FOREST COVER CHANGE AND MIGRATION IN IRAQI KURDISTAN: A CASE STUDY FROM ZAWITA SUB-DISTRICT

By

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ABSTRACT

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Environmentally-induced migration has been raising attention worldwide. However, environmentally-induced migration is more common in developing countries where rural to urban transition often takes place in an unmanaged way, due to many factors. Identifying the drivers and underlying factors behind land cover change is crucial for ecosystem management and planning. Rural to urban migration in Iraqi Kurdistan has increased significantly over the last four decades. The purpose of this study is to investigate the motivation behind rural-urban migration, and to determine the relationship, if any, between changes in the environment (forest cover change specifically) and rural to urban migration. This study focused on the sub-district of Zawita (in Iraqi Kurdistan) and involved three types of data: forest inventory, remote sensing data and household survey data.

To investigate forest cover change, four Landsat images of the study site were used. To minimize the atmospheric effects, radiometric normalization was applied followed by supervised classification to classify the land coverage. The images showed significant change in forest cover between 1986-2015 with an overall accuracy of 84%, 92%, 93%, and 98% for 1986, 1998, 2006, and 2015, respectively. Furthermore, to support conclusions drawn from remote sensing data, forest inventory data showed the degraded condition of the forests within Zawita, most noticeably the broad-leaved forests which appear to be used more frequently as compared to coniferous forests. Migration data were also collected from household surveys. The results of these surveys showed a decline in the villages' populations between 1986-2015. Where forest degradation was observed, village population declines were apparent. Analyses of the householders' responses showed that political factors were the ultimate reason forcing people to migrate. However other factors also influenced the extent and flow of migration and the associated changes in forest cover in Zawita as well.

I dedicate my thesis work to my family and friends. A special feeling of gratitude to my loving mother, Mrs. Asmer Khalid whose words of encouragement and push for tenacity ring in my ears. My loving husband Ammad Zia whom without his support I would've gave up long time ago. My siblings whom have never left my side and are very special.

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KEY TO ABBREVIATIONS

TM…………………………………………………………………………………...Thematic Maps

OLI…………………………………………………………………………...Operational Land Imager

TIRS…………………………………………………………………………..Thermal Infrared Sensor

LCC…………………………………………………………………………….…..Land cover change

LULCC…………………………………………………………………Land Use Land Cover Change

FAO……………………………………………………………Food and Agriculture Organization

KRG……………………………………………….....................Kurdistan Regional Government

GHG……………………………………………………………………………...Greenhouse Gas

CO2……………………………………………………………………………………Carbon Dioxide

GIS…………………………………………………………………Geographic Information System

ID……………………………………………………………………………..Image Differencing

PCA…………………………………………………………………...…..Principle Component Analysis

MID…………………………………………………………………...Modified Image Differencing

PCD……………………………………………………………..Principle Component Differencing

MPCA…………………………………………………...Modified principle Component Differencing

IR…………………………………………………………………………...Image Rationing

MIR……………………………………………………………………...Modified Image Rationing

VID…………………………………………………………………Vegetation Index Differencing

CVA…………………………………………………………...………...Change Vector Analysis

NDVI……………………………………………………Normalized Difference Vegetation Index

cm……………………………………………………………………………………...Centimeter

m……………………………………………………………………………………………….Meter

UTM…………………………………………………………………...Universal Transverse Mercator

RS……………………………………………………………………………………...Remote Sensing

dbh……………………………………………………………………………Diameter at breast height

WGS………………………………………………………………………......The World Geodetic System

Ha…………………………………………………………………………………….....Hectare uni

N……………………………………………………………………………........Northern Hemisphere

USGS…………………………..…………………………………………..United States Geological Survey

MSS…………………………………………………………………...Multispectral scanner system

USD………………………………………………………………………………United States Dollar

KM………………………………………………………………………………………..Kilometer

Sq,Km.………………………………………………………………..………………Square Kilometer

FT…………………………………………………………………………………………......….Feet

GPS……………………………………………………………………..…..Geographic Positioning System

UNEP...United Nations Environmental Program

Chapter 1: Introduction and Background

1.1. Introduction

Environmental change is a critical issue the world is facing and there is no doubt that the increase in population and urbanization has an impact on the climate, disturbing chemical, hydrological and biogeochemical cycles (Foley et al. 2005). Beside these impacts on the environment, it reciprocally affects people movement; this is a two way relationship between human movement and environmental changes (Miller and Small 2003), both of them influence each other continuously.

Migration has been raising the attention of many social and environmental researchers worldwide. It is obvious that migration is being forced by many factors, e.g. social, demographic, political, and economic (Black, Kniveton, and Schmidt-Verkerk 2011). Only recently environmental change has been presented as a critical factor influencing migration (Boano 2008). Since migration is the result of a combination of many drivers (Black, Kniveton, and Schmidt-Verkerk 2011), environmental change is seldom the main factor forcing migration (Carr 2005). However, environmental changes are critical for investigating migration phenomena and should not be excluded (Carr 2005). Myers (2002) estimated that in 1995 there were approximately 25 million people displaced as a consequence of environmental changes. This number will rise to approximately 200 million by 2050 (Myers 2002), taking into account demographic changes and deteriorating environmental conditions. Thus, knowing the extent of the change and factors behind it are crucial for analyzing and investigating its consequences.

Environmental change (land and forest cover change, in particular) is a crucial issue especially in recent decades where humans' interference and manipulation of their environments became greater than any other time (Ojima, Galvin, and Turner 1994). The increased demand for food, fresh water, shelter and other basic human needs have put tremendous pressure on the environment, especially in developing countries, resulting in rapid land use and land cover changes, an increase of forest land conversion, drought, abnormal sea level, and reinforcing global environmental changes (Ojima, Galvin, and Turner 1994). Migration is argued to be another crucial side effect of environment change processes and massive population movements are predicted in the near future.

Migration, both internal and international, have always been an issue for Iraqis (Sirkeci 2005). Internal migration however is more common for Kurds living in the northern parts of Iraq specially in the last four decades (Black 1993). Rural-urban migration has become a critical issue the region's residents are facing. This study investigates the major motivations behind peoples' movements in Zawita sub-district of Iraq. The main hypothesis is that people's movement is somehow related to environmental change, especially forest cover change. In order to test the hypothesis, it's important to know the extent of migration and the changes in forest cover. To do so, a survey was conducted within Zawita to investigate the migration flow. Remote sensing technology along with forest inventory data were also used to detect forest cover change and forests' conditions on ground. The main research questions of this study are:

1. How much has forest cover changed in Zawita sub-district and what are the various factors behind it?
2. What are the factors that motivated people to migrate within the region and how is that related to the condition of the forest?

Zawita is a very important part of Duhok district. It has undergone a series of man- made fires and various military attacks that affected its biodiversity and composition. Halabja is a standing example of the effect of war on forests; the area is still showing abnormalities in both agriculture and forest growth to our present day due to the chemical attacks in mid-eighties (Mansor et al. 2013). Zawita was also subjected to severe man-made destruction by the old Ba`ath regime (Anfal and Arabization campaign) (Black 1993; Mansor et al. 2013). The campaigns resulted in massive human displacement and migration. The incidents not only forced people to relocate and migrate, but resulted in burning of vast areas of natural forests and agriculture areas within Zawita (Black 1993).

A full and reliable set of time-series data for long-term forest trends in Iraqi Kurdistan doesn't exist, nor has any research been done to investigate the relationship between forest cover change and migration within the region. To our recent day, there have been no regular or systematic forestry data collection by the government or any other non-governmental parties (Head of Directorate of Forestry Duhok city, n.d.). A few studies were carried by the FAO on forest composition in Iraqi Kurdistan

(Chapman 1948; Chapman 1950), but the results are outdated and these forests have been subjected to many changes between 1950 and the present day. Forest boundaries, forest composition and condition are still poorly understood, and there has been an absence of Land Use Land Cover Change (LULCC) analysis for the region. The most recent paper on forests in Kurdistan was published by Nasser (1984). More recently a study by Mustafa and Habeeb (2014) have been done to understand forest composition better, but none has been done to understand forest conditions and what are the changes that these forests have undergone and their various implications.

This study provides three main contributions. First, to determine the main motivation behind human's displacement and how is that related to forest cover change. Second, to examine the major changes on forest cover in the past four decades (39 years of forest cover change). And finally, to fill one of the many gaps in knowledge about Kurdistan`s forest condition and composition in the last 4 decades, by studying the Zawita sub-district.

The thesis is organized into five sections besides this introduction. The next section discusses theoretical perspectives on migration determinants, focusing on forest cover change and migration nexus. The following section presents a description of the area under study in Zawita sub-district, with a brief description of demographic characteristics of Kurds and describing Kurdish forests in general. The fourth section describes the data and methods used to answer the main questions. The last two sections provides results of migration survey and forest cover change, it also present the discussion and overall conclusions of the study.

Chapter 2: Background

2.1. Environmentally-induced migration

It is clear that weather-related factors have had a major impact on people`s movement throughout history. For example ‘Homo erectus’ ancestors, possibly driven by unfavorable drought conditions, migrated out of Africa millions of years ago (Wood 1991) and tribes invaded prosperous Egypt 4000 years BP while being pressed by drought and resource deficiency (Lamb 2002). In the past three decades, the concern about environmental degradation as a ‘push’ factor (Borjas 1994) behind massive population movement have been raised. It started with the early work of (El-Hinnawi and others 1985; Jacobson 1988; Myers 1993; Myers and Kent 1995). They noted that environmental disasters such as floods, droughts and earthquakes are displacing large numbers of people not only because of the intensity of the events but also the significant increase in population in certain areas.

Jacobson (1988) stated that, “environmental refugees have become the single largest class of displaced persons in the world.” Castles and Miller (1993) described migration as “an extremely varied and complex manifestation and component of equally complex economic, social, cultural, demographic, and political processes operating at the local, regional, national, and international levels”.

According to Ghosh (1992) and Lohrmann (1994) typology of migration is based on the four main root causes including: survival migration, opportunity-seeking migration, environmental migration, and persecution and conflict migration. In survival migration, climate might play a role since the population seeking a more favorable living condition. This is the case also for opportunity seeking and environmental migration especially in developing countries, where agriculture and natural resources are the main income sources for majority of population and climate change mostly affects these two. In the fourth, climate and environmental degradation could also cause resource conflicts, which might results in migration leading back to climate change as a critical factor.

In theory, no one element can be considered as the single factor in increasing migration pressure, and so far much of the literature considers environment-migration nexus on a general level, and the results are often based on small empirical studies (McGregor 1993). Thereby, when analyzing historical and contemporary cases, climate change is seldom the ultimate reason of migration, but more like an underlying factor, influencing other factors leading back to migration as a result (Kritz 1990). Nonetheless, environmental changes cannot be excluded completely from the migration process, nor can its influence, extent, and interactions with other social, economic, demographic and other factors be determined in isolation (Castles and Miller 1993; Carr 2005).

The Intergovernmental Panel on Climate Change in its first assessment report noted that the greatest effect of climate change might be on human migration, as millions of people will be displaced due to shoreline erosion, coastal flooding and agricultural disruption (OECD 2005). This will affect regions like Africa and Asia that are more dependent on natural resources for their livelihood and are more prone to environmental migration than industrial countries.

In recent times, there have been new, intense environmental disasters like Hurricane Katrina in 2005, in United States, and Bangladesh flood plains (Groen and Polivka 2010; Brammer 1990), that are resulting in people's temporary and permanent displacements. These are all evidence that past and recent climatic changes have contributed to peoples movements in the past and world`s population`s distribution nowadays, and most likely in the future. According to some researcher, people`s movement are being pushed by a combinations of political, demographic, social, economic, and environmental factors (Adamo 2008; Brettell and Hollifield 2014).

In order to investigate the drivers and main factors behind migration, different studies have applied different methodologies. According to (Piguet 2010) there are many diverse methods used in environmental-induced migration analysis, from environmental risk assessment to social identity these methods includes: householders survey, national census data, informant interviews, and integrated models (Carr 2005; Mortreux and Barnett 2009; Barbieri et al. 2010). However, Piguet (2010) argued that these methods failed to bring an extensive view of migration process within environmental context.

Using different methodologies, many other studies have been conducted to examine the relationship between environmental change and population movement and investigate its various implications. Lilleør and Van den Broeck (2011) studied the effect of economic and climate change drivers on migration. They found that climate change has an impact on migration that is being induced by economic factors. (Hugo 2011) stated that climate and demographic change are positively related that ultimately influence migration in a complex way.

2.2. Migration and forest degradation

The dramatic increase of forests land conversion has raised concerns about the implications of land cover change especially in the long term (Houghton 1994; Williams 1994; Hathout 2002). It is evident that forest cover change adversely affects people`s livelihood (Houghton 1994), especially in developing countries where a large proportion of the population is dependent on agriculture and natural resources. Agricultural decline has been causing people to migrate, consequently influencing the deforestation process (Garcia, Soares-Filho, and Sawyer 2007).

With the emerging conceptual work to investigate the environment-migration nexus, the effect of forest cover change as a critical environmental change has been poorly documented within the literature. Few researchers have attempted to look at the relationship between forest degradation and migration [e.g. Rudel, Bates, and Machinguiashi 2002; Sunderlin and Pokam 2002). It is obvious that population movement and forest degradation impact each other continuously. Bilsborrow (1992) examined the effect of migration on forest degradation and deforestation. But little work has been done to investigate the impact of forest degradation on people`s movement instead of examining migration`s impact on forest degradation and deforestation. In February 1994, during the international symposium in Almeria on desertification and migration , the experts agreed on the role of forest degradation and desertification on both internal and international migration (Westing 1994). Cropper and Griffiths (1994) in their study on population growth and environment interaction found that population growth causes deforestation, but again they did not examine the impact of deforestation on migration and population movements.

Many researchers listed deforestation and land degradation as cumulative change that occurs slowly with human interaction (Warner et al. 2010; Leighton 2006; Lonergan 1998), though the question is how does deforestation and forest degradation cause migration ?

Lonergan (1998) said that environmental change (forest degradation and desertification) only acts in combination with other factors like population growth, economic decline, political repression and others. They still can be the force driving migration, especially in those areas that are dependent on forest resources. Leighton (2006) in his book about Governing Global Desertification, said that migration related to forest degradation and desertification is also concerned with economic and environmental changes. He stated that forest degradation and desertification are not the sole direct factors forcing migration (Leighton 2006).

According to Maloney (1991), forest degradation has also been forcing internal migration in India, mainly because of drought that is causing forest degradation and agriculture decline. Myers (1993) claimed that deforestation resulted in the displacement of many indigenous people in Ecuador, Cambodia and Brazil, and other places. In another study on climate change, migration and conflict by Reuveny (2007), showed that in many developing countries forest degradation and deforestation was indicated as a major factors forcing migration. Hence, it is clear that migration and forest change have important relationships that need to be studied further..

Chapter 3: Study area

3.1. Kurdistan region

Kurds are an Indo-European people living in the northern region of Iraq (Figure 1). Major Kurdish cities are located in the plains, surrounded by series of mountains; the area is rich in oil and mineral resources. However, the main income source was agriculture until recently since the plains have a fertile soil. The Kurdish population is estimated to be about 3.8 million in three major Kurdish cities (Duhok, Erbil, and Sulimaniya). However, the lack of recent census data makes it hard to estimate how much of the population lives in rural areas where most of the forest cover is.

Kurdistan's regional boundaries have been unstable; it is now existing as a semi-autonomous region in Northern Iraq until. Over the last four decades, Iraqi Kurdistan has been subjected to a series of major transitions and disturbances, both natural and man-made. Bombarding Kurdish villages is one of the biggest issues the region is still facing (van Etten et al 2008). These attacks on Kurdish resources has cost the region vast areas of natural forests and vegetation cover, thereby affecting people livelihood whom are dependent on natural resources as their income source (van Etten et al 2008).

The problem of migration have increased noticeably in Iraqi Kurdistan mostly internal displacement due to various reasons, (Gibson and Campbell 2011). Worldwide war and institutional changes has been presented as important drivers affecting land use and land cover changes (De Beurs and Henebry 2004; De Beurs and Henebry 2008). Iraq has a long history of agriculture and war, with the last thirty years almost continuously in conflict (Iran war, Gulf war, UN Sanction, Iraq war) (Gibson and Campbell 2011). In addition to that, the unending political conflict between Iraq and Kurdistan region have also impacted people`s livelihood greatly. Each one of the previous wars and conflicts has impacted various aspect on people`s life, natural resources, and the regions environment. But, the extent of these losses and impacts is not well documented.

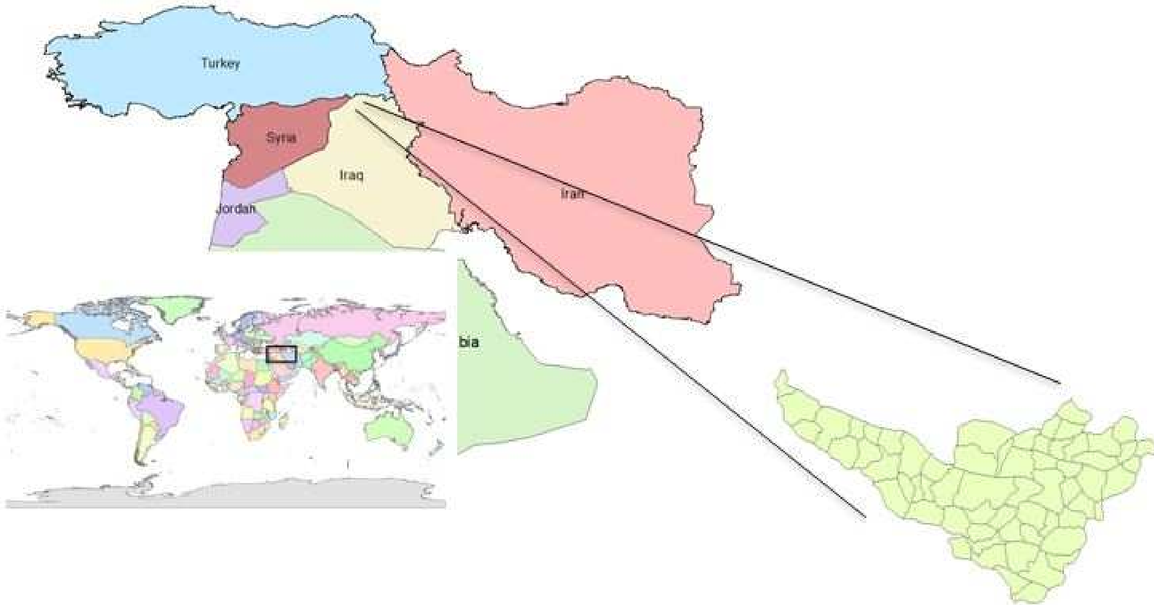

Figure 1: Geographic location of Iraq and Zawita sub- district of Kurdistan.

3.2. Forests in Kurdistan

Forest degradation in Iraqi Kurdistan is a serious problem because of the unique economical, and environmental values of these forests both for the region and the rest of the country. Kurdistan's regional forests are the only remaining forested land in Iraq (Chapman 1950). They play a critical role in the region`s climate and are considered a primary income sources for a wide range of rural communities. These forests have served in the past as the home for a variety of rare and native flora and fauna (Guest and Townsend 1966), but there are few recent studies to document changes in these populations.

Interstate war and political conflict with Kurdistan resulted in widespread destruction and disturbance to Kurdish natural resources (Black 1993). Those incidents resulted in burning vast areas of Kurdish forest and agriculture lands, forcing millions of Kurds to move from their villages (Black 1993). However, little has been published about the effects of war and political instability on forest cover change and people`s displacement. It is not clear how the migration process went, and whether those incidents were the main reason behind migration. Sadly, Kurdistan's forests are receiving little attention from the government or the communities. Many attempts including reforestation campaign, wildfires control, and tree cutting patrol have been carried out by Kurdistan Regional Government (KRG) that were unfortunately unsuccessful due to poor planning and lack of expertise (Head of Directorate of Forestry, n.d.). This also traces back to the quality of forest governance in the region. Mainly, the government has been the only party that is involved in the strategic decision- making process. Indigenous residents are generally excluded from these decisions except in some cases where a region's tribes oppose governmental interference on their land.

Forest policies, where they do exist, are poorly developed and implemented in Kurdistan; there aren't any forest laws and/or policies for forest resources use that are specifically designed for the forest types existing within the region. Most of forest policies were obtained from neighboring countries for example; Turkish brush system policy was the first forest law, which was validated in 1870. Afforestation Law No. 43 was applied in 1943. In 1955 the Iraqi government issued forest law No. 75, which was the only forest law originally issued by the Iraqi government (Chapman 1950). Even though they share some of the same ecological zones, forests in Kurdistan differs from those in Turkey. Thus, Turkish forest policies aren't appropriate for forest`s condition in Iraqi Kurdistan (Chapman 1948, 1950).

In Jan 2009, when awareness about forests important role in mitigating global warming and significant increase in tourism revenues for the region, the KRG planned to issue new forest policies. They specified more laws to ban tree cutting, animal grazing, controlling forests wildfires, and minimizing residential expansion within forests boundaries. No doubt the terms of these policies were intended to be good for forest restoration and conservation, but the problems arose when fulfilling the needs of those whom were dependent on forests resources. The laws, however, were just verbal until the beginning of 2015, when they were 'officially' implemented. To date, no formal studies have been carried out to assess the effects of these policies on human-forest interaction.

Because the "traditional ownership" on land by indigenous groups is dominant in the region, the ownership is not recognized by domestic legal system, and because of peoples' lack of expertise in formal registering of their rights, they are more vulnerable to fraudulent individuals claiming ownership. When forests in the region became a valuable commodity, it resulted in claims of forest resources tenure and new conflict. The issue of enforcing forest policies for tree cutting and forest use need to be further examined and account for the rights indigenous people in forest related decision-making before implementing the rules.

Historical evidence supports the argument that most of Kurdistan mountains were covered with well-stocked and healthy forests compared to the currently degraded forests conditions (Chapman 1950; Nasser 1984). In 1984, Nasser noted that the forest cover in Kurdistan starts in the northwestern part of the country extending from Zakho area near Turkish borders between (37°08'N42°40'E) and (34°40'N 45°30'E) ending roughly on the Iranian border in an area called Horin Shirin. Natural forests were confined to the mountainous areas only, composing 4% of the total area about (438,466 sq.km), and about 60% of the total mountainous region- approximately about 30,000 sq.km, in addition to the ~200 sq.km narrow strip forests growing along the major rivers.

Kurdistan forests are mainly composed of broad-leaved forests (mostly oak (*Quercus*) species) and coniferous forests (pine (*Pinus*) species). Forest types are defined based on the species ratio; here they are defined as: broad-leaved forests are 80% hardwood species and 20% softwood species, while coniferous forests are composed of 80% of pine species and 20% of other softwood and hardwood species. Mixed forests are a combination of 60% and 40% between the previously mentioned species, but most mixed forests were man-made platations so one would rarely find pine and oak trees grown within the same area. Most of the pine trees grown outside the Zawita Valley were planted by the government and the area`s residents (Local residents). There are also riverine forests that grow alongside riverbanks (Nasser 1984; Şefik 1981). According to past studies, broad-leaved oak forests compose the largest percentage of the total forested area about 90%, with the remaining 10% of other forest types such as pine, riverine, plantation, and others (Nasser 1984; Şefik 1981; Chapman 1948). Broad-leaved forests are known to be resistance to grazing and to the region`s harsh weather condition especially during hot and dry summer season. However these forests have suffered various man-made and natural disturbances especially shifting cultivation and fires (wild and man-made), tree cutting and others (Nasser 1984; Şefik 1981; Chapman 1948).

Broad-leaved trees (e.g., *Quercus* species) typically do not exceed 20m in height and 1.5-2m in diameter (Chapman 1948). Three different zones could be seen within these forests, a lower dry zone, an intermediate zone and an upper moist zone. *Quercus aegliops* and *Quercus infectoria* are grown in low altitude (lower and intermediate) zones and *Quercus libani* is found in high altitude (upper moist zone). Other species associated with these forests are: *Pistacia khinjuk*, and *P.mutica*, *Acer cinerascens*, *Crataegus azarolus*, *Pyrus syrica*, and *Celtis tourneforti* (Şefik 1981; Chapman 1950; Chapman 1948). These species have a low timber value, however they are the main source of wood fuel and support the charcoal industry, and shacks built especially during summer when tourism season begin (Nasser 1948). *Quercus infectoria* was being used as a medicine and in tanning industry (Nasser 1984). For the most part these forests can tolerate heavy grazing and cutting because they can grow in the form of coppice sprouts, this is advantageous for villagers but it adversely affects timber availability for the market (Nasser 1984; Chapman 1948). More valuable species are found in moist valleys, including walnut and the plane *Platanus orientalis* more than the common *Populus euphratica*, and *Fraxinus rotundifolia*. These forests are poorly stocked, however, they still attract an appreciable number of tourists, giving the chance for tourism increase in the area (Nasser 1984).

Coniferous forests on the other hand were confined to certain areas; the most famous pine forest exists in Zawita sub-district covering the entire Zawita valley. The indigenous coniferous forests are composed mainly of pine species, extending from Zawita district to vicinity of Atrush, they are lightly stocked with *Pinus Brutia* and eastern Mediterranean pine (*Pinus Halapensis*) (Guest and Townsend 1966). *Juniperus oxycedrus* is another Mediterranean species that grows with pine, it is more widespread than the pine but still confined to the more temperate northern area of the region. There are no other indigenous species, however, *Cupressus sempervirens*, *Thuja orientalis*, and *Pinus halapensis* have been introduced to the area, which were successful to an extent in plantations and irrigated gardens (Chapman 1950). More pine plantations are being grown, and according to Nasser (1984), pine is replacing scrub oak after exploitation.

There are also plantations and naturally grown narrow strips of P. euphratica and Salix species along the riverbanks. Regardless of their poor quality, *Populus* species are of a high value as roofing timber. Other species like P. orientalis, F. rotundifolia, Salix acomophyla, S. Alba, Morus Alba, and Celtis tourniforti also exist alongside those species. Large scale tree planations to the region was almost unknown in the past with the exception of village`s *Poplar* planations (Nasser 1984). Nowadays, more plantations are being established and new species (mostly horticultural tree species) are being introduced for the purpose of increasing local production of certain products. Majority of the plantation are being successful with using new technology and appropriate species that can tolerate the severe weather conditions of the region. Table 1 shows some statistic of forest and its estimated area obtained from Directorate of Forestry in Duhok city.

Table 1: Forests in Kurdistan
Source: Forestry Directorate Duhok City (n.d.). This table shows the different types of forests and tree plantations in Iraqi Kurdistan and their estimated area.

Forest Types	Exploited area (1000ha)	Annual Area (m^3, ha)	Productive age (years)	Total stock (1000 m^3)	Total % forest area
Broadleaf forest	1000	0.5	50	35,000.00	90.50%
Coniferous Forest	2	1	50	100	0.20%
Riverine Forest	2.25	2	15	67.5	0.20%
Plantations	0.75	12.5 (av.)	10 (av.)	93.75	0.10%
Others	100	7.0 (av.)	15 (av.)	17,500.00	9.00%
Total	1105	4.6 (av.)	28 (av.)	52,761.20	100%

3.3. Zawita district

Zawita sub-district is located 17 km away from Duhok city, with an average elevation about 885 m above sea level, and a maximum temperature of 38C (Figure 1). Zawita has around 70 villages; according to Bureau of Statistics in Duhok city 36 of them are populated and the remaining 31 are vacant villages. Zawita is distinguished for its famous pine forests; its extensive shady spots makes it particularly attractive in the summer.

The climate of the study area is similar to the Mediterranean climate conditions, dry summer and a modest amount of precipitation through winter (Koeppe and De Long 1958). The climate of the study area is characterized by cold weather with snowfalls on the high mountains during the early winter season. High relative humidity and low temperature at minimum (1.56°C) during winter season with rainfall rate at minimum 1.20 mm and 358.41 mm at maximum. While summer season is hot and dry with temperature and evapotranspiration at maximum rate about 43.30°C and 13.70 mm, respectively.

Zawita sub-district has an area of approximately 41591ha, with almost 30129 ha of it covered with natural forests (Directorate of Forestry, n.d). Zawita also have 5120ha of grain and crops area. There are several seasonal rivers that pass through the area during rainfall season mainly used for irrigation. Duhok dam is the only dam available in the area, it is located at the southeast side of the sub-district and considered the main water source for irrigation, drinking and other purposes for Duhok district residents.

The study area was selected mainly for several reasons: Zawita is one of the important sub-district within Duhok district. Zawita also has a rich history from the old Assyrian empire which form some of the major attraction points for tourists, and it is distinguished for its remaining indigenous pine forests. Zawita has undergone substantial land cover changes, especially because of the recent wars (the Anfal campaign in particular). Anfal destruction by the old Ba`ath regime resulted in massive fires that burned vast areas of natural forests (Black 1993). Natural fires are also a critical issue within Zawita especially during dry summer season which can also cause massive destructions to the forests.

Zawita was also chosen as the case study because it witnessed a substantial change in its population in the last 4 decades (Forestry Directorate, Local residents. n.d). The changes in Zawita environment and the sudden increase in rural-urban migration during the same time period, and the limitation of data on Zawita made it an excellent choice for investigating the relationship between environmental changes and migration. The gap in knowledge is another major motivation for choosing Zawita as a case study. Since the 1980s, no papers have been published about Kurdish forests conditions and species composition.

Chapter 4: Methods

4.1. Experimental design

Three types of data were used for the purpose of answering the research questions. The data included: household survey, forest inventories, and remote sensing. Survey household`s data will help to answers the question about migration within Zawita, and the major ‘push’ (factors that are forcing people in original location to migrate) (Borjas 1994; Martin and Widgren 2002).

Table 2: Locations of field sites and survey data collection. The table shows the villages selected for conducting migration surveys and collecting forest inventory data

Village Population				
Forest Types		Growing Population (Population No)	Not Growing Population (Population No)	Decreasing population (Population No)
	Broad-leaved	Bari Bohare (330), Baneyi (14)	Rashawer (102)	Beski (11)
	Coniferous	Zawita (1729)		Boteya (62)
	Mixed	Sarki (90)	Sindori (339)	

Data collection (Table 2) was conducted in eight villages within Zawita. The selection process for choosing villages was based on forest type and population status (growing vs. not growing vs. declining). The villages chosen had different forest types and population size. Villages which were regarded as similar to each other or which did not fit within the criteria were excluded.

Information about village population and forest area and forest type were taken from the Bureau of Statistics and Directorate of Forestry in Duhok city. Population status was determined using government census data taken from Bureau of Statistics in Duhok city. Forests types were assigned initially based on information provided by Directorate of Forestry in Duhok city, and by me with the help

Google Earth and 'Esri basecamp' map data as ground reference data. Forest types were later reassessed using remote sensing and data collected from visits to forests (described later). The shapefile of the village boundaries and an estimation of natural forest area, population size, and mayor`s contact information of each village were provided by Bureau of Statistics in Duhok city prior to the forest inventory start date. Systematic sampling was used to select the householders for the survey. Every third house was interviewed in big villages, while all houses were interviewed in small villages, where the number of households was lower than 15 houses. The survey included question about forest conditions from householders' prospective, and how they interact with the forests surrounding their villages in general.

Forest inventory data were collected for the purpose of getting general information about different forests types. The forests selected for inventory were identified with the help from the mayors of the villages and the villager's instructions (forests used by village residents). For forest cover change detection, remote sensing data was used to detect the change over 40 year time period within Zawita. Each set of the data alone or combined provides valuable information about the migration and forest cover change within the study area. Data collection methods are described below.

4.2. Households survey

4.2.1. The survey structure

The surveys served as an instrument for determining the causes and underlying factors behind migration within the study area. The questions I was trying to answer with this data were:

1-What are the motivations behind internal migration in Zawita sub-district?

2-To what extent environmental change (forest cover change in particular) forced or influenced migration decision?

Field trips were necessary to assess each village`s conditions and population; I visited each myself. I found that some of the villages were counted as populated, but were vacant, or had a very small number of houses that were mostly summer houses. I excluded the vacant villages and those that were newly built and were not occupied by indigenous residents of that area. The villages' populations were fairly small in size; household's sample sizes were about a third of the whole village population in some villages and the whole village's households in others. Survey sample size was dependent on the village's size, available time, and safety conditions of the area. I conducted all the interviews myself. I pre-tested the survey and edited the questions that caused confusion as required. The response rate of the survey was 100%, all of the householders were very cooperative during the survey. The survey was structured by me with the help and guidance from Dr. Robert Richardson in Community Sustainability Department at Michigan State University and was approved by the IRB (x-14-496e; i046204).

The survey was conducted between two trips in 2014 and 2015. Some questions in the 2014 survey were modified in 2015 survey to get more insight about forest resources use and forests conditions in general (Appendix D, E). The variables examined were environmental, demographic, political, and social factors. Survey respondents were asked to rate importance of issues on a Likert – scale.

In summer 2014, 50 in-person surveys were conducted from 4 different rural areas within Zawita sub- district including: Bare Bohare, Sarki, Sindori, and Rashawer. The surveys coming from Bare Bohare were 34 percent of total surveys, 22 percent were from Sarki, 28 percent from Sindori, and 16 percent from Rashawer (Figure 2). In summer 2015, 75 more in-person surveys were conducted, which accounted for 60 percent of total number of surveys collected during both trips. The survey took place in 8 villages within Zawita sub-district: Zawita (named after Zawita sub-district), Sarki, Sindori, Rashawer, Baneyi, Beski, Boteya, and Bare Bohare. Survey distributions were: 8.0 percent from Bare Bohare, 5.33 percent from Sarki, 18.67 percent from Sindori, 5.33 percent from Rashawer, 13.33 percent from Baneyi, 13.33 percent from Beski, 9.33 percent from Boteya, and 26.67 percent from Zawita.

The households in the villages were sampled using systematic sampling method. Every third house was interviewed. There were no characteristic for the chosen householders, however non-residents of the villages were excluded from the survey. While the households whom have migrated were tracked down using 'snowball' method based on information provided by their relatives and neighbors living in the villages. This method was very successful given the nature of the people who stay in close contact with their relatives and families.

Survey questions were broken down into two sections (see Appendix), the first section dealt with people's movement and the reasons and underlying factors behind people's decision to migrate. This section included questions related to human and forest interactions, how much people are dependent on forest in those areas, and how the changes in forests and land cover in general affected their lives. The responses from the questions were used to derive the push factors that forced people`s movement. The second section included questions about forests condition and the causes and factors behind forest degradation (war, soil erosion, fires, and land conversion) within the area. This section also included questions about major restrictions for forest use and access, and the implications of forest new policies on forest usage and access. In addition to that, people`s personal observations on the extent of forest cover change around their villages were also included.

The interviews were mostly with the head of the household, or in their absence, the second head of the household was interviewed. Majority of the household members were migrants at some point especially when the massive relocation by the Ba`ath regime happened in the 1980s. However, the distinction between migrants and current village residents was necessary to get separate information about past and current migration process. That is why it was necessary to interview householders whom have migrated from the selected villages based on contact information provided by the villagers and their relatives' residing in the selected villages using snow ball method.

4.2.2. Key informant interview

Key informant interviews were also conducted to enhance the household survey data. Key informant interviews added additional information on forest conditions from government and from the villages' leaders prospective; the interviews included the mayors or the elders of the village (where the mayor was absent). I also interviewed the head of the Directorate of Forestry in Duhok city (Mr. Cheyavan) and other employees. I also got the chance to meet with Dr. Yaseen Mustafa and his graduate student Hindav Saleh whom were also working on a project within the same study area. They provided some valuable information about forest conditions in the area and the populated villages vs. evacuated ones. Information about forest policies and residents attitude toward forest laws were also provided.

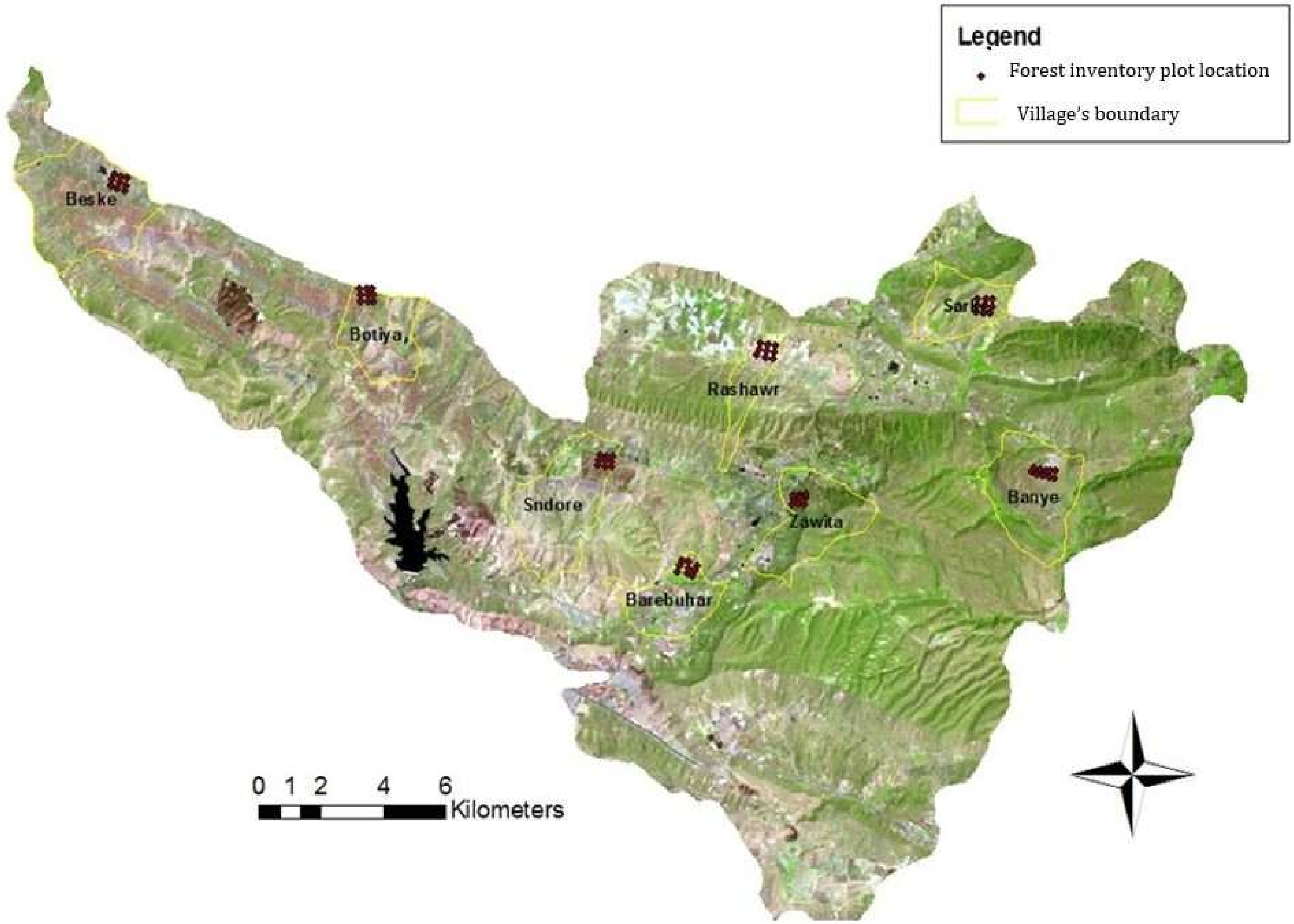

Figure 2: Study area map showing village locations with forest inventory data collection locations.

4.3. Forest inventory data

The forest inventories were divided between two intensive summer trips to Kurdistan region in Northern Iraq (summer 2014, 2015), the first was about two months long and the second was approximately one month long. Prior to the forest inventories, sites for collecting tree data were selected using Google Earth and recent Landsat imageries false color composite based on forest area coverage and forest type. The decision for choosing the sites was also based on forest area per acre, forest coverage information was provided by the Directorate of Forestry in Duhok city in Kurdistan region.

Forestry data were collected to assign forests to three different forests types (broad-leaved, coniferous, and mixed) forests surrounding the eight selected villages within Zawita (Figure 2). The number of plots measured ranged between 9-10 plots per forest, but plot number varied based on forest size and condition. Some forests had empty patches within its boundaries which were also included in the analysis, other forests followed deep valleys, which also required adjustments to the plan; plots were not established in areas of very steep terrain, which would have been hazardous to sample.

Forest measurements were taken using fixed-radius plot sampling method. The plots were distributed systematically by running three parallel transect lines approximately 600 m long and placing a sample plot every 200 m after leaving a 30 m buffer from all edges of the forest. However, in some forests walking in a parallel line led to the outside of the forest. In these cases, using a compass, I made a 90° turn back into the forest to the left or the right side based on the desired direction to get back inside the forest (Figure 3).

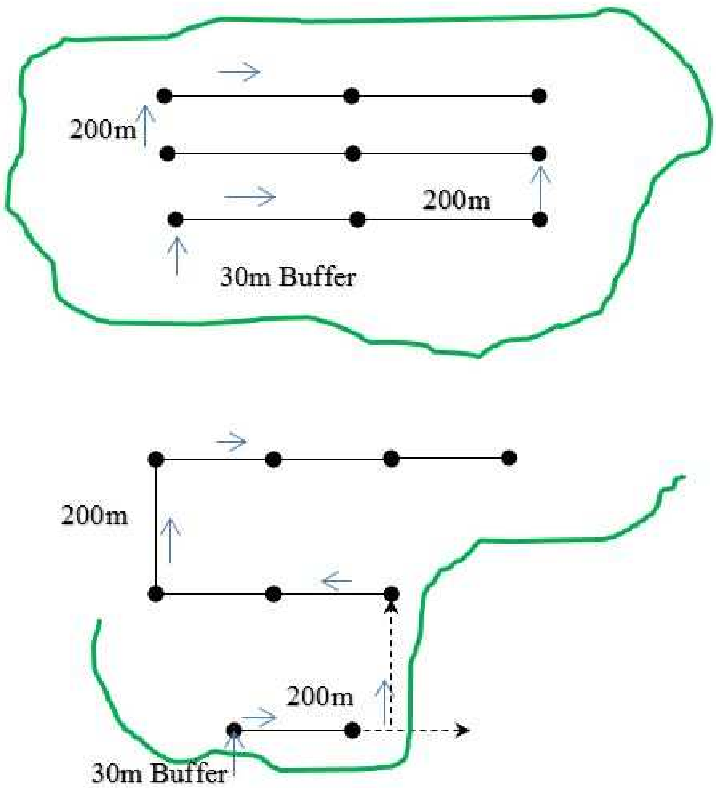

Figure 3: Forest inventory method (Drawing by D.W. MacFarlane, reproduced with permission)

Plot data included tree diameter at breast height (dbh), tree species, tree height, crown class, tree status, and the coordinates for the plot center determined with a Garmin etrex global positioning system (GPS). The 15 m radius plots were used to measure larger trees > 38cm dbh, and another smaller 5 m radius plot (centered in the bigger plot) was used to measure trees ≥ 2.0 cm and ≤ 38cm dbh. Heights of trees were measured on every 10^{th} tree across all plots, starting with the first tree on the first plot.

4.4. LULCC mapping approach

Figure 4 (below) summarizes the LULCC methodology. The data used in this study, the pre-processing, and processing procedures are shown in this flowchart and are described in detail in the following sections.

4.4.1. Data acquisition and sensor parameters

In this study four Landsat images of the study site were acquired over a period of 39 years. The first image was acquired on June 28, 1986 with a MSS sensor, the second and third images were acquired on July 31, 1998, and July 21, 2006 respectively, with a TM sensor. The fourth image was acquired on OIL/TIRS sensor on July 14, 2015. MSS is the first Landsat generation with 60 m spatial resolution. The TM instrument is a second-generation imaging instrument in the Landsat program on Landsat 5. The TM scene has spatial resolution of 30 meter in bands 1 to 5 and 7, while band 6 has spatial resolution of 120 meters (thermal band). The OIL/ TIRS instrument, launched within Landsat 8 in February 11, 2013, it has 9 distinct bands and spatial resolution of 30 meter for multispectral and 15 m for panchromatic bands.

Table 3: The spectral range of each band for Landsat TM and OIL/TIRS

Day and month	Year	Path/Row	Sensor	Satellite	Bands	Spatial resolution (m)
June-28	1986	170/34	MSS	Landsat 5	1,2,3,4	60
July-31	1998	170/34	TM	Landsat 5	1,2,3,4,5,7	30
July 21	2006	170/34	TM	Landsat 5	1,2,3,4,5,7	30
July 14	2015	170/34	OIL/TIRS	Landsat 8	1,2,3,4,5,7	30

Cloud free images were chosen for the same month of the year during growth season were they are not highly affected by atmosphere (scattering and absorption). All imageries were obtained when vegetation is at the highest and of leaf-on conditions, and bare soil is most distinguishable from urban areas. Data were georeferenced to the UTM (Universal Transverse Mercator) map projection zone 38N projection based on the WGS84.

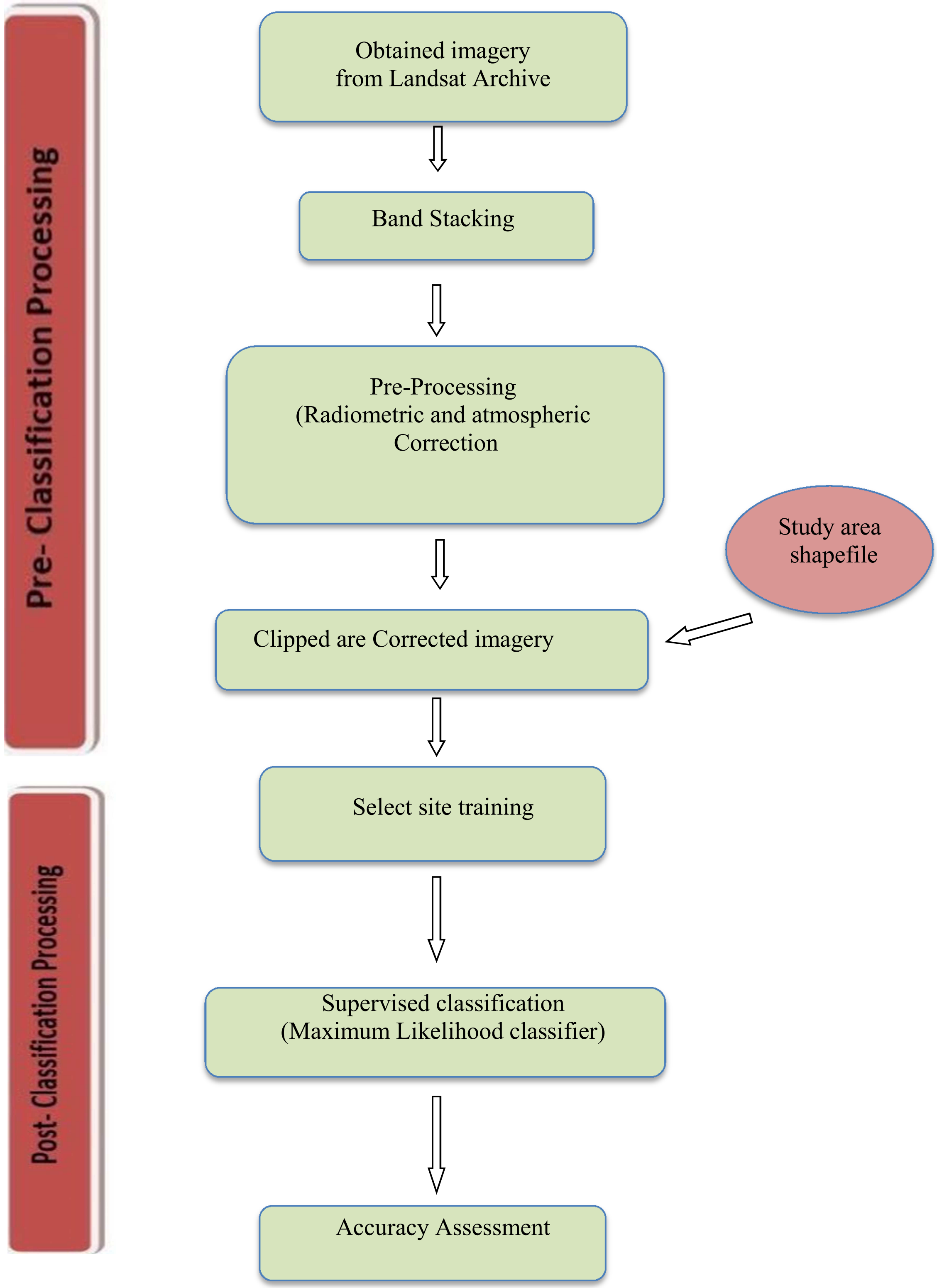

Figure 4: LULC Classification Methodology

4.5. Pre-processing

Satellite images are affected by many atmospheric and radiometric factors. Atmospheric scattering, and change in illumination are examples of parameters that impact the digital number sensed by the instrument, these parameters can cause difficulty in comparing more than one image of the same scene that are taken under different conditions (Schott, Salvaggio, and Volchok 1988).

In order to get accurate results, atmospheric and geometric correction is required, especially when using a set of Landsat images to minimize the impacts of these parameters or to normalize them.

4.5.1. Sensor Radiometric correction

A module developed by Dr. Lusch in Geography Department in Michigan State University was used for performing radiometric correction on the imagery (1986, 1998, 2006) using ERDAS imagine software, while the corrected fourth images (2015) was provided by USGS website upon request. The imageries were corrected from all atmospheric distortions, while geometric correction was not required due to the high locational accuracy we got after removing atmospheric distortions.

ArcGIS software version 10.2.1 was used for image classification and to generate land use land cover classes. The image classification was supported with control points (referenced with UTM map projection zone 38N) accompanied by ground truth control points for different forest types and to verify the accuracy of the imageries verses actual forest on the ground.

4.5.2. Classification method

A supervised classification method was used for this study. In a supervised image classification the operator is in control over the process because of selecting training site samples manually that collects a set of statistics that best represent the spectral signature of each land use class within an image. The accuracy of the training sites depends on the operator skills and knowledge of the area. The more accurate the training sites the more accurate different land use and land covers classes will be assigned to their specific classes. In this study, training samples are selected for all classes over entire images focusing on forested area. For producing forest cover maps and general LULC classification for the study area, I classified the land to level one and level two LULC using Anderson classification system. The following classes of forest cover and other LULC classes were defined based on my knowledge of the area and using Google earth, Esri base maps, and Earth Explorer.

Table 4: Selected LULC classes for 1986, 1998, 2006 TM and 2015 from OIL/TIRS images.

LULC classes	Landsat images			
	1986	1998	2006	2015
Urban	*	*	*	*
Bare soil	*	*	*	*
Water	*	*	*	*
Broad-leaved forests	*	*	*	*
Coniferous forests	*	*	*	*
Mixed forests	*	*	*	*
Agriculture	-	*	*	*
Barren lands	*	*	*	*

In Arcmap, the training sites are created by drawing small polygons over multiple pixels that belong to one land cover, thus different training sites are drawn for each land cover class that exists within the study site boundary. However assigning these training sites to their right land cover class can be a challenging and repetitive process. Furthermore, accuracy is very important for avoiding misclassification of land cover classes.

Training sites were collected from all parts of the scenes for eight land cover classes to be extracted from the multispectral Landsat MSS, TM and OIL/TIRS bands. These classes are urban, water, bare soil, and three types of forests, in addition to barren and agriculture lands. The selection of the training sites basically depends on visual interpretation including tone, color, texture, pattern, and shape of land cover classes within particular band combinations.

A large number of training sites are required for generating accurate statistical parameters used by the classifiers. However, the classifiers need to be aware of different classes in order to avoid commission and omission. To assure accuracy, selected training sites of each land type were compared several times to the imageries taken for Google earth, Google maps and Esri base maps for the most recent imagery since they were the most updated maps of the region.

Compared to 1998, 2006, and 2015 maps, the land classes in 1986 imagery were hard to distinguish due to low resolution of 60m pixel. Having no reference data made it more difficult to assign training sites also. However, knowledge about study area was drawn from the survey and the time periods from 1980 to 1990, looking at areas which had undergone some significant changes. For example Duhok dam was not clearly defined because the dam was completed in 1988 which explains the shape of the dam in 1986 map. Agriculture areas were not identified in 1986 because during that period the villages were destroyed and the villager's farms and lands were burnt. Table 5 shows the number of pixels selected for each class for training.

Table 5: The number of pixels selected as training sites for classifying each image

Images LULC Class	1986 TM Images	1998 TM Images	2006 TM Images	2015 OLI/TIRS Image
Water	62	716	1242	1581
Urban	165	21	21	550
Broad-leaved Forests	1044	11028	2801	5047
Softwood Forests	1267	917	712	1538
Mixed Forests	198	1124	794	615
Barren Lands	1487	2025	1355	2153
Agriculture Lands	-	208	56	374
Bare soil	58	1841	89	317

After collecting a satisfactory amount of training sites for each class, a maximum likelihood classifier is applied to all images using ArcGIS 10.2.1 software to generate LULC maps for different time periods.

4.5.3. Classification validation

The final step in the classification process was validation. Accuracy assessment is crucial to assess the accuracy of the assigned classes of each map. The accuracy of the classification was tested using the “confusion matrix”, to determine how accurate the supervised classification has assigned the subset of pixels used in training site selection to classify land classes. A confusion matrix (Kohavi and Provost 1998) consists of an equal number of rows and columns, which rows normally represent the classification results from remotely sensed data, while columns represent the reference data. Accuracy values are presented as percentages in confusion matrices (see results below). It is a very useful method used widely for accuracy assessment. In addition to calculating different accuracies, commission and omission errors percentages were provided by the confusion matrices, including producers’ accuracy, which defines how well a certain area was classified, and users’ accuracy, which is the probability that a pixel class on the map actually represents that category on the ground.

The “Kappa coefficient” is another measure to assess the accuracy of the classification process. This statistic presents the difference between the actual agreement between the reference data and an automated classifier and the chance agreement between the reference data and a random classifier (Anys et al. 1998). Kappa coefficient ranges between 0 and 1. The actual agreement is a value close to 1, while the non-agreement approaches 0.

Accuracy assessments help to understand the classification errors and reduce training site confusion. For ground reference data, forest inventory plot coordinates were used along with Google Earth, Esri basecamp map. Validation process included integrating ground reference points and other random points assigned based on reference data (Google earth, Esri map) for the four different time periods. Choosing a sufficient number of reference points is necessary. Here, 50 reference points were used for each class. In the next step, the reference points were converted to pixels using points to pixel command in ArcGIS software. The final step was combining the classification map for each image with reference data shapefile. The outcome table containing the number of pixels for each one of the classification and reference data was then exported to a spreadsheet for calculating the user`s, producer`s, omission errors, and commission errors. The overall accuracy and kappa coefficient were also derived from confusion matrix for each image. The change in the total area of each selected class was computed to help understand both natural and man-made changes in LULC, which indicate the expansion or diminishment of that class over time.

Chapter 5: Results

5.1. Survey Summary results

5.1.1. Householder's characteristics

In general, there were more male respondents than female, which reflect the culture dominance of males being the head of the household. However, more female respondents were interviewed in the city than the village taking into account the difference in numbers of householder interviewed in rural area verses urban area. Survey summary is shown in Table 5.

In total, 125 questionnaires were collected from 8 different villages within Zawita sub- district including: Baneyi, Bare Bohare, Beski, Boteya, Rashawer, Sarki, Sindori, and Zawita. Male and female subjects were 88 percent and 26. Their average age was 59.9 with the youngest at 25 and the oldest at 91.

Table 6: Survey statistics summary.
This table shows the villages selected for survey, percentages of female and male respondent's, and respondent's average age.

Village ID	No. of Survey	No. of female householders	No. of male householders	Av. Age (sd, min, max)
Baneyi	6	0	6	68.8(6.2,61,79)
Bare Bohare	20	3	17	44.8(13.3,25,67)
Beski	3	0	3	67.3(10.1,61,79)
Boteya	3	1	2	64.7(9.3,54,71)
Rashawer	8	1	7	46(7.7,37,59)
Sarki	8	1	7	53.8(12.9,32,72)
Sindori	22	2	20	46.3(13.9,28.74)
Zawita	20	1	19	74.8(10.1,52,91)
Total	90	9	81	55.8(16.9,25,91)

In all villages the majority of respondents were illiterate or did not complete primary school. The distribution between subjects' age and their educational background is shown in Table 7.

Table 7: Householders age & educational background.
This table shows the respondents from the eight different village`s by age categories and educational background. The majority of the householders were illiterate or did not complete primary school, whereas only few attended higher education institutions.

Age & education background	Illiteracy or primary not completed	Primary complete	Secondary not completed	Secondary completed	University Incomplete	Graduate school complete	Total
25-34	7.8%	-	2.22%	1.1%	1.1%	1.1%	13.3%
35-44	11.1%	5.56%	2.22%	-	-	-	18.9%
45-54	12.2%	1.11%	-	-	-	-	13.8%
> 55	47.78%	4.44%	1.11%	-	1.1%	-	54.4%
Total	78.9%	11.11%	5.56%	1.1%	2.2%	1.1%	100%

All the householders were from middle class, about 56 percent of them were earning on average about $10,000 US annually, which is the average annual salary for 'middle class' people in Kurdistan. More than 85 percent of the householders said that more than 25 percent of their income comes from agriculture, and only 17% said that forest resources composes more than 25 percent of their households' income.

5.1.2. Migrants characteristics

Information on the characteristics of recent migrants was derived from the survey conducted in the city, though all the householders were migrants at some point. Female and male subjects were 17 and 82 percent, respectively. Their average age was 68 with the youngest at 29 and the oldest at 91 (Table 8).

Table 8: Migrants summary statistics.
This table shows the percentage of male and female interviewed and their average age for each of the villages.

Migrants original location	No. of Survey	% female gender	% male gender	Avg. Age (sd, min, max)
Baneyi	4	0.0%	11.4%	65.5(5.50,59,71)
Bare Bohare	3	2.9%	5.7%	84(5.50,81,91)
Beski	7	0.0%	20.0%	69.2(10.79,53,81)
Boteya	4	2.9%	8.6%	63.5(13.82,49,82)
Rashawer	4	2.9%	8.6%	48.8(22.3,29,74)
Sarki	7	5.7%	14.3%	70(10.7,56,88)
Sindori	6	2.9%	14.3%	75.3(10.8,57,87)
Zawita	0	0.0%	0.0%	-
Total	35	17.1%	82.9%	68.3(14.3,29,91)

Similar to the householder`s characteristics, the majority of migrant respondents were male, though more female respondents were the head of their household in the cities, than the villages. Migrant's educational level was slightly higher than the householders in the villages (Table 9).

Table 9: Migrants age and educational background.

Age & education background	Illiteracy or primary not completed	Primary complet e	Secondary not completed	Secondary completed	University Incomplete	Graduate school complete	Total
25-34	-	-	2.9%	-	-	2.9%	5.7%
35-44	-	-	-	-	-	-	-
45-54	5.7%	-	-	-	-	-	5.7%
> 55	71.43%	8.6%	5.7%	-	-	-	85.7%
Total	77.1%	8.6%	11.4%	-	-	2.9%	100.0%

5.1.3. Survey results- migrants age and destination

The results of the surveys show that younger people tended to migrate more than senior residents. 'Pull' factors are the forces that operate in the destination where migrants are headed toward (Borjas 1994; Martin and Widgren 2002). Pull factors from the city affected senior residents' less than younger residents. People whom lived longer in the villages were more attached to their land and their villages, and it is more difficult for them to adapt to the city life than younger people. However, since senior residents are usually the one in charge of their family, they usually tend to send their sons to the cities to get better education and better job opportunities, while they wed their daughters to individuals from cities to provide a better life for them. According to the surveys, about 33 percent of migrated persons were males seeking better education and job opportunity in the cities, whereas 35 percent of migrated personals were householder's daughters that moved because of marriage and forming a family.

While senior people often had no desire to migrate from their original village, sometimes they had no other options except moving. However, sometimes moving was only in the form of relocating within their own villages. After the 'Arabization' and 'Anfal' campaigns (Black 1993), many villages were destroyed, but their indigenous residents refused to leave, instead they started rebuilding their homes in a different area within their village`s boundaries. Seventy-eight percent of the respondents said they have lived in the same village for more than 20 years, 50 percent of that 78 percent said that they had to relocate several time within their village boundaries for security and safety matters. While 34 percent said they had to move to a different rural areas, only 16 percent said they moved to the city for a period of time during the war.

5.1.4. Survey results – Householders interactions with forests

The surveys showed that forests in Kurdistan have played a major role in people's lives. According to the local residents and the Kurdish fighters (The Peshmarga), mountainous forests had a crucial role in their survival and their victory in the civil war. "Forests protected us from the enemy, without mountain and forests there would be no more Kurdistan or Kurds" said one of the old Peshmarga that I interviewed. The role of forests in harboring resistance fighters was the main reason behind their destruction in the past three decades by the old Iraqi regime and Iraq`s neighboring countries (as told to me by local area residents).

Looking across the different responses of the interviewees to the survey, it is obvious that many factors influence people`s interactions with forest (Table 10, below). During the interviews, it was clear from people responses that forest availability does not have a big influence on people`s decisions to move or stay (Table 10). However, when respondents were asked about their dependence on forest resources in general and for various purposes, forests appear to have a crucial role in their daily life and survival, "we were mostly dependent on the wood that comes from forest, we used it as cooking fuel, charcoal for heating in the winter, fencing our farms, building our houses, and various other uses, so yes forest was a big part of our lives and survival especially during the war" said one of the village`s elders.

Table 10: Householders dependency on forest resources.

Questions	Extremely	Very	Moderately	Little	Not at all
Forest availability influenced on out- moving decision	2.4%	8.0%	36.0%	20.0%	33.6%
Forest availability contributed on moving decision	5.6%	16.8%	40.0%	16.8%	20.8%
How much Household are dependent on forest in general	16.8%	56.0%	17.6%	3.2%	6.4%
People uses forest resources for cooking fuel and fire	75.2%	6.4%	0.8%	10.4%	7.2%
People use forest resources for fencing(house, farm, orchard…etc)	39.2%	20.8%	25.6%	8.8%	5.6%
People use forest resources for making charcoal (cooking, heating)	5.6%	6.4%	16.0%	28.0%	44.0%
People use forest resources for shelter	8.8%	22.4%	44.0%	10.4%	14.4%

Historically, Kurdistan forests did not have any major economic value from a wood products industry; even oak trees have been mainly used as firewood. About 75 percent of respondents said that they were extremely dependent on forest trees for firewood and 39 percent for fencing. Charcoal making according to the respondents is widespread in rural areas near Erbil and Sulimaniya cites. However, nowadays people rarely turn the forest`s wood into charcoal, they mostly use it in its raw form for fuel and heating during winter season.

When the respondents were asked what they and their family think of the forest, in general, about 51 percent said that they look at forest as a scenic place. Whereas 57 percent said it is like a shelter and a safe haven for them, and only 5 percent said that forest is another income source for their families.

Overall, the results indicated some disagreement, and possibly confusion, over the relative value of forest resources to the respondents. On the one side they consider forest mainly as a scenic place, while the same people said that they were extremely dependents on forest for their survival. 46 percent said they mainly use the forest for hunting, daily burning fuel, while the remaining 54 percent said they use forest for agroforestry, for recreation as well as a shelter and a safe place especially during the war.

5.1.5. Survey results- Migration degradation and government forest policies

According to the survey respondents, forests policies, land degradation and migration were positively related (Table 11). The householders were asked how the policies and forestry laws affected their decision to move or relocate and their influence on forestry in general. About 22 percent of the respondents said that the policies extremely restricted their access and use of forest resources, while 57 percent said the policies were very strict or moderately restricted their forest access and use. The remaining 21 percent said that the policies somehow or did not restrict forest access and usage at all

Table 11: Forest policies influence on people`s movement.

Questions	Extremely	Very	Moderately	Little	Not at all
Government rules limited your access to forest resources.	22.4%	24.8%	33.6%	12.0%	7.2%
How satisfied are you with these rules?	7.2%	8.0%	31.2%	46.4%	7.2%
Government rules contribute to the problem of deforestation and forest degradation negatively.	25.3%	17.3%	8.0%	17.3%	32.0%
How much these rules contributed in forest degradation?	6.4%	1.6%	20.8%	34.4%	36.8%
Government rules contribute to the problem of deforestation and forest degradation positively.	17.3%	4.0%	1.3%	26.7%	34.7%
How important these restrictions will affect your decision to leave the place in the future?	4.0%	18.4%	31.2%	18.4%	28.0%

Exploring the details of the responses, after Rapareen (the Kurdish revolution in 1990-1991), the government put in place new forest laws, banning tree cutting and forest access in certain areas. It was a matter of security at the beginning, because the old Ba`ath regime had planted explosive material and Land Mine under the ground in many mountainous areas. However, these rules expanded and had a negative impact on rural populations and landowners afterwards. People soon didn't have any rights over their land, and their lands were taken away from them for reasons like oil discovery or other valuable natural energy sources. Several people told me that they were not properly compensated for their land loss, which caused many issues and conflicts between the tribes and the government, and many land owners were sent to jail because they cut trees within their property. A few said they were sentenced up to 5 years in jail with a fine of around $1000 US. Another problem was that these laws and policies were only verbal; there were not any written policies or forestry laws with clear term and conditions. About 69 percent of the respondents said that these rules were put in place in 1990 and 1995, while 30 percent said they were applied in 1995 and became official in late 2014. According to Directorate of Forestry in Duhok city, these rules were verbally applied after 1991 and only were officially written and implemented in the beginning of 2015. Regardless of the date when these laws were applied, it is obvious that they influenced people's real or perceived access and use of forest resources (Table 10).

In terms of forest degradation, fires appeared to have the most impact on forest degradation and other land cover in the area, both in the past and in the recent times. According to the villagers, fires were strongly related to the government and the conflict within the area, followed by forest policies which are also contributing to forest degradation.

Many poor landowners would burn their land because that was the only way to convince the government that the land was no longer covered with vegetation and now they can build a house (recreational house) on their land. Many of these fires grew too big and caused significant financial damage and even caused the death of some forestry patrol personal while trying to control the fires from spreading. The government could not stop these fires from happening due to lack of equipment and forestry protection funding. Furthermore, the respondents claimed that some of the corrupt government personnel contributed to increasing these events, by taking bribes from rich people to manipulate the investigation in finding the responsible people behind causing the fires. Thus, many people were against these new laws and policies because they were biased and not in the benefit of the poor landowners.

Some of the respondents had the impression that the government was conducting this research. Throughout the interviews some householders asked me repeatedly whether I am from a government office and what is the purpose of my research. While I repeatedly assured them that this was not the case, it likely affected how honestly their answers were, especially questions relevant to forest policies and forestry laws. They also talked informally about how government rules contributed to increasing natural forest conversion into recreational communities and parks. The rules are very biased; "if you have the money then you are exempt from the charges and the consequences" said majority of the respondents during the interviews. This shows a clear feeling of bias regarding the extent that the new forest policies influenced people's access and use of forest resources.

5.1.6. Survey results-Migration motivation

Out of total 125 surveys collected in the summers of 2014 and 2015, 83 householders indicated that one or more of their immediate family members have migrated internally or internationally. Out of total 75 surveys collected in 2015 said that one or more of their family members have migrated internally or internationally, the number of their family members whom have migrated reached 200 personas in total. In 2014, the survey was not modified to include the number of migrants per household, thus the number for migrated members is missing. A set of six push factors was derived from householder's responses (shown in Table 12).

Table 12: Push factors influencing migration in rural areas.

Percentage %	
Poor facilities	9.59%
Farming degradation	27.40%
Poor education	8.22%
Poor job opportunity	43.84%
Poor transportation	15.07%
Marriage	43.84%
Others	5.48%
War	56.16%

The results from both surveys indicate that some factors are stronger than others. Only 9 percent of respondents said that poor facilities was a strong factor pushing their migration. Farming degradation was a stronger factor; about 27 percent said it strongly affected their decision to migrate. Poor education was of less importance in migration decision-making. People are used to sending their children to primary schools, which are normally available in all rural areas, and only a few people sent their children to cities to complete their education past primary school. 'Poor job opportunity' was another strong push factor from rural areas toward the cities, where 43 percent of total respondents indicated that one or more of their family members migrated because of lack of job opportunity. Job opportunity is strongly related to forestry and agriculture because it composes the main income sources for people living in those areas, so job opportunity is indirectly related to the natural resources economy.

Only 15 percent of the respondents said that poor transportation was an important factor in their migration decision. Given the hilly and mountainous topography of the region, people are used to navigating through the mountains, making forests accessible even with the absence of proper roads.

Marriage was also a strong factor influencing migration. However, majority of the people who migrated because they were a forming family were woman, whom their parents wed to people from the cities to provide a better life for them.

The most important and most frequently mentioned factors by the respondents during the interviews and during the informal conversation in-betweens was war, 56 percent said war is the ultimate reason behind their decision to migrant. This is typically normal giving the fact that the region has long been in war and conflict, especially during Anfal campaign and Arabization campaign.

The householders whom indicated war and job decline as the ultimate reasons behind their migration were further asked why war was very important and what have caused job decline. They were also asked why job opportunities did not remain the same or even increase since population increase means an increase in demand on agriculture and wood products after the war. The Kurdistan region was heavily invested in agriculture, especially grain products; it was the main grain resource for the region, as well as the rest of the country. Thus, the decline in agriculture products affected the region greatly and forest products were not a primary part of the economy.

No doubt that the war affected people`s farming production. In addition, people`s access and use of forest resources got restricted because of the new government policies. Almost all respondents said something like "war burned our land and farms, we were force to relocate near the city, and the remaining of our lands were given to Iraqis from the south during the Arabization campaign."

Though it is complicated to link migration solely to these incidents and Anfal campaign, nevertheless burning the villager's main income source acted as a major push factor that forced for migration some temporary relocating and other permanent moving. Some of these villages are currently unhabituated including those villages within the study area.

5.2. Forest inventory results

Ground-based forest inventory data was analyzed for each forest and all forests combined. The numbers of measured plots for different forests types were (46 plots) for broad-leaved forests, mixed forests (18 plots), and coniferous forests (9 plots). Forests types were assigned based on forest species proportions.

Total basal area of forests varied between (3.26) m^2 /ha and (106.5) m^2 /ha (Table 13). The majority of forests were broad-leaved,composed mainly of *Quercus* species; five out of the eight selected villages were surrounded by broad-leaved forests. While only one village was surrounded by coniferous forests (mainly pine species), the last two villages had mixed forest coverage.

Table 13: Forests summary statistics by village.

Village ID	Forest Type	Basal area (m2 / ha)	Density(stems/ha)
Baneyi	Broadleaves	3.26	978.9
Bare Bohare	Broadleaves	21.42	5220.3
Beski	Broadleaves	38.57	905.4
Boteya	Broadleaves	23.39	1630.1
Rashawer	Broadleaves	31.05	1691
Sarki	Mixed	46.94	1051.0
Sindori	Mixed	14.48	815.8
Zawita	Coniferous	106.51	221.6

Forests density varied among different forests. Broad-leaved forests had the lowest basal area with the highest density (Table 13). Coniferous forests on the other hand had the highest basal area with the lowest number of tree per hectare. This is because the trees were much larger in coniferous forests while smaller and denser in broad-leaved forests. Mixed forests also had relatively higher basal area (Sarki forests) compare to broad-leaved and lower tree density. These were dominated by a coniferous canopy with an understory of hardwoods.

Table 14: Forest plots summary statistics.

Forest Type	No. of plots	Height (m)	dbh mean (sd, min, max)
Broad-leaved forests	46	7.7 [6.3; 1.2, 29.1]	20.8 [19.7; 2.0, 103.9]
Coniferous forests	9	18.9 [9.8; 3.1, 33.7]	82.4 [44.5; 5.8, 200.2]
Mixed forests	18	7.6 [6.0; 1.7, 21.0]	31.6 [24.9; 5.1, 102.1]

In broad-leaved forests more than 70% of trees had a dbh smaller than 20 cm, while 52% of pine trees had a dbh more than 80 cm. This shows the significant variation between tree size in hardwood and softwood species in these forests. Tree sizes varied greatly between different coniferous and broad-leaved forests. Broad-leaved forests are denser with small size trees dbh averages about 20 cm especially the forests surrounding growing population villages and those close to urban areas. While coniferous forests were less dense with an average dbh about 82 cm.

Trees were also categorized into four different classes based on their growth form (cut stumps, multi stem trees, shrub growth trees, and single main stem trees with no branches below dbh bigger than 2 cm). In broad-leaved and mixed forests, multi-stems trees and trees grown in shrub growth were dominant with approximately 50% of total tree number. The remaining trees were single stem and cut stumps trees about 19 % and 31% respectively (Figure 5). In coniferous forests, about 77% of trees were single stemmed, followed by cut stumps and multi-stemmed trees, about 11% and 10%, respectively. This is because people tend to cut small trees due to lack of technology and resources. People are also afraid of the consequences related to tree cutting, because of the region`s cutting policy and forestry patrol, especially in areas that are considered scenic places (coniferous forests, in particular). In addition, the indigenous residents are aware of their forest value, and are usually advised by their elders to cut small trees unless it is a safety matter. On the other hand, outsiders or new residents in the area tend to cut both small and big trees.

The majority of cut stumps trees in all forests were *Quercus* species with a dbh smaller than 20 cm. Especially in broad-leaved forests where the majority of tree were in the form of shrub growth or multi stem trees about 55%, the remaining 28% were mostly single stem trees with a dbh >30 cm. Shrub growth trees pattern was only observed within hardwood species (Figure 5).

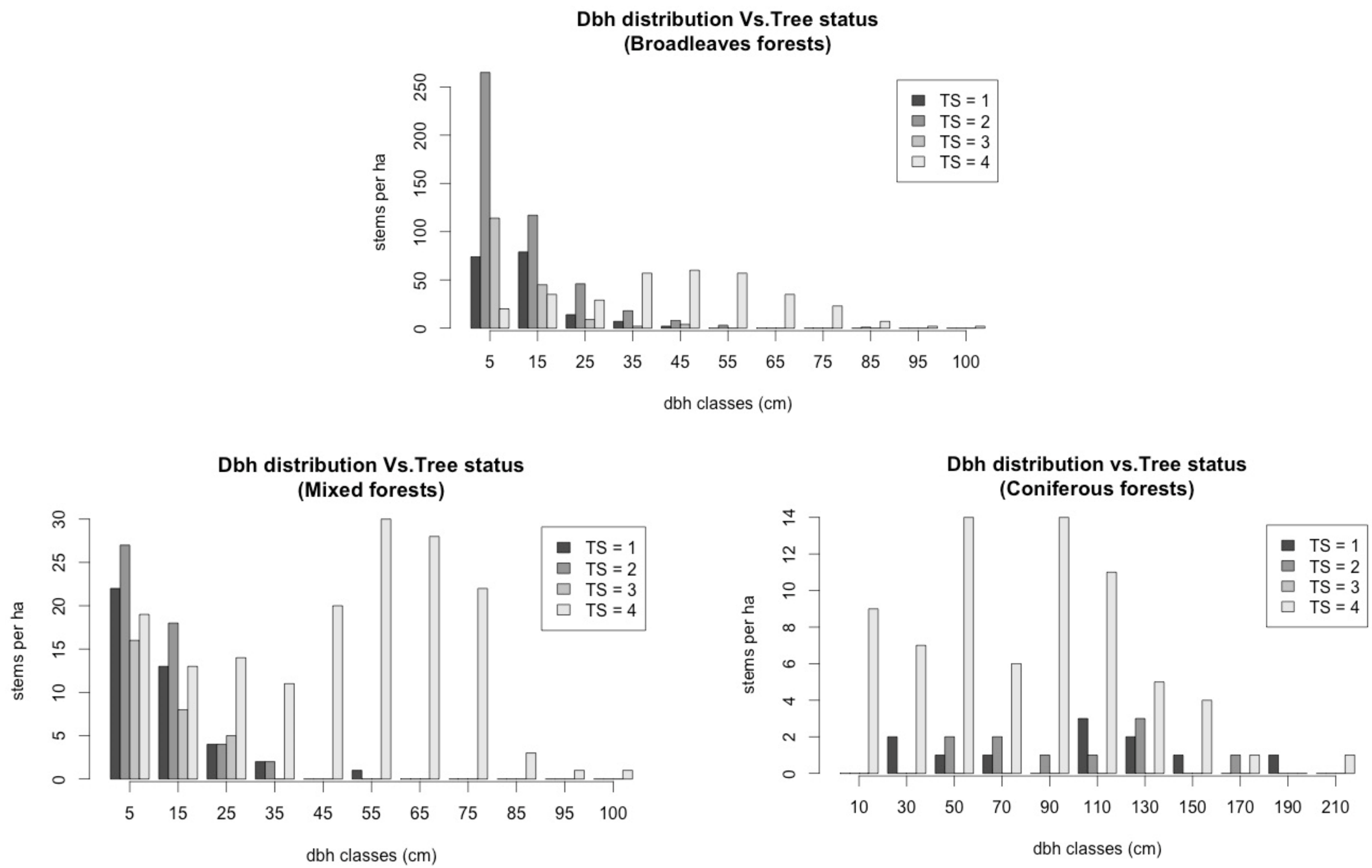

Figure 5: Tree 'status' for broad-leaved, coniferous, and mixed forests.
Tree status 1= cut stumps, Tree status 2= multi-stem trees, Tree status 3= shrub growth tree, and Tree status 4= single main stem trees

Trees were also categorized based on their crown class. Trees were assigned into six different crown classes (suppressed, mostly suppressed, dominant, co-dominant, emergent, cut stumps). Broad-leaved forests trees fall mostly in cut stumps, suppressed and mostly suppressed crown classes (Figure 6). While coniferous forests trees had less cut stumps trees per hectare and the majority of trees fall under emergent crown class with a single main stem.

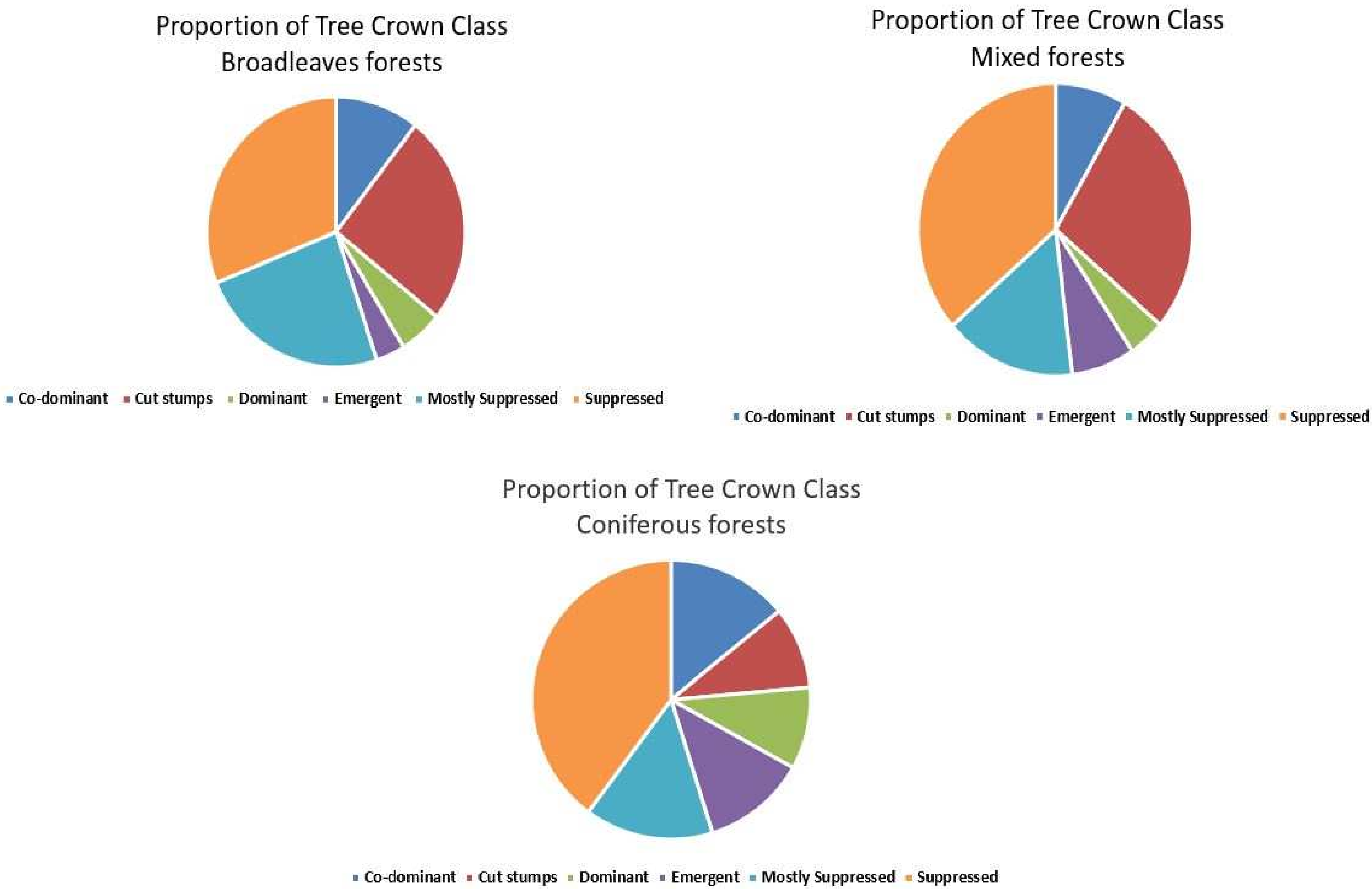

Figure 6: Tree Crown class proportions for all forests.
Overall, the village forests had more suppressed and mostly suppressed tree crowns. However, broad-leaved and mixed forests had a higher proportion of cut stumps than coniferous forests.

In term of tree species, the biological diversity was quite low; in broad-leaved and coniferous forests only five tree species were found during forest inventories, three main species (*Pinus brutia*, *Quercus aegilops*, *Quercus infectoria*) and two secondary species(*Juniperus oxycedrus*, *Pistacia mutica*). In broad-leaved forests, measured trees were mostly *Quercus aegilops* and *Quercus infectoria*, followed by *Pinus brutia* composing about 15% of total tree number. Whereas coniferous forests consisted of almost all softwood species mostly *Pinus* and *Juniperus.* Species proportions varied among different forest types, in term of stem density broad-leaved forests had more softwood species than coniferous forests, where 60% of total trees measured in coniferous forests were pine trees and the remaining 40% composed of other softwood species. *Juniperus* species appeared to be grown within broad-leaved forests more than pine species. Mixed forests also had more hardwood than softwood species, their proportions were about 70% to 30% of hardwood and softwood, respectively. See Figure 7 below.

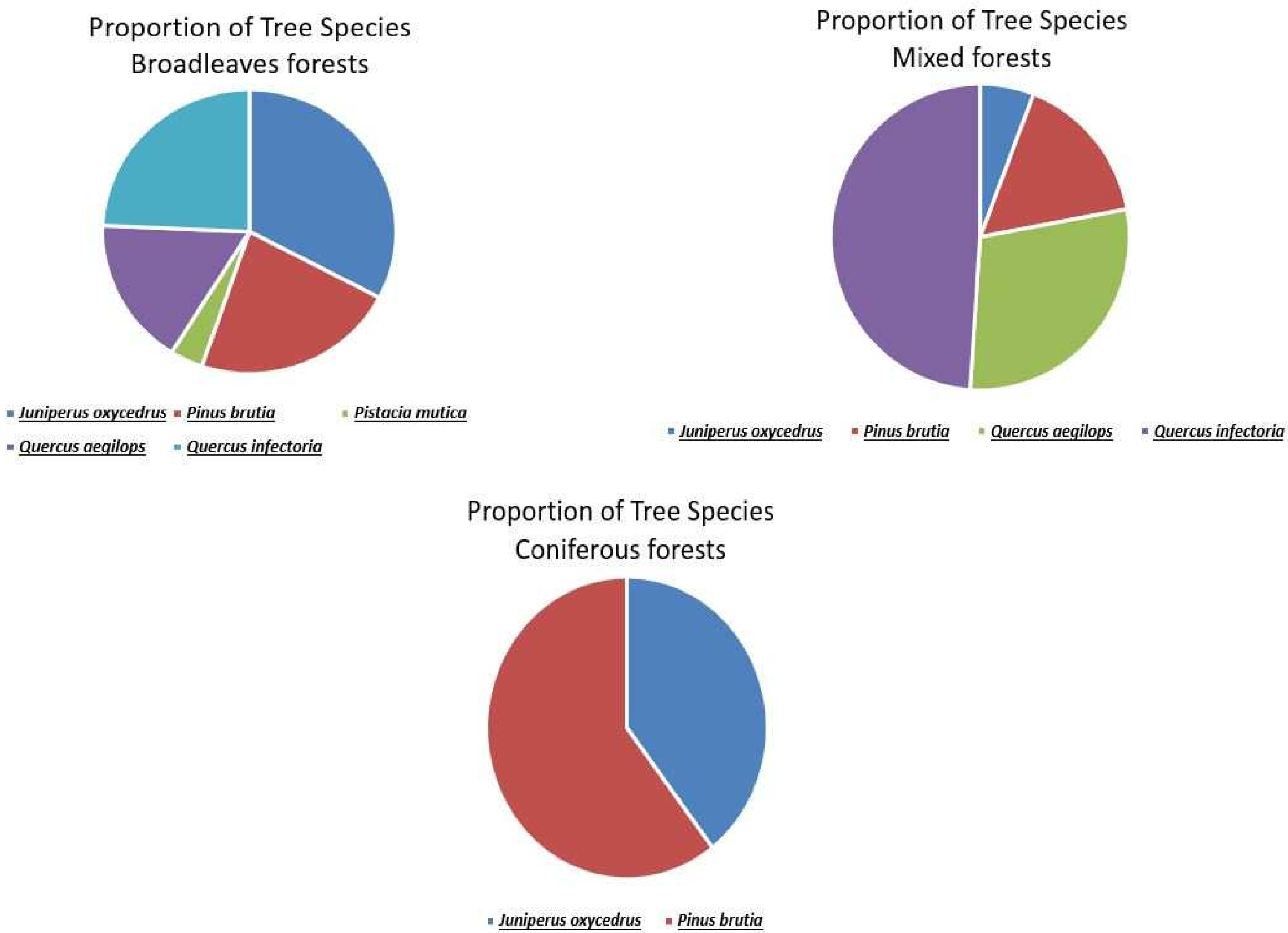

Figure 7: Tree species relative abundance per ha for all forests.
This figure shows the abundance of each species for different forest types. Broad-leaved forests are composed mainly of *Quercus* species, while mixed forests are a mix between *Quercus* and *Pinus* species, coniferous forests are all softwood species mainly *Pinus* and *Juniperus* species

5.3. Forest conditions and disturbances

Evidence of both natural and man-made disturbance were found in all forests inventoried, including firewood collection, timber harvesting, cattle grazing, wildfire damage, soil erosion, and land conversion. Land clearing was also obvious especially near main road going through Zawita.

Broad-leaved forests, according to the respondents and field observations, are more accessible and used by the villagers than coniferous forests. Zawita forests were the less disturbed one in addition to the broadleaved forests further away from the city. This is because pine trees are less preferred species for making charcoal, cooking fuel, fencing, and other purposes. In addition to that, coniferous forests have a special value to the area`s residents because of their significant role in preventing soil erosion in Zawita valley. These reasons made these forests more protected and cared for both by the government and area residents as well. Zawita forests, however, are mainly used for recreation and because of their recreational value they are also more subjected to clearing for development and building recreational houses. Unfortunately, a combination of a lack of proper forest management and poor governance there are not any monitoring process for such projects for minimizing their effects on forests.

During the interviews, the householders were asked about forests conditions and the effect of various factors on forest degradation in order to better understand forest degradation beyond what was found in the forest inventories; the results are shown in Table 15.

Table 15: Factors affecting forest degradation in Zawita forests.

Questions	Extremely	Very	Moderately	Not very	Not at all
Forests have degraded over time?	8.8%	44.0%	27.2%	10.4%	9.6%
Fire caused deforestation and forest degradation	82.4%	8.8%	7.2%	0.00%	1.6%
Forest land conversion to agriculture effected deforestation and forest degradation	2.4%	38.7%	40.0%	12.8%	6.4%
Soil erosion caused deforestation and forest degradation	2.4%	3.2%	32.0%	43.2%	19.2%
Tree cutting contributed in deforestation and forest degradation	10.40%	50.40%	28.80%	4.00%	6.40%

Fires seems to be causing the most damage to the forests, mainly because of the lack of fire control, carelessness, and the dry, hot summer conditions that promote wildfires. About 82 percent of the respondents said that fire was an ‘extremely important’ influence on forest degradation and that majority of deforestation and forest degradation happens because of fires. Fires are one of the techniques that is being used by the villagers as a method for hoeing and weeding, which often gets out of control and because of the lack of proper fire control technology. “The government cannot prove who caused the fire nor it can or will investigates, thereby giving people more chances to keep burning forests” said some of the householders. Fires are also a major consequence of the political conflict between Kurdish parties and Turkish forces that have been continuously bombarding the villages in the area causing major fires and both financial and civilian casualties.

Fire control is very restricted; the government has no effective mechanism for fire control especially on very steep mountainous areas. Often the fires are left out until it is extinguished on their own, or by the villagers in the area if it becomes a threat to their villages. Until our present day, KRG is still lacking a proper fire control management.

During the interview with the head of Directorate of Forestry in Duhok city Mr. Cheyavan, he stated that fires are still the major factor causing forest destruction. “People burn the land for agriculture, or to have an excuse to clear the land for building recreational houses. Especially in the recent years after the demand on recreational houses in the area have increased."

Shifting cultivation is another factors affecting forests. There are no restrictions over shifting cultivation, and forests areas were and are still not demarcated or formally reserved. Shifting cultivation is a very serious issue as it leaves the area bare and subjected to erosion, thereby causing forest degradation. In recent years, the effect of shifting cultivation has decreased because majority of people left their lands and are not farming anymore.

Soil erosion is another outcome of fires; land clearing with fires leaves the soil bare and susceptible to erosion, and because Kurdistan forests are mountainous forest and sometimes grown on very steep valleys, it makes them more subjected to soil erosion.

Other man-made disturbances like grazing were also observed. However, villager's small goat and sheep are yet to cause a major damage to the forest. However, signs of over-grazing were only visible in some villages with bigger livestock cattle.

Cutting has also been causing damage to region`s forests. About 60% of the surveys indicated that cutting was extremely and/or very influential to forest degradation. Cutting small trees is most common, because people think this will go unnoticed and they are also easier to carry and process. Cutting may be becoming less of an issue, since there are more forest police patrolling.

Weather-related factors also impacted these forests. In addition to lack of adequate rainfalls especially in the past three decades, severe winter conditions also had some serious effect on forests in Zawita area, especially on Mediterranean coniferous forests. According to the village's residents, in the mid-fifties severe winter condition caused the death of the majority of all *Pinus halapensis*.

5.4. Remote sensing results - Classification accuracy

The classification accuracies varied for the four generated maps (Figure 8, shown below).

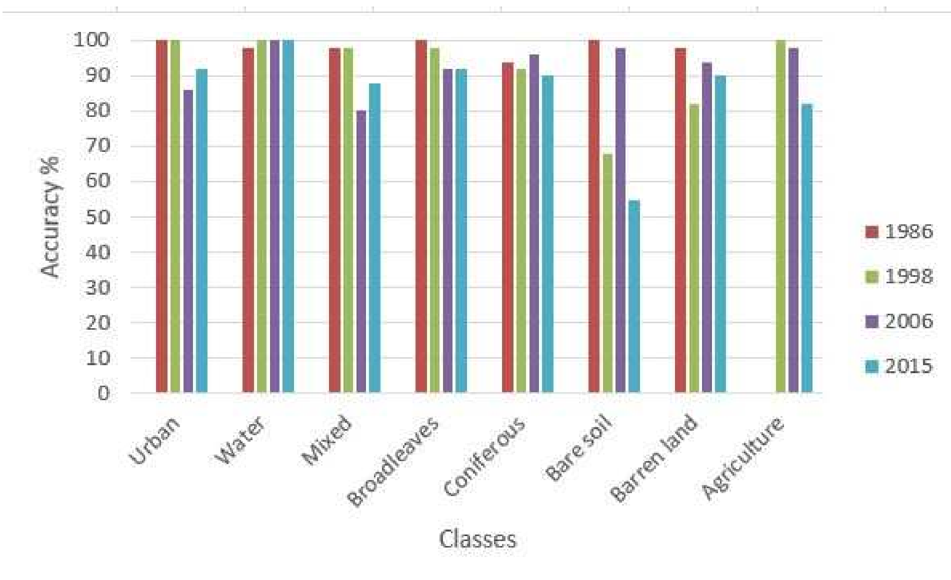

Figure 8: The accuracy of the selected classes.

The validation results shows that 1986 map had the highest overall accuracy of 98.3%, while 1998 map accuracy was 92.2%. The overall accuracy of the 2006 map is 93.0% only 0.77% higher than 1998 map. While 2015 map was 86% with the lowest accuracy among the four generated maps. The overall accuracy and Kappa coefficients for different classification maps is shown in Table 16. The maps kappa coefficient values are close to 1, meaning the classifications of the imagery were good.

Table 16: The overall accuracy and Kappa coefficient for the 1986, 1998, 2006 and 2015 classification maps.

Classification Accuracy (%)	Overall accuracy	Kappa coefficient
1986	98.28%	0.98
1998	92.23%	0.91
2006	93.0%	0.92
2015	86.0%	0.83

Accuracy for different land classes varied within and between classes for the four different classification maps. The 1986 map had the lowest accuracy of coniferous forest class about 94.0%. The 4% of the pixels were assigned to the mixed forest class; indicating commission error, and the 6% omission error was due to incorrect assignment to broad-leaved, mixed, and barren land classes. In the 1986 map, agriculture areas were not identified. However, the main purpose of the classification was to identify and distinguish forest area and types, thus, not classifying agriculture in the 1986 was not a major issue for this analysis. Mixed forests were also misclassified for Sindori village, as either broad-leaved and coniferous forests. For the other land classes, accuracies ranged from 98 to 100%.

The overall accuracy of the 1998 map was 92%, with the lowest accuracy for bare soil at 68%. The highest error of commission and omission were also for bare soil. The overall error of omission for bare soil class was 32%, while 30%, and 2% of the pixels that should have been assigned for bare soil are assigned to the barren land, and broad-leaved forests, respectively. Commission error was 26.1%, with 18% of pixels assigned to barren land class and the remaining percentage to broad-leaved and coniferous forests. The 1998 map also showed clusters of barren land in urban areas, due to similarity in reflectance of some urban materials and barren lands. Agriculture areas were also confused with bare soil, which occurred when crops were not yet planted. The overall classification accuracies ranged from 82% for barren lands, 92% coniferous forests, 98% for broad-leaved forests and 100% for water, urban, and agriculture classes.

The 2006 map was also highly accurate (Table 16), with the lowest accuracy at 80% for the mixed forest class. Omission error of mixed forests class was 20%, where the 14% and 6% of pixels were assigned incorrectly to broad-leaved and coniferous forests. Commission error for mixed forest classes was only 7% of pixels, assigned to either broad-leaved and coniferous forests. Due to the similar reflectance of the bright soil and barren land in this map some barren lands were classified as soil in the northwest side of the area.

The 2015 map had the lowest accuracy of the four different maps (86%). Bare soil class had the lowest accuracy among all land classes. Bare soil also had the highest omission errors with 22%, 14%, 6%, and 4% of pixels assigned to barren land, agriculture, broad-leaves, and urban classes, respectively. The confusion matrices for the 1986, 1998, 2006, and 2015 classification are presented in appendix F. Overall, the classes were more defined in 2015 map, though agriculture areas were over classified and confused with bare soil class. Beside commission and omission errors producers and users accuracies were also calculated for the four maps. The results of producer`s and user`s accuracies are shown in Table 17.

The maps accuracy variation was attributed to several reasons including reference sources for each map. The most recent map (2015 map) had the most available reference sources yet the accuracy was the lowest. On the contrary the generated map for 1986 had the highest accuracy with the absence of reliable reference data.

Table 17: Producer and User accuracies for 1986, 1998, 2006, and 2015 maps for all land classes.

Land Classes	1986		1998		2006		2015	
	Producers Accuracy	Users Accuracy	Producers Accuracy	Users Accuracy	Producers Accuracy	Users Accuracy	Producers Accuracy	Users Accuracy
Water	98%	100%	100%	100%	100%	100%	100%	100%
Coniferous forests	94%	96%	92%	100%	96%	94%	90%	94%
Broad-leaved forests	100%	98%	98%	96%	92%	78%	92%	76%
Mixed forests	98%	98%	98%	96%	80%	93%	88%	94%
Barren land	98%	98%	82%	73%	94%	90%	90%	73%
Bare soil	100%	100%	68%	74%	98%	94%	54%	100%
Urban	100%	98%	100%	100%	86%	98%	92%	90%
Agriculture	-		100%	100%	98%	100%	82%	75%

5.5. Remote sensing - Land cover change assessment

The overall LULC classification results showed that forest cover has changed significantly between 1986 and 2015. During the classification of 2015, 2006, 1998 imagery, eight land cover classes were identified; whereas, for 1986 MSS imagery where pixel size was 60 m, seven land cover classes were identified. From 1986 to 2015, the LULC analysis of the maps shows a significant decline and then regrowth of urban areas, a large increase in agriculture areas over the most recent decade, and diminishment of forested areas, except mixed forests which showed a small increase. The percentages of area covered by each class at different points in time are shown in Table 18.

Table 18: LULCC over time from 1986, 1998, 2006, and 2015.

LULC Classes	1986 Map	1998 Map	2006 Map	2015 Map
Urban	6.91%	0.46%	0.77%	6.11%
Agriculture	-	3.75%	3.76%	21.57%
Water	4.69%	0.31%	0.43%	0.49%
Bare soil	0.68%	9.87%	7.83%	0.74%
Barren Land	15.29%	9.62%	14.10%	9.39%
Broad-leaved forest	50.38%	58.76%	60.79%	46.10%
Coniferous forests	16.95%	10.64%	4.81%	7.9%
Mixed forests	5.12%	6.59%	7.51%	8.50%

Broad-leaved forests were covering about 50% of the total area in 1986 map, increasing by 8% and 10 % in 1998 and 2006 maps, respectively, while decreasing by 14% in 2015 map. These forest areas were replaced by mixed forests, and converted into agriculture and urban areas.

Coniferous forests in 1986 map were about 16%, continuously decreasing to 10%, and 4 % in 1998 and 2006 maps, while gaining about 3% back in 2015 map. These forests similar to broad-leaved forests are being replaced by mixed forests, agriculture and urban areas. These forests are becoming more confined to Zawita valley and the Northeast side of Zawita.

Mixed forests on the other hand are increasing, 1986 map they were covering about 5% of the total areas, increasing by 1.5% in each year from 1998, 2006, and 2015. Mixed forests are replacing other forests types. Because of the nature of these forests that are mostly planted, and softwood species are more preferred for planting than hardwood species, mainly because of the physical structure. Hence, bare and degraded forests that resulted from fires or cutting are being replaced with mixed forests.

Water class also witnessed a change in its areas. Water occupied about 4.69% of the total area in 1986 map, while it declines to 0.49% for 2015 map. Other land classes like urban, agriculture, barren land, and bare soil classes also varied from 1986 to 2015. The area percentages of each classes are shown in Table 17.

Visual comparison between the 1986, the 1998, 2006, and 2015 maps clearly displays the changes in forest cover over time. The expansion of towns throughout Zawita is also obvious, decline in forested area in general. Figure 9 shows the output map of the study site for the 1986 image. Urban class, forest types, barren land, and bright soil can be clearly distinguished on the map. In the 1986 there were more populated area than other time periods, but less expansion of Duhok city in to the sub-district. Also there were more forested areas than the other maps.

Figure 10 and 11 shows the classification map of the 1998 and 2006 image, respectively. 2006 map had a high accuracy in training sites and multiple references sources for that time period. Maps 2006 shows a decline in coniferous forests especially in Zawita city center and Northeast part of the area.

Figure 12 Shows 2015 map with more visual preciseness in the classes. This is due to the high radiometric sensitivity and accuracy of the OLI/TIRS sensor. In 2015 map the expansion of agriculture areas, with decline in forested areas especially coniferous forests in the center and northeast sides of the Zawita is obvious. Expansion of Duhok city on the Southwest part is also observed during this time period especially between 2006-2015. The expansion of Duhok city in to the sub-district is also observed. On the other hand, the decline in forested area is obvious, especially in the center of Zawita. Comparing the forest inventory data and field observation with remote sensing, these forest are less disturbed than mixed and broad-leaved forests. There is also an increase in coniferous forests especially in Zawita city center and Northeast part of the area, this is due to the tree planting campaign carried by the Kurdish government in attempt to increase and preserve forests and to alleviate forest losses.

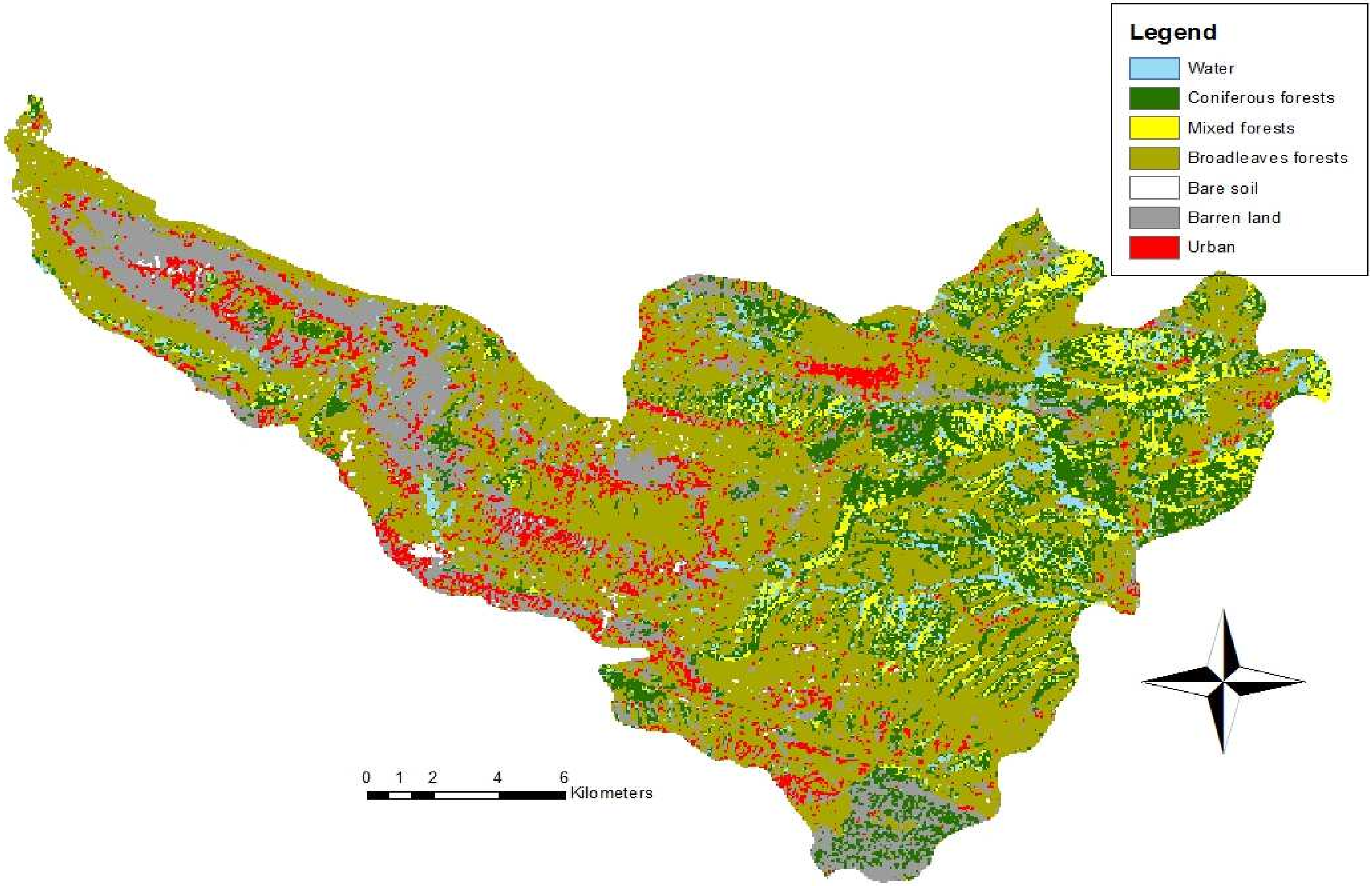

Figure 9: The 1986 classification map of Zawita sub- district.

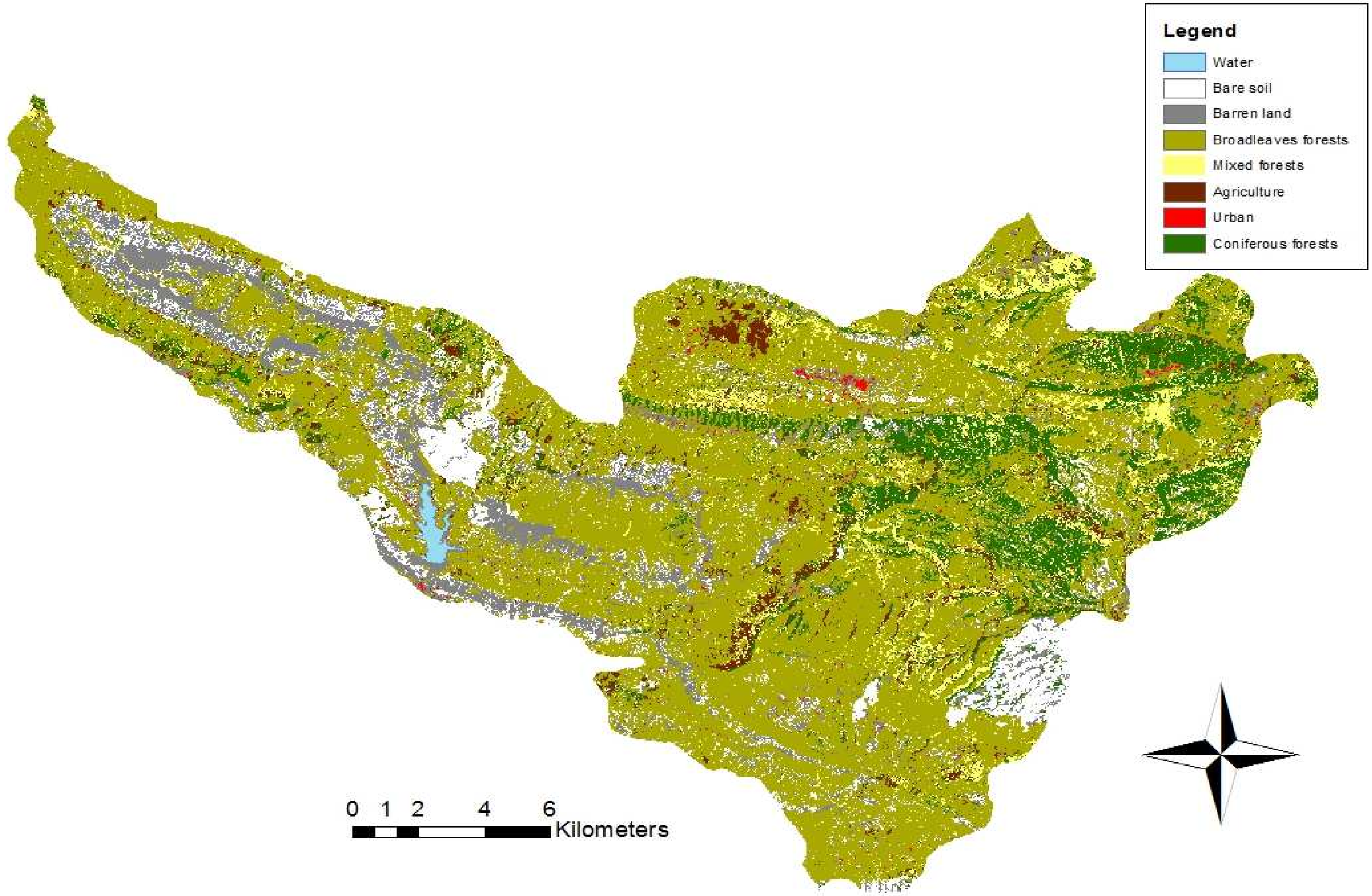

Figure 10: The 1998 classification map of Zawita sub- district.
This map shows declines in forested areas, especially in center and northeastern side of Zawita. It also shows increases in agriculture areas in the upper part of the sub-district.

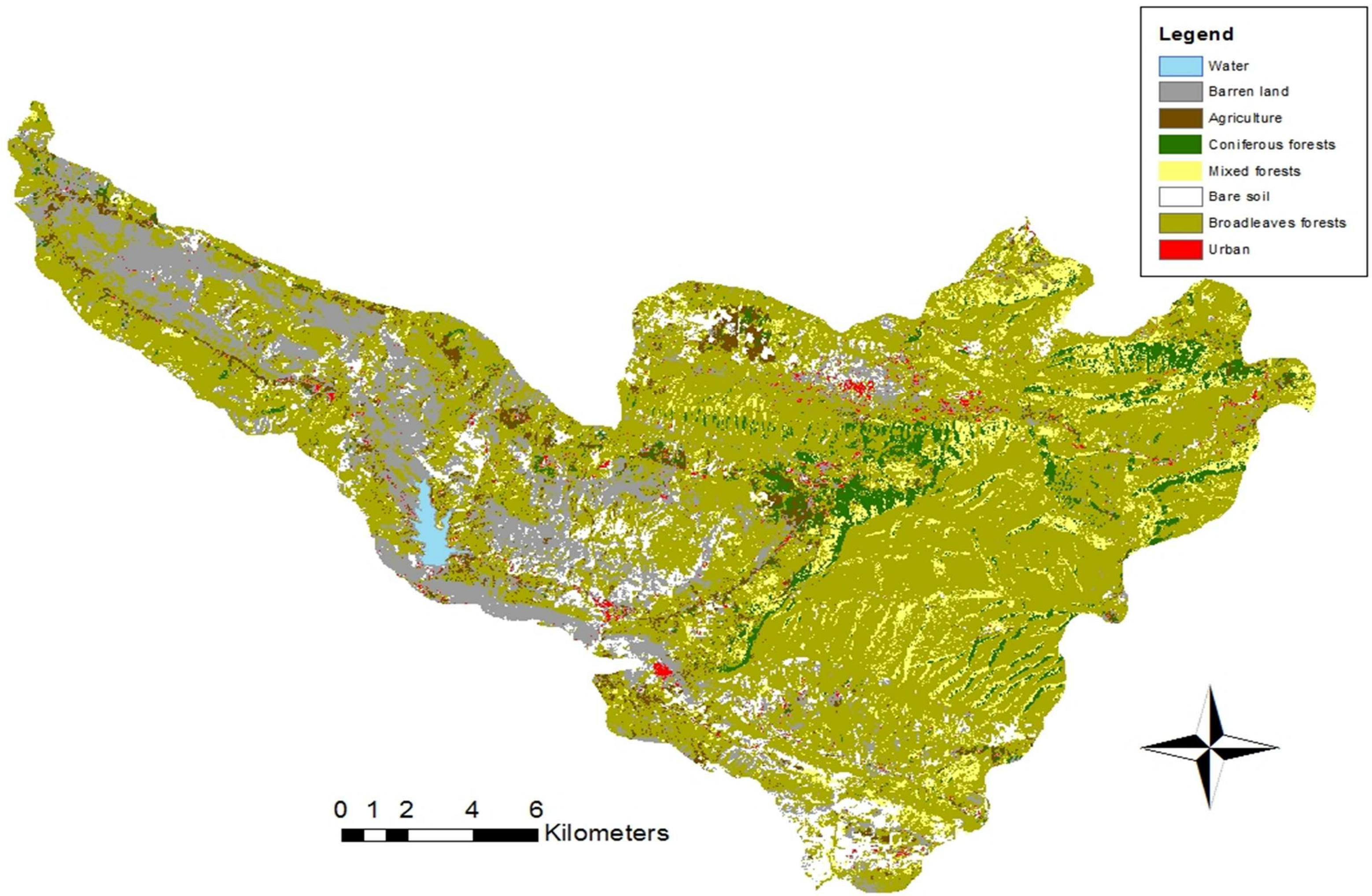

Figure 11: The 2006 classification map of Zawita sub- district. The map shows an increase in agriculture areas in upper and lower Zawita, and a significant decline in coniferous forests

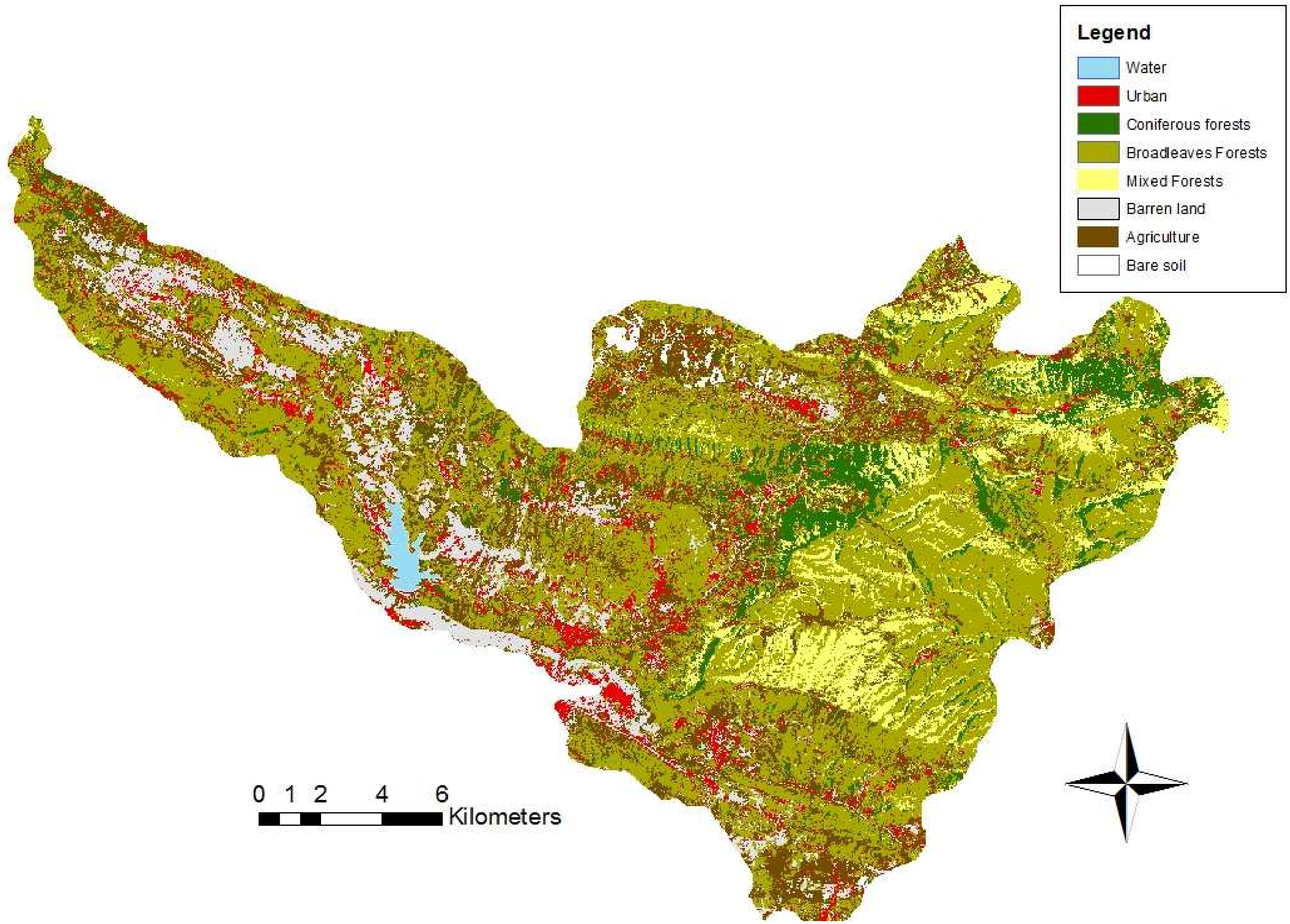

Figure 12: The 2015 classification map of Zawita sub-district.
The map shows a significant increase in urban and built-up areas, throughout Zawita, and an increase agriculture areas and mixed forests.

Forested areas covered most of Zawita in 1986 map, with less agriculture areas / bare soil. Compared to 2006 and 2015 maps, there is an obvious increase in agriculture areas and towns. The circles on Figure 13 shows the widespread-forested areas in center Zawita and on the Northeast side. Circles (a), (b) show Goret Gavana/Rashawer, and Etit villages that were expanded during 1986 (Figure 14). Circle (c) on the center shows the extent of coniferous forests surrounding Zawita village and villages on the Northeast part of Zawita sub district (Figure 15). When compared to 1998 and 2006 map these villages have shrunk down in size significantly. However, the villages are showing again in 2015 map after people moved back to their villages. Coniferous forest and mixed forest are also more spread out in the center of Zawita and Northeast side in this map.

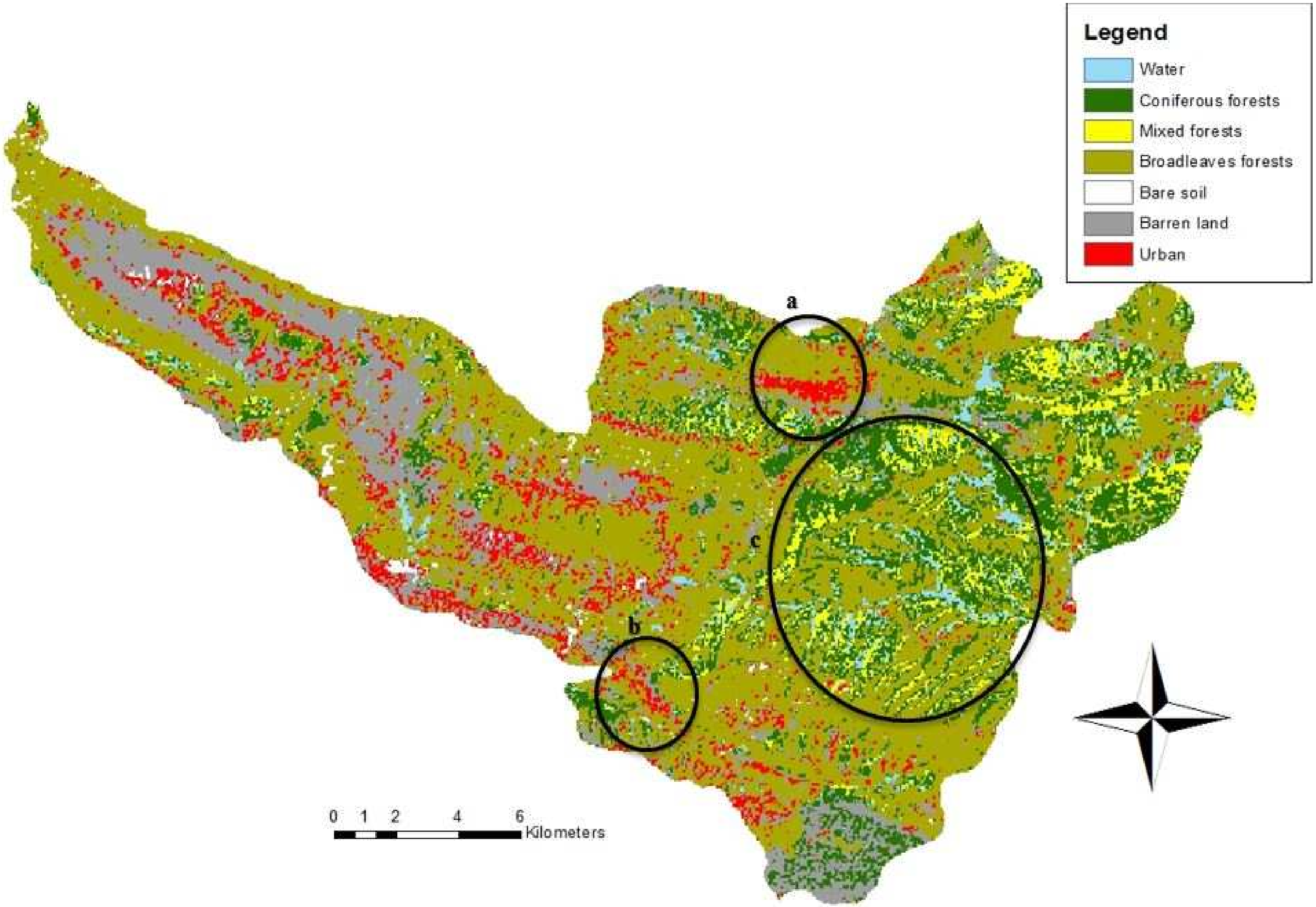

Figure 13: The 1986 view of Zawita sub-district and expansion of villages within.

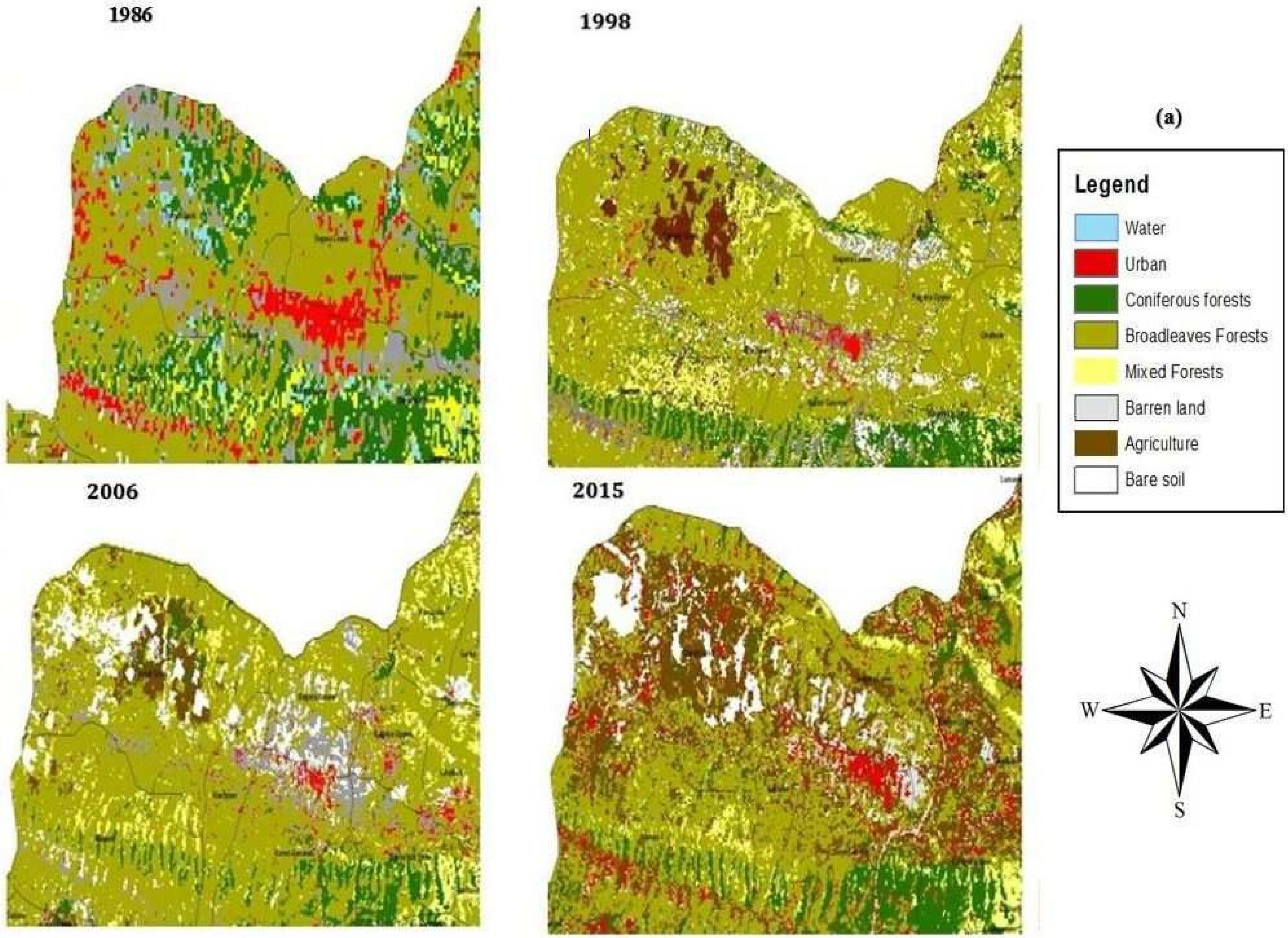

Figure 14: Rashawer and Goret Govana villages' expansion.
These villages were expanded back in 1986, then during the eviction campaigns their population decreased tremendously, until 2015, where they show a repopulation of the area.

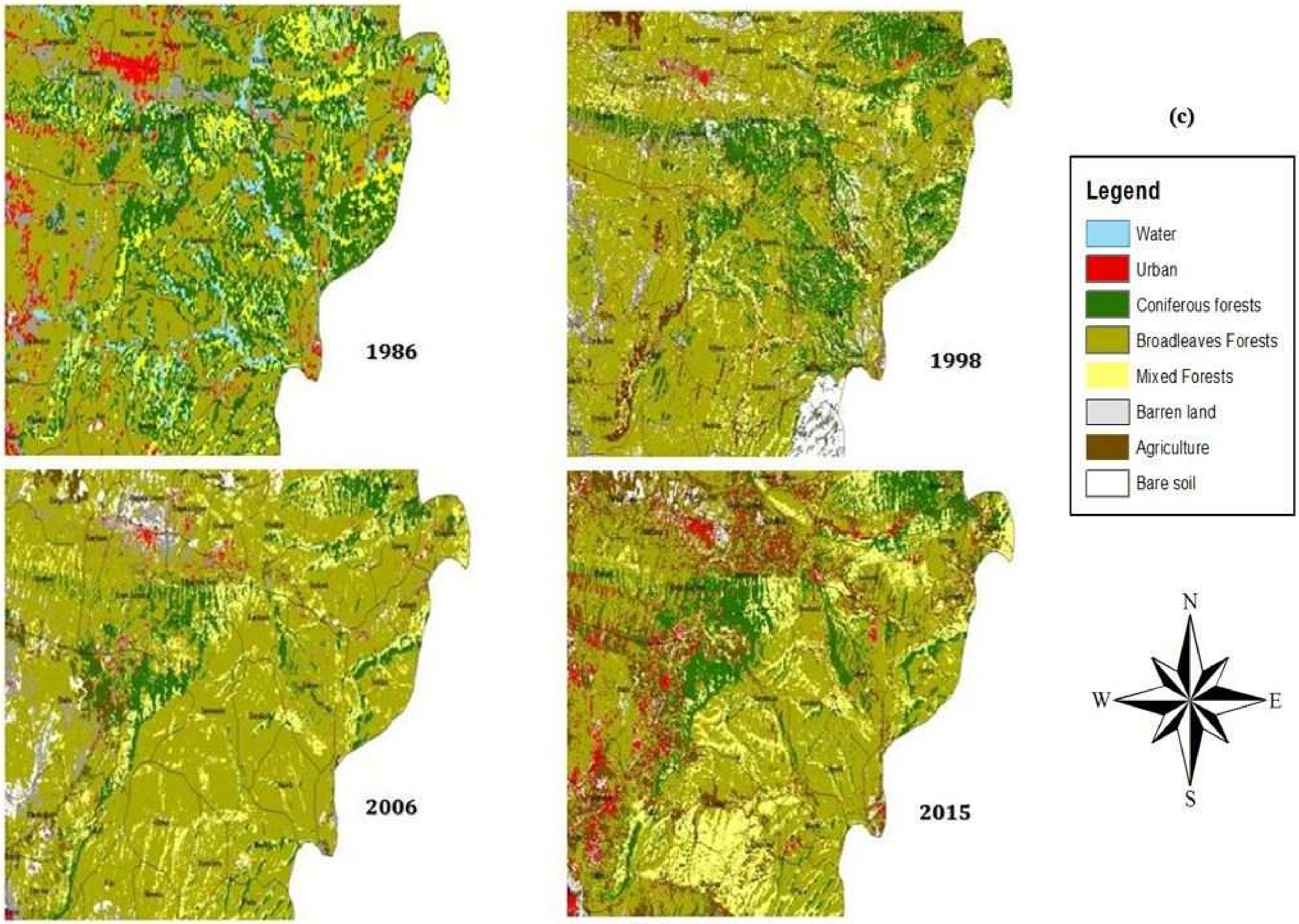

Figure 15: Change in coniferous forest cover in center and Northeast part of Zawita over three decades.

The circles on Figure 16 map of 1998 shows the expansion in agriculture areas. In 1986 because of the several destruction campaign that Zawita have gone through, agriculture areas were not classified, because the resolution of the image was 60 m instead of 30 m and the lack of reference sources for that period of time (e.g., there was no readily available images from Google earth). Thus, the extent of agriculture lands were not accurately estimated for 1986 map, however it is believed that agriculture areas were destroyed and burned during that time period. Circles (a) and (b) show upper and lower part of Zawita, where agriculture areas expanded in 1998, 2006, and 2015 compared to 1986 map (Figure 17, 18).

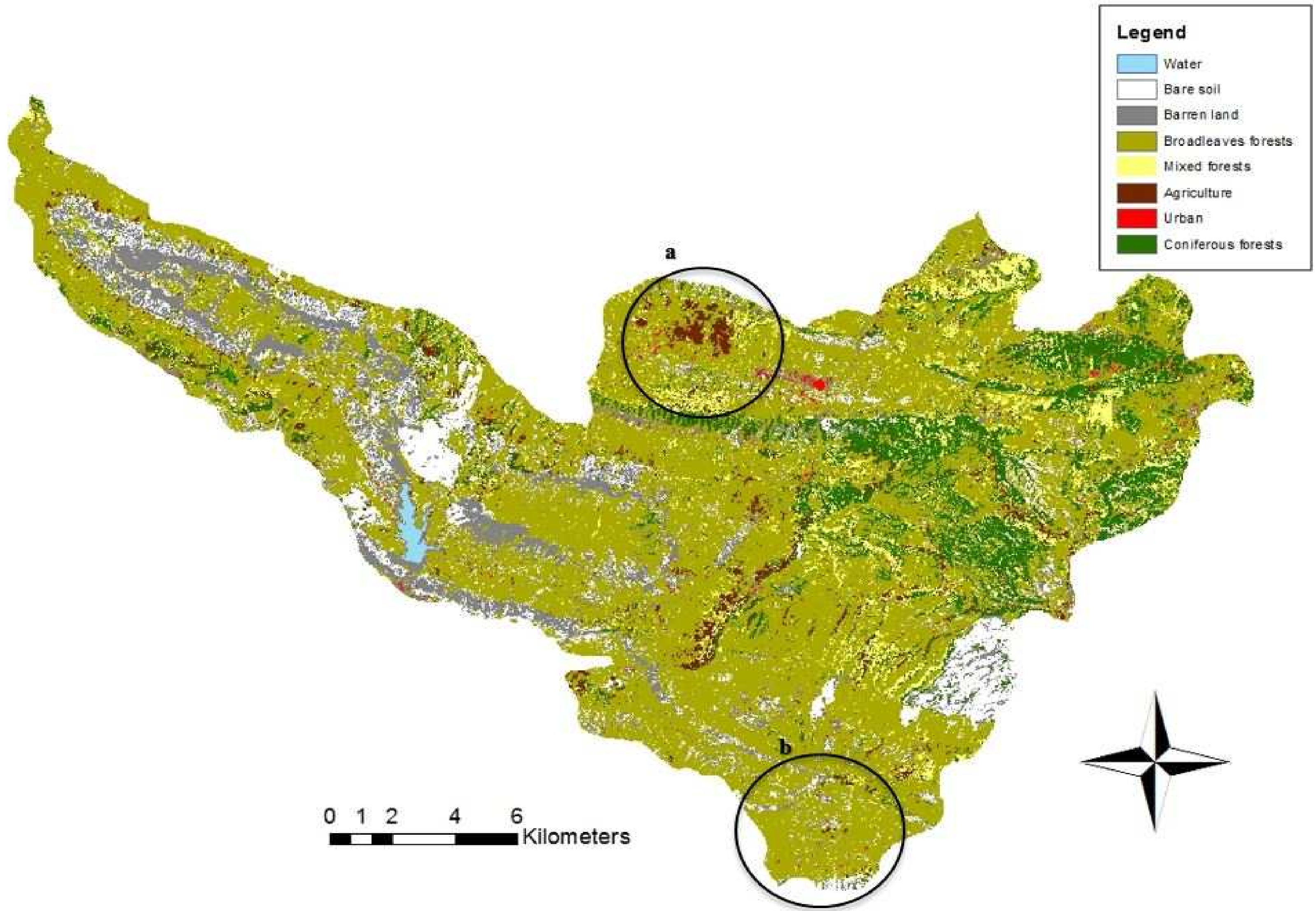

Figure 16: The 1998 view of Zawita, showing expansion in agriculture areas in lower and upper Zawita.

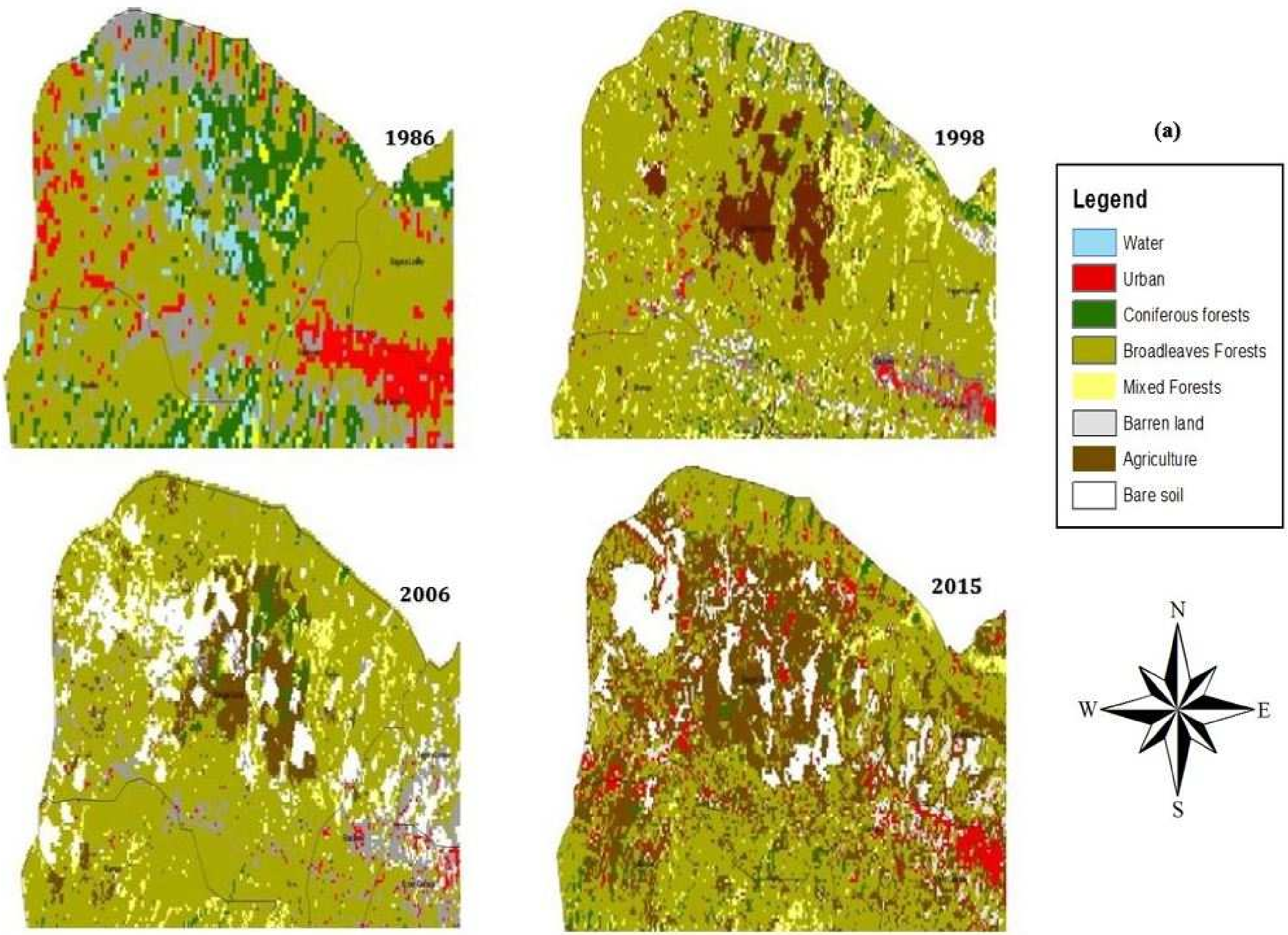

Figure 17: Agriculture areas expansion in upper Zawita.
Agriculture area were not classified in 1986 map, but we can see the expansion of these areas in in 1998, 2006, and 2015 maps; these areas are much expanded in 2015.

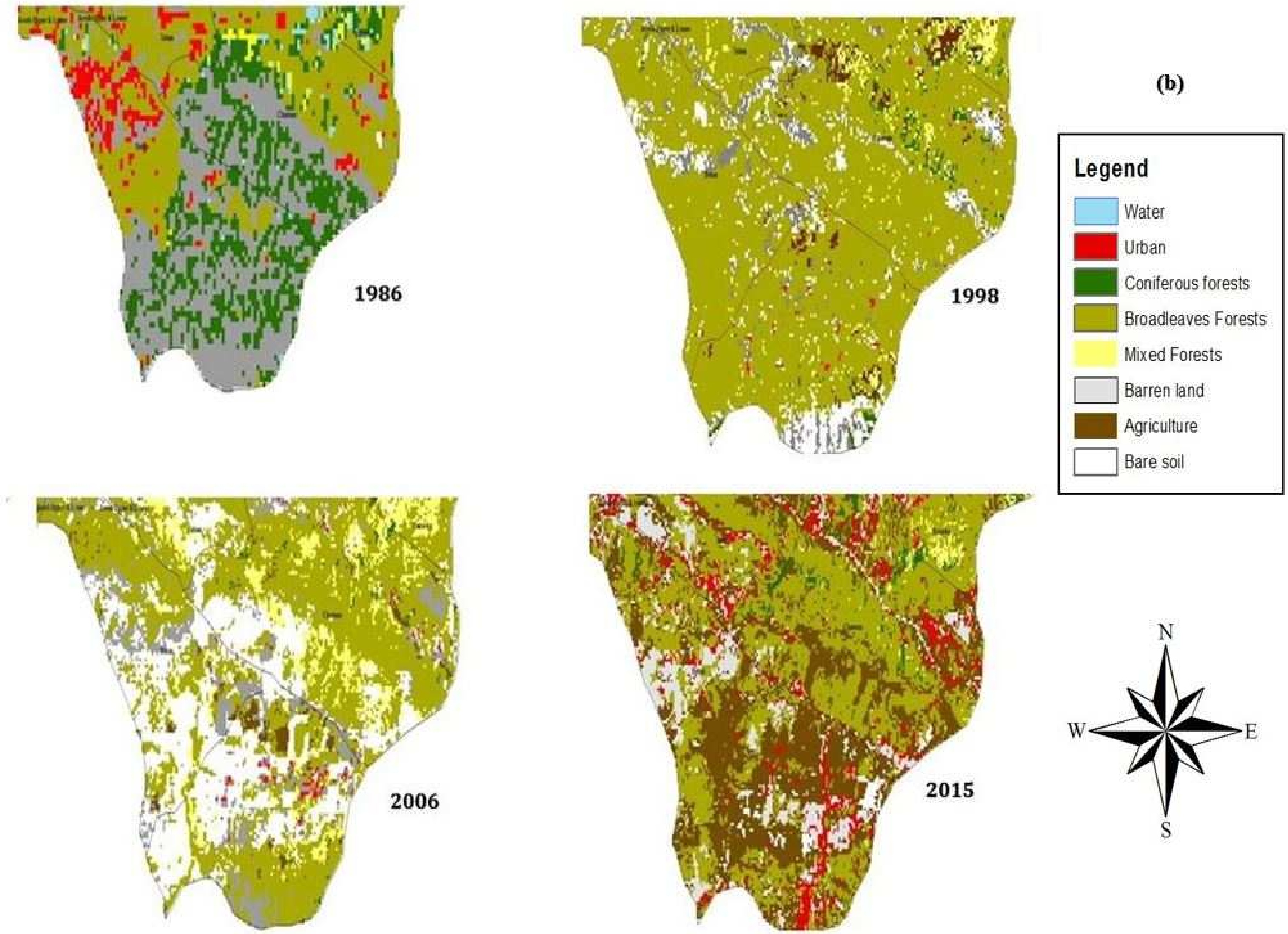

Figure 18: Expansion of agriculture areas in lower Zawita.
The maps shows an expansion of agricultural areas between the four time periods. However, 2006 maps classified some agriculture areas as bare soil (these were winter crops).

On the 2006 map the circle (on Figure 19) shows a significant decrease in forested area, especially coniferous forests. Circle (a) (Figure 20) shows the decline in coniferous forest in the center Zawita. Comparing maps of 1986, 1998, 2006, and 2015, coniferous forests become more confined to Zawita valley and to the areas surrounding the village. Agriculture areas also increased in the lower part, however, due to the nature of the crops, which are grown during winter time and the land is left bare in summer, they were classified as bare soil.

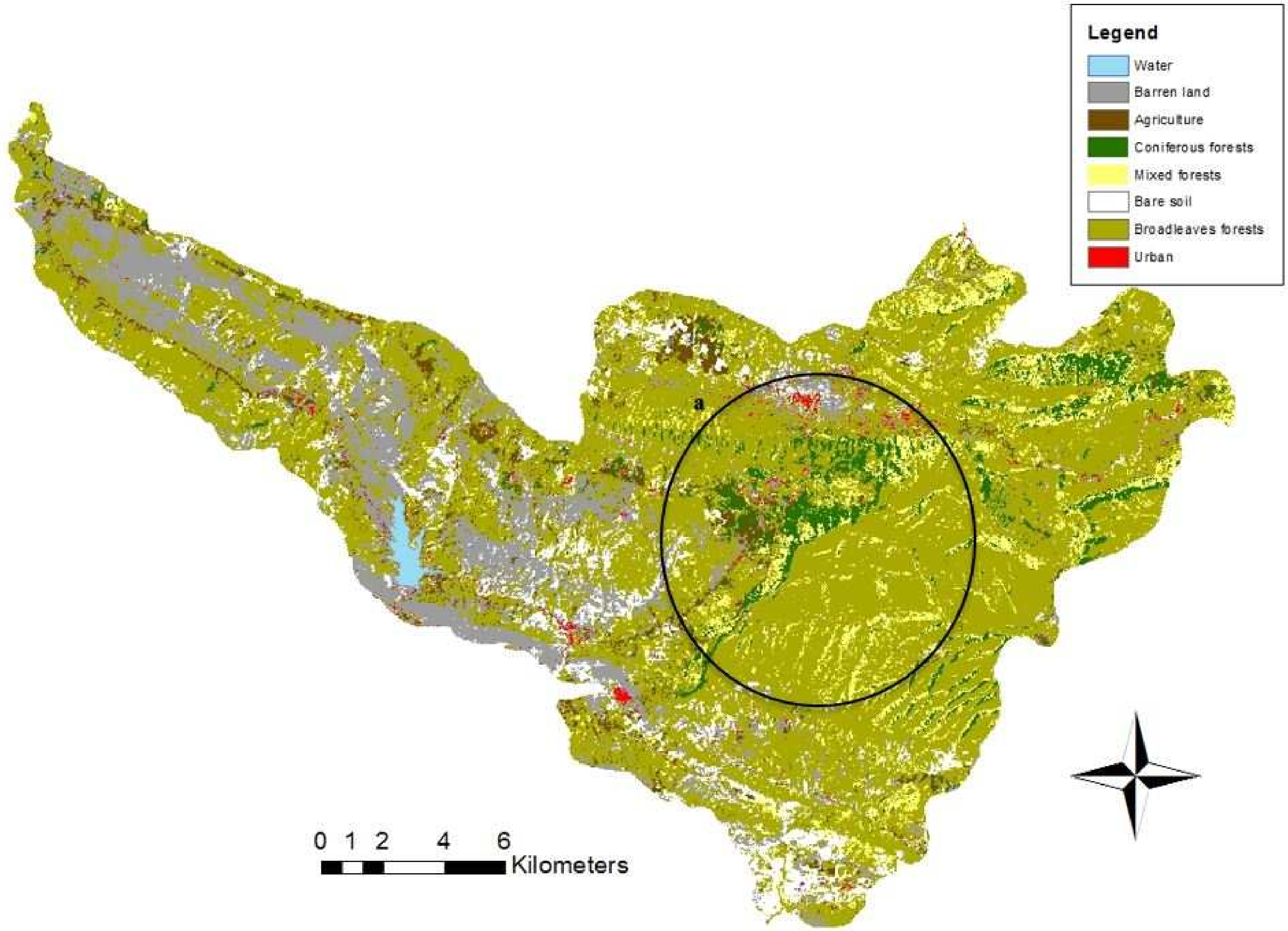

Figure 19: The 2006 view of Zawita; decline in coniferous forests in seen in the center part of Zawita from earlier maps.

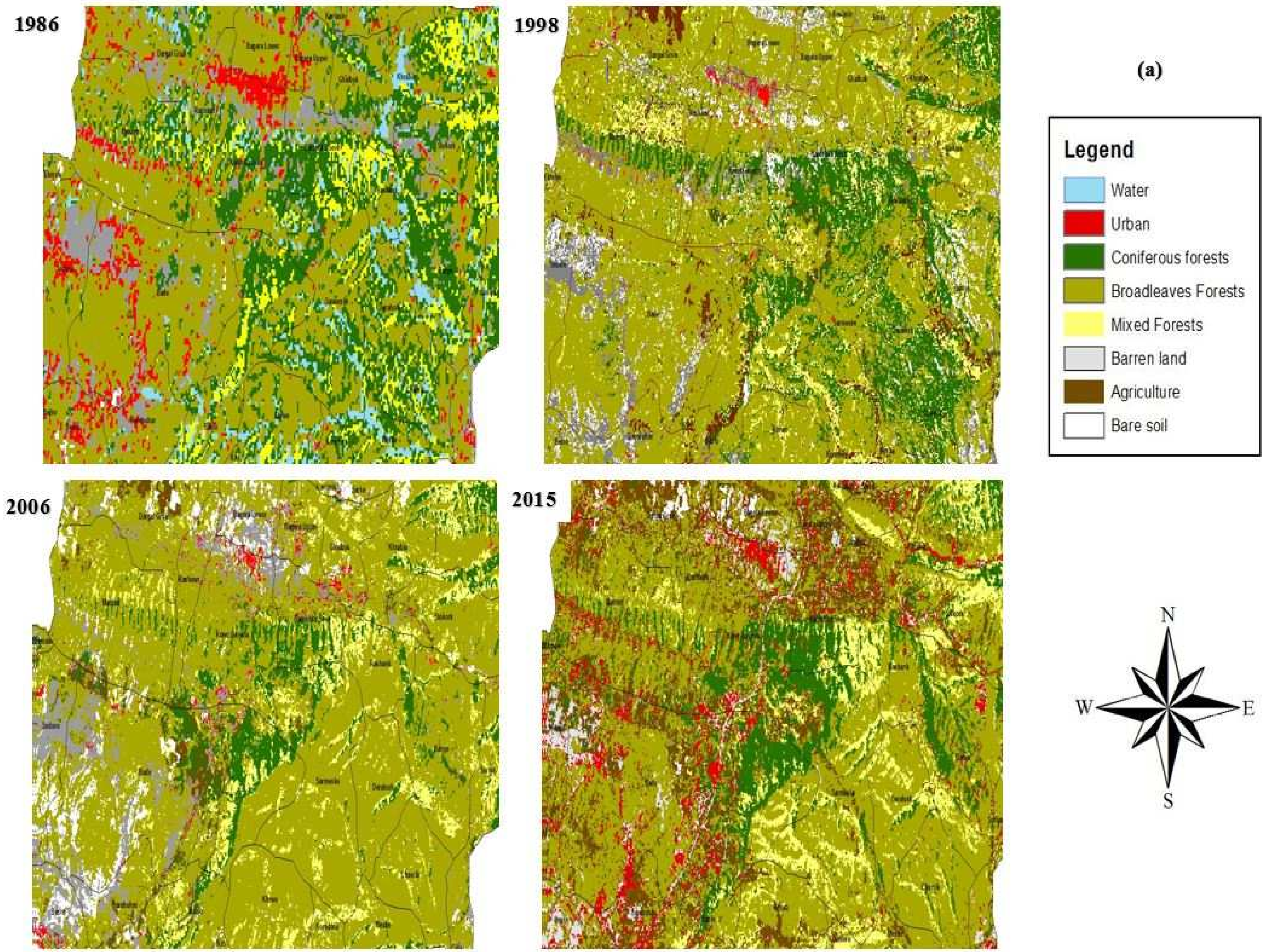

Figure 20: Decline in coniferous area in center part of Zawita. Coniferous forests are declining in center and Northeast part and becoming more confined to The Zawita valley.

The 2015 map (Fig. 21) shows the recent forest extent and other LULC changes over the course of 39 years. The cities on upper and lower part of Zawita, and Duhok city expansion into Etit village is observable. There is a significant increase in agriculture land, as shown in circled areas of the map (Fig. 21). Due to errors in classification and the nature of agriculture crops grown in upper and lower Zawita, those areas are classified as bare soil instead of agriculture.

The circled areas on 2015 map (Figure 21) shows the significant difference Zawita have gone through between 1986 and 2015. Circles (a) and (f) shows the expansion in agriculture areas in upper and lower Zawita. However, due to reflectance similarity and nature of planted crop that is planted and cultivated in winter, some of the agriculture areas were confused with bare soil (the picture was acquired during “leaf-on” season.

Urban areas also increased significantly in some villages. Typically people tend to return to their villages when they are within a close distance from Duhok city, and near the single main highway that connects Duhok city with almost all the villages within Zawita. Circles (b), (d), and (e) shows the increase in some towns in lower and upper Zawita, and circle (d) shows where Etit town almost merging with Duhok city. Circles (b) and (e) shows the expansion of Rashawer and Avreke, respectively.

Broad-leaved forests (in brownish green color, Fig. 21) are almost covering all Zawita sub-district. Coniferous forests, however, are confined to Zawita valley and are planted mixed with broad-leaved forests in the Northeast part of Zawita. Pine trees are the main species in coniferous forests and are hard to regenerate naturally. Thus, it is among the species that are encouraged to be planted. However, to plant them, pine saplings are needed, which are hard to get and expensive. Only when such planting campaigns are carried out by the government and saplings are provided it pushes people to plant pine species, and this is where mixed forest existed from.

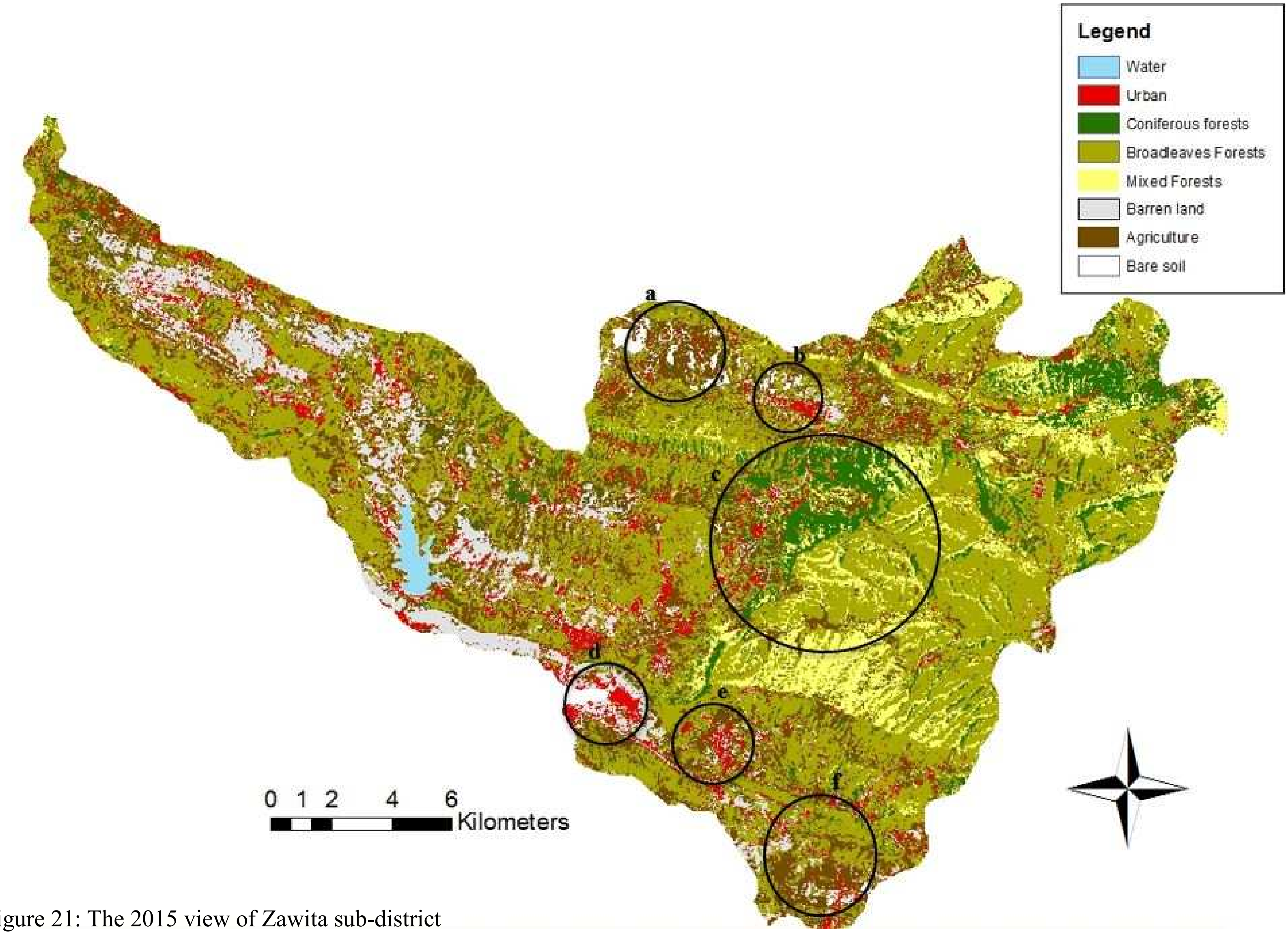

Figure 21: The 2015 view of Zawita sub-district
The map shows a decline in coniferous forests and an increase in agriculture and urban areas throughout the area. Coniferous forests are restricted to the center and northeast parts of Zawita.

5.6. Integrating results from the different data types in a causal loop diagram

A causal loop diagram was derived from the survey responses to draw a conceptual model of factors influencing migration, especially forest changes and policies (Fig. 22). The diagram helped to better understand the causal relationships between various factors and highlights the intertwined and complicated relationship between different drivers that influences the extent and flow of migration and how migration have also impacted forest cover change over the years.

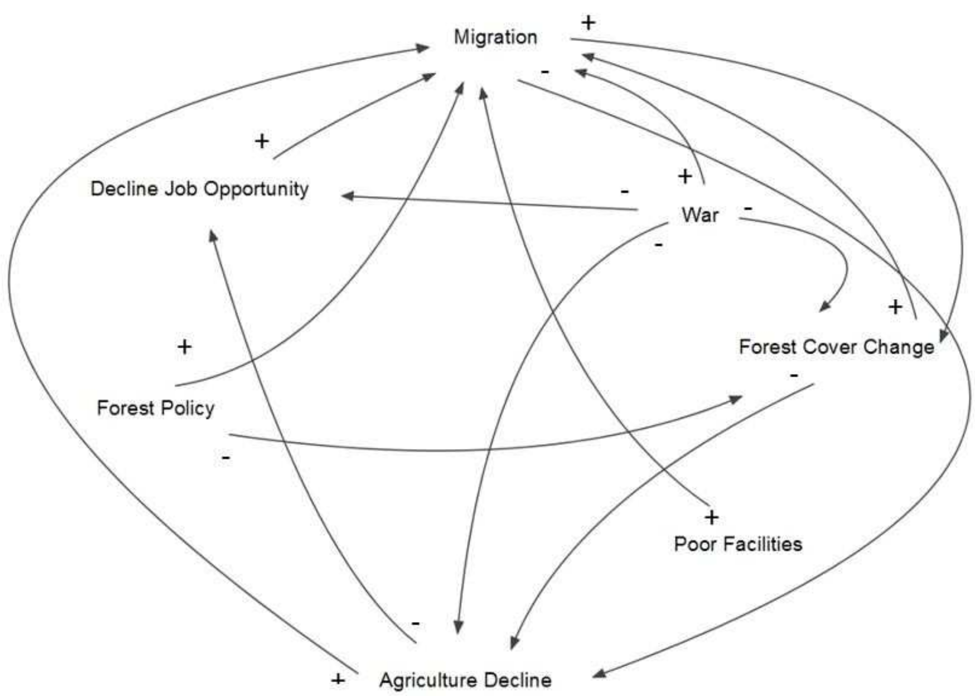

Figure 22: Causal loop diagram describing drivers of migration and its influence on other factors.

As shown in the diagram, migration not only is impacted by many factors, but it also affects them. For example migration positively impacts forest cover change. When people move and forest cover increases, while forest cover change negatively impacts migration when people move because forest cover have decreased.

According to the survey, the main reason behind people`s movement is war. However war itself is not the only direct factor and appears to be affecting many other factors that indirectly result in migration and feedback into other causal loops. War (and political conflicts in general) caused shortage in people`s income resources, since the majority of rural communities are dependents on natural resources for their income and daily life requirements. This forced people to relocate or/and migrate not only because of safety and security reasons, but also because of lack of life necessities also.

The diagram also helps link the survey results to the remote sensing and ground observations. It was observed from remote sensing results that, when the most migration happened and before householders began to return to their villages, there was a gain in forested areas and a noticeable decline in agriculture and urban area (see Figures 13, 17, and 20). The two-way relationship between agriculture, migration, and forest cover change was obvious in the landscape as shown in the diagram, when population decreases, agriculture also decreases, thereby increasing forest cover.

The loop diagram shows the positive and negative relationship between various factors affecting forest cover change and how each factor directly or indirectly affects migration process in each village, as well as the overall pattern; relevant results from each village are discussed in the next section.

5.7. Village level results

When looking at the data at the village level, each forest and each village display specific characteristics. The villages' location and boundary is shown in Figure 23. The summary statistics of forest inventory data of all villages are shown in Table 19. Other information on village`s natural resources and livestock cattle are shown in Table 20 below.

Table 19: Forest statistics broken down by village

Villages	Number of plots	dbh mean (sd, min, max)	Density (stems/ha)	Basal area (sd) (m^2 / ha)	Percentages of cut stumps	Forest type
Baneyi	10	14.4(9.6,5,56.8)	978.9(53.21)	3.26(3.15)	0.07	Broadleaves
Bare Bohare	9	15.1(12.1,2.7,68.5)	5220.3(51.39)	21.42(0.83)	0.46	Broadleaves
Beski	9	34.9(25.4,5,103.8)	905.4(53.2)	38.57(2.71)	0.04	Broadleaves
Boteya	9	22.0 (21.2,89)	1630.1(56.6)	23.39(1.71)	1.32	Broadleaves
Rashawer	9	24.9(9.2,2,33.1)	1691(56.7)	31.05(1.97)	0.08	Broadleaves
Sarki	9	36.3(26.3,5.1,91.2)	1051(54.4)	46.94(31.98)	0.14	Mixed
Sindori	9	24.4(20.7,5,102.1)	815.8(56.6)	14.48(1.93)	0.16	Mixed
Zawita	9	82.4(44.5,5.8,200)	221.6(27.95)	106.51(9.63)	0.12	Coniferous

Table 20: Village`s natural resources and livestock

Villages	Number of Households	Natural forest area (ha)	Crops and grain area (ha)	Pasture area (ha)	Goat	Sheep	Cows
Baneyi	14	1329	93	1450	0	0	0
Bare Bohare	80	660	318	826	477	313	0
Beski	11	2903	330	1134	0	0	0
Boteya	62	1343	254	745	950	200	0
Rashawer	102	594	340	101	580	175	0
Sarki	90	1500	90	800	0	0	40
Sindori	100	912	191	1950	230	47	0
Zawita	400	-	-	-	0	0	0

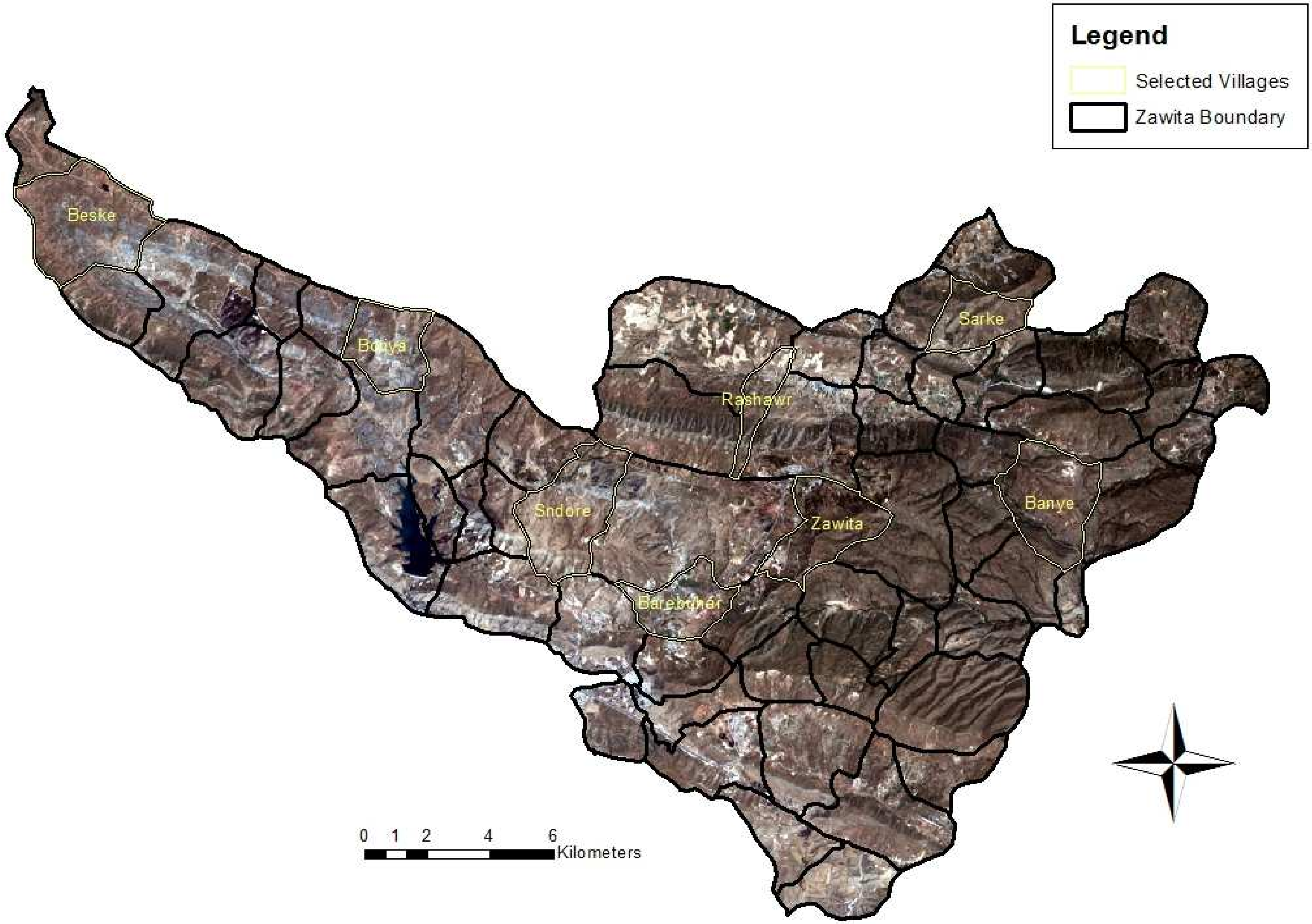

Figure 23: The locations of study villages within the boundaries of Zawita.

5.7.1. Baneyi

Baneyi village was almost evacuated until recently. The majority of new residents are refugees whom were given the houses by the government. Baneyi is within about 21 km from Duhok city center. The indigenous population was only around 14 houses in total. The lands, however, are still owned by the indigenous people that no longer live in Baneyi. Baneyi lies on the edge of a cliff surrounded by broad-leaved forests; the area suffers from drought due to lack of water sources for irrigation thus Gem (Kurdish term for fruit farms) and Raz (Kurdish term for vegetables and other products farm) are rarely found within the villages. The villages are easily accessible with the main road connecting Baneyi with Duhok city and a series of other villages within Zawita sub-district. Baneyi forests were the most disturbed forests with the lowest basal area and average tree dbh. The forests were poorly stocked with small *Quercus* trees. The village population has been growing in the past decade, thereby increasing the demand on forest resources for various purposes.

The visual comparison of Baneyi village from 1986 to 2015 (Figure 24) shows an increase in urban areas in 2015 where people have returned to their villages after Iraqi war in 2003. Agriculture areas are also expanding in the northern areas near the village boundaries replacing forested areas. There is also an increase in coniferous area between 2006 and 2015 surrounding the village. Baneyi broad-leaved forests are also declining, recalling the field data collected in Baneyi the forests are in a very bad condition and the size of the trees are relatively small compared to other forests. This is reflected in the RS data, where an obvious decline in broad-leaved forests is observed from 1986 to 2015. Survey results also showed that the villages population in increasing which increase the use and access to forest resources, thereby increasing tree cutting and ultimately causing forest degradation.

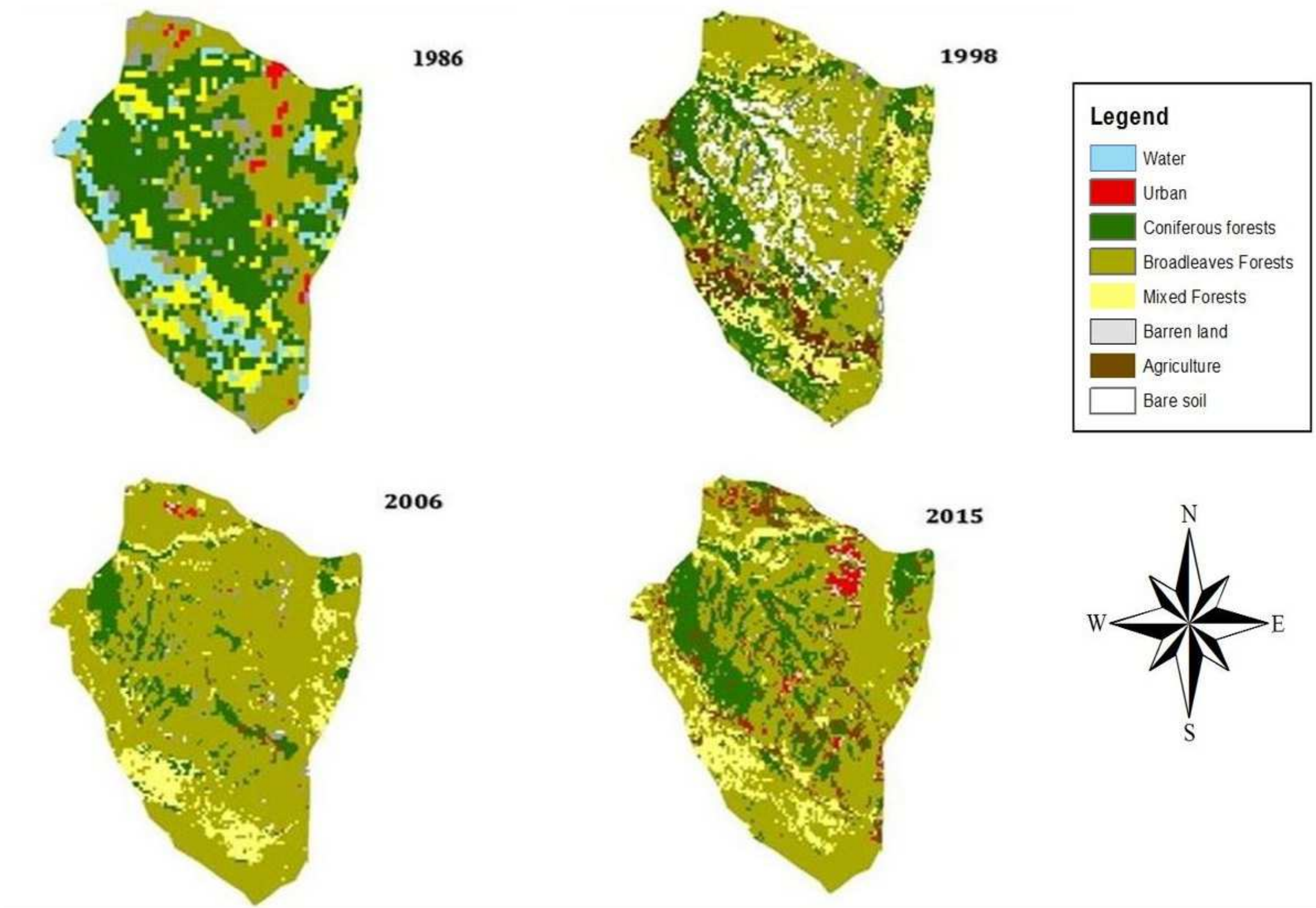

Figure 24: Baneyi village land cover changes between 1986-2015 time periods.
The map shows an increase in urban areas and coniferous forests while showing a decline in broad-leaved forests.

5.7.2. Bare Bohare

Bare Bohare is the closest village to Duhok city, the population is around 80 householders, around 20 of those are indigenous Bare Boharians whose ancestors werefounders of the village. The total village population however was overestimated by the Bureau of Statistics in Duhok city in their most recent survey in 2010, with no record of the population in the past. The village`s topography is hard to navigate through and roads were only available to the main parts of the village, as it is located between valleys and surrounded by series of mountains and high hills. The hills and mountainous surrounding Bare Bohare are covered mostly with broad-leaved forests.

The village is also surrounded by a number of Gem and Raz; up to 1 km away from the village's boundaries. Bare Bohare is one of the large villages in this study in terms of population size. Bare Boharians only have sheep and goats that are being raised on the edge of the forests and near the seasonal river that passes through. According to the survey, Bare Bohare suffered from migration during the political instability in the last three decades. However, the village is rebuilding and its population has been rapidly increasing. The survey results also shows that the main factors forcing people to migrate from Bare Bohare were a combination of political and environmental drivers.

The forests exist on the side of the village and are easily accessible by the villagers, so Bare Bohare forests tended to be more disturbed than other broad-leaved forests visited, because of its high population and the because of the newly rebuild recreational area around the village, and closeness to the city (within 7 km distance); these projects brings more traffic on the surrounding forests. According to the mayor, forests in Bare Bohare are in a very good condition and there is very little tree cutting and the forests are being used for small purposes and are well taken care of. This perception was not supported by the forest inventory data, which showed that the forests were very disturbed, with a high density of small stems. This shows that the trees are being continuously cut by the villagers, since *Quercus* species grow in the form of coppice sprouts majority of the trees were of small size with a shrub growth form.

The village is mostly surrounded by broad-leaved forests, however, small pine plantations owned by some villagers are located in the Southeastern part of the village. Bare Bohare classification map (Fig. 25) shows a significant increase in urban area. Bare Bohare village has expanded to cover almost the whole area within the village's boundary. In addition, the increase in agriculture areas is related to population increases, as the demand for food and other agricultural products to meets people`s needs (Fig. 25).

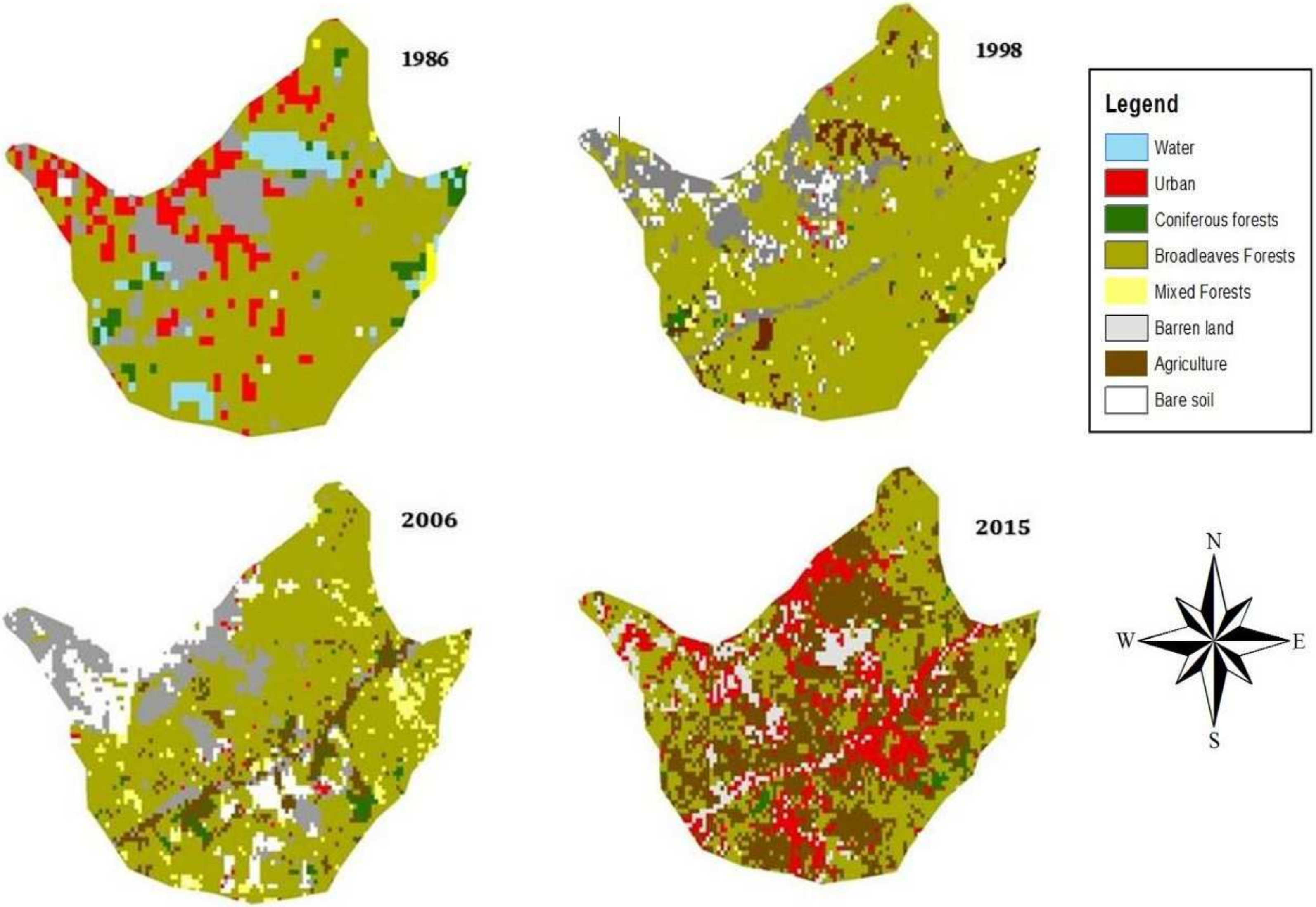

Figure 25: Bare Bohare village land cover changes
There is a significant increase in urban and built-up areas and agriculture areas covering almost the entire village, with a decline in broad-leaved forests

5.7.3. Beski

Beski is a very small village located on the Southwestern side of Zawita sub-district, miles away from Boteya. This village was abandoned after the Anfal campaign and although expanding, the returning population is only about 20 households. Areas around Beski are covered with broad-leaved forests, and the indigenous residents have small livestock cattle with poultry mostly used for their personal use. Beski residents were very supportive of the survey and provided valuable information including contact information of people who migrated from the village.

Beski's landscape have changed significantly between 1986 and 2015. There is a noticeable increase in urban and agriculture areas, and vast forests areas are converted to agriculture areas (Figure 26). Broad-leaved forests surrounding Beski village were similar to those found in Rashawer and Boteya. Trees, however, were bigger in size, with an average dbh about 35 cm. Beskis` population in total is about 20 households scattered throughout the village, while only 11 houses are located in the center of the village. Because its location is far away from the city, there is reduced traffic in the forests.

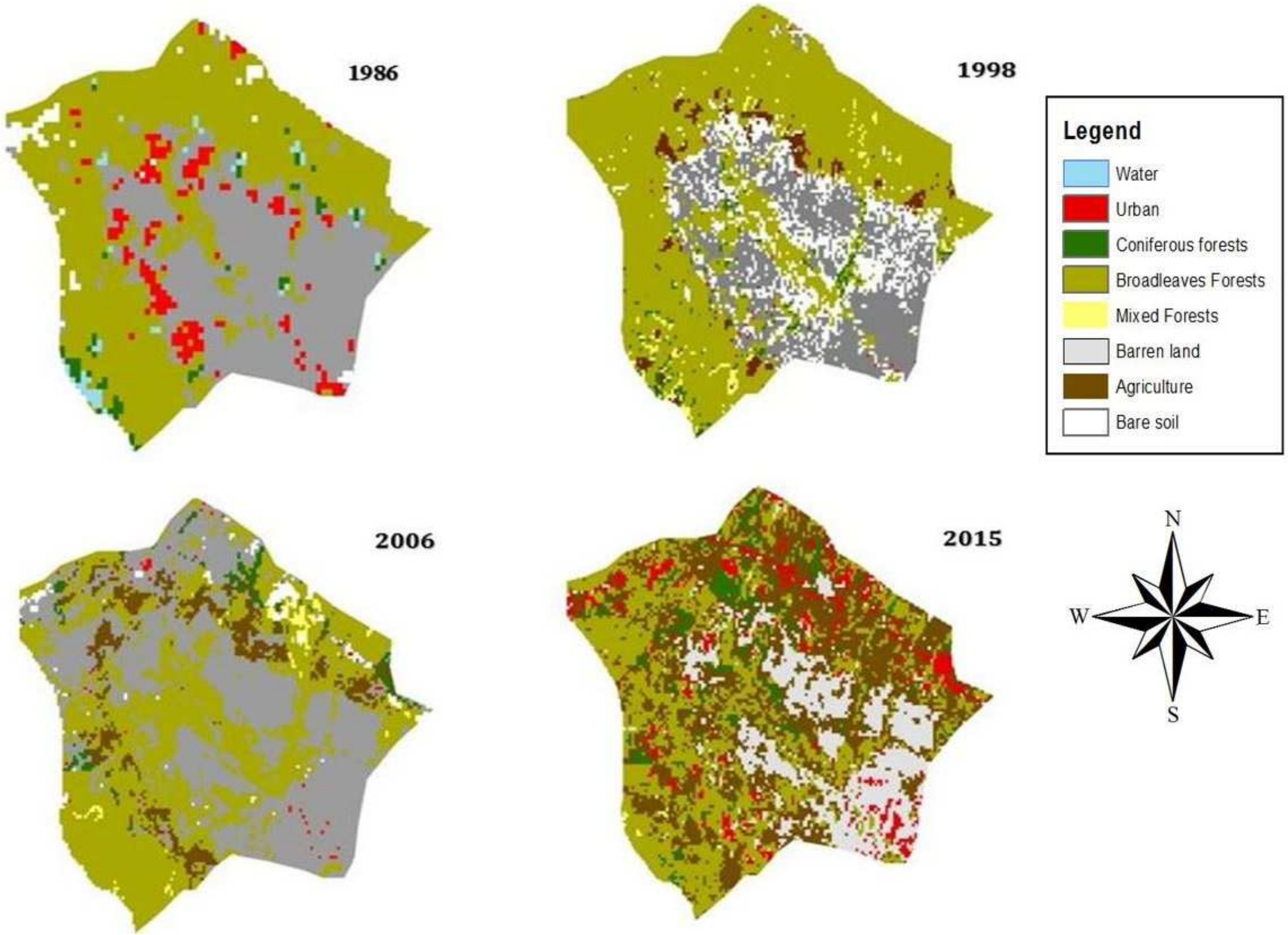

Figure 26: Beski village LULC changes.
Increase in urban and agriculture areas. Decline in broad-leaved forests

5.7.4. Boteya

Boteya is a small village located on the Southwestern side of Zawita. This village was mostly evacuated, with the number of houses not exceeding 15. According to the villagers, the village was vacant for the longest time and only in the past decade has its population been rising a little. Survey results showed that most of the migration from Boteya happened during the political instability that that region was undergoing. After the Anfal, the indigenous people did not return to rebuild their villages. However, according to Bureau of Statistics in Duhok city, up to 40 houses are built scattered within the village's boundaries. The village is surrounded with vast areas of broad-leaved forests. According to the villagers, it is not difficult for outsiders to live in the village, but it is not preferred. There are few Gem and Rez within forest boundaries in addition to some poultry and cattle. Various pastures, crops and grain also exist around Boteya. The mayor of the village was not available when I conducted my fieldwork, nor was the elder of the village, thus I had limited information about the history of the village.

Forests near Boteya had relatively low tree density and higher basal area with an average tree size of 22 cm (dbh). Boteya forests were very similar to forests in Rashawer and Beski in term of tree size and forests condition. Boteya visual comparison of the four time periods (1986-2015) shows an increase in agriculture and urban areas and decline in broad-leaved forests (Figure 27), which have been expanding at the expense of forests.

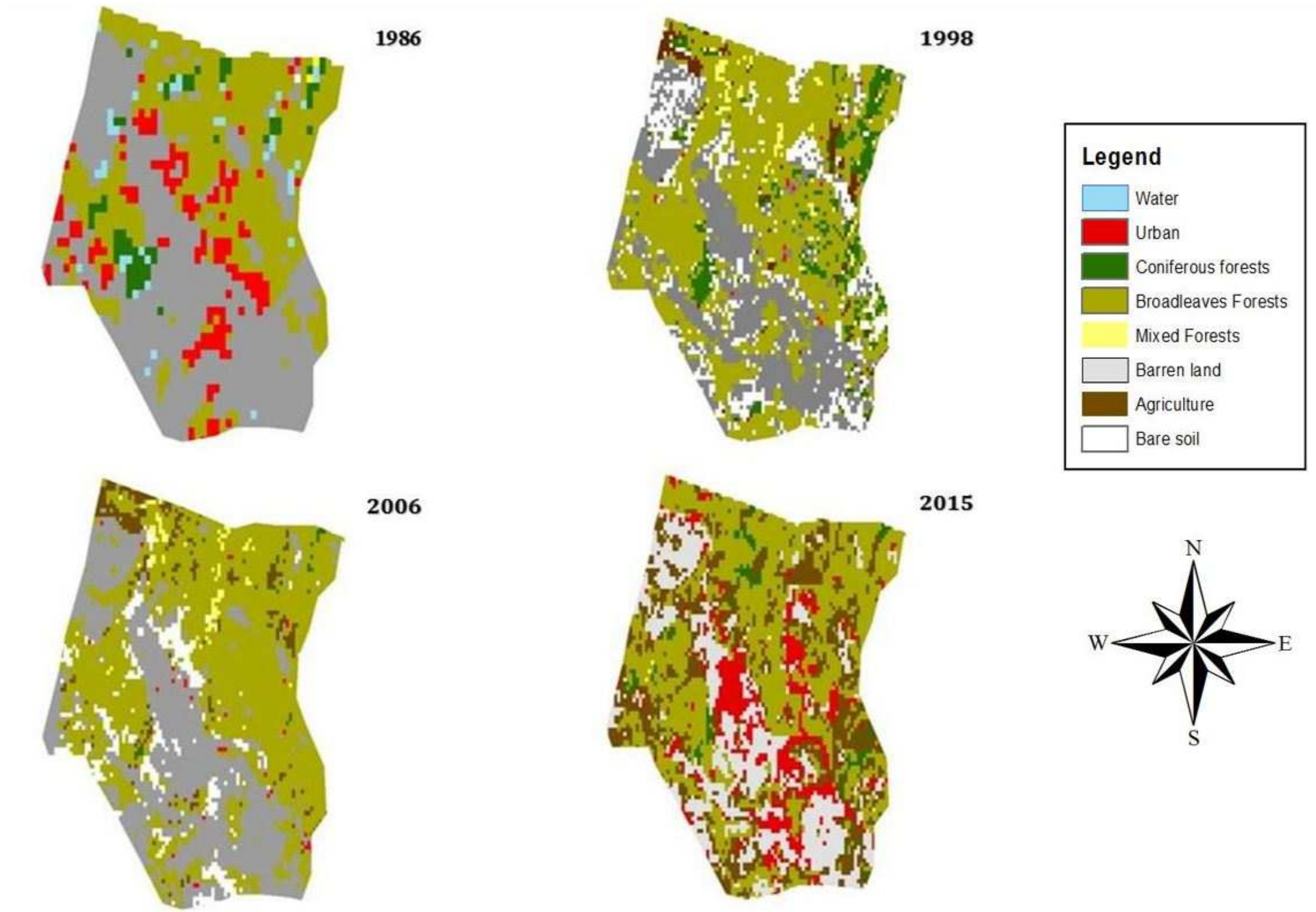

Figure 27: Boteya village land cover change.
The maps shows a decrease in forested areas, with an increase in urban and agriculture areas.

5.7.5. Rashawer

Rashawer is a small village in the northern part of Zawita sub-district; its population is about 100 houses in total. Rashawer is located on flat ground with a main road passing through it. Broad-leaved forests mostly surrounding it, with a large number of Rez and Gem inside forest boundaries, where areas were cleared for this purpose.

The villagers own livestock that are being raised near forest boundaries; signs of grazing are spread out in the forests close to the village`s boundaries. Cutting of trees is typically done for land clearing for agriculture purposes, rather than daily personal usage. The residents of Rashawer were a bit difficult to deal with during the survey. They were very concerned about the outcome and results of the survey, because of the traditional ownership of their land, which makes them vulnerable to claims of fraudulent ownership.

Migration in Rashawer also increased during political instability. War was mainly the main reason forcing people to relocate to other villages or in the cities. Rashawer was never completely vacant and its population is increasing slowly since outsiders are not allowed to live in the village.

Rashawer forest inventory results were similar to Boteya and Beski villages, they all had relatively bigger trees than other broad-leaved forests observed and higher basal area. Figure 28 shows the visual comparison of Rashawer between the four time periods, it shows a general increase in agriculture areas and decline in coniferous forests within Rashawer. Broad-leaved forests are also declining and being replaced by agriculture areas.

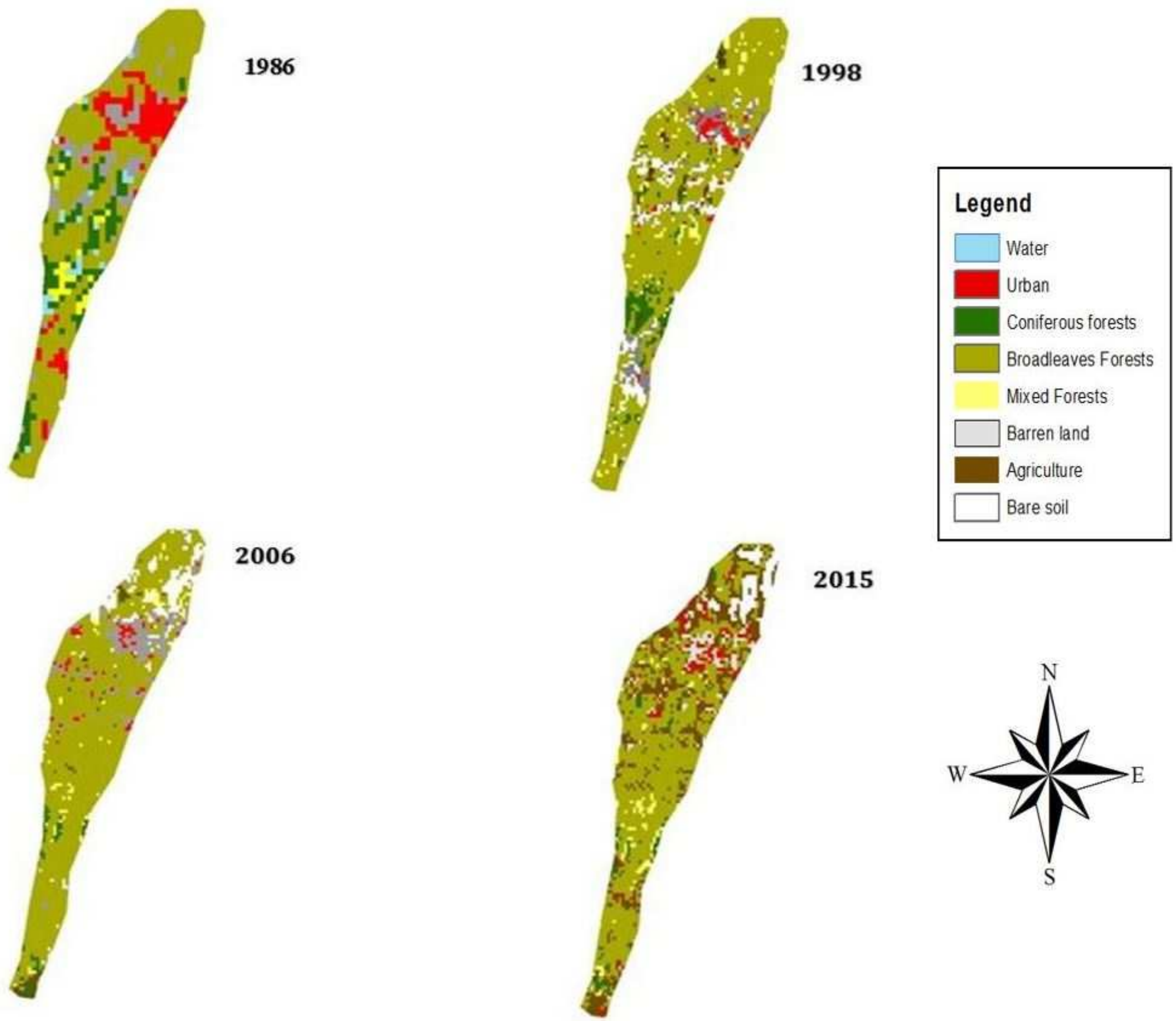

Figure 28: Rashawer village land cover change.
Map shows a decline in coniferous forests and broad-leaved forests being replaced by agriculture areas

5.7.6. Sarki

Sarki is located at the northern east part of Zawita sub-district near the border with Mangeshk; it is one of the growing villages where the residents were relocated multiple times due to political reasons. It is surrounded by mixed forests on its eastern side, while covered with broad-leaved forests on its western and southern sides. The village has many water sources for irrigation which have made Sarki known for its Gem and Rez. The entire village was relocated to another area during the war. Only recently people have been returning to rebuild their old village. The new village was built a few km away from the original village location; the indigenous residents of the area are building few houses at the old location, but it is still lacking services and access.

Sarki forests are very similar to the forests surrounding Sindori village. However, trees in Sarki forests were bigger in size, denser, and had a bigger basal area than Sindori. Sarki forests are also at a higher altitude than Sindori and are less accessed and used by the population compared to Sindori forests.

Visual comparison of land cover change in Sarki (Figure 29), shows an increase in agriculture areas and mixed forests, where softwood sapling are being planted in pure oak forest. Map also shows decline in coniferous and broad-leaved forests, many of which are being replaced by urban and agriculture areas. According to the villagers, softwood species were mainly planted in mixtures with hardwood species. Originally, only broadleaved forests were covering most of the areas around the village.

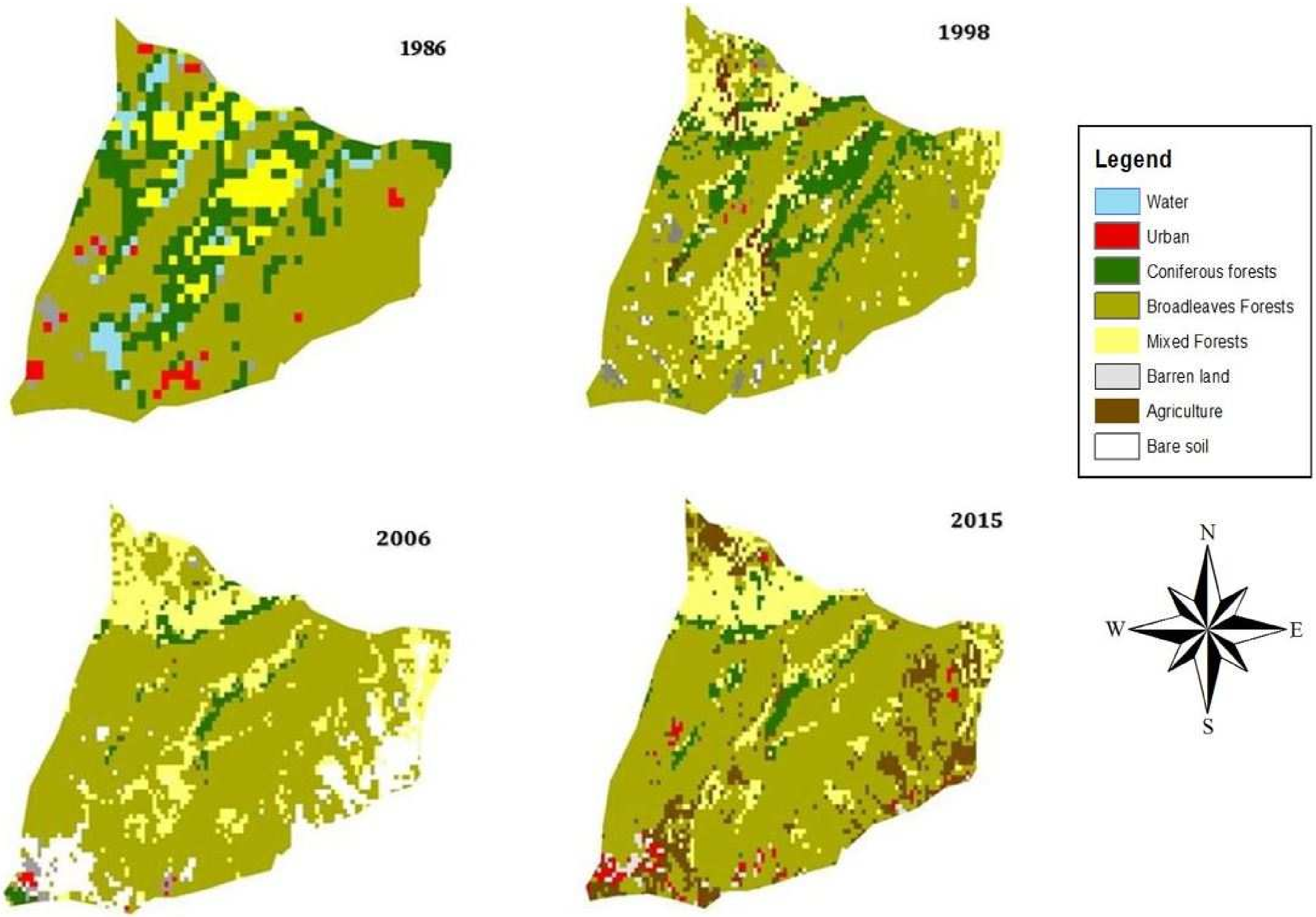

Figure 29: Sarki village land cover change.

5.7.7. Sindori

This village is located at the center part of Zawita, the number of householders is about 100 houses. It is very difficult for outsiders to live in this village, since all of the residents are the descendants of Sindori founders, and thus its population hardly grows. Sindori is located on the top of a hill covered mostly with broad-leaved trees on the east side and south side and mixed forests on the northern, Northeastern, and south sides. Sindori Gem and Rez are mostly located inside a steep valley where water for irrigation is available.

Vast areas of natural pastures, crops and grain fields surround Sindori villages. Livestock include small sheep and goat cattle along with poultry that are mostly for personal use. Forest access was restricted when the villagers developed their Gem and Rez inside forest boundaries; this is a common method for claiming ownership over forest areas. Forests were easily accessible but difficult to navigate through the high mountainous areas. The villagers were also evicted due to war, forcing people to relocate to the cities, which after Rapareen (Kurdish revolution) they started to go back to their villages to claim their lands. The forests surrounding Sindori villages were a mix between broad-leaved and coniferous forests. Similar to Sarki, the villagers stated that mixed forests came into existence when softwood species were planted with broad-leaved to protect soil from erosion.

Sindori had relatively high population compared to the other villages that their population is not growing. Mixed forests surrounding Sindori village were more disturbed than those in Sarki village. According to the villagers these forest are mainly used for daily cooking fuel, fencing, and other purposes, the forests are not being cleared for agriculture or logging. However, during the forest inventory it was observed that many areas inside the forests were cleared for agriculture and building recreational houses. Sindori land cover change shows a significant increase in agriculture land and a decline in forested area (Figure 30). Mixed forests in Sindori were classified as coniferous and broad-leaved separately. This is because the canopy was dominated by softwood species while the understory were covered with hardwood species (see previous results).

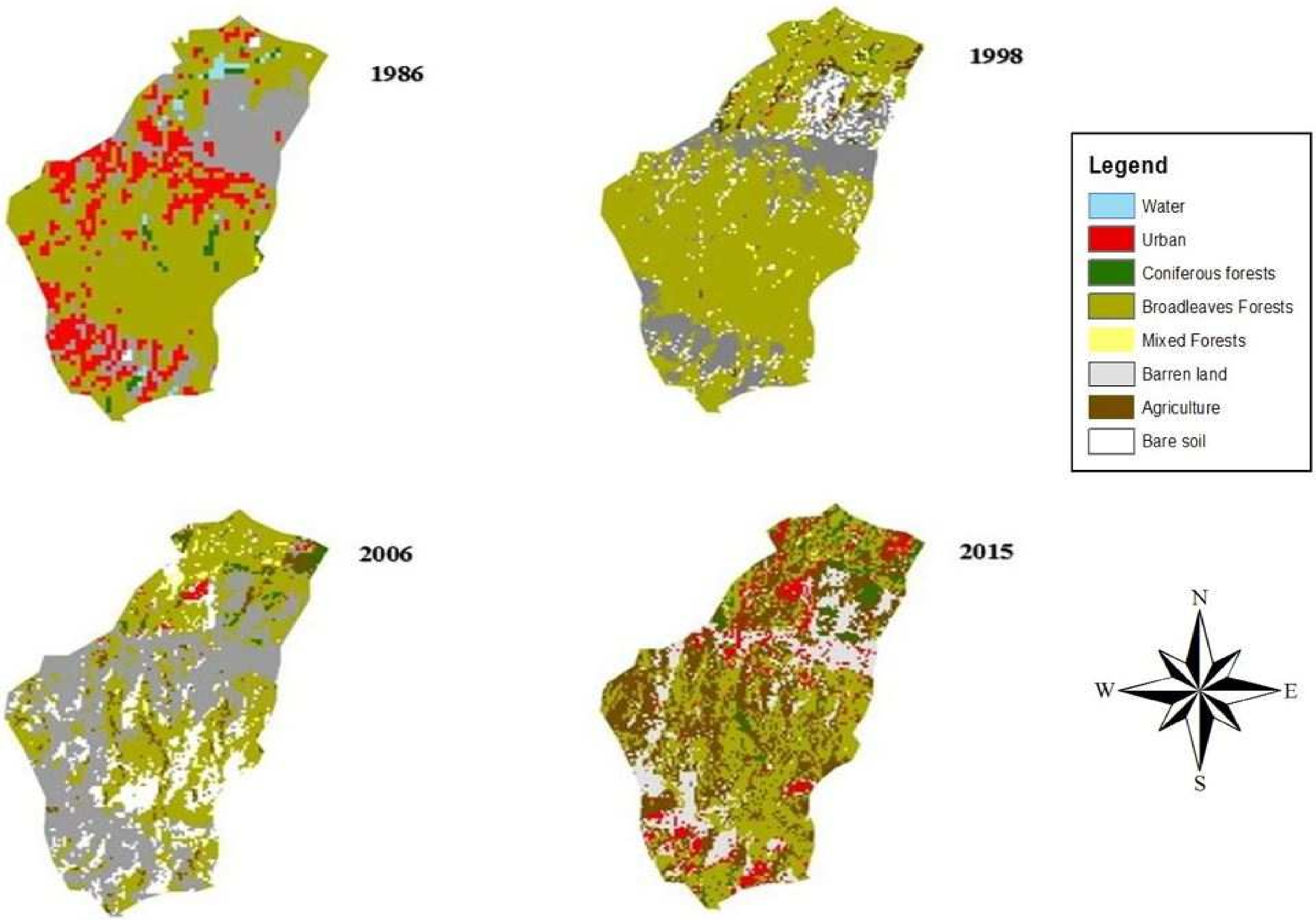

Figure 30: Sindori village land cover changes. This map shows misclassification of mixed forests.

5.7.8. Zawita village

Zawita village (bearing the same name as the district) was previously a small village that is now more developed to include hotels, restaurants, bakeries and other commercial shops, because of the areas touristic and recreational value; the area is known for its historical places and attractive points. Zawita is also famous for its coniferous forests and especially Zawita pine trees that are covering the mountains surrounding the area. Zawita`s population is increasing significantly, and most of its residents are indigenous residents of the area from different religions that have returned to their villages after the war ceased.

Zawita village is located at the center of Zawita sub-district; its population is around 1000 householders that are scattered in different areas, the survey took place in the oldest location. The areas has a number of fruit orchards and livestock that are mostly being used for householder`s own use. The extra products are being sold or given away to people`s relatives. Zawita forests were easily accessible, the government and private companies that were building recreational houses inside the forests have fenced some areas, but they were still accessible for field work. Zawita is the only village included in the forest inventory that is surrounded by coniferous forests. These forests had the highest basal area among all villages, and given the old age of the forests, the trees were very large in size (averaging to about 83 cm dbh).

Zawita is within 12 km distance from Duhok city center. Tourism makes these forest more accessed and used by the population. Recently vast areas of these forests are being cleared for recreational purposes. However, the remaining forests are not very disturbed, except for e.g., small camp fires that get out of control. Animal grazing and agriculture activities are very restricted in these forests, because of their economic value, making them less degraded. These forests have been protecting Zawita valley from harsh winter weather and most importantly protecting soil from erosion. Zawita village is given more attention by the government and, recently, a Zawita regeneration project has been carried out by the Forestry department / College of Agriculture in Duhok University for enhancing regeneration in Zawita pine forests.

The LULC change shows an expansion of Zawita village, especially in 2015. However, people tend to build their house around the main road for easy access and to avoid tree cutting which is very problematic due to new forest policies. Coniferous forests within Zawita shows a decline between 1986, 1998, and 2006. Between 2006 and 2015 there was a gain of 3.09% of forested areas as a result from pine planting campaign carried by the government and Directorate of Forestry in Duhok city (Figure 31). According to the survey and key informant interviews results, there is a noticeable increase in Zawita village population, and a corresponding decrease in the pine forests, despite the protection and planting efforts.

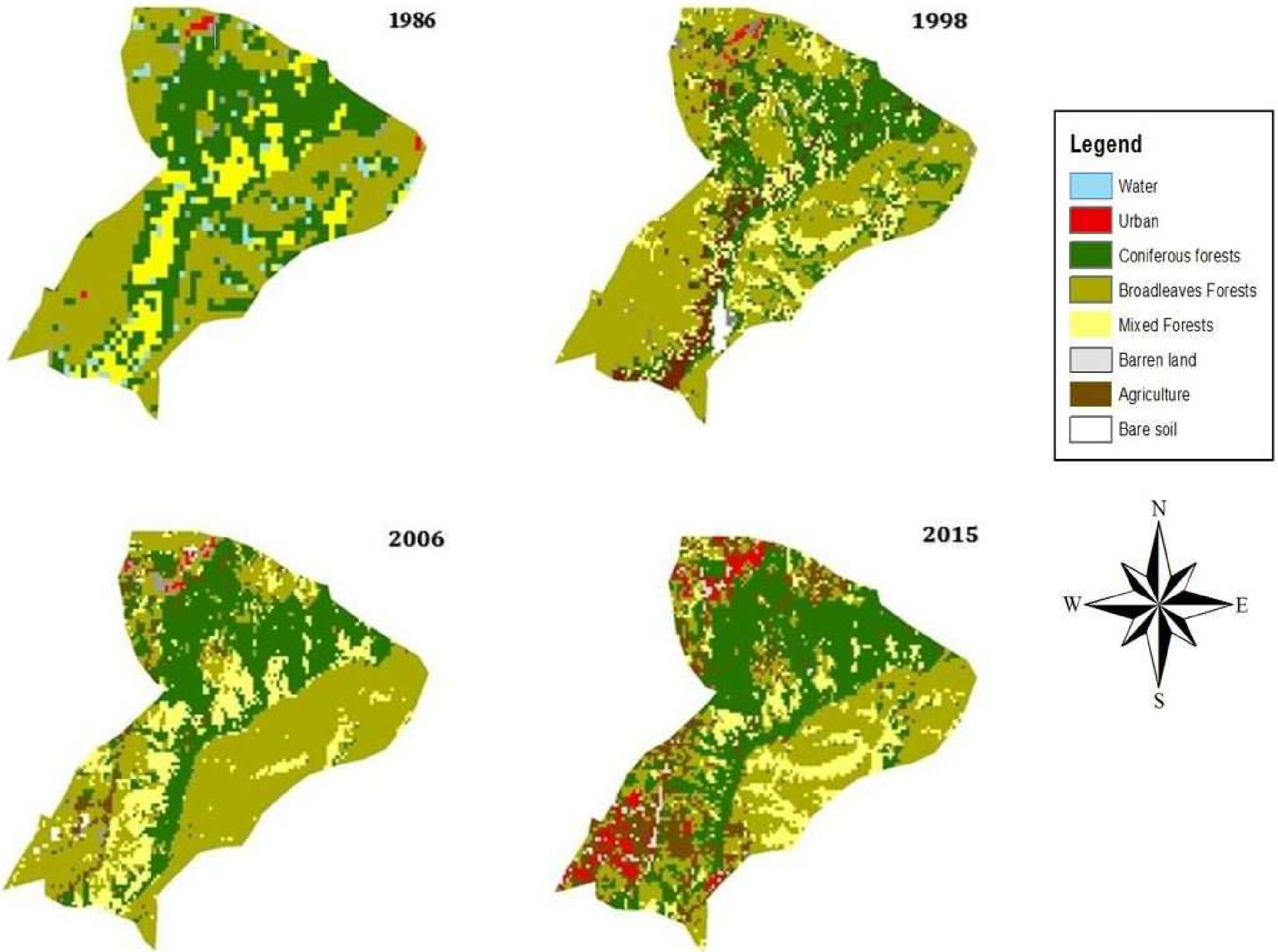

Figure 31: Zawita village land cover changes over four time periods

Chapter 6: Discussion and conclusion

The main goals of this study were to investigate the motivations behind migration and the influence of forest cover change on migration in Zawita and to assess forest cover change to fill the 40-year gap in knowledge about forests and forest conditions in Zawita.

Analysis of the data revealed that there are many factors behind people's displacement. Some factors, however, are stronger than others. Strong factors like war directly force people to migrate, though other factors combined can also force migration. Migration, according to the residents surveyed, was primarily the outcome of war. People were mostly fleeing for their lives where the area was no longer secure. However, even when the war deceased, rural-urban migration still increased. The conflict and war within the region not only kill millions of Kurds and caused destruction to the cities, but it also caused destruction to the natural resources of the region, especially after several attacks and campaigns carried by the Ba'ath regime in attempt to Arabize Kurdish regions. Those incidents resulted in the destruction of vast areas of forest and the destruction of more than 4000 Kurdish villages including those in Zawita sub district. Thereby, forcing millions of Kurds to relocate to the cities temporally or permanently.

My study regions are not unique in that political factors have been forcing people to migrate in many countries. For example Korean researcher Lee (2001) argued that majority of migration and people`s movement are associated with political and economic factors; all other factors are elements strengthening or weakening the influence of political and economic drivers. In this case, political factors were the main reason behind migration, but in contrast to what Lee stated, environmental factors were the outcome of political factors (war), they did not appear to weaken or strengthen the impact of political factors.

Man-made disturbances played a key role in migration process in Zawita, similar to Myers and Kent (1995) study on migration where they linked migration to man-made disasters. De Haas`s (2011) study on examining migration drivers in Mediterranean regions also found that political and economic drivers were forcing people to migrate. No doubt that migration was forced by war in Zawita, but the fear of instability also forced people to seek migration even when the wars had ended. Thus, political factors are driving migration, though its impact is magnified by other drivers.

Political factors appear to be the main driving force behind migration in Iraqi Kurdistan in general and especially in Zawita area, but other social drivers such as economic factors also influenced the extent of migration, where thousands of young ambitious Kurdish man and woman were seeking better education and job opportunities in other countries even nowadays. Economic drivers had an impact on both rural-urban and international migration; wage differentials and income volatility played key role in driving migration, especially during the period when the Ba`ath regime put a blockade on Kurdistan boundaries affecting the region`s economy greatly. This forced many people to migrate seeking job opportunities. Some researcher argued that migration is increased by income variability in migrant's destination (Lilleør and Van den Broeck 2011). This is true for many Kurdish families that have migrated to Europe and North America, because of better incomes and living conditions and most importantly, safety and security in those areas.

Demographic drivers also contributed to migration in Zawita. For example religion played a critical role in people's decision to migrate, though not in the case when political drivers were severe. People from religions like Christianity (Kurdish Christians) were more likely to migrate because of their beliefs and instability in a non-Christian country, and as a minority they were more vulnerable to be attacked by other religious extremists.

Class and race also played a big role in migration decision from rural areas to the cities, farmers and rural residents are more worried about adaptation than surviving. In a book published by Marouan and Simmons (2013), they argued that race have been influencing people displacement throughout the history. Class and race played a role in people`s displacements after Hurricane Katrina, where different races responded differently to the sudden change and the forced movement. Namely, African Americans were less inclined to migrate than white people (Elliott and Pais 2006). Kurdish people have tended to migrate to areas where they feel the sense of belonging, more than areas with better opportunities. For example Bahdni people tend to migrate to Duhok and Zakho cities, instead of Erbil and Sulimaniya where job opportunities are higher, because the dialect and the life style are different in the latter from what they are used to. Similar reasons apply to Soranis as they prefer to move to Erbil and Sulimaniya more than Duhok city.

Haas (2010), however, has argued that demographic driver's role in migration process is probabilistic and less important than often thought, and that its effect is largely mediated through economic and political factors. Black (2001) stated that demographic drivers combined with economic factors can be strong force behind migration. Though, it is clear that demographic drivers played a role in migration process in Zawita, but when combined with other factors they are even stronger forces pushing for migration.

The results from the migration survey showed that environmental changes, especially forest cover change, impacted migration decisions. Though it was impossible to link forest cover change solely to human induced crisis. I concluded that the increase in forest cover conversion and forest degradation were largely related to the human crisis-induced changes instead of the reverse, i.e., people were migrating because of forest changes. My conclusion is based on the fact that majority of the householder responses supported the fact that political factors were the main reasons behind forests' destruction. Hence, both householder survey data and remote sensing data supported the fact that forest have undergone significant changes, especially during the time where migration increased due to political upheaval. Other studies on migration have shown that forest cover change is the outcome of climate change, clear cutting, urbanization, drought and others (Geist and Lambin 2002). However, human crisis seems to be the driving force behind forest degradation and deforestation in Zawita.

Despite the fact that population growth causes forest degradation, rural population in Zawita have decreased significantly due to the massive migration flow, forest cover change however continued. In addition to that, due to the low economic value of Kurdistan`s forests, clear cutting was never been an issue for the region (Chapman 1950), nor was shifting cultivation at least not the past three decades. According to Chapman (1950) shifting cultivation was the main factor behind deforestation in Kurdistan`s forest in the past where agriculture was peoples' main income source.

Prior to the oil becoming the main industry in the region, peoples' main income sources were forest resources and agriculture. The villagers used the forest not only for protection during the war but also used forest resources for their daily uses of wood, fruits, nuts, natural herbs and medicine. Forest played an important role in their life and survival. Though after the war burned and caused destruction to villagers/ houses and farms, people were no longer able to live in those areas without any sources of income or forest resources to use. Thus, political factors (war) not only caused migration but also caused environmental changes (forest cover change) by burning forested areas.

It is realistic to link forest degradation to political crisis based on the study results and not on other factors that are less important, but that does not necessarily mean that these factor have increased forest degradation solely. Other factors like forest policies also contributed to the forest degradation process. In the recent years forest have been getting more attention that called for new forest policies that are more suitable for forest`s current conditions. Though, these policies were developed without involving people whom are dependent on forest resources. This in turn impacted forest greatly when people start reacting to these policies in a negative way.

The survey results suggested that if the government applied new policies that were more appropriate to the forests conditions in Iraqi Kurdistan, they would have been very beneficial for both the forests and people whom are dependent on forest resources. However, these policies were misused by the government as well as the population. According to the householders oil discovery and tourism were reasons behind the policies being misused. People's lands were taken away and claimed by the government with little or no compensation, either for the reason of oil discovery or to be converted to a touristic project. People themselves started converting their lands into touristic projects, though the only way to be able to clear cut a land is by convincing the government that the land is no longer covered with vegetation. So, people would clear the land by burning it, but often the fire would get out of their control, thereby burning not only the land, but also the natural forests surrounding the land causing much damage to the forests. Despite the great damage to forests, the government generally did not investigate all of the fires and often would take bribes from people to cover the identity of whom caused the fire.

It is important to note that the opinions of the survey respondents on forest policies might not reflect the actual truth, because people were afraid of the government or had a conflict of interest affecting their response. Thus, the results might have been biased. Regardless, the region is in need for a better forest policies and regulation that not only protect forest and natural resources but also protect people land and area, in addition to that, to hold those people accountable of land conversion and forest fires without any bias.

The results of the forest change and forest inventory analyses were satisfactory, overall, adding new data to better understand what was going on in the region. It was useful to link visualizations of forest cover change over time to time periods when migration peaked. Remote sensing and forest inventory data results showed that there were many factors are behind the changes in forest cover. There was a significant limitation in finding reference data for one of the imagery, but it did not significantly impact the results because other reference sources were available. This limitation only influenced the validation process of the imagery where agriculture areas were not classified. Beside that the lack of forest inventory and population census data also had an impact on this research. Lack of data formed a constraint on the amount of data been collected and the precision of villages population when estimating migration and number of migrants.

To conclude, this research investigated the assumption that forest cover change and forest conditions indirectly forced people to migrate from Zawita. The results show that migration in Zawita was often driven by a combination of factors and multiple factors have impacted the condition of the forests over the last four decades. In Zawita, political instability, lack of natural resources, and war were important factors contributing in migration decision. Political factors appears to be the ultimate reason behind people migration. However, people also indicated that the changes that were brought up to their environment were also the outcome of war, the war burned peoples' land and resulted in forests destruction, taking away one of the peoples' main income source.

Forests in Zawita have undergone substantial changes in the district in the 30 year time gap that was filled by this study. Main factors impacting forest cover change according to the householders were man-made fires, shifting cultivation and soil erosion. These factors affected forests differently: broad-leaved forests were more vulnerable to man-made destruction such as fires than coniferous forests were weather related factors were stronger factors impacting these forests conditions. To add, this study is one of the first steps toward building a database for the forests in Kurdistan region. It will help other researcher when conducting studies on the area to overcome one of the difficulties that I have faced when conducting this research.   Many researcher showed that various man- made crisis can accelerate the process of deforestation (e,g. Sunderlin and Pokam 2002).

On a hopeful note, the study results support the idea that humans are usually resilient and can adapt to various changes (McLeman and Smit 2006, Piguet 2010). Even when the damage is severe they often choose to start over and rebuild than relocating. For example after hurricane Katrina, the majority of people choose to rebuild and started over than moving (Groen and Polivka 2010). Though, this might not be the case in less developed countries where migration happens in unmanaged ways (McLeman and Smit 2006). In this study, there was clear evidence that some migrants were willing to migrate back to areas they had vacated after a disturbance had passed. While others stayed in the cities or migrated to another country.

APPENDICES

Appendix A: Extent of broad-leaved forests for 1986, 1998, 2006, and 2015 map

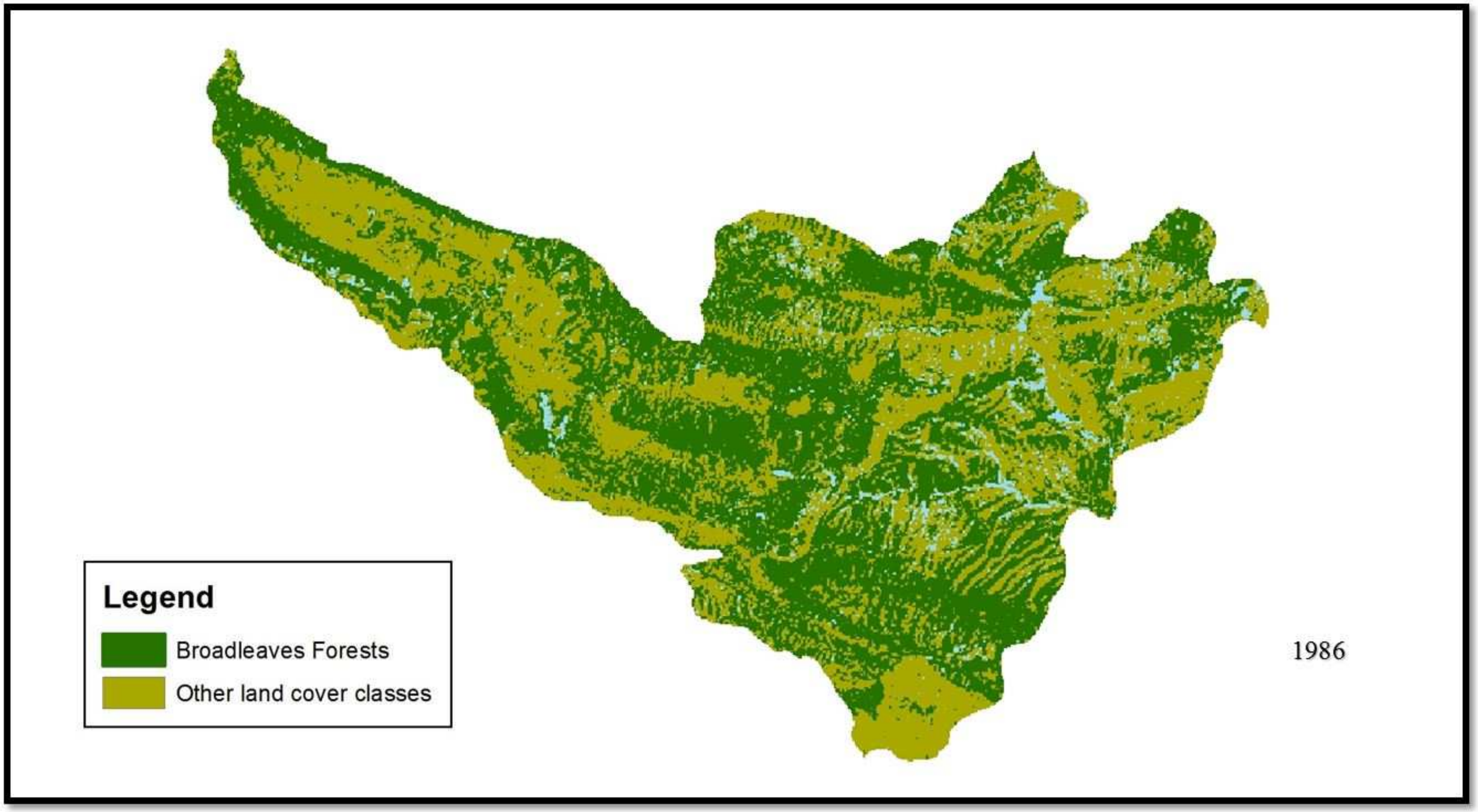

Figure 32: Broad-leaved forests extent in Zawita sub-district for 1986.

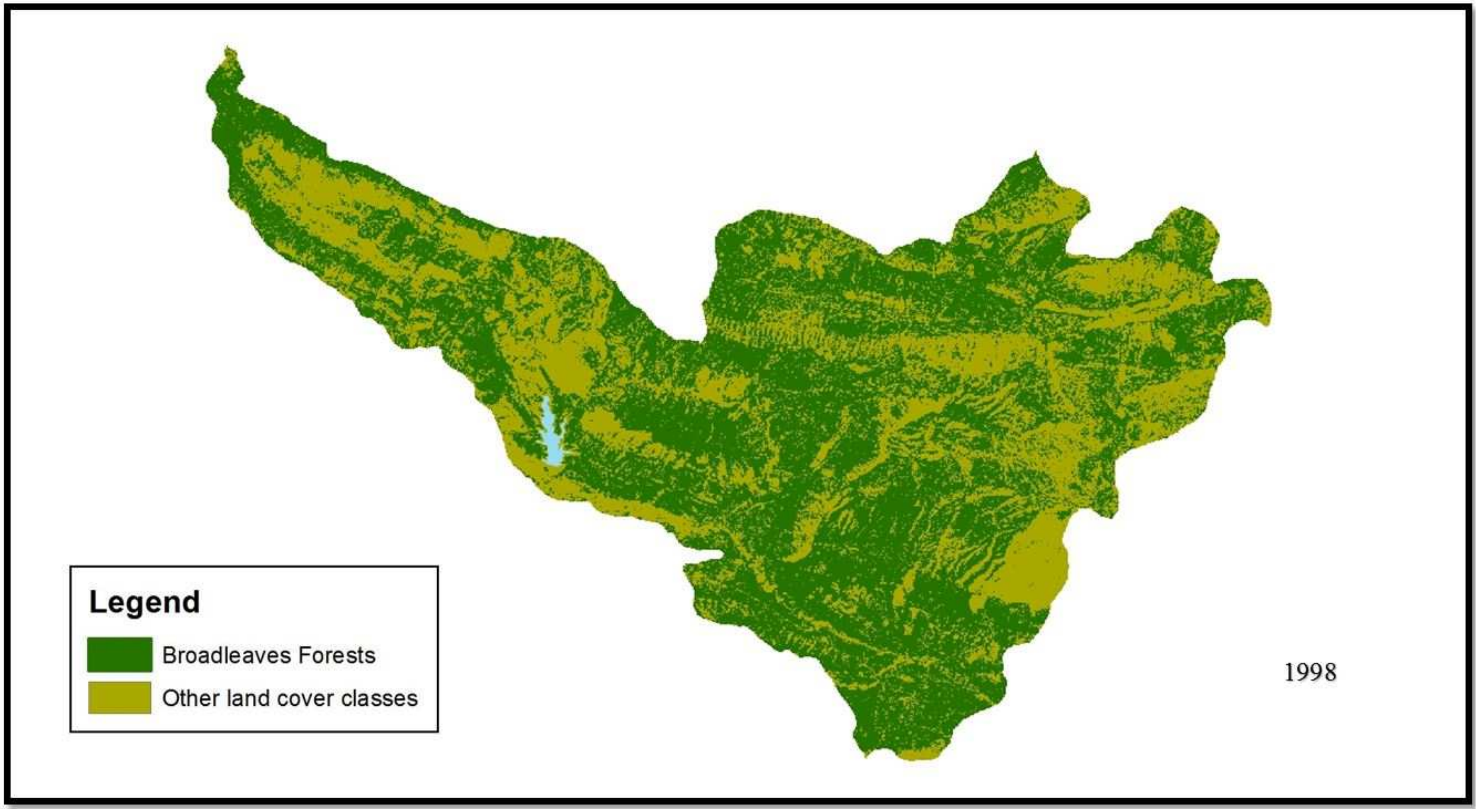

Figure 33: Broad- leaved forest extent in Zawita sub-district for 1998.

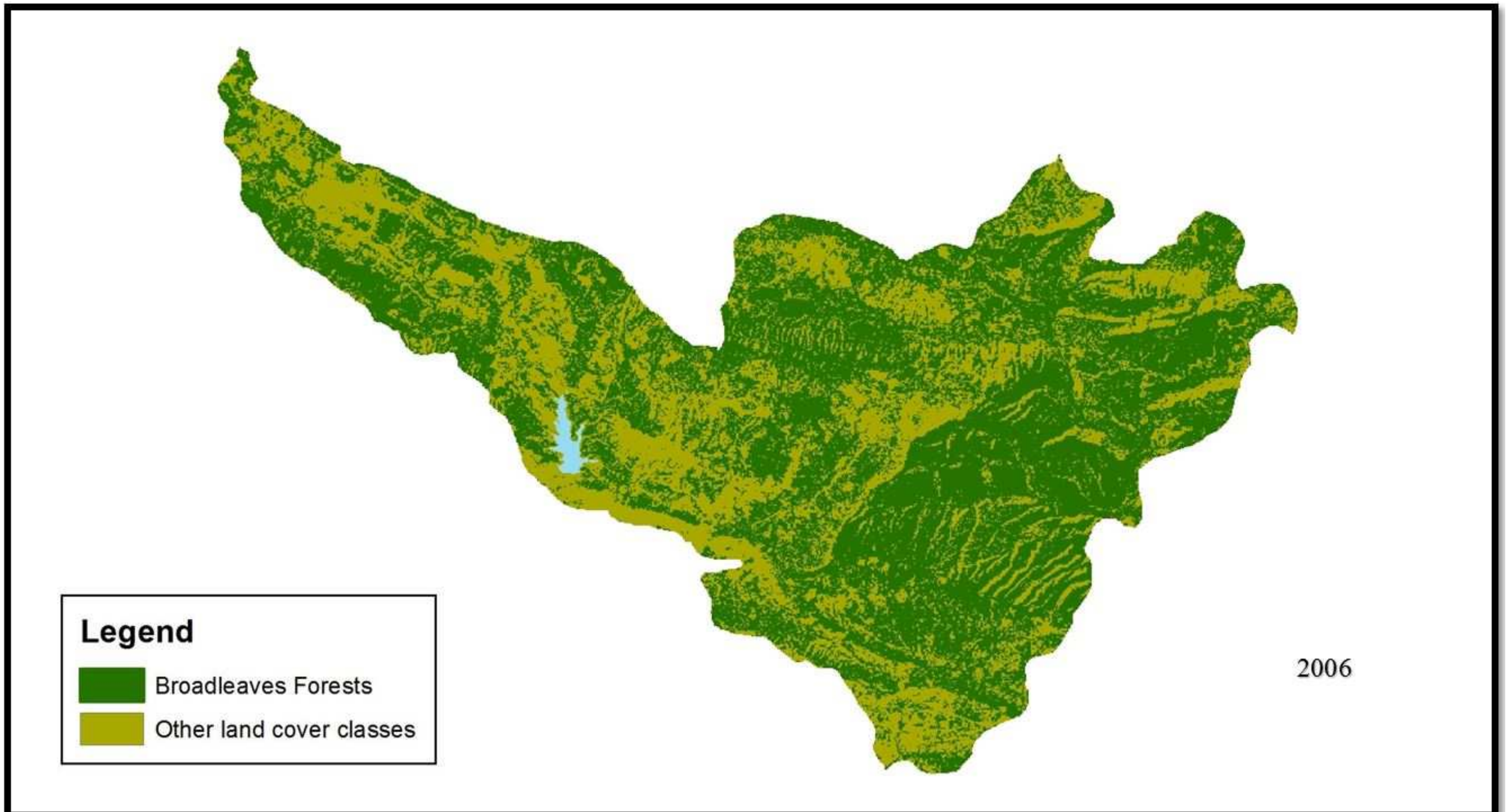

Figure 34: Broad- leaved forest extent in Zawita sub-district for 2006.

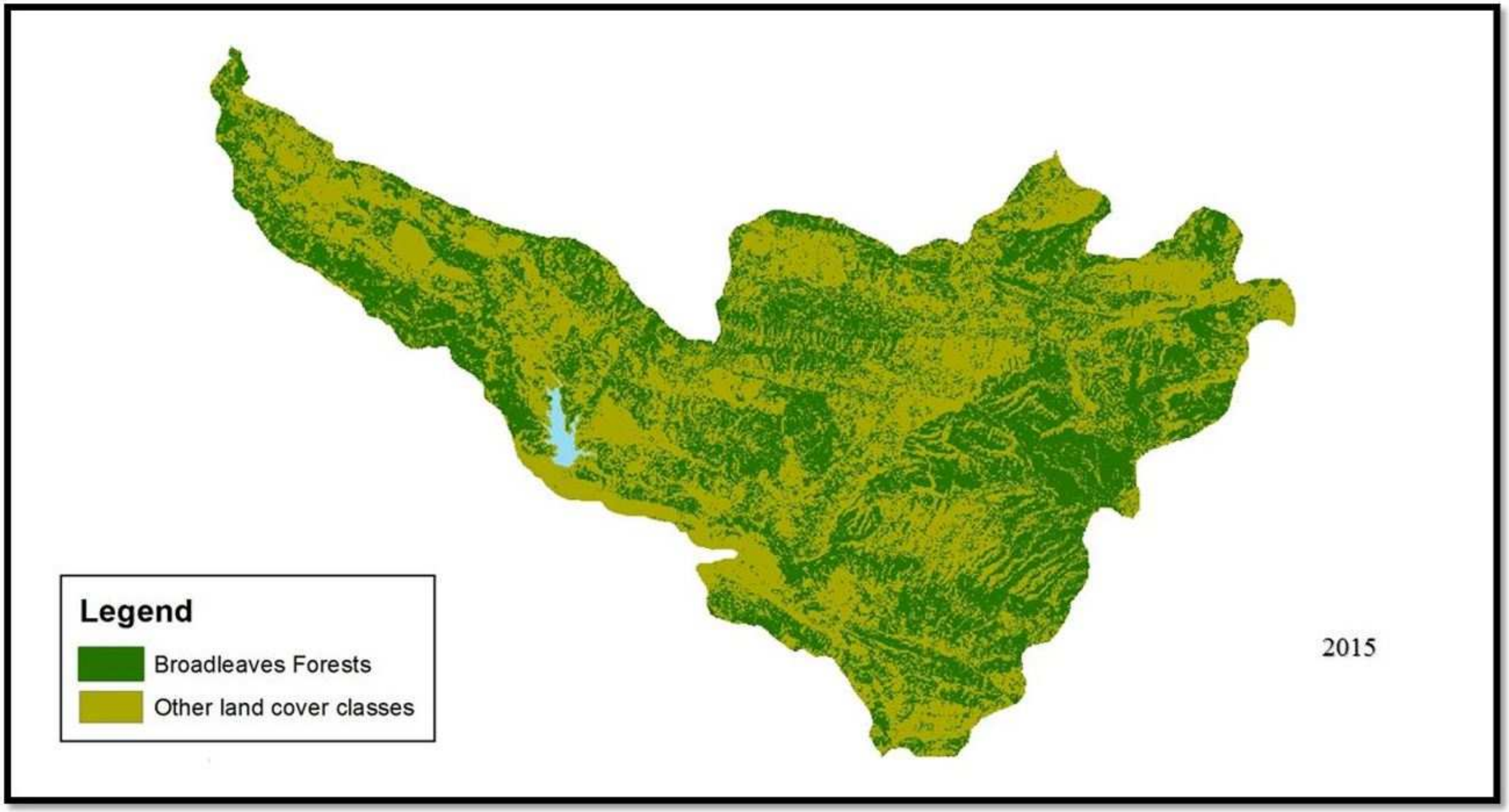

Figure 35: Broad-leaved forest extent in Zawita sub-district for 2015.

Appendix B: Extent of coniferous forests for 1986, 1998, 2006, and 2015 maps

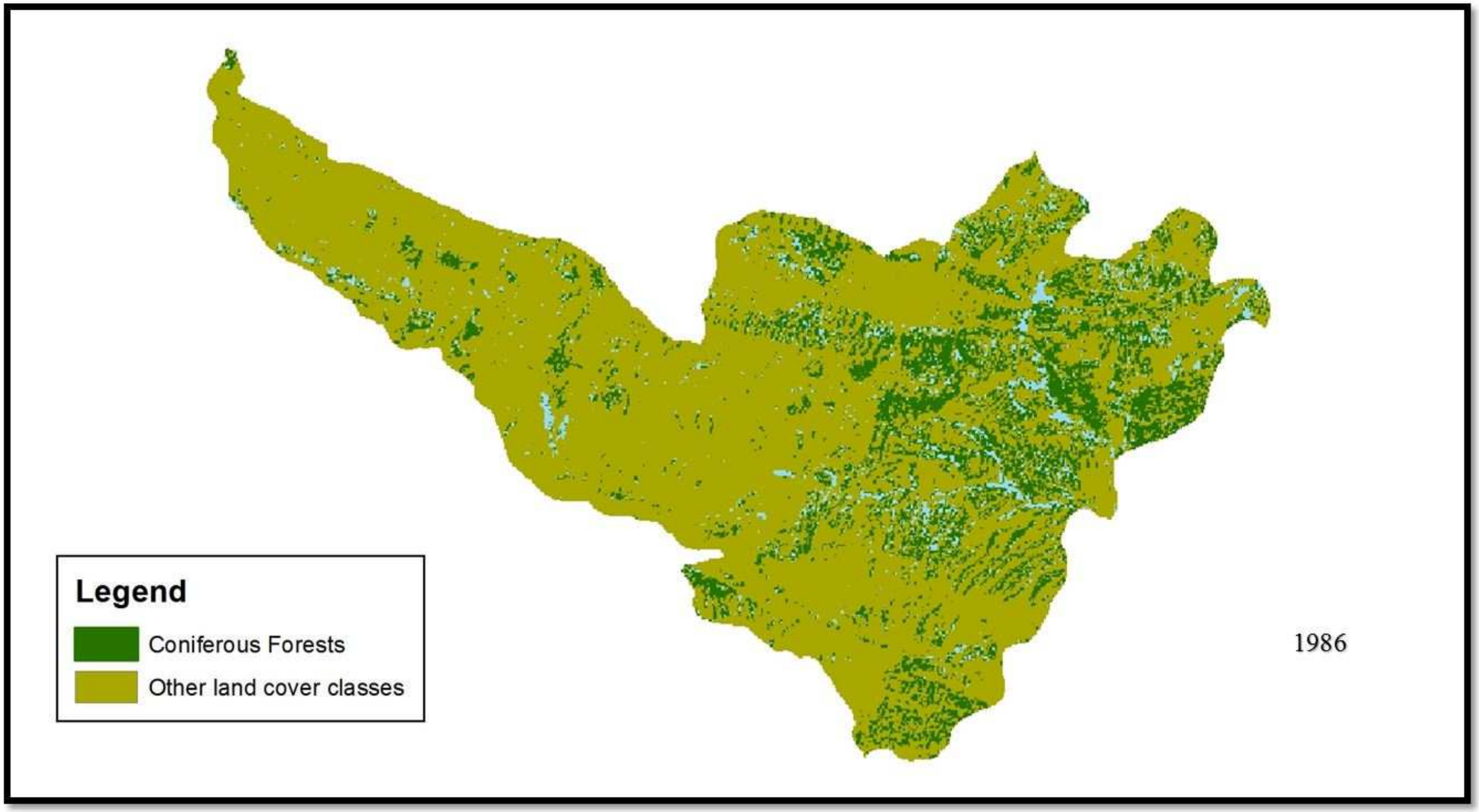

Figure 36: Coniferous forest extent in Zawita sub-district for 1986.

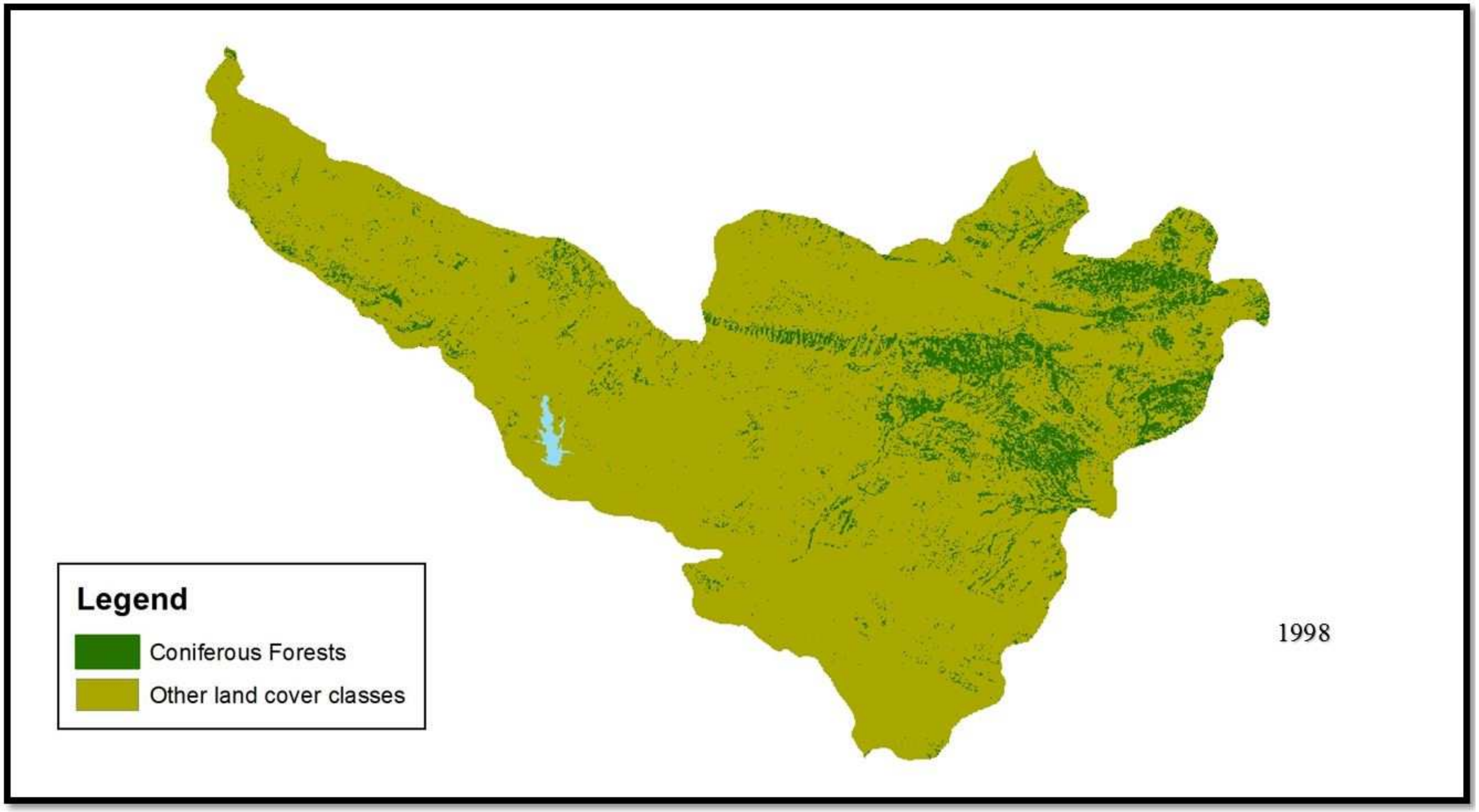

Figure 37: Coniferous forest extent in Zawita sub-district for 1998.

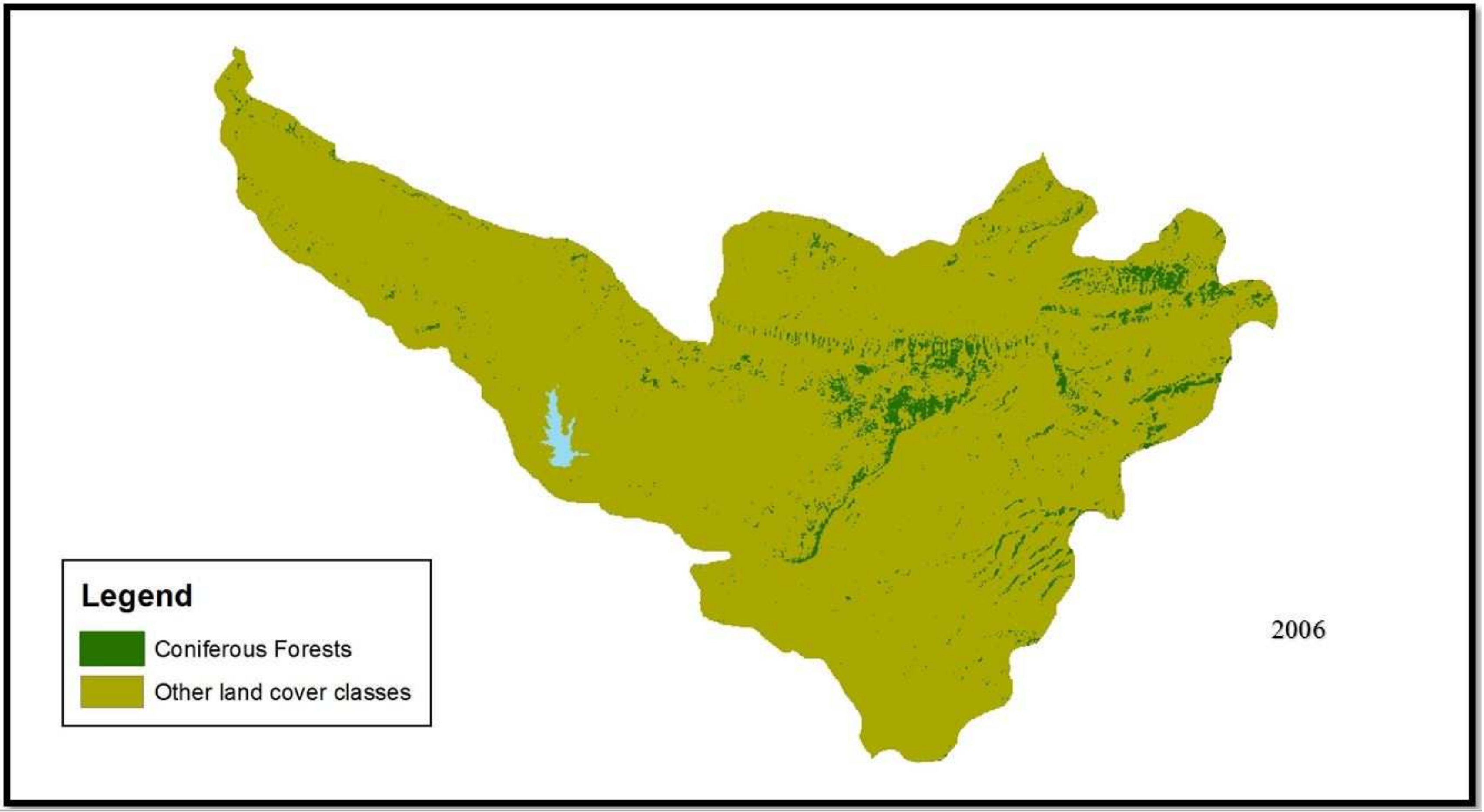

Figure 38: Coniferous forest extent in Zawita sub-district for 2006.

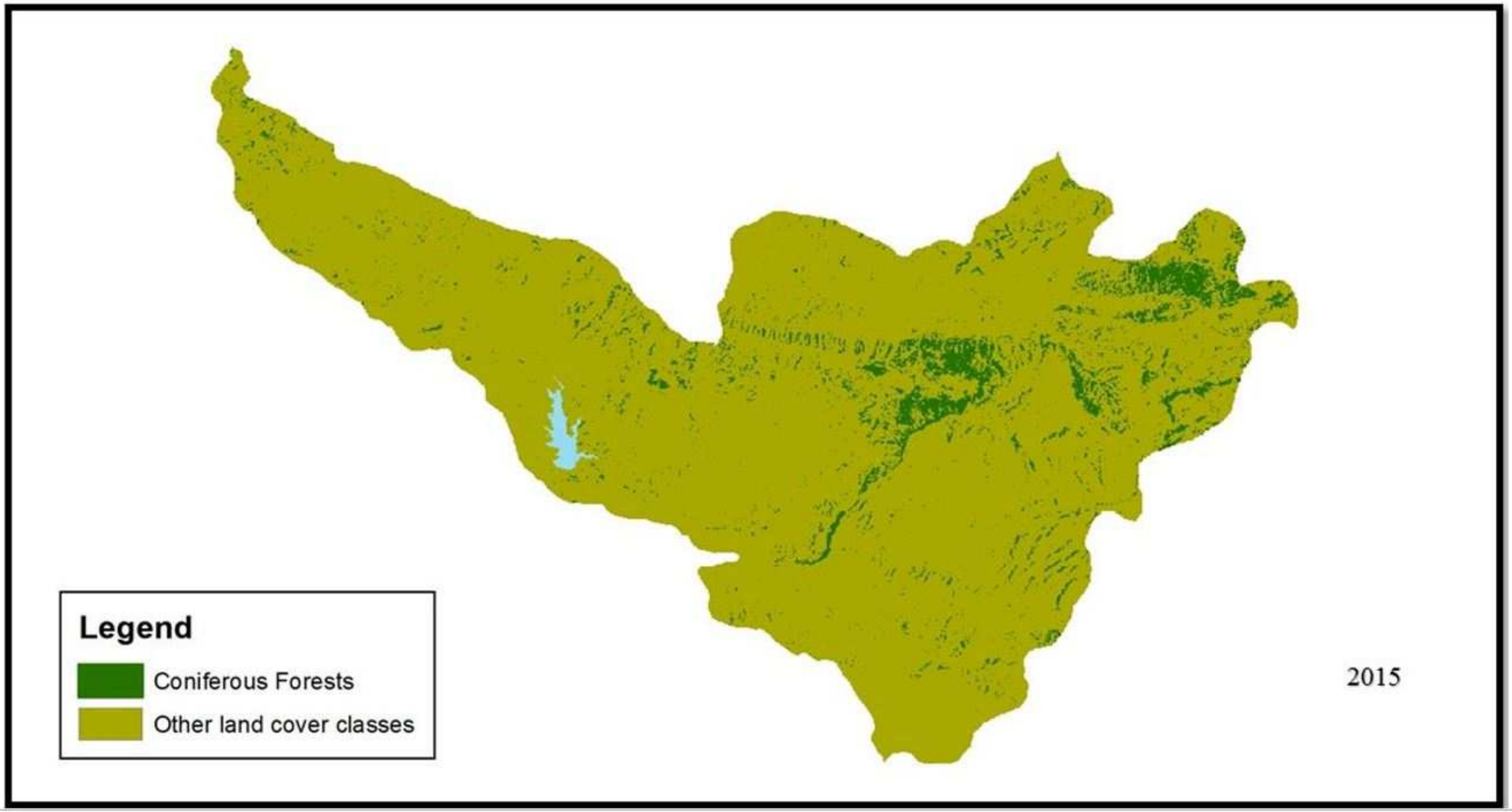

Figure 39: Coniferous forest extent in Zawita sub-district for 2015.

Appendix C: Extent of mixed forests for 1986, 1998, 2006, and 2015 maps

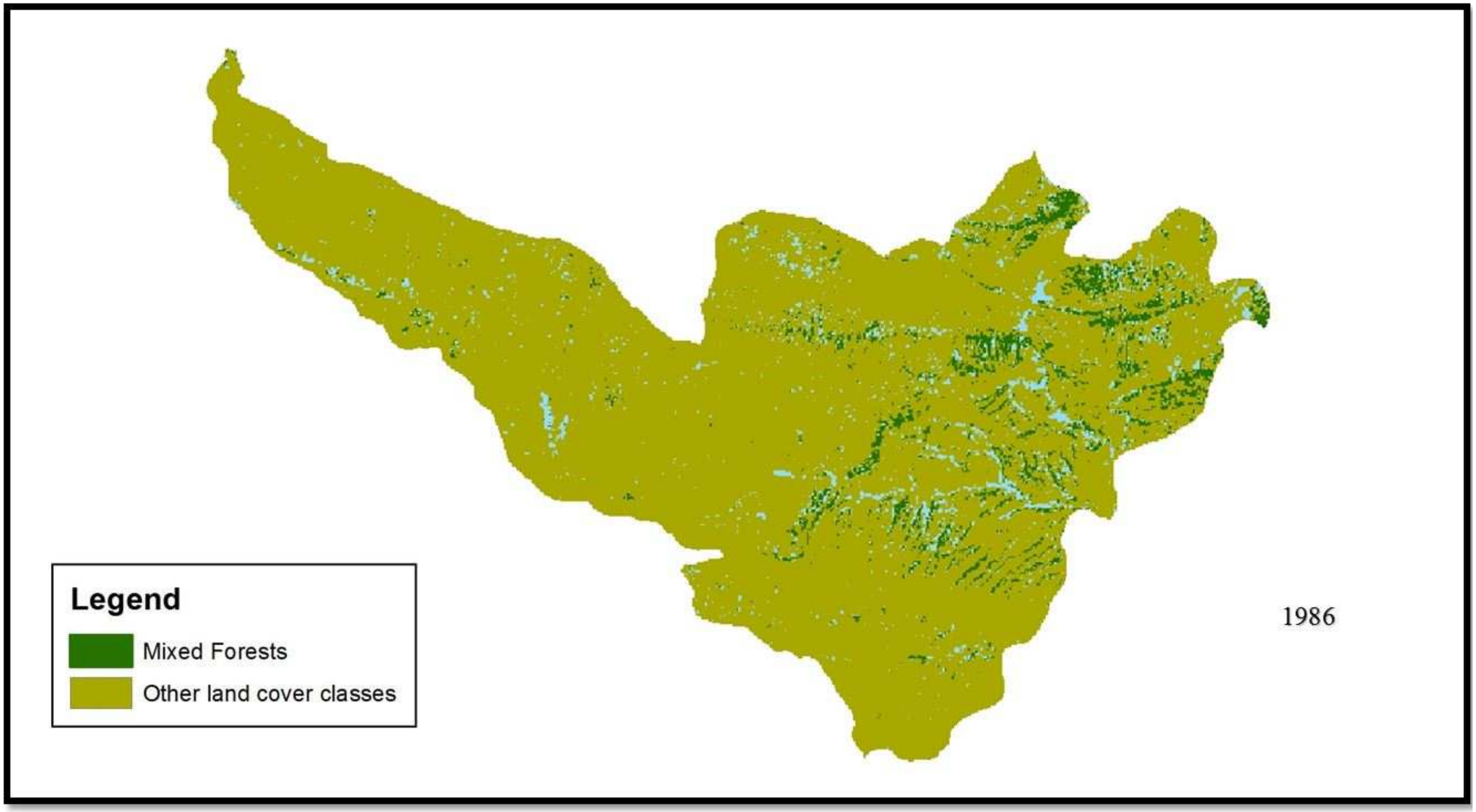

Figure 40: Mixed forest extent in Zawita sub-district for 1986.

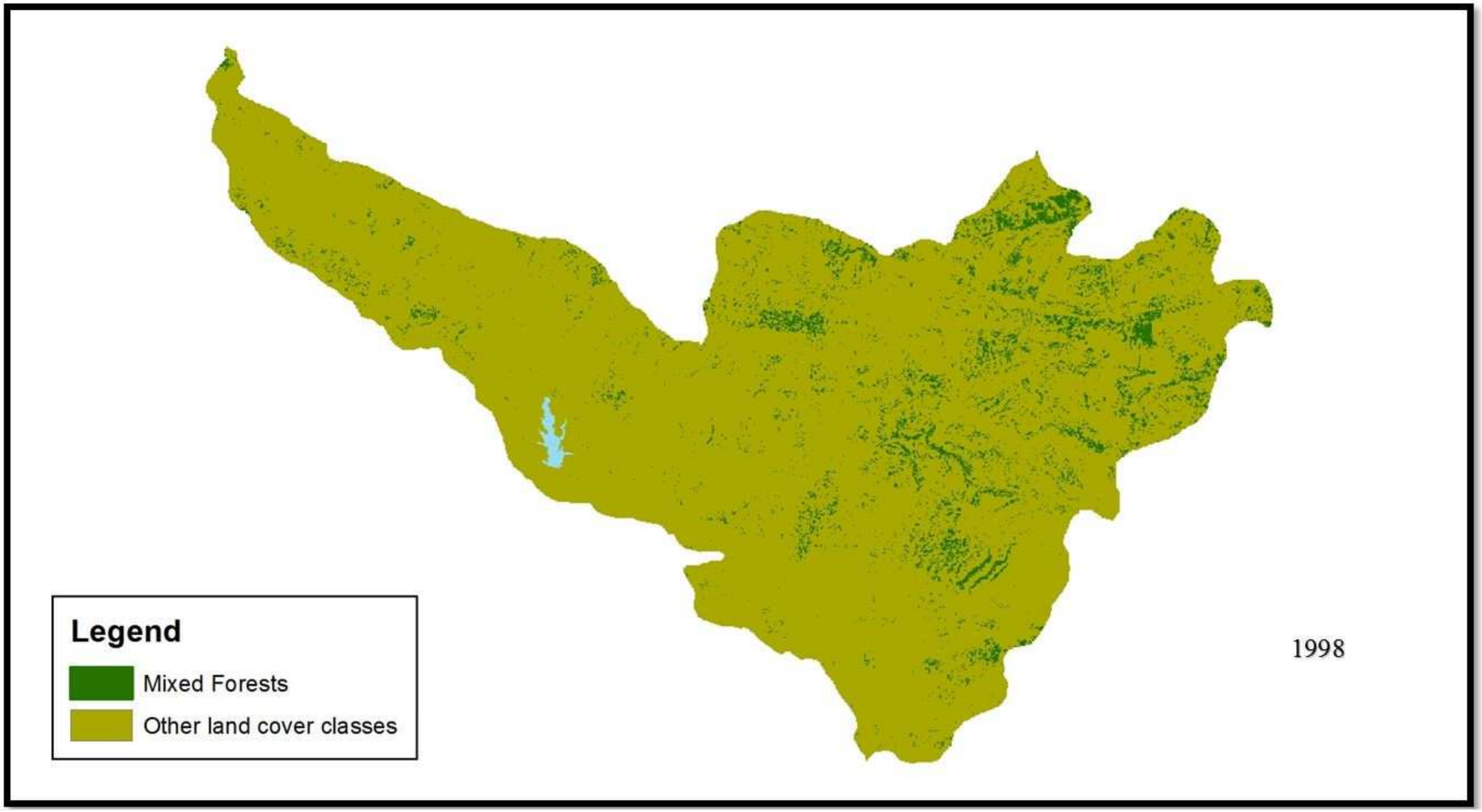

Figure 41: Mixed forest extent in Zawita sub-district for 1998.

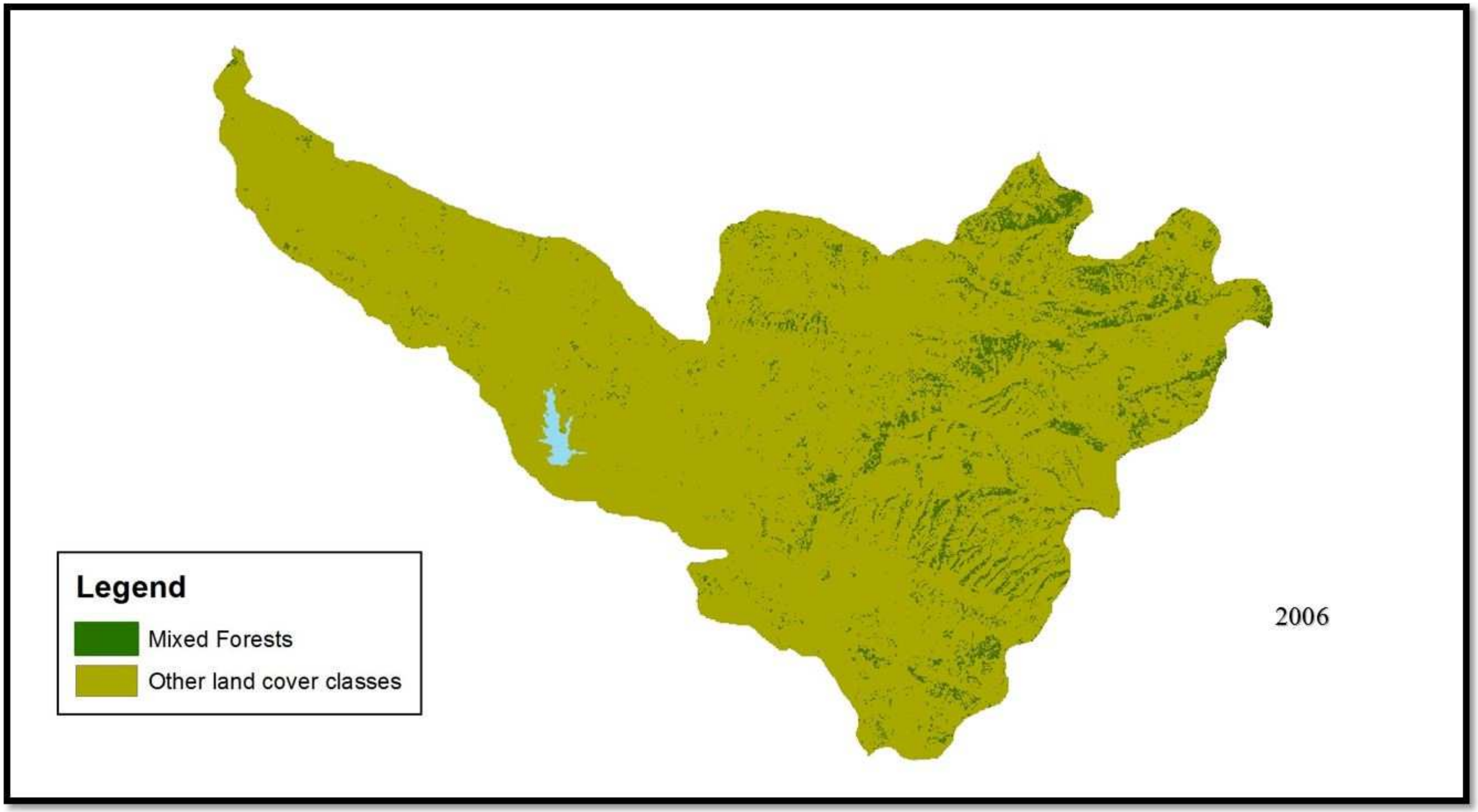

Figure 42: Mixed forest extent in Zawita sub-district for 2006.

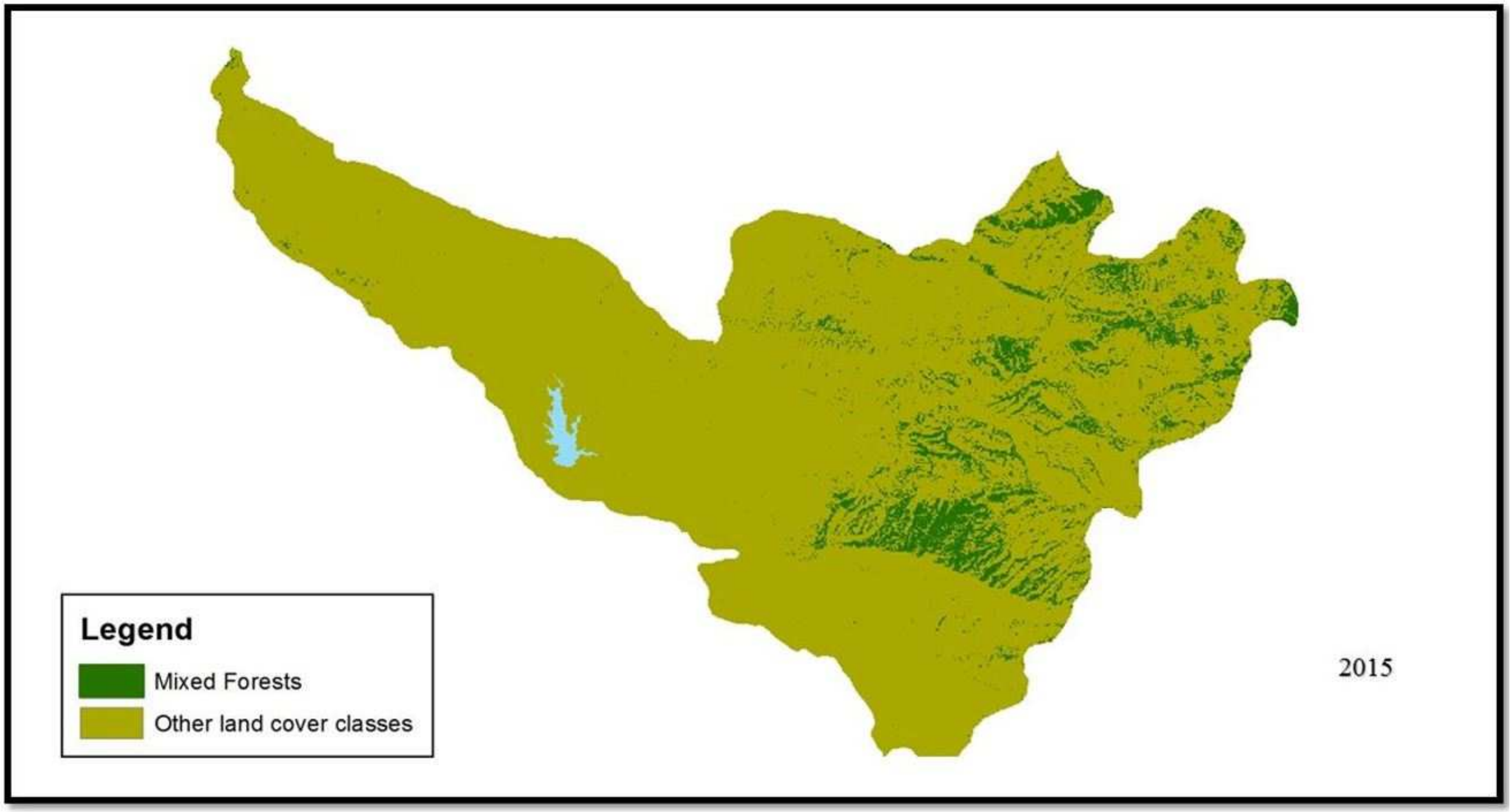

Figure 43: Mixed forest extent in Zawita sub-district for 2015.

Appendix D: Survey sample 2015

Village:	Date of visit:
Household ID:	GPS coordinate of house
Section 1. Household Information	

1. How long has your family been living here?	Check that Apply	
	a- 1-5 years	
	b- 6-10 years	
	c- 11-15 years	
	d- 16-20 years	

2. Where were you living previously?	Check that Apply	
	Urban areas (please check below)	
	1- Erbil	
	2- Sulimani	
	3- Duhok	
	4- Zakho	
	Other rural area (please check below)	
	1- Barware Bala	
	2- Doski area	
	3- kochar area	
	4- Muzori area	
	c- Same village (different house)	
	d- Others	

3. Has any member of your household have had migrated from the village to the city?	Write your answer below			
	Relationship to the household	Where they are migrated to	Reasons	year
	a-Father	a-city	a- Poor facilities	
	b-Mother	b- Another village	b- Poor transportation	
	c-Brother	c- outside the country	c- Poor job opportunity	
	d-Sister		d- Poor education	
	e- daughter		e- Farming degradation	
	f-son		f- Marriage	
			g-War	
			h- Others	

4- Your family thinks of forests in general as? Choose one or more	Write your answer below	
	a- As a scenic place	
	b- As a shelter	
	c-As a safe place	
	d- As an income source	
	e-others	

5. How important was forest availability in your decision to live here?	Check that apply	
	a-Extremely	
	b- Very	
	c- Moderately	
	d- Not very	
	e- Not at All	

6. Did forest availability influence your decision to move?	Check that apply	
	a-Extremely influential	
	b- very influential	
	c- moderately influential	
	d- not very influential	
	e. Not influential at all	

7. How important is forest availability in your decision to live here?	Check that apply	
	a-Extremely	
	b- Very	
	c- Moderately	
	d- Not very	
	e- Not at All	

8. How much does your household depend on forest resources?	Check that Apply	
	a-extremely dependent	
	b-very dependent	
	c-moderately dependent	
	d- Not very dependent	
	e- Not dependent at All	

9. How important are forest resources for firewood for your household?	Check all that Apply	
	a- Extremely important Cooking fuel	

	b- Very important	
	c- Moderately Important charcoal	
	d- Not very important	
	e-Not important at All	

10. How important are forest resources for fencing for your household?	Check that Apply	
	a- Extremely important	
	b- very important	
	c- Moderately important	
	d- Not very important	
	e- Not important at All	

11. How important are forest resources for making charcoal for you and your family income?	Check that Apply	
	a- Extremely important	
	b- very important	
	c- Moderately important	
	d- Not very important	
	e- Not important at All	

12. How important are forest`s resources for shelter for your household?	Check that Apply	
	a- Extremely important	
	b- Very important	
	c- Moderately important	
	d- Not very important	
	e- Not important at All	

13. What tree or/and plant species do you prefer for the following purposes, please indicate their availability within the forest you use?	Please specify		
	Purpose	Tree or/and plant species *Please specify	Availability
	a- Firewood		a- widely available
	b- House fencing		b- somewhat available
	c-Charcoal		c- rarely available

	d-Others		d-unavailable

14. How much do you think the forests you use or visit degraded over time?	Check that Apply	
	a- Extremely degraded	
	b- Very degraded	
	c- Moderately degraded	
	d- Not very degraded	
	e- Not degraded at All	

15- How important is/was tree cutting to deforestation and forest degradation?	Check all that Apply	
	a- Extremely important	
	b- very important	
	c- Moderately important	
	d- Not very important	
	e- Not important at All	

16- How important is/was fire to deforestation and forest degradation?	Check that Apply	
	a- Extremely important	
	b- very important	
	c- Moderately important	
	d- Not very important	
	e- Not important at All	

17- How important is/was soil erosion to deforestation and forest degradation?	Check that Apply	
	a- Extremely important	
	b- very important	
	c- Moderately important	
	d- Not very important	
	e- Not important at All	

18- How important is/was land clearing for agriculture to deforestation and forest degradation?	Check that Apply	
	a- Extremely important	
	b- very important	
	c- Moderately important	
	d- Not very important	
	e- Not important at All	

19. Using a scale of 0 = not important to 5 = very important to rank the following factors that restrict or limits forests access and use by you and your neighbors?	Check all that Apply

Factor	0	1	2	3	4	5	No Opinion
a-Poor transportation	☐	☐	☐	☐	☐	☐	☐
b-fencing	☐	☐	☐	☐	☐	☐	☐
c- Patrol	☐	☐	☐	☐	☐	☐	☐
d- Government rules	☐	☐	☐	☐	☐	☐	☐

20- How much government rules limited your access to forest resources?	Check that Apply	
	a-Extremely	
	b- very	
	c- Moderately	
	d- Not very	
	e- Not at all	

21-How satisfied are you with these rules?	Check that Apply	
	a- Extremely Satisfied	
	b- Very satisfied	
	c- Moderately satisfied	
	d- Neither Unsatisfied Nor Satisfied	
	e. Not satisfied	

22- For how long have these rules been in place?	Please specify your answer in (year)s.

23- Government rules contribute to the problem of deforestation and forest degradation positively.	Check that Apply	
	a-Strongly agree	
	b- Agree	
	c- Neutral	
	d-Disagree	
	e- Strongly disagree	

24- Government rules contribute to the problem of deforestation and forest	Check that Apply

degradation negatively.		
	a-Strongly agree	
	b- Agree	
	c- Neutral	
	d-Disagree	
	e- Strongly disagree	

25. How important these restrictions will affect your decision to leave the place in the future?	Check that Apply	
	a-Extremely important	
	b- Very important	
	c- Moderately important	
	d-Not very important	
	e-Not important at All	

26. How much land you or your family own?	Write your answer below

27. What kind of ownership people have over forestland/ agriculture land in this region?	Check that Apply	
	a- Traditional ownership	
	b- Private ownership	
	c- Government owns the land	

28. Ownership over the land has an influence on the decision to migrate?	Check that apply	
	a-Strongly agree	
	b- Agree	
	c- Neutral	
	d-Disagree	
	e- Strongly disagree	

29. For which of the following you and your our family uses the forest and forest resources	Write your answer below

for?		
	a-Hunting	
	b-Daily burning wood	
	c-Recreation	
	d-Shelter	
	e-agroforestry	
	f-other	

30. How difficult it is for migrants from other areas to reside in this village?	Check that Apply	
	a- Extremely difficult	
	b- Very difficult	
	c- Moderately difficult	
	d- Not difficult	
	e- Not difficult at all	

Section 2: Now I just have some final questions. These are general questions about you and your family.

1- What is your gender?	Check that Apply	
	Male	
	Female	
	Others	
2- How old are you? _____________		
3-How much is your annual income?	Check that Apply	
	a-5000-10000	
	b-10000-15000	
	c-15000-20000	
	d-More than 20000$	
4- What is your religion?	Check that Apply	
	a-Muslim	
	b-Christian	
	c- Yazidi	
	d- others	

5- What is the highest level of education that you have competed?		Check that Apply	
a-Primary Incomplete or No education		e- University Incomplete	
b-Primary complete		f- University Degree Complete	
c- Secondary Incomplete		g- Graduate School (Incomplete or Complete)	
d- Secondary Complete			

6- How much of your income comes from agriculture?	Check that Apply	
	a- Entire income	
	b- 50% of the income	
	c-25% of the income	
	d-5% of the income	
	e- Nothing at all	

7-How much forests resources compose of your income?	Check that Apply	
	a- Entire income	
	b- 50% of the income	
	c-25% of the income	
	d-5% of the income	
	e- Nothing at all	

Appendix E: Survey sample 2014

Village:	Date of visit:
Household ID:	GPS coordinate of house
Section1. Household Information	

1. How long has your family been living here? If you answer A, B, C and D, please answer question number (2), (3), and (4) too.	Check that Apply	
	a- 1-5 years	
	b- 6-10 years	
	c- 11-15 years	
	d- 16-20 years	

2. Where were you living previously?	Check that Apply	
	Urban areas (please check below)	
	1- Erbil	
	2- Sulimani	
	3- Duhok	
	4- Zakho	
	Other rural area (please check below)	
	1- Barware Bala	
	2- Doski area	
	3- kochar area	
	4- Muzori area	
	c- Same village (different house)	
	d- Others	

3. What were the reasons behind your decision of moving?	Check that Apply	
	a- Poor facilities	
	b- Poor transportation	
	c- Poor job opportunity	
	d- Poor education	
	e- Farming degradation	
	f- Marriage	
	g-War	
	h- Others	

4. How much forest limited availability influenced your decision to move?	Check that apply	
	a-Extremely	
	b- very	
	c- moderately	
	d- not very	
	e. Not at All	

5. How important was forest availability in your decision to live here?	Check that apply	
	a-Extremely	
	b- Very	
	c- Moderately	
	d- Not very	
	e- Not at All	

6. How much does your household depend on forest resources?	Check that Apply	
	a-extremely dependent	
	b-very dependent	
	c-moderately dependent	
	d- Not very dependent	
	e- Not dependent at All	

7. How important are forest resources for firewood for your household?	Check all that Apply	
	a- Extremely important Cooking fuel	
	b- Very important	
	c- Moderately Important charcoal	
	d- Not very important	
	e-Not important at All	

8. How important are forest resources for fencing for your household?	Check that Apply	
	a- Extremely important	
	b- very important	
	c- Moderately important	
	d- Not very important	
	e- Not important at All	

9. How important are forest resources for making charcoal for your household?	Check that Apply	
	a- Extremely important	
	b- very important	
	c- Moderately important	
	d- Not very important	
	e- Not important at All	

10. How important is forest resources for shelter for your household?	Check that Apply	
	a- Extremely important	
	b- Very important	
	c- Moderately important	
	d- Not very important	

	e- Not important at All	

11. What tree or/and plant species do you prefer for the following purposes, please indicate their availability within the forest you use?	Please specify		
	Purpose	Tree or/and plant species *Please specify	Availability
	a- Firewood		Yes No
	b- House fencing		Yes No
	c-Charcoal		Yes No
	d-Others		Yes No

12. How much do you think the forests you use or visit degraded over time? If your answer is A or B, please answer question number (10) too.	Check that Apply	
	a- Extremely degraded	
	b- Very degraded	
	c- Moderately degraded	
	d- Not very degraded	
	e- Not degraded at All	

13- How important is/was tree cutting to deforestation and forest degradation?	Check all that Apply	
	a- Extremely important	
	b- very important	
	c- Moderately important	
	d- Not very important	
	e- Not important at All	

14- How important is/was fire to deforestation and forest degradation?	Check that Apply	
	a- Extremely important	
	b- very important	
	c- Moderately important	
	d- Not very important	
	e- Not important at All	

15- How important is/was soil erosion to deforestation and forest degradation?	Check that Apply	
	a- Extremely important	
	b- very important	
	c- Moderately important	
	d- Not very important	
	e- Not important at All	

16- How important is/was land clearing for agriculture to deforestation and forest degradation?	Check that Apply	
	a- Extremely important	
	b- very important	
	c- Moderately important	
	d- Not very important	
	e- Not important at All	

17. Using a scale of 0 = not important to 5 = very important to rank the following factors that restrict or limits forests access and use by you and your neighbors?	Check all that Apply	0	1	2	3	4	5	No Opinion
	a-Poor transportation	☐	☐	☐	☐	☐	☐	☐
	b-fencing	☐	☐	☐	☐	☐	☐	☐
	c- Patrol	☐	☐	☐	☐	☐	☐	☐
	d- Government rules	☐	☐	☐	☐	☐	☐	☐

18- How much government rules limited your access to forest resources?	Check that Apply	
	a-Extremely	
	b- very	
	c- Moderately	
	d- Not very	
	e- Not at all	
19-How satisfied are you with these rules?	Check that Apply	
	a- Extremely Satisfied	
	b- Very satisfied	
	c- Moderately satisfied	
	d- Neither Unsatisfied Nor Satisfied	
	e. Not satisfied	
20- For how long have these rules been in place?	Please specify your answer in (year)s.	
21- In your opinion how significantly have government rules contributed to the problem of deforestation and forest degradation?	Check that Apply	
	a- Extremely	
	b-Very	
	c-Moderately	
	d- Not very	
	e- Not significant at All	

22. How important these restrictions will affect your decision to leave the place in the future?	Check that Apply	
	a-Extremely important	
	b- Very important	

	c- Moderately important	
	d-Not very important	
	e-Not important at All	

23- What kind of ownership people have over forestland in this region?	Check that Apply	
	a- Traditional ownership	
	b- Private ownership	
	c- Government owns the land	

Section 2:
Now I just have some final questions. These are general questions about you and your family.

1- What is your gender?	Check that Apply	
	Male	
	Female	
	Others	
2- How old are you? _______________		
3-How much is your annual income?	Check that Apply	
	a-5000-10000	
	b-10000-15000	
	c-15000-20000	
	d-More than 20000$	
4- What is your religion?	Check that Apply	
	a-Muslim	
	b-Christian	
	c- Yazidi	
	d- others	

5- What is the highest level of education that you have competed? Check that Apply			
a-Primary Incomplete or No education		e- University Incomplete	
b-Primary complete		f- University Degree Complete	
c- Secondary Incomplete		g- Graduate School (Incomplete or Complete)	
d- Secondary Complete			

Appendix F: Confusion matrix of 2015, 2006, 1998, and 1986 classification map respectively

Table 21: 1986 confusion matrix.

Land Classes	Water	Urban	Coniferous Forests	Broadleaves Forests	Mixed Forests	Barren land	Agriculture areas	Bare soil	Ground truth
water	50	0.0	0	0	0	0	0	0	50
Urban	0	46.0	0	0	0	3	0	2	51
Coniferous forests	0	0.0	45	0	2	0	1	0	48
Broad-leaved forests	0	0.0	1	45	4	0	6	3	59
Mixed forests	0	0.0	2	1	44	0	0	0	47
Barren land	0	4.0	0	0	0	45	2	11	62
Agriculture areas	0	0.0	2	3	0	2	41	7	55
Bare soil	0	0.0	0	0	0	0	0	27	27
References	50	50.0	50	49	50	50	50	50	399

Table 22: 1998 confusion matrix.

Land Classes	Water	Barren land	Agriculture areas	Coniferous forests	Mixed forests	Bare soil	Broad-leaved forests	Urban	Ground truth
water	50	0	0	0	0	0	0	0	50
Barren land	0	47	0	0	0	0	0	5	52
Agriculture areas	0	0	49	0	0	0	0	0	49
Coniferous forests	0	0	0	48	3	0	0	0	51
Mixed forests	0	0	0	1	40	0	2	0	43
Bare soil	0	0	0	0	0	49	2	1	52
Broad-leaved forests	0	2	1	1	7	1	46	1	59
urban	0	1	0	0	0	0	0	43	44
References	50	50	50	50	50	50	50	50	400

Table 23: 2006 confusion matrix.

Land Classes	Water	Bare soil	Barren land	Broad-leaved Forests	Mixed Forests	Agriculture areas	Urban	Coniferous Forests	Ground truth
water	50	0	0	0	0	0	0	0	50
Bare soil	0	34	9	1	0	0	0	2	46
Barren land	0	15	41	0	0	0	0	0	56
Broad-leaved forests	0	1	0	49	1	0	0	0	51
Mixed forests	0	0	0	0	49	0	0	2	51
Agriculture areas	0	0	0	0	0	49	0	0	49
Urban	0	0	0	0	0	0	50	0	50
Coniferous forests	0	0	0	0	0	0	0	46	46
References	50	50	50	50	50	49	50	50	399

Table 24: 2015 confusion matrix.

Land Classes	Agriculture areas	Water	Coniferous forests	Mixed forests	Broad-leaved forests	Bare soil	Barren land	urban	Ground truth
Water	-	49	0	0	0	0	0	0	49
Coniferous forests	-	1	47	1	0	0	0	0	49
Mixed forests	-	0	1	49	0	0	0	0	50
Broad-leaved forests	-	0	1	0	50	0	0	0	51
Bare soil	-	0	0	0	0	50	0	0	50
Barren land	-	0	1	0	0	0	49	0	50
Urban	-	0	0	0	0	0	1	50	51
References	-	50	50	50	50	50	50	50	350

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