LAND COVER AND LAND USE CHANGE IN MOUNT LEBANON

Master Thesis

By

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DEDICATION

I dedicate my thesis work to my family and many friends. A special feeling of gratitude to my loving parents, Jaafar and Nada Naser Aldine whose words of encouragement and push for tenacity ring in my ears. My beloved wife, Alaa who has never left my side and is very special. I also dedicate this thesis to my many friends who have supported me throughout the process. I will always appreciate all they have done.

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I have taken efforts in this project. However, it would not have been possible without the kind support and help of many individuals. I would like to extend my sincere thanks to all of them.

Thanks, and appreciations also go to my colleague in developing the project and people who have willingly helped me out with their abilities.

ABSTRACT

Monitoring and detecting the changes of land use and land cover of the earth's surface is extremely important to achieve and maintain continual and precise information about study area for any kinds of planning of the development. Geographic information system (GIS) and remote sensing technologies have shown their great capabilities to solve the study issues like land use and land cover changes. The aim of this thesis is to produce data in form of maps and statistics of land use and land cover of Mount-Lebanon Area (Aley, Souk Al-Ghareb, Bmakine, Ain-Remmeneh, and Qmatieh) over 18 years period (2005-2022) to monitor the possible changes that may occur particularly in urban or built-up land, agricultural land and forestry Land , and detect the process of urbanization in these areas. Three High Resolution satellite imageries data; IKONOS, BASEMAP, and SAS for the years namely: 2005, 2017, and 2022 were used respectively in this thesis. Also LANDSAT data of three different years (2005, 2017, and 2021) were used in this study using different approach.

In this study, CORINE classification and supervised classification were the major classifications approach to provide classified maps, and four land use and land cover categories were identified and mapped.

TABLE OF CONTENTS

LIST OF TABLES

TABLE OF FIGURES

CHAPTER 1. INTRODUCTION

The land resource is one of the most important resources for human beings. Exploring and using land resource reasonably is the basic principle for development of human society. Therefore, the issue of the land use and land cover changes (LUCC) is an extremely valuable subject to be studied. In addition, as a symbol of human culture, the urbanization which can be related to the LUCC is also worth studying. In this chapter, the whole background knowledge of the LUCC and urbanization are introduced in the first section. Moreover, the aims of this study and the structure of this study are also drawn in the following section.

1.1. BACKGROUND

The knowledge of the LUCC is essential for human activities such as population dynamics, land management, education and data for future use. The study of gradual or sudden natural changes in the surface of the earth provide valuable understanding of the interactions between natural environment and human activities. The land resource is one of the essential and basic resources for living and developing of human. To be able to achieve the sustainable use of land resource, it is necessary to know the changes, historic and present status of the land resource. The changes of natural environment and impact from human activities which occur suddenly or gradually in the earth's surface are the core of LUCC. The urban area where the human beings live in is the symbol of human civilization, and it is an important place for humans to do their social activities. Urbanization is a significant characteristic of humans' modern lives. For hinterlands such as Aley, Souk Al-

Ghareb, Bmakine, Ain-Remmeneh and Qmatieh. The level of urbanization can be used to estimate the level of development of economy, social, science and technology. Meanwhile, it is an important data to monitor the inflation rate at which the general level of buildings is rising and, consequently, the land cover (grass, trees, irrigation…) is falling.

Monitoring of LUCC from multi-period satellite images which contain plentiful information about earth surface will provide the comprehensive data to analyze the changes between different ground features. There are two general applications of satellite image which are generating map of land use and land cover by image classification and then the results of the changes of land use and land cover can be achieved by change detection. The primary use of satellite pictures in this research is to map the land cover and identify changes to the land cover using an image classification approach. Thus, one way of monitoring the process of urbanization is to perform the classification-based change detection by using the satellite images of the urban areas. Change detection is not only used for urban applications but also for forest application or other changes of land cover. (taff, 2014)

1.2. WHY REMOTE SENSING?

Tracing paper and topographic maps were once used to detect changes in land use and cover when there were no remotely sensed data or computer assistance. However, this method was tiresome and took a lot of time and effort to investigate broad areas. Traditional ground-based land use mapping techniques require a lot of work, take a long time, and are used less regularly. Thus, with the advent of satellite remote sensing techniques, preparing accurate land use land cover maps and monitoring changes at regular intervals of time is relatively simpler. In case of inaccessible region, the only method of obtaining required data is by applying this technique. (MAJUMDER, 2010)

Today, remote sensing and GIS technology has enabled ecologists and natural resources managers to acquire timely data and observe periodical changes. With multi-temporal analyses, remote sensing gives a unique perspective of how rural area evolves. The most important element for mapping land use change due to mining is the ability to discriminate between rural uses (farming, forests and water body) and quarries. “Remote sensing methods can be employed to classify types of land use in a practical, economical and repetitive fashion, over large areas.” (Dr.T.RAVISANKAR, 2017)

1.3. AIMS OF THIS THESIS

The long-term aim of this study is using GIS technologies and RS data to monitor and analyze the LUCC especially the urban growth in Mount-Lebanon. To achieve the long-term aim, three short-term aims should be completed. To be more specific, firstly, prepare the satellite imageries data and assign different band combinations in order to maximize the information revealed from the RS images for image classification. Secondly, carry out CORINE classification (visual interpretation) and supervised image classification based on which layer represents which type, in order to perform urban change detection. Thirdly, analyze LUCC, especially urbanization and verify changes which are worth to use based on results of urban change detection.

1.4. ORGANIZATION OF THIS THESIS

This thesis can be divided into three parts from a macro view which are the introduction and description to the important component of the thesis, the steps to complete the data processing, and the explanation and illustration of the results. First of all, this thesis is organized in eight chapters, and it is starting with an introduction part to a description of the thesis. In the introduction part, the whole background information and knowledge is introduced. The following chapter provides a literature review which introduces some helpful background of techniques used in this study. A description of the study area and the satellite image data is followed by an introduction of the process of this thesis.

After then, the detailed preprocessing and processing are illustrated and explained. The fifth chapter is the detailed steps of the whole processes, and the important figures are used to explain the processes. In the sixth chapter, the results of LUCC in Mount-Lebanon area from three different periods are presented and analyzed, and then some discussions of the results and the problems of this thesis are completed. The seventh chapter is the conclusion of this thesis. And the following two chapters are the references and appendices.

CHAPTER 2. LITERATURE REVIEW

In this chapter, the reviews of literatures which are related to the subject of this study are introduced. First of all, the methods from literatures to realize the detection of LUCC are introduced and explained.

Land cover is the observed biological and physical properties of the earth surface, such as grass, asphalt, trees, water … ETC. A land cover map should discriminate between natural and manmade features. While, land use describes the utilization and activities people undertake in certain land cover type in order to change or maintain it, such as agriculture, forestry, and building construction. Thus, land use is derived from land cover, and one land cover type may be associated with different land use.

Respectable researches of LUCC have been achieved Over the last decades. The understanding and the knowledge that researches and workers have developed of LUCC has improved the methodologies to monitor and analyze the LUCC. Improved understandings of the dynamic changes of land use and covers will allow more valuable and reliable progress to detect the changes of land resource on the earth's surface. Besides, improved knowledge of LUCC provides an understanding of impact from human activities.

The combination and utilization of GIS and RS to research the issue of LUCC is valuable. Using technologies of GIS to analyze the RS data is a convenient way to monitor the changes of land use and covers. To be more specific, RS is the science and art of acquiring spectral, spatial and temporal information about both natural and humanistic features by devices without any physical and directly contact with the objects of measurement on the earth (WIley, 2004). The satellite image of remote sensing contains a wide area of the earth. In this case, the study area of land use and land cover changes is always a large area. That means the remote sensing technology can provide detailed and quantitative data of land surface in a wide range (Remote Sensing-Based quantification of the relationships between Land Use Land Cover Changes, 2004).

2.1. HISTORY & EVOLUTION OF LAND COVER/LAND USE MAPS

Traditional land cover/land use mapping was a challenging task, and the resulting maps lacked precision and accuracy. Nowadays, with the evolution of remote sensing and GIS techniques establishing, updating and monitoring the land use/cover changes is more reliable, precise, dynamic, and constant (Land-Use & Cover Change Modeling, 2006).

The degradation of the land is not always implied by changes in land cover due to land use. However, a range of societal factors, such as shifting land use patterns, lead to land cover changes that have an impact on biodiversity, water and radiation budgets, trace gas emissions, and other processes that interact to affect climate and the biosphere. (A LITERATURE REVIEW ON LAND USE LAND COVER CHANGES, 2018).

Land cover changes may also be triggered by natural occurrences including weather, flooding, fire, climate fluctuations, and ecosystem dynamics.. Globally, land cover is mostly changed by direct human activity, such as agriculture and livestock raising, forest harvesting and management and urban and suburban construction and development. There are also incidental impacts on land cover from other human activities such as forest and lakes damaged by acid rain from fossil fuel combustion and crops near cities damaged by tropospheric ozone resulting from automobile exhaust (Meyer, 1995).

In july, 2003, the remote sensing and geographic information science center at Michigan State University was reorganized and renamed, once, one more to become remote sensing and GIS research and outreach services (RS and GIS). The expert staff and the commitment to the advancement of geospatial technologies in the primary areas of agriculture and natural resources has remained the same. At present time, RS and GIS are leading the IMAGIN (Improving Michigan's Access to Geographic Information Network) land cover/use classification committee, authoring a working white paper addressing modifications to the Michigan land cover/use classification system and standarized methodology for updating land cover/use (Noehles, 2000).

2.2. IMAGE CLASSIFICATION

Mapping from remotely sensed data is typically based on an image classification. This may be achieved by either visual or computer-aided analysis. The classification may be one that seeks to group together cases by their relative spectral similarity (unsupervised) or that aims to allocate cases on the basis of their similarity to a set of predefined classes that have been characterized spectrally (supervised). In each situation, the resulting classified image may be treated as a thematic map depicting the land cover of the region. Although remote sensing has been used successfully in mapping a range of land covers at a variety of spatial and temporal scales, its full potential as a source of land cover information has not been realized (Land Cover, 1992).

2.2.1. Visual Interpretation

Visual interpretation is the photo interpretation of images based on features tone, pattern, shape, size, shadow, texture and association. Most of the conventional digital image processing techniques are based on color or size or texture or tonal variation of each pixel in the image. In contrast to digital analysis of the images, a human interpreter does not interpret the image pixel by pixel. Instead, he or she exploits the aggregate information related to various basic image-features of unknown objects along with his scientific knowledge of the phenomena (American Society for photogrammetry & Remote Sensing), general knowledge of the phenomena as well as experience to do classification. As a consequence, the interpretation result for land use and land cover produced by a well-trained human interpreter is often less crude than the same obtained using digital techniques (D.C, 1997).

2.2.2. Supervised Classification

In supervised classification, the spectral signatures are developed from specified locations in the image. These specified locations are given the generic name ‘training sites’ and are defined by the user. Generally, a vector layer is digitized over the raster scene. The vector layer consists of various polygons overlaying different land use types. In this technique we classify the various land uses in GIS and image processing software.

2.2.3. Unsupervised Classification

Unsupervised classification techniques do not require the user to specify any prior information about the features contained in the images (Remote sensing & image interpretation, 3rd edition, 1994). In this technique we classify the various land uses that was done.

2.2.4. Corine Land Cover (CLC)

The European Union began CORINE, or "Coordination of Information on the Environment," or "CLC," as a program in 1985 to address various environmental challenges. Its objective was developing a land cover with 44 classes and presenting it as a cartographic output at a scale of 1:100,000. The Landsat TM image data collected between 1986 and 1995 served as the main source of data. For the management of natural and environmental resources, information on land cover is just as crucial as information on relief, drainage systems, etc. As a result, statistics on land cover serve as an important reference for a number of CORINE database initiatives. Most of the countries in central and eastern Europe, as well as some in the Maghreb, have used this dataset. An update of the CLC database has been launched in January 2000 (Corine land cover technical guide, 2000)

By using the process of visual interpretation, items seen in satellite images are identified and categorised. The set of characteristics of CLC classes will help the interpreters in image analysis, making use of interpretation elements like texture and pattern. This approach helped to clarify the many landscape types and geographical characteristics of Europe.

The CORINE land cover nomenclature is composed of three levels (Table 2-1). The first level, which consists of 5 elements, lists the major classes of land cover on earth (Artificial areas, Agricultural areas, Forests and semi-natural areas, wetlands, water bodies). The second level, which has a scale between 1:500 000 and 1:1 000 000, consists of 15 items. And finally the third level contains 44 items and used for projects on scale 1:100 000.

A fourth level could be added for some or all of the items in level 3, but the newly added items must be compatible with the scale, and the size of the smallest area to be mapped. Level 4 of CORINE is used for relatively large scale mapping, since on this level classes are more detailed.

1. Artificial surfaces	1.1. Urban fabric	1.1.1. Continuous urban fabric
		1.1.2. Discontinuous urban fabric
	1.2. Industrial, commercial and transport	1.2.1. Industrial or commercial units
		1.2.2. Road and rail networks and associated land
		1.2.3. Port areas
		1.2.4. Airports
	1.3. Mine, dump and construction sites	1.3.1. Mineral extraction sites
		1.3.2. Dump sites
		1.3.3. Construction sites
	1.4. Artificial, non-agricultural vegetated areas	1.4.1. Green urban areas
		1.4.2. Sport and leisure facilities
2. Agricultural areas	2.1. Arable land Cultivated areas regularly ploughed and generally under a rotation system.	2.1.1. Non-irrigated arable land
		2.1.2. Permanently irrigated land
		2.1.3. Rice fields
	2.2. Permanent crops	2.2.1. Vineyards
		2.2.2. Fruit trees and berry plantations

		2.2.3. Olive groves
	2.3. Pastures	2.3.1. Pastures
	2.4. Heterogeneous agricultural areas	2.4.1. Annual crops associated with permanent crops
		2.4.2. Complex cultivation
		2.4.3. Land principally occupied by agriculture, with significant areas of natural vegetation
		2.4.4. Agro-forestry areas
3. Forests and semi-natural areas	3.1. Forests	3.1.1. Broad-leaved forest
		3.1.2. Coniferous forest
		3.1.3. Mixed forest
	3.2. Shrub and/or herbaceous vegetation associations	3.2.1. Natural grassland
		3.2.2. Moors and heathland
		3.2.3. Sclerophyllous vegetation
		3.2.4. Transitional woodland/shrub
	3.3. Open spaces with little or no vegetation	3.3.1. Beaches, dunes, and sand plains
		3.3.2. Bare rock
		3.3.3. Sparsely vegetated areas
		3.3.4. Burnt areas
		3.3.5. Glaciers and perpetual snow
4. Wetlands	4.1 Inland	4.1.1. Inland marshes
		4.1.2. Peatbogs
	4.2. Coastal wetlands	4.2.1. Salt marshes
		4.2.2. Salinas
		4.2.3. Intertidal flats
	5.1. Inland waters	5.1. 1. Water courses

5. Water bodies		
		5.1.2. Water bodies
	5.2. Marine waters	5.2.1. Coastal lagoons
		5.2.2. Estuaries
		5.2.3. Sea and ocean

Table 2-1 CORINE land cover nomenclature, NOTE: Reprinted from About CORINE Land Cover, 2016, retrieved from http://ec.europa.eu Copy right 2016

2.3. LUC SERVICES, NOMENCLATURE, AND SCALE

2.3.1. Global Land Cover/Use

a- Service of a global land cover/use:

For land cover/land use projects, a variety of services and techniques are employed. In order to track global land usage, the Kyoto Protocol produced global land cover mapping in the year 2000. The overall goal was to create a global, standardized land cover database for the year 2000. In fact, the year 2000 was used as a benchmark for environmental assessment in relation to a variety of initiatives, particularly the international conventions on ecosystems organized by the United Nations in response to the demands of an environmental assessment in the context of international conventions. The Kyoto protocol could be considered as the driving force behind this project. (GMES) Global monitoring of environment and security is part of global land cover mapping where its main aims are: desertification, land cover change and food security. In order to carry out a good-working monitor system, this global classification should be performed each 5 years. The ability to more effectively monitor the environment is one of GLC2000's main benefits. As a result, it will be easier to forecast weather, avoid natural and man-made disasters, and research ecosystems, biodiversity, and climate change. We can keep a closer eye on how human activity and climate change are affecting the environment. Furthermore, GLC2000 maps can close a significant information gap in terms of how vegetation and land cover are distributed around the earth as seen in figure 1. By cooperating, scientists from all around the world have provided us with a distinct, precise image of the condition of our planet's surface as we approached the third millennium, according to European Research Commissioner Phillippe Busqion.

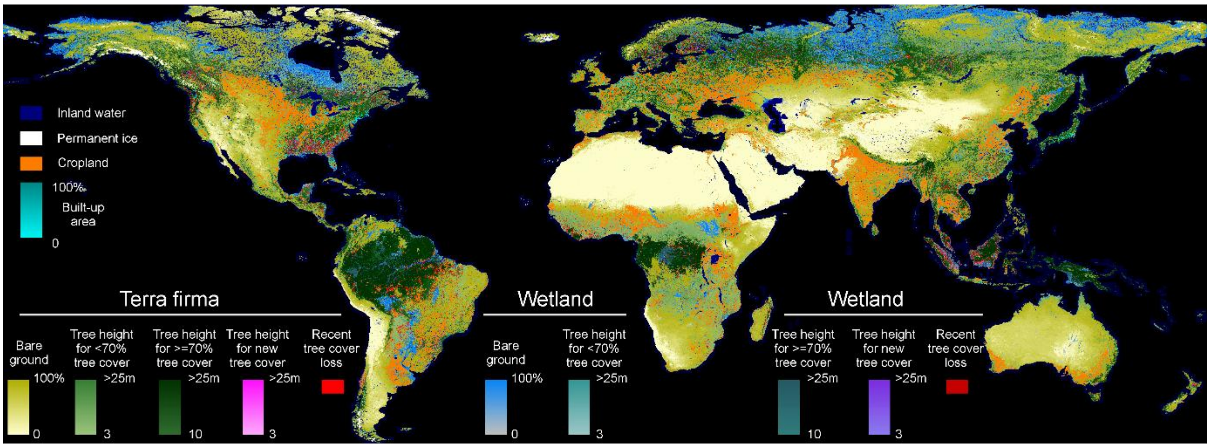


Figure 2-1: Example of Global Land Cover/Use Map

b- Scales used in Global Land cover/use:

Scales used in global land cover mapping program ranges between 1:5000 000 for continental reconnaissance surveys to 1:1000 for intensive surveys of local soil management problems surveying proceeds on a grid (for large scales) or free survey patterns (for small scales).

Its resolution is approximately 1 km and the source is known as International Geo-sphere Biosphere-project.

c- Nomenclatures used in Global land cover/use map:

The nomenclatures, which are lists of categories used to synthesize and organize information, are names used in an art or science, were based on 19 categories.

With the introduction of Earth observation polar orbiting satellites in the 1970s, mapping the whole surface of our planet finally became simpler. Images from space were used to map different parts of the world, but it took until the 1990s to gather, process and analyze the first complete global data set. Based on satellite data acquired between 1992 and 1993, the resulting land cover map has been extensively used for climate modeling, resource management and ecosystem studies. Nevertheless, since 1993 our planet’s land cover has changed and, in some cases, these changes have been quite considerable. For instance, since 1993, each year over 6,000,000 hectares of humid tropical forest have vanished. At the same time, more advanced sensors have been placed in orbit, and scientists have learned more about how to use the data these sensors produce to construct maps of the land. The GLC2000 project is a step in this process of scientific and technological development.

CHAPTER 3. METHODOLOGY

The detailed methodology adopted in this thesis to achieve the above objective is described in this chapter.

Two methods or systems for land cover/use classifications were used in this study. The Corine Land Cover classification system and the supervised classification system. Each system will be examined alone taking into account the criteria and classifiers used in deriving subclasses.

After studying the nomenclature of each system, a comparison can be set out between the numbers of classes in the two systems. Comparison between the two systems can be applied on the same level, leading us to figure out the amount of details being captured after this comparison. Moreover, the best method of comparison is to convert the system with more details (Corine Land Cover System) to level one of classification (as the supervised classification system) due to the different number of classes in each system.

Finally, in order to evaluate the feasibility of the comparison, a specific study area of Lebanon will be chosen to be subjected to CORINE and Supervised classification, and the results will be tested to see its efficiency.

Flowchart of the broad steps followed in this work for deriving statistics of land use pattern of the area is shown in Figure 3-1.

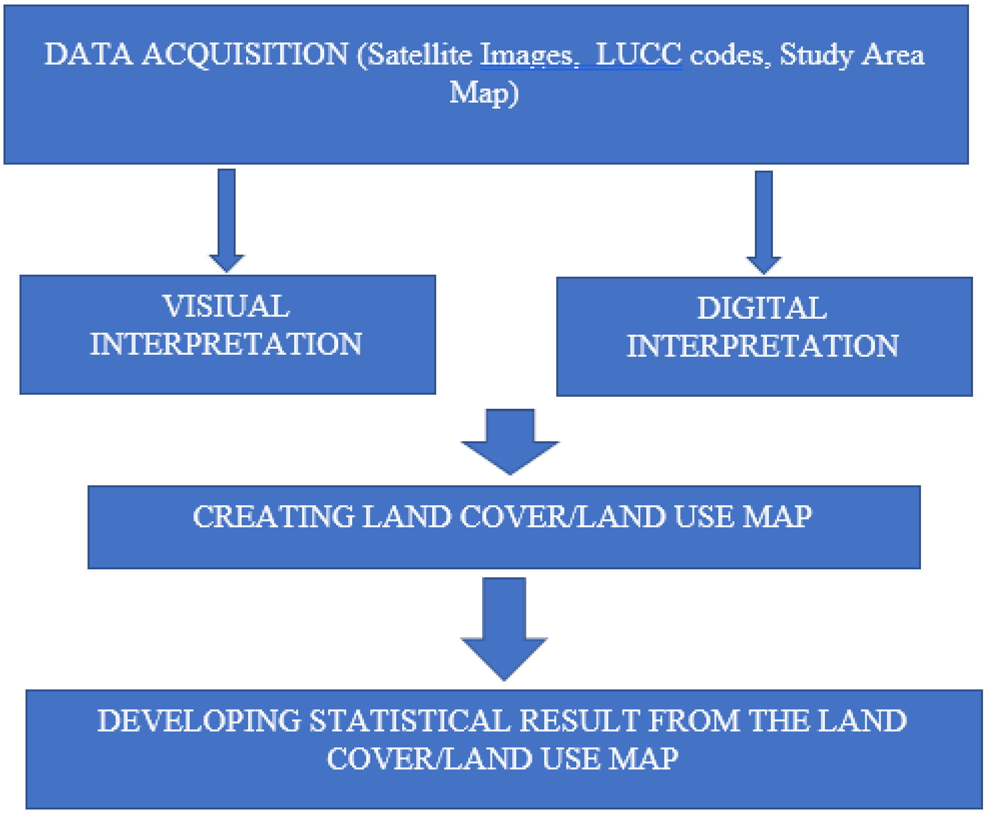


Figure 3-1: Flowchart of the methodology

3.1. DATA ACQUIRED AND SOURCE:

For the CLC study, IKONOS, base-map, and SAS satellite data of Lebanon were acquired for three years namely, 2005, 2017 and 2022 respectively. All the Satellite images have been taken from CNRS. The 2005 image has a resolution of 1m, while 2017 and 2022 images have a resolution of 30 cm. Moreover, for the supervised land cover study, multispectral, multi-temporal LANDSAT satellite data of Lebanon were acquired for same years namely, 2005, 2017, and 2022. All the LANDSAT images have been taken from EarthExplorer. All the LANDSAT images have resolution of 30 metres, and all were brought to Universal Transverse Marcator (UTM) projection in zone 36N.

SI No.	Data Type	Data Production	Scale	Resolution	Source
1	Landsat image (TM)	2005	30m	30m	EarthExplorer https://earthexplorer.usgs.gov/
2	Landsat image (TM)	2017	30m	30m	EarthExplorer https://earthexplorer.usgs.gov/
3	Landsat image (TM)	2021	30m	30m	EarthExplorer https://earthexplorer.usgs.gov/
4	IKONOS	2005	1:20,000	1m	CNRS
5	Base-Map	2017	1:20,000	30cm	CNRS
6	SAS	2022	1:20,000	30cm	CNRS

Table 3-1: Data Source

3.2. SOFTWARE USED IN THIS THESIS

Three following softwares were used for this project:

ARCGIS 10.3 - This was used for classification by digital and visual interpretation and to create the land cover/ land use pattern.

GOOGLE EARTH – This was used as an aid for the visual interpretation to get a clearer image of the scene under investigation.

EXCEL- This was used to create and develop statistical results for the LUCC using graphs and tables.

3.3. CORINE CLASSIFICATION

Land use/Land cover maps for the years 2005, 2017, and 2022 have been created using ArcMap for land use analysis (shown in figure 4-6). The steps followed for analysis are - (a) Digitization of different classes using polygon tool, (b) displaying all the different classes in the same layer, and (c) calculating area of each class. These data of three years were analyzed and changes in land use pattern detected by creating a land use table (Table 4-1) with which featured area of different classes are mentioned.

3.3.1. CLC Classification of Study Area at Level 4

Digging deeper into more details the IKONOS satellite image of 2005 was first added to the ArcMap and an editing session was started at a scale of 1/20,000. Then we started delineating the polygons according to CORINE nomenclature adopted for Lebanon at level 4, while taking into consideration the minimum representative area in the land cover/land use map is 10,000 square meters according to the minimum representative scale. Later on, after the delineation was finished and the attribute table was filled, a sum of the area of the classified types at level 4 was measured and calculated and then also transformed into level 1 classification to compare it with the results of the LUC maps that are obtained from the base-map satellite image on 2017 and SAS satellite image on 2022 at level 1 and 4 (see figure 3-2 and 3-3).

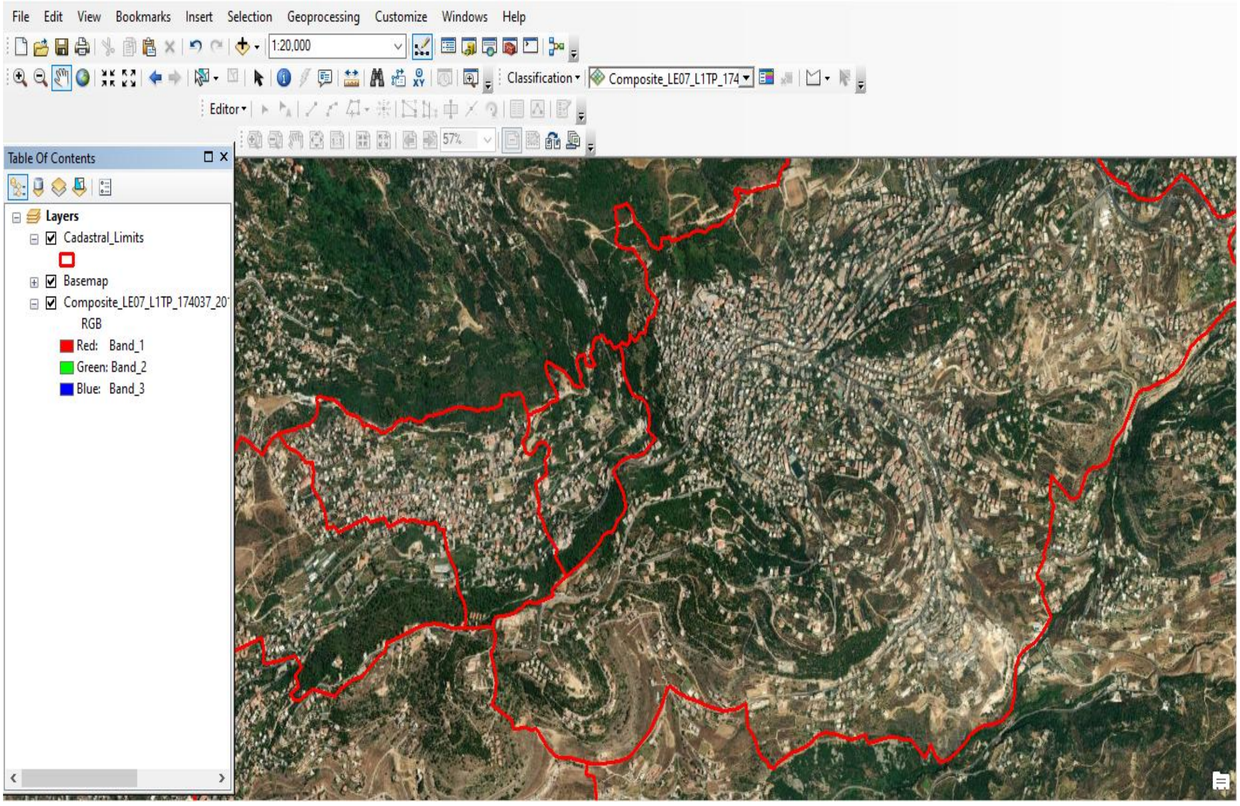


Figure 3-2:The Use of GIS(ArcMap) in the LUC Mapping

Figure 3-3:Example of Digitizing and coding using CORINE Classification

3.3.2. CLC Classification of Study Area at Level 1

In order to translate the LUC maps created using CLC classification at level 4 for the years 2005, 2017, and 2022, some steps were followed starting by selecting classes by the mean of attribute and then merging them in an editing session into one class that correspond to each category (Artificial, Agricultural, wooded land, or unproductive area). Later, after the translation was completed, areas were calculated and measured and maps were produced for each year alone (see figures 3-3 and 3-4) .

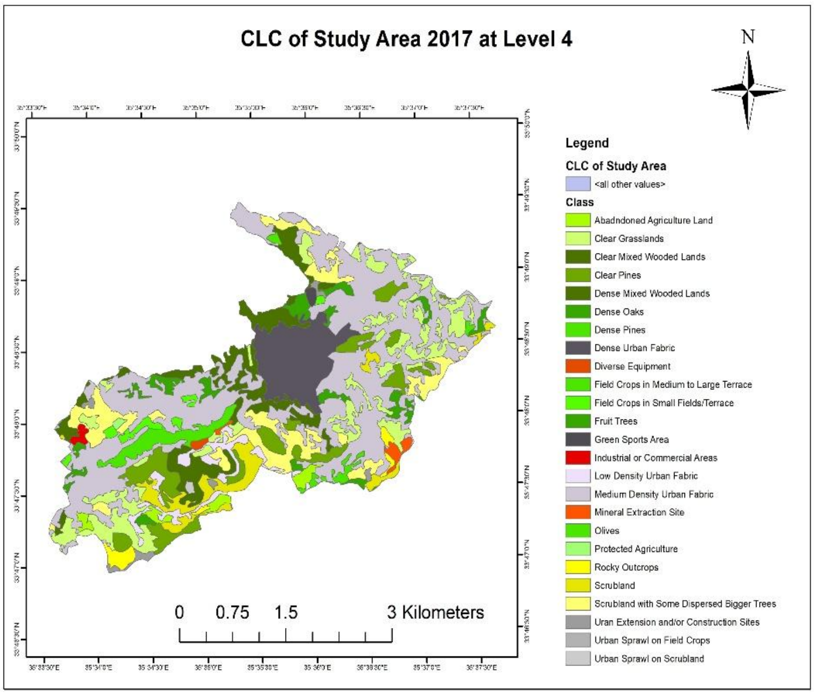


Figure 3-4:CLC of Study area 2017 at Level 4

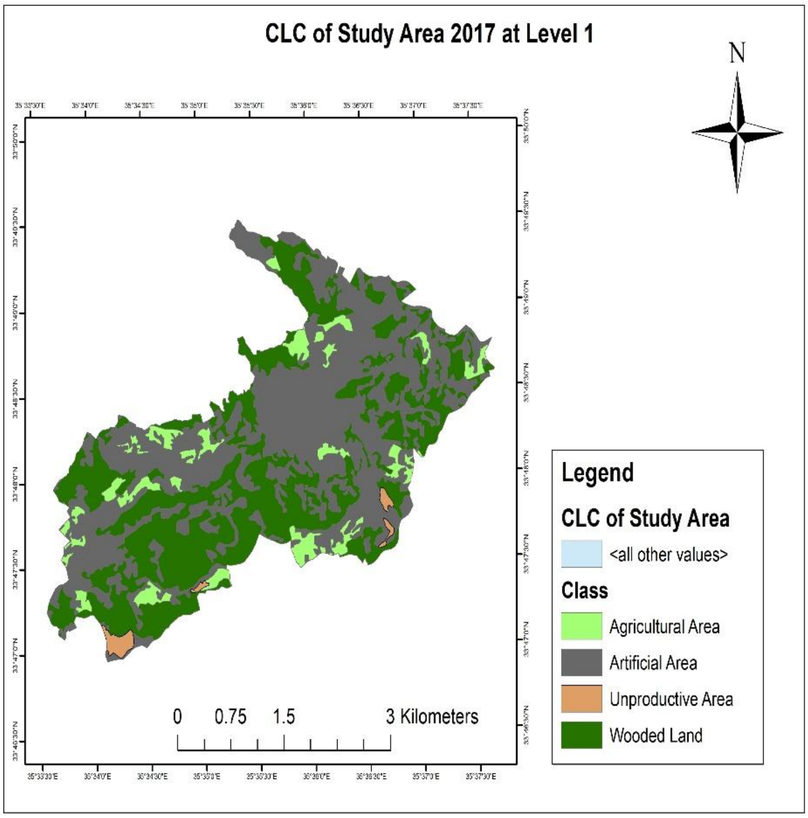


Figure 3-5:CLC of Study area 2017 at Level 1

3.3.3. CLC classification of each village at level 1

Studying the land cover/use of each village in the study area is essential in this thesis to know where the changes has occurred most in the area of interest and where it could had remained the same.

In this step, clipping the CLC of study area at level 1 using village area of interest was applied and maps were created for all villages in the study area (Aley, Qmatieh, Bmakine, Souq Al-Ghareb, and Ain-Remmeneh) (see figure 3-3).

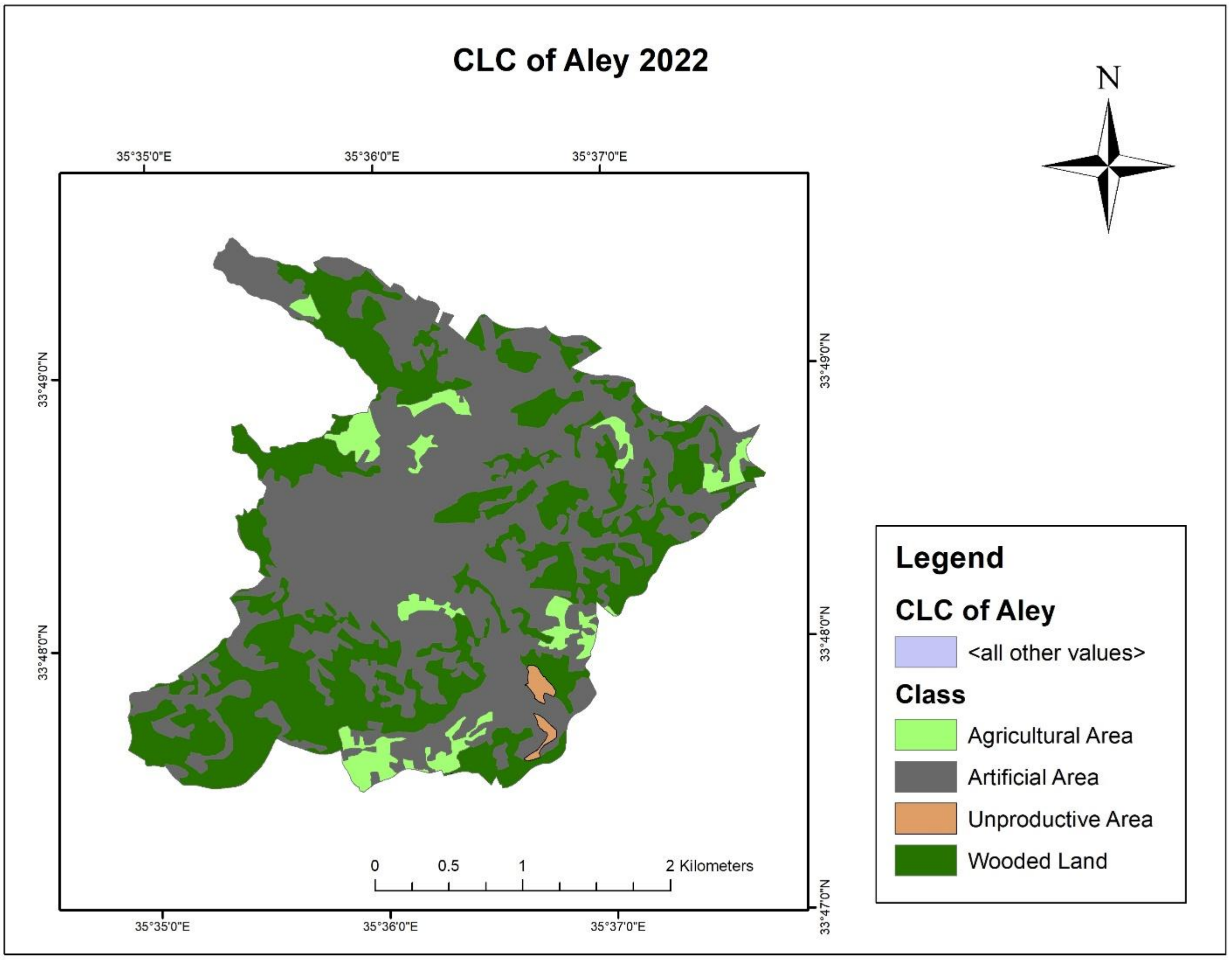


Figure 3-6:CLC of Aley Village 2022 at Level 1

3.3.4. Limitation of this study

The major limitation of the study is that the resolution of all the three images is not the same. The 2005 image has a resolution of 1m whereas the 2017 and 2022 images have a resolution of 30cm. Therefore, accuracy of results yielded from 2005 image is less than that from 2017 and 2022 image.

3.4. SUPERVISED CLASSIFICATION

The procedure followed by supervised classification is categorizing all pixels in a digital image into different land use / land cover classes. Depending on the interaction between computer and interpreter during classification process. This classification process involves conversion of multi-band raster imagery into a single-band raster with a number of categorical classes that relate to different types of land cover. Using this method, an image is classified using spectral signatures (i.e., reflectance values) obtained from training samples (polygons that represent distinct sample areas of the different land cover types to be classified) as seen in the following figure.

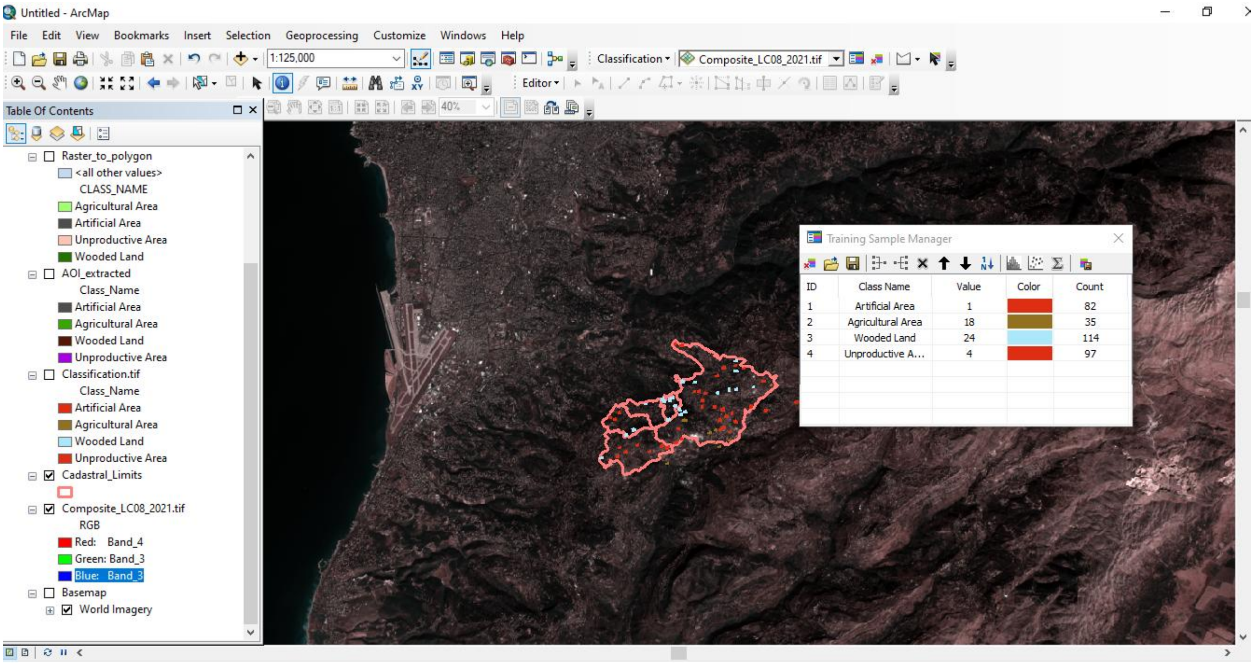


Figure 3-7:Training Samples of the supervised classification

To start with Landsat TM image-bands (band 1 to band 7) were added to the ARCMAP software and a composite image was created using image analysis tool. Next step was adding the area of interest (AOI) which belong to Governorate Lebanon Mountain (see Figure 4-1) and training samples are then captured using different band combinations (see figure 3-3). Later on, after the training samples were collected, classificatin image was created using interactive supervised classification. The classified AOI image has been extracted using extract by mask tool and then transformed into vector format using “Raster to Polygon” tool in order to know the area for each class.

Finally, the LUC images were created for the study area and the areas were measured and calculated for all the assigned classes and then extracted in order to be used for comparison and delivering the end results needed.

3.5. LUC COMPARISON BETWEEN CORINE AND SUPERVISED CLASSIFICATION

After studying and working on each system alone, and developing LUC end result maps for the three years (2005, 2017, and 2022) using Corine and Supervised classification, a comparison can be set out between both systems.

First, a translation method was applied to CLC maps created at level 4 to transform them into level 1 (see section 3.3.2) in order to match the classes obtained with LUC supervised maps.

Finally, results were extracted for both systems and compared using tables and graphs (see figure 4-21, 4-22, 4-23, and 4-24).

CHAPTER 4. RESULTS AND DISCUSSION

In this part of this study, the results of changes of land use and land cover in the area of interest (AOI) or the study area which is Mount-Lebanon area (Aley, Souq al-Ghareb, Qmatieh, Ain-Remmeneh and Bmakine) will be introduced and discussed with the figures and tables respectively of three different years: 2005, 2017, and 2022. Also, will undergo classification by means of geographic information system *GIS* in both classification systems CLC and Supervised Classification.

4.1. STUDY AREA

The study area chosen for testing purpose lies between latitude 33 48’ 31” to 33 49’ 36” N and longitude 35 37’ 39” to 35 43’ 33” E is a part of Mount-Lebanon area which includes the villages of Aley, Souq Al-Ghareb, Qmatieh, and Bmakine (shown in figure 4-1 and 4-2). These villages are almost 23 km away from Beirut city and the average elevation is 650m above mean sea level.

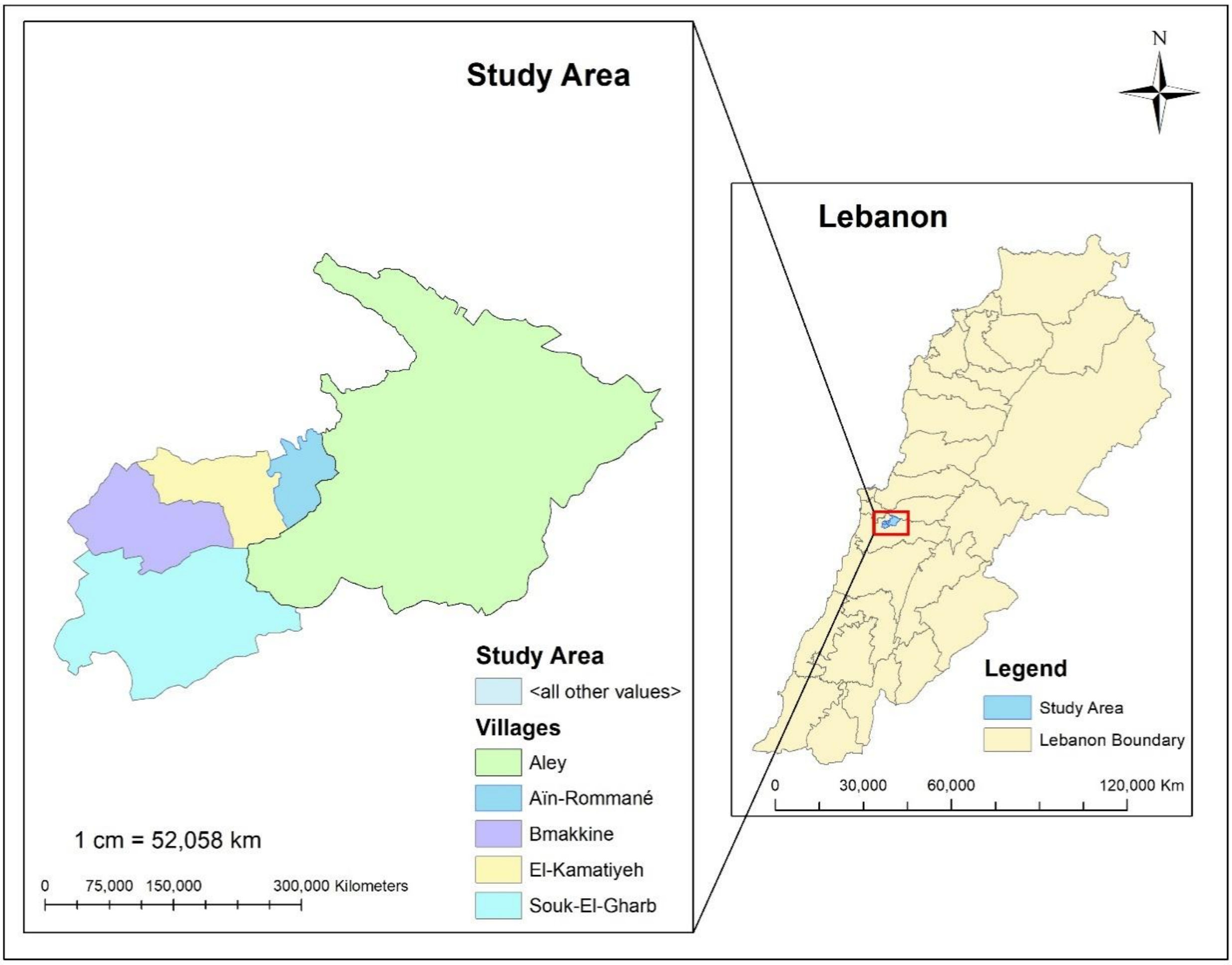


Figure 4-1:Study Area of Lebanon

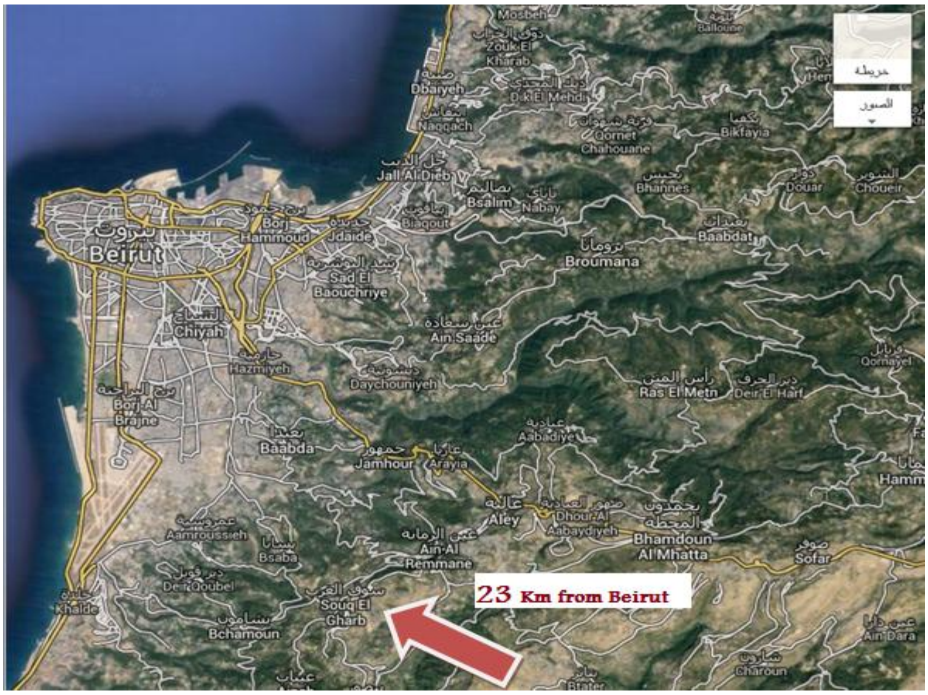


Figure 4-2:Location of the Study Area with respect to Beirut

Village	Area_Km
Aley	8.54
Ain-Rommaneh	0.43
Qmatieh	0.87
Bmakkine	1.11
Souk-El-Gharb	2.51
Total	13.45

Table 4-1:Cadastral Areas:

4.2. LAND COVER/USE CLASSIFICATION OF STUDY AREA

The raster map is transformed into a vector format of land cover/use by visual interpretation and digital methods using ArcMap software using CORINE fourth and first level classification (figure 4-3 and 4-4) and supervised first level classification (figure 4-5). The LUC maps of both classification systems were prepared at a scale of 1:20,000, with a minimum representative scale of 10,000 m^{2,} and a drawing scale of 1:10,000.

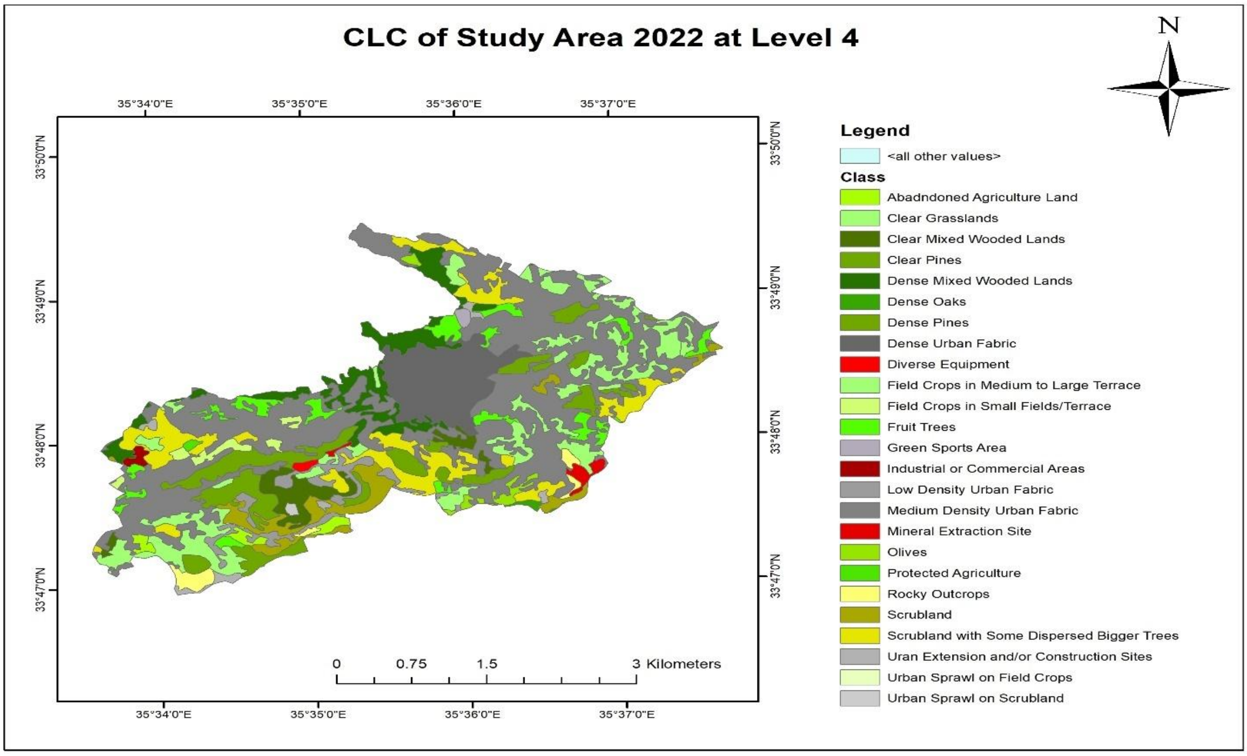


Figure 4-3:CLC of Study Area 2022 at Level 4

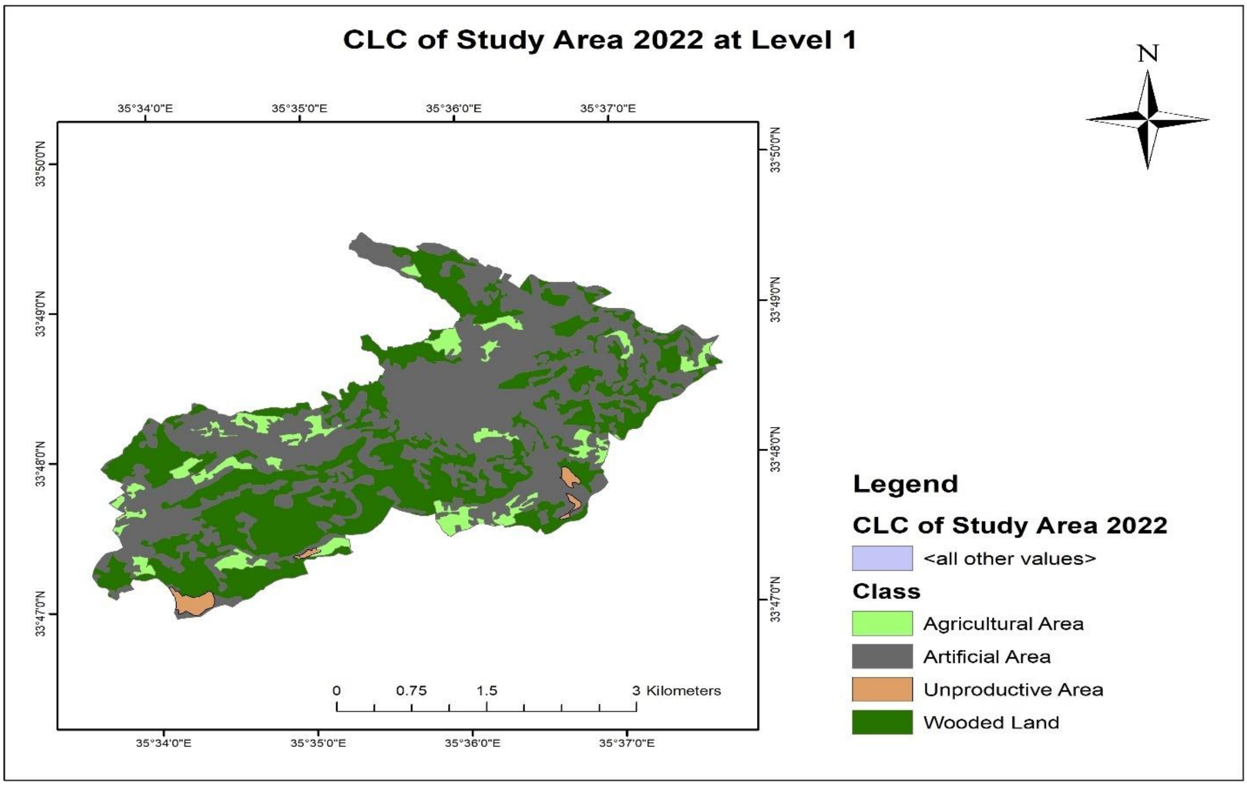


Figure 4-4:CLC of Study Area 2022 at Level 1

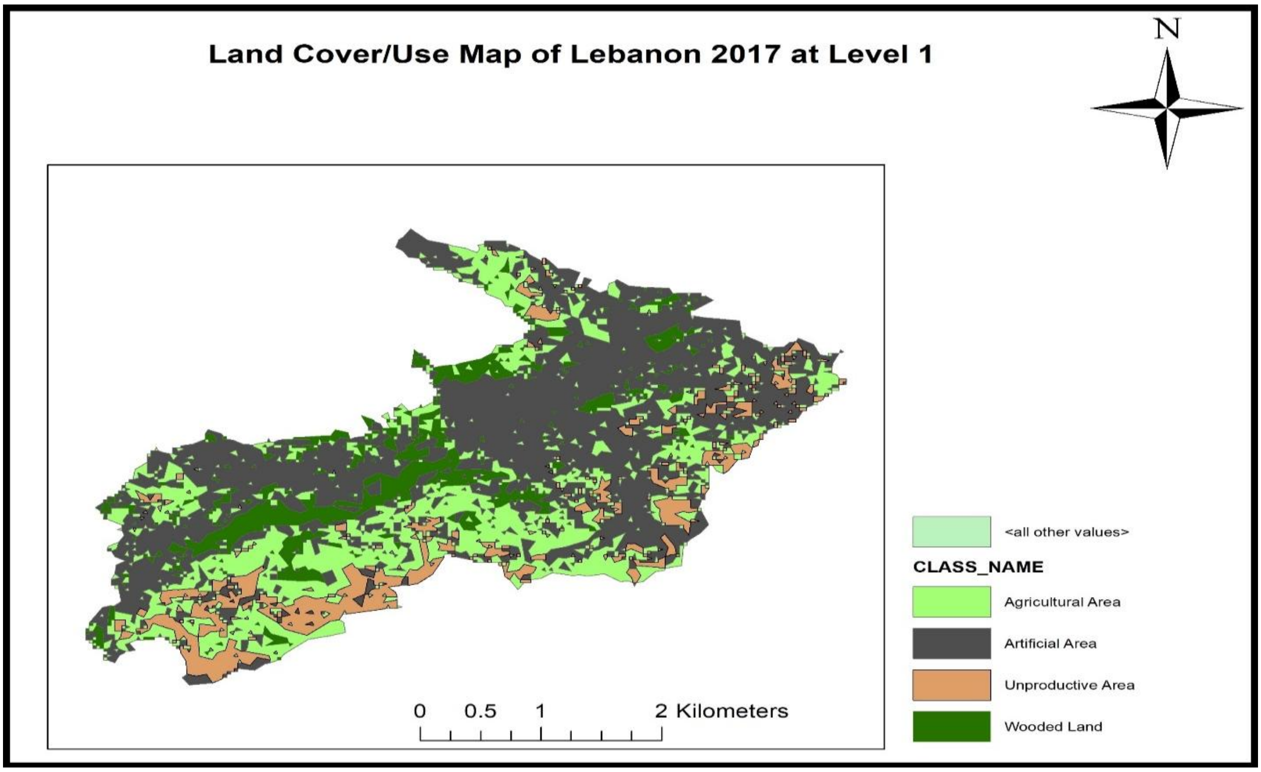


Figure 4-5:LUC of Study Area using Supervised classification at Level 1

4.3. LUCC RESULTS USING CORINE CLASSIFICATION AT LEVEL 4

In the last decade many changes occurred on the chosen study area either by nature or by man, the thing that reflects an effect on the LUC. Thus, the following figures and table explain or list these changes (figure 4-6, and table 4-1). In addition, graphs were created explaining the end result of these changes (see graph 4-7).

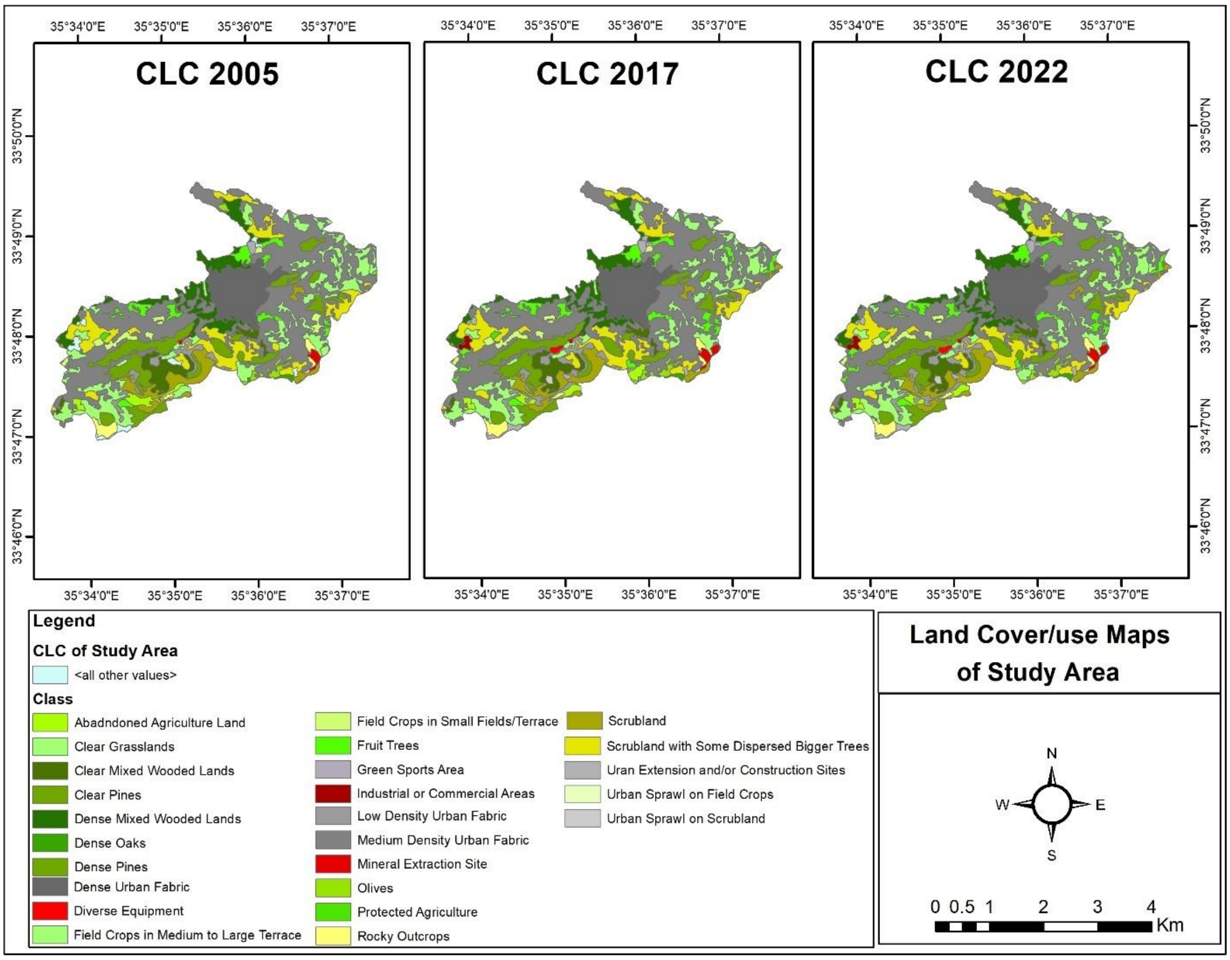


Figure 4-6:CLC Maps of Study Area of 2005, 2017, and 2022 at Level 4

Class	Area_km_2022	%LUC 2022	Area_km_2017	% LUC 2017	Area_km_2005	% LUC 2005
Dense Urban Fabric	1.05	7.81%	1.05	7.80%	1.05	7.80%
Medium Density Urban Fabric	5.12	38.03%	5.05	37.57%	4.89	36.32%
Low Density Urban Fabric	0.37	2.71%	0.36	2.68%	0.24	1.77%
Diverse Equipment	0.03	0.19%	0.03	0.19%	0.00	0.00%
Industrial or Commercial Areas	0.04	0.29%	0.04	0.29%	0.00	0.00%
Mineral Extraction Site	0.08	0.58%	0.08	0.58%	0.06	0.41%
Uran Extension and/or Construction Sites	0.10	0.76%	0.10	0.76%	0.16	1.16%
Green Sports Area	0.03	0.22%	0.03	0.22%	0.03	0.22%
Urban Sprawl on Field Crops	0.00	0.01%	0.00	0.01%	0.00	0.01%
Field Crops in Medium to Large Terrace	0.07	0.54%	0.02	0.12%	0.27	2.01%
Field Crops in Small Fields/Terrace	0.13	1.00%	0.15	1.10%	0.19	1.44%
Abadndoned Agriculture Land	0.12	0.89%	0.18	1.33%	0.15	1.10%
Olives	0.10	0.76%	0.10	0.77%	0.10	0.77%
Fruit Trees	0.53	3.97%	0.54	4.00%	0.36	2.71%
Protected Agriculture	0.02	0.12%	0.02	0.12%	0.02	0.12%
Dense Pines	0.32	2.37%	0.32	2.40%	0.36	2.67%
Dense Oaks	0.02	0.17%	0.02	0.17%	0.03	0.20%
Dense Mixed Wooded Lands	0.81	6.00%	0.81	6.04%	0.86	6.40%
Clear Pines	0.94	6.95%	0.94	6.96%	0.94	6.96%
Clear Mixed Wooded Lands	0.39	2.88%	0.39	2.89%	0.42	3.11%
Urban Sprawl on Scrubland	0.02	0.12%	0.02	0.12%	0.00	0.00%
Scrubland	0.53	3.92%	0.53	3.97%	0.52	3.88%
Scrubland with Some Dispersed Bigger Trees	1.11	8.25%	1.12	8.34%	1.13	8.40%
Clear Grasslands	1.40	10.38%	1.41	10.48%	1.43	10.67%
Rocky Outcrops	0.15	1.08%	0.15	1.08%	0.15	1.11%
TOTAL	13.45	100.00%	13.45	100.00%	13.45	100.00%

Table 4-2:CLC Results of Year 2005, 2017, and 2022 at Level 4

In the above table (table 4-1) we noticed that it is classified at level 4 of CORINE nomenclature adopted for Lebanon. This table illustrated the area and percentage of every polygon summarized at level 4 in order to see the differences between the three CLC maps. For example, dense urban fabric area has remained the same (1.05 squared Kilometers with 7.81%) through out the years of 2005, 2017, and 2022. While on the other hand, we can see that field crops in medium to large terrace has significantly decreased from 2.01% in year 2005 to 0.12% in 2017 and then increased a little in 2022 to become 0.54%.

Upon delineating and classifying, many features have appeared that we couldn't find a suitable class for it such as, schools, universities, and security centers. In addition to that, during the classification of some polygons having same class nae at level 4, we have noticed that there are some differences between these polygons even though they are from the same class. For example, in the class of dense urban fabric of code (111a or 1111) at level 4 a clear difference can be noticed which is the manner of the buildings if it is covered with brick stones or not…

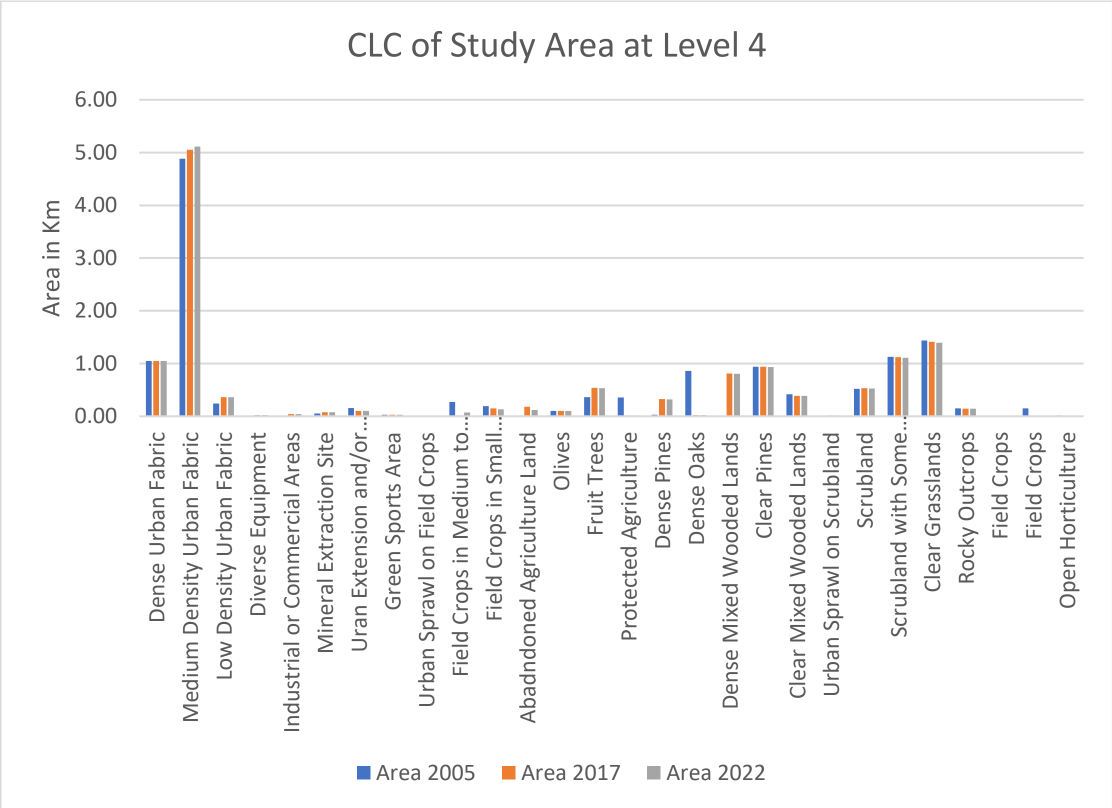


Figure 4-7:CLC Bar Graph Results at Level 4

4.4. LUCC RESULTS USING CORINE CLASSIFICATION AT LEVEL 1

Translation method was performed to the CLC maps created at level 4 and CLC maps at level 1 was created (See figure 4-7). Many classes were merged together into more general classes such as Artificial, Agricultural, wooded land, or unproductive area class. Later, areas were calculated and measured and graphs and tables were produced for each year alone (see table 4-2 and graph 4-9).

Class	Area 2005	(%) 2005	Area 2017	(%)2017	Area 2022	(%) 2022
Artificial Area	6.41	48.01%	6.74	50.07%	6.81	50.59%
Agricultural Area	1.1	8.24%	1	7.43%	0.98	7.28%
Wooded Land	5.69	42.62%	5.57	41.38%	5.52	41.01%
Unproductive Area	0.15	1.12%	0.15	1.11%	0.15	1.11%
Total	13.35	100.00%	13.46	100.00%	13.46	100.00%

Table 4-3:CLC Results of Year 2005, 2017, and 2022 at Level 1

The data presented in Table 4-2 represents the area of each land use land cover category of the three different years. During the period from 2005 to 2022 Artificial area increased by 0.4 square kilometer, a percentage increase of 2.58%. The change in area of artificial lands was the maximum when compared with all the classes. Agricultural area saw a slight decrease during the same period from 1.1 to 0.98 square kilometer. Wooded land area decreased from 5.69 to 5.52 square kilometer during the period 2005-2022. There is stability in unproductive area where it remained the same through that period. The land cover land use maps of the year 2005, 2017 and 2022 are shown in Figure 4-8.

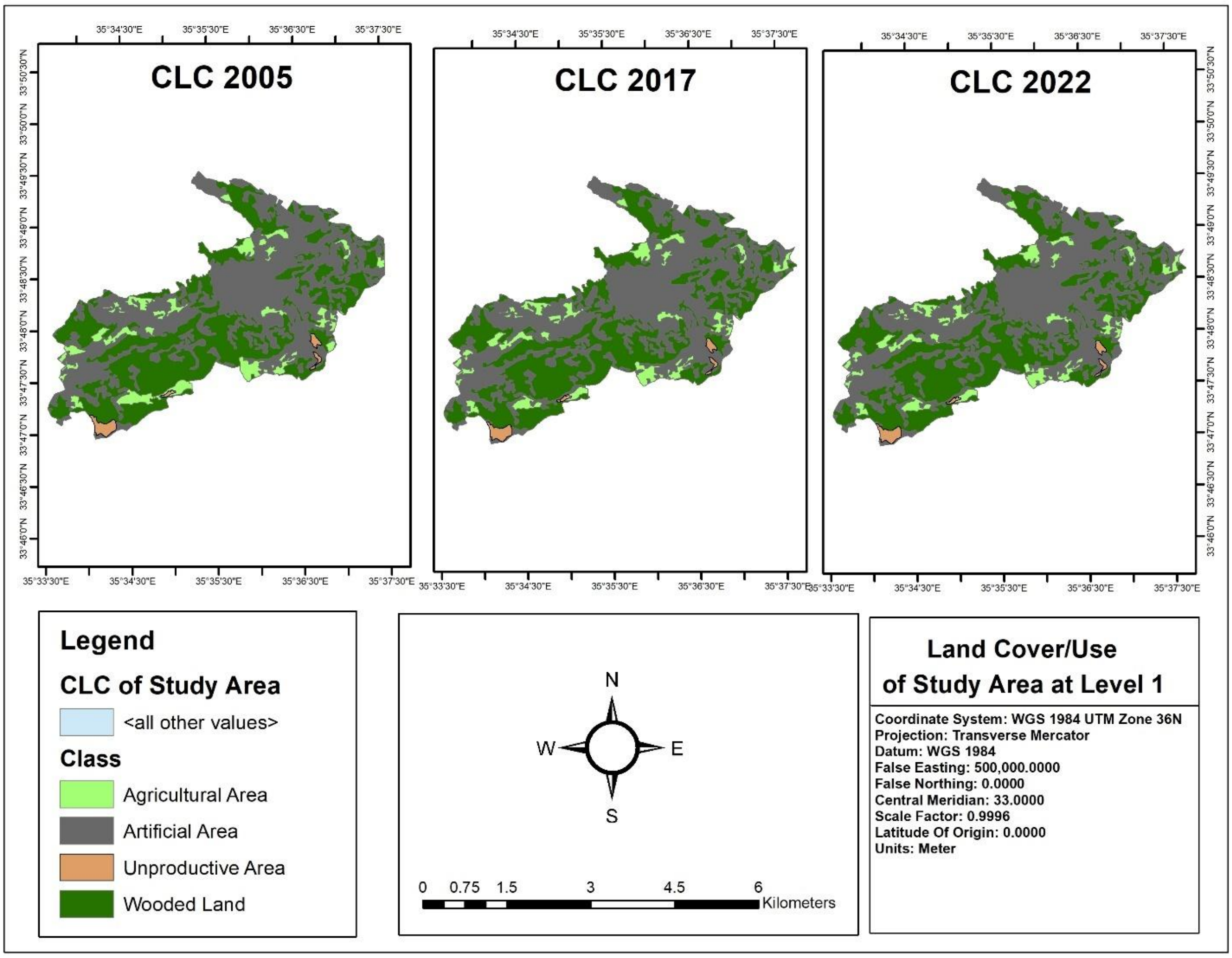


Figure 4-8:CLC Maps of Study Area of years 2005, 2017, and 2022 at Level 1

The 2005 map shows that most of the study area is covered by artificial lands. In 2005 area occupied by agriculture was 1.1 square kilometer, 8.24 percent of the total area. Wooded land occupied 5.69 square kilometer, which is equal to 42.62 percent of the total study area. Area of unproductive land was 0.15 square kilometer, only 1.12 percent of the total study area. In 2005, unproductive land occupied the minimum area whereas wooded land and artificial land percentage was the maximum.

In 2017, land use land cover pattern has changed somehow with respect to 2005. Area under wooded land witnessed the highest percentage decrease that is equal to 1.24 percent. Area occupied by artificial lands such as urban, industrial, or commercial lands increased from 6.41 square kilometer to 6.74 square kilometer. This was accompanied by a decrease in agricultural area from 1.1 square kilometer to 1 square kilometer. In 2017. Moreover, unproductive area has remained the same through out that period between 2005 and 2017. Artificial area and wooded land occupied the largest classes with total of 90.63% of the total class. Unproductive area takes up the least percentage of the total class. It is estimated that almost all the decrease in wooded land area is due to the fact that forest land have been utilized for mining and related activities and also due to human pressure on forest for firewood as well as grazing of cattle in the forested area.

In 2022, area under artificial land increased to 6.81 square kilometer which is more than 0.5 percent of the study area. This increase was due to increase in settlement area since migration of population took place due to the pleasant weather and how close this area is to the city Beirut. There was a slight decrease in wooded land area from 5.57 square kilometer to 5.52 square kilometer. This decrease can be attributed to the increase in mining area. Agricultural area decreased from 1 square kilometer to 0.98 square kilometer. Unproductive area remained the same having an area of 0.15 square kilometer.

The results shown in the above table and graph show the area of each year of the study and it is percentage according to CLC level 1. The results show an increase in the artificial area in the area of interest (48.01% of the total area was categorized as artificial areas in 2005, then it increased to 50.07% in 2017 and then slight increase in 2022 to reach 50.59%). Vice versa areas of agricultural land were decreased from 2005 (8.24%) to 2017 (7.43%) and then 2022 (7.28%). Same for wooded lands and unproductive areas. This shows that these areas were decreasing in response to the increase of urbanization and artificial areas in this region (also see graph 4-9).

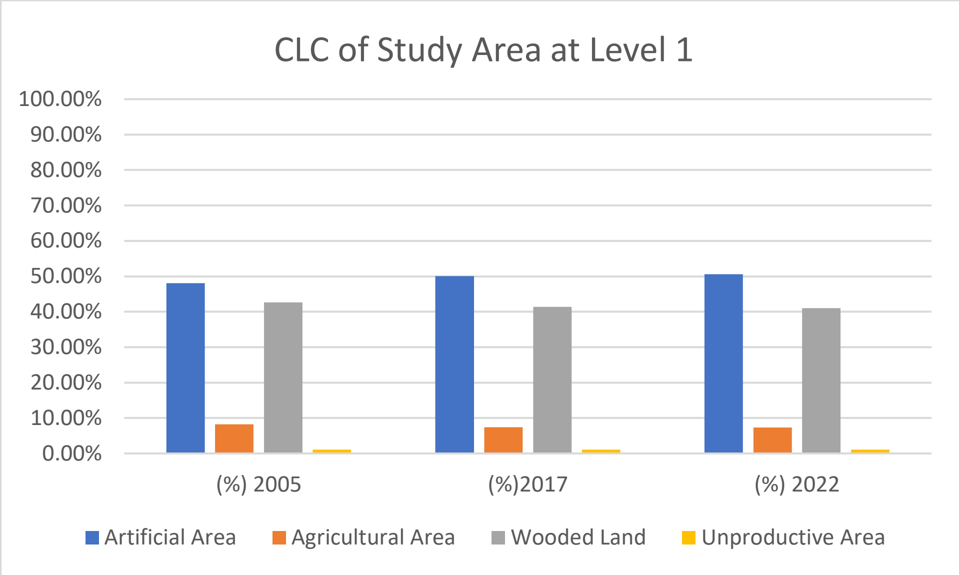


Figure 4-9:CLC Bar Graph Results of Area 2005, 2017, and 2022 at Level 1

4.5. LUCC RESULTS FOR EACH VILLAGE OF THE STUDY AREA

In order to know where the change has more effect in the study area, a study of each village was performed to create CLC maps for each village alone, and areas were measured and presented as tables.

4.5.1. LUCC RESULTS OF ALEY VILLAGE AT LEVEL 1

Class	Area 2005	(%) 2005	Area 2017	(%) 2017	Area 2022	(%) 2022
Artificial Area	4.51	52.81%	4.7	55.04%	4.76	55.74%
Agricultural Area	0.52	6.09%	0.52	6.09%	0.5	5.85%
Wooded Land	3.46	40.51%	3.27	38.29%	3.23	37.82%
Unproductive Area	0.05	0.59%	0.05	0.59%	0.05	0.59%
Total	8.54	100.00%	8.54	100.00%	8.54	100.00%

Table 4-4:CLC Results of Aley at Level 1

In the above table, we can see that area of artificial land has increased by 0.25 square kilometer during the period of 2005 and 2022, a percentage increase of 2.93%. The change in area of artificial lands was the maximum when compared with all the classes. Agricultural area saw a slight decrease during the same period from 0.52 to 0.5 square kilometer. Wooded land area decreased from 3.46 to 3.23 square kilometer during the period 2005-2022. There is stability in unproductive area where it remained the same through out that period. The land cover land use maps of the year 2005, 2017 and 2022 are shown in Figure 4-10.

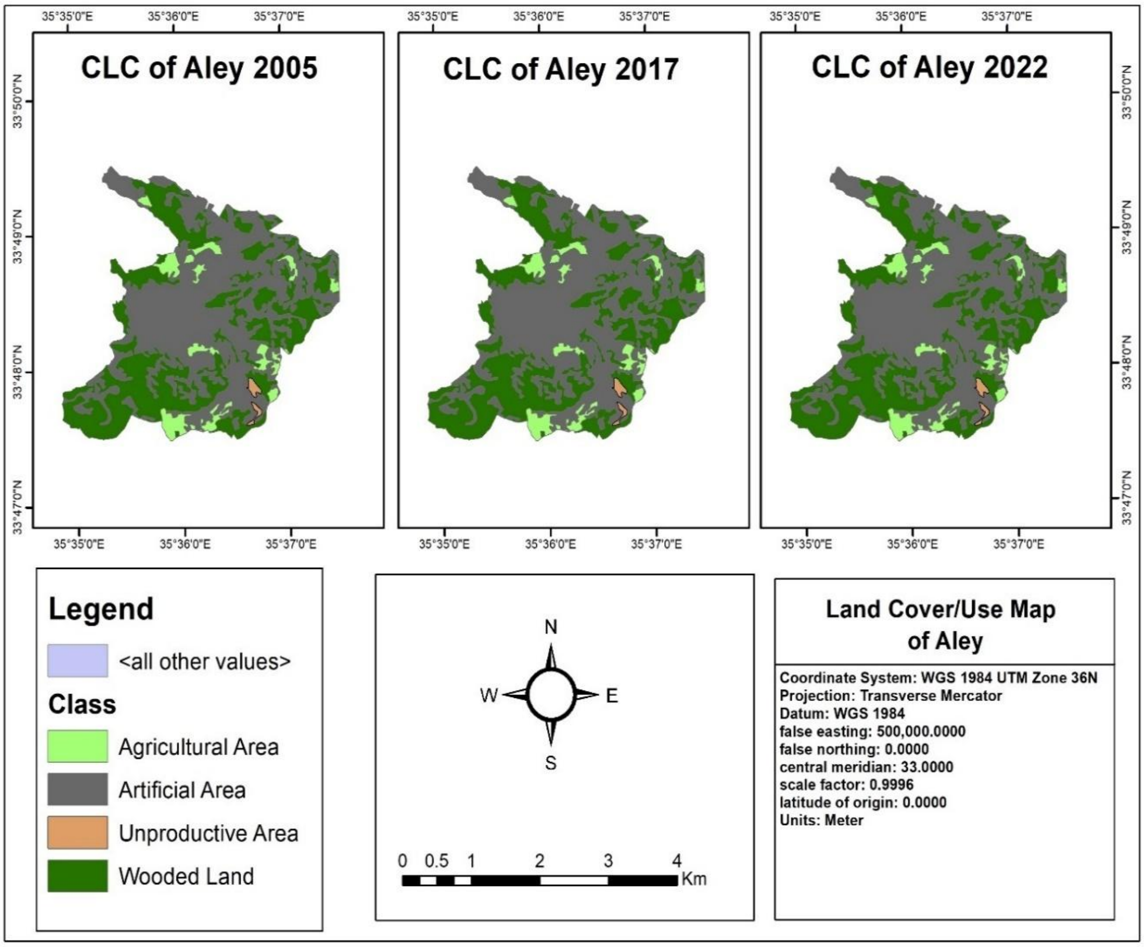


Figure 4-10:CLCs of Aley at Level 1

4.5.2. LUCC RESULTS OF QMATIEH VILLAGE AT LEVEL 1

Class	Area 2005	(%) 2005	Area 2017	(%) 2017	Area 2022	(%) 2022
Artificial Area	0.56	64.20%	0.56	64.46%	0.56	65.04%
Agricultural Area	0.15	16.99%	0.15	16.99%	0.15	16.99%
Wooded Land	0.16	18.82%	0.16	18.55%	0.16	17.98%
Total	**0.87**	**100.00%**	**0.87**	**100.00%**	**0.87**	**100.00%**

Table 4-5:CLC Results of Qmatieh at Level 1

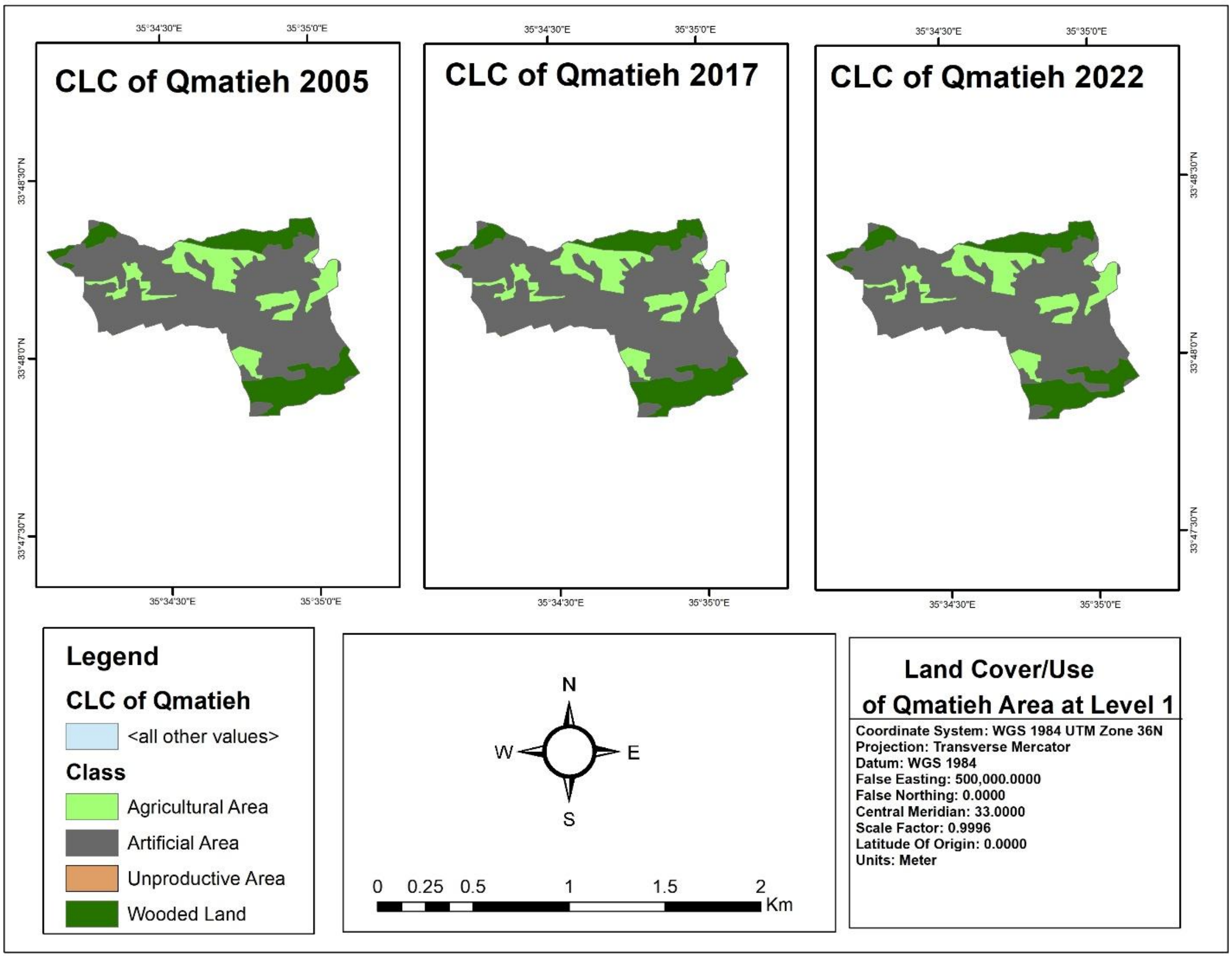


Figure 4-11: CLCs of Qmatieh at Level 1

4.5.3. LUCC RESULTS OF BMAKINE VILLAGE AT LEVEL 1

Class	Area 2005	(%) 2005	Area 2017	(%) 2017	Area 2022	(%) 2022
Artificial Area	0.39	35.23%	0.41	36.86%	0.41	36.86%
Agricultural Area	0.13	12.06%	0.12	10.75%	0.12	10.75%
Wooded Land	0.58	52.72%	0.58	52.39%	0.58	52.39%
Total	1.11	100.00%	1.11	100.00%	1.11	100.00%

Table 4-6:CLC Results of Bmakine at Level 1

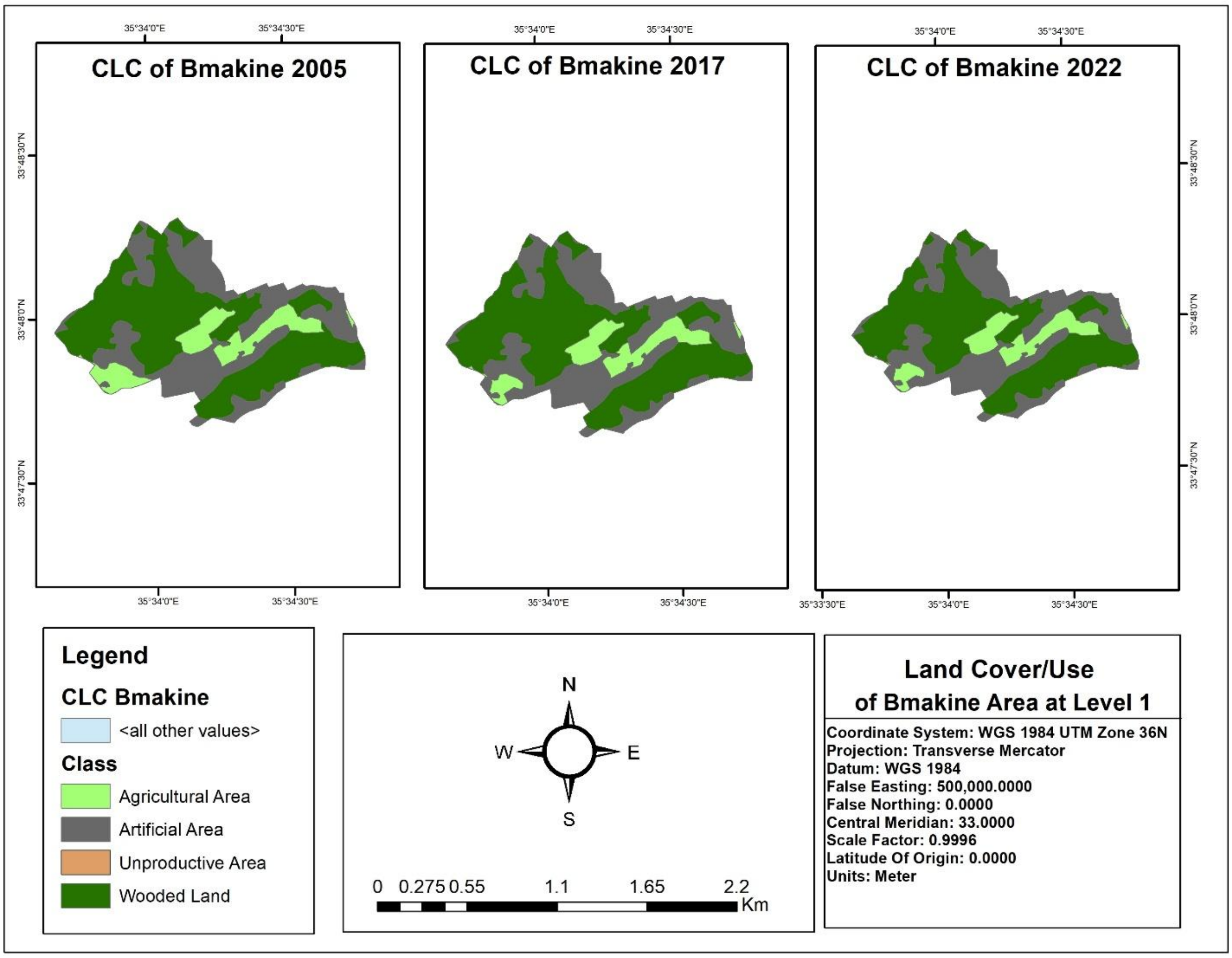


Figure 4-12:CLCs of Bmakine at Level 1

4.5.4. LUCC RESULTS OF SOUQ AL-GHAREB VILLAGE AT LEVEL 1

Class	Area 2005	(%) 2005	Area 2017	(%) 2017	Area 2022	(%) 2022
Artificial Area	0.76	30.28%	0.85	33.76%	0.85	33.76%
Agricultural Area	0.27	10.92%	0.19	7.67%	0.19	7.67%
Wooded Land	1.37	54.67%	1.37	54.61%	1.37	54.61%
Unproductive Area	0.10	4.13%	0.10	3.96%	0.10	3.96%
TOTAL	**2.51**	**100.00%**	**2.51**	**100.00%**	**2.51**	**100.00%**

Table 4-7:CLC Results of Souq Al-Ghareb at Level 1

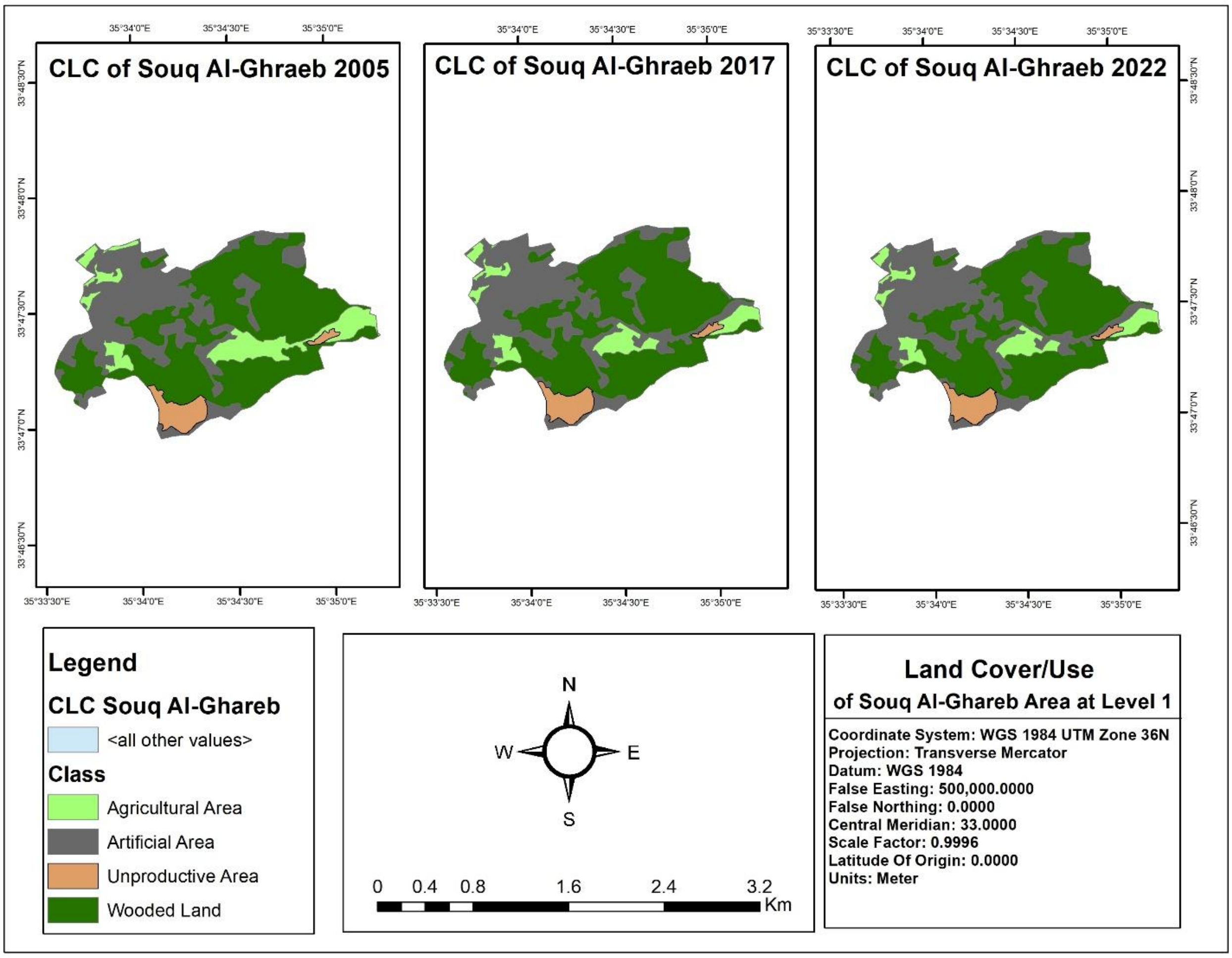


Figure 4-13:CLCs of Souq Al-Ghareb at Level 1

4.5.5. LUCC RESULTS OF AIN-REMMENEH VILLAGE AT LEVEL 1

Class	Area 2005	(%) 2005	Area 2017	(%) 2017	Area 2022	(%) 2022
Artificial Area	0.20	46.52%	0.22	51.92%	0.22	51.92%
Agricultural Area	0.02	5.16%	0.02	5.16%	0.02	5.16%
Wooded Land	0.21	48.32%	0.18	42.92%	0.18	42.92%
Total	**0.43**	**100.00%**	**0.43**	**100.00%**	**0.43**	**100.00%**

Table 4-8:CLC Results of Ain-Remmeneh at Level 1

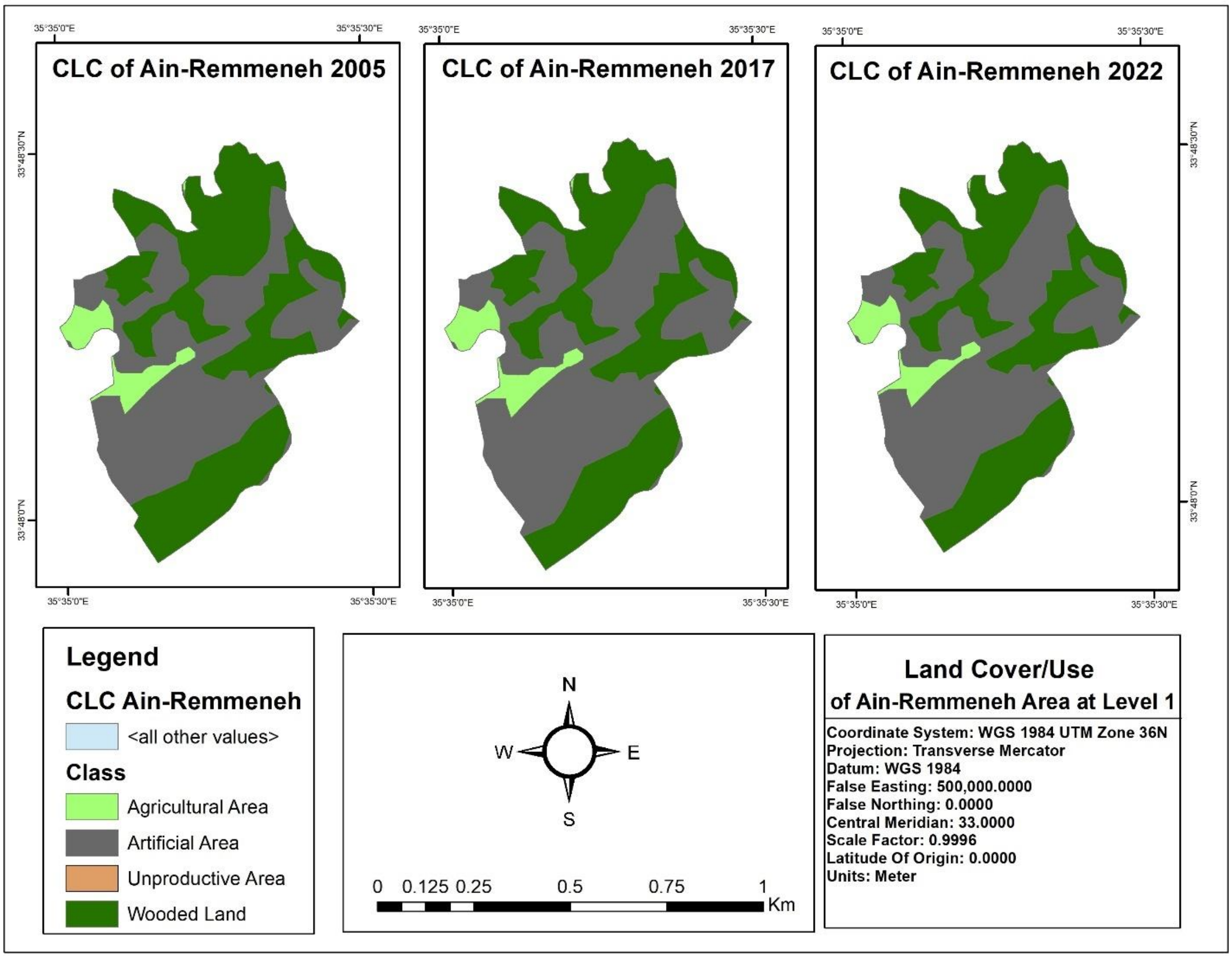


Figure 4-14:CLCs of Ain-Remmeneh at Level 1

4.5.6. COMPARISON BETWEEN LUCC VILLAGES

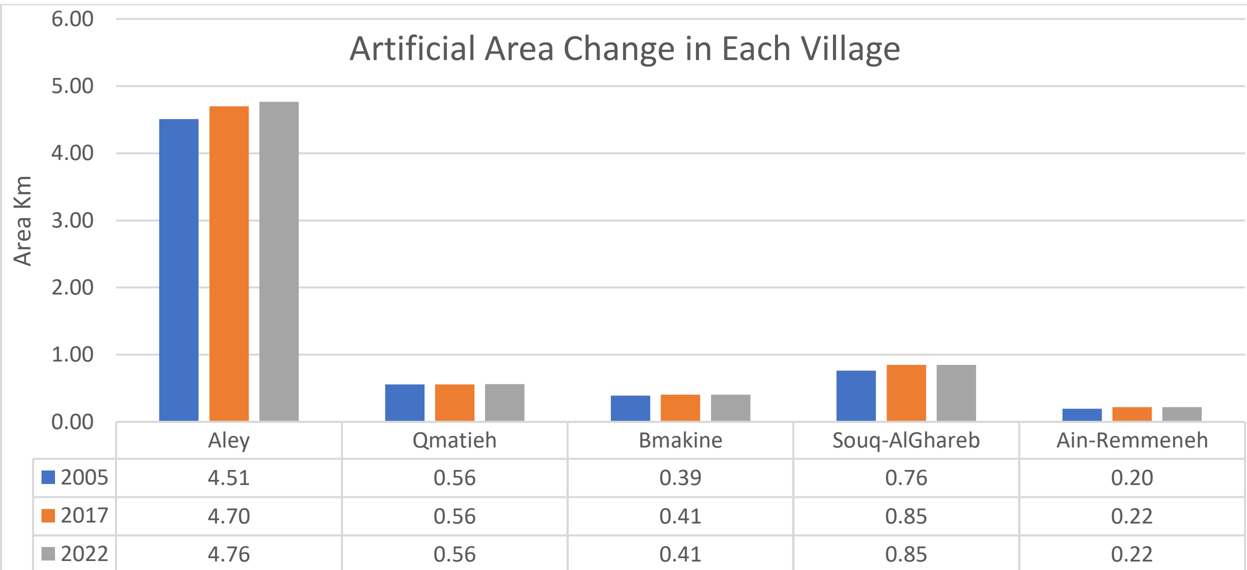


Figure 4-15:Artificial Area Change in Each Village

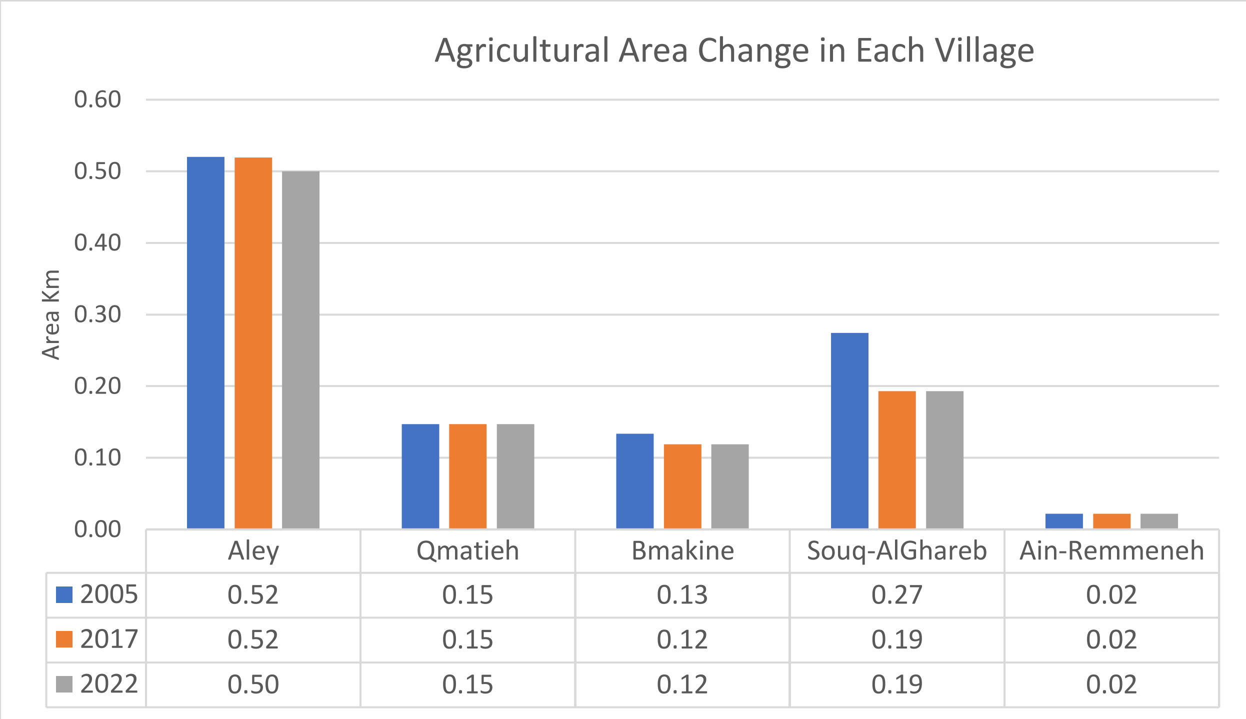


Figure 4-16:Agricultural Area Change in Each Village

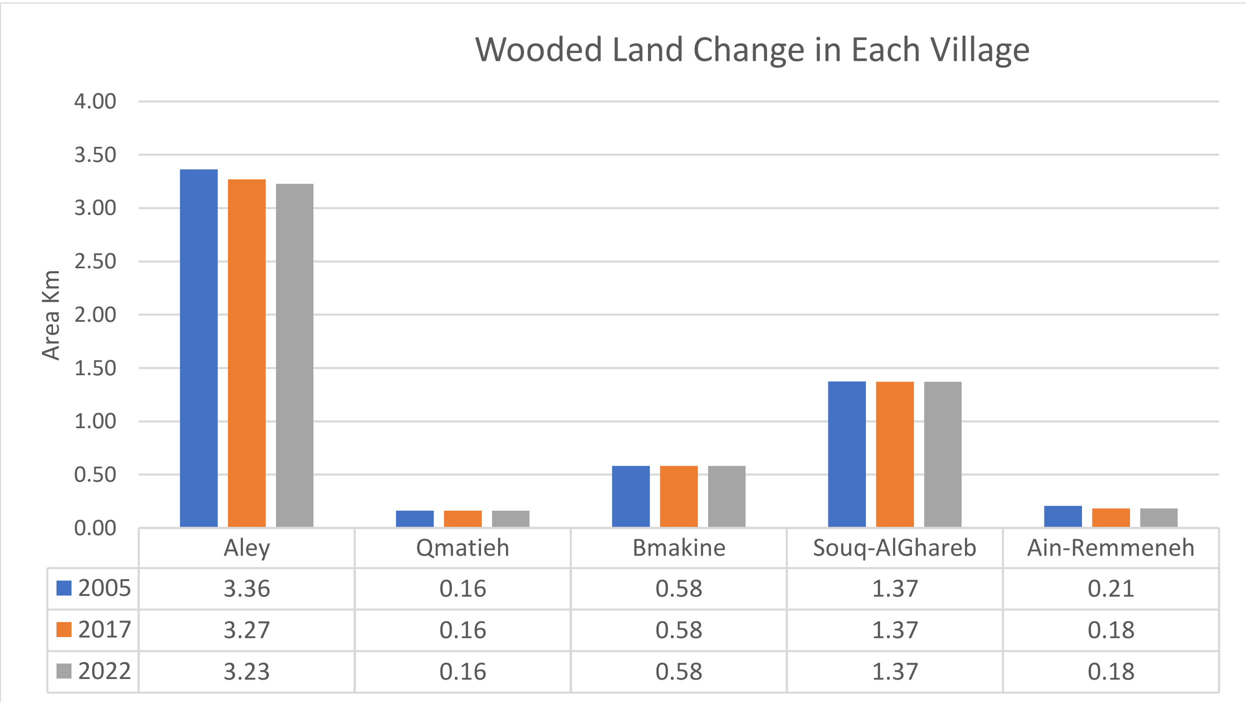


Figure 4-17:Wooded Land Change in Each Village

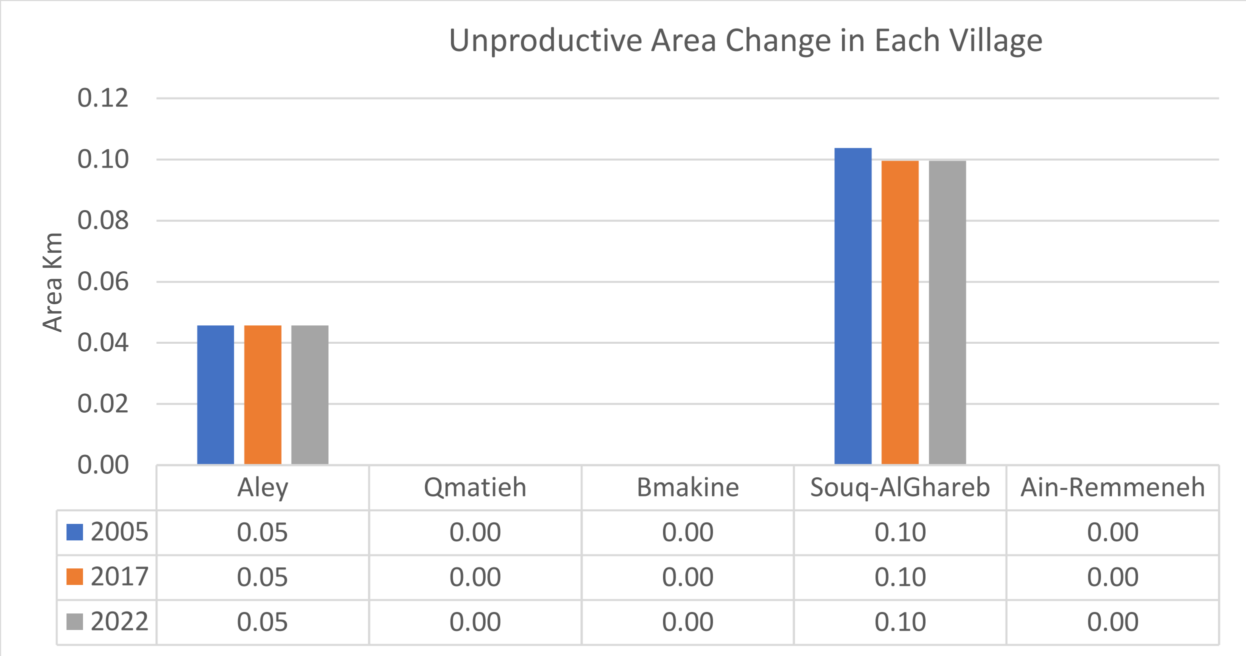


Figure 4-18:Unproductive Area Change in Each Village

In figure 4-15, 4-16, 4-17, and 4-18, the results indicates that changes in artificial area and wooded land area were mainly observed in Aley village and slight change in the other villages.

Changes in agricultural area were mainly indicated in Souq Al-Ghareb village where it showed significant change in area.

Qmatieh, Bmakine, and Ain-Remmeneh villages showed no sign of unproductive area. While Aley and Souq Al-Ghareb have showed no sign of change with unproductive lands

4.6. LUCC RESULTS USING SUPERVISED CLASSIFICATION AT LEVEL 1

This chapter describes results of land cover and land use analysis of multi-spectral satellite images. The results are shown in Table 4-8.

CLASS	Area 2005	(%) 2005	Area 2017	(%) 2017	Area 2021	(%) 2021
Agricultural Area	2.01	14.99%	1.92	14.32%	1.69	12.59%
Artificial Area	6.49	48.30%	6.72	50.04%	6.66	49.61%
Unproductive Area	0.51	3.76%	0.73	5.44%	0.80	5.94%
Wooded Land	4.42	32.94%	4.06	30.19%	4.28	31.86%
Total	13.43	100.00%	13.43	100.00%	13.43	100.00%

Table 4-9:LUC Results of Year 2005, 2017, and 2022 at Level 1

The information in Table 4-8 shows how much of each land use and land cover category there was in each of the three years. Artificial area expanded by 0.17 square kilometers, or 1.31%, between the years of 2005 and 2021. During the same time frame, the agricultural area decreased from 2.01 to 1.69 square kilometers. When compared to all the classes, the change in agricultural area was the greatest. Between 2005 and 2021, the extent of wooded land declined from 4.42 to 4.28 square kilometers. There was an increase in unproductive area which may be attributed to an increase in settlement area, barren land and deforestation activites. Figure 4-15 displays the land cover and usage maps for the years 2005, 2017, and 2021.

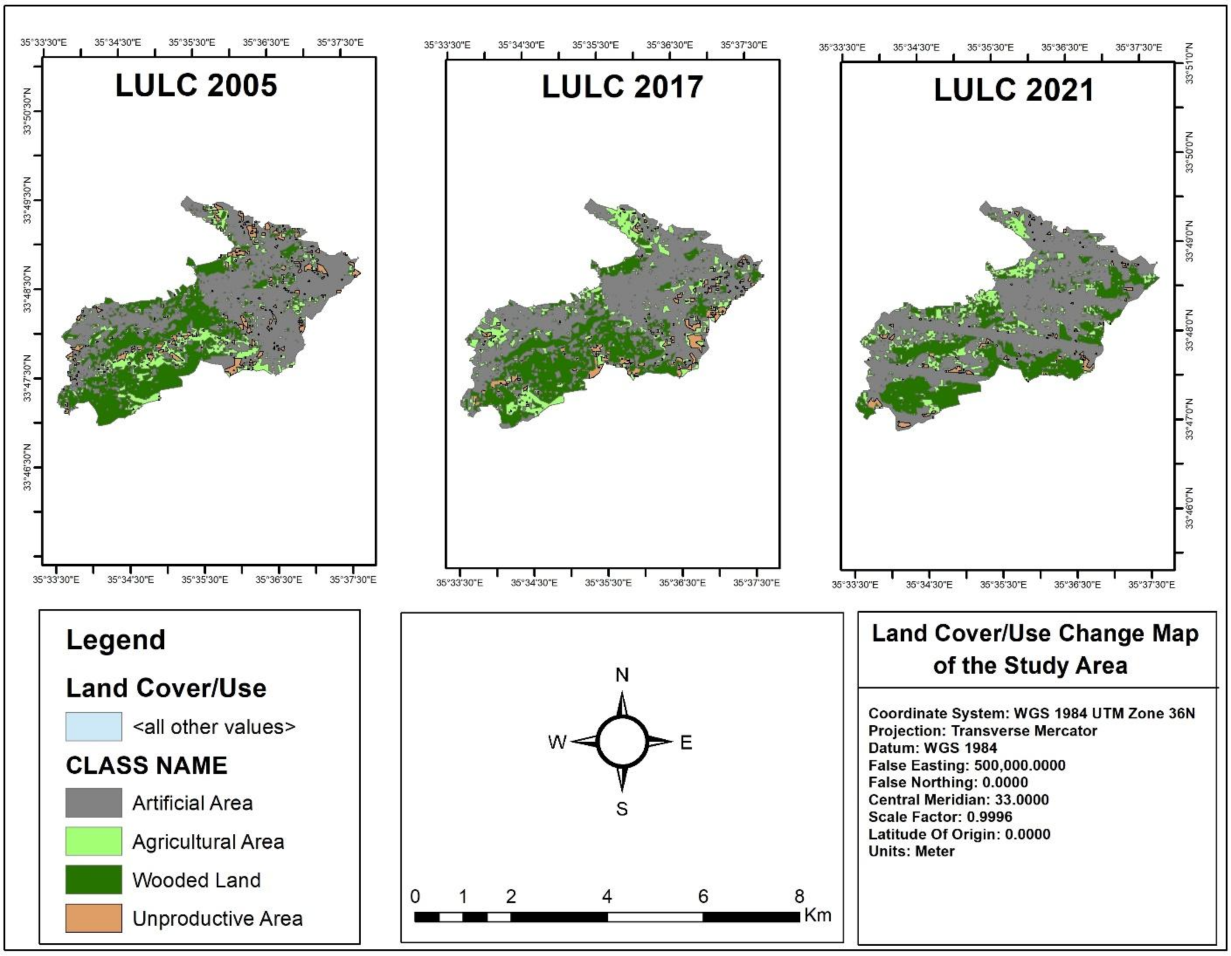


Figure 4-19:LUCs of Study Area Using Supervised Classification at Level 1

The map shows that artificial lands is the dominant coverage of the study area during the period 2005 and 2022. In 2005 area occupied by agriculture was 2.01 square kilometer, 14.99 percent of the total area. Wooded land occupied 4.42 square kilometers, which is more than 32 percent of the total study area. Unproductive area was 0.51 square kilometer which was 3.76 percent of the total area. In 12005, unproductive area occupied the minimum area whereas Artificial area and wooded land percentage was the maximum.

Compared to 2005, the pattern of land use and land cover has altered in some way in 2017. The greatest percentage decline, at 2.75 percent, was seen in the area covered by wooded land. Area occupied by artificial lands such as urban, industrial, or commercial lands increased from 6.49 square kilometer to 6.72 square kilometer. Along with it, the agricultural area shrunk from 2.01 square kilometers to 1.92 square kilometers. Moreover, artificial area has shown the biggest increase throughout that period at 1.74 percent. Artificial area and wooded land occupied the largest classes with total of 80.23% of the total class. Unproductive area takes up the least percentage of the total class. It is estimated that almost all the decrease in wooded land area is due to the fact that forest land has been utilized for mining and related activities and also due to human pressure on forest for firewood as well as grazing of cattle in the forested area.

In 2021, More than 49 percent of the study area—or 6.66 square kilometers—was covered by artificial land. Due to population migration brought on by the region's favorable climate and proximity to Beirut, there has been a rise in settlement area. The area of wooded land decreased somewhat, from 4.42 square kilometers to 4.28 square kilometers. This decrease can be attributed to the increase in mining area. Agricultural area decreased from 2.01 square kilometer to 1.69 square kilometer. Unproductive area has also showed some increase from 0.51 square kilometers to 0.80 square kilomters, a percentage increase of 2.18 percent. (See figure 4-16)

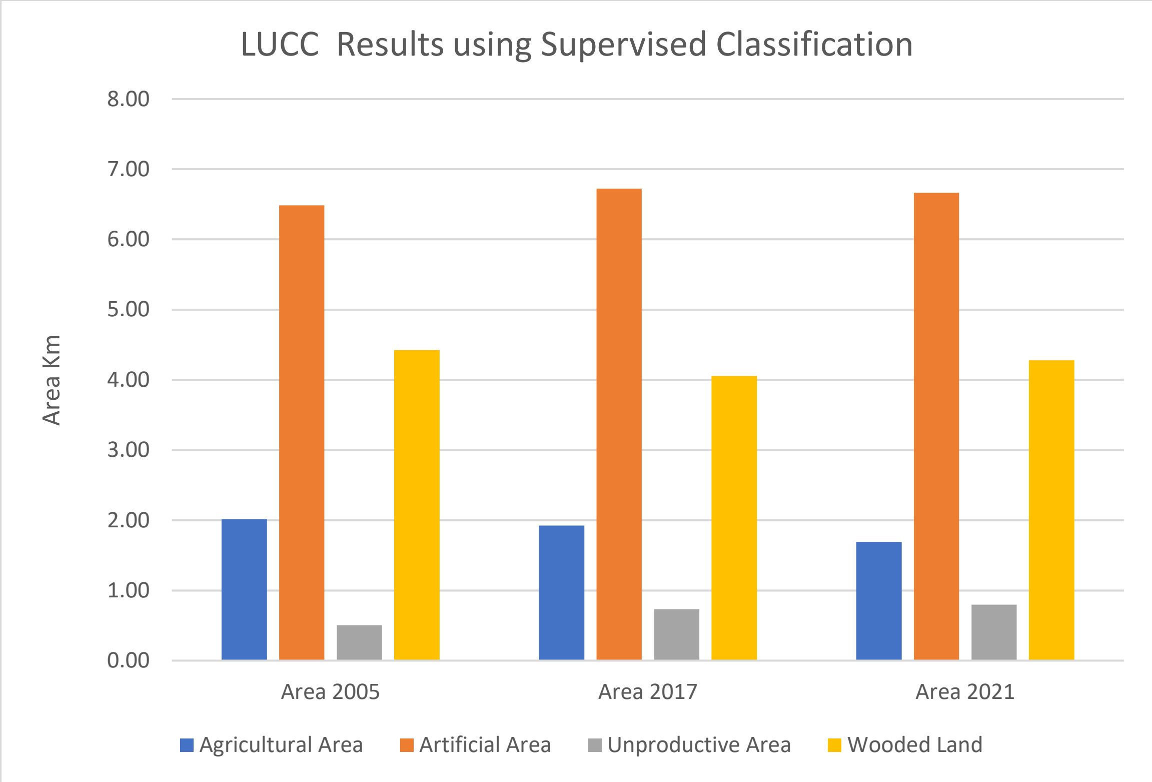


Figure 4-20:LUCC Results of Study Area using Supervised Classification

4.7. COMPARISON BETWEEN CORINE AND SUPERVISED CLASSIFICATION

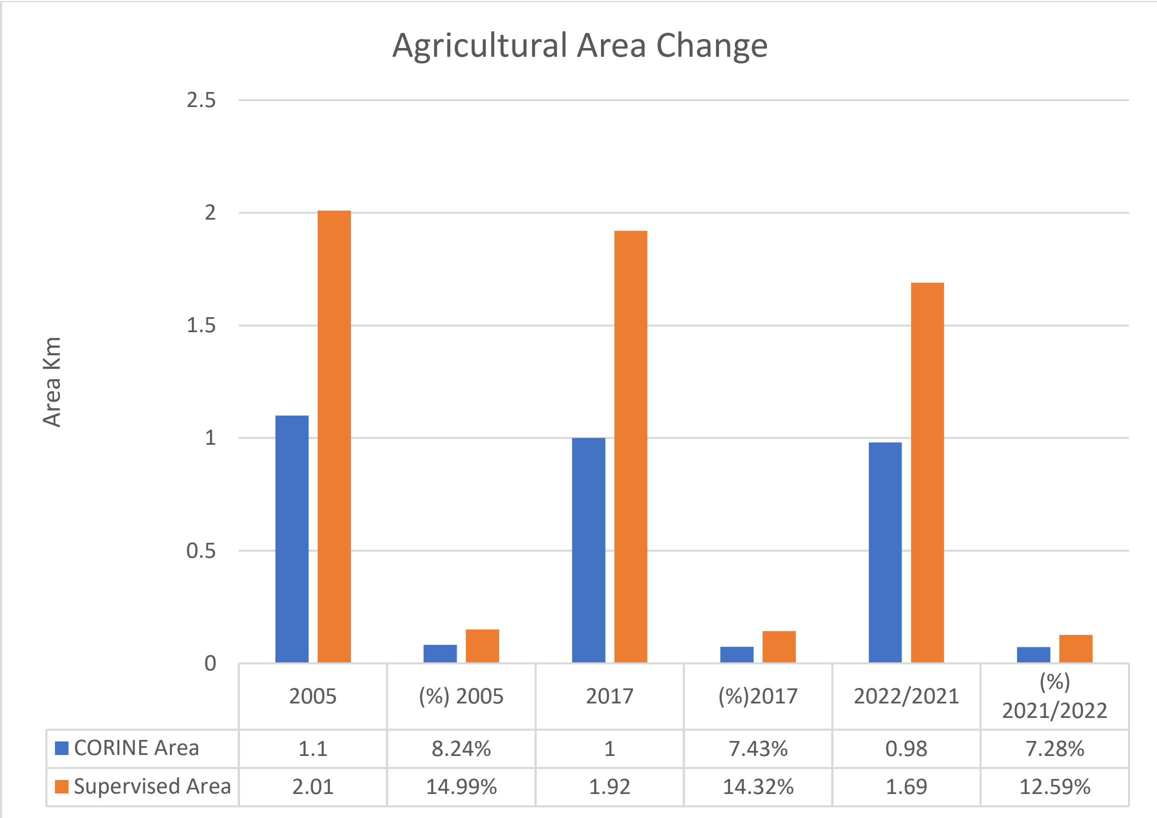


Figure 4-21:Agricultural Area Change in Both Systems

In figure 4-17, agricultural area results shown from supervised and CORINE classification is quite different. In 2005 area occupied by agriculture using supervised classification was 2.01 square kilometers while same area within the same year occupied only 1.1 kilometers using CORINE classification, a difference of 1.05 kilometers was noticed. Moreover, area occupied by agriculture in 2017 and 2021/2022 using both systems also showed significant difference, 0.92 square kilometers in 2017 and 0.71 square kilometers in 2021/2022. It is estimated that almost all differences occurred because each system uses different interpretation method. The CORINE system uses visual interpretation as an aid for classification while, supervised system uses digital interpretation. Also, the reason could be is that the satellite images acquired for both studies have different resolution (see table 3-1).

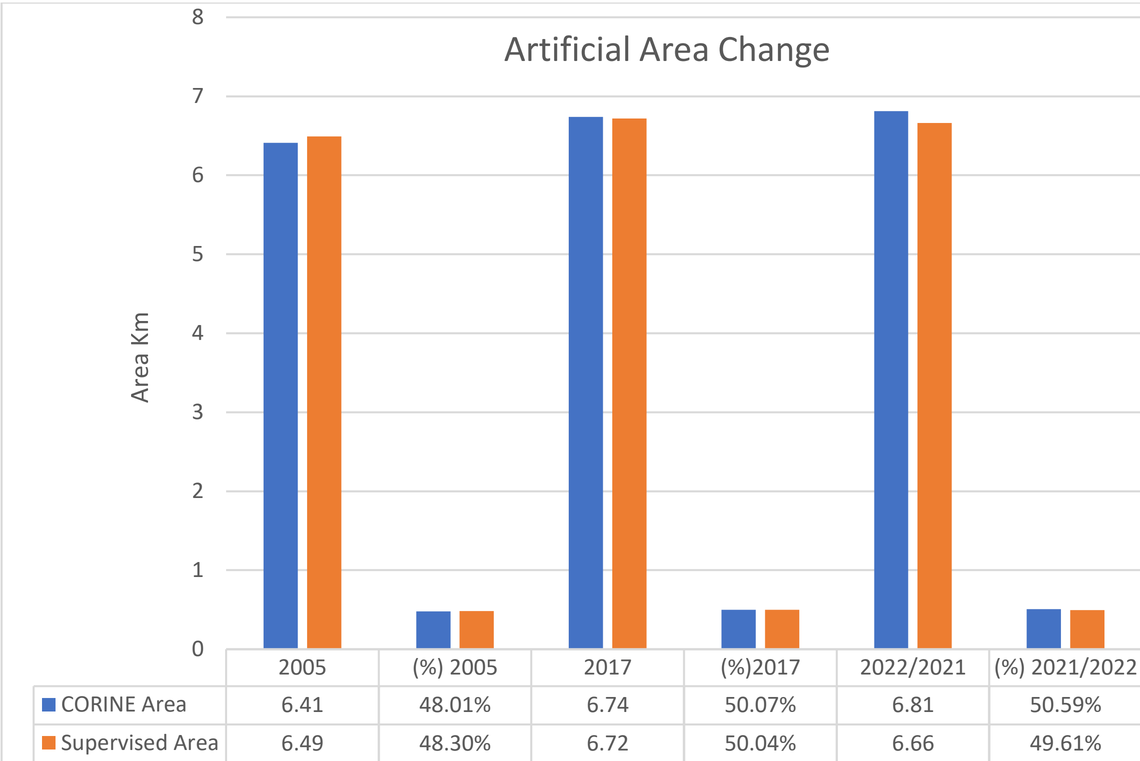
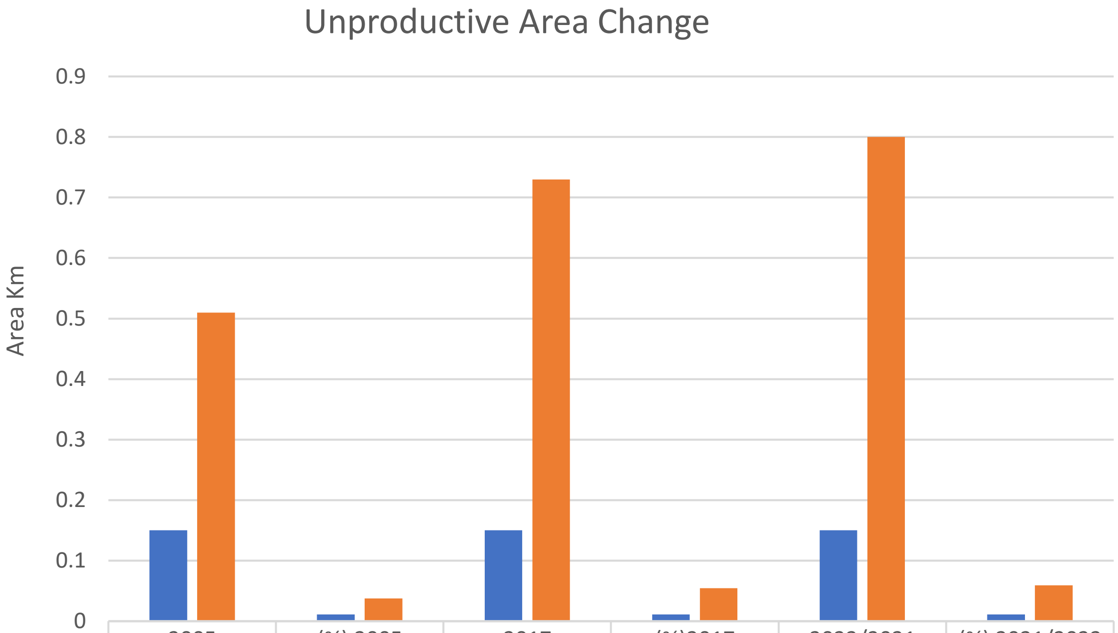


Figure 4-22:Artificial Area Change in Both Systems

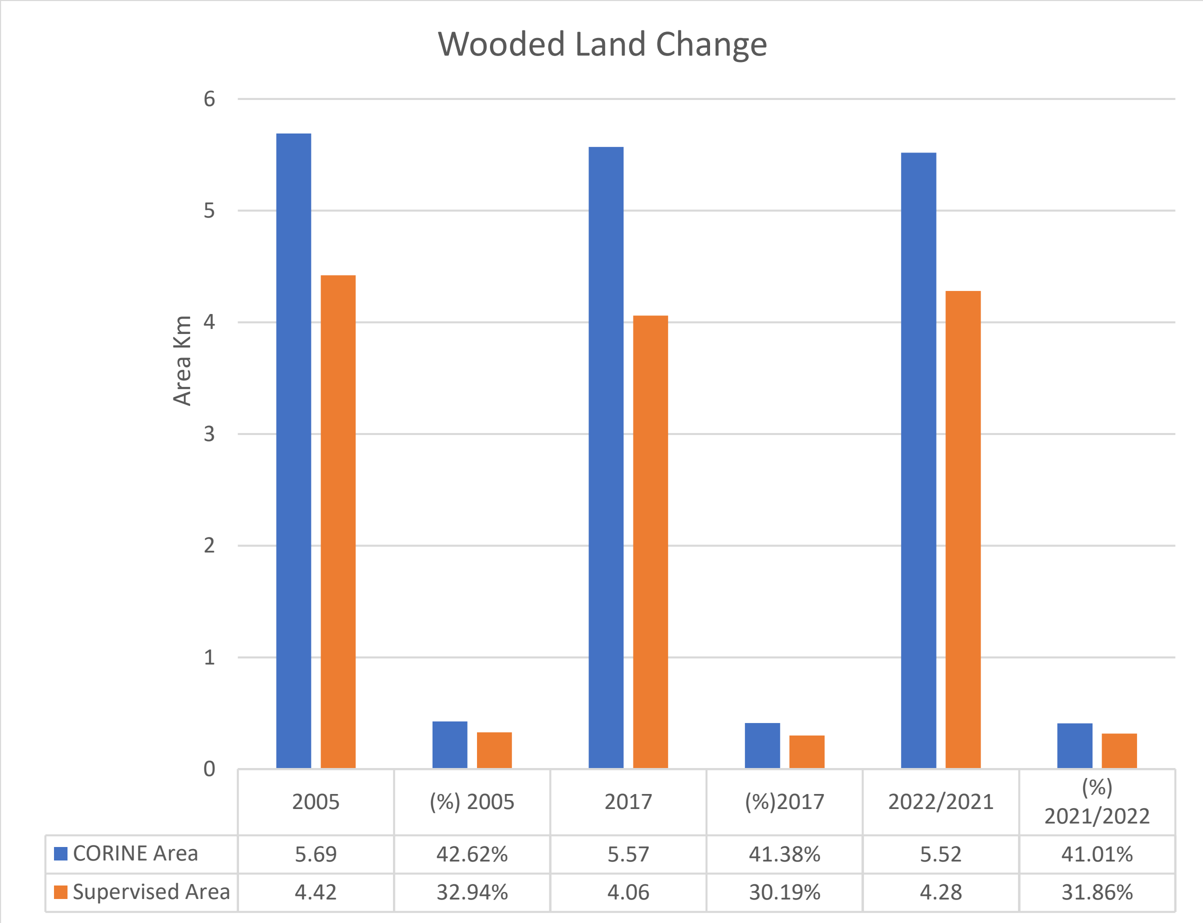
Artificial Areas from both systems shows interesting results as seen in figure 4-18, where only 0.08 square kilometers difference were measured in year 2005. Also, year 2017 and year 2021/2022 has slight differences with an average of 0.05 squared kilometers-nothing to be mentioned.



	2005	(%) 2005	2017	(%)2017	2022/2021	(%) 2021/2022
CORINE Area	0.15	1.12%	0.15	1.11%	0.15	1.11%
Supervised Area	0.51	3.76%	0.73	5.44%	0.8	5.94%

Figure 4-23:Unproductive Area Change in Both Systems

The results shown in figure 4-19 indicates significant difference in terms of area for the unproductive lands. In year 2005, 0.51 square kilometers were occupied by unproductive land using supervised system while only 0.15 square kilometers were measured using CORINE system. Moreover, in year 2017 and 2021/2022 the difference has increased quite more than year 2005 to record 0.58 square kilometers in year 2017, and 0.65 squared kilometers in year 2021/2022. Unproductive area remained the same through out the period from 2005 and 2022 using CORINE system where only 0.15 square kilometers were occupied.



	2005	(%) 2005	2017	(%)2017	2022/2021	(%) 2021/2022
CORINE Area	5.69	42.62%	5.57	41.38%	5.52	41.01%
Supervised Area	4.42	32.94%	4.06	30.19%	4.28	31.86%

Figure 4-24:Wooded Land Change in Both Systems

In figure 4-20, CORINE system and Supervised system showed some differences in the area occupied by wooded land. In 2005, wooded land occupied 5.69 square kilometers using CORINE system and 4.42 square kilometers using Supervised system. A difference of 1.27 square kilometers.

In 2017, the difference has increased to become 1.51 square kilometers and then decrease in year 2021/2022 to become 1.24 square kilometers.

CHAPTER 5. CONCLUSION

5.1. CHANGES IN DIFFERENT LAND USE/LAND COVER

Land use/land cover changes of Mount-Lebanon area have derived a conclusion which states that mining operation possess a threat to the vegetation. It is affirmed that the mining activities, migration of people from other villages into the area, and the human pressure on forest for firewood as well as grazing of cattle in the forested area led to the change in the natural topography of the region. With the advent of above reasons, considerable portion of the wooded land was converted to non- forest area such as settlement, roads and grasslands. Most of the dense forest areas and agricultural fields were converted into mining areas and settlement areas. Thus, the increase in mining and settlement areas can be attributed to the decrease in dense forest and agricultural land. Increase in mining activities caused increase in settlement by migration of people into the area.

The result of the work showed that there was a slight to medium change of artificial area and wooded land during the period from 2005 to 2022. Therefore, it can be concluded that increase in mining activities and settlement of migrated people are damaging the vegetation. The present study can be useful to identify the vegetation areas which are under risk due to above mentioned reasons.

5.2. COMPARISON BETWEEN CLC AND SUPERVISED CLASSIFICATION

The LUC classification is a method that describes the earth properties according to a certain system of classification. Each land cover/use classification system has its own perspective in dealing with earth cover delineation. Each system focuses on different criteria at each level, and uses different classifiers. comparing a Land cover/use map from one system to another requires the understanding of the definitions of classes in each system, as well as identifying where the two system show up discrepancies and compatibility.

The comparison demonstrated in this article shows its success in certain positions, and highlights its weak points. Obviously, comparison between CORINE classification and supervised classification at level one is the most effective and safe, since it bands together most of the classes. The comparison between the two system fails in some positions when the resolution of the satellite imageries is different. More realistic comparison could happen only if we have same satellite imageries having same resolution and have been taken within the same year.

Finally, the results produced by both systems are somehow close to each other, which indicates that using lower resolution images such as LandSat TM 30m resolution are more than sufficient, reducing subsequently the expected cost by using very high-resolution images such as IKONOS (1m). Moreover, supervised classification is less time consuming and very systematic.

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APPENDIX 1: LANDCOVER LEVELS WITHIN THE LEGEND (MOSS, 1999)

Level 1	Level 2	Level 3	Level 4
100- Artificial area	110- Urban area	111- Continuous urban fabric	111a- Dense urban fabric
			111b- Dense informal urban fabric
		112- Discontinuous urban fabric	112a- Medium density urban fabric
			112b- Medium density informal urban fabric
			112c- Low-density urban fabric
			112d- Low-density informal urban fabric
			112e- Tourist resort
			112f- Diverse equipment
			112g- Archeological site
	120- Activity area	121- Industrial or commercial area	
		122- Port area	
		123- Airport	
		124- Railway station	
	130- Non built-up artificial area	131- Mineral extraction sites	
		132- Dumpsites	
		133- Landfill site	
		134- Urban extension and/or construction site	
		135- Urban vacant land	
	140- Artificial, non-agricultural vegetated areas	141- Green urban area	
		142- Sport and leisure facilities	
200- Agricultural area	210- Field crops	211- Field crops in medium to large fields	
		212- Field crops in small fields/terraces	
		210/112c- Urban sprawl on field crops	
	220- Permanent Crops	221- Olives	
		222- Vineyards	
		223- Fruit trees	
		224- Citrus fruit trees	
		225- Banana	
		220/112c- Urban sprawl on permanent crops	
	230- Intensive agriculture	231- Open horticulture	
		232- Protected agriculture	
		230/112c- Urban sprawl on intensive agriculture	
	240- Agricultural units		
300- Wooded land	310- Dense wooded land	311- Dense coniferous wooded land	311a- Dense Pines
			311b- Dense Cedars
			311d- Dense Fir
			311e- Dense Cypress
		312- Dense broadleaved wooded	312a- Dense Oaks

Level 1	Level 2	Level 3	Level 4
		land	312b- Dense - other types of broadleaved trees
		313- Dense mixed wooded land	
		310/112c- Urban sprawl on dense wooded land	
	320- Clear wooded land	321- Clear coniferous wooded land	321a- Clear Pines
			321b- Clear Cedars
			321c- Clear Juniper
			321d- Clear Fir
			321e- Clear Cypress
		322- Clear broadleaved wooded land	322a- Clear Oaks
			322b- Clear - other types of broadleaved trees
		323- Clear mixed wooded land	
		320/112c- Urban sprawl on clear wooded land	
	330- Scrubland	331- Scrubland	
		332- Scrubland with some dispersed bigger trees	
		330/112c: Urban sprawl on scrubland	
	340- Burnt wooded land		
400- Grassland	410- Dense grassland		
	420- Clear grassland		
500- Wetland	510- Inland wetland		
	520- Marine wetland		
600- Unproductive area	610- Bare rocks		
	620- Bare soils		
	630- Beaches		
	640-Dunes		
700- Water bodies	710- Continental water bodies	711- Lake	
		712- Hill lake	
	720- Marine water bodies	721- Sea	
		722- Port basin	
l Water courses	lp- Permanent water course		
	lt- temporary water course		
r Road Network	r1- Highway		
	r2- Principal road		
	r3- Secondary road		
	r4- Other road types		