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DEPARTMENT OF GEOGRAPHY

MONITORING URBAN GROWTH USING REMOTE SENSING AND GIS: A CASE STUDY OF MUSCAT GOVERNORATE

BY

MOZA KHALAF SAID AL-RIYAMI

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ABSTRACT

The objective of this research is to study the use of remotely sensed data. The data under investigation is obtained from Landsat 5, 7 and 8, which are integrated with the GIS system and the MOLUSCHE framework. The study focuses on urban growth between the years 2008 and 2016 by projecting the use of land cover (LULC). Then, Classification technique was used in GIS to classify land sat images in 2000,2008 and 2016 which were covered by barren/rocks, urban population, vegetation cover, and water show a percentage of the overall land size. The rocks have coverage of 94.92%, 91.84%, and 89.71% that signify the records for the years 2000, 2008 and 2016 respectively. The trend decreases steadily in percentage across the years, with a difference of 3.08%, and 2.13% between the years 2000 and 2016 respectively. The vegetative area covered by percentage entail 1.23%, 1.68% and 2.01% for 2000, 2008 and 2016 respectively. This is an increasing trend in the percentage land cover and implies a developing area with good climatic conditions for the vegetative growth. Similarly, the area covered by water bodies in terms of percentage includes 0.04%, 0.03%, and 0.12% for 2000, 2008 and 2016 respectively. This trend increases across the years, with a difference of 0.01% increase between 2000 and 2008, and 0.09% between 2008 and 2016.

Validation tool applied in MOLUSCE to predict LULC for 2024, 2032, 2040 on the basis of classified images from 2008 and 2016. The results indicate that the probability change in urban, vegetation and water are increasing from 2024 to 2040. Urban increases reputedly in 2024, 2032, 2040 as 9.015%, 10.541%, 11.849%. Vegetation covers 1.982%, 3.301%, 0.038%. Water covers 0.051%, 0.085%, and 0.084 %. However, the barren is decreasing during this period 88.953%, 86.073%, 84.280%.

This study is imperative because it aids the users of the information to plan and make decisions on the future of land use in Oman.

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DEDICATION

I hereby declare that this thesis is my own work and effort and that it has not been submitted anywhere for any award. Where other sources of information have been used, they have been acknowledged.

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MOZA AL-RIYAMI

CHAPTER 1: INTRODUCTION

1.1 Introduction

Most countries struggle managing their populations citing the scarcity of land. However, land economists argue that there are large parcels that ought to be utilized to resettle people. They reiterate that there is sufficient land to support the global population. However, the economists observe that the challenge that exists is the utilization of idle land which is left bare. This realization makes it important for governments to develop initiatives that will make good use enhance the reclamation of bare land with the intention of improving it to sustain Land use is an important topic because it is a natural resource that is important for the economy and the general livelihood of people. Whereas some regions have productive land, others are barren. The productivity of land depends on the natural conditions and factors that facilitate the productivity of the land. For instance, dry areas are known to be less productive that the regions that experience little to no rains. However, the use of technology and new skills from research makes it possible for people and organizations to rehabilitate land and make proper use of it (Chen, 2013). In fact, research indicates that even dry areas can offer sustainable solutions through agriculture. The aspect that changes the attitude towards land use is research and proper education on the various methods that can be used to improve the quality of soils and the environment. Urbanization plays a crucial role towards the shaping of the environment. Construction of structures on land changes the arability of a region. For instance, urbanization converts land that is considered useless to become more useful, a situation that reduces wastage. Another perspective of urbanization is the element of deforestation which tends to have detrimental impacts on the land. However, recent developments show a positive progress on the way people handle the issue of urban development and land use. For instance, the heightened campaigns on sustainability and environmental conservation are evidence that the world is making positive progress towards matters land. Despite the efforts taken by environmental conservationists on developing land positively, there are concerns about the sustainability of future generations. For this reason, it is imperative for communities to develop projects to seek long-term solutions to the climatic challenges and address concerns such as land shortage. One of the most profound solutions to the problem is a land simulation (Critchley *et al*., 2016). The process entails using mechanical, scientific and natural methods to convert land to become more beneficial to the community. Land simulation is a procedure that seeks long-term solutions. Controlled urban planning and population management are important to enhance a well-coordinated development process. For this objective to be achieved there needs to be information on the likely land cover and population changes, which can be obtained through simulation tests.

1.2 Statement of the Problem

Muscat has undergone a series of expansive growth and development, a situation that is enhanced by urbanization. Over the recent decades, the capital city has experienced aggressive deforestation, the erection of buildings as well as road construction, activities that have dominated the country since the early 1970s (Al Gharibi, 2014).The census that was held in the country bin the year 2010 showed that the population in Muscat was 730,967. These figures accounted for 26.36% of the overall Oman population. However, the 2003 census showed that the population was 593,426, which translated to 25.35 %. From the figures, it is evident that the population had increased, and resulted in aggressive expansion and urbanization in Muscat to accommodate the growing number of people in the city (Andy, 2013). The construction of the road network created a link between Muscat Governorate and its suburbs (Al Gharibi, 2014). This study intends to study this problem with the remote sensing technique. The study intends to monitor the land use cover (LULC) in 200, 2008 and 2016. The study will also simulate land use and cover in the years 2024, 2032 and 2040. For this reason, Muscat Governorate is the most appropriate area to be studied.

1.3 Aim and Objectives

1.3.1 Aim

This study intends to map the land use and cover in Muscat Governorate. The objective of the mapping is to detect changes experienced in areas that have been developed over time, and predict the likely changes that may take place in future in the same region.

1.3.2 Objectives

This study will focus on the following specific objectives:

- To map land use and land cover for the specific years.
- To study the dynamics of urban land use variations in the selected periods
- To determine the trend and extent of land use changes within specific periods
- To predict and measure future patterns of LULC in Muscat Governorate.
- To recommend potential measures that can be used to mitigate the impacts of the land use changes.

1.4 Research Questions

This study will have three principal questions that it intends to satisfy: -

1. What is the chief class change in LULC during the sixteen years?
2. In what ways does the expansion influence land cover?
3. How can this data utilized to develop the land between the years 2024 and 2040?

CHAPTER 2: LITERTURE REVIEW

2.1 Approaches to Urbanization

According to John and Wan (2013), the latest urbanization projections by the UN, especially in China and India, require a substantial comprehension of the drivers and trends of urbanization. The researchers hold that the previous studies have failed to focus on the issue of urbanization and urban concentration comprehensively. In the study that aimed at identifying the determinants of urbanization, the researchers utilized the UN prospects to identify the gross domestic products among the two countries under study. The study focused on some items including education population growth, industrialization, trade, and infrastructure. The study sought evidence on the impacts of education growth, industrialization and education on the rate of urbanization in the countries. While relating the GDP growth with urbanization, the authors augured that growth leads to urbanization and not the other way round. This is based on the estimate that was done on the causal effect of growth with regard to a large number of previous studies that linked urbanization with growth as well as the fact that the previous attempts to determine the influence of urbanization on growth have not had any success. The study utilized a quantitative study that came up with results showing a 1% increase in growth corresponding to 0.9% growth in urbanization. There was a significant relationship between education and urbanization whereby higher education levels translated to higher urbanization. The authors suggest that there is a need for more research to verify whether the lagged values of covariate present sensible instruments and whether the impacts of growth, industrialization, education on the urbanization process are homogenous.

A study by Idowu (2013) identifies the challenges of urbanization and urban growth through the survey that was carried out in Nigeria. The author noted that urbanization in Nigeria was seen as a non-issue in the 1960s. However, in the 1970s, as the oil industry was booming, there were increasingly high numbers of people that were shifting to the urban areas in search of better living standards. People were attracted to the better housing facilities that were available at the urban centres and the availability of jobs that would offer them returns to boost their standards of living. People were also attracted by the availability of social amenities that enabled then to boost their social interactions. It is estimated that the proportion of the people staying in urban areas was below 5% in the 1800s. This figure (1) rose by over 47% in 2000 and is expected to rise up to 65% by the year 2030. There is a close link between urbanization and environmental degradation. Urbanization leads to depletion of resources as they are used to carry out development projects. Urbanization leads to clearing of vegetation hence leading to deforestation which is a major factor that causes droughts. Other issues associated with urbanization with regard to environmental degradation include the generation of wastes that causes pollution to the environment. The study asserts that the number of people migrating to the urban centres is increasing exponentially thus leading to population pressure in the urban centers. Notably, population pressure in the urban centers is attributed to some issues including higher security concerns, development of slums and poor settlement thus leading to the increased spread of diseases among the residents in the urban areas. The World Bank identifies poverty as a lack of food, shelter and contacting diseases without the ability to see a doctor. It also identifies lack of capacity to attend school as being poor. There is also very high unemployment due to the rising urbanization in the country. Other issues identified by the study arising from urbanization include climate change due to the increase in the number of industries that emit a heavy amount of greenhouse gasses to the environment. The figure below show the migration patterns in Nigeria from 1985 to 2005.

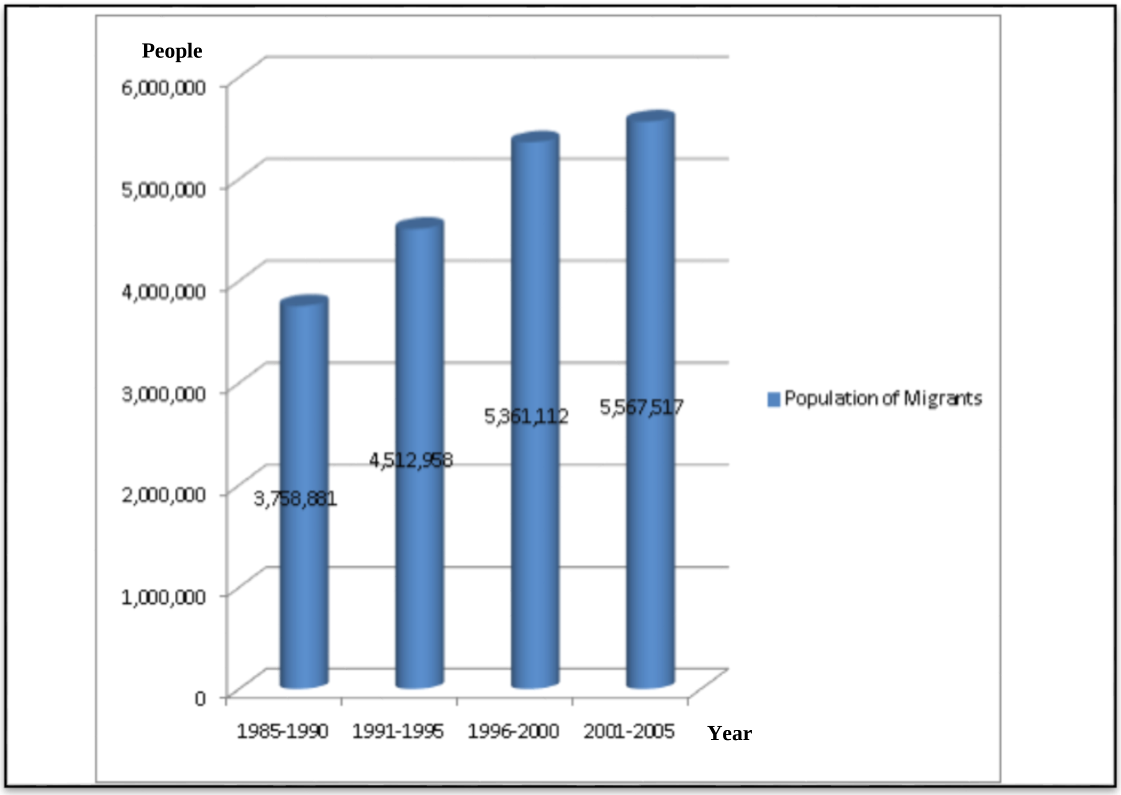

Figure 1: Population of Rural-urban Migrants in Nigeria from 1985 to 2005

The author identified a number of challenges likely to face urban centres in the future such as collapsing of carrying capacity and a further decrease in the unemployment rates. The study also noted further cases of insecurity, climate change, and environmental problems.

A study by Henderson (2003) was carried out a survey to offer guidance on the relationship between urbanization and economic development. The authors noted that urbanization is a transitory process that has seen populations move from traditional cultural environments that were characterized by informal political and economic systems to a relative anonymity and more formal urban set ups. Urbanization spatially separates the people from different families within different generations as the young ones move to stay in urban areas leaving the older people behind. The countries are regarded as urbanized when over 60% of their total populations live in urban centers. The study that was mainly based on China identified some key issues and policies of the Chinese urbanized systems. Firstly, the Chinese cities are small and equally sized unlike most other cities in different countries. The study noted that the city of Shanghai had a population of 12.3 million in the year 2000. This is far below the top 10 largest metro cities in the entire world. China has just 9 metro areas having over three million inhabitants with another 125 metro areas with about 1 to 3 million people.

The un.org (2014) revealed that 54% of the world people reside in urban areas as compared to 1950s when only 30% of the world population resided in urban areas. Currently, there is over 82% population residing urban areas in North America, 73% in Europe, 80% in the Caribbean regions, 40% in Africa and 48% in Asia. The report suggests that rural populations of the world have been growing at a very slow rate and are likely to its peak in the next few years. The rural population now stands as 3.4 billion, and the report notes that the population is likely to decline further to 3.2 billion by 2050. Asia and Africa host the highest numbers (about 90%) of the rural dwellers in the world. Of all the world population, India remains the country with the largest population of 857 million people ahead of China whose population stands at 635 million. China, India, and Nigeria are expected to be responsible for over 37% of the predicted growth of the world population from 2014 to 2050. China is expected to have 292 million urban populations while India will have 4040 million and Nigeria is estimated to have 212 million.

In a selected literature survey in India that utilized a secondary research, an examination of the changing urban landscape and its influence on the society was described (Mohr, 2011). This was considered an important aspect of study as it helped to identify the economic progress in the regions and the world as a whole. The study held that private urbanism is rising in India thus leading to a fragmented space due to the specialization of all the urban regions as the firms and boundaries are necessary to identify all parts. The researchers further noted that planned settlements are available for a few sections of individuals who belong to the middle class (Mohr, 2011). Meanwhile, the poor people live in overcrowded slums hence the authors are stressing on the fact that there is a need for proper planning that incorporates the needs of the poor people in slums.

2.2 Urban Expansion

Rapid urbanization has turned out to be increasingly important socially, economically, and ecologically (Balakrishna *et al*., 2012). During the current decades, urban growth has become a noteworthy feature of urban growth throughout the planet (Abdulrahman, 2015). Expanding urbanization is defined as the people immigration from a rural to an urban area (Al Gharibi, 2014). This is because of economic growth and a growing population which has created elevated insistence on land cover resources, together with household food and water provisions (Albalawi and Kumar, 2003). Zhang (2004) has offered an alternative description of urban sprawl as “the outline of urban expansion that has been considered being out of control. Sprawl is a phrase frequently considered in the portrayal of low-walkable societies defined by decreased density, isolated land exploitation as well as separated streets. The era of mid-20th century saw the acceleration of sprawl as an urban design form, catalysed mainly by the huge numbers of residents possessing automobiles and able to cruise long distances to various destinations. In accordance with Foran (2009), urban sprawl can be defined as “disseminated expansion that upsurges traffic, destroys open space as well as tapping local resources, while on the other hand Maciocco (2008) considers the appearance of sprawl being in form of a city adrift beyond others since it portrays itself as a shapeless urban expansion.” in accordance with Hayden (2004) another definition of sprawl is considered as the method of expanding an extensive real estate leading to urban centers that are distributed, car-reliant construction that is discontinuous, typically on the margin of decreasing aged suburbs and shrinking city centers (DePriest and Banai, 2014). These “urbanized areas” are solely inclusive of those representing developed suburban or urban census blocks (contrary to “metropolitan statistical regions,” comprising of extensive vacant land) and distributed populations within such regions into central city and suburban populace. Sprawl is simply the expansion of a city and its outskirts over gradual rural land at an urban area’s periphery. This comprises the transformation of open space (rural land) into urbanized, established land with time. Concerning the UN, above 50% of the globe’s population resided in urban centres in 2006 with this percentage expected to rise to 60% by the year 2020, while the highest growth expected to occur in developing nations (Pourahmad *et al*., 2011).

The researchers indicated that urban development is among the key aspects of the urbanization process is the already established nations like the USA, Canada as well as Australia as of the World War II. In consideration of the previous three decades, the technique of remote sensing images has been considered an excellent application in the detection of an urban change (Galli *et al*., 1993). Currently, there has been a tremendous growth of urban regions in Southern Europe as well as some nations under development like India. In his study, Daniels (2001) argues that a considerable range of growth happens in the outskirts of an affordable urban region defined by sufficient land capable of hosting structures. There has been an incredible increment in Europe's urbanization over the last one century. Currently, the urban regions in the European Union have extensively hosted a vast number of residents with the rural areas remaining densely populated with several small and medium sized towns. This is the equal idea (of township settlement) applicable in Denmark which is a state whose population is quite dense and creates a complex web of cities. On the other hand, Sweden has a moderate sparse population with the process of urbanization being quite young- it only commenced in early 20th century (Möllers and Madureira, 2006).

The experience of urban expansion has become progressively vital in Sultanate of Oman since it is enlarged as a result of economic growth and land reserves such as explorations of oil and educational growth (Al-Awadhi and Azaz, 2005). An excellent demonstration of educational expansion is the Sultan Qaboos University, which was instituted during 1986 as the earliest university within Al-Seeb Wilayat in Oman. The university is attracting scholars from across Oman due to this service, which has brought about urban growth (Al-Awadhi and Azaz, 2005). By this reasoning, Al-Awadhi and Azaz (2005) demonstrated that within remote sensing and GIS techniques, the aerial photos of 1991 and satellite images of 2000 and 2003 were used to detect urban land use changes in Al-Seeb Wilayat.

The outcome showed that the overall of built-up area extended significantly by 27.93% between 1991 and 2003. Another case of fast socioeconomic expansion and urban development in current decades is Al Jabal Al Akhdar, which has affected the water resources (Al-Kalbani and Price, 2015). The growth of any metropolitan region surrounded by a catchment creates several influences on the land (Chang, 2013).

2.3 Causes of Urbanization

Researchers have noted that the majority of the people view rural areas as places with hardships and primitive lifestyles (Cohen, 2006). As such, they move to towns where life looks advanced. There are some reasons that make the urban centres more habitable as compared to the rural areas. First, researchers link the development of industries in the urban centers to the increased migration towards the regions. Previous studies hold that the industrial revolution is the main aspect that attracted people from the rural areas to the urban centres. Industrialization has been attributed to increased employment opportunities to the people who come in to fill the positions hence seeking to settle near the regions with industries. The settlements gradually increased thus leading to expansion of urban areas. Apart from industries, there are some sectors that offer people job opportunities such as sectors of health, education, sports, transport, recreation, and business. Expansion of these services in the urban centres has created gaps that the people from the rural regions who migrate to fill hence increasing the population pressure in the urban areas (Cohen, 2006). Higher population calls for more settlements and hence increased housing is experienced in the urban centers. Another factor that leads to urbanization is the rural-urban transformations since the local people become more productive hence improving their living standards that are characterized by improved housing and increased economic activities in the rural areas.

A study carried out by Shahbaz and Lean (2012) identified the extent to which urbanization and industrialization are connected with energy consumption and financial development. This study based in Tunisia utilized data between 1971 and 2008. The findings revealed that there was a connection between economic growth, industrialization financial development, and urbanization in Tunisia. Financial development, which is mainly influenced by industrialization, directly influences the amount of energy consumption while industrialization and financial development directly increase the rate of urbanization. The study's findings have played a key role in helping the investors to come up with other significant findings that support major decisions relating to environmental planning.

2.4 Impacts of Urbanization

Urbanization leads to both positive and negative outcomes. Among the positive impacts is technological advancement, improved infrastructure, higher quality education and also better living standards. These are mostly the main factors that attract many people to the urban areas. However, the rising in a number of people is urban areas leads to overcrowding thus increasing competition for resources thus leading to their depletion (Cohen, 2006). There is also the development of slum regions that arise due to the rise in the number of people as compared to the available housing facilities. Additionally, the people mostly face water and sanitation problems as the rate of consumption is higher than the available resources. Other issues experienced in the urban areas include traffic congestion that leads to pollution which in turn leads to climate change hence leading to further problems in the world. Family.jrank.org (n.d) notes that urbanization is more of a social process that transforms the societal organizations, the family roles, the demographic structures, the people's lifestyle and the nature of work. The fertility rate among the people in the urban centres is significantly lower than those of rural areas. In such countries as Europe and Northern America, urbanization has often led to reduced fertility rates as the people in the cities are engaged in economic activities for considerably longer periods of time as compared to their counterparts in the rural regions. As such, families reduce in numbers due to less number of children per family in the urban areas and the fact that extended families are not common in urban areas (Family.jrank.org, n.d.). Urbanization has rearranged the family and living arrangement thus declining the status of the household.

2.5 Remote sensing change detection

Satellite images through remote sensing are useful for the recognition and scrutiny of the spatiotemporal tendencies and dynamics of municipal widening and land-cover alterations (Dewan and Yamaguchi, 2009; Estoque and Murayama, 2012). Moreover, the growing accessibility of satellite imagery and digital orthophoto, several of which are at no cost, significantly assists in this urban development and change discovery (Ma and Xu, 2010). For instance, The United State Geological Survey (USGS) have been offering free, constant, worldwide coverage of satellite information that has had a spatial degree of 30 m since 1982 (Bagan and Yamagata, 2014). These kinds of images are helpful, owing to their capability to release land-cover transformations in both anthropogenic and natural features in regional zones, as shown in different researchers (Dech *et al*., 2013; Jiao, 2015). By analyzing primordial images for the time sequence, land use (build up area) and land cover (vegetation, water, and open area) changes (LULC) can be created and then employed together for the forecast of future growth for the confirmation of the increase of model productivity (United Nations, 2001). With the application of these data, Al-Awadhi and Azaz (2005) confirmed monitored and scrutinized urban expansion within Al-Seeb Wilayat by means of satellite imagery and GIS from 1991 to 2003 and highlighted that the statistics, with the improvement of technologies, can bank effort, time, and cost (Al-Awadhi and Azaz, 2005). The remote sensing approach is implemented to research the geological land application alterations that occurred during the research duration. TM and ETM+ Landsat imagery of the Vijayawada city region is gathered from the USGS Earth Explorer website. The result of change discovery examination reveals that about 372% has augmented the Build-up region, over 65% has reduced the farming region, and the desolate area decreased by about 60% (Balakrishna *et al*., 2012).

Several spatial layers of the motivating forces of urban expansion were received from a formerly generated digital orthophoto (Coleman *et al*., 2015). Mapping municipal coverage and its temporal alterations by determining impermeable surface regions from Landsat satellite distantly sensed information in combination with digital orthophotography (Xian *et al*., 2005). It is clear that the employment of high-tech satellite images could be especially economically effective in various respects, in contrast to orthophoto mapping with its dependence on customary aerial cinematography. It is anticipated that the majority of difficulties could be conquered using such elevated resolution satellite images for orthophoto mapping (Chhatkuli, 2015).

2.6 Future Growth

The future intensification has been estimated by employing a noteworthy model within remote sensing and geological data system software (Tongkumchum and Chuangchang, 2014). Markov-Cellular Automata (M-CA) is one among the significant models that assist urban planners during the procedure of choice making, which is targeted at dealing with problems that might take place within the atmosphere surrounding the urban region by detecting alterations (Abdulrahman, 2015). This model works with the LULC change map and population data to predict and simulate the development areas. This kind of study is also very useful in demonstrating the grounds for changes (Abdulrahman, 2015). With the use of this archetype, it was confirmed that the future municipal area might enlarge by around 16.09% within Mansoura and Talkha. The augmented urbanization might have numerous influences on energy utilization, infrastructure, and the nation's economy (Kaloop and Hegazy, 2015).

Conversely, Cellular Automata (CA) systems are considered discrete dynamic schemes with their behaviour being entirely defined by local associations. They are composed of four elements, inclusive of states, cells, adjacent cells, as well as transition rules. Cells simply denote the objects in dimensional space beside being next to each other. A single cell is capable of taking the form of a given state at any specified instance from the various states making up the system's attributes. A given cell's state is highly dependent on the state of the other cells in the system (Leao *et al*., 2004). Also, any cell's state highly depends on the state of neighbouring or adjacent cells, while; transition rules hold considered in driving deviations in each of the system's cells. Such rules applicable during transitions are considered functions of the ongoing activities on the environs of each cell (Chima, 2015).

Large Scale Urban Models (LSUMs) can be considered as models attempting to delineate functional wise an entire urban region, with respect to land use, demographic, spatial, and economic relations. These initially appeared as extensively mathematical models, existing in an era corresponding with the initial application of computers in planning (Leao *et al*., 2004). These LSUMs were utilized as models of spatial interaction, in an application with inputs from macroeconomic theories. By then, such models executed a top-down technique. This revealed some consistency with the then rationality that land expansion was modeled regarding stabilized, macroscopic and deterministic approaches (Chima, 2015).

Large Scale Urban Models (LSUMs) described by Lee (1994) as models that seek to describe in a functional form an entire urban area, in spatial, land use, demographic and economic terms. These were largely mathematical models, which thrived in a period that coincided with the introduction of computers in planning (Leao *et al*., 2004). The LSUMs were used as spatial interaction models, who worked with inputs from macroeconomic theories. The models at this time adopted a top-down approach. This was in line with the thinking at the time that land development was modeled in equilibrium, macroscopic and deterministic ways (Chima, 2015).

Managing urban growth has turned out to be one of the main difficulties of the 21st century. Simultaneously, the idea of urban domination has itself experienced a key revolution over the previous one and a half decade. Governance of municipalities all throughout the developing globe has been influenced by shifts in the direction of political pluralism and democratization, stress on decentralization, and the growth of the civil community. Several lawful and institutional changes in several nations have offered a form to institutional transformations at the regional and municipal Heights (United National, 2001).

Subsequently, answers to urban challenges are gradually being searched for at the local instead of the state or countrywide level. These patterns underline the crucial necessity to construct and support the capability of resident administrations to administer the ecological and community service difficulties that go along with fast urban expansion (Cohen, 2006).

To sum up, urban development has significant social, economic, and ecological consequences across the globe. The pattern of increasingly growing urban development witnessed across the world has brought about significant benefits. Some of the benefits include good housing and creation of job opportunities. On the other hand, it has resulted in negative effects such as encroachment of the water sources by human beings. Others include deforestation, whereby the majority of the forests have been cleared to provide space to the expanding municipalities. Therefore, the constant urban growth due to the contributing factors will result in further consequences, both positive and negative.
To monitor land use and land cover, remote sensing has been applied significantly. Satellite images have been used to monitor the rate of urban expansion and the future expectations. Such images enable the collection of data that helps in the prediction of the future rate of urban growth. Researchers have also used such data to carry out researches to analyze some of the effects of urban expansion. Others have used the statistics to predict the future of the ever-changing urban expansion.

Several models have been used to predict more about the future of urban development. *MOLUCSE* (Methods of Land Use Change Evaluation) is one of the models that have been widely applied in the prediction about the future. *MOLUCSE* was applied in this research to gather data that were used to predict the future and help manage the urban expansion. However, it has become difficult to manage urban expansion in the 21st century. Despite it being a challenge, some measures must be undertaken so as to manage the rate at which urban expansion is increasing.

CHAPTER 3: METHODOLOGY

This section will have explanations of the study methods that were employed to obtain the results as well as the information over the data that was used and how it has been managed.

3.1 Study Area

In this study, a case in point is Muscat Governorate, and it will be used to show the expanded of urban development on the land cover. The figure below is an illustration of the region that was studied. The Muscat Governorate is situated in the northeast of the Oman Sultanate which happens to be the capital of Oman. It is located about 23° 30' and 23° 45' north latitude and 57° and 59° east longitudes. It has six administrative units in Oman which are Wilayat of Muscat, Mattrah, Bausher, A'Seeb, Al'Amarat and Quariyat. It covers from A'Seeb in the north to the Quariyat and is beyond the Gulf of Oman by 3165 Km.

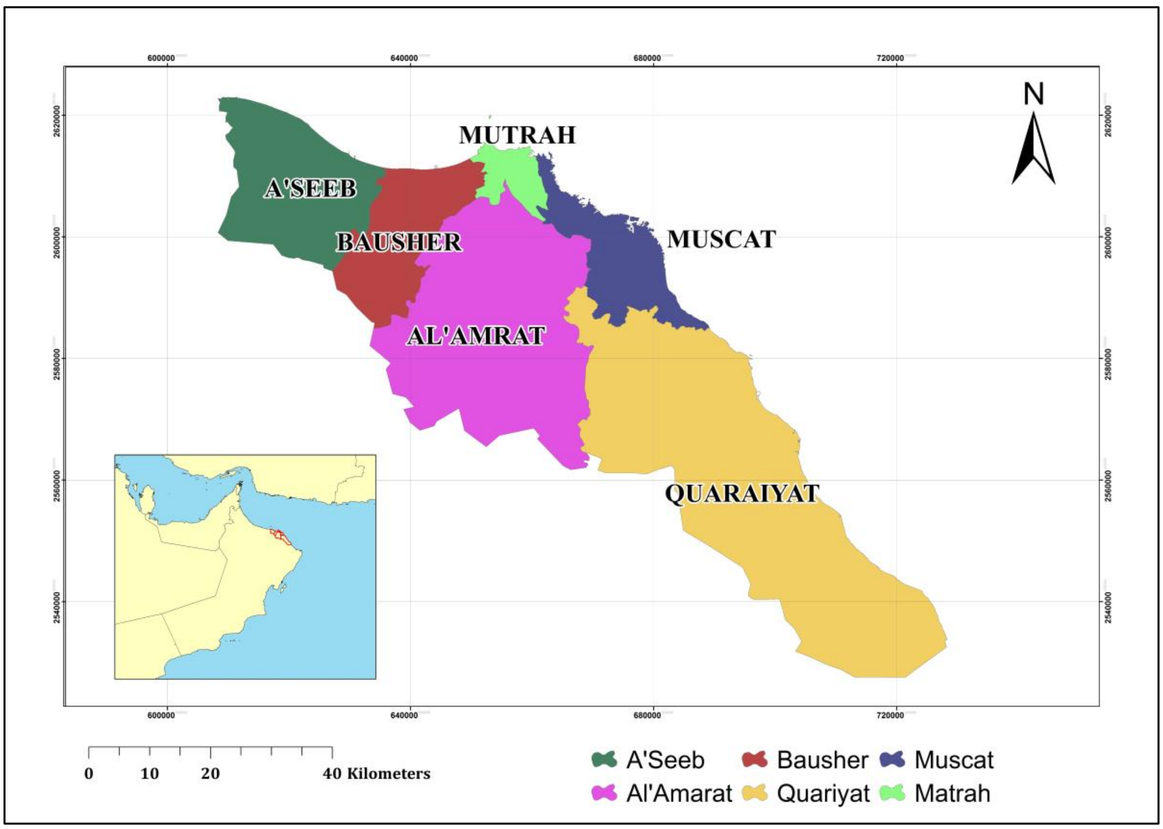

Figure 2: Study Area of Muscat Governorate within Six Wilayats

The Muscat Governorate lies on a space of about 3900 km square and harbors a population of about 775,878. Table 1 shows the population of each Wilayat in reference to the 2010 census (Ncsi.gov.om, 2017).

Wilayat	**Population**
Mutrah	150,124
Bawshar	192,235
As Seeb	302,992
Al Amrat	58,400
Muscat	27,216
Qurayyat	44,911
Muscat Governorate	775,878

Table 1: The total population of each Muscat Wilayats in 2010 census

3.2 Data Acquisition and Collection

Two different sources of spatial data have been used for this study:

1. Raster data (Satellite images, slope)
2. Spatial data (Local government boundary of study area and roads)

3.2.1 Raster data

Satellite images

The region is situated between 23° 30' and 23° 45' north latitude and 57° and 59° east longitude taking hold of the Oman capital. The satellite equipment that was used in this research was courtesy of Landsat satellite imagery through their United States Geological Survey (USGS), and it was free for download on the internet through the link http://earthexplorer.usgs.gov. The research made use of two landstat5, two landstat7, and two landstat8 images. The Landsat 5 pictures were obtained on 19th October 2008 and 11th November 2008. The Landsat 7 pictures were attained on 21 October 2000 and 28 October 2000. Furthermore, the Landsat 8 Operational land imagery (OLI) images were acquired on 09 October 2016 and 16 October 2016. 0% cloud cover was seen, and the entire images had 30 meters of resolution. The figure shows the images of Landsat 5, 7 and 8 images in the original colour. The Metadata over this information can be viewed in Table 2.

Satellite	**Landsat5**		**Landsat7**		**Landsat8**	
Entity ID	LT51570442008293KHC01	LT51580442008316KHC01	LE71570442000295SGS00	LE71580442000302SGS02	LC81570442016283LGN00	LC81580442016290LGN00
Acquisition date	19th October 2008	11th November 2008	21st October 2000	28th October 2000	9th October 2016	16th October 2016
Sensor	TM	TM	ETM+	ETM+	OLI	OLI
Path	157	158	157	158	157	158
Row	44	44	44	44	44	44
Projection	UTM Zone 40N	UTM Zone 40N	UTM Zone 40N	UTM Zone 40N	UTM Zone 40N	UTM Zone 40N
Datum	WGS 84	WGS 84	WGS 84	WGS 84	WGS 84	WGS 84

Table 2: Metadata over satellite data

Slope

The Slope data of Muscat Governorate was acquired from Ministry of Environment and Climate Affair to use it as a factor in predicting urban growth. The slope tool is used to determine the maximum change rates between cells. All cells that are in the output raster have their values. The terrain flattens with a reduction of the slope values and vice versa. The value of the output slope raster is obtained by calculating the degree of the slope.

3.2.2 Spatial data

Further data was acquired from Ministry Of Environment and Climate Affairs to state that the local government boundary and roads data of Muscat Governorate. This brought about to Universal Transverse Mercator projection in zone 40N. The figure (3) illustrates the local authority's boundary, road, and slope as a background map of Muscat Governorate.

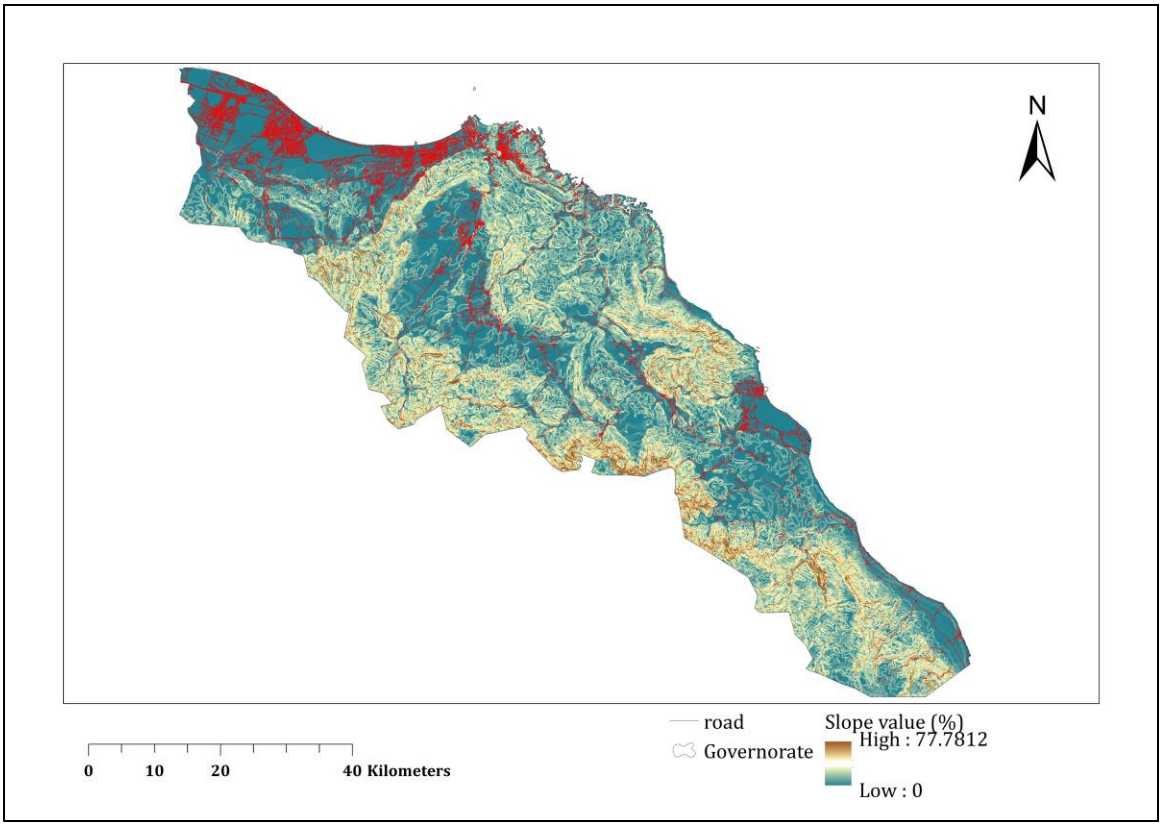

Figure 3: The Study Area within Slope and Roads Map

3.3 Method Used in this study

The objective of this research is to observe the change in LULC in Muscat Governorate from 2000-2016 while using remote sensing and the geographical information system and to foresee the style of urban development in the future. Mainly there were six software that was used for this project namely: ERDAS IMAGINE (2014) was used for preprocessing, enhancement and for classify and analyze the images, ArcGIS 10.4 was acquired from the ESRI company, and it complimented the processing of the information and map the result, and *QGIS* program will be employed to simulate the development region in Muscat Governorate. The figure shown below is a summary of the stages and the methods that were employed in this research. Three satellite images of the study area were downloaded freely from http://earthexplorer.usgs.gov (2000, 2008 and 2016). ERDAS IMAGINE software was used to pre-process the images such as staking, radiometric calibration, mosaic, and subset. Using Maximum-likelihood algorithm, which was in supervised classification, was employed to classify the image into four classes mainly, build up area, vegetation, barren rocks, and water. Signature means of each land cover was used to classify each land cover. Almost 300 signatures for all four classes were collected using the AOI polygon tool in ERDAS IMAGINE. Land cover change maps and area of each land cover was calculated using ArcGIS software. The increase in each land cover and percentage increase in each land cover was shown using Excel graphs. The future land cover change was estimated using *MOLUSCE* in *QGIS* program from the year 2008 and 2016, which will result probably, prediction of urban growth for next 16 years. Figure (4) was explained Methodology.

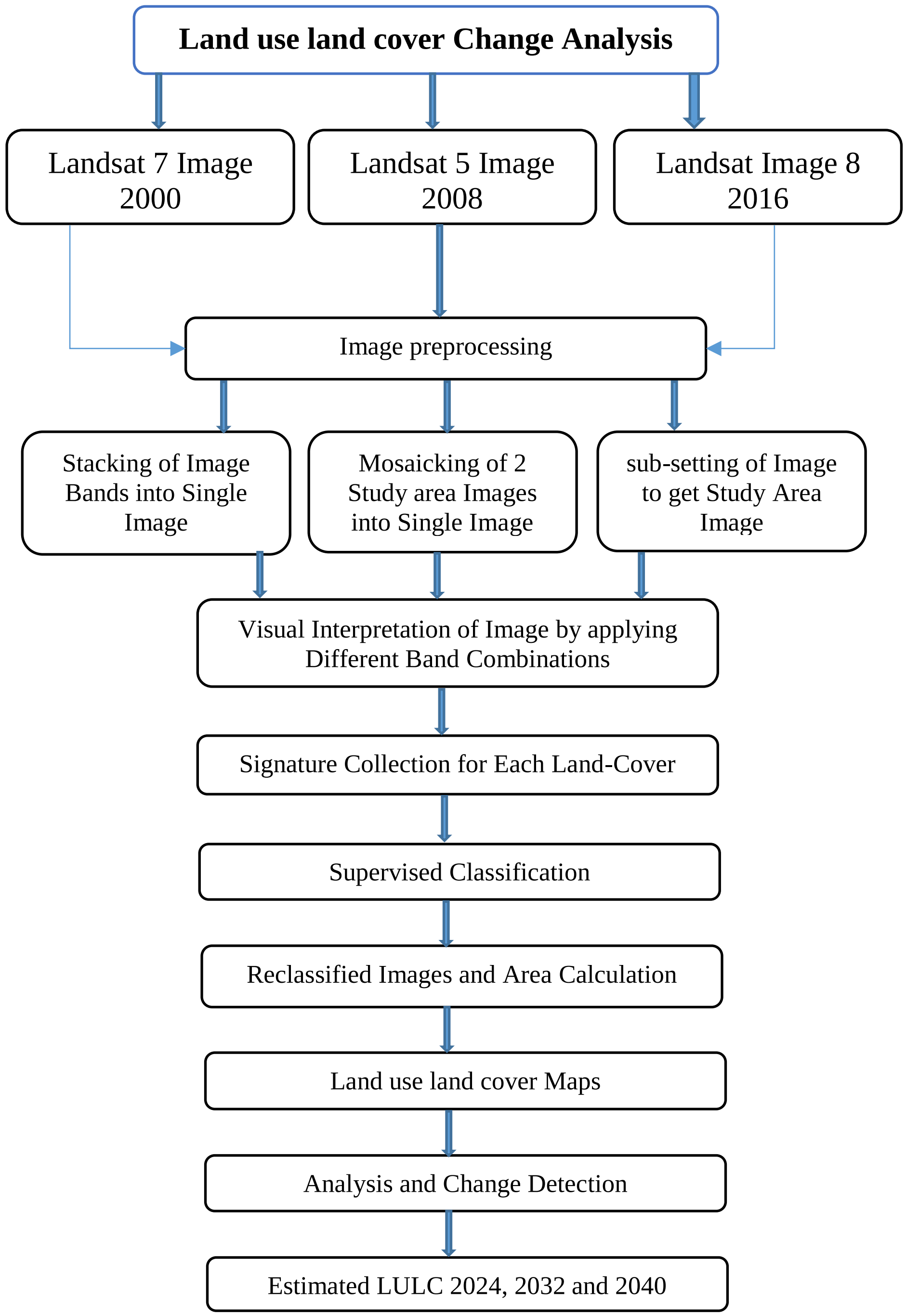

Figure 4: Cartographic Model Shows the Procedures of Detecting Change and Estimating LULC Types

3.4 Image Pre-processing

Satellite image processing entails a set of procedures and techniques that are used to pre-process image data and extract information from it (Furtado *et al.*, 2010). All basic image-processing tasks were carried out using ERDAS IMAGINE software. The ERDAS IMAGINE model maker provides the facility to perform all the image pre-processing using different models. All the tasks from image pre-processing till image classification are performed using ERDAS IMAGINE software. Before implementing change detection analysis, some pre-processing must be performed on the Landsat images before they will be useful for analysis. The following conditions were made:

i. Layer stacking
ii. Radiometric Calibration.
iii. Mosaic two images in the same year.
iv. Resize or subset the area of the study.

3.4.1 Layer Stacking

In this study, there were three different Landsat images were used which were from Landsat 5 TM, and it has seven bands in GeoTIFF format in each band. In ERDAS IMAGINE program, Layer Stacking technique was employed to stack the image bands into a single multispectral layer. This was done to aid further analysis. All bands, except 6 were extracted.

3.4.2 Radiometric Correction

It is imperative to note that satellite images from a similar geographic area register diverse radiometric values because of the variations in sensor calibration (Du *et al*., 2002). The radiometric calibration is required necessarily for the images. ERDAS IMAGINE model builder provides an opportunity perform major procedures in image pre-processing such as reflectance and image calibration.

3.4.3 Mosaic the images

The study area Muscat not covers by one scene of Landsat Image. The study area is completed using two satellite images of Landsat. A mosaic of various size and shape patches (Brooks and Bell, 2001). Satellite image also requires pre-processing such as mosaicking the frames together and geo-referencing the imagery before spatial analysis

(Kaufman, 2007). ERDAS IMAGINE mosaic tool was used to mosaic the images into one image; creates an image from overlapping images of the same data type, referencing system, and pixel resolution. The tool offers the option to match image gray levels, creating what looks like a more natural single image. This tool was used for two images covering the study area. Each of the images was pieced together using the MOSAIC as figure (5) was shown.

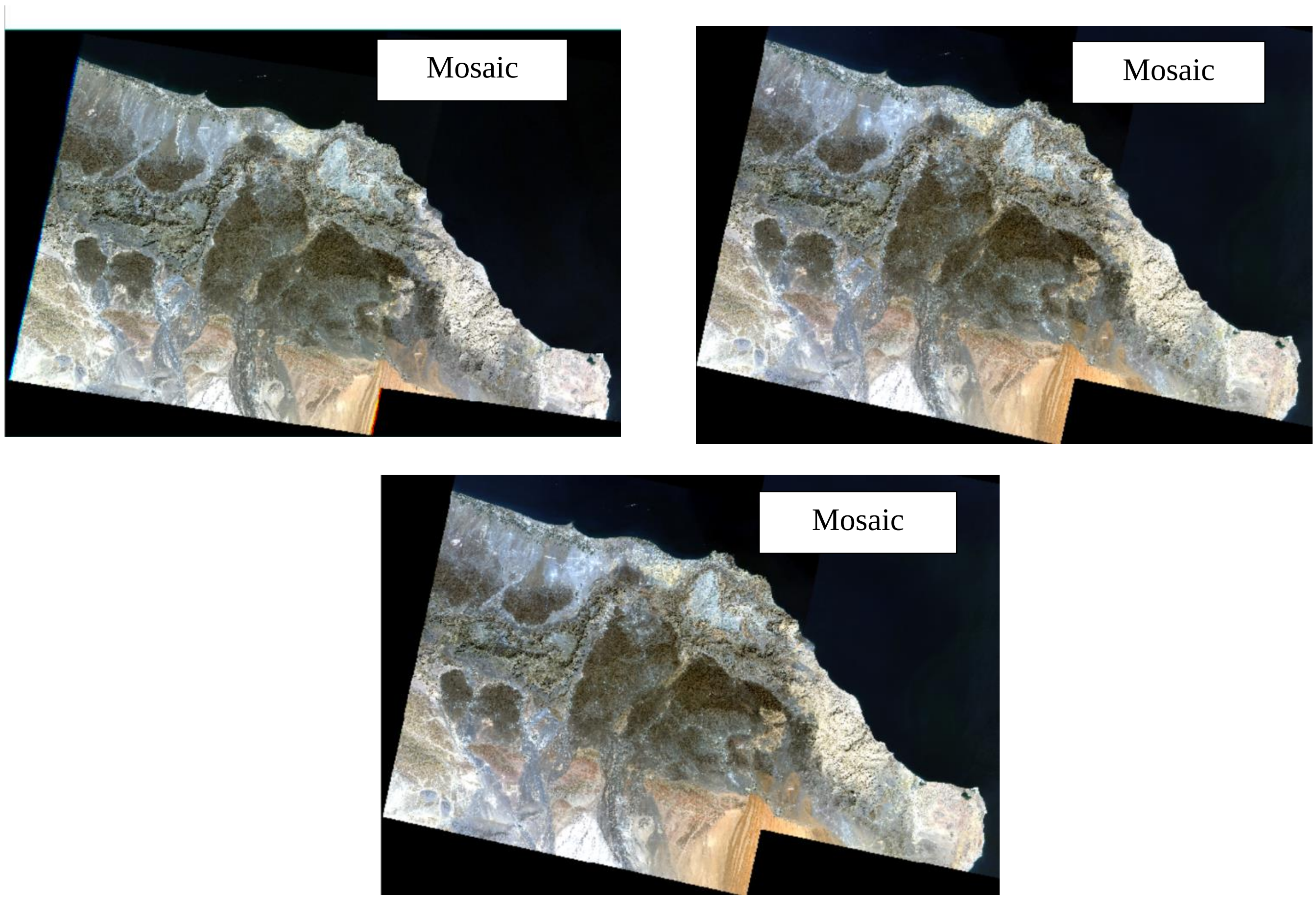

Figure 5: Mosaic the Satellite images of Study Area

3.4.4 Subset of the Study Area

The subset of the study area was extracted using subset tool of the ERDAS IMAGINE. The shapefile of the study area was opened in ERDAS IMAGINE and converted to AOI to subset the image.

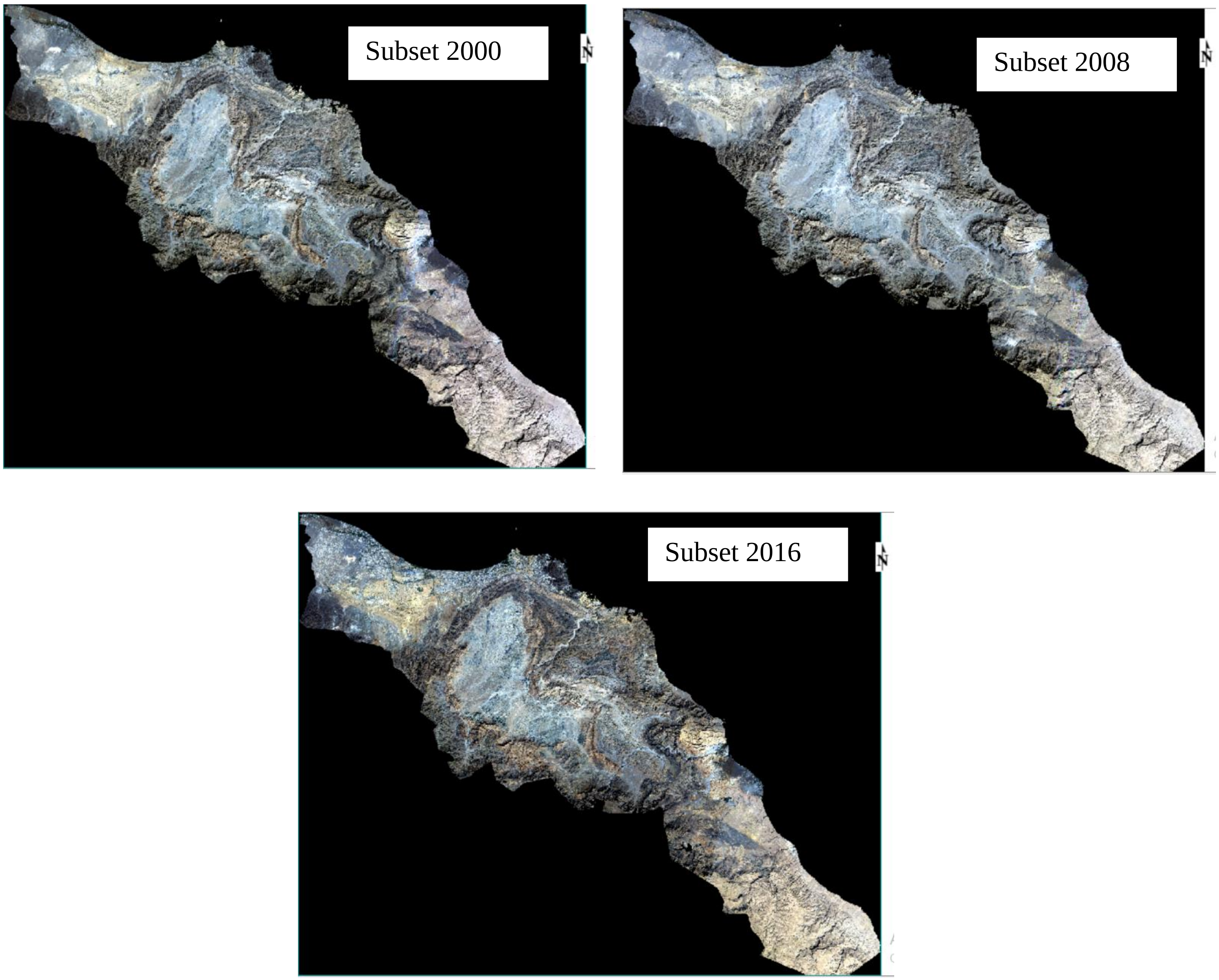

Figure 6: Subset of the Study Area (AOI)

3.5 Image Classification

Satellite images are converted to classified images through grouping the pixels of an image to specific clusters to categorize themes (Lillesand *et al*., 2008). This can be done through a supervised or an unsupervised classification (Janssen *et al*., 1990). This study has been conducted through a supervised classification. The land classes over the study area have been grouped into four different classes, urban areas, water bodies and vegetation and barren land.

The classified images constructed in Figure 4 were obtained using a supervised maximum likelihood classification algorithm using the ERDAS IMAGINE software. This method was used since no reference data existed and it is the classification method that takes the most factors into account (Janssen *et al.*, 1990). Some classes used during the maximum likelihood classification seemed optimal after several attempts. The intersect function was used between the urban features for the different years. The reason for this was so that urban features in the earlier years only would remain if they also were present in the later ones. This was done to reduce error because it is not probable that urban features are present in earlier years and not in later if a city is expanding.

According to Mather (2004), image classification entails the changing of pixel values for LULC classes. This study uses a supervised classification of the background information using four classes; water bodies, bare land, build-up area and vegetation. An average of 100 signatures was used for each of these classes and used the algorithm in ERDAS IMAGINE. While selecting the signatures for each land cover, proper attention should be given that each signature should be collected from pure class. If it would be collected signatures from mixed areas, then this should result in mixing of classes with each other. Pure signatures lead us to pure classification results.

3.6 Reclassify of all Raster Images

With the aid of the reclassify tools, it is possible to use different methods reclassify values. The following are the major reasons for reclassifying data:

a. Using new information to replace values.
b. Group certain values.
c. Use a common scale to reclassify values
d. Set specific values to No Data or set No Data cells to a value.

To perform change detection analysis and to calculate the area of each land cover, it has to reclassify all classified images into the same common scale. Before reclassifying the classified raster, it should take care of some steps mentioned below.

- The input raster should have valid statistics. Statistics can be calculated using data management tools.
- It should be carefully assigned unique values to all classified categories. Each category should be assigned one unique value.

3.7 Change Detection

Change detection is the process of making observations on some phenomena in different periods (Singh, 1989). Change detection is imperative to monitor and manage natural resources and analyze urban growth. Macleod and Congation (1998) uses four steps on the monitoring of Natural resources to define change as follows:

a. Observe/detect changes that occur over some time period
b. Defining the nature of the change
c. Calculating the area of change that is observed
d. Defining the spatial pattern of change detection

The remote sensing data with satellite images provides a very accurate and precise platform to analyze the change detection over the different time periods. Without time availability of time series data of different satellite images, it is not ever possible to look back into many years. Their many techniques and a variety of algorithms are available to perform change detection analysis over the time period of many years. Singh (1989) and Coppin *et al*. (1996) make a summary of all available algorithms that were available for change detection:

I. Mono-temporal change delineation.
II. Delta or post classification comparisons.
III. Multidimensional temporal feature space analysis.
IV. Composite analysis.

V. Image differencing.
VI. Multi-temporal linear data transformation.
VII. Change vector analysis.
VIII. Image regression.
IX. Multi-temporal biomass index
X. Background subtraction.
XI. Image rationing

It is not necessary that growth or change always be beneficial for future some time land use land cover change may cause disastrous social, economic and environmental impact to the area (Moshen, 1999).

Therefore data of change detection is very important for planners, government agencies for monitoring and management of natural resources in a better way. This can also be help planners and managers to observe present changes and look into future by applying a different kind of change detection analysis.

It is observed that over the period and series of studies that were conducted in the past that Landsat data provides a vast coverage to conduct change detection studies and to map land use land cover in all regions of the world. This all leads us to get rid of expensive and time-consuming surveys and also help us to save financial resources as well. Keeping in view all above matters and the nature of my research topic decided to choose Landsat image data for mapping the land use and land cover over the time period of 16 years. This also helps to save time, resources and provides accurate change detection maps.

3.8 Change Detection using Raster Calculator

Change detection includes a simple subtraction method. However, there are a few things that need to be accounted for to obtain the correct results. First and foremost, the two rasters need to be resampled on same cell size and projections. This will guarantee that are subtracting the same cell from the different time steps.

This will show that a very simple sort of maps that will show how the landscape is changing over the period. If reclassified image of 2000 from 2008 is subtracted, it is observed that the urban area is increasing and barren land is decreasing. This shows that urban land is increasing due to the increase in population. Gentle slope areas near to the cities are converted into urban land mostly. There is no major change in the area of water bodies. But one good sign is that with an increase in population people are also growing trees in the urban area. The area of vegetation is increased in 2008 from 46.6 to 63.7 Square Km. This is very healthy sign on future urban growth. The same kind of trend can also be analysed if developing change detection maps by using 2008 and 2016 images.

3.9 Methods of Land Use Change Evaluation (MOLUSCE)

MOLUSCE is well designed to handle tasks such as analyse the land use and changes in forest cover within different periods. The plugin is also suitable in measuring the transition of model land use and areas that risk activities such as urbanization and deforestation. Lastly, *MOLUSCE* is effective in the simulation of future changes in forest cover and land use. *MOLUSCE* has the following elements:

a) **Input module-** Land use and cover maps from different epochs, biophysical and socio-economic driving factor data such as population, road network and topography. These data elements are fed into the input module.

b) **Area change analysis-** This element calculates the cover and land use and cover changes within a specified time (2008 and 2016). The process produces land use change maps as well as land use and covers maps.

c) **Modelling methods-** This approach employed Logistic Regression (LR) to model the transition potential of the land use/cover change.

d) **Simulation-** This element shows the certainty function and results as well as displaying transition potential maps. The Cellular automata model determines the production of the simulated land use and cover map.

e) **Validation-** This element has the kappa statistics to assist the validation of the accuracy of the cover and land use maps.

In this research, Methods of Land Use Change Evaluation (*MOLUSCE*) were used to forecast future change in LULC. Based on Land use land cover maps and spatial variables were input data for the simulation model that implemented in *MOLUSCE* plugin for *QGIS* to predict changes in 2024, 2032 and 2040. The calibration of the simulation models utilized the Logistic regressions (LR). On the other hand, the Cellular Automata (CA was employed to make the prediction. According to the validation of the test models, the quantity of land cover was predicted successfully. The results also indicated the fusion figures for individuals improved coherence between the reference data and the simulation. The ultimate models project a probable change in land cover between the years 2024 and 2040, in which the results predicted an intensification of the cover. According to the past and future land cover changes, Muscat Governorate is likely to experience increased urban growth. The results of the approach projected LULC on the basis of previous changes.

CHAPTER 4: Findings and Results

4.1 Image Classification

Richards (1986) defines image classification as the act of taking out information classes from a multiband raster image, with the help of the Image Classification toolbar. This toolbar allows easy creation of training samples that are used to characterize classes that are supposed to be extracted. The subsequent raster from image classification process can be applied in the creation of thematic maps that also help in providing Geographic statistics. In accordance with the communication between the Geographical specialist and the computer system in the course of classification, image classification can be divided into two – the supervised and unsupervised image classification.

A raster Calculator changes detection method, accomplished using ArcGIS was used by the research. The detection technique of change classification has been effectively applied by some researchers in an urban environment as a result of its effectiveness in sensing the location, nature, and rate of changes in land use (Butt *et al*., 2015). Thus, the use of ERDAS imagines, ArcGIS and Excel in this project enhanced the production of a new thematic layer from maps, containing different combinations of images showing change classes.

The maximum likelihood classifier is widely used classification method in all methods which classify all unknown pixels to some specific class by statistics. Supervised classification was performed by using signature means. The supervised classification type employs the spectral signatures acquired from training samples to classify an image as appropriate. Any analyst can also effortlessly generate a signature file from the training samples, which is considerably used by the multivariate classification tools that effectively help in image classification. Also to note, the area was classified into four main classes, namely: barren land, urban land, vegetation, and water.

As cited, the study area consists of four classes counting barren land, urban land, vegetation, and water. The result of classifying the images determines that modifications have taken place and differed among the classes for the periods from 2000, 2008 and in 2016. The Land Use and Land Cover (LULC) data files explain detailed descriptions on the condition of the vegetation, water, natural surface, and cultural features on the land surface. The land cover defines the bio-physical coverage of an available piece of land that includes its vegetative growth (Gutman and Radeloff, 2017). On the other hand, land use defines the socioeconomic use of land that mainly explores the activities conducted in the resource such as agriculture and residential use.

In this study, the classified LULC map of classified image in 2000, 2008 and 2016 is given in Figure 7, 8 and 9 respectively. The accomplished general classification accuracies were 97.23% and 97.65%. Band color classifications are used to identify the image composites (Melesse and Abtew, 2016).

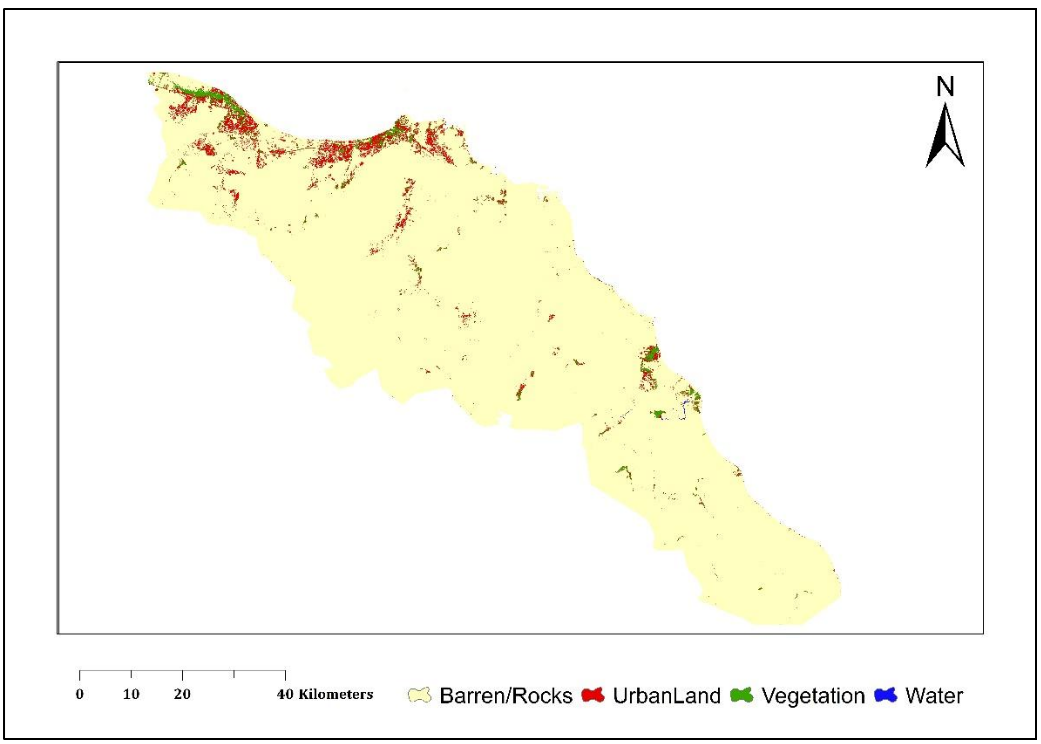

Figure 7: Classified Image of Muscat Governorate in 2000

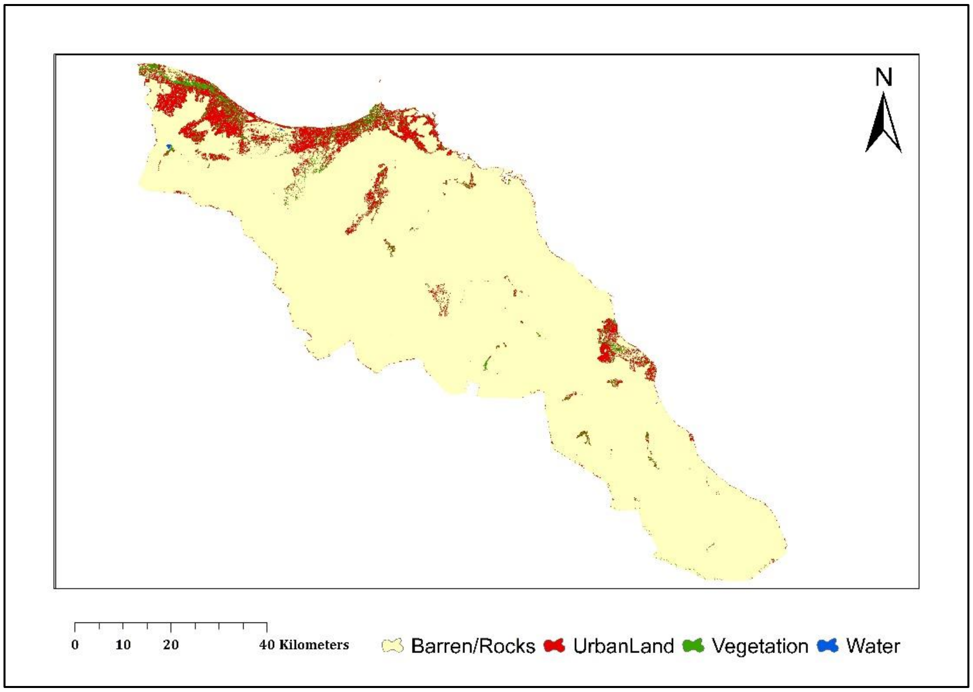

Figure 8: LULC Classes of Muscat Governorate in 2008

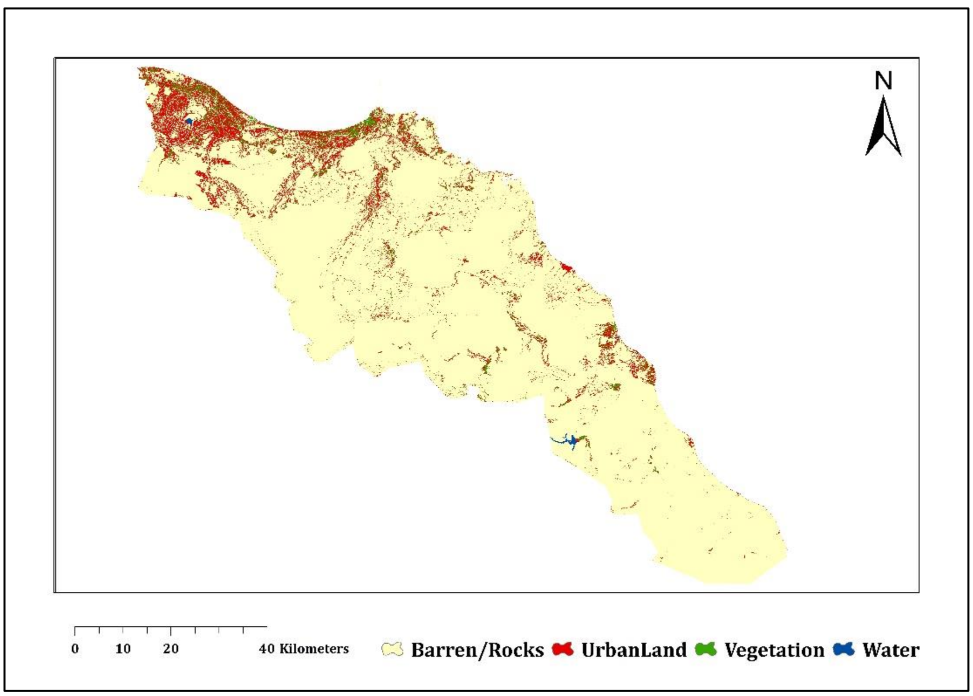

Figure 9: Classified Image of Study Area in 2016

4.2 Land-use /Land-cover Mapping

The classification results for 2000, 2008 and 2016 are summarized in Table 3. Percentage of classes of land use/land cover in accordance with these results indicate the Land-use Land-cover practices seen in surveying region during 2000, 2008 and 2016.

Land-use Land-cover	**2000**		**2008**		**2016**	
	Square Km	Area (%)	Square Km	Area (%)	Square Km	Area (%)
Barren/Rocks	**3607**	94.92105263	**3490**	91.84210526	**3409**	89.71052632
Urban	**145**	3.815789474	**245**	6.447368421	**310**	8.157894737
Vegetation	**46.6**	1.226315789	**63.7**	1.676315789	**76.4**	2.010526316
Water	**1.4**	0.036842105	**1.3**	0.034210526	**4.6**	0.121052632
Total	**3800**	**100**	**3800**	**100**	**3800**	**100**

Table 3: Land-use Landcover Mapping Detail Table for All Years

The first class that experienced a decrease in the total area was Barren soil/rocks with 198 Square km, and the decrease accounts for about -5.2 % reductions in the overall area during the study period (2000-2016). This decrease in the bare soil area, which might have been caused by fast deforestation in the region that led to the removal of vegetation cover from the land and reduced it to merely a barren and exposed piece of land. A reduction change of area size in the barren land cover was mainly linked to natural variations in the degree of natural water bodies and vegetation cover, considering the changes to and from barren soil occasioned by variations in the precipitation regime, which led to a small net change of 5.2% of barren land size. This typically implies some land reclamation done in the area of study to restore the productivity of the soil in the area (Drummond and Loveland, 2010).

Similarly, the barrenness must have been caused by the losses of soil from deforestation practices hence leading to less productive lands that were finally left by agriculturalists for crop production attributable to economic ineffectiveness, leading to a large decrease in the barren land area while rehabilitating the wasteland. In another study, Rawat and Kumar (2015) found out that barren land reduced in size over time and it demonstrates that remote sensing and GIS are essential technologies for time-based analysis and quantification of spatial spectacles which is otherwise not likely to succeed using conventional mapping methods. Hence, change detection is made easy by these technologies in using a little time, at reduced cost and with improved accuracy.

The results show that urban growth was evident from 2000 to 2016, with a difference of 165 square km land size in Table 3. During the years of monitoring, the urban growth increased by about 4.3% over time. Urban growth is a global phenomenon although the rate of urbanization is extremely fast in developing nations. It is considerably and chiefly motivated by disorderly development, growing cases of immigration, speedily growing human population, among others. In this perspective, land use and land cover change are regarded one of the key elements in the contemporary approaches to managing natural resources and monitoring environmental fluctuations. In this study, it was found out that urban growth has led to considerable losses of farming land and water bodies, along with a variety of urban environmental concerns such as low air quality, excessive surface runoff and ensuing flooding, higher local temperature, reduction of water quality, among other issues. The third LULC is vegetation, which has a steadily increasing extent in the region's coverage. From 2000, 2008 to 2016, the vegetation grew by 29.8 square km, giving an increase of 0.79% respectively. Classification results maintained the above-cited facts that Vegetation area increased over the past 16 years by 0.79% from 2000 to 2016. Vegetation in the study area chiefly comprises forest covers. In addition to forestation, reduced cutting off fuelwood by the native dwellers and limited wide cattle grazing have given vegetation and other plants are existing in the area to growing big bushes and in other regions and have reduced the extent of barren lands while increasing forest covers.

The LULC element is water, which increased by 3.2 square km from 1.4 to 4.6 between 2000 and 2016 respectively. It represents a percentage area of 0.085% land coverage increase during that period. The increase in water coverage implies high amounts of precipitation, and that implies a corresponding increase in vegetation cover in the region under review. Between 2000 and 2008, water decreased by 0.1 square km, a reduction of 0.002% land coverage in 8 years. The land is leading natural resource for healthy and comfortable life support system. Daily, it is evident that the land and land cover changes are similarly significant fundamentals of the larger challenge of international and regional environmental variations. In the modern day, remote sensing techniques and satellite data coverage are very imperative to the detection of variations in LULC between 2000 and 2008. The growing urban population densities are exerting great pressure on the LULC of the region. The growth of agriculture land can also be connected to growing need to take care of the growing population regarding provision of food (Kuldeep and Kamlesh, 2011). The water body is seen to reduce from 2000 to 2008 before sharply increasing seasonal streams, which has indicated little variation in the area as a result of encroachment slum inhabitants and land developers.

4.3 Area of Each Land cover

Land cover for the barren land/ rocks in the area covers an expanse of 3607 square km, 3407 square km, and 3409 square km for the years 2000, 2008 and 2016 respectively. The figure (10) are very categorical in the large area of land covered with rocks, indicating a large area of bare land. Barren land is a scrub region with a class showing a decreasing trend and hence resulting in the interpretation that the population pressure mounting in that location is playing a very critical role in boosting the extent of the existing vegetation cover (Kuldeep and Kamlesh, 2011). As a result, this is very much apparent from the figure 10 below, demonstrating a general trend. From 2000 to 2016, there was a noticeable decline in a barren land, commonly referred to as the bare soil, while on the other hand, there was an increase in open water and vegetation cover in the area of study. Nevertheless, decreasing trend in bare lands implies that the environment is rehabilitated and can support agricultural practices as it displays a decrease by 198 square kilometers. In another study, Madurapperuma *et al*., (2015) claimed that satellite imagery gives an effective opportunity to detect changes taking place and influencing land-use and land cover. The fluctuating land-use forms over the six years are a sign to give priority to vulnerable regions to conversion processes within the area being investigated.

Figure (10) also shows an increase in an urban growth trend, from the year 2000 to 2016. In this perspective, Kaloop and Hegazy (2015) claim that land use and land cover change are regarded as one of the major elements in modern-day approaches for managing natural resources and observing environmental variations. In other countries, urban growth has resulted in grave damages of agricultural land and water bodies, which ultimately compromise the healthy living of organisms and dwellers of such regions. The Figure (10) proves the that the area's vegetation, which is in keeping with a study conducted by Agaton *et al.*, (2016), rapid urbanization was revealed to be the change maker and the leading force motivating LULC in the study area.

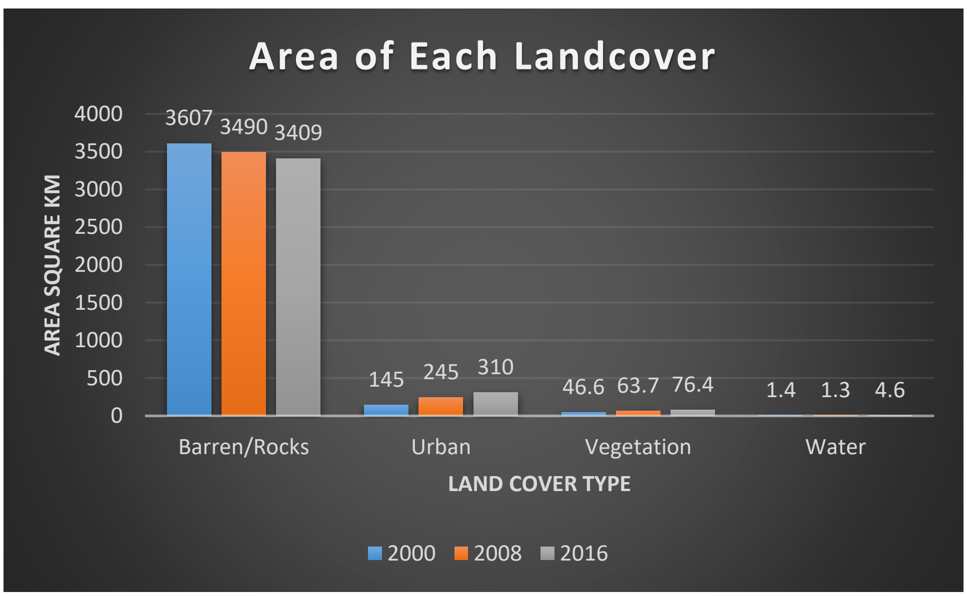

Figure 10: Area of each land cover in square km

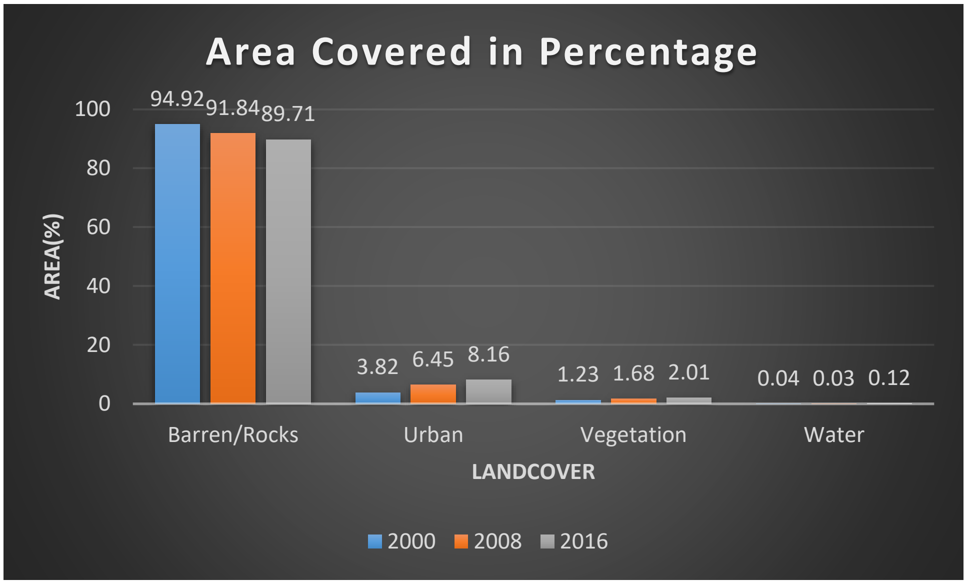

Figure 11: Area of each land cover in percentage

The findings for the area covered by barren/rocks, urban population, vegetation cover, and water show a percentage of the overall land size as figure (11) is shown. The rocks have a coverage of 94.92%, 91.84%, and 89.71% that signify the records for the years 2000, 2008 and 2016 respectively. The trend decreases steadily in percentage across the years, with a difference of 3.08%, and 2.13% between the years 2000 and 2016 respectively. The vegetative area covered by percentage entail 1.23%, 1.68% and 2.01% for 2000, 2008 and 2016 respectively. This is an increasing trend in the percentage land cover and implies a developing area with good climatic conditions for the vegetative growth. Similarly, the area covered by water bodies regarding percentage includes 0.04%, 0.03%, and 0.12% for 2000, 2008 and 2016 respectively. This trend increases over the years, with a difference of 0.01% increase between 2000 and 2008, and 0.09% between 2008 and 2016.

4.4 The simulation change of LULC

The study classified Muscat into four areas based on land cover. The four sections include barren land, urban land, water and vegetation. However, the four sections covered the entire land in different proportions. From the geographical perspective, different land covers are subject to change because of human activities and climatic conditions. For instance, dissertation and reclamation are common developments that take on land. However, human activities play a crucial role towards changing the land cover.

This research used the *QGIS* software with the *MOLUSCE* plugin to conduct the analysis. The technology proved to be effective because of its ability to analyze the use of land. Besides, the software can determine the urban changes over time. The software was also useful in the determination of the cover transition and the risks attributed to urbanization. The software was of great importance in simulating future land use and changes in urban.

From the study, different simulation maps were derived from the area under study. The maps showed different proportions on land coverage. The pictures of the maps showed barren, urban and vegetative land as well as the area covered by water. The first map showed the simulation results of 2024. The map indicated an extensive barren land with minimum vegetation. The results also indicated an insignificant amount of land covered by water. The land was also largely rural because the area covering urban proportion was minimal. The simulation indicated that urban development and vegetation was concentrated along one region, implying that the people in this area depended on rain-fed circumstances.

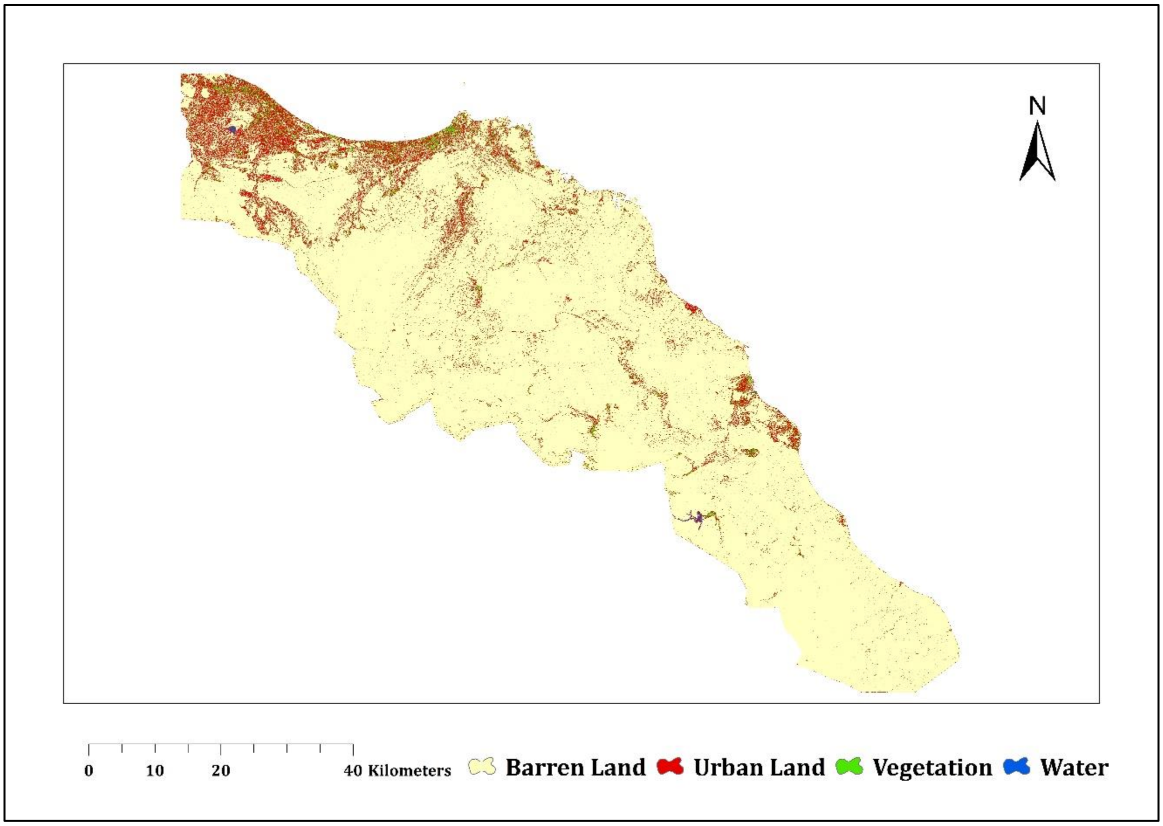

Figure 12: Simulation map of Muscat Governorate in 2024

Another simulation map showed results for 2032. The results showed a remarkable improvement in urbanization. The map also indicated a slight increase in vegetation. However, a large percentage of the region was still barren, meaning that the land was not productive. However, the slight increase in vegetation cover showed significant efforts to rehabilitate the land.

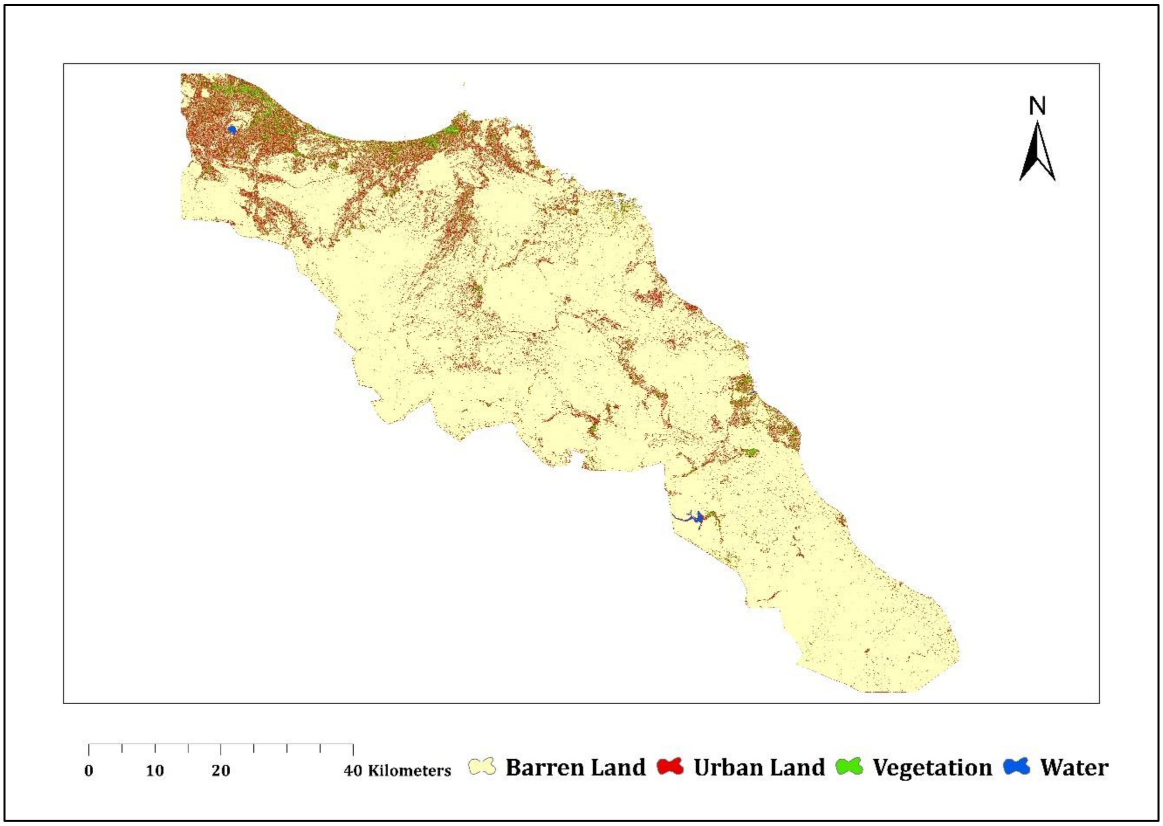

Figure 13: Prediction LULC Types within the Muscat Governorate in 2032

The third and last simulation map indicated that vegetation covered a significant percentage of land. Though the proportion of vegetation was insignificant when compared to the barren area, the improvement from the simulations for 2024 and 2032 was evident. An improvement in the rate of urbanization was also evident. It was notable that vegetation improved around urbanized areas. The trend of the proximity between urbanization and vegetation was consistent throughout the region. In the 2040 simulation, urbanization and vegetation were beginning to spread to other regions of the area under study.

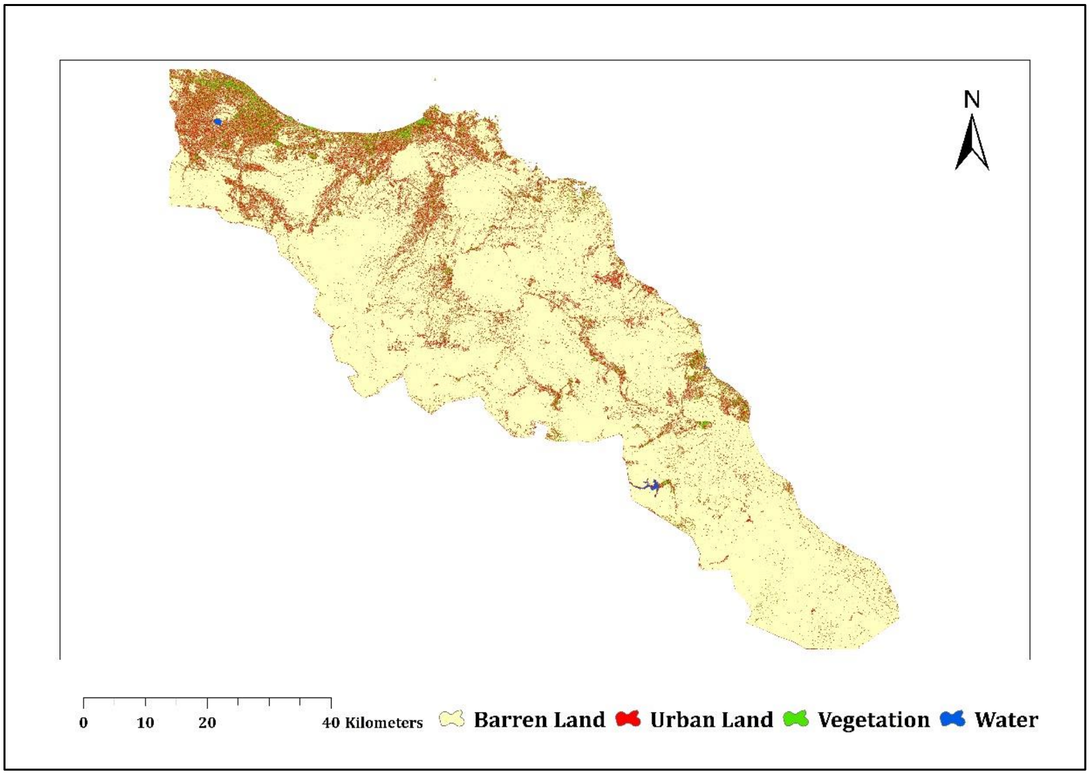

Figure 14: Simulation Map of Study Area in 2040

The *QGIS* software gave numerical figures on the environmental conditions and percentage of land cover. The results were tabulated in the table below.

Landuse Landcovr	**2024**		**2032**		**2040**	
	Square Km	Area (%)	Square Km	Area (%)	Square Km	Area (%)
Barren/Rocks	**3380.2**	88.953	**3270.77**	86.073	**3202.65**	84.280
Urban	**342.553**	9.015	**400.54407**	10.541	**450.25918**	11.849
Vegetation	**75.3237**	1.982	**125.452**	3.301	**143.892**	0.038
Water	**1.9233**	0.051	**3.23393**	0.085	**3.19882**	0.084
Total	**3800**	**100**	**3800**	**100**	**3800**	**100**

Table 4: The probably changed from 2024 to 2040

From the table, it is evident that as time progresses, the percentage of barren land that is covered by rocks reduce. The simulation results indicate that the percentage area that will be covered by rocks will be 88.953%. In the year 2032, the area will reduce to 86.073% and down further to 84.280% in 2032. The reasons behind the phenomena are the increased human activity that reduces the barrenness. It is essential to note that increased human activity in rocks results in disintegration, a situation that breaks them down to finer particles (Geman, 2015). Over time, the big rocks are transformed in to soil that is favorable for farming and construction.

The results from the simulation as shown in the table indicate that the percentage of land that is urban in 2024 will be 9.015 percent. The proportion of urban land will also increase to 10.541% in 2032 and later on to 11.849%. The trend showing an increase in urbanization is grounded on the deliberate measures that people take to enhance construction of roads and other facilities to facilitate service delivery. The increase in the trend of urbanization is also enhanced by modernization as people strive to use technology to make their lives easier (Braimoh and Huang, 2015). Urbanization transforms a barren land to become productive, thus increasing human activity.

The simulation results also indicate a change in vegetation cover over time. For the area under study, the percentage of land that will be covered with vegetation will be 1.982% in the year 2024. However, the level will rise to 3.301 % in 2032. The increase in vegetation cover is attributed by the deliberate move by human beings to do cultivation. There is also a projection of probable climate change that will be favorable for vegetation to develop. Finally, the amount of water cover on land in 2024 is projected to be 0.051 %. The water cover will increase to 0.085%. The increase in the amount of water will result from the natural response to the climatic changes that are influenced by human activity and other factors such as an expansion of vegetation cover (Bierlaire *et al*., 2015).

CHAPTER 5: **Discussion**

5.1 Land use and Land Cover Change Detection

Kaloop and Hegazy (2015) postulate that land use and land cover change forms one of the major driving forces of international environmental transformation. Presently, it is fundamental to the sustainable development discussion and can be explored to a greater depth so as to come up with environmental resolutions for sustainable growth and development. The authors acknowledge that land use/land cover change has been explored before from different viewpoints with the purpose of identifying the main factors driving land-use/land cover change, their course, and significances. Urban growth, especially the change of suburban and commercial land to rural regions at the edge of metropolitan zones, has long been regarded as a sign of regional economic strength as figure (15) shows.

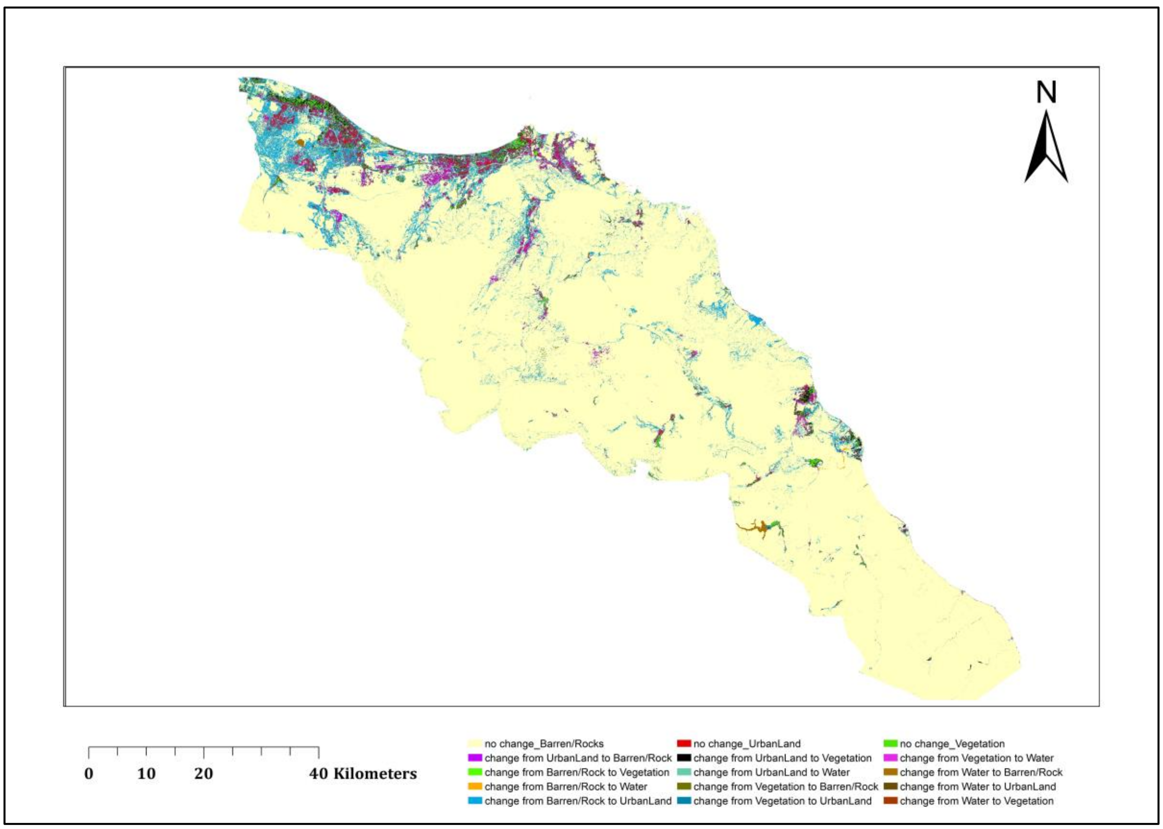

Figure 15: LULC Change detection of Study Area from 2000 to 2008

The fast modifications of land use and cover than ever before, especially in developing countries, are frequently accompanied by extensive urban sprawling, degradation of the available land, or the change of farming land into shrimp agriculture following huge cost to the surrounding environment. In this Discussion chapter, geospatial technologies such as the used ERDAS Imagine, ArcGIS and Excel and remote sensing methodology offered essential tools that can be used in helping the discussion of land use change detection into greater depth.

The district was chosen for the present study in the view if it's multi-spectral growth and fast commercialization. Different land uses identified in the district are explained below: Barren Land, Built up Area, Vegetation, and Water. Change detection comparison by raster calculator in ArcGIS software was applied to observe the changes in land cover that had observed, over the time. It is most simple and commonly used method used for showing land cover change detection over the time (Campbell *et al*., 2003, Lu *et al*., 2004 and Fan *et al*., 2010).

According to Mölders (2012), change detection is defined as the process of identifying differences in the condition of something or phenomenon by closely monitoring it at different times. It is an essential process frequently engaged in monitoring and managing natural resources. At the same time, the technique is central in monitoring urban development since it offers quantitative analysis of the spatial distribution of the population under review. In doing monitoring, it is important to consider different aspects such as the detection of the actual changes that have taken place, identify the condition of the change, examine the spatial pattern of the change, valuating the area coverage of the change and determining the spatial pattern of the change taking place. Land cover change detection explains the objectives it lays for explaining the condition of land cover and the variations of the variables being used in the practice.

Mallupattu and Reddy (2013) noted that the foundation of using remote sensing data for change detection is to enable changes in land cover to lead to corresponding changes in radiance values that can be remotely sensed. Methods aimed at performing change detection with satellite imagery have presently turned out to be common using increasing flexibility in changing digital data and aggregating computer power for better performance. The ArcGIS software used in this study helped in complimenting the display and adequate handling of the data processing. Similarly, the Excel program that was used essentially helped in the presentation of the research findings and discussion into greater depth. Microsoft Excel program was also used in generating the bar graphs used in this study, to allow for quick and accurate comparison of data from the year 2000, 2008 and up until 2016.

In the modern day spatial analytics, the use of the latest and innovative digital change detection techniques by applying multi-temporal satellite imagery assists in comprehending landscape dynamics. In another study, land use/ land cover change detection was considered to be a very vital aspect for a better understanding of landscape dynamics for a definite period of time-based on the goal of achieving a sustainable management (Rawat and Kumar, 2015). Land use/ land cover changes are also known to be a widespread and accelerating practice, predominantly steered by natural phenomena and anthropogenic practices, which in turn motivate variations that would give a noticeable impact on the natural ecosystem.

The area covered by water bodies regarding percentage includes 0.04%, 0.03%, and 0.12% for 2000, 2008 and 2016 respectively as Figure 11 is illustrated. This trend increases over the years, with a differentnce of 0.01% increase between 2000 and 2008, and 0.09% between 2008 and 2016. A significant element of change detection is to ascertain what is really changing, and to what form it becomes. For instance, it denies the actual land use class that is changing into another. "Land use/ land-cover change detection analysis is a critical component in understanding the interactions of the human activities, and thus it is necessary to monitor and maintain a sustainable water resources management" (Ramamohan *et al.*, 2014, p. 174). The information on change detection analysis will disclose both the necessary and unnecessary changes and classes that are comparatively stable eventually. Such helpful information will also act as a strategic tool in management decision-making. Therefore, the change detection process incorporates a pixel to pixel evaluation of the research on the three years (2000, 2008, and 2016) images through the overlay.

5.2 Modelling land use land cover change

The world today experiences a common phenomenon where people settle in patterns. People align themselves near facilities and proper conditions that make life easier. For instance, most people move to urban centers, a situation that results in over population in metropolitan areas. The population pressure prompts the people to expand the region by constructing more facilities, buildings and improving infrastructure. The new developments attract more people, making the process continuous as figure (16) shows. The overall result of the continuous developments is urbanization. The expansion of metropolitan regions raises the value of land as people utilize the resource to earn a living. One of the strategies that people use to add value to land is irrigation for food. As a result, urbanization, which in this case is developing on formerly barren areas changes land cover. Since the population is ever-growing, there is a progressive improvement in urbanization, thus forming the basis of the findings of the QGIS software, which suggest that land cover changes over time.

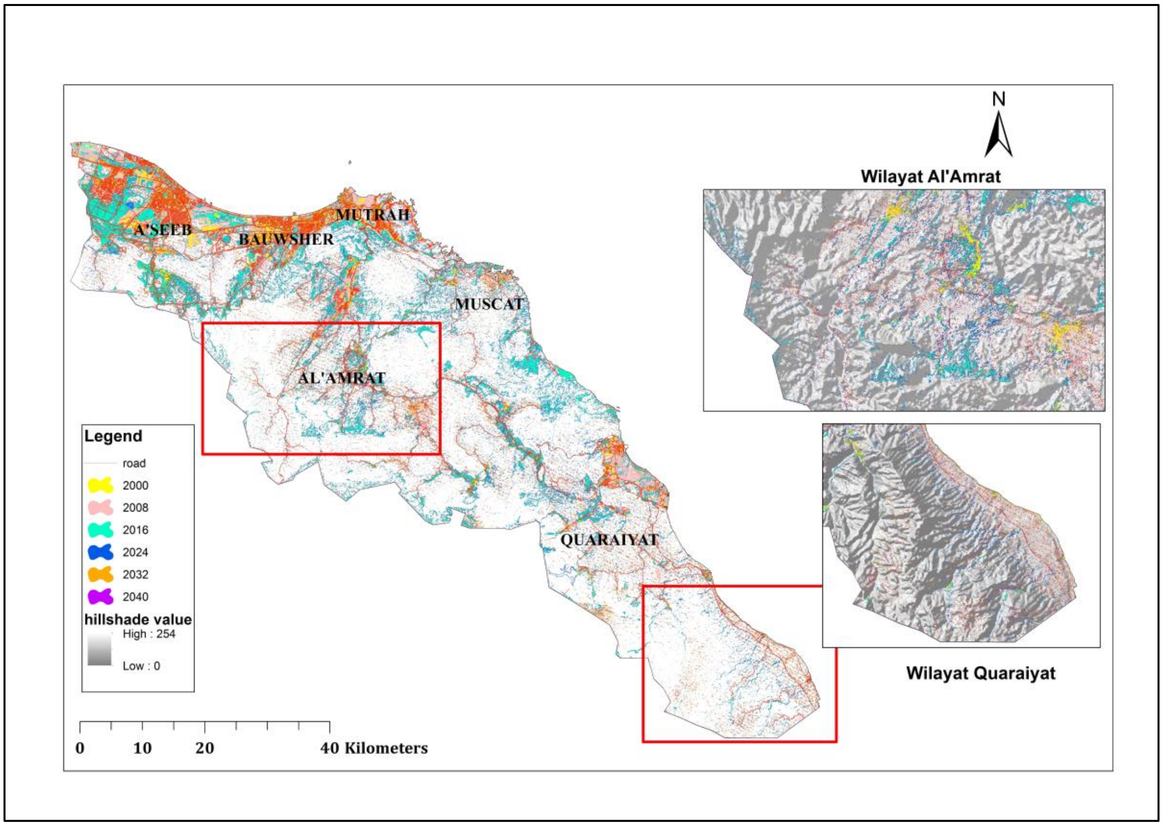

Figure 16: The Expansion Urban Land from 2000 to 2040

From the QGIS results, it is apparent that the growth in urbanization causes a significant improvement in vegetation. Urbanization implies that there is an increased human activity on land. In arid areas, people settle in clusters and leave some section completely barren. The regions that are left barren hardly develop. The absence of much activity leaves it isolated. In the long-run, vegetation does not grow because of the adverse conditions that make it difficult for life to be supported. It is essential to observe that urbanization is a deliberate activity by people to improve the quality of living. However, for the urbanization to be achieved, the quality of land has to be improved by influencing certain changes such as fertility to facilitate crop production. In the long-run, continuous activity influences other changes such as climate trends, which also affects the proportions of land cover.

Land use is an important topic because it is a natural resource that is important for the economy and the general livelihood of people. Whereas some regions have productive land, others are barren. The productivity of land depends on the natural conditions and factors that facilitate the productivity of the land. For instance, dry areas are known to be less productive that the regions that experience little to no rains. However, the use of technology and new skills from research makes it possible for people and organizations to rehabilitate land and make proper use of it (Chen, 2013). In fact, research indicates that even dry areas can offer sustainable solutions through agriculture. The aspect that changes the attitude towards land use is research and proper education on the various methods that can be used to improve the quality of soils and the environment. Urbanization plays a crucial role towards the shaping of the environment. Construction of structures on land changes the arability of a region. For instance, urbanization converts land that is considered useless to become more useful, a situation that reduces wastage. Another perspective of urbanization is the element of deforestation which tends to have detrimental impacts on the land. However, recent developments show a positive progress on the way people handle the issue of urban development and land use. For instance, the heightened campaigns on sustainability and environmental conservation are evidence that the world is making positive progress towards matters land. Despite the efforts taken by environmental conservationists on developing land positively, there are concerns about the sustainability of future generations. For this reason, it is imperative for communities to develop projects to seek long-term solutions to the climatic challenges and address concerns such as land shortage. One of the most profound solutions to the problem is a land simulation (Critchley *et al*., 2016). The process entails using mechanical, scientific and natural methods to convert land to become more beneficial to the community. Land simulation is a procedure that seeks long-term solutions.

The geospatial advances and models make it possible for authorities and responsible institutions to change the land use patterns. The simulation model for Land Use Land Cover (LULC) uses the *QGIS* framework to establish models to solve global matters. The simulation method relies on prediction and changing the spatial patterns to benefit future generations. The use of simulation to issue predictions on land use is imperative because it offers a scientific approach to the problem. It also paints a clear picture of the future state of land if certain conditions are observed, the simulation approach, therefore, is important because it gives an advisory assistance to the concerned parties to make effective amendment’s to their practice to improve land for the better.

Simulation is important because it offers solutions to population problems. In regions that are predominantly barren, people cling to one area that has ample conditions that support life such as water, energy, and facilities. Another section of the region is usually left open and deserted because of the adverse conditions that make it tough for people to survive. Since the population increase has proven to be untamable, it is essential or the concerned organizations to develop strategies that will relocate people to the densely populated areas. One of the approaches for this move is to urbanize the deserted areas by instituting watering project, developing facilities and lauding people to resettle. The presence of human activities on the desolate land improves vegetation which in the long run changes the picture of the location (Campbell and Palutikof, 1978). However, such transitions take long to achieve, thus prompting the concerned institutions to develop a structured strategy to address the matter.

The simulation maps of Muscat show a progressive development of the region and a corresponding improvement in vegetative cover. The maps indicate that as time progresses, the population of the region gets distributed to other areas that were previously deserted. The redistribution of the population is an automatic socio-economic process that is prompted by the decision by people to move to areas that have minimal pressure. In the process of the redistribution, the region experiences more human activity on land, which improves its quality and enhances the growth of vegetation.

For a barren area to be improved it is essential to use the minimal resources that are available responsibly and in a way that expands its benefits. Research indicates that even the regions that are surrounded extensively by water experience the challenge of the bareness (Mokma, 1995). The revelation is a sign that there is need for policies to manage resources for the benefit of the residents. In the case of Muscat, there is evidence of the availability of water in some areas. However, the larger part of the land is dry, implying that people have no access to water. Proper marine management is important to provide long-term solutions to such areas. The management of marine resources assists the barren areas to improve their environmental conditions such as through irrigation projects. In fact, shifting the focus from rain-fed agriculture to mechanized and irrigation-based farming is one of the most apt interventions that can be used to transform such areas.

5.3 Research Limitations

In as much as this study gave convincing results, it was subject to several limitations that undermined the credibility of deductions. It is crucial to note that the performance of this study is technology-based, which cannot be trusted in entirety because it cannot be used to make observations. The technology relies on human knowledge and abilities which collect information and feed it into the system for interpretation. In the process of collecting and harmonizing the information, there is room for errors in recording and transferring the data. The chances of errors reduce the level of confidence on the system.

Another limitation to this study is the lack of sufficient information on the area under study. The study was performed on a large area, and the scope of the simulation results was wide. The information that was used to make deductions on the entire area was representative and not actual as estimates were used in some regions. In geography, information especially on climatic conditions, land cover and population influx is only estimated as it is subject to change within a short period. The fact that the information used was not exact opens a window of doubt on the results.

In addition, the simulation test was complicated to understand. The generation of the results used complex mathematical functions that also translated to an impression on the future land cover. The complexity implies that it would be difficult to detect miscalculations and discrepancies in the results that were given from the test. The lack of sufficient knowledge on the key principles in the simulation machines also widens the room for errors in calculations.

Accessibility of high-quality data is noted as a major limitation for this project. This is a quite limited what data and resolution have been available (Kristinsdóttir, 2015). This research was used Landsat images which have low resolution. However, there are more than other types like IKONOS, Quickbird, and orthophoto which has high spatial resolution such one and half a meter. However, these images are very expensive for a small area (Abdulrahman, 2015).

While the method and techniques identified in this study have been limited for classified land use land cover method (Liu and Yang, 2015). A supervised pixel-based technique is, for example, criticized for producing inconsistent ―mixed pixels (Barren Land and Urban Land) output. Spectral methods, pixel to pixel classification of satellite imageries using supervised classification was in patronage, though, supervised classification has its limitation of overlapping or very similar signatures of different land use classes (Jat *et al*., 2017).

A further limitation is the study area is a mountainous region which has a high and low slope. Due to this, the detailed field survey is not possible. Moreover, *MOLUSCE* modeling for predicting future by open software *QGIS* which was based on two classified images 2008 and 2016 and various factors like road network and slope without considering on criteria of these factors. The modeling calculates the forecast of land use/land cover without consider on how many percent of slope can build and how far from the road can make in future. Future work will consider all these limitations and apply an advanced modeling approach that would allow for long-term (Araya and Cabral, 2010).

CHAPTER 6: Conclusion and Recommendation

It is evident that in as much as countries face population settlement problems, there are solutions that can be used to make land arable. Technology plays a significant role in aiding studies on land utilization and change. Sufficient information on climatic changes, population distribution patterns and land cover are important because it assists policy-makers to develop approaches that will assist in resettling the people. Technology plays a significant role in aiding experts to obtain the information on future land cover changes, which is necessary to assist in planning. For instance, this project studies Muscat Governorate, a region that has population distribution challenges. The study used the QGIS software to perform the study. The procedure uses the *QGIS* software to make predictions on land cover and use patterns. The software allows experts to measure and predict the components of land cover in the future. The technology also used the *MOLUSCE* plugin which issued values that are used to calculate the land cover percentages. According to the information obtained on Muscat, the simulation map indicated a potential increase in vegetative land cover. The results showed a progressive increase in vegetation and urbanization in the next three decades. The technology was used to estimate and predict future change from 2024 to 2040 using open source *QGIS* software. Classified images of LULC were classified into four classes: Barren Land, Urban Land, vegetation, and water bodies. Raster Calculator technique was performed to detect the change of land cover/land use types. The analysis projected an increase in urban land over time, with a decrease in the barren land category. The literature in the study suggested a number of factors that contributed to the current patchy urban pattern. An example of such factors is the emigration of the population from rural areas to urban areas. Social, economic and political factors were also suggested to play a role in the change in population redistribution and land over changes. Finally, the changes are also influenced by the nature of physical conditions. For instance, Muscat Governorate has a lot of mountains which discourage people from developing the land.

The literature on this topic with the results of the study indicates that land cover changes in the coming years are imminent. For this reason, it is important for researchers and land development experts to gather sufficient knowledge on the likely patterns that will influence the settlement of people. The organizations that are tasked with the responsibility of planning and executing urban development projects should tap into the information to have a clearer perspective on the most effective methods and approaches to urbanization. Through sufficient information and expertise, they will come up with effective approaches that will facilitate proper population redistribution. Sufficient research is required to enhance the execution of the programs.

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