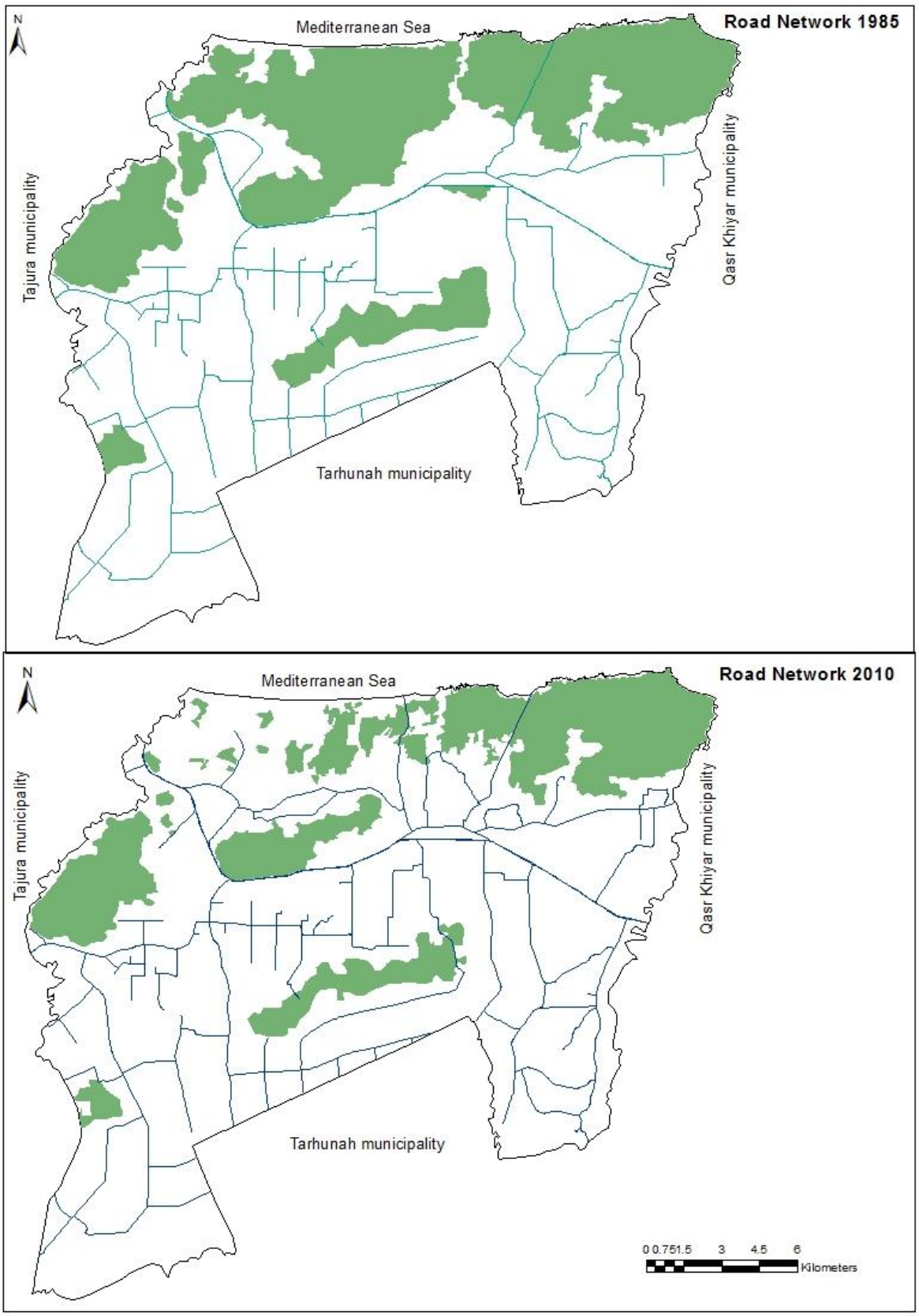

Figure 5.10: The development of road networks in the Algarabulli district between 1985 and 2010

5.3.4 Forest degradation

As well as forest clearance, forests also experienced a reduction in density due to forest degradation. The patterns of forest degradation observed in the field included forest fires, cutting, overgrazing, the death of the trees over time and, because management was stopped, diseases and insects.

High density forest is where there are more than 200 trees/ha and low density forest is fewer than 200 trees/ha (Idris *et al.*, 1993). The results of the supervised classification show the forest degradation rate in table (5.8), the area of high density forest was estimated in 1985 to be 11,011 ha, but in 2010, the high density forest decreased and was estimated to be 1,215 ha, while low density forest increased from zero to 5,791 ha. 52% of forest area was degraded from high to low density between 1985 and 2010. In 2013, low density forest was estimated at 2,182 ha, representing 86% of the total area of the forest and low density forest was estimated at 350 ha. The rate of forest degradation from 1985 to 2010 was estimated at 286 ha per year, or 2.6% ha per year, and was estimated between 2010 and 2013 at 1,609 ha per year or 28% ha per year.

Table 5.8: Forest density during the years of 1985, 2010 and 2013

Class of forest*	1985	2010	2013
High density forest	11011	1215	350
Low density forest	-	5791	2182
Total forest	11011	7006	2532

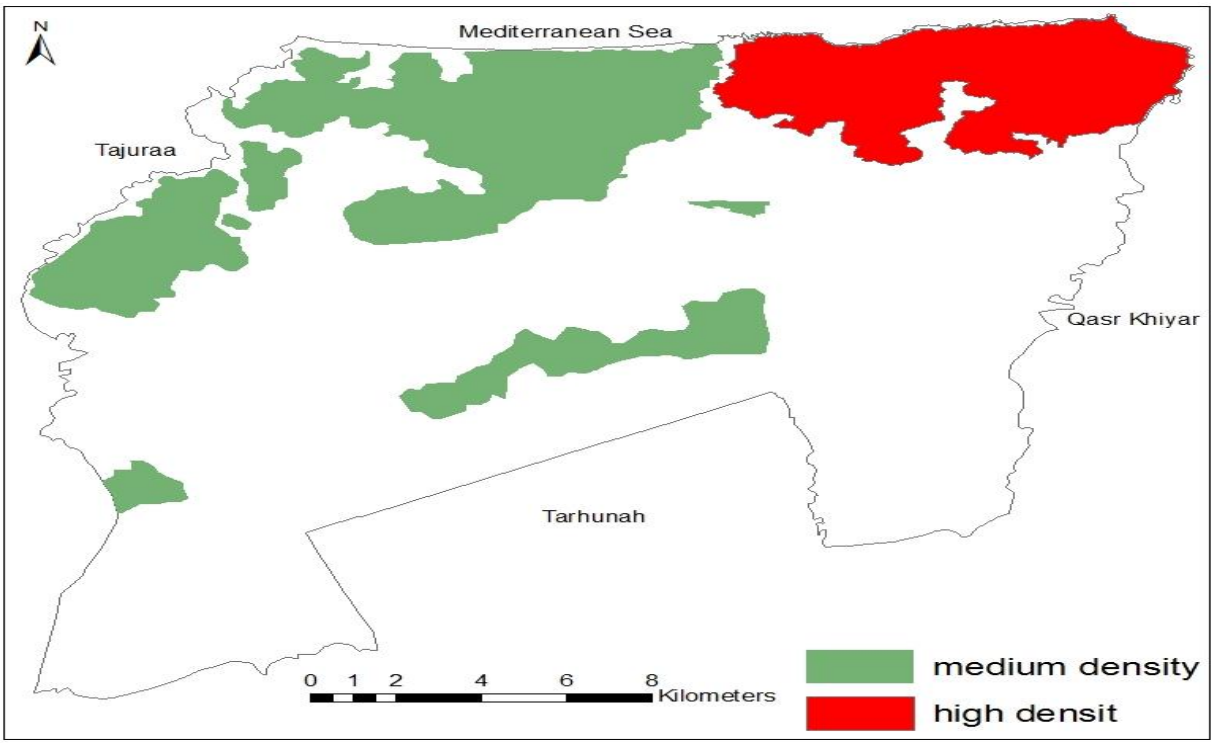

Figure 5.11: Forest cover and density in Algarabulli forest blocks in 1985.

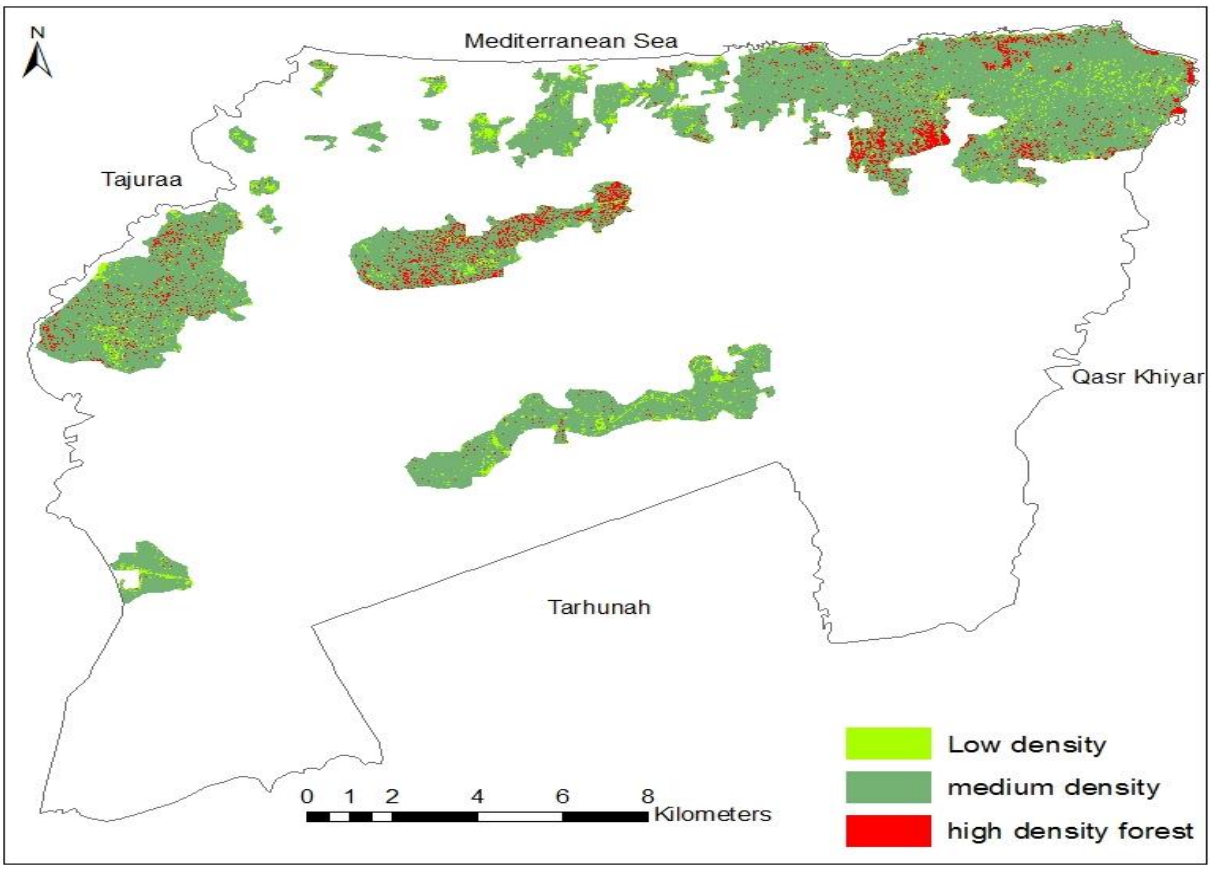

Figure 5.12: Forest cover and density in Algarabulli forest blocks in 2010.

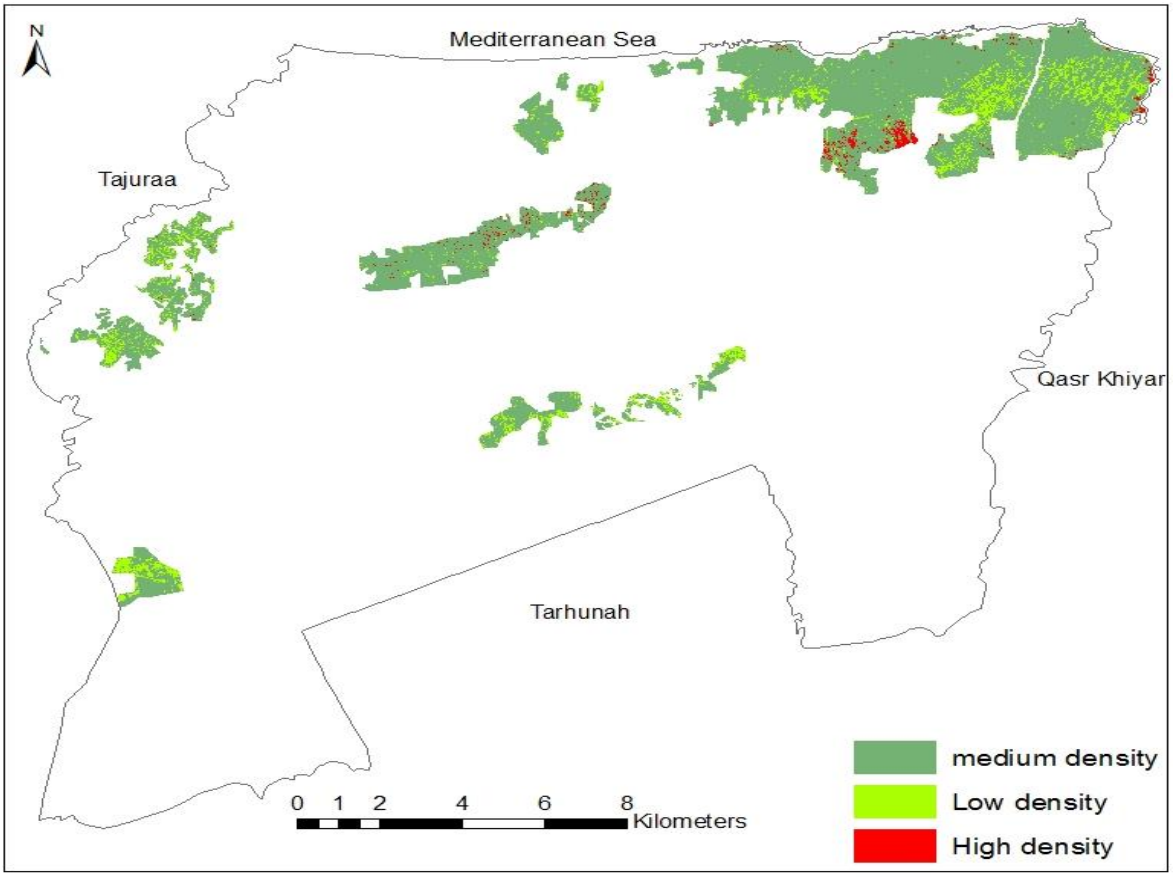

Figure 5.13: Forest cover and density in Algarabulli forest blocks in 2013

In general, forest cover continues to be degraded in all regions of Libya in quality and density (Ben-Mahmoud, 2013). Natural and planted forests alike are under severe pressure due to cutting, overgrazing and fires. Some reports estimated that forest fires in the natural forest in the Al-Jabal Al-Akdar region burned 24,905 ha in the period between 1988 and 2005 (Forestry Department, 2006). Government reports have also found that forest fires increased after 2011. However, no data has been made available estimating how the forest fires happened or providing the forest degradation rates in these areas.

On average, 1% of all forests were reported to be significantly affected each year by forest fires (FAO, 2011a). Forest fires in Tunisia have recently affected a larger surface area compared to previous years (1,700 ha in 2011 and 2,050 ha in 2012). This acceleration is due to a range of factors, such as the lack of forest law enforcement and long-term conflicting relationships between local populations and the forest administration (Daly-Hassen, 2013).

5.4 Conclusions

Remote sensing is a powerful tool for the regional mapping of natural resources. Therefore, the current chapter discusses how land cover was changed using some imagery during the past four decades and the stages of development it was used to supervise classification.

The result shows that, within this period, the land changed from negative (sand dunes before 1960) to positive (forest cover); however, the land cover experienced other changes, from positive (forest cover) to negative (sand dunes again).

The results of supervised classification for land use change and deforestation have shown how the forest land was changed and to which type of land cover forests change.

The deforestation rate of the whole forest area was higher after the 2011-2013 uprising, estimated at 2017 ha/year. The percent of forest loss was 41% of the total forest area; however, within the period 1986-2010, the deforestation rate was 198 ha/year and the percent of forest loss was 37% of the total forest area, where the remaining forest was 22% of total forest area. In addition, the deforestation rate in each forest block is different.

Comparing the estimated rate of deforestation obtained using remote sensing with the respondents' estimated rate deforestation revealed that the two were almost the same.

Currently only 36% of the originally planted forest remains which is also suffering from severe degradation such as selective cutting and thinning. Forest department records showed that forest clearers in the study area numbered just 150 people (representing just 2% of all households) who between them cleared approximately 6907 ha from 1986 to 2013.

If deforestation continues at the current rate, all forest will be lost within three years or by 2016. Due to the total breakdown in governance, deforestation in Libya nowadays is one of the biggest environmental challenges.

The following chapter 6 explains the contribution of Libyan forest policy and management to forest cover change and focused mainly on the forest laws and land laws and why and how forest governance was changed and contributed to deforestation.

6 The Contribution of Libyan Forest Policy and Management to Forest Cover Change

6.1 Introduction

Forestry law encompasses national, regional or international laws, particularly those concerning the conservation of biological diversity, forest management and resource use rights; it also considers legislation on property tenure, the rights of indigenous people and labour and community welfare (Heeswijk and Turnhout, 2013). Forestry legislation comprises specific laws and their implementing regulations for the sector (Schmithüsen, 1986). In some countries, forestry legislation is a very complicated issue because of the existence of an excessive number of laws concerning the same issue (Athanasiadis and Andreopoulou, 2013). Growing concerns have arisen with regard to illegal activities in the forestry sector, and efforts have been made towards understanding the causes and consequences of non-compliance with forestry laws (Foundjem-Tita *et al.*, 2014). In forestry, illegal activities include the degradation of forests and forest-related goods and services; complying with the laws and regulations that govern these activities is therefore crucial in achieving good governance in the forestry sector (Contreras-Hermosilla and Peter, 2005).

Under such laws, illegal forestry activities are defined as spanning a wide range of acts, amongst which are the occupation of forest lands and the illegal harvesting, transportation and trading of forest products (Foundjem-Tita *et al.*, 2014). Although illegal forestry activities are not limited to developing countries, such practices tend to be more widespread and severe in these regions (Suominen and Hansen, 2012). In these countries, laws are an important part of a forestry policy framework (Voitleithner, 2002) and land use development law (Sparovek *et al*, 2012), which is a product of political processes and an instrument for the implementation of forestry policy (Voitleithner, 2002).

Human–forest relations, protection, conservation and forest development are approached under forestry laws with multiple use principles as foundation, with implementation aiming to fulfil the need to plan on the basis of use values (Coşkun and Gençay, 2011).

Compliance with laws plays a critical role in ensuring good governance and sustainable development (Suominen and Hansen, 2012), and 'compliance' is defined as all actor behaviours that respect the prescribed rules that govern specific activities (Foundjem-Tita *et al.*, 2014). Lack of compliance is associated with illegal activities, corruption, inequality and unsustainable use of resources.

Globally, long-standing national efforts have been exerted to enhance forestry law compliance, but this issue has recently elicited increased regional and international attention because of documented high levels of illegal forest activities in many countries, particularly in developing nations (Hansen, 2011). The forestry landscape in these countries is characterised by a long history of non-compliance with forestry law, with violators engaging in extensive deforestation. For example, numerous Brazilian producers have been undertaking illegal or illegitimate operations. Producers typically convert forests into agricultural lands, thereby prompting developed and developing countries to issue forest acts that mandate full compliance with forestry laws (Sparovek *et al.*, 2012).

In some countries, weak law enforcement, combined with corruption and connivance, has resulted in tremendous forestry-related losses. In most Mediterranean countries, forestry laws regulate the management of forest protection services, and this law is particularly strongly implemented in Bulgaria, Croatia and the former Yugoslav Republic of Macedonia (FAO, 2013); in Brazil, forestry law is the most important legal framework for the conservation of most of the remaining 367 Mha of forest in the region (Sparovek *et al.*, 2012).

Definition of 'forest' is critically important because it delineates the scope of forest science (Athanasiadis and Andreopoulou, 2013). Libyan forest legislation has no precise definition of 'forest', but it defines 'environment' in the first chapter of Article 1, Law No. 7 of 1982 under environment protection. In this chapter, 'environment' refers to the realm where humans and all animate organisms (which include the air, water, soil and trees in residential areas) live, work or engage in other activities. The definition also includes all other similar places. This definition indicates that environmental legislation is only a scientific description of any act (e.g. those that involve the use of chemicals and natural or man-made activities) that may directly or indirectly affect the environment.

The government of Libya has been one of the leading developing countries to give due attention to environmental protection, as confirmed by the inclusion of such protection in several laws, legislations and regulatory frameworks. Although Libya has no laws that protect genetic plant resources, it regulates the importation and exportation of plant materials through quarantine and phytosanitary legislation. All plant materials visibly free from any infection can be transported to and from Libya. Furthermore, the country is a party to the 1951 Plant Protection Convention in Rome. The protection laws signed during the convention provide for the protection of forests and rangelands, agricultural lands and trees.

The policy of forest plantations in Libya is intended to combat desertification, stop sand dune movement and protect forest resources. Whether preventing illegal logging or clearance, the government has developed a range of laws and regulations under forest protection legislation since 1947 and has regulated the management of forests and investments in forest trees. The latest law that has been issued is Law No. 14 of 1992, which is still in force but has not been developed or amended.

The research question of this chapter is; how Libyan forest policy and management contributed to forest cover change. Therefore, to address this, the chapter focuses on Libyan forest policy and management - primarily on forest protection laws, land ownership and forest governance summarising relevant laws and decrees issued in Libya. It also evaluates these issues specifically in relation to whether the increased deforestation in the country over the last three centuries is the result of the weak forest protection laws issued and enacted by legislative authorities. These policy-making and regulatory bodies may need to tighten Libyan laws and regulations or modify forest governance, under which the laws are implemented. Vulnerabilities in law enforcement or corruption can strongly constrain sustainable forest management. These problems give rise to an urgent need to control illegal activities or flawed legal/regulatory implementation through initiatives that improve forestry law enforcement and governance. Finally, this chapter seeks to identify whether forest land ownership is determined by law or custom.

To tackle this issue, a review of forest and land laws that were issued with regard to protecting the forest was undertaken, including the resolution. This was then followed by an evaluation of these laws and historical forest management. How forest management was changed, based on interviews with current government officials and legal experts was then investigated.

6.2 Methods

Semi-structured interviews using open-ended questions and face-to-face interviews were conducted with 10 government officials, mainly the Minister of Agriculture, the Deputy Minister of Agriculture, the head of the Forestry Department, the Director of the Environment Public Authority, the Director of the Public Authority for Combating Desertification, and the Director of Forestry Department and Agriculture in the study area. All these interviews were conducted in their offices. Interviews were also conducted with five legal experts in civil law (forest protection laws, land law and the system of land registration), as well as some judges to assess the causes of deforestation in Libya, to determine whether Libyan forestry laws are indeed deficient and to ascertain whether any changes have been applied to forest administration or governance, (see Appendix 2).

Also informal interviews was conducted with five ex-government officials (from the former regime and during the period of the Kingdom of Libya) who were in charge of the Forestry Department from 1951–1969. These interviews were conducted between December 2013 and March 2014.

All the interviews were conducted in Arabic and the selected quotes were translated to English for coding and categorizing patterns or themes found in the qualitative data. All the respondents were guaranteed anonymity.

In addition to interview, archival materials on official reports on forest legislation dating back to 1947 were consulted. These sources were obtained from the Ministry of Agriculture and some of forestry experts.

6.3. Results and Discussions

6.3.1 Libyan forestry law

To prevent encroachment in Libya's national forests, the legislative and administrative authorities of the state issued forestry legislation (for natural and planted forests) and protective measures, followed by decision making on which forests are to be declared as protected areas (FAO, 1955). The first law was enacted during the Italian colonisation, with Italy issuing a Royal Decree in 1930 to protect the forests that had been cultivated by the Italian government in Libya; this law was in effect in Tripolitania state up to 1950 (FAO, 1955).

During the British Administration in 1947, the higher legislative committee of Cyrenaica state issued the first law regarding forest and pasture protection. The law was considered an important deviation from legal and legislative versions and was intended to enable the state to face the challenges presented after the Second World War. These challenges included the poverty experienced in Libya, especially during the British Administration. The aforementioned law was in effect in Cyrenaica state up to 1950, at which period the state then issued Law No. 25 of 1950, another forest and pasture protection law (FAO, 1955). This law was not enacted for technical reasons (FAO, 1955).

Table 6.1: Laws issued to protect forest in Libya.

Act No	Years	Title of text	Comment
1	1947	Protection of grasslands and forests	Abolished in 1950
8	1951	Protection of grasslands and forests	Abolished in 1952
12	1956	Protection of grasslands and forests.	Abolished in 1971
47	1971	Protection of grasslands and forests	Amended with law no75 of 1972
75	1972	Protection of grasslands and forests	Abolished in 1982
5	1982	Protection of grasslands and forests	Amended with Law No. 14 of 1992
14	1992	Protection of grasslands and forests	Still in force

Source: Ministry of Justice /Libya, Information and Documentation Centre.

When the programmes for sand dune stabilisation and forest plantation were initiated, the government issued Law No. 12 of 1956 for forest protection. The formulation and enactment of this law highlighted the need for qualified forestry personnel, thereby prompting the government to establish a forest guardian school in April 1955; the school was later converted into a forest police centre that is mandated to document meetings, submit such records to the current jurisdiction and appeal forestry cases in courts (Aljduaa, 1970).

After the changes of governance system from monarchy to military in 1969, forest protection Law No. 47 of 1971 was issued and then amended with Law No. 75 of 1972, which was abolished in 1982. Under Law No. 47, the most important article is Article 4, which mandates forestry administration and land registry and documentation to compel the registration of forest lands. The other articles covered by Law No. 47 include those that guarantee protection, mandate inspection, impose punishments, fines and liabilities and regulate investments. After Law No. 47 of 1971 was abolished, Law No. 75 of 1972 was issued. Law No. 5 of 1982 was ratified to identify all the forests and pasture lands (whether public or private) over which Libya has jurisdiction.

This law comprises 20 articles on punishments and fines. It restricts plant/tree burning and cutting and the disposal of harmful materials on forests and pasture lands. It also requires land owners to rehabilitate the sand dunes located within their lands and to preserve soil.

In 1992, Law No. 14[27] was amended with Law No. 5 in an attempt to rectify the errors committed by some officials of the agricultural authorities in certain regions of Libya. These errors include the issuance of usufruct contracts for forest areas. Article 1 of Law No. 14 stipulates the adaptation of some Law No. 5 articles on the operations of regulatory authorities and illegally issued usufruct contracts. Article No. 23 of 1992 indicates the following:

1. A Fine of not less than 1000 LD and not more than 3000 LD shall be imposed on those who disobey the rules stipulated in Articles 6,7, 14, 16, 17 and 22 of this law.

Articles 6 and 7 prohibit investment in forest trees, especially those located in areas that are declared as conserved forests, without Ministry of Agriculture resolution that outlines investment conditions. Article 14 prohibits setting fires in forests and pasture lands or in sites that are less than 200 m away from such lands without obtaining written consent from the Agricultural Inspection Centre. Article 16 prohibits the cutting, collection, burning, transport or extraction of forest or pasture materials for production. The article also forbids forest cleaning, cultivation or ploughing for any reason, as well as the construction of buildings and the closing, construction or establishment of roads, paths or water canals. Finally, Article 16 prohibits the installation of traps or nets on forest or pasture lands, the use of firearms, toxic materials or explosives and the discharge of materials that can affect forests or pastures.

[27] This law considers that all usufruct contracts that are awarded on forest lands are illegal.

Article 17 forbids the destruction, removal and transport of forest and pasture materials, installation of signs or separating fences and installation of information signs or signs that indicate forest or pasture production on the edges of the lands in question. It also prohibits modifying or destroying existing marks or signs regarding wood/forest or pasture production.

Article 22 mandates the abolition of activities that negatively affect forest lands, such as the issuance of usufruct contracts and the revocation of all such registrations. This article also covers effective packing regulations and the demolition of all buildings and establishments that are erected on forest lands, with expenses charged to violators. Article 22 can be used as reference in turning over issuers of usufruct contracts to the jurisdiction of authorities who can apply sanctions in accordance with the legislation in force. Another specific stipulation in the article is as follows:

2.A fine of not less than 100 LD but not exceeding 200 LD shall be imposed on anyone disobeying Article 21 rules, which declare that anybody who wishes to cut or invest in trees via a forest usufructs should obtain a license from the Ministry of Agriculture. The applicant should declare his/her reasons for wanting to cut and invest in trees and to outline procedures that should accord with the regulations indicated in the license. Otherwise, all such activities will be deemed illegal.

Several other resolutions have been issued by the executive administrative bodies of the state. These resolutions revolve around forest protection and the prevention of deforestation, for which the Ministry of Agriculture is the administrative managing body. These resolutions, which were issued by the General Popular Committee on Agriculture and Land Reform, are as follows:

Table 6.2: Resolutions issued to protect forest in Libya

Resolution No	Year	Title of text	Purpose
3	1984	Forest and Pasture Protection	Actions necessary to protect forests and pastures from fire
127	1990	Forest and Pasture Protection	Protection of animals and forest trees
676	1993	Forest and Pasture Protection	Stipulates the rectification of harmful acts imposed on forests lands

In addition to a series of agreements on environmental protection, the agreement drafted during the Rio Convention on Biological Diversity was signed by Libya in 1992 and ratified in 2002 (Jibril, 1999). When Libya became highly vulnerable to desertification and land degradation problems, the government ratified the laws indicated in the United Nations Convention to Combat Desertification on 22 July 1996 and assigned the People's Committee of the Agriculture General Authority as the focal regulatory body (Jibril, 1999).

The Forest Law Enforcement is amongst the recent attempts to combat deforestation and promote the crucial role of the state in such endeavours; it focuses on law enforcement and sustainable forest development (Heeswijk and Turnhout, 2013). In some countries, many forestry laws are unenforced or under-utilised and that non-compliance can be attributed to five general factors: (i) flawed policy and legal frameworks, (ii) low enforcement capacity, (iii) lack of information about forest resources and illegal operations, (iv) corruption and (v) high demand for timber (Hansen, 2011). In Cambodia, for instance, the deficiency of current forestry laws is one of the factors that contribute to increased deforestation by illegal logging or illegal occupation of forest lands (Callister, 1999).

Table 6.3: International Convention that Libya signed on

Convention Name	Place of Convention	Date	Date of ratification	Contractor
International Convention for the Protection of Plants	Rome	06/02/1951	18/05/1972	The Ministry of agriculture
International Convention on Biological Diversity	Paris	05/06/1992	2001	The Environment Public Authority
United Nation Convention to Combat Desertification	Rio de Janeiro	17/06/1994	22/07/1996	National Committee to Combat Desertification

Libyan forestry laws have been enacted and conceived as instruments that guide sustainable forest management, the manner by which forests and forest lands are protected and the strategies that local people adopt in complying with government-imposed procedures. A significant finding, however, is that the main causes of increased deforestation are governance decisions that contradict certain laws. The problem therefore resides not in the legal provisions *per se*, but in their application. In Romania, for example, more than 60% of forest areas have been lost—a decline that began in 1990—not because of controlled exploitation, but because of forestry-related crimes, of which the most important is corruption (Măgureanu, 2013).

To assess the forestry laws and resolutions that have been issued to protect the forests in Libya and still in force and to determine whether they are suitable for application or why they have not been applied, focus group discussions with five legal experts and five officials in the current administration were conducted. The legal experts pointed out that all the laws issued are sufficient measures for forest protection and are continually updated or developed in accordance with current forest protection legislation. Most of the articles under the current laws favour the prevention of forest encroachment. However, the government officials stated that the current laws have not been applied in accordance with the stipulations, especially in terms of imposing the fines (100–200 LD) and punishment measures indicated in Article 23. The officials considered the fines to be ineffective because individual incomes have exponentially increased 100% over 1992 levels. They also stated that the fines cover forest clearing, for which a clear definition of punishable clearing scope has not been provided. Thus, the punishment for violators clearing a 1 ha site is the same as that imposed on violators who clear a 15 ha area; such incommensurability increases the persistence of forest clearing because violators do not fear sanctions.

Except for the issues discussed above, all the focus group participants agreed that the laws are sufficient measures for forest protection when ownership is clear. In terms of application, however, previously effective governance has declined to a poorly implemented approach given the constant interference of higher authorities in forestry policy making. The respondents highlighted the need for good governance and the fact that most articles under the act 14 of 1992 has not been applied yet. The current government officials and legal expert respondents explained that the non-application of this act is due to corruption by some ex-government officials in the Gaddafi regime era, who have become forest clearers and have illegally obtained forest lands. These corrupt individuals hinder the application of the laws or violate the regulations issued by legislative authorities by taking advantage of the contradictions between governance decisions and the laws. Despite the issuance of several ministerial resolutions that support their application. The most important article that has been disregarded is Article 4, which stipulates the following:

- Forest land must be registered in the Land Registry Centre.
- Usufruct contracts issued in forest lands must be abolished.

6.3.2. Administrative status of forests in Libya

As previously stated, many Libyan laws were enacted to protect the country's forests, but application is extremely limited and does not correspond with legal stipulations, that is, with regulatory and judicial authorities taking active jurisdiction over application. According to the focus group of law experts and forest officials, changes in forest governance, and not weaknesses in the laws, are the causes of increased deforestation.

This section explains how forest governance has changed (from effective to ineffective) and how such change has affected Libya's forests.

The manner by which forests are governed influences the extent of deforestation that is caused by various factors (Umemiya *et al.*, 2010). Internationally recognised problems, such as illegal logging and uncontrolled deforestation, are increasingly attributed to weak governance structures (Monditoka, 2011),and weak forest governance is regarded as a major constraint in planning for sustainable management (McNeill *et al.*, 2014).

The issue of governance is gaining importance in the forestry sector. Good governance often pertains to the desired qualities of governing institutions; these qualities include transparency, absence of corruption, effectiveness and adherence to forestry rules (Muller and Tuomasjukka, 2010). Forest governance refers to new modes of regulation in the forest sector, such as decentralized, community-based and market-oriented policy instruments and management approaches (Arts *et al.*, 2014), and different governance-related problems have been identified. These problems include corruption, political instability, lack of capacity, lack of transparency, weakness of institutions and accountability, low motivation, unclear regulations and conflicting laws (Muller and Tuomasjukka, 2010). Weak governance in the forest sector engenders a negative image, which in turn, adversely affects the willingness to protect and invest in the sector (Muller and Tuomasjukka, 2010). Good governance and effective institutions at all levels of the forestry sector have been particularly recommended as important drivers of sustainable forest management (Foundjem-Tita *et al.*, 2014).

Before its independence in 1951, Libya was considered to consist of three provinces (or states), Tripolitania in the northwest, Cyrenaica in the east, and Fezzan in the southwest, each with a governor and an administrative body. The first forestry department was established in Cyrenaica during the British Administration in 1946. The role of this department was to protect natural forests in Al-Jabal Al-Akdar of the state of Cyrenaica .

After the acquisition of independence, the Ministry of Agriculture was established, thereby prompting the establishment of forestry departments in Tripoli, Fezzan and Cyrenaica states. The roles of forestry departments continued to revolve around forest protection, but in Tripoli state, the forestry department began developing programmes for sand dune stabilisation and forest plantation to combat desertification. For this purpose, the Tripoli forestry department sent employees overseas for training on sand dune stabilisation and afforestation. The first group returned to Libya at the end of 1952. At the time, therefore, the Tripoli Forestry Department was considered one of the most important administrative bodies in Libya. The department prepared well respected and authoritative reports and conducted research on sand dune fixation and afforestation; from the end of the 1950s to the early 1960s, Libya was regarded as a pioneer in the field of sand dune stabilisation and afforestation (FAO, 1955).

Abolition of the three states and unity was declared in Libya in 1963, during which the country was renamed the Libyan Kingdom. The Ministry of Agriculture and Animal Wealth was established with three sub-division, and each deputy was responsible for managing a region in adherence to the regulations of the main forestry administration in the ministry at Tripoli. The forestry administration continued to prepare reports and conduct scientific research on sand dune stabilisation, which was the most significant challenge confronting forest administration at that time. The Libyan forest experts implemented a number of dune stabilisation methods, in which new approaches that feature the use of crude oil was adopted. This approach was later applied in many countries and was globally referred to as the ‘Libyan experience’. A retired Libyan forest expert indicated that forest management during the period of sand dune stabilisation and afforestation was extremely difficult (1952–1970). For instance, if the success percentage of afforestation was less than 80%, the project inspector responsible was interrogated and severely punished. He also stated that 90% of the reports and studies conducted by the forestry administrative bodies were carried out before 1986.

In 1972, a new body with functions equivalent to those of the Ministry of Agriculture was established which is the Agricultural Development Council aimed to increase cultivated areas by reclaiming land and controlling desertification. As an independent body, the Council executed its independently developed agricultural schemes, separately from the forestry department of Ministry of Agriculture, which contributed to the sand dune stabilisation and afforestation programmes of the 1970s.

The Agricultural Development Council, which participated in sand dune fixation and afforestation but did not interfere in forest management affairs, was abolished in 1982. Forest management was the exclusive domain of the Ministry of Agriculture, which successfully participated in all activities, economic, legal and social, including scientific and technical endeavours that were particularly intended for sand dune fixation, afforestation and organisation of forest protection laws. The Ministry employed forest police, which had jurisdiction over seizure proceedings and was equipped with a fleet of cars and equipment to be used for protection. Up to 1986, the forest police used cars, motorcycles and horses in inspecting and observing encroachments on forests. The Director of Forestry Department in Algarabulli district indicated that the outcomes of policing were the effective prevention of forest land encroachment (zero violations recorded, excluding a few cases involving shepherds) and the delivery of severe punishments. These achievements were possible because unlike the current context in Libya, the forestry department in office at that time was unencumbered by the negative effects of nepotism.

Forest administration began experiencing a dangerous decline when higher state authorities abolished the Ministry of Agriculture in 1986, after which the agricultural sectors in all Libyan regions were managed by the sector directors. The effectiveness of the desertification measures that had been implemented for the past 35 years gradually diminished, because the Director of Agricultural sector in Tripoli municipality (which has, within its boundaries, large forest tracts that also span the forests of study area) was instructed to issue usufruct contracts for some state officials. The forest guard, which was the cornerstone of forest protection, was also abolished, thereby resulting in failed protection efforts.

Considering this context, one of the forest experts in the focus group stated that after the issuance of usufruct contracts, he and some of his former colleagues in the forestry department of the Ministry of Agriculture resigned and some transferred to other sectors when they opposed the newly imposed procedure. The 2013 deputy of the Ministry of Agriculture indicated that the issuance of usufruct contracts for forest lands was initiated by the Committee of Military Farms. The Ministry of Defence followed suit, allocating some of the forest lands by the army in 1986 after the American bombings. Responsibility for the administration of these forest lands was transferred to the Ministry of Defence, which began granting the lands to some officers in July 1986. In late 1986, the agricultural sector in Tripoli municipality issued usufruct contracts for forest lands to some then-serving state officials.

The 2013 deputy of the Ministry of Agriculture also averred that because of the continual demands from some organisations and countries, such as Italy and Greece, for Libya to limit activities that harm forests, the previous regime in 1992 assumed the role of a Libyan patriot and went by himself to the police centre to report the agricultural sector officials in Tripoli municipality as having destroyed forests through the issuance of usufruct contracts. A few days after the report of the previous regime, the Ministry of Agriculture was tasked to immediately resume work on legislation and issued act No. 14 of 1992. As previously mentioned this law is devoted to forest and pasture protection, is an amendment of act No.5 of 1982, which remains in force. The most important article of act No.14 is Article 22, which stipulates the withdrawal of all forestry-related actions, such as the issuance usufruct contracts. This law inspired hope amongst forestry employees with regard to rectifying administration errors, regardless of whether these were intended to destroy Libyan forests. The forestry department also resumed work, with its employees committed to reviving as many of the previously established efforts as possible. Despite the advantages presented by Law No. 14, however, the 2014 Director of Forestry Department indicated that that this law, especially Article 22, has yet to be applied.

One of the forestry experts interviewed stated that technically, Article 22 is currently inapplicable given that most of the forest areas in Libya have been cleared for other land uses. Under the act No. 14 of 1992, only Article No. 2 of Article No. 28 has been executed in the court trials of contract issuers. Nevertheless, even though violators were subjected to court trials and imprisoned, they were released after a few months. This situation has driven people to consider such proceedings as superficial shows of implementation, designed only to exhibit that the Gaddafi regime denounced the forest encroachment caused by usufruct of contract issuance. Some of the government officials working in the forestry department pointed out that these actions directly or indirectly facilitated the prevalence of corruption in forest protection and investment in forest wood. Corruption took on many forms, including bribery.

The 2013 deputy of the Ministry of Agriculture declared that the issuance of usufruct contracts for forest lands was discontinued for three years (1993–1996), but at the end of 1996, the Gaddafi regime modified the existing policy into an administrative approach wherein municipalities and corresponding facilities are to be managed by army officers. This change was considered a shift from civil administration into military management, under which the trend of increased forest destruction continued.

Tripoli municipality's agricultural sector coordinator, who was a military official from 1997 to 2000, started issuing numerous usufruct contracts and implementing agricultural projects owned by the state.

The deputy also stated that the Ministry of Agriculture was re-abolished in March 2000 and authorities were assigned to the respective sectors, which were managed by military officers. Under this structure, new allocations were apportioned as usufruct contracts, numerous usufruct contracts were issued and issuance was implemented not only by the Ministry or the agricultural sectors, but also by state officials. After five years, a ministerial resolution that reinstates the Ministry of Agriculture was enacted in 2006, but the jurisdiction of military officers over agricultural liabilities remained in force.

Some of the legal experts participating in the focus group discussions argued that the administrative and legal contradictions in the manner by which authorities allocated liabilities were a factor in the destruction of Libyan forests. The experts criticised the creation of an agricultural policing body through a ministerial resolution under No. 131 of 2006 (encroachment limits) as an erroneous decision given the technical conflicts in liability allocation between this policing body and police centres. Another contention of the experts was that reinstating the forest guard would have been a more effective measure.

With regard to forest management in the studied region, these employed for such purpose were unable to execute their work. Such inability is attributed to the lack of financial and technical support, such as the provision of cars for monitoring encroachment-prone areas on forest lands.

According to the administrative structure, forest encroachment monitoring must first be undertaken by the employees of the forestry department. Upon witnessing deforestation activities, they are to prepare a report, which should include details such as location of encroachment, name of violator (forest clearer), size of cleared area, duration of clearing and tools used for clearing. The report should then be submitted to the agricultural policing body. The manager of the forestry department in Algarabulli district revealed that corruption impedes the success of this process; the reports that are referred to the agricultural police are perfunctorily addressed and the claims submitted or the forest clearer in custody is transferred to another jurisdiction after police officers are bribed. Between 2006 and 2010, the number of encroachment cases that were recorded and referred by the forestry department in Algarabulli district was about 40, but only 10 reports were referred by the agricultural police to the

corresponding jurisdictions. To limit encroachment, the Prime Minister issued Resolution No. 442 in 2007 and another resolution in 2008 for the rapid implementation of the resolution.

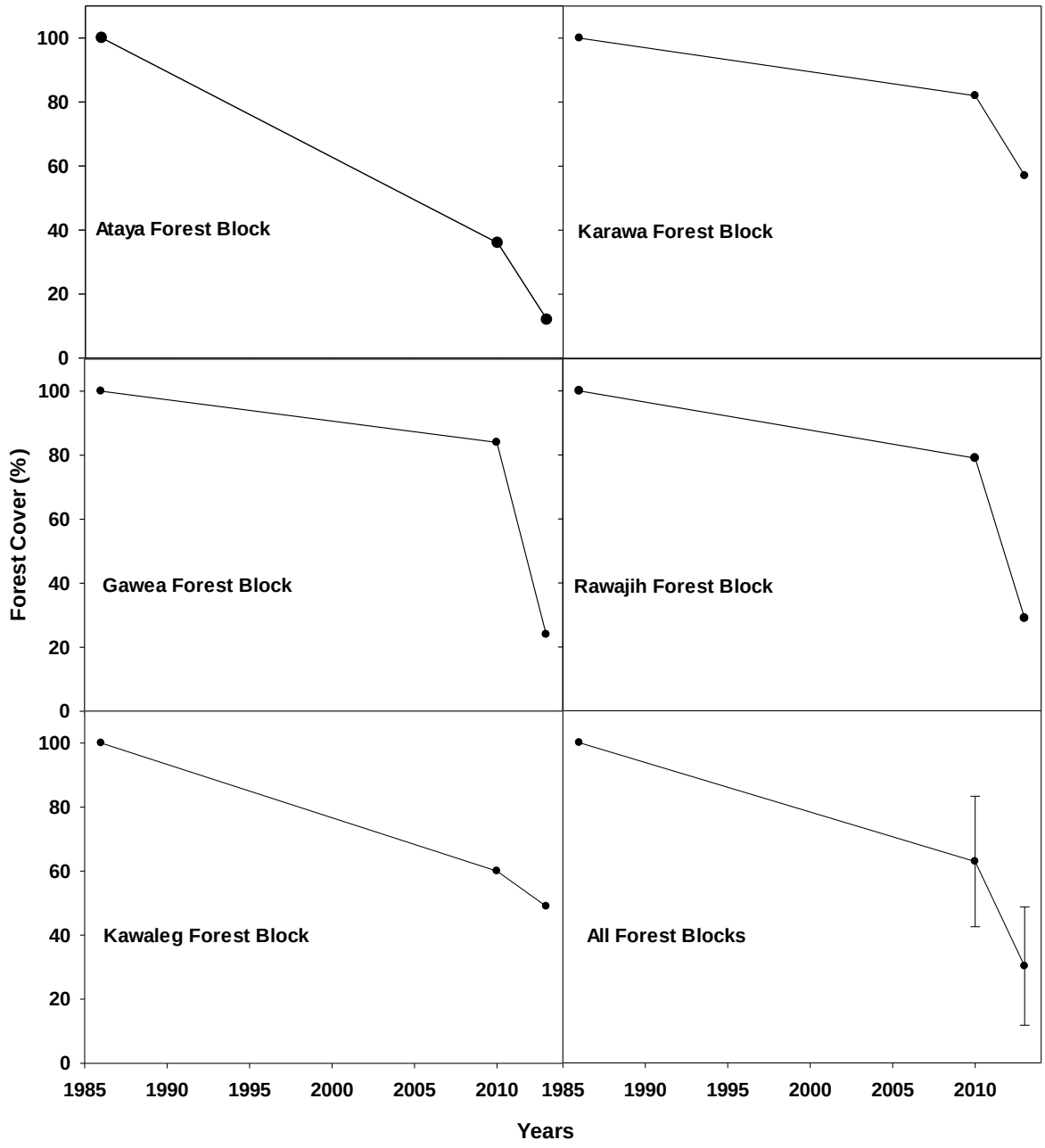

Figure 6.1: Index of forest clearance in percentage (standard deviation in brackets) in the whole area and in each forest block. Source: Forest Department Records (1986-2013).

The decline of governance from being an effective to an adverse approach is influenced by a number of factors. Under good governance, the forestry administration and the Ministry of Agriculture successfully implemented the planting of trees in a huge forest area in Jefara plain. This area was also effectively protected from encroachment through adherence to the rules stipulated in the then-in effect forestry law and policy.

The World Bank defines 'corruption' as the abuse of public office for private gain (Callister, 1999). In the Cambodian forestry sector, for instance, corruption persists because of lack of transparency and accountability in timber concession allocation policies. The Indonesian sector similarly suffers from the absence of effective concession management planning for forestry and regulatory frameworks (Callister, 1999) because of various factors such as widespread corruption in government institutions and decreased government control over the intensity of illegal logging after the fall of president Suharto (Heeswijk and Turnhout, 2013). In Bolivia, illegal forest clearing was extensive but is currently decreasing because of improvements in the implementation of forest legislation in the country (Pacheco, 2004). On the whole, forest management in developing countries is confronted with problems that limit these countries' ability to carry out their mandates.

With regard to the situation faced by the forestry department after the February 2011 uprising in Libya, the 2014 minister of agriculture stated that despite the disgrace that the forestry departments and agricultural police attempts conducted by the Ministry, security problems and the arms spread have restricted control over forest encroachment. The state is currently unable to effectively protect Libya's forests.

6.3.3 Property rights and tenure systems

In the recent era, property rights, tenure systems and land usufruct standards in the entirety of Libya have been grounded on traditions and social morals that are based on Islam. Islamic values place a premium on supporting friendship and cooperation amongst individuals because they are the basic entities of society, and the general relations between human beings are represented by tribal affiliations, which form the backbone of the social structure of Libya (Jibril, 1999).

The dry climate conditions of Libya play an important role in the formation of its fragile environment and natural resources. In turn, these characteristics considerably affect the economic structure of Libyan society, which is characterised by a long history of herding as the primary economic profession. To compensate for the decreasing number of pasturable lands, Libyans maximised the distance that they covered in shepherding by leading nomadic lifestyles (i.e. they camp out in a given location and move once the resources of this location are exhausted). This practice was adopted for a long period, eventually becoming a social norm, with Libyans living their lives as desert inhabitants and creating a unique method of group ownership. This ownership method was designed to promote understanding and a peaceful co-existence amongst people, especially with regard to territorial issues; management was carried out by tribes in accordance with specific conditions that formed the basis of contemporary usufruct terms and individual ownerships that are determined under the principle of water and pasture ownership for all (Jibril, 1999).

Libyan legislators have attempted to retain the original stipulations of traditional contracts whilst incorporating additional restrictions, which then served as reference and the moral basis of contemporary laws. The decision on which practices to include or exclude depended on simplicity and flexibility, as reflected in ownership rights and prevailing usufruct patterns.

In many Africa and Southeast Asian countries, most of the forests are owned or directly controlled by the state (Martinus and Makoto, 2000) and all the forests (even privately owned forests) are administered by the state. Libya's Law No. 5 of 1952 states that all natural forests, esparto grassland, any land covered by plants as may be determined by the Secretary of Agriculture, stabilised sand dunes or sand dunes slated for stabilisation and government plantations are owned by the state. Even private forests, which account for 10% of the total number of plantations, are managed on the basis of the guidelines stipulated in the Forest Law (FAO, 1993). Forest lands in Libya currently suffer from many problems. Property rights issues are very common in developing countries, especially in Libya, where such problems are the most prominently debated (Oram, 1997). Land tenure issues are the main problem in relation to rangeland development.

6.3.3.1 Land tenure and property rights during the Ottoman period

The Ottoman state took a series of administrative measures to protect rights and public and private property through issuing land laws in 1858, and the Al-Hagani[28] booklet (a land register) was prepared in 1864 to regulate land ownership (Bin Kayal, 1995). While the most important action comprised the formation of a committee to delimit the state lands and tribal lands in Cyrenaica (Jibril 1999), practical controls were also established to regulate the use of these lands in line with the prevailing social customs and traditions. Thus, Turks succeeded in mapping the land in Cyrenaica and then categorising it according to the many different types of land tenure that existed there, recognised in the land code of 1858 as privately owned land (*mulk*), state land (*miri* or *kharaj*), religious endowments (*waqf*), 'no man's land' (*matruka*) and dead land (*mawat*) which all are controlled by the state and the utilization by certain tribes (Al-Hajjaji, 1989).

The Ottoman land code reflected a mixture of Turkish tribal practice and Islamic law. The designation of *mulk* granted full ownership ('*hiaza*' and '*ragaba*' are terms for full ownership), whereas *kharaj* land granted only the right of possession while the state kept the right of *tasaruf* (usufruct). The Ottoman land code also included the category of *timar*, in which the state owned the land and leased it to a territorial Ottoman cavalry, called *sipahi*. The *sipahi* were appointed by the state to collect taxes from the peasantry, part of which they kept for themselves, and in return provide supplies and men to the state in times of war. In short, the state recognised private property, state land (m*iri),* as well as (t*imar).* The Ottoman land code of 1858 was not applied equally around the empire, however, since ecological and local factors conditioned its enforcement (Ahmida, 1970).

The main type of land ownership, *mulk* (privately owned land) referred to land over which an individual or a family held full rights of ownership and usufruct as a result of succession, sale, donation or development .Aside from paying taxes in kind to the state, holders were free to sell or donate their land. *Mulk* land existed in the settled agricultural area along the Jefara plain coast of Sahel and Al Manshiyya, the villages of Al Jabal and Al Gharbi, and in the lands of the Sahara oases of Tripolitania and Fazzan, where semi-feudal relations existed. The landed merchant class used sharecroppers and tenant-peasants to work the large palm groves of Fezzan, which provided Libya with most of its dates (Ahmida, 1970).

[28] (الدفتر الخاقاني , الطابو , التسجيل العقاري)

The second type of land ownership was state land, *or miri,* where the state had direct right of usufruct, individuals who had leases to cultivate *miri* land had no right of usufruct. Desert ecology and the lack of state revenues limited settled agriculture to coastal Tripolitania, the Jabal and the oases of the Sahara. This situation held true only for the period prior to the 1860s.

The third type of land ownership, *waqf* or *habs* (Religious endowments land), was *mulk* land donated to Islamic religious foundations, such as mosques, shrines or holy cities in Islam. This type of land could not be subject to any type of legal alienation. In urban north Africa, the merchant classes acquired *waqf* to avoid state confiscation and to provide crucial services to major cities. *Waqf* land was not predominant in western and southern Libya, yet the bulk of agriculture land in Cyrenaica was *waqf* land, because of strong tribal loyalty to the Senussi. The Sanusi lodges' *zawaya* land was *waqf*, donated and cultivated by the tribes of Cyrenaica. This was estimated at 600,000 acres(240,000 ha) at the turn of the century and mostly used for cereal cultivation and the herding of animals (Ahmida, 1970).

The fourth type of land , *matruka* or waste land, was that owned by the state but possessed, or used collectively by a tribe or village. Nevertheless, Libyan tribes regarded certain der valleys (wadi) as their tribal homeland. This type of land was not irrigated, but cultivated during rainy seasons with barley and wheat and used as animal pasture. It is essential to note that tribal land was held in common and could not be alienated for individual use without the consent of the tribe. Collective ownership of land was most common in the Cyrenaica, but in 1858 the Ottomans attempted to register land individually and settle tribes as a result of the capitalist developments within the Ottoman ruling class in Istanbul. This policy enjoyed only partial success in rural Tripolitania, and none at all in Cyrenaica or Fazzan (Jibril 1999).

The purpose of the land Code of 1858 was to collect taxes efficiently and directly, without village or tribal heads as intermediaries. Thus, the state administration took over the function of all tribal councils. By 1902, all tax exemptions were abolished in Libya (Ahmida 1970).

6.3.3.2 Land tenure and property rights during Italian occupation: 1911-1942.

Perhaps the most important aim of Italian colonialism after the occupation of Libya in 1911, was attesting ownership rights and usufruct regarding its new colonies and encourage Italian families to inhabit.

Where Italian embarked on re-titling land which was taken by force or confiscation of the Libyans lands to newcomers through royal decree No 48 of 1912. This royal decree was considering that land registry certificates and instruments (property deeds) documents are recognized, which can be depend on in acquiring land ownership rights, which was in force till Libyan independence in 1951 (Jibril, 1999).

The Italian Ministry of Colonies began establishing special bodies to execute farms and inhabiting Italians in, and prepared accurate maps for all Libyan tribal lands that will benefit especially tribe or more, according to the regions and has taken all necessary measures to confiscate located them in the range of schemes settlement projects and taken by force from its owners or beneficiaries according to the expropriation procedures, which carried out in the manner that they give legalization and legal nature, which ensure that future returns to claim land or pay appropriate compensation for. However, in regard to the land code, they kept the same code as the Ottoman state and also the private lands in principle.

Regardless of what happened after that confiscation of private and tribal lands for political reasons which related to constantly war against the Italians particularly in eastern Libya, but in general Italian did respect private land and with the beginning of the establishment of farm settlements in Libya, and people whom their lands was entered within the scope of the Italian agricultural projects were compensate (Al-Hajjaji, 1989). The area of land which was expropriated in 1913 was estimated at more than one million ha, and increased by 738,316 ha in 1938 across Libya and the number of Italian settlers reached 108,405 persons by 1940 (Ahmida 1970).

6.3.3.3 Land tenure and property rights during the British administration 1942-1951:-

After losing the Second World War, Italy evacuated from Libya, although hundreds of Italians remained settlers in Libyan cities and farms without a government to protect them. Libya was under British administration and the colonists felt endangered , so they began selling land, farms and real estate to Libyans (Jibril, 1999).

6.3.3.4 Land tenure and property rights during the Royal Regime (1951–1969)

Since Libya's independence, property rights, tenure systems and land usufruct standards became priority issues in planning and in economic and social development. The fundamental priority items are described as follows:

a) All tribes were forcefully evicted during the Italian occupation. Consequently, the evicted tribes sought to return to what they regard as their own lands—a situation that can lead to conflicts and differences in beliefs or interests between any two tribes. In turn, problems that a new state may fail to resolve or prevent emerge.

b) The development of the economic and social infrastructure of the country necessitates the creation of stable societies, which causes dislocation in the social structure. Within this structure, the first dimensions to be affected are property rights, tenure systems and land utilisation patterns.

c) The development of certain aspects of life is imposed on individuals who have been living in accordance with traditions, and new concepts of land-related problems are unfamiliar to these individuals. Existing customs and traditions are no longer sufficient for identifying solutions to contemporary problems. This disconnect between tradition and development leads to the gradual decline of the importance of traditional concepts and roles in the affairs of the land.

d) The advancement of economic and social development and the establishment of civil society necessitate the implementation of measures that are greater in scope and effect than are laws and legislation that govern land use, acceptance of regulations and compliance by the population.

e) Adhering to the previously enumerated points will not necessarily require incorporation into appropriate economic and social policies; these policies are designed to maintain the essence of prevailing norms, customs and traditions regarding development processes and to preserve relationships amongst groups when it comes to land ownership issues (Jibril, 1999).

To achieve the aforementioned aims and address related issues, a series of comprehensive social and economic studies were conducted in early 1952; these studies were interlocking, complex and associated with forest land ownership that resulted in the enactment of Civil Law No. 1 in 1952. This association is especially evident in Articles 680 and 811 of the law. Under this law, the restrictions on property systems indicate that all lands that cannot be reclaimed (e.g. sand dunes, sandy deserts, marshes, mountains and valleys) are owned by the state (this stipulation remains in effect); the restrictions also stipulate that current forest lands that were converted from sand dunes are the property of the state (Jibril, 1999).

Then, Law No. 9 was issued in 1959 to regulate tribal land conflicts and Law No. 4 was issued in 1963 to establish a national agricultural settlement organisation. This organisation has implemented some measures for the protection of property rights, amended the land tenure system developed by the state, determined and implemented conditions and private control measures for distributed lands and developed usufruct patterns.

Furthermore, the 1965 Law on land registry and documentation systems was issued. This law is a combination of the laws that were enacted in Libya during an earlier period and some stipulations of the Land Registry Law of Egypt issued in 1946. The 1965 Law also regulates investigations into the ownership and registration of estates and registry disputes; the regulation is carried out by the land registry departments and offices throughout Libya.

6.3.3.5 Land tenure and property rights under the roll system (1969–2011)

The Land Registry Centre continued its work until the roll system was changed in 1969, after which extensive changes in property ownership legislation occurred. Thus, legislators issued special basic regulations regarding home ownership and determined the areas of land that are available for ownership. This development was followed by the confiscation of properties from some officials of the monarchy and the expropriation of some lands and compartments that are in excess of the needs of their respective owners. Finally, the state was dispossessed of numerous properties.

The most important legislation issued in relation to agricultural holdings and real estate ownership was Law No. 142 of 1970, which pertains to tribal lands that are considered fully state owned if unregistered in the Land Registry Centre. These lands are recorded as properties of the state. Under such conditions, the tribes are not compensated for the acquisition. Law No. 142 also exerted the most extensive effects on the Land Registry Centre.

Under this law, however, tribal lands can be used as usufruct items only under the terms set by the Ministry. Another high-impact legislation was Law No. 123 of 1971, which pertains to rights regarding the agricultural and reclaimed lands owned by the state. Such lands are to be managed by a foundation for agricultural land reform.

Some of the interviewed forest officials argued that the previous regime attempted to apply Italian policy in establishing certain agricultural and settlement projects, which mandate the demolition of all small farms and the provision of compensation for the residents. In reality, however, the residents were forcefully evicted and denied compensation. In actuality, the

establishment of agricultural projects and settlements was a disharmonious process. A good example of the agricultural and settlement projects that were implemented under the aforementioned conditions is the Algarabulli agricultural project (within the study area), for which the number of target farms was estimated at 1200. Each farm was projected to be 25–30 ha in extent and was distributed to Libyan citizens in 1980 via usufruct contracts.

In 1977, a new law governing the ownership of real estate, Law No. 38, was introduced. Article 1 of this law states that laying claim to property, regardless of the date of alleged ownership or the duration of ownership, is insufficient grounds for owning property, acquiring legitimate rights to the property, registering property or staking a claim on it. Article 2 stipulates that all registrations of real estate ownership in the Land Registry Centre that date back to 7 October 1951 for properties acquired through claims or expression of possession shall be revoked (Jibril, 1999). Article 3 specifies that all grants of ownership issued by occupiers (Italian or Ottoman) as rewards for workers' loyalty shall be void.

Additionally, all ownership registrations for such properties shall be revoked. These properties shall belong to the state. One exception is for ownership registered with no evidence or intent of fraud. Article 6 states that anyone who claims previous ownership of real estate for which ownership was transferred to the state in accordance with Law No. 38 can sue the state and request the court to confirm his/her ownership. In this case, the state shall not abate rights or insist on adherence to the transfer conditions. Claims of ownership shall be based on cause of ownership and not on the expression of possession or on possession by inheritance.

Implementation of the Real Estate Record law 38 of 1977 was suspended and Law No. 4, which was developed by the previous regime, was implemented in 1978. The land registry department maintained cadastres, but on 17 November 1986, land registry offices across Libya were destroyed by revolutionary committees for fear landowners may someday lay claim to estates. The records documented all property rights, including those of citizens, the state, embassies, mosques, cemeteries and other institutions. Individuals attempted to prevent the destruction and help employees store the documents elsewhere for re-registry, in accordance with the legislation. These efforts were to no avail.

Complications emerged regarding the 1986 issuance of Law No. 7, which stipulates the abolition of land ownership. Article 1 of this law indicates that land cannot be owned by anyone but the state. Some interviewed officials confirmed this decision, made in accordance with the

instructions of the Gaddafi regime. One factor that motivated this law was the intention of the previous regime to make it easy for some officials to obtain state land, such as forest land.

Table 6.4: Real Estate Registration in the civil law issued (1969-2011).

Law No	Year	Title of text	Purpose	Comment
142	1970	Regarding tribal lands	This law pertains to tribal lands that are considered fully state owned if unregistered in the Land Registry Centre. These lands are recorded as properties of the state. Under such conditions, the tribes are not compensated for the acquisition. However tribal lands can be used as usufruct items only under the terms set by the Ministry.	This law was suspended in 1977
123	1971	Real estate ownership	This law pertains to rights regarding the agricultural and reclaimed lands owned by the state. Such lands are to be managed by a foundation for agricultural land reform.	This law was suspended in 1977
38	1977	Real estate ownership	Abolition of all registrations that have been taken on the lands, based on laying hand or by possession since 7 of October 1951.	This law was suspended
4	1978	Real estate ownership	Issued to suspend the law No 38 of 1977	
7	1986	Real estate ownership	Which stipulates the abolition of land ownership, Article 1 of this law indicates that land cannot be owned by anyone but the state.	In this year, 17 November 1986, land registry offices across Libya were destroyed by revolutionary committees for fear landowners may someday lay claim to estates. The records documented all property rights, including those of citizens, the state, embassies, mosques, cemeteries and other institutions .Also Abolition of Land Registry in Libya.

Table 6.4: Followed

Law No	Year	Title of text	Purpose	Comment
11	1988	Real estate ownership lands	This does not recognise the validity of previous documents.	
12	1988	Real estate ownership	Resumption of work at the Land Registry	
10	2006	Real estate ownership	It was issued for the regulation of property and the nullification of confiscation claims for properties that were allocated to the state, where Article 1 declares that the properties acquired by state in accordance with legislations in force are to be recorded in land registries from the date of confiscation. Article 2 indicates that any claim of ownership on the properties owned by the state in accordance with legislations in force, whether the claimant is the incumbent state or a citizen, shall be rejected. The properties shall be classified as vacant properties.	
164	2011	Ministerial resolution on Real estate ownership	It was issued to abolish the laws on confiscated properties for the public benefit of the state.	the current government found that this resolution was incorrect and inaccurate for many legal reasons and is therefore inapplicable (reasons is mention below)

Later, the Libyan legislature issued Law No. 11 of 1988. This law pertains to the land registry, which does not recognise the validity of previous documents. Another law issued that year was Law No. 12, which revolves around the resumption of work by land registry centres.

Despite the issuance of these laws, the registration of real property did not proceed in its intended form because of the confiscation of some real estate properties and their subsequent allocation to other interested parties by certain state officials. These illegal actions remained unpunished even with the existence of legislation regarding sanctions against violations.

In 2006, Law. No 10 was issued for the regulation of property and the nullification of confiscation claims for properties that were allocated to the state. Article 1 of this law declares that the properties acquired by society (i.e. the state) in accordance with legislations in force are to be recorded in land registries from the date of confiscation. Article 2 indicates that any claim of ownership on the properties owned by society in accordance with legislations in force, whether the claimant is the incumbent state or a citizen, shall be rejected. The properties shall be classified as vacant properties.

The 2013 Minister of Agriculture stated that in the beginning of the uprising in Libya in February 2011 the Gaddafi regime attempted to sway the population, especially those affected by the laws and decisions issued under the regime's rule. Resolution No. 164 of 2011 was issued to abolish the laws on confiscated properties for the public benefit of the state. Nevertheless, some of the interviewed officials stated that although this decision concerns lands that were confiscated for the public benefit of the state (presumably for the establishment of agricultural projects and not for the occupation of forest lands, on which planting was implemented during the monarchic reign), some individuals exploited the decision and encroached on forest lands. These individuals also staked claims over the lands, using the fact that these forests were cleared by the individuals as a basis, as recently determined either through court proceedings or otherwise. Very recently, however, the current government found that this resolution was incorrect and inaccurate for many legal reasons and is therefore inapplicable for the following reasons:

1. A resolution issued by the General People's Committee (Prime Minister) to abolish some laws issued by the previous General People's Conference (Parliament) cannot be executed; a decision cannot abolish law. In application, if the law opposes the decision, the latter is considered abolished and the law is the applicable regulation. Thus, the high court issued a statement in 4 February 1986, declaring that state legislation is to be classified under three categories: basic legislation (third level), normal legislation (i.e. law) and individual legislation (second level) and executive and organising/seizing declaration (fist level); this categorisation between legislations in force is intended to enable the reviews of law at the lower level before

elevation to the higher level. Consequently, Decision No. 164 of 2011, which was issued by the General Popular Committee as an executive authority, shall be considered void because it conflicts with Law No. 127 of 1970, which was issued by the same committee.

2. The number of the aforementioned laws regarding the decision does not accord with the purpose that drove the issuance of the decision, indicating that Decision No. 164 of 2011 was formulated and issued on the basis of laws that are unrelated to the matter at hand. It was grounded on Law No. 127 of 1970 as law that mandates the seizure of neglected lands for state benefit. This law reflects association with the allotment of income to general reserves. Consequently, this mistake can be regarded as an unconventional act of the General Popular Committee; such act may result in the failure to recognise or nullify the decision. Even though the decision was evaluated as void, however, some courts continued to refer to it. For example, a judge of the Agricultural Crimes Court in Algarablli district said that, in accordance with this resolution, some lands have recently been returned to citizens who laid claims over properties.

After the fall of the Gaddafi regime after the uprising of 2011, massive deforestation occurred, with local people occupying forest lands on the basis of expression of possession or documents confirming that they cleared such forests. Land possession issues were discussed with the 43 interviewees during a survey conducted in 2014 (Chapter 7). The results showed that the types of land possession were usufruct contracts, property deeds (instruments), certificate sheikh[29] (administrative certificates), contracts of sale and claims without proof of land acquisition and as a consequences illegal felling of trees, deforestation conversion to agriculture land. These types of possession are illegal because forest lands are owned by the state, as stipulated by law. The types of land possessions are described in the succeeding sections.

6.3.4 Types of land possession by forest clearer:

6.3.4.1 Usufruct contracts (land allocation)

Usufruct contracts are regarded as land tenure and not ownership which is also an agreement issued by the state through administrative bodies with individuals claiming to be deserving of the usufruct. Specific conditions are stipulated in the contract and the individuals are mandated to commit to protecting the forests and use it in investments in forest trees and beekeeping;

[29] A head of a tribe or locality.

a usufruct can also be referred to as tenure over forest lands, wherein the tenure helps determine whether local people are willing to participate in the management and protection forests (Gibson *et al.*, 2000). However, these contracts were issued by bodies that were not authorised by the state, the Ministry of Agriculture or the agricultural sectors responsible for management from 1986 to 2006.

These contracts, which are erroneously represented as legal allocations, can be regarded as void because they violate Law No. 123 of 1970. Despite such violation, the contract versions issued were based on other contracts that were distributed for certain agricultural projects that people needed.

The legality or validity of the contracts has therefore become unclear or difficult to ascertain. Legislators recognised this legal flaw, and to avoid the consequences of such a flaw, they issued Law No. 14 of 1992, which was amended with Law No. 5 of 1982. The issuance of Law No. 14 meant the abolition of all issued contracts between the state and people in forest lands. Therefore, land tenure over forest areas is considered illegal, and occupants must evacuate and turn over tenure to the state. These stipulations are indicated in a number of resolutions that mandate evacuation.

6.3.4.2 Property deeds (instruments)

An instrument is a document that confirms land ownership agreed upon by two individuals (a land owner and a beneficiary). Instruments are of many types, depending on type of agreement (i.e. selling, waiving and Almoarsah30). After the Italians withdrew from Libya in 1942, many conflicts arose between citizens because of land ownership issues. Everyone alleged that he/she had cultivated a tree somewhere: such as act makes an individual the rightful owner of the cultivated land. This situation led to conflicts with regard to utility ownership. As a result, the King of Libya decided in the early 1950s that everyone with an old agreement (instrument) that was established during the Turkish period shall be registered in the land registry department for the instrument holders to obtain a land registry certificate.

No instruments related to the Italian period were drafted because selling, buying, waiving and inheritance activities were registered in the Italian land registry. These were later turned over

[30]*Almoarsah* is the contract for the lease of an orchard. It is only a contract for the agreement entered into by a land owner and investor. As indicated in this contract, an investor shall plant trees on part or on the entirety of land for a given period, after which the planted areas shall be owned by the investor, as stipulated in a plantation contract or instrument. The history of these instruments is related to the Turkish period.

to the Libyan government after independence. The government then issued Law No. 20 of 1977, which is a civil law that nullifies Almoarsah contracts.

The interviewed legal experts stated that anyone with an instrument that dates back to the Turkish period but was not recorded during the Italian Administration had to register the land to prove ownership. Thus, the King issued a law that rejects instruments drafted during the Turkish period.

Civil Law No. 1 of 1952 was issued for legal plantation forests. This law, as indicated by Articles 680 and 811, stipulates that all lands that are classified as deserts, sandy dunes, mountains, valleys, rivers and marshes are owned by the state. In accordance with this law, therefore, the forestry department planted forest trees on sand dune areas in 1952–1984. One of the forestry experts, who was the superintendent of the forest plantation programmes in Algarabulli district (1956–1974), confirmed that although this law stipulates that the sand dunes are owned by the state, the local residents demanded that the government stabilise the sand dunes and carry out afforestation in exchange for the citizens giving up their lands. To execute its plantation programmes and avoid any problems with the population in the future, the government demanded that local people limit the number of occupants in lands and that anyone with an ownership instrument, especially for sandy dunes, present such instrument to the authorities for treatment in relation to the state plantations.

Given the desire of the state to combat desertification by forest plantation and to overcome all the difficulties that may prevent the achievement of this goal, the government required all avowed owners to prove ownership of a certain land and a commitment to plant trees on this land by themselves. In exchange, the state shall freely provide tree seedlings for planting to prevent desertification. The superintendent also indicated that despite the fact that trees were planted on only 150 ha of forest land by some families to whom private land ownership in Algarabulli district was allocated, these forests are protected under Libyan law.

The legal status of these lands is reflected in two different arguments: The first is the argument proposed by an agricultural jurisdiction judge in Algarabulli district, who presides over conflict cases related to forest land ownership. The argument indicates that the jurisdiction can resolve relevant conflicts in accordance with laws regarding land ownership.

These laws recognise and accept old property deeds (old instruments), and judges decide on cases in favour of local people or the state, depending on the strength of the documents presented by each party.

This approach reveals the contradiction between the instruments and the aforementioned laws, which disregard the validity of instruments. The judge stated that although Law No. 5 of 1982 declares that forests and pasture lands are legally owned by the state (these lands do not include those that are not typically used by individuals as natural forest areas, lands with esparto growth, lands forested by the government and sand dunes that have been stabilised by the government), the law alone is insufficient. Without proof of ownership (i.e. land registry certificate that indicates ownership by a citizen or by the state), this issue is difficult to resolve. When documents that confirm state ownership are lacking and when agricultural members fail to attend court proceedings, a judge rules in favour of the opposing party who presents complete documents. A preliminary judgment is then provided to the opposing party. If the state presents documents that convincingly nullify the submitted instruments, the succeeding ruling shall be considered final because the preliminary judgment cannot be considered the ultimate ruling. Nevertheless, people clear forests in accordance with preliminary judgments; such acts are prohibited.

The second argument is that proposed by legal experts in land registry law. These experts pointed out that the review of the legal possession of forest lands that were sand dunes before being planted on the ruling regarding land ownership shall be the bases for the granting of land registry certificates. Old instruments are not to be used as basis in such decisions. Thus, if somebody has a land registry certificate that proves ownership, the land shall be kept by the state but the owners are to be compensated even if plantations are intended for public benefit. In reality, however, no land registry certificates were provided at that time. Forest lands are therefore regarded as general forests owned by the state, thereby nullifying instruments, regardless of whether these were recorded for registry.

This difference in opinion, in which the recognition of general forests as owned by the state is based either on laws or ownership documents from the land registry centres, contributes to the increased deforestation in Libya. An interviewed land registry manager indicated that most of the instruments that were claimed as dating back to the Turkish period were inaccurate; the period at which these instruments originated is a mere estimate. For this reason, the King of Libya disregarded the instruments dating back to the Turkish period.

6.3.4.3 Administrative certificates

An administrative certificate is a written document issued by tribal chiefs or quarters as an official document that declares the holder as the owner of a given property. Some of the legal experts who participated in the focus group discussion stated that the issuance of this document was a product of mismanagement. The error created multiple liabilities amongst state bodies. For instance, when forests were managed by the Forestry Department of the Ministry of Agriculture. Thus, the forests were assigned under the direct management of the Ministry and the regional agricultural sectors, with each regulatory body implementing its own decisions. Contravening resolutions may be related to possession because the Ministry issues conflicting resolutions in addressing individual possession of certain lands. At the same time, other agricultural sectors issued another resolution for somebody else.

In many countries, the majority of forest management is centralised (Martinus and Makoto, 2000). The same holds true for Libya before 1986. After 1996, however, improvements to this approach were implemented to encourage tribal chiefs or quarters to issue administrative certificates that confirm ownership. At that time, these documents were being issued under family or social pressure or in return for bribes, thereby prompting the Sheikh to issue documents that declare land ownership on the basis of heritage and after the guaranteed attendance of three individuals as witnesses. This document, however, is regarded by law only as an administrative document and not a record that verifies ownership.

In short, if any individual is required to register land in the land registry centres, a set of documents should be submitted to acquire official ownership status or initiate a formalisation process. Four different documents are needed to obtain a formal land registry certificate, but this study did not find land register certificates for the respondents who have been inhabiting forest lands that they cleared in different periods. Even the land registry manager stated that despite years of massive encroachments on forest lands, no land registry certificate has been awarded to forest clearers. Any such certificate must be forged. Thus, all the processes by which land was obtained are illegal.

6.4 Conclusions

In chapter one, it was argued that the real indirect cause that led to deforestation was the change from good governance to bad governance in 1986 due to the abolition the Ministry of Agriculture and burning of the land registry centres. Therefore, this chapter focused deeply why and how forest governance was changed particularly in 1986.

The results, which were obtained through semi-structured interviews and focus group discussion with government officials, some legal experts and the findings in archives of the Ministry of Agriculture as well as how these changes in the governance contributed to deforestation, including the legislation or forest protection laws and administrative and land tenure laws, showed that deforestation commenced in 1986 and were not recorded before this time, due to several factors where higher state authorities abolished the Ministry of Agriculture in 1986, after which the agricultural sectors in all Libyan regions were managed by the agriculture sectors directors whom were instructed to issue usufruct contracts for some state officials and military officers in the beginning which encouraged some local people to encroach the forests. Also, the forest guard, which was the cornerstone of forest protection, was also abolished, thereby resulting in failed protection efforts.

In addition, the burning of the land registry centres which caused land ownership problems where forest has not registered in the Land Registry Centre to be officially state-owned, although for state-owned under the forest act 5 of 1952. Even private forests, which account for 10% of the total plantations, are managed on the basis of guidelines given in the Forest Law.

In this context, it was found that legal experts stated that forest is state-owned under the forest act 5 of 1952, however it was argued by other legal experts stated that the ownership of land by the law is not enough to recognized as state forest unless be registered in the land registry. Where some judges have ruled to get forest land back to whom claims the ownership the lands in other areas in Jefara plain. Therefor forest must be registered in the Land Registry Centre to be obtained ownership certificate, where there are some people claiming the ownership of forest land.

Although the Ministry of Agriculture resumed work in 1990 and a new forest act was issued in 1992 to repair what has been destroyed, this act inspired hope amongst forestry employees with regard to rectifying administration errors, regardless of whether these were intended to destroy

Libyan forests. The forestry department also resumed work, with its employees committed to reviving as many of the previously established efforts as possible.

Despite the advantages presented by Law No. 14, of 1992 where some it article declare that forest land must be registered in the Land Registry Centre and usufruct contracts issued in forest lands must be abolished, this act has yet to be applied.

Poor forest governance has been prevalent since 1986, and a range of problems have arisen, including corruption, political instability, lack of capacity, lack of transparency, weakness of institutions and accountability, unclear regulations and conflicting laws. These factors have driven locals to continue engaging in forest clearing. Corruption within law enforcement is also a major cause of deforestation in the area.

The legal instruments and policies are fine, but the real problem with simply floating of policy and ignoring of the policy (policy Breakdown) where Policy and laws are existed.

As the findings of this chapter showed that the main causes of deforestation is policy issues that led to change of forest governance. So the following chapter focused on socio-economic drivers of deforestation that led to deforestation, who and why they cleared forest.

7 Socio-economic drivers of deforestation

7.1 Introduction

Increasing pressure from human activities has caused global changes in land cover, particularly in forest land and other similar expanses of vegetation. Such changes are one of the most important issues in global change research. This environmental problem has become especially remarkable in the last few decades, being compounded by population growth that has contributed to progressive deforestation (Pahari and Murai, 1999).

The role of people in deforestation and the impact of population density on this environmental problem have been contentious issues (Chakravarty, 2012), but most researchers recognise population growth as one of the most critical socio-economic factors that alter the patterns of forest resource use (Giliba *et al.*, 2011). The association between population increase and deforestation in most developing countries has prompted intensified concern over the clearing of forests for other land uses (Dilip and Mwchahary, 2012).

The majority of the literature states that the strongest drivers of deforestation include logging, conversion to agricultural land, wildfires, cutting down of trees for firewood and conflict over land rights; these practices tend to be occasioned by increased population growth and the consequent need for more land, mostly for agricultural production (Megan, 2012).

The problem of deforestation in the developing world is often exacerbated by rapid population growth. Such growth is the primary cause of deforestation in Africa and Madagascar (Megan, 2012). Nevertheless, some argue that increased population is not always the strongest driver of deforestation, with scholars disagreeing on the exact role played by population growth and pressure. Some researchers underscore the demographic dimension as the key cause of deforestation. Under this dimension fall factors such as the increased need for arable land for the purpose of absorbing excess labour and keeping pace with growing demand for food from a larger population, as well as the increased fuelwood and timber consumption brought about by rapid population growth. Scholars who downplay the influence of demographic factors view deforestation as rooted in political economy and therefore a problem caused primarily by the uneven distribution of income and land, as well as unbalanced access to credit and capital (Stonish,1989).

The most representative examples of political economy's effect on deforestation today are the province of Rondonia in Brazil and the rapid increase in deforestation in Indonesia after 1966, neither of which stemmed from population pressure. After President Sukarno's ouster, an issue that became evident was that the deforestation in the country was a consequence of the president Suharto's views on development in general and his administration's utilisation of forest resources in particular. Another notable case is the deforestation in Malaysia, which began around 1960, after the Communist insurgency was defeated. As these cases indicate, population pressure cannot always explain the rapid initiation of deforestation in various regions around the world (David, 1992).

Despite the increasing severity of deforestation the world over, the breadth of research devoted to affected regions is unbalanced. For example, a considerable literature exists on deforestation in sub-Saharan Africa (Megan, 2012), but little research has been directed towards the specific circumstances of Libya, particularly on the socio-economic factors that influence deforestation in the country.

As stated in chapter two (fig 2.15) that according to the census of 1984,1995 and 2006 population growth rate experienced decreasing from 4.2, 2.8 to 1.7% p.a. respectively, as the country had reached the stage of maturity and stability of the population. Moreover, according to the Libyan population survey in 2012, which was conducted one year after the 2011 uprising, the population growth rate had fallen further to 0.4% p.a. because of the war, displacement and others became refugees in other countries.

With regard the family size, according to the census of 1995 mean family size was 6.9, but in 2006 family size reduced to 6.0, this decline being due to many factors: some families adopted birth control, a decision considered to be one of the manifestations of urbanisation (BSC, 2006). Another factor is the increase in the average age of marriage, which is attributed to improved educational levels and the tendency of numerous women to carry on with their education till late in adulthood, their mid-to-late 30s (Helen, 2010).

With regard to the age groups in Libya in 2006, the BSC divided them into three group, less than 15 years represents 31.3% and from 15 to 64 years represents 64.7% and more than 65 years represents 4.2% (BSC, 2006); in contrast in 1995 the first category represented 39.1% and 57.0% and 3.9% respectively (BSC, 1995).

Other important factors affecting forest use include the specific characteristic of forest clearers, such as education and income. Libyan education history has been influenced by several

different countries but none lasting as long as the Ottoman occupation; this empire occupied Libya for 360 years (1551–1911). Education in this period received minimal attention, and even when educational initiatives were actively pursued, these focused on religious matters; the efforts towards sustaining religious education through instruction in small mosques (*Zawiya*) were somewhat disorganised (Moh, 2013). Mosques were more widely spread around the country than modern educational institutions. As a consequence of this history, the country bears many characteristics that were forged during the long period of colonisation. In the subsequent 100 years, Libya was occupied by the Italians, the British and the French before the country acquired independence (establishment of monarchic rule and rise of the revolutionary government).

In 1943, Libya became a key battleground in the Second World War, essentially because of its strategic position in the North African region; as a result, all schools were closed (Moh, 2013). Thereafter, the British and French administrations that succeeded the Italian government re-opened the schools and substantially committed to providing education to the Libyan people and generally improved the weak educational system (Tarhoni, 2011). The British provided all Libyans with access to education and offered short courses designed to train teachers, as well as established teacher training institutions for both men and women. The British government viewed these measures as the only means of achieving economic and social progress. When the level of illiteracy in the country reached 95%, parents considered sending their sons to the schools in the southern region of Libya as a more acceptable strategy. The French then introduced primary education that covered five years of schooling.

In 1951, Libya was granted its independence and established monarchic rule under the kingship of Idris. During this period, the monarchy acknowledged the need to provide free general education and build universities. The efforts of the monarchy accelerated the development of the country.

During the 42-year period spanned by the revolutionary regime initiated by Gaddafi in 1969, the government substantially expanded educational provision in an effort to elevate understanding of and commitment to Libyan culture. Education was made available to all Libyans as schools, institutions and universities were established all over the country, and the Ministry of Education introduced major changes to improve education and engender significant benefits to the nation.

An example of these measures is the 1975 Law Number 95 on Compulsory Education (Al-Hajjaji, 1989), which requires parents to register their children (males, females) in primary education, wherein the children are to study from the age of 6 until they reach the age of 15.

The 2006 census shows that the proportion of Libyan household heads with educational levels lower than a primary certificate education was estimated at 32 %. The levels of education recorded were illiterate, read only and read and write levels of individuals. Primary and secondary school certification or its equivalent was estimated at 48 %. Gaining undergraduate certification was estimated 19% and for post-graduate level it was estimated as 1%. The same census indicates that the percentage of enrolment in studies increased from 91.3% in 1995 to 97.1% in 2006 and that the illiteracy rate for adults decreased from 18.7% in 1995 to 11.5% in 2006 (BSCL, 2010).

Some reports in Libya stated, that increasing the knowledge of people about the importance of forests was through the educational institutions and also increasing their income led to a reduction in the rate of deforestation, particularly in natural forests in 1970s (The Ministry of Agriculture, 2004).

The research question of this chapter is; what are the drivers of deforestation? This was addressed in two ways:

- Firstly population growth was investigated - whether there is relationship between population and deforestation. This was done using historical population deforestation data to look at whether there is a link between population and deforestation.
- Secondly, a comparison of people who cleared forests with other people who had no such experience was undertaken in two ways:
    - i) In terms of their basic characteristics (education status, income and occupation etc.),
    - ii) By comparing them in terms of attitudes and knowledge they had of forests and deforestation.

This was done using a survey of people who cleared forests, comparing them with the general population and looking whether there are specific characteristics that are more prevalent.

7.2 Methods

Social research uses various methods to collect both quantitative and qualitative data (Oppenheim, 1992). This chapter is focused in two parts to address the research question.

The first part of the chapter deals with population and deforestation to determine whether there is a link between them. The population aspect is based on census information and deforestation is based on Forest Departmental records.

The second part of this chapter, focuses on forest clearers' characteristics, knowledge and attitude (education status, income and occupation etc.) and is compared with those of other people who had no forest clearance experience. The latter is based on survey data.

Questionnaire survey

To explore the main drivers of deforestation in Libya's Algarabulli District, in terms the characteristics and knowledge of forest clearers, a questionnaire survey was conducted between January and March 2014. Detailed responses were obtained from people who had cleared forest. The study collected both quantitative and qualitative data, highlighting the main perceived drivers of deforestation to determine whether there is any significant difference between forest clearers and non-forest clearers in terms of their education status, income and occupation and attitude of forest and deforestation This followed on from determining the main causes of deforestation using semi-structured interviews (open questions) as described in chapter 4.

7.2.1.1 Questionnaire design and administration

Careful questionnaire design and administration is critical (Lorelle and Meredith, 2000). Before distributing the questionnaire to the respondents, a pilot research stage was conducted to determine the expected extent of response. Due to poor postal service in most of Libya, ten questionnaires were distributed by the drop-and-pick-up method. Only one out of 10 questionnaires was collected afterward due to various reasons; for example, some respondents said they believed that this questionnaire came from a government institution and could negatively affect them in the future. Some respondents refused to see the researcher again.

Therefore, to achieve the study's goals, another method of administering the questionnaire was used. Although it consumed time and effort, the researcher conducted in-person or face-to-face interviews, providing more explanation and asking the questions in different ways to elicit

answers. When respondents showed dissatisfaction with a question, the researcher adjusted it in simple ways or changed the topic of conversation to general issues in Libya.

The respondent's education and culture played a role in administering the questionnaires, especially because the researcher dealt with citizens who had cleared the forest against the law (forest clearers). Additionally the researcher filled out some questionnaires for respondents unable to read or to write.

Finally, some respondents only accepted the questionnaire after the researcher guaranteed that the study belonged to the researcher and his university and that the individual results would never be provided to any Libyan institution nor affect the respondents in any way.

7.2.1.2 Type of question

This study used closed questions with respondents (those clearing the forest) who were expected to refuse the questionnaire. This type of question made it easier to process answers, compare answers and clarify the meaning of a question for a respondent. Respondents also found this type of question easier to complete.

The closed questions were designed to have short answers, making them simple to conduct. These included questions addressing the research problem of this study. Care was taken to ensure cultural sensitivity. Additionally, closed questions avoided incomplete or poorly completed answers. All questions were about the characteristics of forest clearers and their knowledge about deforestation (such as their education status, family size and age group, income, the purpose of clearing forest etc, (see appendix 3).

7.2.1.3 Sampling

Following certain guidelines reduced the danger in this case, and the fieldwork became more rewarding, more enjoyable and possibly a little easier. During an in-depth discussion with the Forestry Department, officials in the Algarabulli District, along with some of the researcher's colleagues.

This study used a simple random sample, the most basic form of probability sample (Bryman, 2012).The sample size was selected according to the number of forest clearers that recorded by the Forest Department in the Algarabulli district since May 1986 when deforestation commenced until January 1, 2014. The number of forest clearers consisted of only 150 people in all forest blocks. As many respondents as possible were targeted out of the expectation that

some respondents would refuse to participate in the questionnaire. Therefore, 80 respondents, or forest clearers, were selected after ensuring they posed no threat to me.

This sample represented 53% of the 150 forest clearers in this area. People who were suspect or who had cleared forest areas recently using weapons were not selected for this research sample due to the dangers involved (7.1).

Table 7.1: The number of forest encroachers in each forest block selected and subsequently unselected for the study.

Forest block & locality	Total in area	Selected	Deselected for safety reasons	Refused	Interviewed
Ataya	80	46	34	23	23
Karawa	35	17	18	9	8
Gaweaa	16	8	8	3	5
Rawajih	15	7	8	2	5
Kawaleg	4	2	2	0	2
Total	150	80	70	37	43

The questionnaire was administered as planned without any difficulties; 43 out of 80 respondents agreed to fill out the questionnaire and 37 politely refused. The questionnaire was written in the Arabic language and translated into English.

7.2.2 Documents

Documents are secondary sources and can be treated as a source of data in their own right; in effect, an alternative to questionnaires, interviews or observation and the source of documentary data (Denscombe, 2003) In this chapter were used :

1) The Ministry of Agriculture's reports and Forest Department's records and census obtained from Bureau of Statistics and Census Libya, and economic information about Libya from government institutions.
2) Books or literature that related to the issues of socioeconomic factors and the history of education etc.

7.3 Results and discussion

7.3.1 Population

This section delves into the relationship between deforestation and population (growth and density) to determine whether the rise in population in the study area contributed to the destruction of forest cover in the region. This issue is examined first in relation to the entirety of Algarabulli district, after which deforestation in the district's localities is analysed. An important requirement to consider is that quantitative research on deforestation commonly uses two measures of population pressure: absolute population growth and population density (David, 1992).

Algarabulli district, which is an extension of Tripoli City, is home to a relatively small population. In 2010, its population accounted for 0.9% of the total population of Libya. To study the Algarabulli's population growth rate, the general population censuses conducted in the district were reviewed.

7.3.1.1 Population growth

According to the 1954 census, the total population of Algarabulli District was estimated at 9258, which increased to 10,366 by 1964 (Fig 7.1). This increase, which represents a growth rate of 3.73% p.a., is attributed to the appeal of the district's high standards of living and to migration motivated by the distribution of Algarabulli farm development projects to residents outside the district. The highest population growth rate in this area occurred between 1984 and 1995, with the population rising to 38,857 inhabitants or 4.55% p.a. This growth was a consequence of increased migration to the area because of the housing projects that were established in the region, along with intermarriages with non-Algarabulli residents.

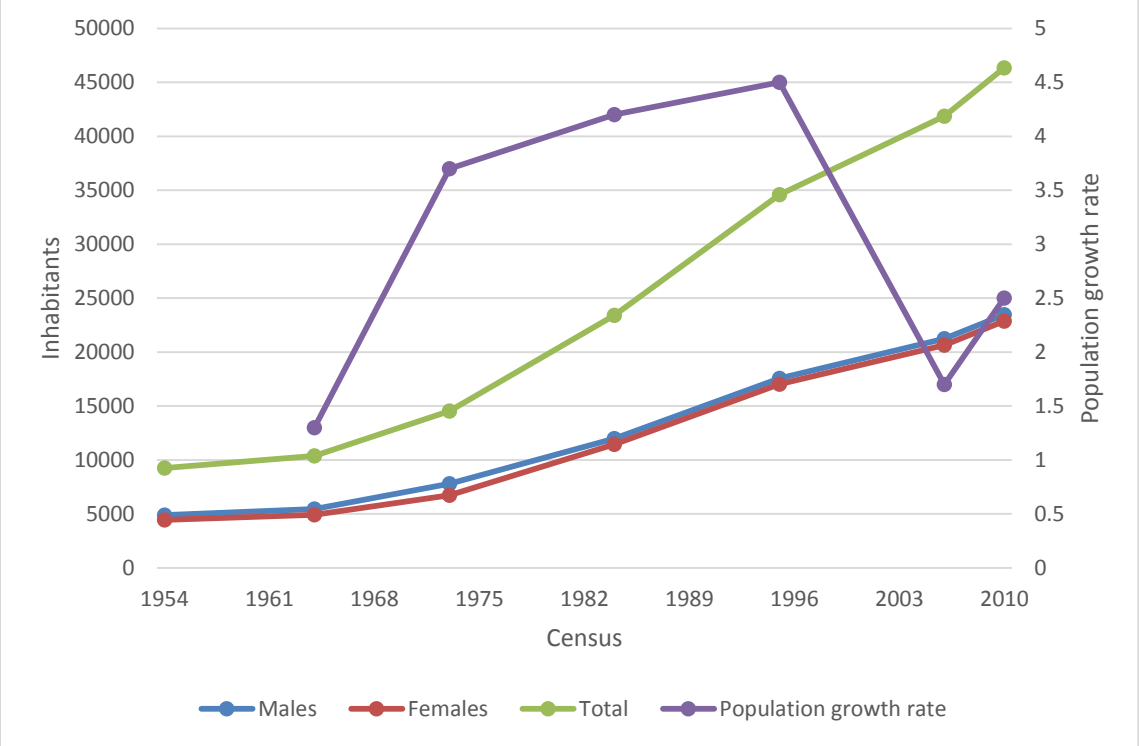

Figure 7.1: Population censuses and population growth in Algarabulli District (1954, 1964, 1973, 1984, 1995, 2006 and 2010) (Source: BSCL, 2010).

The 1995 was a significant decrease in population growth rate from 4.5% p.a. in 1995 to 0.7% p.a. in 2006 because of a combination of factors, including the global economic recession in the mid-eighties, the decrease in oil prices and sales and the economic sanctions against Libya during the nineties. Because of the sanctions, all the development programmes and projects in the country were suspended, thereby negatively reflecting on the average age at which Libyan citizens married and had children. This development also negatively influenced fertility rates (BSCL, 2010).

In more detail table 7.2 shows the population distribution and population growth rates in localities of Algarabulli district, which witnessed an increase in growth rates, as indicated in the 1984–1995 censuses. As stated in the 2006 census, growth rates declined in all the localities, except for Al-Rawajih, which experienced a slight growth. The 2010 census registered a rise in growth rates in all the localities, except for Al-Rawajih. Although population increases are clearly observed, an issue that requires resolution is whether the slight increase in the population growth rates of all the localities have intensified deforestation in the district.

Table 7.2: Population censuses and population growth in the localities of Algarabulli (1954, 1964, 1973, 1984, 1995, 2006 and 2010).

Censuses	Locality	Population			Population growth rate	From total district (%)
		Male	Female	Total		
1984	Al-Karawa	3954	3810	7764	4.24	33.2
	Al-Ataya	2183	2109	4292	4.12	18.3
	Al-sharqiya	1882	1751	3633	3.91	15.5
	Al-Gawea	1198	1124	2322	2.19	10.0
	Al-Rawajih	1739	1638	3377	5.03	14.4
	Al-kawaliq	1015	1007	2022	4.59	8.6
	Total district	11971	11439	23410	4.24	100
1995	Al-Karawa	6201	6132	12333	4.13	35.5
	Al-Ataya	3344	3182	6526	3.75	19.0
	Al-sharqiya	2562	2397	4959	2.80	14.3
	Al-Gawea	2081	1968	4049	4.93	11.8
	Al-Rawajih	1951	1878	3829	1.14	11.1
	Al-kawaliq	1433	1455	2888	3.21	8.3
	Total district	17572	17012	34584	4.50	100
2006	Al-Karawa	6658	6599	13257	0.65	31.5
	Al-Ataya	4600	4411	9011	0.29	21.5
	Al-sharqiya	2908	2746	5654	1.19	13.5
	Al-Gawea	2542	2476	5018	1.02	11.9
	Al-Rawajih	2883	2738	5621	3.44	14.4
	Al-kawaliq	1634	1662	3296	1.19	7.2
	Total district	21225	20632	41857	1.72	100
2010	Al-Karawa	7423	7352	14775	2.6	32.0
	Al-Ataya	5255	5089	10344	3.44	22.5
	Al-sharqiya	3231	3046	6277	2.61	13.5
	Al-Gawea	2973	2917	5890	3.99	13.0
	Al-Rawajih	3045	2855	5900	1.21	13.0
	Al-kawaliq	1774	1813	3587	2.11	6.0
	Total district	21681	21059	46327	2.53	100

Source: (BSCL, 2010).

7.3.1.2 Population and forest cover

Algarabulli's population grew at a considerably lower pace in previous years than in recent periods. Figure 7.2 illustrates the proportion of forest cover versus the population in the district. The percentage of forest cover from 1961 to 1985 increased to a more rapid extent than the rise in population. Since 1986, however, forest cover has begun gradually diminishing, and in 2010, it decreased to more drastic proportions than that observed in the district's population.

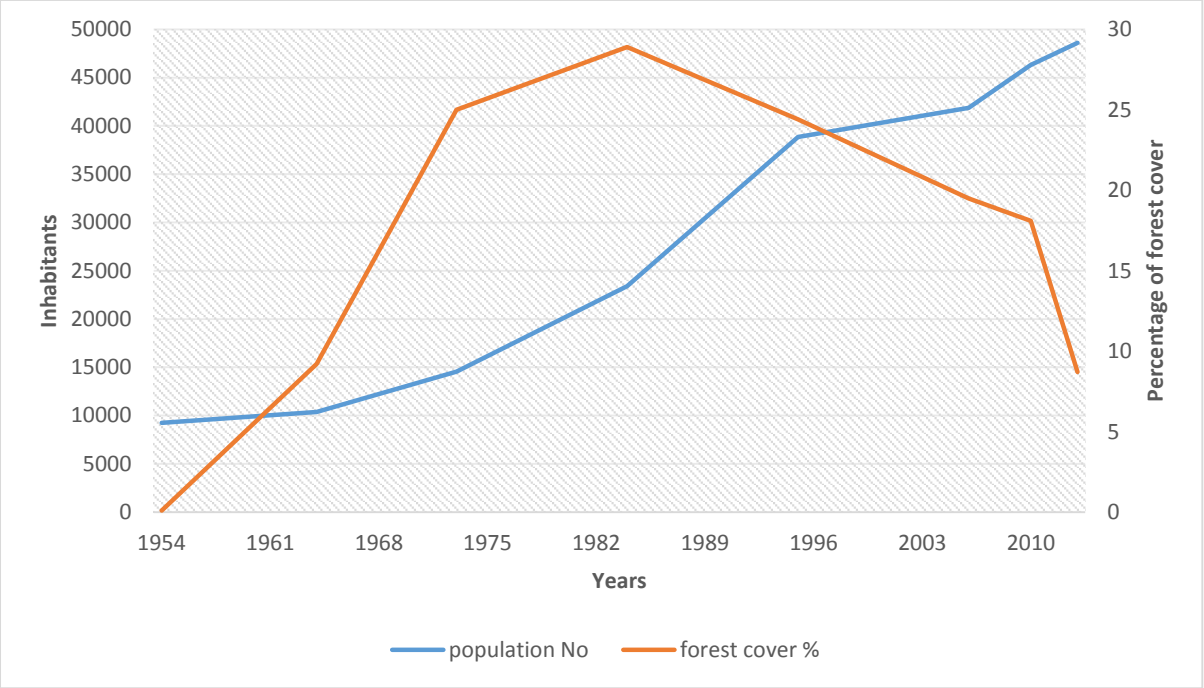

Figure 7.2: Population and percentage of forest cover in Algarabulli district (1954, 1964, 1973, 1984, 1995, 2006, 2010 and population estimates of 2013)

7.3.1.3 Family size

The number of households in Algarabulli in 1954 was estimated at 1973 families. This number gradually increased to an estimated 8706 families in 2010 (see Fig 7.3). Household size in the district continued to increase. Between the 1954 and 1995 censuses, no regular fluctuations or decreases in family size were registered. After the discovery of oil in Libya, economic development and rising standards of living did nothing to reduce family size in Algarabulli. In Western societies, such economic changes typically reduce household size. The opposite trend occurred in Algarabulli: the developments increased average family size because of the strengthening of familial and tribal bonds, early marriages and high birth rates.

Contrastingly, the 1995 and 2006 census indicates that the average household size in Algarabulli dropped from 6.7 in 1995 to 5.8 in 2006. This decline is due to many factors that was stated in the chapter introduction.

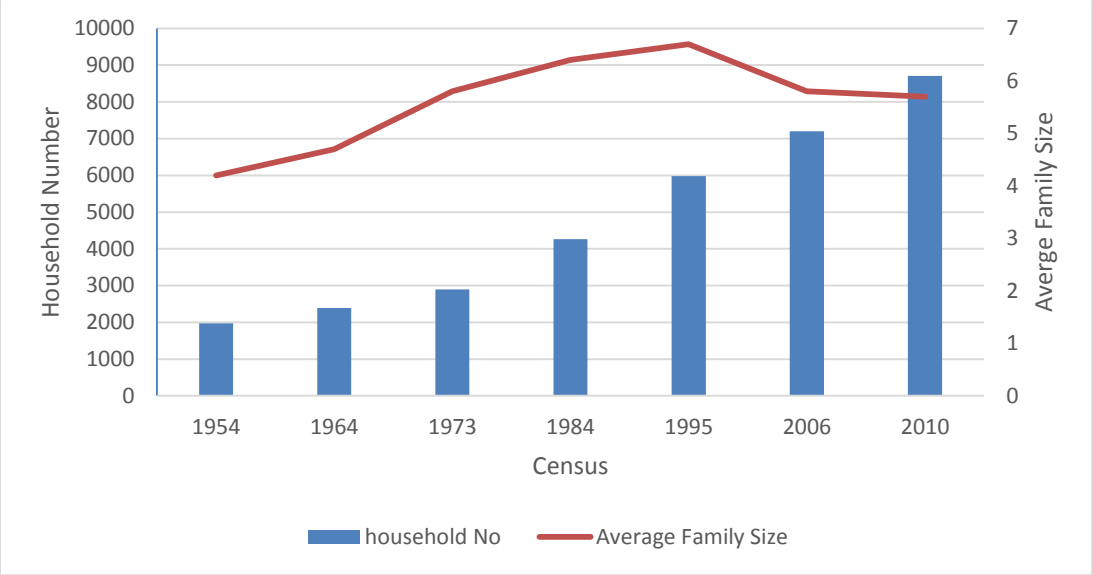

Figure 7.3: Number of households and family size in Algarabulli (1954, 1964, 1973, 1984, 1995, 2006 and 2010 (Source: BSCL, 2010).

7.3.1.4 Population density and deforestation

According to the 2006 census, the population of Libya grew by 1.7% p.a and population density rose to 3 people/km^2. The density is minimal because 95% of Libya's total land area is constituted by desert land. Some regions, however, particularly the north, are characterised by high population densities. An example is Jefara plain, which accounts for 1% of Libya's total land area but is home to 60% of the Libyan population.

The population density in Algarabulli District is 111 people/km^2, but within the localities, population densities contrast. Karawa, for instance, has a higher population density because the urban area of Algarabulli District is situated within this locality; all administrative and financial services are provided from this centre. The locality with the lowest population density is Kawaliq (see table 7.3).

Table 7.3: Population density in Algarabulli localities in 2010

Locality	Area (km^2)	Density (Population/ km^2)
Karawa	79	187
Ataya	78	132
Sharqiya	63	99
Gawea	67	87
Rawajih	73	80
Kawaliq	55	65
Total area	415	111

As was stated in the methodology section, according to the records of forestry departments in Algarabulli district, 150 heads of household encroached into forests from 1986 to 2013, clearing about 7643 ha of forest land for other uses. These individuals represent 0.3% of the total population in the district or 1.7% of the total number of households.

To comprehensively analyse the number of households and the extent of land cleared in the entire district and within the various enclosed localities (Figure 7.4); it was determined that the household densities in non-forested and deforested areas that were converted to other land uses was investigated. Household density was calculated by subtracting the number of forest clearers (obtained from Forestry Departments) from the total household number indicated in the 2010 population census. Although the exact number of inhabitants in the deforested areas is impossible to determine accurately, estimating the population is possible by referring to the number of households in these regions. As ascertained through the analysis, the densities in non-forested and deforested areas differ substantially. The density in the non-forest area is 0.3 ha. per household, whereas in deforested areas it is 32 ha/per household. The densities within Algarabulli's localities are shown in table 7.4 which supports the observation that there is no clear strongly between population and deforestation, these findings confirm that there is no consistency with the findings showed in figure 7.2. However it can be explained that a very some of household are cleared a very large amount of land per household comparing to the average of household in the district.

Table 7.4: Household density in the non-forested and deforested areas within Algarabulli's localities (2013)

Locality	Area/ ha	Household in non-forested area			Household in cleared forest area		
		Non-forested area /ha	Household (No of residents)	Household no/area per ha	Deforested area (in ha)	Household (No of forest clearers)	Household No/area per ha
Karawa	7900	4691	2761	0.5	2360	35	67
Ataya	7800	3228	1802	0.5	3959	80	49
Gawea	6700	4948	1119	0.2	1202	16	75
Rawajih	7300	6079	1016	0.1	831	15	55
Kawaliq	5500	5243	716	0.1	127	4	4
Total	37900	24189	7414	0.3	8479	150	32

7.3.1.5 Forest clearer and deforestation rate

As previously stated, household heads cleared the forest land in Algarabulli for conversion into other land uses. Figure 7.4 compares the forest areas that were cleared before and after the uprising. The figure shows the forest clearers from the Forest Department records (150 household heads), the forest clearers selected for the questionnaire survey (80 household heads) and the forest clearers who agreed to participate in the study (43 household heads). The result shows in figure 7.4 that the sample of clearers interviewed are broadly representative (in terms of area cleared) of the sample selected and of the population of clearers as a whole.

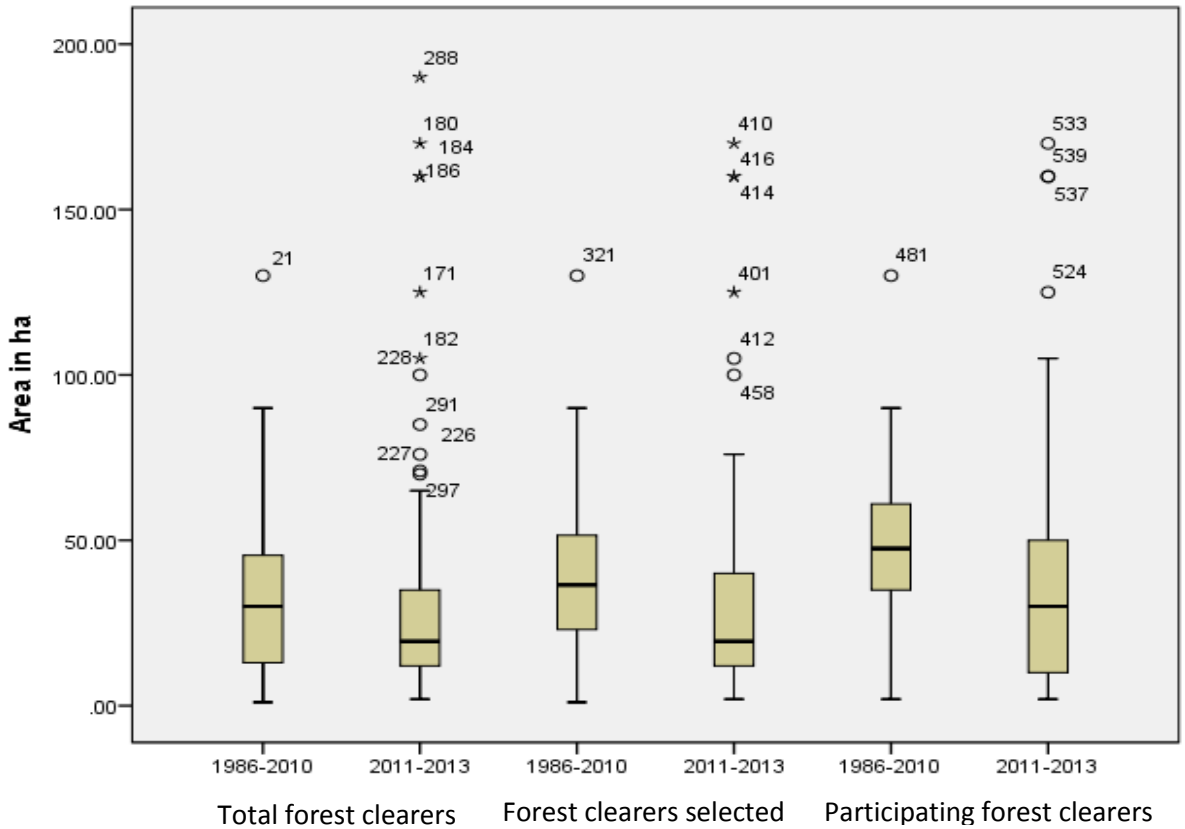

Figure 7.4: Box and whisker plot of area cleared before and after the 2011 uprising by all forest clearer, those selected as safe enough to interview, and those who participated in the interview. Thick lines represent medians, upper and lower box limits represent 75th and 25th percentiles respectively. Numbered outliers are >2 box heights above or below the box (Source: Forestry Department in Algarabulli district, 2014).

7.3.2 Forest clearers compared to others

The aim of this section is to show characteristics, attitudes and knowledge for forest clearers comparing to other local people as explained below;

7.3.2.1 Social and demographic characteristics

7.3.2.1.1 Family size of forest clearers

In terms of family size, the results showed that there is no difference between the forest clearers and other locals, where the average family size of forest clearers is 5.8 and other locals is 6.

7.3.2.1.2 Age group of forest clearers

Figure 7.5 shows that the oldest age group amongst the 43 individuals who cleared the forests in the study area is 51–65 years, to which 55.8% of respondents belong; 23.3% of respondents are in the 40–50-year age group; 18.6% of respondents are more than 65 years old; and 2.3% is less than 40 years old. Also, it was found that the age groups below 51 years represented 25% of the total group populations being responsible for forest cleared after the 2011 uprising.

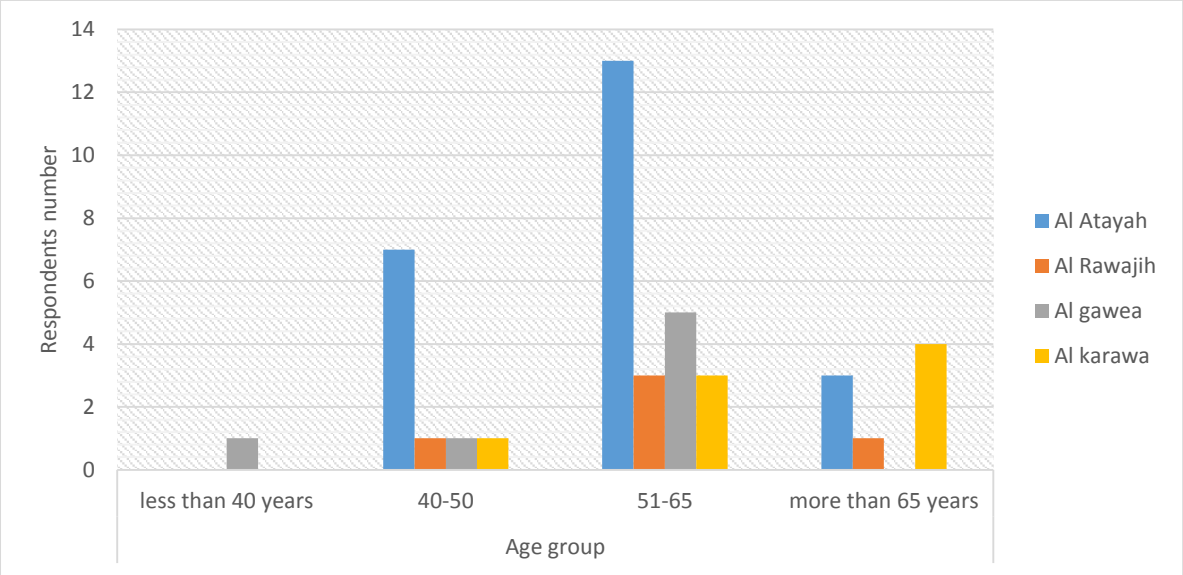

Figure 7.5: The distribution forest clearers' among age groups in Algarabulli District (N = 43)

In contrast, age groups in Algarabulli District, based on the 2006 census, shows that 66 % of the population is in the 15–64 year age group. This age group is an acceptable working age in Libya. The remaining population consists of 29 % representing those under 15 years and the other 5% represents people over 65 years.

7.3.2.1.3 Educational status

The result in the figure 7.6 illustrates that many of the forest clearers (17 of 43) hold average educational attainment, which covers higher than secondary education and lower than a college degree. Amongst the respondents, 16 have primary and secondary education, 7 hold undergraduate and post-graduate degrees and 3 have only reading and writing proficiencies. In summary, 93% of the respondents are educated and 7% are uneducated.

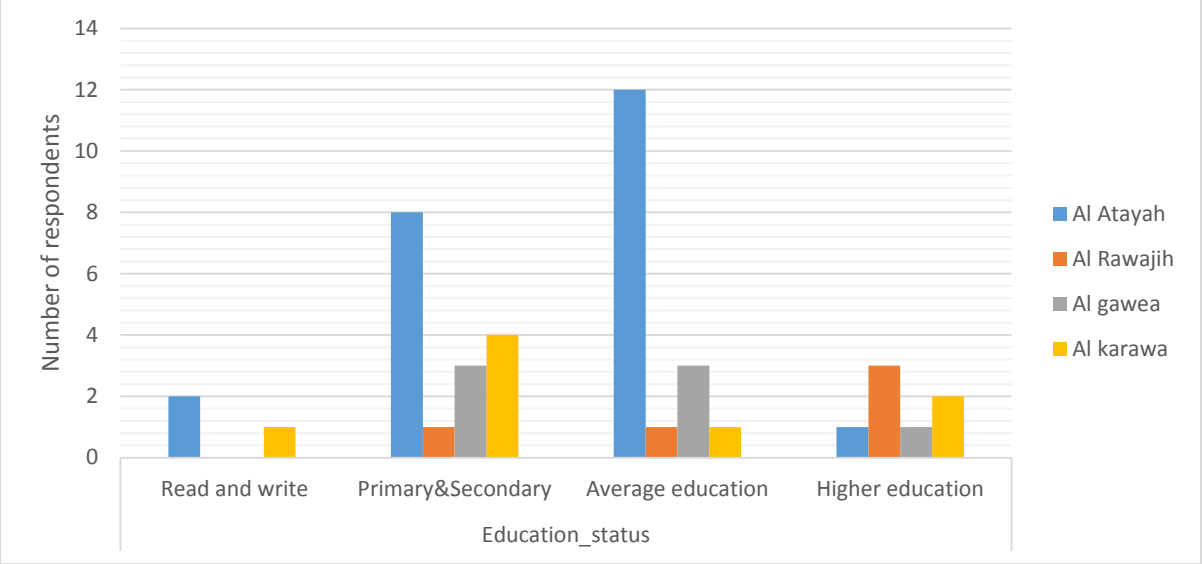

Figure 7.6: Forest clearers' Educational status in Algarabulli District (N = 43)

Education in Algarabulli district in the past was not available in its current form. Until the late 1960s, students acquired elementary education in the district. Should they desire to continue their education, they were compelled to travel to large cities where education was more developed, with an increasing number of schools having been established in the 1970s. The number of primary and secondary schools, or their equivalent, was one school in 1950. After 5 years there were 10 schools, in 1980 there were 35 schools, with an estimated 65 schools and one higher Institution by 2010. Some universities also had two branches by this time.

7.3.2.1.4 Occupation of forest clearers

With regard to primary occupation of forest clearers, the results show 39 of the respondents are employees in the public sector. The occupations were categorised into four types (Fig 7.7): officials (14 respondents), army and police officers (5), retired employees (3) and currently employed individuals (17). Amongst the forest clearers, four work in the private sector. As explained in chapter four, the non-forest clearers stated that deforestation was initiated by army and police officers and officials of state institutions who held authority acquired from the previous regime. Ordinary citizens then followed suit. In fact, the records of the forestry departments confirm that state officials and officers were the ones who initiated forest clearing in the study area.

The findings also indicate that people who cleared the forests before the uprising live close to the forest land (forest neighbours) and some government officials and officers from outside the

district. However, after the uprising, those who cleared the forests are people who claim ownership of the land includes forest neighbours, local non- forest neighbours and armed gangs. These findings agreed with findings of chapter four.

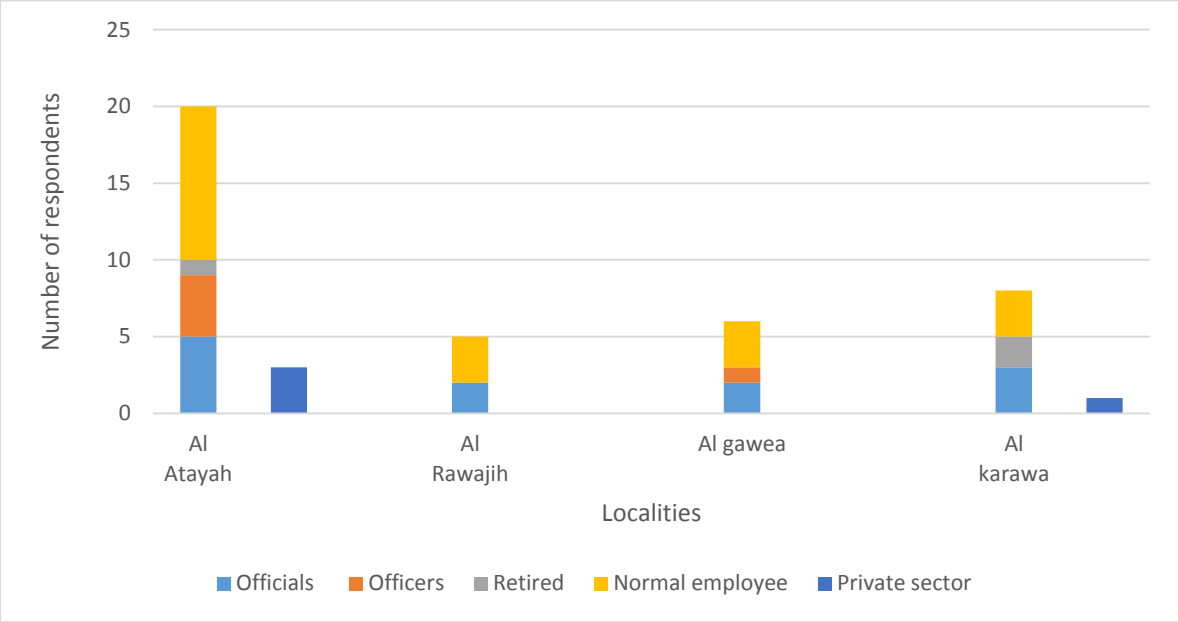

Figure 7.7: Forest clearers' occupation in Algarabulli District (N = 43)

7.3.2.1.5 Income

To determine if there's a statistically significant difference between the respondents of forest clearers and respondents of non-forest clearers in their income within the localities.

A two factor ANOVA, examining where the forest clearers and non-forest clearers differed in income showed no significant interaction between location and land user ($F=0.04$ $p=0.988$). There was no significant effect of location ($F=0.670$, $p=0.573$) but the average income of forest clearers (9860.5 LYD) was significant higher than that of non-forest clearers (8230.2 LYD) ($F=13.78$, $p<0.001$). Residuals were approximately normally distributed with no significant heterogeneity of variance (levenes statistic 0.690, $p= 0.681$).

7.3.2.2 Forest clearers: attitudes and knowledge

7.3.2.2.1 Awareness of forest clearers regarding the importance of forests

During the forest plantation campaigns that occurred from 1960 until 1984, the government made a great effort to raise awareness among the local people of the importance of forests.

They did this through schools, mosques and NGOs, such as Tree Friends Association. However, all of these efforts were suspended in 1986.

So, most of the individuals who engaged in forest clearing are educated and should have been cognizant of the importance of forest land. These individuals also witnessed the suffering that the residents experienced because of sand dune movements. The problems caused by sand dunes are what drove forest planting. As the non-forest clearers stated in chapter three, amongst these forest clearers are officials, officers, teachers and religious leaders, who should have taken the lead in preventing people from clearing forests. Some of the non-forest clearers also stated that the unfavourable state policies after 1985 accelerated deforestation. The non-forest clearers declared that although the forest clearers were aware of all forest protection-relevant information, whether it be on the importance of such land cover or forestry laws, they ignored such information because of greed and their desire for land ownership. Figure 7.8 compares the forest clearers and other local respondents in terms of their awareness of the importance of this land cover and forestry laws. The forest clearers claimed to be less aware of the importance of forests and forestry laws than that observed amongst the non-forest clearers. Of the 43 forest clearers, 41 (95%) stated that they were unaware of the importance of forests, and 26 (60%) indicated that they were uninformed about forestry laws. By contrast, all the non-forest clearers (43) stated that they knew of the significant role of forests in environmental health; although they aware of all the forestry laws and they read some articles about the current state of forest land and regulations that prohibit cutting and clearing.

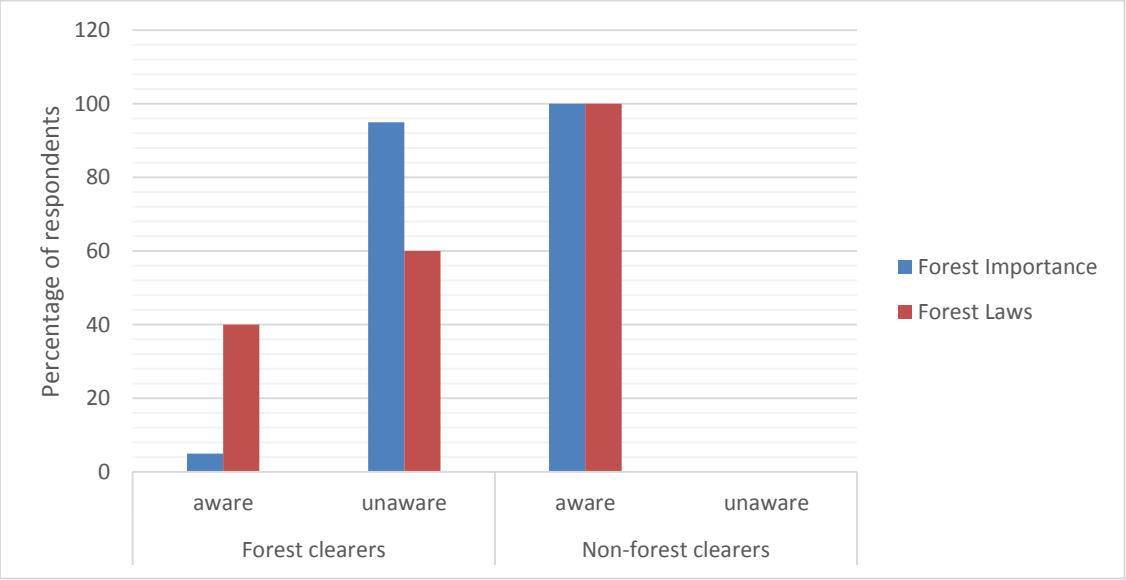

Figure 7.8: Comparison between forest clearers (N = 43) and non-forest clearers (N = 43) in terms of awareness about forest importance and forestry laws in Algarabulli District.

The perceptions of forest clearers about the importance of forests are uncertain, but as the non-forest clearers indicated, most of the forest clearers disregarded the importance of forests and the laws designed to protect these resources in the name of land ownership. They wanted to obtain lands for later sale. The non-forest clearers clearly expressed concern over the consequences of deforestation.

To verify the truthfulness of the responses, we presented additional questions regarding afforestation, who participated in these initiatives and why. These questions were raised because they serve as a respite from the investigation into deforestation and were therefore a strategy intended to assuage the discomfort that the respondents may have begun to experience.

The first question centred on land cover types before afforestation. As presented in figure 7.9, 40 of the 43 forest clearers stated that sand dunes were the dominant land cover type before forests were planted; 2 identified natural land as the primary land cover type; and 1 indicated that he had no idea what cover types were dominant before forest planting.

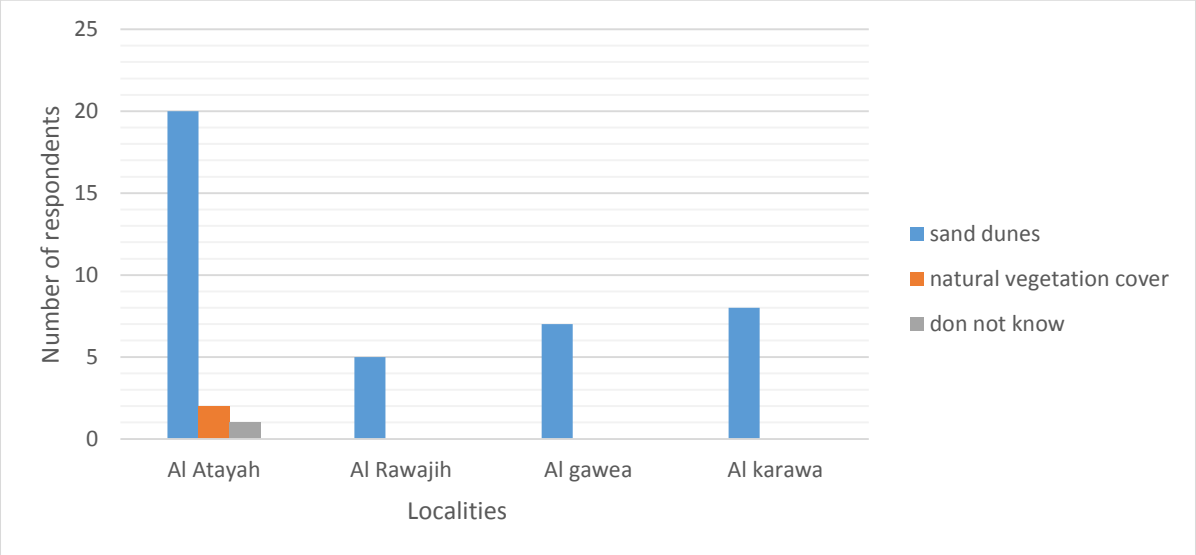

Figure 7.9: Forest clearers' awareness about land cover before forest planting (N = 43)

The second question revolved around the agents who participated in forest planting. Amongst the forest clearers, 42 identified the government as an agent and 1 exhibited no awareness of this issue (Figure 7.10).

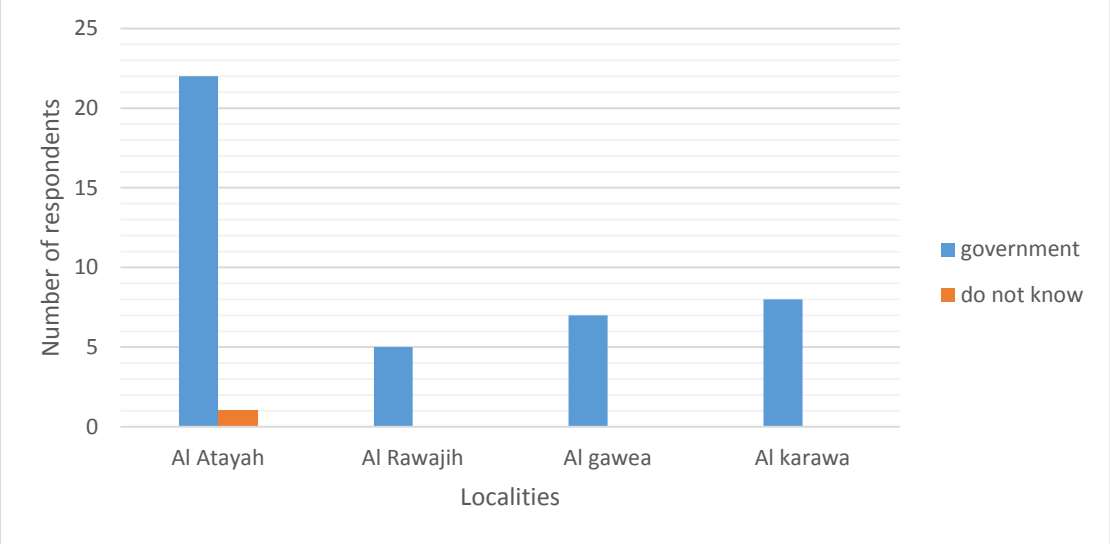

Figure 7.10: Forest clearers' responses regarding participants in forest planting

In terms of why the government implemented forest planting measures, 25 of the forest clearers evaluated the measures as being designed to stop sand dune movement, 17 perceived them as a means of combatting desertification and 1 could provide no answer to the question (Figure 7.11).

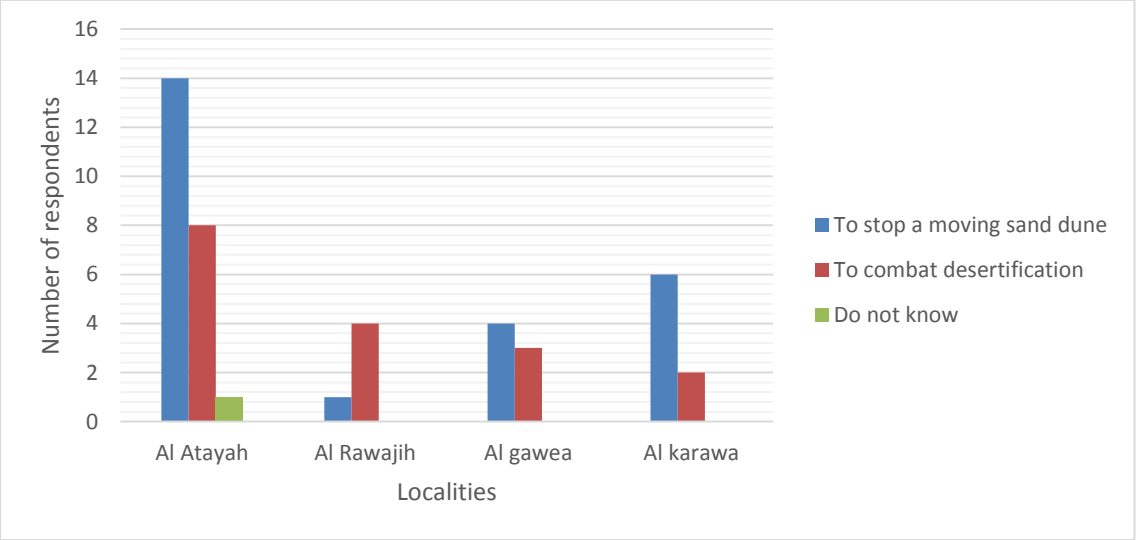

Figure 7.11: Forest clearers' understanding of why forests were planted

Although most of the forest clearers could respond to the questions, the results reflect a huge contradiction between their afforestation-related answers and responses to the questions regarding awareness of forest importance. They should have been fully cognizant of this issue given that they were completely aware of the afforestation efforts being made in the study area.

In summary, the non-forest clearers understood the value that forests present and exhibited concern over forest clearing, whereas the forest clearers were unconcerned about the consequences of deforestation. Their justification for clearing forests was that because no benefits could be derived from planted forests, these land types had to be cleared for other purposes.

Moreover, the Director of the Forestry Department in Algarabulli district and other government officials stated that ignorance does not play an important role in forest clearance. Instead, he argued that the forest clearers were well aware of the importance of forests, therefore they were not telling the truth to me. Indeed, there are many sources of information and guidance about the importance of forests in Libya, including schools, mosques and NGOs. It will be discussed these below:

7.3.2.2.1.1 Social institutions and their role in forest conservation in Libya

As an important component of a country's natural resources, forests can contribute to the economic and social welfare of people. Eckholm (1979) states that the three basic human resources obtained from forests are food, clothing and shelter.

The FAO (1987) classified forest plantations into two groups, namely, industrial and non-industrial plantations. Industrial plantations are established partly or completely for the production of wood for industry use, whereas non-industrial plantations are established partly or wholly for the production of fuelwood and charcoal and for ecological maintenance measures, such as soil protection.

Although the primary purpose of forest land is wood production, it can also serve other purposes that are equally beneficial to socio-economic development processes. The aims of establishing forest plantations are to satisfy the requirements of an increasing population and to cater to the needs of specific types of plant species to accelerate their growth and usage in rapidly expanding industries. In Libya, however, forest plantations were established primarily to guarantee ecological balance. In this regard, the measures implemented in the country revolve around catchment protection, soil erosion control and the maintenance and safeguarding of flora and fauna. All these factors figure importantly in the maintenance of a viable land use system and environmental equilibrium.

Other potential benefits of planted forests at the local and national levels in Libya are the creation of jobs and the generation of economic surpluses, as in the case of the beekeeping industry. According to available data on investments in timber in 1985, which was stopped after this time, the country's annual mean production of wood is about 20 cubic metres/ha, which results in an overall production of 626,000 m^3. Of this volume, 85% is used as firewood (charcoal) (FAO, 1993) where some specifically in rural areas people still prefer charcoal for heating, barbecues and cooking for special occasions or social events such as weddings so as to produce particular flavour in the food. Despite the availability of other forms of energy (electricity, gas, kerosene, etc.) and with low prices, as a result of state policy and higher incomes (FAO, 1993). People especially in the countryside prefer to use wood especially for cooking. The country imports all its forestry products, especially wood (FAO, 1993).

In the 1950s and the 1970s, the main sources of livelihood of Al-Jabal Al-Akdar residents were the private ownership of livestock (goats), which were left in the forest and valley slopes to graze, and the cutting of trees for firewood or for sale to the charcoal industry. These practices negatively affected the forest land in the area, and later, the plantation forests. These adverse effects prompted traditional social institutions to initiate measures to protect these land covers.

7.3.2.2.1.2 Family

Libyan culture can be described as traditional, especially with regard to behaviours and attitudes. Libyan society generally consists of major social units based on the family, clan, tribe and village, in which the idea of the extended family is most important and widely promoted (Moh, 2013). In general, the extended family and tribe represent the social units that contribute most to strong social belonging. The father is the main authority in the family, and his decision is always unchallenged by family members, irrespective of the academic qualifications held by these members. Despite the rapid development of all areas of life within the last decade, Libya remains fundamentally a traditional society, where loyalty to a given region and to one's tribe is stronger than allegiance to other units (Moh, 2013).

In such environment, particularly in traditional communities, individual interests are part and parcel of family interests, but in cases wherein conflicts of interest arise, family interests take precedence.

In relation to the issue at hand, the family plays a critical role in the conservation of vegetation. Land is sanctified by rural communities because of the values and meanings that it represents;

that is, these values bear on the physical and moral perspectives and behaviours of community residents. The practice of agriculture, for example, is positively reflected in the respectful expansion of land that is cultivated with various crops and trees.

The family also assumes responsibility for educating succeeding generations in terms of the need to ensure that forests are treated as national treasures.

7.3.2.2.1.3 Mosque

Religion is always highly valued amongst Libyans, to the extent that it serves as one of the determinants of social behaviour. Religious values in Libya have been deeply rooted since the early Ottoman occupation and during the royal era, at which religious leaders governed the country and stringently oversaw all aspects of life (Moh, 2013). The domination of religious leaders continued through 1969 (Moh, 2013). The fact that religious leaders were highly respected by the public and the high social status that they retained afforded them an advantage over other social groups; these granted them licence to lead society and occupy key positions in politics, education, administration and the judiciary.

Given this backdrop, Islamic societies revere the mosque as the traditional institution that guides people's actions, with particular focus on practices that benefit the public and the community. People attach considerable importance to Islam as a guiding principle in the maintenance of vegetation. The Quran itself highlights the importance of trees in many of its verses, which encourage the planting of trees and the prevention of tree cutting or any form of damage to vegetation. To illustrate the reverence with which plant life is regarded, three chapters of the Quran are labelled with the names of trees: the fig, olive and palm trees. The lessons delivered in mosques play a major role in enlightening community members regarding the need to preserve vegetation and increase the area of cultivated land. Additionally, booklets about Islam and the environment elucidate the role of Islam in environmental preservation and protection, which extends to forests. Sometimes, the information in these booklets is delivered as speeches in mosques for the young and the elderly, as well as those for men and women.

7.3.2.2.1.4 Schools

Schools are equally significant avenues from which to disseminate information on planting values and the common good. This information includes principles for maintaining vegetation

and measures for educating people regarding the importance of forests and their role in maintaining ecological balance and creating a beautiful and healthy environment.

In the 1960s to the 1980s, Libya's Ministry of Agriculture, in collaboration with the Ministry of Education, initiated efforts to educate people about the importance of forests, their role in preserving the environment and the ways in which people can protect forests. These issues were accorded priority in the state's implementation of environmental policy. Many lectures were held for school students, youth leagues, scout organisations and citizens to encourage them to participate in afforestation campaigns.

7.3.2.2.1.5 Government and non-government organisations

Agricultural and forest lands diminished amid economic development, with large sections of forest cover converted into barren land through burning, cutting and ploughing. Non-government organisations were therefore established to maintain vegetation cover, increase the amount of cultivated areas and combat desertification and erosion, as well as the destructive exploitation of forests and natural resources (soil, water, forests). These organisations were intended to work towards optimal resource use.

In the domain of national cooperation and education on environmental safety and forest protection, a number of activities and programmes were designed and developed to raise environmental consciousness amongst people and educate them about the unfavourable environmental effects resulting from intentional or unintentional human activities. Guidance was also broadcast over radio and TV stations to inform people about appropriate forest management and protection techniques.

Additional measures included authorities' contribution to local newspaper and magazines in the form of articles on the environment and forests to raise levels of awareness and interest amongst the public. In the education sector, a curriculum related to agriculture in general and forestry in particular was adopted.

The environmental education campaigns and information programmes enabled stakeholders to achieve the desired degree of progress in enhancing environmental protection across all social layers. Nevertheless, key informants and recently available reports indicate otherwise. That is, the measures and initiatives implemented by the government and non-government

organisations in schools and mosques were terminated in the mid-80s because of the enactment of non-complementary state policies after 1985.

These policies negated the early efforts established for the purpose of protecting forests and plantation forests and directly influenced the manner by which families and mosques engaged in environmental protection.

7.3.2.2.2 Land tenure

In Libyan society, land is regarded as the source of life. The influence and strength of a family is measured by how much land it owns. In particular, Bedouins believe that compromising land translates to compromising one's dignity. Because of the strong link between morality and land, land-related conflict always engenders violence, typically in the form of murder (Al-Zeni and Bayoumi, 2006).

Before the uprising, the people of Algarabulli district were engaged in moderate problems in relation to the acquisition of forest land, but disputes on forest land acquisition after the uprising began taking on a more deadly turn, with one case resulting in the murder of a family member. Each party claimed ownership of a given section of land—a dispute that was aggravated by other problems arising from the spread of weapons and the absence of state regulation. Under this situation, land ownership documents were used as grounds for forest clearing, figure 7.12 shows claims to land tenure or proof of ownership.

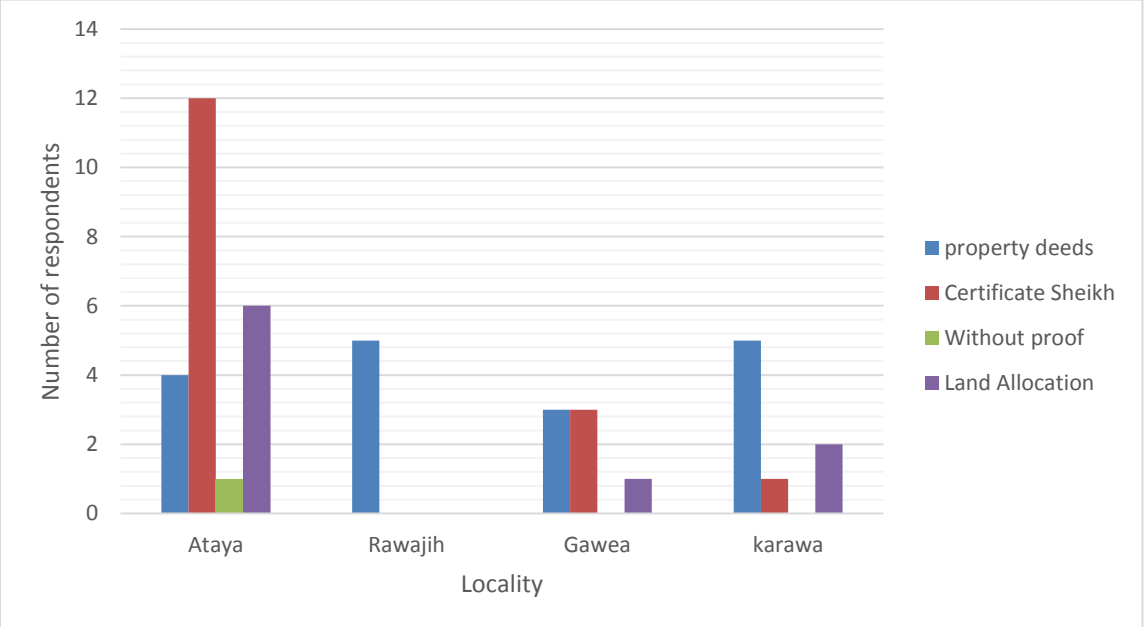

Figure 7.12: Claims to land tenure or proof of ownership by forest clearers

The respondents stated that land rights were reinforced by property deeds or Sheikh certificates. When the state stabilised the sand dunes and planted trees on them, the respondents and their parents believed that the goals of the programme were sand dune stabilisation and land reclamation for agricultural purposes. However, they claimed that the state took the land from them by the power of the law. Another justification offered for forest clearing was that although forests facilitate the biocycling process, no tangible benefits can be derived from this land cover, hence the decision to remove the forests for purposes that were deemed important by the clearers. This explanation was expected by the respondents who are relatives of the forest cleaners and by officials who disproved of this practice, regardless of whether it is permitted by law and custom. These individuals criticised the practice as dishonest and primarily motivated by the desire to acquire land by any means possible.

As described in a previous chapter (the legal status of these claims to land tenure or proof of ownership explained in section 6.3.4) the documents that supposedly confirm land ownership and that were used by the forest clearers as licence for acquiring land are illegal.

The forest clearers were asked about how may plots of land they obtained to identify the economic status of these respondents. Amongst the participants, 18 indicated that they own only one plot of land, 19 stated that they own two plots of land, 5 shared that they possess three plots of land and 1 owns four plots of land (Figure 7.13). These results demonstrate that the forest clearers are well off and therefore have no need to clear forests.

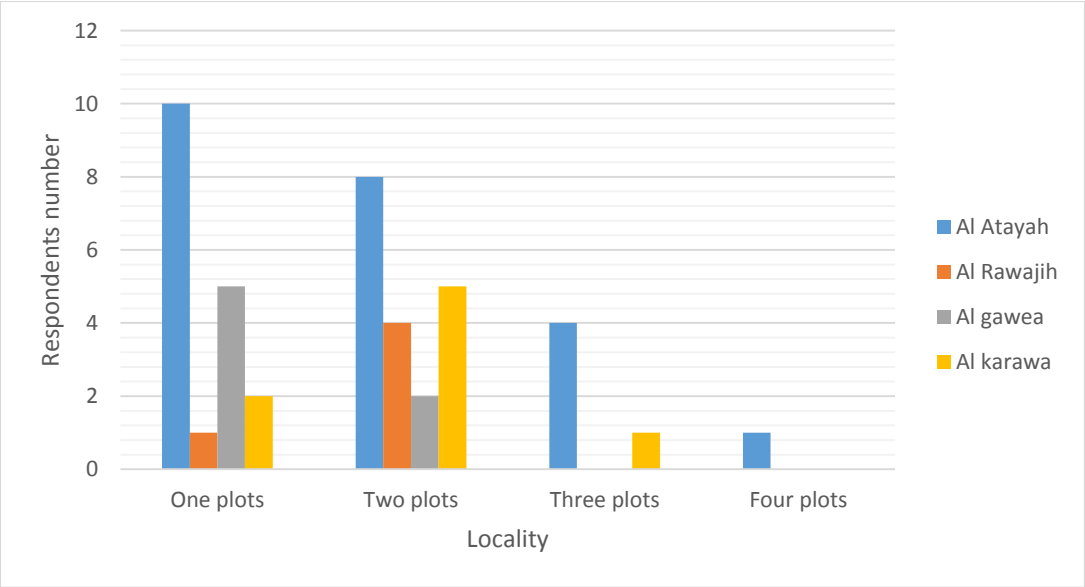

Figure 7.13: Number of plots of land owned by forest clearers

7.3.2.2.3 Purpose of forest clearance

The forest clearers were directly asked to explain why they cleared forests even as they suffered from the effects of deforestation and sand dune movement before forests were planted in the study area. Most of the respondents (26) mentioned agricultural expansion as justification, some (10) indicated the need to build houses and the rest (7) raised both these factors as explanation for their actions (Fig 7.14).

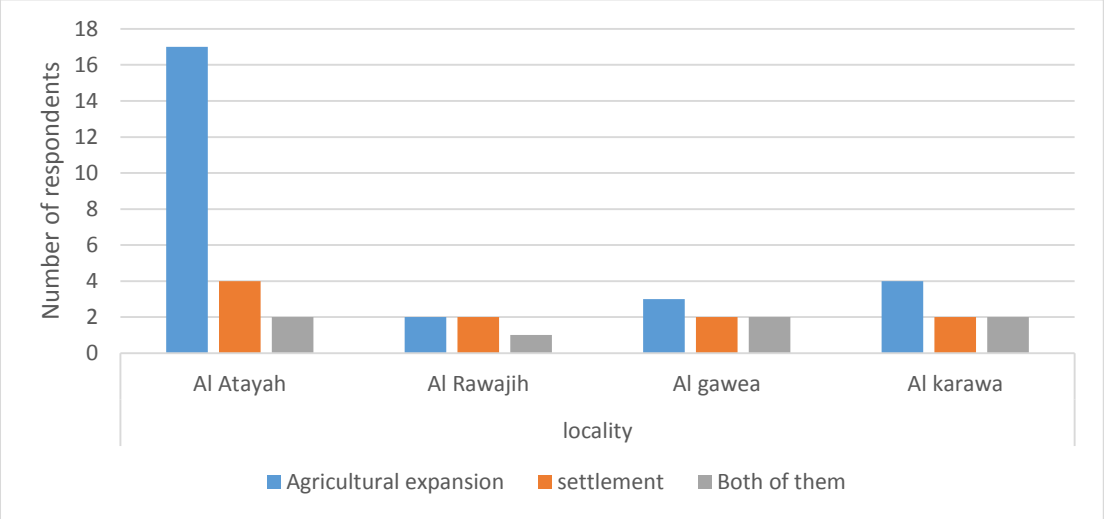

Figure 7.14: Purpose of forest clearance

7.3.2.2.3.1 Agricultural expansion

An important question that arises from this situation is whether the forest clearers were aware of the positive and negative effects of converting forest land to cropland. Available soil and water data (see chapter 2) illustrate that forest land is unsuitable for growing crops because it is composed of sandy soil and poor-quality organic matter. As shared by the non-forest clearers (see chapter 4), most of the cropping practices over the land failed and dunes were re-established. We experienced this phenomenon, as well, during the fieldwork. The forest clearers who engaged in forest removal for the purpose of cropping before the uprising were asked to share their reasons for engaging in forest clearing. Amongst them, 95% stated that the decline in agricultural production prompted their decision to clear forests.

7.3.2.2.3.2 Building expansion

The economic development of Libya after the exportation of oil altered some of the cultural attributes and population patterns in the country. Before the advent of oil production and export, families resided in small houses with a large number of family members, even until after sons were married. After the discovery of oil, household size increased to three times the previous level. Furthermore, upon marriage, family members constructed a separate house located within the same area on which the ancestral house stands.

Some of the forest clearers identified the lack of housing projects that would have enabled them to provide housing for their sons as the factor that drove them to clear forests. To determine the correspondence between the forest clearers' explanation and actual circumstances, forestry department data were examined. The records show extensive encroachment of up to hundreds of ha per person. With this volume, each forest clearer is assumed to have 10 children and to own a house occupying an average area of 500 m^2. For the forest clearers to build houses for their children, they would need half a hectare. Therefore, if one clears an estimated area of 100 ha for residential purposes, this expanse of land can accommodate more than 2000 houses for the families.

The forest clearers did not mention clearing forests for the purpose of building a second house, specifically in areas where forest land neighbours the sea. Some of the respondents identified housing as a driving factor of forest clearing, but these individuals inhabit the houses only on weekends, seeing as their employment as officials and officers required residence in the capital. Some of these officials and officers obtained the lands through allocation contracts.

7.3.2.2.4 Land price

As discussed in Chapter 4, the non-forest clearers identified increasing land price as one of the important factors that precipitated rising deforestation, particularly after the uprising and the lack of intervention on the part of the government. To verify this response, land prices before and after deforestation were obtained from land dealers' records and compared. Figure (7.15) shows the average land prices in deforested and non-forested lands, indicating increasing land prices in the study area. The prices considerably differ between cleared land and land used for other purposes.

An official in Algarabulli district stated that the land price in deforested area was lower than that in other land types before the uprising because most people were aware that forest land was being claimed by the state and that they would be expelled should the law warrant such

action. Because deforested lands do not come with official documents, most people preferred purchasing non-forested lands, for which ownership is validated by official documents.

In addition, land prices from 2005 to 2010 rose because of increased interest in the lands. The state continued to disregard the behaviours of the forest clearers and the people who bought these properties.

As stated earlier, that deforestation rate was higher during the uprising than before the conflict. The primary purpose underlying this practice was land sale. The forest clearers were asked about whether they have sold parts of their land. A total of 40% have sold sections of their land, whereas 60% have not. As observed during the field work, however, some of respondents who declared that they have not sold land had 'for sale' signs over their properties. Their neighbours also confirmed that the respondents sold some plots of lands. Some of the forest clearers recently cleared land sections and divided these into smaller square segments (residential schemes) for road paving and electricity projects. These efforts were initiated without approval from the state or consultation with competent authorities. At the time, the state was incapable of preventing people from selling land for millions of dinars. Road paving and electricity provision projects necessitate huge amounts of money; these programmes were previously carried out by the state but are now initiated by forest clearers.

Forest land prices are higher than those of other types of land, for which ownership is validated by official papers. The land which had very high price which are located along the coast which is forest, therefore these properties are therefore priced at more than half a million LD (£200.000). In spite that buyers who are interested in such lands are also knowledgeable regarding land documents.

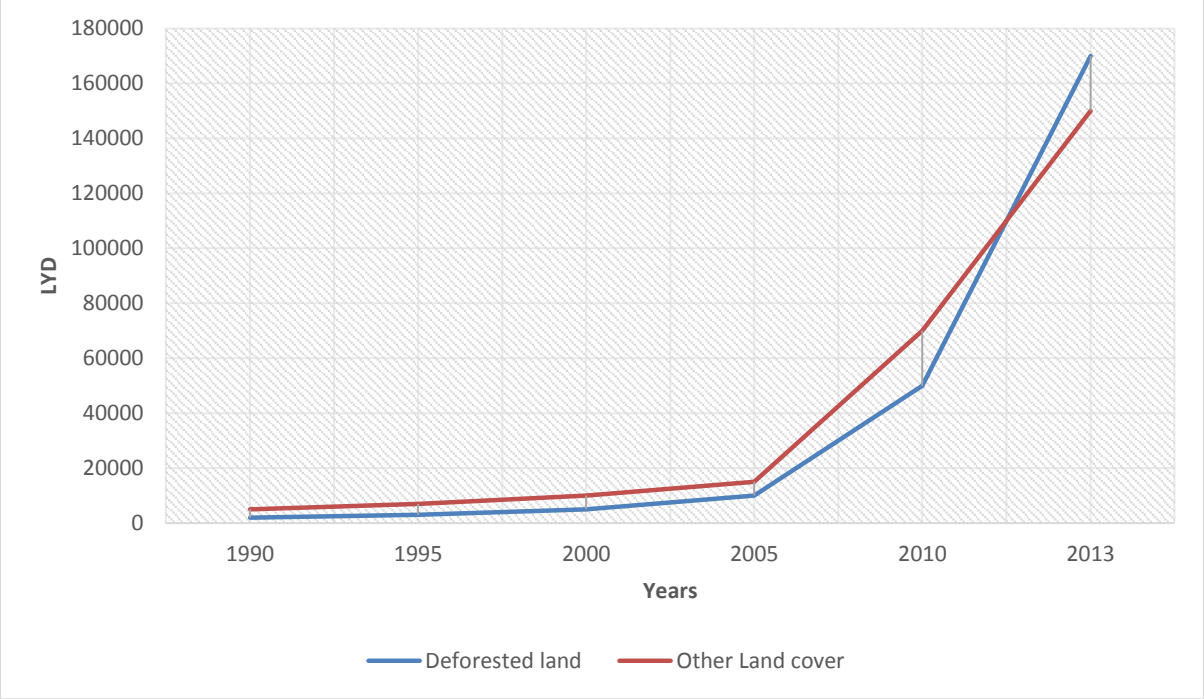

Figure 7.15: Real prices of deforested comparing with other land types/ per ha (1990–2013)

Although no official reports are available to explain the increase in land price, the economist and dean of the Faculty of Economics at the University of Tripoli shared the following insights:

1. The state did not control or impose restrictions on land prices before or after the uprising. During these periods, land dealers determined price on the basis of supply and demand.

2. After the fall of the Gaddafi regime or the period between 2011 and 2013, a total breakdown in governance and a tenfold increase in land prices occurred, thereby incentivising land speculation and forest clearance.

3. After the fall of Gaddafi, some armed militia members stole state funds to buy real estate (land, buildings) as a means of money laundering.

4. Some people from outside the region, especially displaced citizens and people who require asylum because of continued armed conflict in their home countries, are interested in purchasing land in the study area. These individuals perceive ownership as a route towards stability and regard the study area as relatively safer than other regions. Other motivating factors include the proximity of Algarabulli District to the capital. To a certain extent, the procedures and restrictions adopted and imposed by Libyan banks encouraged customers to withdraw their money from these financial institutions. Additionally, the armed robbery in

some banks and the lack of financial liquidity as a result of the suspension of oil exportation in recent years, led to loss of confidence in banks. Customers, specifically traders, tended to invest their money in land or buildings because these were regarded as the most stable form of investment during a period of low security and safety.

7.4 Conclusion

On the basis of the population censuses (population growth and density) in the Algarabulli District and in its localities, it was concluded that population is not a contributory factor to deforestation in the area. Moreover, all the cleared lands were cleared by only 150 people, all of whom are heads of household. This number represents 0.3% of the total population and 1.7% of the total household head population in Algarabulli District. The forest clearers recognised that the state initiated forest planting as a means of alleviating the suffering originating from sand dune movements. They also admitted that they were educated by the state educated regarding the importance of forests and forest protection through school and mosque activities. From their point of view, however, forests are not as important as they are projected to be, with some of the respondents attempting to justify their decision to engage in forest clearing. They argued that they owned the forest lands but that the government forcibly took these from them given that the property titles that they obtained are illegal (see chapter 5). They also believe that forests present no value, hence the decision to clear this land cover for other purposes. The respondents engaged in this practice despite the fact that most of them are educated people (average or higher education level).

In terms of economics, most of the forest clearers are employed. Another justification offered in this regard was that forests were cleared for agricultural expansion, even as all the government reports on soil and water composition indicate the unsuitability of these lands for cropping. Some of the forest clearers identified decreasing production due to poor soil quality and water shortage as motivators of forest clearing. Nonetheless, the results show that the main reason for the rapid progression of deforestation after the uprising is the increase in land prices, which is due to increased demand from people living outside the district. The individuals include people who stole funds from the state after the fall of Gaddafi for money laundering or citizens displaced by continuing war. The findings demonstrate that increased land prices caused progressive deforestation. Against this backdrop, the principal purpose of forest clearance is land sale. This problem is exacerbated by the government's inability to prevent encroachment into forest land, the buyers' disregard of forest land as valuable natural resources and the fact that such land cover belongs to the state. The comparison of incomes between the forest clearers and non-forest clearers also indicate that the income of the former is slightly higher than that of the latter.

8 General discussion

8.1 Summary

After Libya gained independence in 1951, priority was given to sand dune stabilization, regulation of grazing, control of soil erosion, and the growing of drought-resistant species in arid areas. These measures were taken in order to partially control the process of desertification; 95% of Libya's total land area is desert.

During the 1960s and 1970s, various measures were taken to combat desertification, particularly on the Jefara plain. These included sand dune fixation with dry plant residues, crude oil, which became known internationally as the Libyan Technique for stabilizing sand dunes and with synthetic rubber. The most effective proved to be tree planting and, by 1984, 248,000 ha of trees had been planted. The forest area in the zone of this study was fairly stable from 1955 until 1973.

However, these planted areas are now suffering from severe deforestation, which has once again resulted in serious encroachment by sand dunes. This study found that the deforestation commenced in 1986, due to a range of direct and indirect causes, and increased dramatically after the fall of Gaddafi regime in 2011.

8.1.1 Causes of deforestation

The direct causes of deforestation differ between two periods: before the fall of the Gaddafi regime and after. The direct causes from before the regime's fall were agricultural expansion, road construction and building construction, the last of which included homes, holiday homes and resorts.

As for agricultural expansion, though all reports on the soil and water in study area have stated that these lands are not suitable for agriculture, it was found in chapter four and chapter seven that some people had cleared areas of forest for cropping. They stated that their agricultural production was decreasing—as was noted during the field visit—due to the poor soil, which contains little organic matter, and suffered from groundwater shortages. However, the respondents who had not cleared forest areas claimed that the forest-clearing residents were, in fact, attempting to claim the land for their own by growing other crops, such as fruit trees and vegetables, upon it.

Building construction was found to be the second most significant cause of deforestation. The building of the second homes or holiday homes by ex-government officials was the initial purpose for clearing the forest; later, houses were built by local residents. In recent years, some people have cleared areas of forest to build resorts, particularly in forests located in the coastal strip.

Road construction contributed to increased deforestation in the study zone, particularly in the Ataya block of forest, where the government established a paved road which crossed forest areas and where people have established other paved roads without government permits.

With regard to the indirect causes of deforestation before the fall of the Gaddafi regime, it was found that there is a very complex set of causes which are all about the change of governance of the forest. These include the issuing of illegal permits for land allocation (i.e., usufruct contracts), the lack of law enforcement, various forms of corruption whether by government institutions or officials mismanagement by officials, administrative instability and lack of registration of forest lands. Also involved are immigration and a lack of public awareness of the importance of forests.

Non-forest- clearing respondents and government officials contended that land allocation (i.e., the issuing of illegal permits) was the main cause of deforestation, leading to conflicts over forest land, increasing land title fraud, and lack of respect for the law.

Given this result, how the governance of forests changed was investigated and why deforestation commenced in 1986. Respondents among government officials explained that deforestation commenced in that year because of changes in the Gaddafi regime's policy regarding forests. Gaddafi abolished the Ministry of Agriculture, and afterward the agricultural affairs in all municipalities of Libya were managed by the Directors of Agricultural Sectors, who issued land allocations or usufruct contracts. For instance, the Agricultural Sector in Tripoli Municipality issued usufruct contracts for forest lands to some of the state's officers and officials, which in turn encouraged some local people to clear parts of the forest.

The Ministry of Agriculture resumed its work in 1990 after four years of suspension. New laws of forest protection were issued under Law No. 14 of 1992, which made the issuing of usufruct contracts illegal and required whoever had obtained them to evacuate their forest land. However, this law has not been applied yet. Moreover, the Ministry of Agriculture was abolished again for another four years, and more usufruct contracts were issued by the agricultural sector in Tripoli Municipality.

Though there are very good laws in place to protect forests, as law expert respondents stated, the corruption of government institutions and officials that followed the issuing of land allocation has contributed to weakening the enforcement of laws.

Administrative instability and interference by authorities in forest management have also contributed to deforestation. This instability is indicated by the fact that the name of the Ministry of Agriculture has changed many times, from the Ministry of Agriculture, to the Ministry of Agriculture and Livestock, to the Ministry of Agriculture, Livestock and Marine Wealth. These changes indicate the constant separation and amalgamation of ministries. In addition, there have been changes in the administrative subordination of forested regions which have led to the interference of authorities in forest management. The change of administration in Libya in the 1990s, from civil administration to military administration—from qualified people to unqualified people—resulted in the sheikhs of various localities holding authority over forest lands.

Another issue occurred in 1986: the burning of the Land Registry centres in Libya. The result was that forest lands were no longer registered. In legal terms, forest lands are state-owned, but the destruction of the registry has led to increased deforestation as various parties may claim that a given piece of land belongs to them. Some law expert respondents stated that the law is not enough to establish that forest lands are state-owned—to be truly state-owned, they must be registered as such in the Land Registry. Other law expert respondents disagreed, saying that the law as written is enough to consider a forest state-owned. This situation has led to increasing disputes of land tenure and land ownership. Where sheikhs of various localities hold authority, they issue certificates of ownership of forest land, though this is illegal.

With regard to population growth, censuses have shown that the population growth rate has remained low—from 1995 to 2006, the rate of increase was actually decreasing. Records of the Forestry Department in Algrabouli district showed that the number of people who had cleared forest was only 150, all of whom were heads of households. This number represented 0.3% of the total population and 1.7% of the total household head population in Algarabulli District. Before the fall of the Gaddafi regime, all of the forest clearers were officials, military officers and people who lived neighbouring the forest. This strongly suggests that population growth is not an important driver of deforestation.

The underlying causes of deforestation after the fall of the Gaddafi regime in 2011 are many. They include the total breakdown in governance and a tenfold increase in land prices, which

incentivised land speculation and forest clearance as a means of money laundering. Land prices increased greatly due to the increasing demand from a number of sources: Displaced people wanted to move to the forest land, where they would feel more secure. Other people tended to invest their money in land or buildings because these were regarded as the most stable forms of investment during a period of low security and safety, during which the procedures and restrictions adopted and imposed by Libyan banks encouraged customers to withdraw their money from these financial institutions. Additionally, armed robberies at some banks and the lack of financial liquidity—the result of the suspension of oil exportation in recent years—led to loss of confidence in banks , this causes people to put their money into tangible assets rather than in banks.

It was found that the majority of the forest clearers were aware that the forests were planted because of sand dune encroachment. All forest clearers were government employees and most of them were 40–50 years old and had received an average level of education. Despite this, they have ignored the importance of forests and forest laws.

In terms of economics, all of the forest clearers were employed, and their income was slightly higher than that of non-forest clearing respondents. They have sizeable plots of land, and their purpose in clearing the forest was, they claimed, for cropping and building—however, it was found that most of them had sold some part of their land in the absence of regulatory agencies and state legislation. All documents used for selling the land are illegal but, nonetheless, there are people buying these properties.

8.1.2 Quantifying deforestation using multiple methods

Three methods were used to determine the rate of deforestation between 1986 and 2013; whether taken over a large area or small blocks of forest, they showed a remarkable degree of agreement[31] (see Fig 8.1).

[31] See Appendix 9 for the difference between these methods in 2010 and 2013.

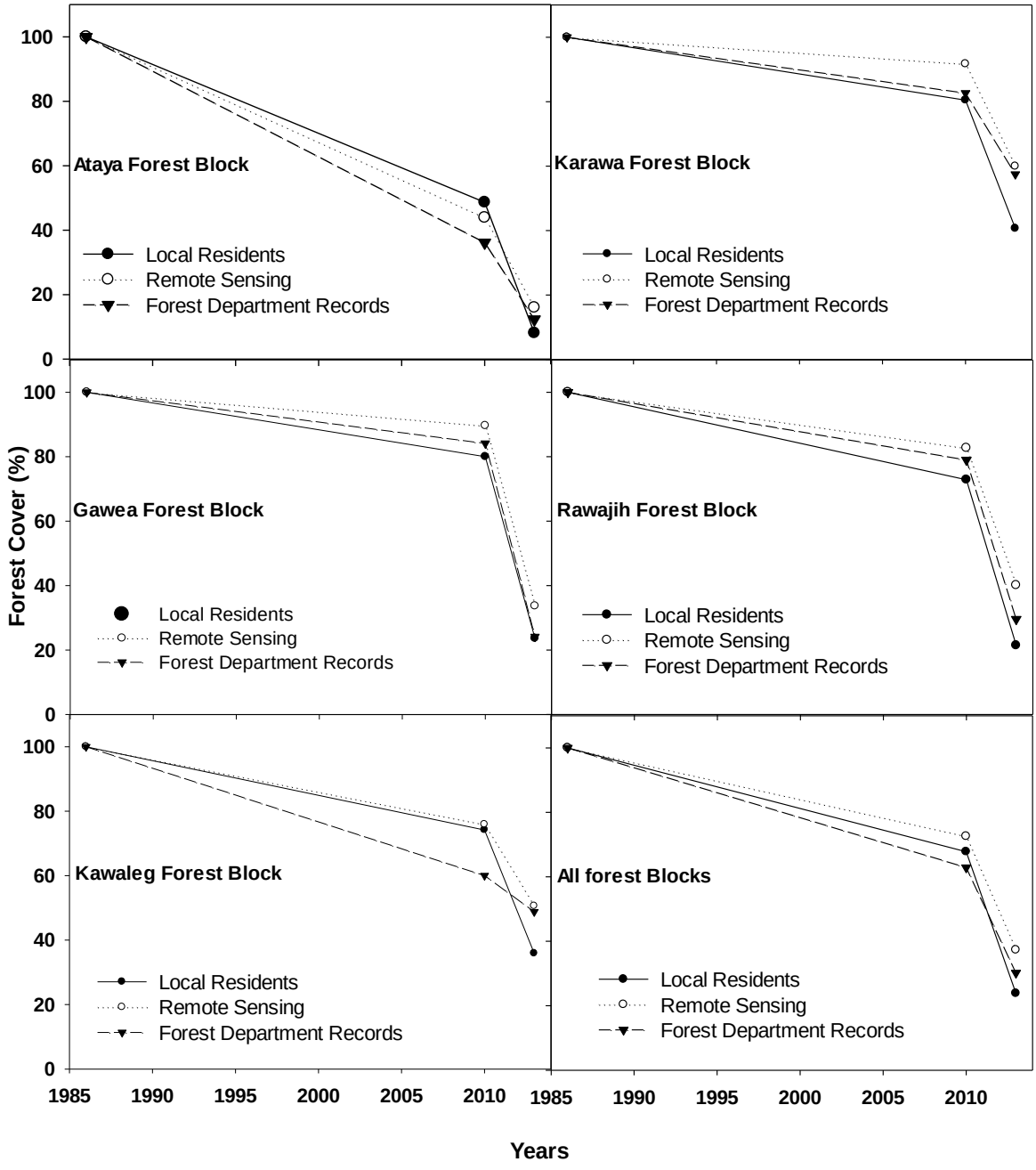

Figure 8.1: Comparison of the three methods used to estimate, the index of forest cover (1985=100) for the whole area and in each forest block.[32]

Twenty-seven per cent of total forest area was cleared between 1986 and 2010, with an annual forest loss of 142 ha. After the fall of the Gaddafi regime, another 35% was cleared between 2011 and 2013, with 1584 ha of annual loss. Thus, the rate of annual forest loss increased by more than an order of magnitude after 2011, amounting to a 64% change in forest total area.

[32] See Appendix 7 for the raw data of respondent estimations (local residents). Also see Appendix 8 for the raw data of Forest Department Records).

Of the cleared land, 56% was converted to rain-fed agriculture, 9% to irrigated agriculture and 4% to settlements, whilst 31% reverted to sand dunes.

The war taking place in Libya, combined with the spread of weapons and the complete absence of government institutions, both security and regulatory, made this study a significant challenge to conduct. However, with some support, the study was carried out successfully and achieved its goals using multiple research methods.

Because of the lack of previous studies on the social, economic and political causes of deforestation in Libya, the highest priority was to determine the local perception of the issue through a survey using the semi-structured interview method. To this end, 50 respondents—all non-forest clearers—were interviewed regarding the causes and consequences of deforestation. These interviews helped to identify which method should be used for a deeper investigation of the policy issues involved, as local respondents stated that the main cause of deforestation is the change in governance of the forest. The survey method also brought other significant issues to the researcher' attention, such as the measurements of the extent of deforestation.

The second research method used in this study was the examination of satellite imagery, which was used to determine the extent of deforestation. The challenge was to obtain very high-resolution imagery with which to compare the rate of deforestation in very small areas before and after the fall of the Gaddafi regime. This was achieved using SPOT-5 (2010) and SPOT-6 (2013); the results of remote sensing agreed almost exactly with respondents' estimates. Also, some maps were created showing which type of land use the deforested areas were used for.

The semi-structured interview method was also applied with a set of current and ex-government officials who were willing to help tell the real story of how governance of the forest changed from good to bad and why. The researcher also conducted interviews with Libyan law experts about forest and land laws.

The final method used was a questionnaire survey administered to the forest clearers themselves. The biggest challenge was deciding how the subjects should be selected and how the survey should be conducted? In the end, the researcher asked 80 forest clearers out of the 150 total recorded by the Forest Department from 1986 to 2013. Of these, 43 agreed to participate, which was a high percentage in light of the region's lack of security. Later, their answers were assessed by their neighbours. There was a striking correspondence in the results obtained by the three methods used as presented in figure8.1. in the case of the Forest

Department has very good records, and forest is not very large area of forest and so it is relatively easy to monitor any forest encroachments and what is going on in these forests.

Using these three methods, the main objective of this study was achieved successfully: to determine when, how and why Algarabulli's forests were cleared, the extent of deforestation, and the consequences of deforestation on the people.

8.1.3 Limitations

Obviously, there are major limitations in operating in an area with very bad security. These constraints considerably limited the researcher's freedom to act. With more time and resources, the researcher would have expanded the study, including more thorough surveying of the involved parties and deeper investigation of the forest clearers in terms of land tenure, land ownership and how the problem could be addressed from their point of view.

8.1.4 Future challenges

With regard to the future challenges, this study has global implications in that it measured effects which are common in war zones. Natural resources often become the first casualties of war—there is no time to protect trees when human beings are dying. The battle of sand dunes with land is common to many desert area in the world, especially in the Mediterranean; hence, constant vigilance and the continual planting of trees are important. Natural pockets of forest in the Mediterranean, e.g. those in Libya or neighbouring countries, are under the constant threat of development. The challenges will be to continue protecting these environments.

Deforestation, especially in the tropics, is of major concern to the global carbon budget and to biodiversity conservation (Myat Su *et al.*, 2012; Phelps *et al*., 2010; Laurance *et al.*, 2008). The patterns and processes that lead to deforestation have been widely analysed using human and demographic factors, including remote sensing data and geographic information systems (Ryan *et al*., 2014; Skutsch *et al*., 2014; Myat Su *et al*., 2012).

Deforestation, over the years, has been given some context, and the causes and drivers that motivate the causes of deforestation are, notably, the most important theme in the deforestation process. The three most important causes are the expansion of agriculture, wood extraction and infrastructure development, while the underlying drivers of these causes are summarised by researchers as the economic status of the community, demographic characteristics, cultural

tendencies, technological advancement and policy and institutional frameworks (DeFries *et al.*, 2007; Geist and Lambin, 2002; Ryan *et al.*, 2014; Herold *et al*.,2012).

The fact that environmental degradation leads to conflict is well-known among managers of natural resources and the international community, and it has dominated the argument over environmental security (Barnett, 2000). Solinge and Boekhout (2010) relates a case of conflict in the Amazon thus:

> *"In May 2008, pictures of a small Amazonian tribe became world news. They were taken from an airplane flying over the Amazon in the border area of Brazil and Peru. It showed a dozen tribe members, mostly naked and painted red, around their thatched huts surrounded by dense Amazonian jungle. Some of the tribesmen were pointing arrows at the airplane from which the pictures were taken. Many newspapers and websites around the globe showed the pictures, usually accompanied by the news that they showed an undiscovered tribe in the Amazon rainforest".*

Similar stories have occurred in various parts of the world, from the recent fall of the Gaddafi regime, which lead to massive deforestation and land degradation, to conflicts among locals in the Congo, the USA, Mexico and Nigeria (Macias, 2008; Peter and Odjugo, 2010; Al Jazeera channel, 2012).

Political conflicts and civil unrest have also contributed to escalating deforestation in a number of countries. For instance, soon after the political revolution in Tunisia in 2011, incidences of illegal logging, forest fires and forest clearing increased considerably as law enforcement was lax or absent during that time (Indufor, 2013). However, some approaches were established in Tunisia to reduce deforestation which helps to understand the conflicts and complementarities that occur between users of goods and services to develop better coordination and governance between stakeholders for improved sustainability. To meet these challenges, some considerations for a sustainable strategy for the sector could be executed which indulging; Elaborate regional plans of development of forest resources including research, training, information and forestry and range extension. Also involve local people who are beneficiary of forest products in the monitoring and develop activities of products transformation or tourism to increase their income; Moreover, recognize the ecological and environmental function of forests and promote a proactive policy of protection, rehabilitation and extension

of Tunisian forests, In addition to regenerate deforested lands as a result of population pressure by introducing suitable tree species (FAO,2013).

The destruction of arid and semi-arid forests around the world raises a number of issues. It obviously creates much ecological harm and social tension. It not only causes human suffering but also leads to ecological degradation, destruction and the disappearance of animal and plant species (El-Tantawi, 2005).

While it seems relatively easy to identify the victims, it is very difficult to identify the perpetrators responsible for the harm that is being caused. What, and who, are the main causes and drivers of deforestation? These issues lead to conflicts that sometimes result in years of hardship and anarchy.

In order to reduce conflict, the environmental and livelihood implications of increasing deforestation need to be addressed in order to promote sustainable economic development among the community and the managers of natural resources (Saad *et al.,* 2011).

In Libya, there are many challenges for the future from a Libyan perspective, where the greatest priority is to restore the rule of law. To protect the forest, the first thing that must be achieved is, to stop the Libyan civil war. This is an ongoing conflict between two rival organizations seeking to control Libya. In 2014, the internationally recognized government of the Council of Deputies was democratically elected. This is also known as the "Tobruk Government" recognised internationally as the "Libyan Government". However, there is currently an established rival Islamist government of the new General National Congress based in the capital Tripoli. This is led by the Muslim Brotherhood, backed by the wider Islamist coalition. Also existing in some parts of Libya, between these two 'governments', is the spread of people with extremist views that are outside the respective control of the two currently existing 'governments'.

The protection of forests and regulation relating to this aspect, depends on restoration of the rule of all laws. This can only be achieved, by the creation of one strong single internationally recognized government exhibiting integrity and transparency. One of the first tasks of this new integrated government will be to eliminate terrorism groups. They then need to achieve social justice by application of the country's laws. This will only be achieved by taking advantage of the important advice available from the United Nations envoy appointed to support a new emerging Libya. This envoy came into office in 2011 to protect civilians and assist the new Libyan government in legal and administrative areas together with development of appropriate policies when the war ends. This includes reorganization and reform of the legal protection for

forests by activating the agreements previously set out between Libya and the United Nations. These agreements aim to protect forests in Libya and combat desertification and other related issues.

A specific challenge for a new 'Forestry Department' of government would be, the planting of forest areas in the western part of Libya with more suitable tree species rather than using Eucalyptus and Pines which have proved not to be appropriate for this region.

There are other, better, more suitable, native or exotic plants that should and can be used, such as:

Pistachia atlantica or *P. lentiscus* (Battoum), *Ceratonia siliquia* (Kharoub), *Acacia victoreae* (Sant) *Acacia farneesiana*, *Acacia cyanophylla, Acacia legulata*, *Acacia karoo* (Souk), *Acacia salicina*, *Acacia tortilis* (Talh), or local shrubs such as *Rhus tripartite* (Jdari), *Periploca angustifolia* (Halab), *Parkinsonia aculeana*, *Prosopis spp.* (Al Ghaf), *Tamarix aphylla* (Athel), *Zizphus lotus* (Seder), *Atriplex nummularia*, *A. halimus* (Ghataf) and others.

The initiative suggested above, such as the plantation of more suitable tree species, should be implemented within a master national forestry development or afforestation plan that integrate the experiences gained from previous developmental activities.

In addition, there needs to be an increased national awareness raising campaign concerning forestation, afforestation or reforestation – different terms for the same goal. This is in order to educate local people and officers within government organizations of the importance of trees in a country's landscape. Trees and their roots can contribute to sand dune stabilization and reduce or prevent encroachment; provide shelter for farm stock and other wild animals; establish a dominant layer beneath which shrubs and herbs can then colonize additionally contributing to the sand dune stabilization process. Wood from trees can in future, provide fuel for cooking, particularly if successional planting regimes are employed and the forests are managed. Planting of different species may also result in different uses of the wood such as for building, or for e.g. honey production from bee keeping in areas where suitable eucalyptus trees species which the bees favour are planted.

The tree planting campaigns should be properly established, to reduce and eventually eradicate the current use and management of trees by the general population. Instead, implementation of the criteria within the "Development of Rangelands Community Approach or Participatory Approach" should be instigated and sustained, in order to ensure the proper establishment of a range of plants and better use of the rangelands after development. This process may start on private (farmer) rangelands, later expanding to rangelands owned by the farmers' respective

families and tribes. (A rangeland being an open area owned by farmers or the state in which natural vegetation grows). The Rangelands Department is within the government Agriculture Department and is separate from the Government Forestry Department. The Rangeland Department has instigated and supported some very good work. A possible future development could be the amalgamation of the Forestry and Agricultural Departments within the new government of Libya or at the very least the development of an effective working partnership between the two departments. Another initiative could be the availability of tree planting grants to farmers and or communities in key target areas supported by an education campaign for farmers, the community and government officers of that area. This could then be held up as an example of good practice as the agricultural afforestation initiative is gradually rolled out over years within the country.

To increase peoples' awareness and participation in decision-making in afforestation and irrigation is very important to the economy. It results in job creation, lumber for industries and firewood for the population in the forests, thus maintaining local communities of people that will benefit whilst still living in the countryside.

Distrust of the previous Gaddafi led Government existed in Libya. That government allocated tribal lands to the people and planted trees on the land using tenant labour. Tenants thought, that they would be evicted or removed from their holdings by the government, sometime in the future. As a result, a strange state of affairs developed. This was the planting of trees by government workers during the day and the removal of those same trees at night by the local people.

To overcome this issue, during the past fifteen years the Rangeland Department has worked hard to deal with this issue. The Department adopted the participatory approach, especially in the tribal lands, where people refuse to plant trees (forests) fearing the taking of the land by the state later. They cited the example that occurred in some of the Al-Jabal Al-Akhdar and the Nafusa Mountain areas. To address this problem, the state asked people in this area to plant various trees "afforestation diverse forests" and fruit trees, to remove the uncertainty or fear amongst communities that the ownership of the land will revert to the state. This was to demonstrate they would not be evicted or moved and could have confidence in the government once again.

The other solution was undertaken in the Al-Jabal Al-Akhdar area where half a million seedlings from the native olive trees were distributed to the local people without charge. All

the people who received these seedlings were then educated, about how they could be grown, during presentations held at mosques. After one year, a Committee from Rangeland Department inspected the state of the young trees. Where the grower had successfully grown and cared for his seed allocation, the state gave three Libyan dinars for each seedling. This further ensured their maintenance by the people who continued to look after them and water them.

Initially, and according to the Rangeland Report (2006) the idea was a great success during the first three years. However, the committee from Rangeland Department, were thought whether justly or not, to be corrupt by other government departments. Those who were responsible for this project and other officials in Rangeland Department were subject to investigation. The focus was, whom they provided with free seedlings and who did they subsequently award money for seedling growth and care. The issue was free provision of seedlings, and subsequent money for plant care, other government officials believing there should be a charge for each quota. Therefore, this project was suspended and the National Centre of Vegetation Cover abolished.

Another participatory approach was implemented in the Al-Jabal Al-Akhdar area. In this area, the population was affected by desertification due to overgrazing. The state decided, after hard negotiations with the local population, to stop grazing in the Al-Jabal Al-Akhdar area. Additionally, the state provided the people with feed for their flocks of animals at a nominal cost for a period of five years. This participatory approach had succeeded in the early years, but the state refused to continue this program later, due to the high cost of this approach.

All these different approaches were initially successful. The aim is therefore to establish a very good government with integrity, trust of the communities and no corruption. This can only occur, of course, with the end of the war. Different departments can then either merge or work effectively in partnership to deliver practical policies. These policies, can subsequently be implemented by, the various government officers, community foresters and/or farmers. Funding for initiatives needs to be secured and allocated in a transparent way so that no charges of corruption can be made.

The funding stream also needs to be long term, with planning for succession in afforestation, focusing on prioritisation of sand inundated areas using a set of agreed criteria made known to all. This can only be achieved, if key individuals within the industry and community leaders are educated and informed of government strategies and plans, so that they in turn, can facilitate

the education of people in local communities with which they work. Currently, the country imports its entire allocation of forestry products; especially wood (FAO, 1993). This can and should change so that Libya produces its entire allocation for wood. At the same time planning for tree planting to supply the charcoal industry can occur leading to the establishment of small community, family or tribal businesses. Alongside this, the establishment of stands of tree species such as Eucalyptus whose flowers are favoured by bees can result in a thriving parallel bee-keeping, honey producing industry. Fruit trees and fruit production will also prosper because of an increased bee population. This again highlights the need for education and training for the agricultural and forestry communities in e.g. beekeeping, tree pruning and care, fruit based product production such as jam making etc. The other vital goal aimed for is, of course, stabilisation of sand leading to increased areas available for agriculture, forestry and the building of homes.

8.2 Conclusion

The forest areas of Algarabulli were fairly stable from 1973 until 1986, when deforestation commenced. This was due to a range of factors, such as a change in governance of the forest and all forms of corruption aimed at acquiring the use of land for agriculture and building whether for temporary accommodation (i.e., second homes), permanent accommodation, or road expansion.

However, deforestation increased dramatically in the area under study after the fall of the Gaddafi regime in 2011. This increase was due to the total breakdown in governance and a tenfold increase in land prices, which incentivised land speculation and forest clearance as a means of money laundering.

Due to the issuing of illegal permits that allowed the inequitable distribution of forest land to some government officers and officials, some of the local people began to clear the forest as well. These actions violated the law of forest land ownership and forest protection law.

The total number of forest clearers is only 150, and all are the heads of households. This number represents 0.3% of the total population and 1.7% of the total household head population in study area. Most of the forest clearers are government employees, and the majority are educated. The forest clearers before the uprising in 2011 were government officials, military officers and people living near the forest; however, from 2011 to 2013, the forest clearers were armed militia, people living near the forest and people who claimed ownership of pieces of forest land.

Although the forest clearers are aware who planted the forests and why they have ignored the forests' importance in favour of their own economic purposes. It was discovered during the fieldwork that they have done this by selling the land.

According to the 2010 census, population growth data does not show a large population increase, but it seems as if the population has increased in recent years through migration. It is difficult to restrict (and account for) the migrants when they are registered in their own cities but do not transfer their registration to the council of Algarabulli District. After the 2011 uprising, the number of migrants seeking permanent or temporary residence increased. This is because this area is safer than other areas in Libya, it did not witness the war, and it is close to the capital.

Despite all the illegal documents upon which the forest clearers base their claims of ownership, in Libya, all natural forests, sand dunes (stabilized or to-be-stabilized) and government plantations are considered to be state-owned under the Forest Law (5/1952). Even private forests, which account for 10% of the total plantations, are managed on the basis of guidelines given in the Forest Law.

Measurements of the extent of deforestation showed that 29% was cleared before the fall of the Gaddafi regime (1986–2010) and 34% was cleared after the fall of the Gaddafi regime (2011–2013). Currently, only 36% of the originally planted forest remains. The remainder is suffering from severe degradation caused by negligence, diseases and insects, lack of investment and selective cutting and thinning. The consequence of such wholesale deforestation is the serious encroachment of sand dunes, which puts at risk those areas converted to agriculture. There are also other issues, such as the spread of dust. If deforestation continues at the current rate, all forest in the study area will be lost within three years—by 2016. Due to Libya's total breakdown in governance, deforestation is one of the country's biggest environmental challenges.

8.3 Recommendations

Hopefully, peace and stability will one day come to the country. If so, the researcher has developed some recommendations to the Ministry of Agriculture, the Ministry of Justice, the NGOs and other international organization policy and actors such as FAO policy that may be applied to the problem of deforestation. They include the following:

1- Protection

The remaining forest should be protected by enforcing existing laws of protection; legal experts have stated that these are strong enough to suffice if applied. Meanwhile, the government should reassess the current forest protection and land laws with an eye to the current situation, especially in terms of imposing fines on violators.

2- Forest encroachment (i.e., forest clearance)

A national effort and in-depth legal studies are needed to address the issue of forest encroachment, particularly with regard to the property rights of the land, which is already state-owned by Law No. 1 of 1951 (articles 878 and 926), and Law No. 5 of 1952. All of the encroachments made into forested lands were illegal, whether the land was simply claimed or was obtained through usufruct contracts. Law No. 14 of 1992, which is still in force and which requires all forest cleaners to evacuate forested lands, has not been developed or amended, and people still clearing the forest. Therefore, the researcher recommends selecting one of the following options, which are also recommended by non-forest clearing respondents and official respondents.

Option one

Evacuate all forest clearers from deforested lands by force of law, even those who bought the land from forest clearers, because they bought the land with illegal documents. The state should announce that it will not buy back these lands, and it should remove what has been built. This will be an example to others who consider attempting to clear the forest in the future. If the state does not punish the forest clearers, others may feel encouraged to clear forests. As forest areas are state-owned, this may cause conflict over the land between citizens, such as what happened in 2013 fighting between families because everyone claimed ownership of the land

In addition, it is unfair that some people obtained land illegally and the state failed to enforce the law because the people had already settled in these lands and built houses. This will create many problems or disappointment to non-forest clearers.

Option two

The government should assess whether correct property deeds exist for these lands, and then the lands should be expropriated by the state, based on Law No. 1 of 1951 (articles 878 and 926) and Law No. 5 of 1952, for the benefit of the public. If they find people who have property deeds but did not register their land in the Land Registry, the government should expropriate the land and provide the owners with fair compensation, in accord with the rules of administrative law. Libyan law experts recommend that forest clearers should pay a fine for clearing forest without government authorization, even if the lands belong to them; not even those who own a piece of forest can clear it without government authorization because the forests are managed on the basis of guidelines given in the Forest Law.

Libya's government may benefit from some countries' and NGOs's experiences with the issue of forest encroachment and how to address it. They should take note of the international laws that are applicable to comparable cases.

3- Forest management

Forests must be managed through centralized administration (i.e., the Ministry of Agriculture and its regional forest departments) and free from interference by any other institutions or government officials (e.g., mayors or sheikhs of localities). Also, the specifics of forest jurisdiction, between the agricultural police and the general police force, should be sorted out.

4- Raise awareness of the importance of forests

The government must contribute to raising people's awareness of the importance of forests and the risk of infringement on forests. People can learn about the environmental and legal aspects of this issue through NGOs, schools, or the mass media—radio, television and the distribution of leaflets, posters and pamphlets.

One Libyan NGO, called Tree Friends Association, was recently established to raise awareness among school pupils of the importance of forests. These pupils were attending primary and secondary schools in some areas of the Jefara plain. Despite the critical situation in Libya, this NGO has contributed to the planting of a huge number of trees. Most of these campaigns were conducted by the pupils themselves; it was found that pupils were interested in looking after and irrigating the trees (see appendix 8 and 9).

5- Tree planting campaigns

Because of the alarms being raised by experts over desertification, tree-planting campaigns should resume in order to combat the phenomena of desertification and soil erosion with good policies, good management and a good, sustainable approach. Such campaigns would select suitable types of trees that would be adapted to the local environment; poor choices for this include Eucalyptus trees, which are locally called by bio pumps, because the root of this type of tree absorbs the groundwater dramatically in a region that already suffers from water shortages.

Finally, I made clear this study is useful for both government of Libya and state organization, but also including local and international researchers in this area.

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Appendices

Appendix I

Semi structured interview (questions) to non- forest clearers respondents (In chapter 4)

Q1- What is the most serious environmental issue facing Algarabulli District?

Q2- What is the most important direct causes of deforestation?

Q3- What is the indirect causes of deforestation?

Q4- What is the most important underlying causes of deforestation after the fall of the Gaddafi regime?

Q5- When deforestation started?

Q6- What is your evaluation of forest status before/after deforestation started and after the fall of the Gaddafi regime?

Q7- What is your estimate of deforestation rate before/after the fall of the Gaddafi regime?

Q8- What is the consequences of deforestation at present?

Appendix 2

Semi structured interview to Government Officials respondents

(In chapter 6)

1- Name (optional).....

2- Position……

3- When deforestation started

4- Why deforestation started in this time?

5- Have you recorded any forest encroachments before this time?

6- How forest governance was changed?

7- What is your evaluation about forest protections laws?

8- What is your evaluation about forest land laws?

9- What is the solution to address the problem of deforestation ?

10- Do you think that these are possible to apply :Yes ( ) No ( )

If no why?

Appendix 3

Questionnaire to forest clearers respondents

(In chapter 7)

Name of locality ….....

Section (1) personal information

1- Name (optional).....

2- Age …

3- Number of family members M ( ) F ( ) total ( )

4- Primary Occupation …..... secondary Occupation…….

5- Educational status. : Illiterate ( ) reads and writes ( ) primary& secondary schools ( )

6- Average education ( ) Higher education ( ).

7- Length of stay in this farm: less than 4 years ( ) 4- 10 ( ) 10-20 ( ) more than 21 years ( )

8- What is your annual income?

Section (2) Forest clearers' awareness **(Forest importance) :-**

1- Do you know the area cover where you live what it was before 1950 ? Yes ( ) no ( )

2- Do you know who planted forest: family ( ) government ( ) I don't know ( )

3- Do you know why it was planted trees: because of …..... I don't know

4- What is the importance of forest?

5- Why you cleared forest?

6- Did you get permission to clear forest? Yes ( ) No ( ) if yes from who…….

7- Are you aware of the forest law? Conscious ( ) Unconscious ( )

8- Are you concerned about the future situation if deforestation is still continue Yes ( ) No ( )

Section (3) Land information (Land tenure)

1- Means of land acquisition?

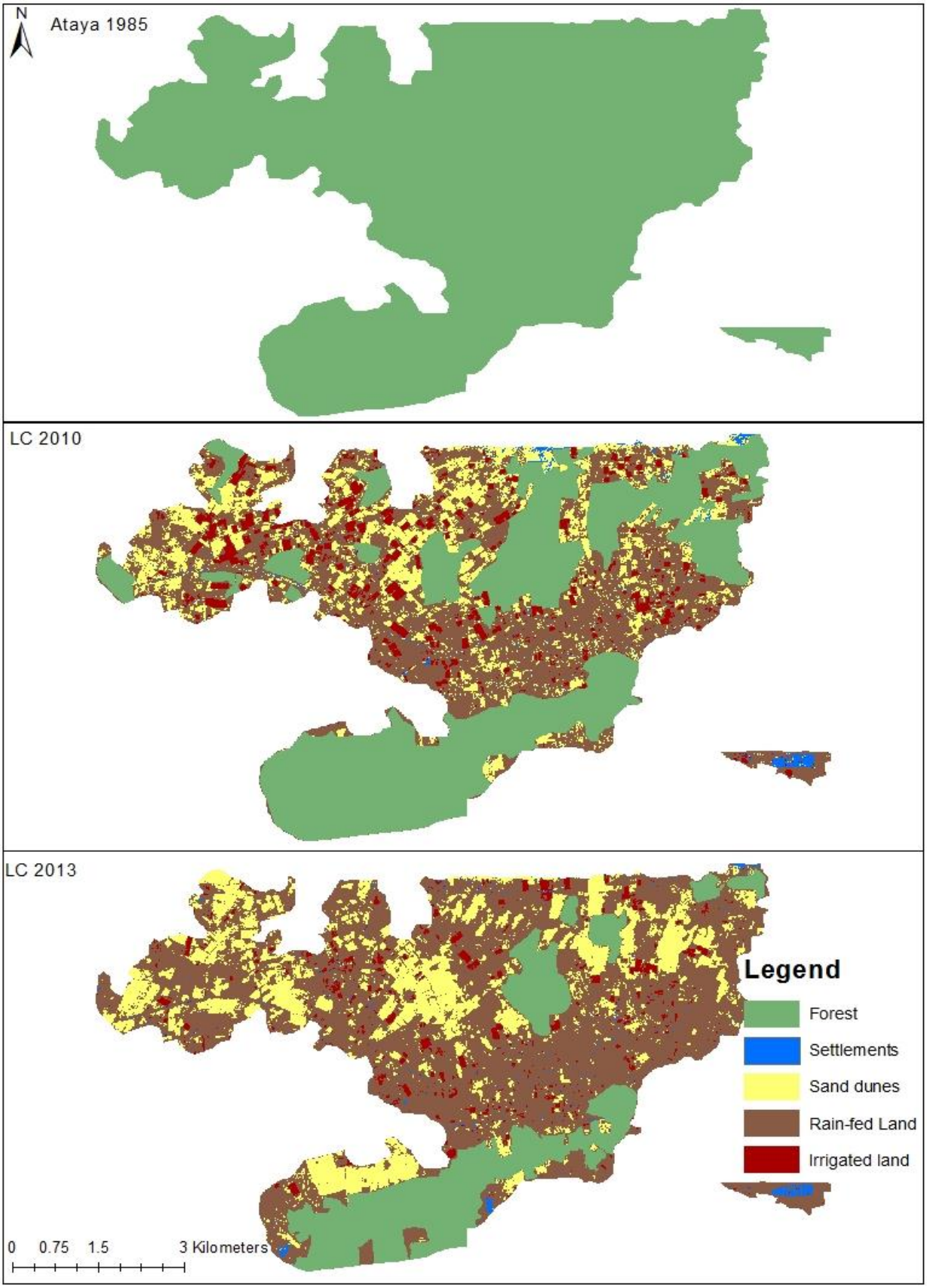
2- Did you record this land in the land register yes ( ) no ( )

3- How many plots of land do you own … total in hectares…?

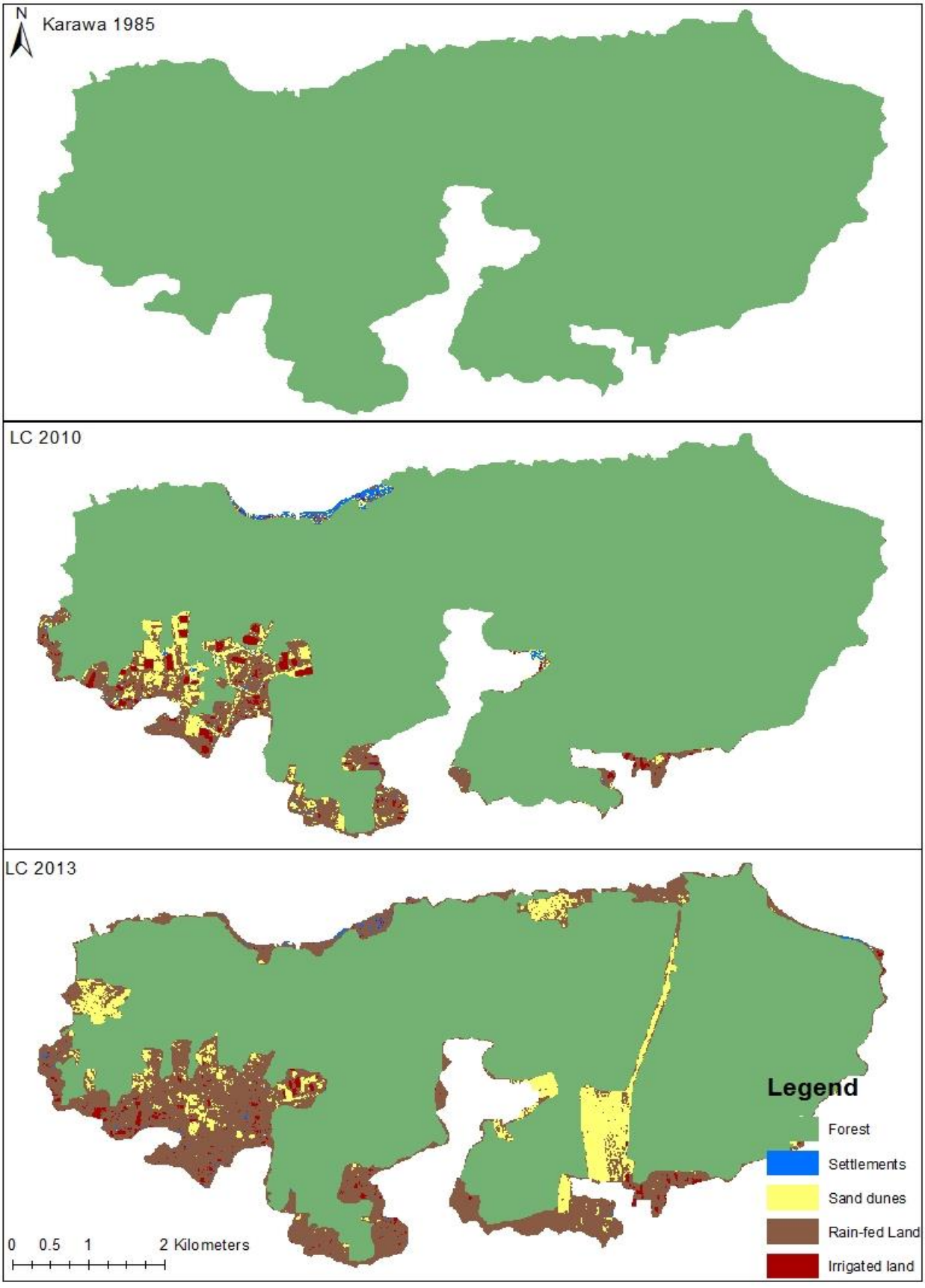
5- Did you sale a plot of land recently Yes ( ) No ( )

Appendix 4 Land cover change in Algarabulli District' localities

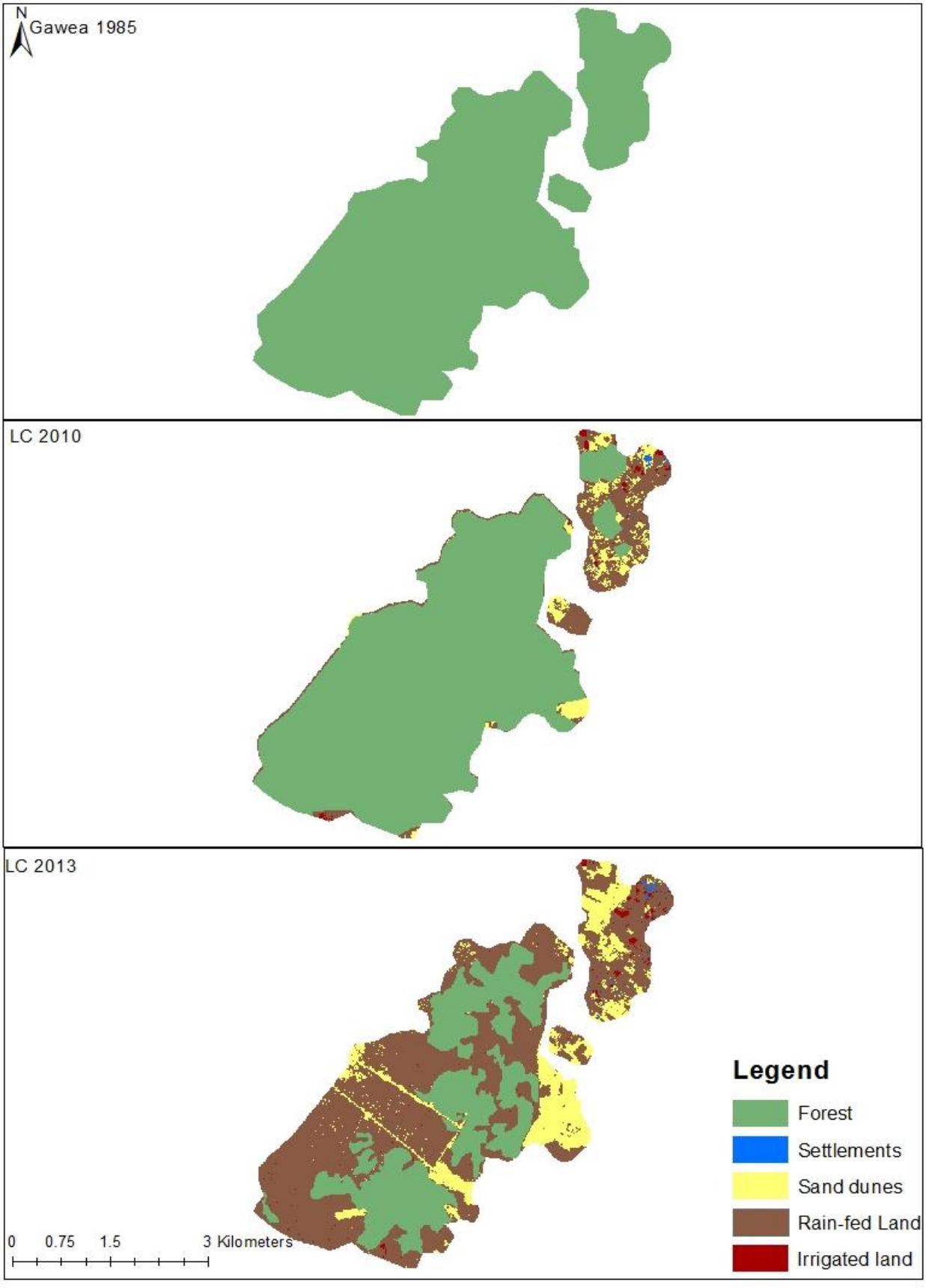
Forest cover change in the Ataya forest block (1985, 2010, 2013)



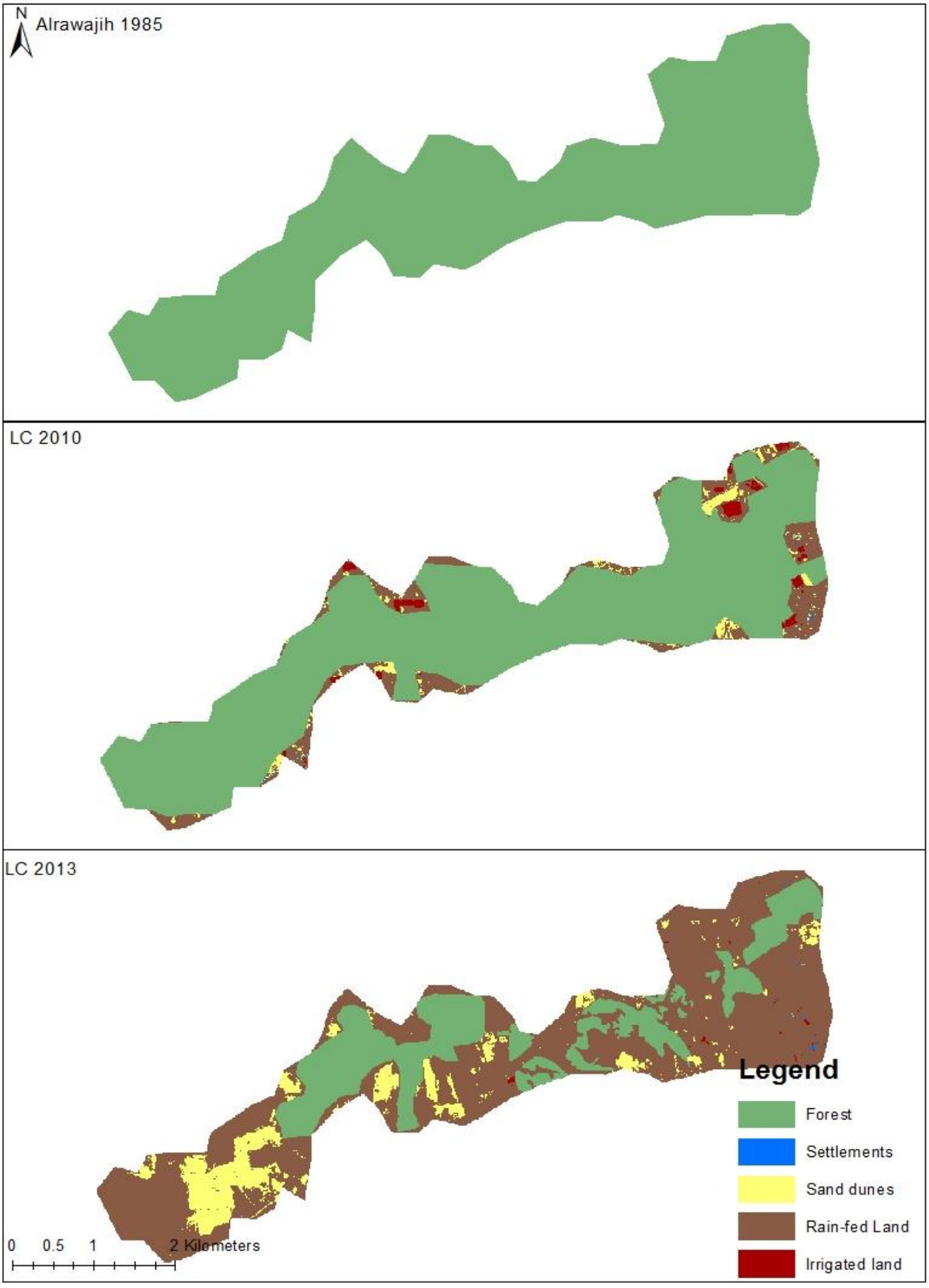
Forest cover change in the Karawa forest block (1985, 2010, 2013)



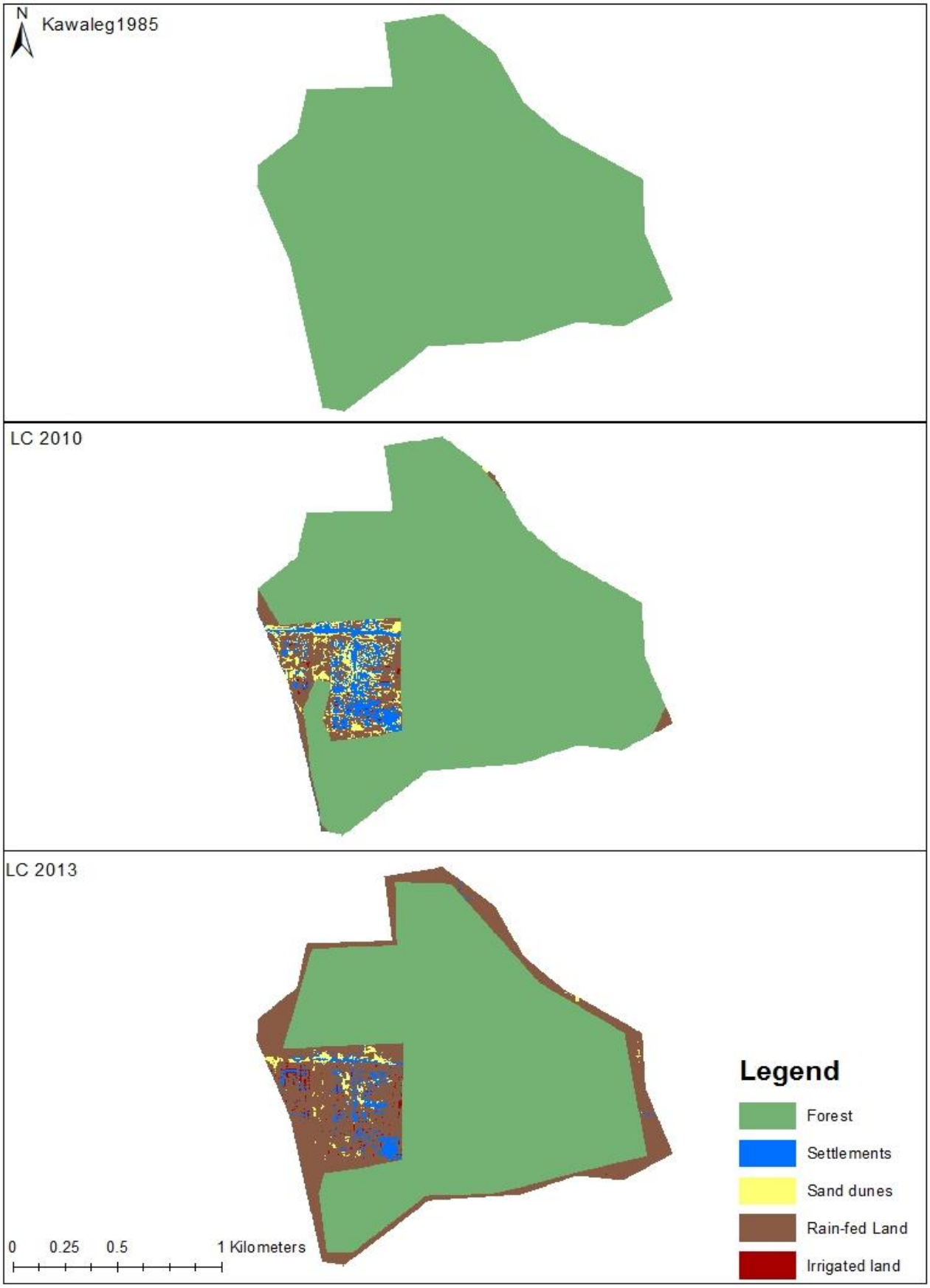
Forest cover change in the Gaweaa forest block (1985, 2010, 2013)



Forest cover change in the Rawajih forest block (1985, 2010, 2013)

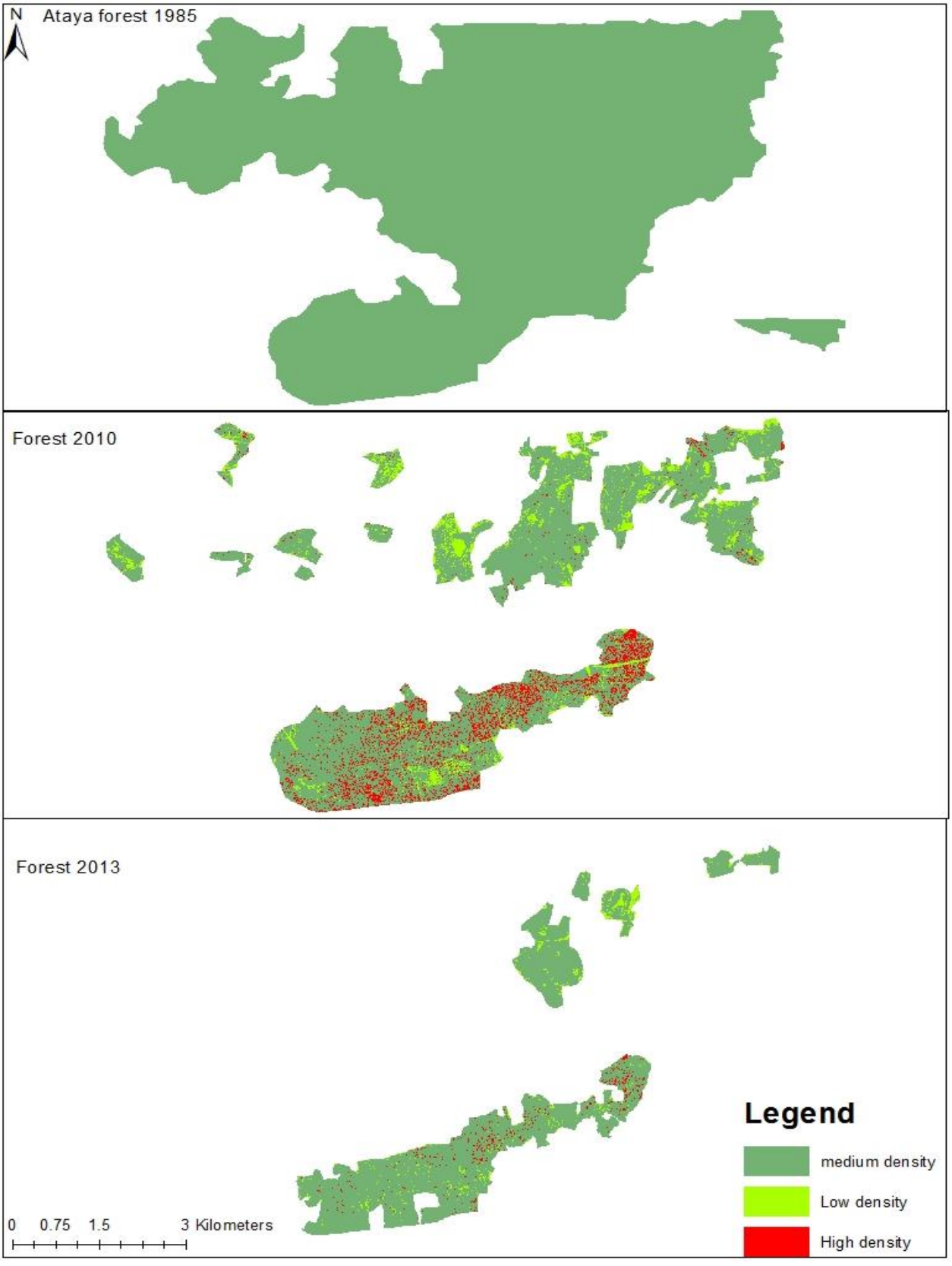


Forest cover change in the Kawalig forest block (1985, 2010, 2013)

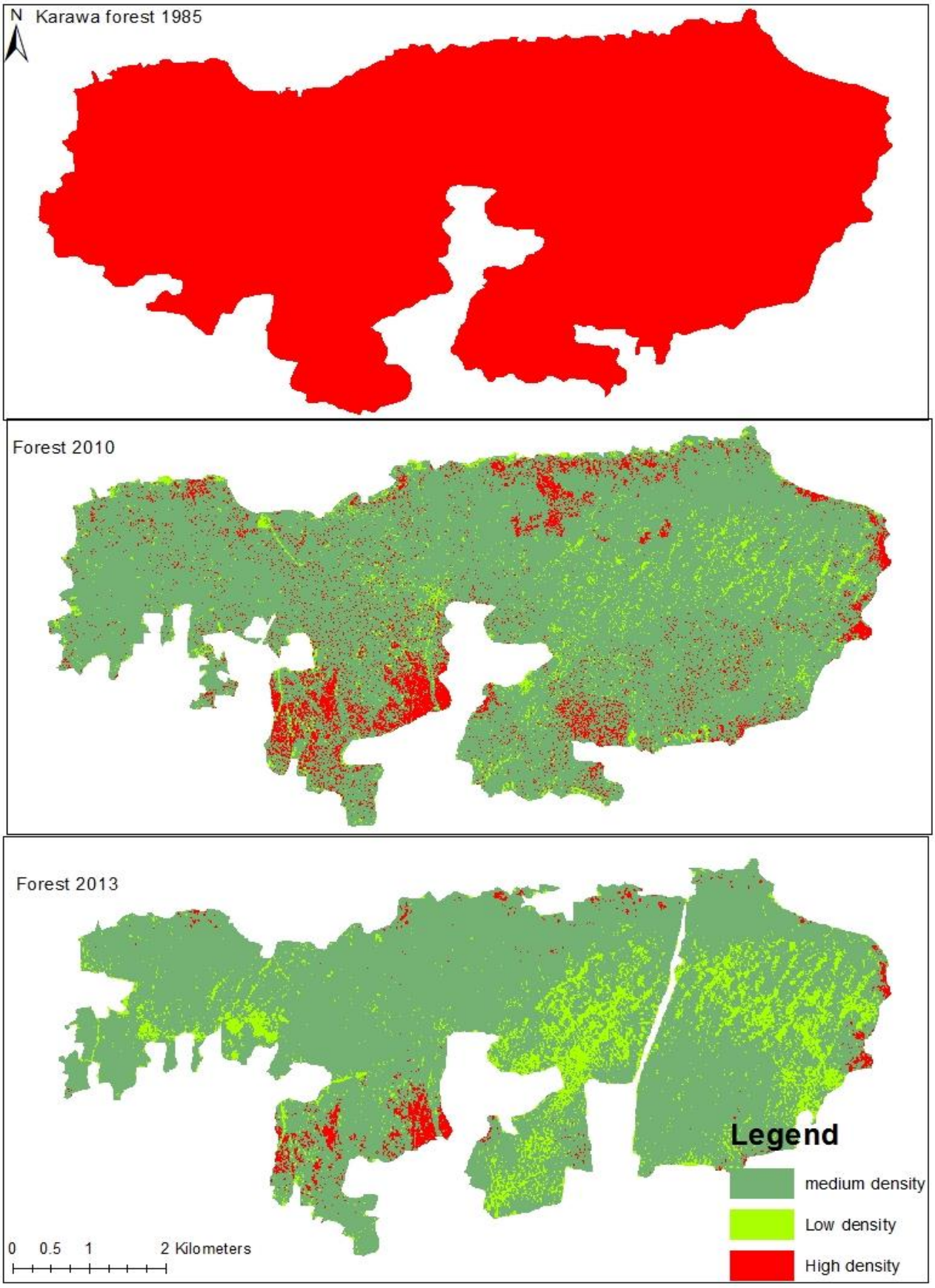


Appendix 5 Forest density in Algarabulli District' localities

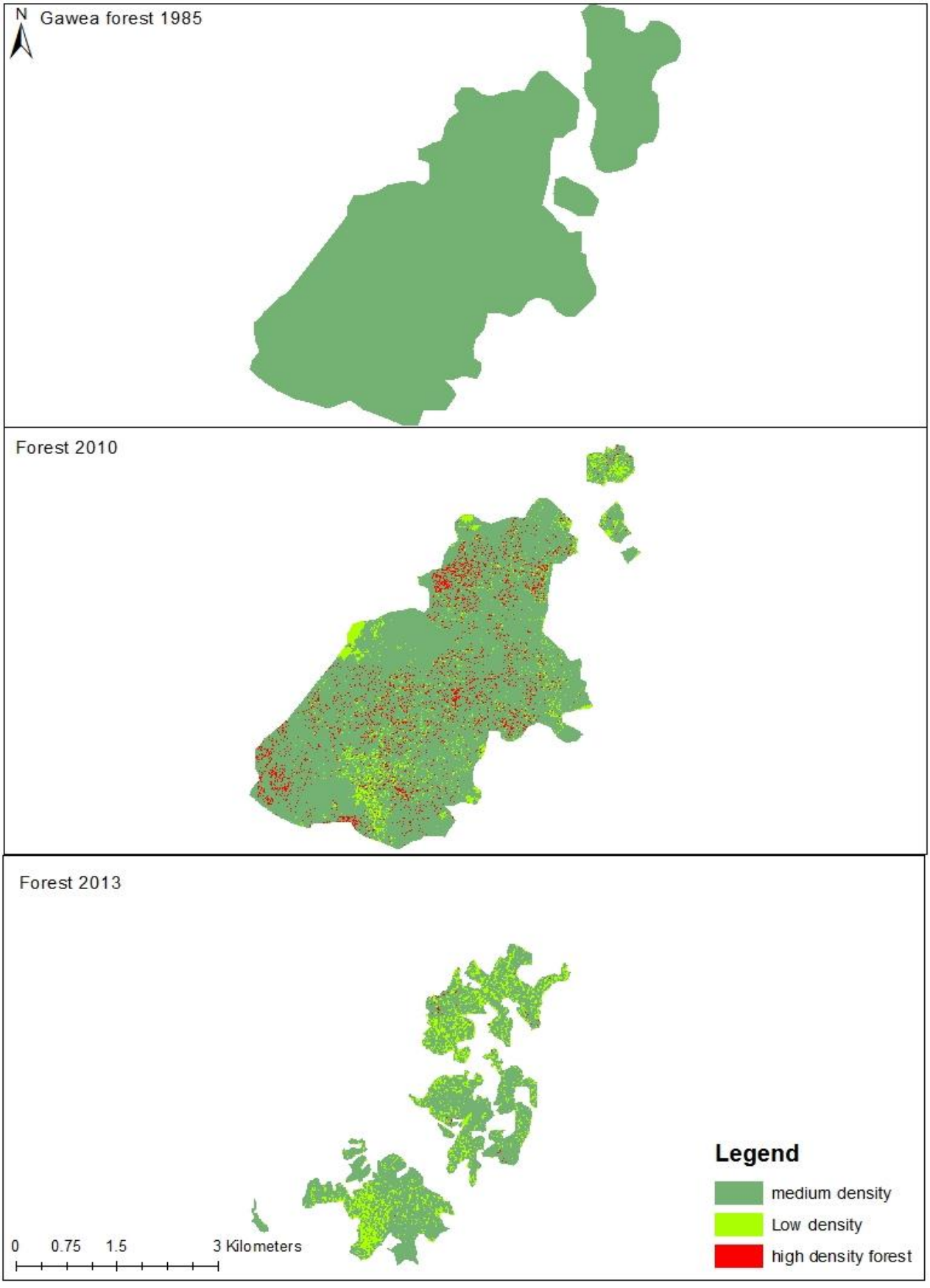
Forest cover and density in the Ataya forest block (1985, 2010, 2013)



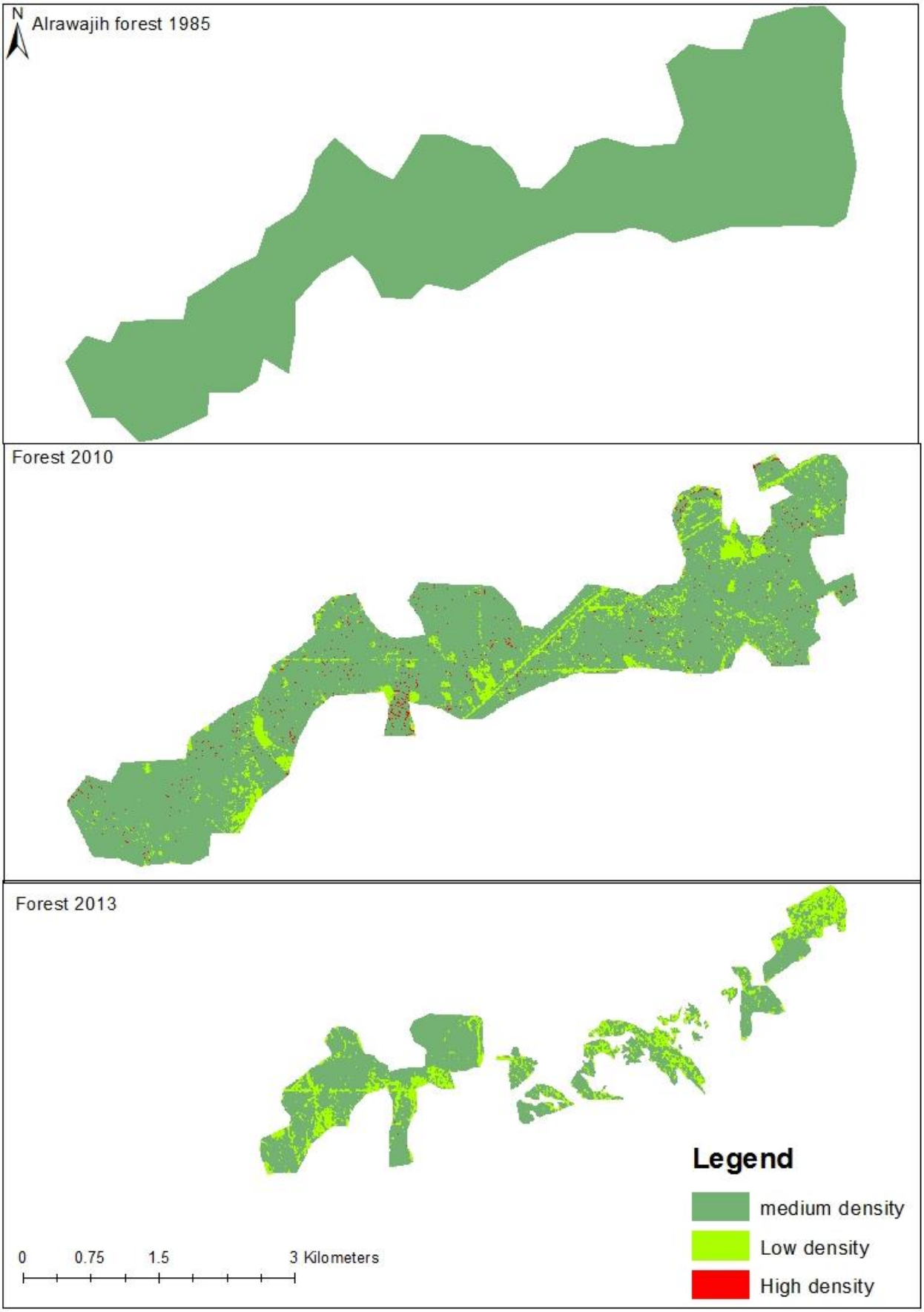
Forest cover and density in the Karawa forest block (1985, 2010, 2013)



Forest cover and density in the Gaweaa forest block (1985, 2010, 2013)

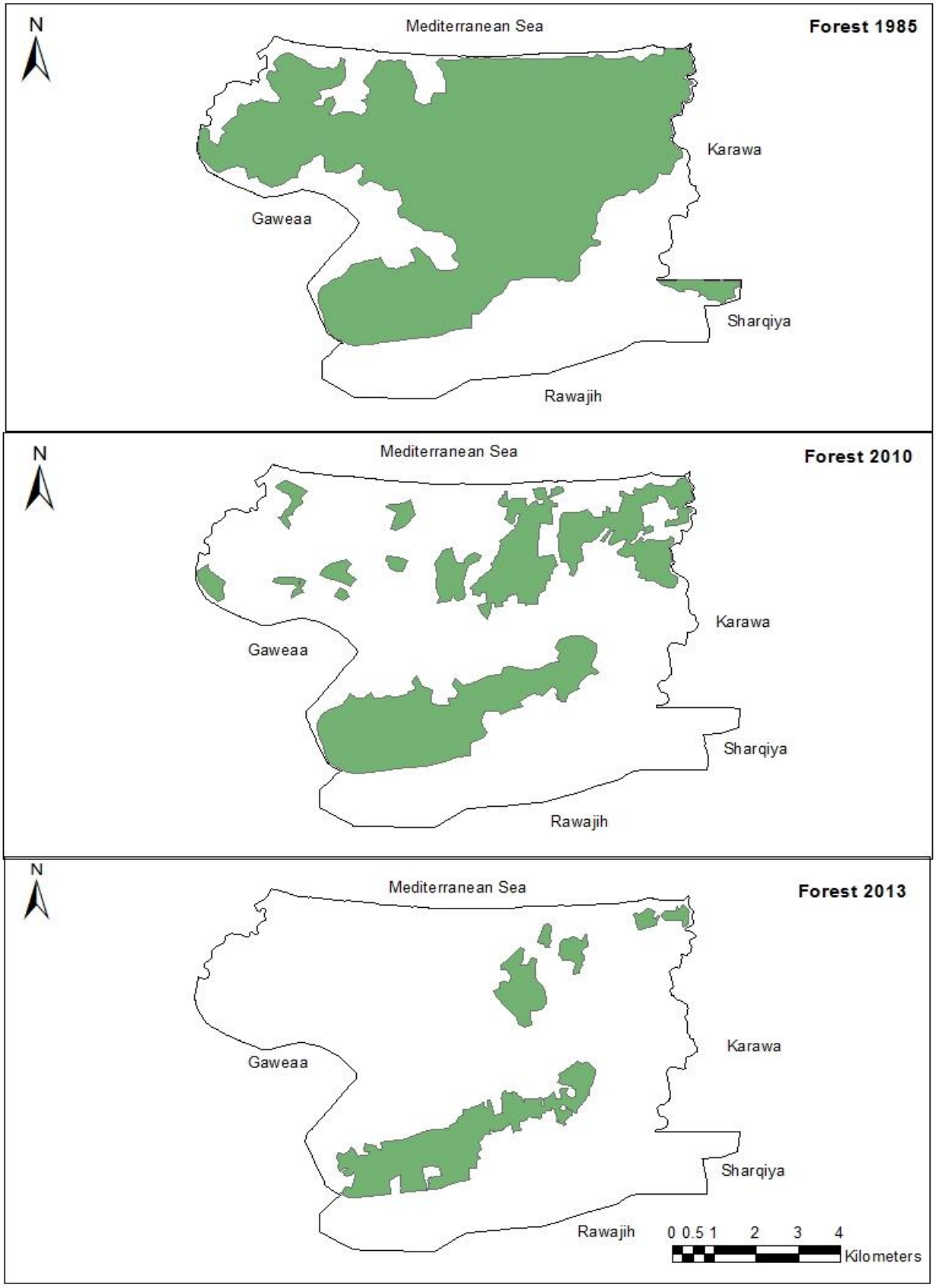


Forest cover and density in the Rawajih forest block (1985, 2010, 2013)

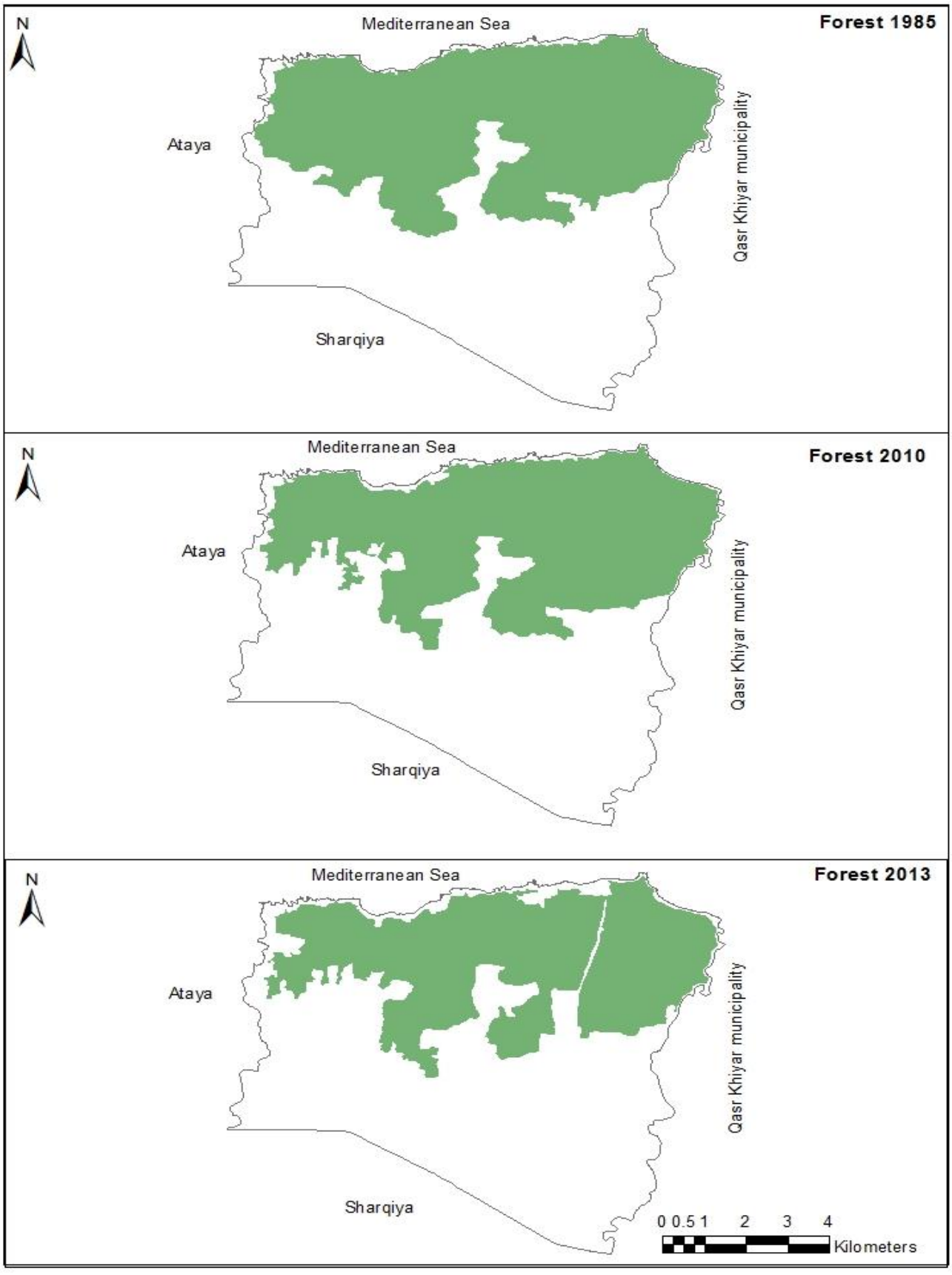


Forest cover and density in the Kawaleg forest block (1985, 2010, 2013)

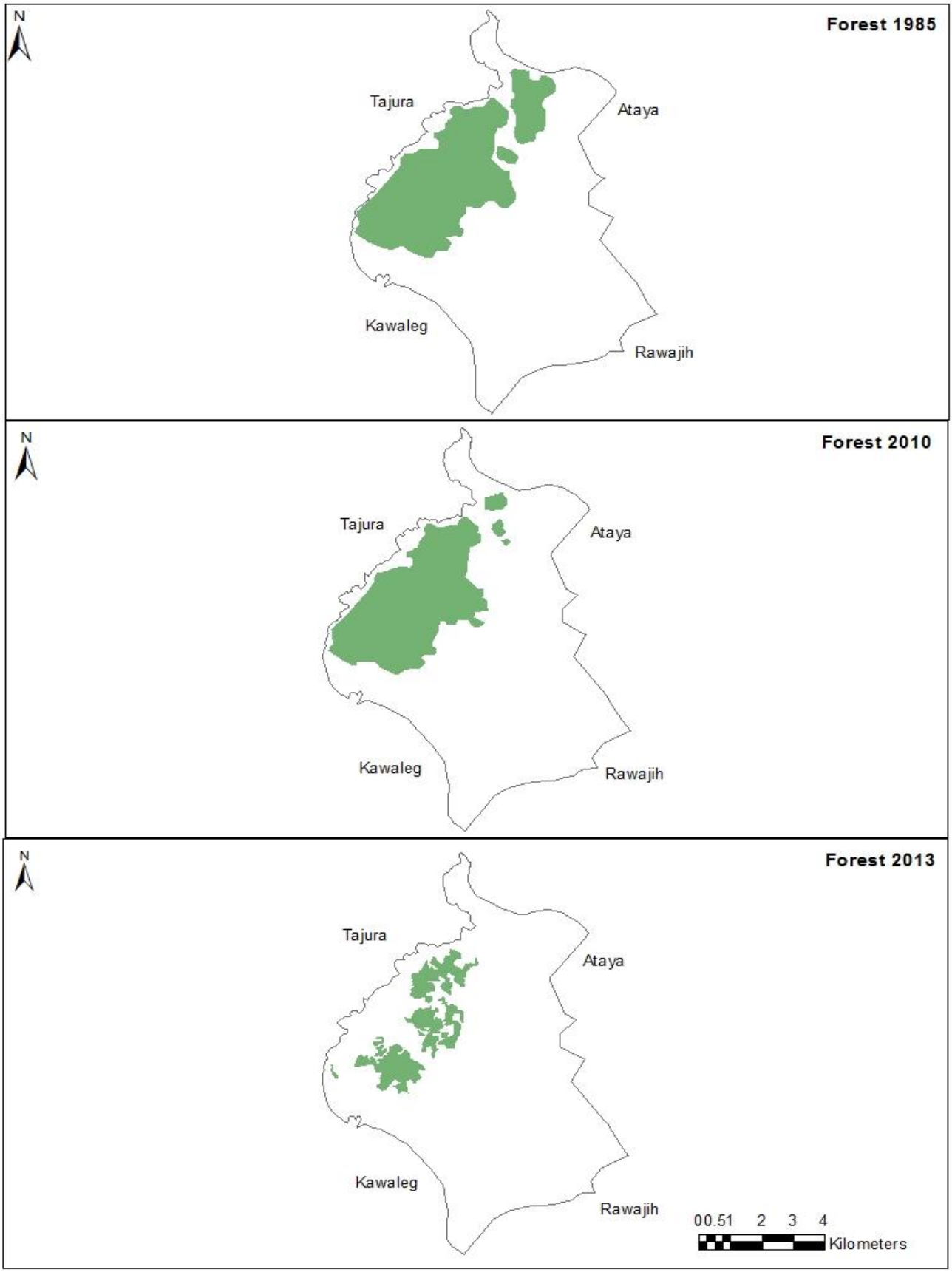
Ataya forest block in 1985, 2010 and 2013



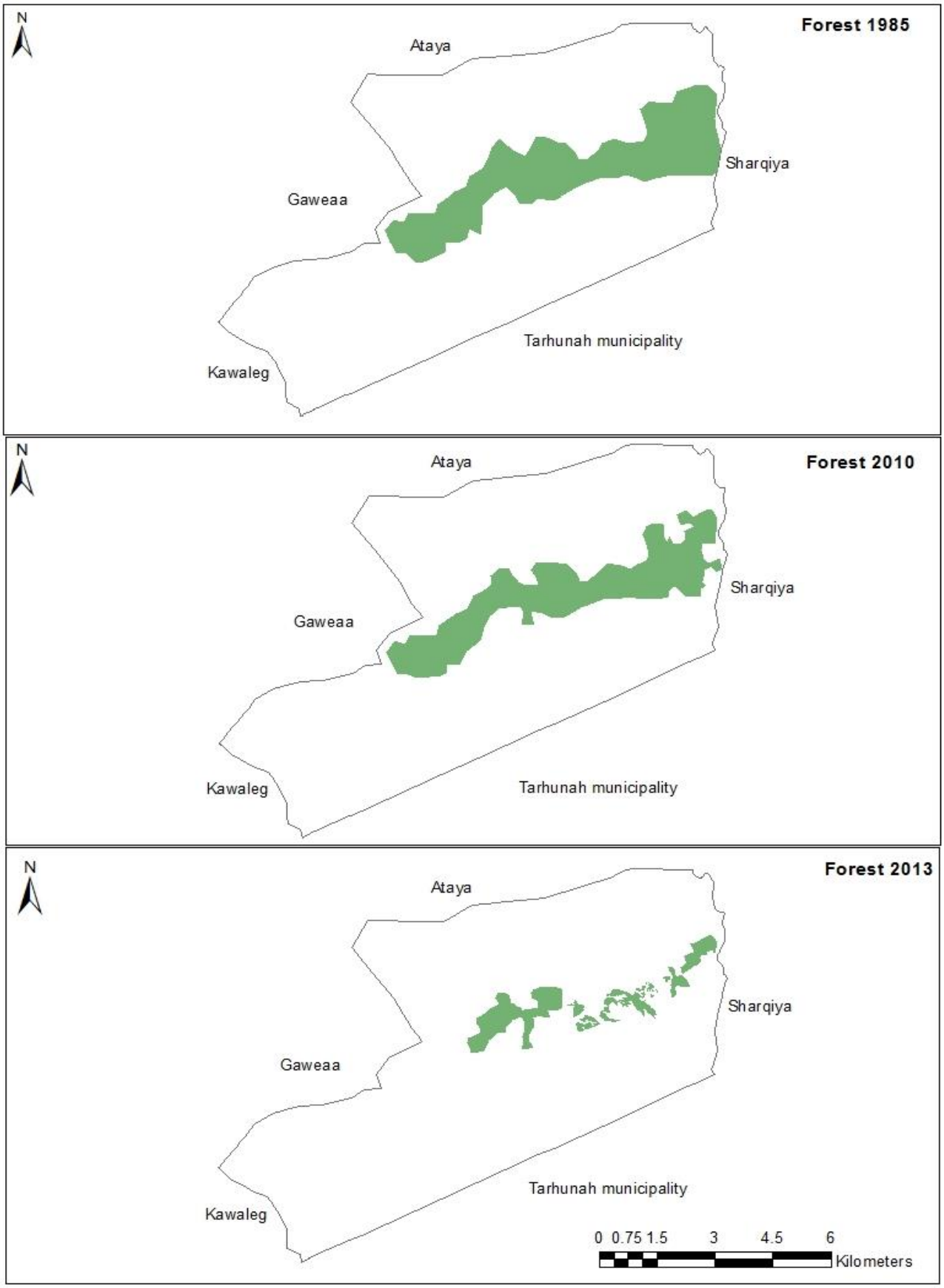
Karawa forest block in 1985, 2010 and 2013)



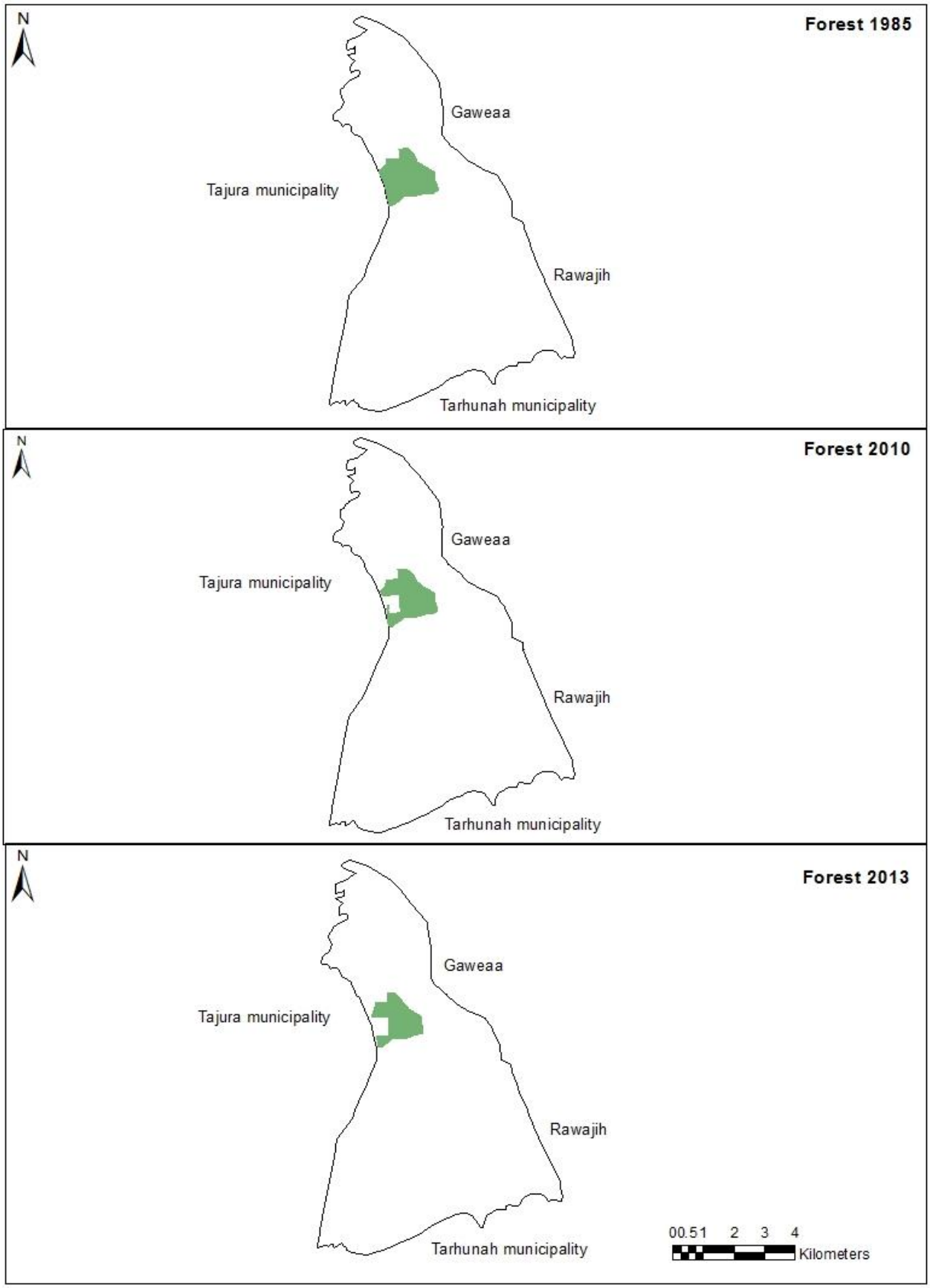
Gawea forest block in 1985, 2010 and 2013



Rawajh forest block in 1985, 2010 and 2013



Kawaliq forest block in 1985, 2010 and 2013



Appendix 6: This CD contains video footage of forest clearing operations after the 2011 uprising, filmed by the researcher from helicopter in 02/01/2012

Appendix 7

The primary data of local resident estimate (7a) and Forest Department records (7b)

Appendix (7a) the raw data of respondents estimates about defrosted area in percentage before and after the 2011 uprising in Libya in each block of forests in Algarabulli District and the researcher worked out the other data to obtained forest cover in hectare and percentage in 2010 and 2013

Table 1: Respondents estimates in Ataya Locality in deforested area in Ataya Forest block

Respondent No	1985 (based on **RS data**)	**Deforested in % before 2010**	Forest cover 2010/ha	Forest cover in % 2010	**Deforested between (2011-2013)**	Forest cover 2013/ha	Forest cover in % 2013
1	4020	**50**	2010	50	**30**	402	10
2	4020	**55**	1809	45	**30**	271.3	6.7
3	4020	**50**	2010	50	**30**	402	10
4	4020	**50**	2010	50	**35**	301.5	7.5
5	4020	**55**	1809	45	**30**	271.3	6.7
6	4020	**60**	1608	40	**25**	241.2	6
7	4020	**40**	2412	60	**45**	361.8	9
8	4020	**50**	2010	50	**35**	301.5	7.5
9	4020	**55**	1809	45	**25**	361.8	9
10	4020	**50**	2010	50	**30**	402	10
11	4020	**50**	2010	50	**30**	402	10
12	4020	**50**	2010	50	**35**	301.5	7.5
13	4020	**55**	1809	45	**25**	361.8	9
14	4020	**50**	2010	50	**40**	201	5
15	4020	**50**	2010	50	**35**	301.5	
Average		**51.3**	**1956.4**		**32**	**325.6**	
Sdv							

Table 2: Respondents estimates in Karawa Locality in deforested area in Karawa Forest block

Respondent No	1985 (based **on RS data**)	**Deforested in % before 2010**	Forest cover 2010/ha	Forest cover in % 2010	**Deforested between (2011-2013)**	Forest cover 2013/ha	Forest cover in % 2013
1	3761	**20**	3008.8	80	**30**	1504.4	40
2	3761	**25**	2820.7	75	**25**	1410.4	37.5
3	3761	**15**	3196.8	85	**30**	1758.3	46.7
4	3761	**30**	2632.7	70	**20**	1316.3	35
5	3761	**15**	3196.8	85	**30**	1758.3	46.7
6	3761	**20**	3008.8	80	**35**	1353.9	36
7	3761	**20**	3008.8	80	**30**	1504.4	40
8	3761	**15**	3196.8	85	**35**	1598.4	42.5
9	3761	**20**	3008.8	80	**30**	1504.4	40
10	3761	**15**	3196.8	85	**35**	1598.4	42.5
Average		**19.5**	**3027**	**80.5**	**30**	**1530.7**	**40.7**
Sdv				**4.97**			**4.02**

Table 3: Respondents estimates in Gawea Locality in deforested area in Gawea Forest block

Respondent No	1985 (based on **RS data**)	**Deforested in % before 2010**	Forest cover 2010/ha	Forest cover in % 2010	**Deforested between (2011-2013)**	Forest cover 2013/ha	Forest cover in % 2013
1	1752	**20**	1401.6	80	**50**	420.48	24
2	1752	**10**	1576.8	90	**60**	473.04	27
3	1752	**15**	1489.2	85	**55**	446.76	25.5
4	1752	**20**	1401.6	80	**50**	420.48	24
5	1752	**25**	1314	75	**45**	394.2	22.5
6	1752	**15**	1489.2	85	**50**	521.22	29.7
7	1752	**25**	1314	75	**50**	328.5	18.7
8	1752	**30**	1226.4	70	**45**	306.6	17.5
Average		**20**	**1401.6**	**80**	**50.6**	**413.91**	**23.6**
Sdv				**6.54**			**4.05**

Table 4: Respondents estimates in Rawajih Locality in deforested area in Rawajih Forest block

Respondent No	1985 (based on **RS data**)	**Deforested in % before 2010**	Forest cover 2010/ha	Forest cover in % 2010	**Deforested between (2011-2013)**	Forest cover 2013/ha	Forest cover in % 2013
1	1221	**35**	793.6	65	**45**	158.7	13
2	1221	**30**	854.7	70	**40**	256.4	21
3	1221	**25**	915.7	75	**40**	320.5	26.2
4	1221	**25**	915.7	75	**45**	274.7	22.5
5	1221	**25**	915.7	75	**45**	274.7	22.5
6	1221	**20**	976.8	80	**50**	293	24
7	1221	**30**	854.7	70	**40**	256.4	21
Average		**27.1**	**889.6**	**72.8**	**43.5**	**262.1**	**21.4**
Sdv				**4.88**			**4.15**

Table 5: Respondents estimates in Kawaleg Locality about deforested area in Kawaleg Forest block

Respondent No	1985 (based on **RS data**)	**Deforested in % before 2010**	Forest cover 2010/ha	Forest cover in % 2010	**Deforested between (2011-2013)**	Forest cover 2013/ha	Forest cover in % 2013
1	257	**20**	205.6	80	**30**	102.8	40
2	257	**25**	192.7	75	**30**	86.7	33.7
3	257	**30**	179.9	70	**25**	80.9	31.5
4	257	**25**	192.7	75	**20**	106.0	41.2
5	257	**25**	192.7	75	**25**	96.3	37.5
6	257	**30**	179.9	70	**25**	80.9	31.5
Average	**257**	**25.8**	**190.6**	**74.17**	**25.8**		**35.9**
Sdv				**3.76**			**4.27**

Appendix 7 b: Forest Department records.

Figure1: Forest loss in Algarabulli forest blocks from 1986-2013

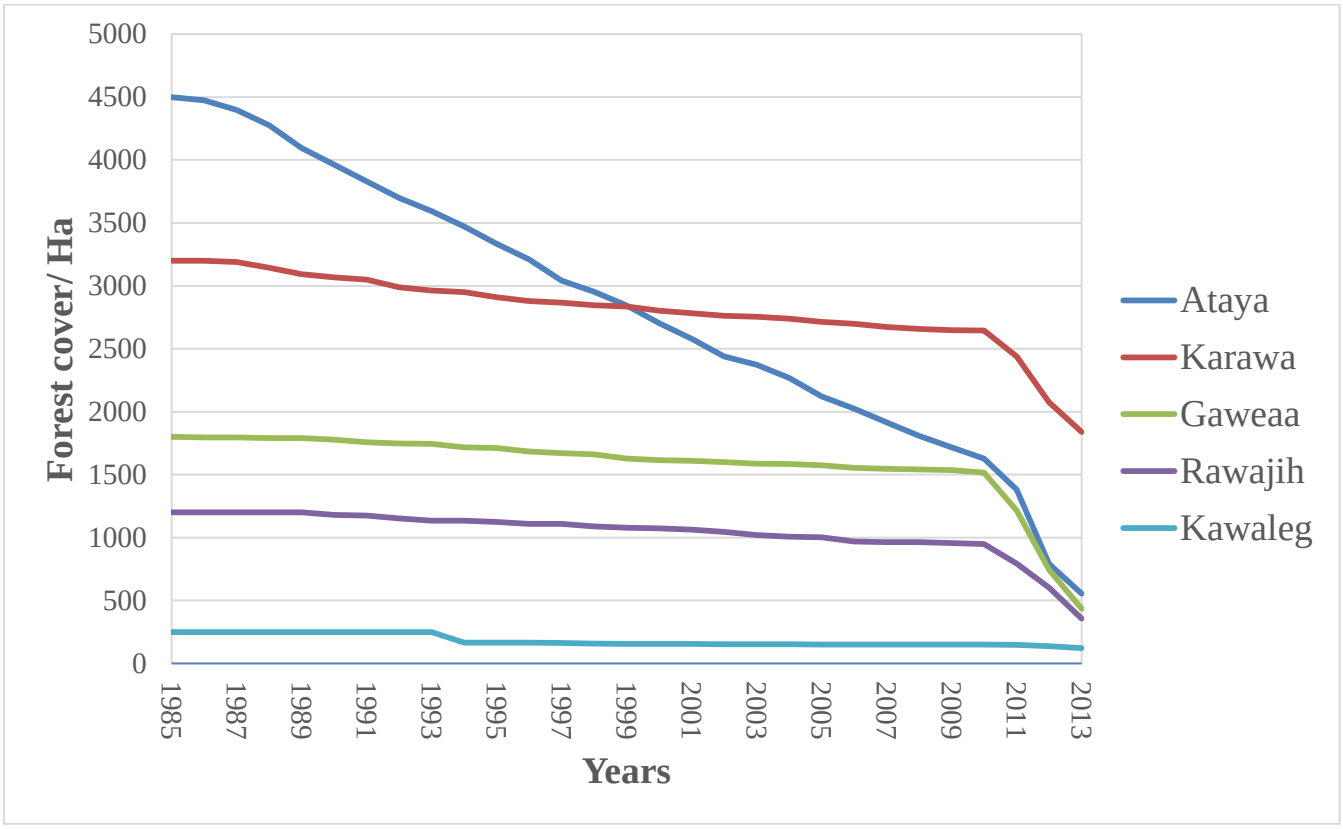
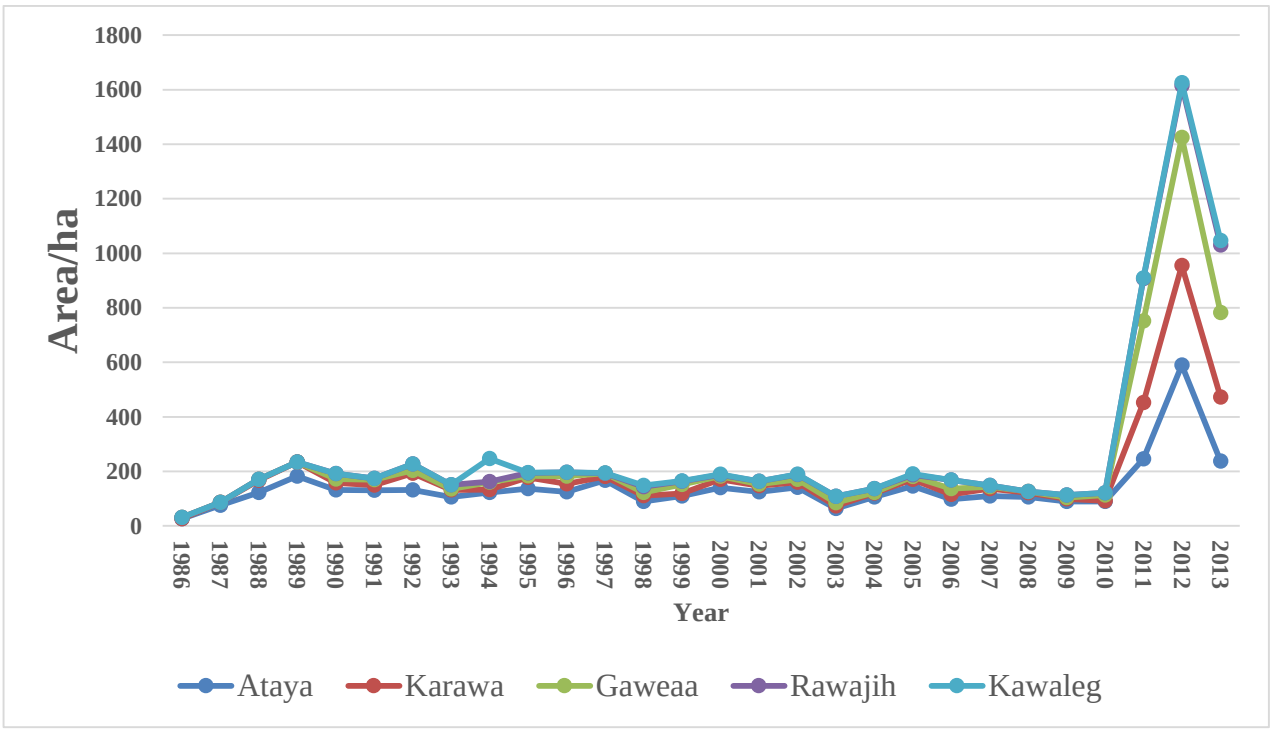


Figure 2: Annual forest loss in Algarabulli forest blocks from 1986 -2013



Appendix 8

The role of Tree Friends Association (NGO) to raise awareness of pupils about the importance of forests and afforestation in one of study area' schools

Appendix 9

Pupils taking part in the afforestation campaigns 1970 (above), 2013 (below)

Appendix 10

The researcher participating with Tree Friends Association in one of the afforestation campaigns at Alshaavien forest reserve, Msallata on 09.01.2014.

Appendix 11

Celebrating ‘Tree day’ before 1985 as the sign shows

Appendix 12

Some forests are cleared to establish subdivided small plots, with paved roads and electricity for future sale (without government permits).

Appendix 13

Forest degradation: The death of some trees as a result of drought, disease and neglect

Appendix 14

Converting forest land to irrigated land.