

**A thesis submitted to the Department of Environmental Sciences and Policy of
Central European University in part fulfilment of the
Degree of Master of Science**

**Detecting urban sprawl in the Middle Nile Delta region to assess the
effects on Egypt's agriculture**

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This thesis is submitted in fulfilment of the Master of Science degree awarded as a result of successful completion of the Erasmus Mundus Masters course in Environmental Sciences, Policy and Management (MESPOM) jointly operated by the University of the Aegean (Greece), Central European University (Hungary), Lund University (Sweden) and the University of Manchester (United Kingdom).

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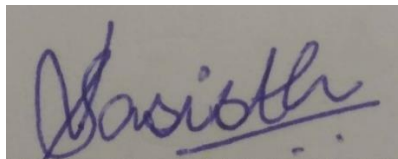
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CENTRAL EUROPEAN UNIVERSITY

ABSTRACT OF THESIS submitted by:

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for the degree of Master of Science and entitled: Detecting urban sprawl in the Middle Nile Delta region to assess the effects on Egypt's agriculture.

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Urban growth is a growing threat along with climate change affecting Nile Delta Region of Egypt. Assessing the impacts of urbanisation to understand the causal factors is very important to be able to combat this problem. For this research, LANDSAT 5 TM for 1997 and 8 OLI TIRS satellite images 2017 were used to study the change in land use/land cover in the study area of Al-Gharbiya and Menoufia governorate in Middle Nile Delta Region. Hybrid or Combined classification method was used to assess the growth of urbanisation in the study area. Random Stratified sampling and Kappa statistics was used for accuracy assessment. The accuracy assessment result for the multi-temporal classification was found to be 89% and 84% for the year 1997 and 2017 respectively. Classification showed increase in the agriculture areas by 6.10% while urban areas increased by 21.19 % during the same period. Decrease in surface water and barren areas recorded was by 25.70% and 63.52% respectively. This thesis identified various factors contributing to the rapid urban growth in the Nile Delta region affecting its arable lands. This thesis makes four key recommendations for researchers and policy makers of Egypt to tackle the growing problem to combat future crisis situation.

Keywords: Remote Sensing, GIS, Urban Sprawl, Nile Delta, Al-Gharbiya, Menoufia.

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List of Abbreviations

FAO – Food and Agriculture Organisation

GIS – Geographic Information System

LU/LC – Land Use/Land Cover

MSS - Multispectral Scanner System

NASA – National Aeronautics and Space Administration

OLI - Operational Land Imager

RBV - Return Beam Vidicon

RS – Remote Sensing

TIRS – Thermal Infrared Sensor

TM – Thematic Mapper

USGS – United States Geological Survey

WFP – World Food Programme

1. Introduction

1.1 Background

At present times, with rapid increase in population need of basic amenities such as food and shelter are also increasing. With human intervention in every sphere of natural resources, there is an imbalance in usage of land and its management resulting in rapid land use-landcover changes (Lambin et al. 1999). As a result of increasing population, intensification of agriculture to counter huge demand has become a necessity for developing modern society. These changes occurring at such accelerating rates exceeds the adaptive capacity of soil as well as human societies, especially in arid and semi-arid regions, where ecosystem is sensitive and fragile in nature (Hall et al. 1979). Changing land-use patterns as a result of human's socio-economic activities induces change in land cover resulting in ecological imbalance disrupting ecosystems which affects the biosphere as a whole (Riebsame et al. 1994).

Land Use/land cover change in arid and semi-arid regions has extensive consequences. Arid and semi-arid regions are generally categorised as sensitive and fragile regions due to variability in the carrying capacity of these lands with respect to space and time (Verstraete et al. 1991). The human exploitation of its renewable resources such as soil, water etc. exceeds the natural rate of replenishment of these regions which results in degradation of its ecosystem (Verstraete et al. 1991). Therefore, for having sustainable development in the arid and semi-arid regions, there is a vital requirement of continuous monitoring and evaluation of the resource base to understand its evolution.

Egypt is one such country situated in the arid and semi-arid regions of the world which is spread across an area of one million sq. km in the north of the African continent. Out of this one million sq. km, more than 96% of the total land area in Egypt is desert (Alfiky et al. 2012). The rest 3.4% of the total land area (34,000 sq. km) is situated near the Nile river and its delta where most of the

cultivation of Egypt takes place (Alfiky et al. 2012). River Nile adds an interesting feature to Egypt and acts as its lifeline as it provides 97% of all the water available in Egypt (Abdel-Shafy et al. 2002). River Nile branches out as two main distributaries namely the Rosetta (Rashid on the west) and the Damietta (Dumyat on the east) (Hereher 2010) from the north of Cairo spreading out as V-shaped fan towards the north of Egypt finally ending up in the Mediterranean Sea. The Nile delta was formed by the sediments from the Nile river which got accumulated during the flood seasons (Hereher 2010).

Nile delta formed due to accumulation of nutrient rich sediments is fertile in nature and most of the Egypt's agriculture takes place in this region (Alfiky et al. 2012). Due to this unique geographic feature of Egypt, more than 95% of Egypt's 93 million people (as per 2017) resides in the Nile Delta region (Alfiky et al. 2012; CAPMAS 2018). There is a rapid rise in the population of Egypt, which is mostly concentrated on the Nile delta region. This has resulted in an increasing imbalance in the ratio of population to agricultural land. The per capita area of arable land (hectares per person) is decreasing constantly from 0.09 ha/person in 1961 to 0.06 ha/person in 1990 further reducing to 0.029 ha/person in 2014 (World Bank 2015). As a result, there is widening of the gap between the potential capacity of agricultural production of Egypt and the estimated growth of population. This imbalance has also resulted in environmental degradation of the finite arable land available to the Egyptians in Nile Delta due to urban sprawl which may lead to desertification in future (Power 2014).

This has various consequences, one of the major being decrease in agricultural production of Egypt due to change in land-use from agricultural to urban areas. Heavily dependent on River Nile and its Delta for Egypt's food production, rapid growth of population in this region has resulted in decrease in agricultural areas and increase in urban areas in Nile delta region. As per the Global Food Policy Report, 2015 published by the International Food Policy Research Institute, the

average annual growth of agricultural output percentage of Egypt decreased from 4.5% in 1991 to 1.9% in 2012 due to decrease in Total Factor Productivity from 2.1% in 1991 to 1.9% in 2012.

This has resulted in formulating and adopting various food subsidies and policies by the Egyptian Government aiming to expand cultivation area, intensification of agriculture in present cultivated areas for maximising food production. Also, several plans have been taken up by the Egyptian government since past years, to reduce the population density in the Nile Delta region to curb the land-use change by distributing the population horizontally on the edges of Nile Delta region and the desert areas of Egypt (A. Shalaby et al. 2007).

1.2 Research Questions and Aim

To understand the growing problem of urbanisation in Nile Delta region, it is very essential to analyse land-use/land-cover change. This will help us in understanding the rate of urbanisation. Assessing and detecting these changes are very vital for better planning of growing urban areas so as to not hamper the limited available agricultural land of Egypt. This study will aim to studies will help in formulating efficient policies by the Egyptian Government to combat this urgent need of growing food insecurity.

The thesis aims to answer the following research questions:

1. What is the rate of change of agricultural areas to urban settlements in Menoufia and Gharbia governorate of the middle Nile Delta region (due to change of land-use patterns in last 20 years since 1997)?
 - Literature review on land-use/land-cover changes in Nile Delta region
 - Determine the LU/LC changes in the area in past 20 years.
2. What are the factors of urbanisation on the Nile Delta region and its effects on the agriculture system (food security) of Egypt?
 - Literature review about the major factors leading to urbanisation in Egypt

- Literature review about the effects of urbanisation on the agriculture system (food production and security) of Egypt

There has been lots of ongoing research on the land-use and land cover change across the world to understand its impact on climate change and greenhouse gas emissions. Nile Delta region of Egypt is one such area of interest for conducting similar research studies due to its unique geographic features and its importance for the people of Egypt. This thesis aims to understand the implication of land-use/land-cover change due to urbanisation on the middle Nile Delta Region and its effects on the agricultural system of Egypt at present with purview on the future

1.3 Thesis Outline

The thesis consists of 6 main chapters.

Chapter 1 gives a background to the nature of the problem addressed in this research and the specific problem(s) aimed to be addressed. As per the identified the gaps in knowledge outlined, specific research questions are presented.

Chapter 2 the researcher conducted a systematic literature review to introduce to the basic topics of research along with further understanding of the topic of research.

Chapter 3 outlines the methodologies used to conduct the land use/land cover analysis for creating land use maps along the method used for literature review and further analysis and discussions

Chapter 4 presents the results and main findings of the land use/landcover analysis done to answer RQ1.

Chapter 5 present the discussion of the comprehensive literature review conducted and answer RQ2 and assist in answering RQ1.

Chapter 6 presents the main conclusions of the research analysis, explaining the contribution of the research work to the literature/knowledge. Further, it provides recommendations directed to the other researchers and decision makers.

2. Literature Review

2.1 Agriculture in Egypt – Why is it important?

Agriculture is generally considered as an important aspect of development which contributes to the growth of an economy as it provides food as well as employment. Various research studies in fact states that agriculture is considered the primary sector as a source of income for economic growth (Ravallion et al. 2007) (Loayza et al.). Poverty alleviation and reduction of inequality in a society is directly linked to growth in agriculture and is proportional to each other as it brings large gains to the poor and generates positive externalities(Ravallion et al. 2007) (Ravallion 2005).

Agriculture can be considered as one of the most important part of the ancient Egyptian civilisation which can be tracked back to as long as 12000 years along the River Nile(Janick 2016). Egyptian civilisation were the pioneers in designing key agricultural tools such as the hoe, the plow etc. and also introduced irrigation concepts such as systematic irrigation and hydraulic engineering for combating irregular levels of River Nile (Janick 2016). Their contribution to agricultural technology is of immense importance. Many historians believes Egyptians mastered the art of agriculture in the dry and arid region, laying down the foundation stones of a successful Egyptian civilisation (Janick 2016).

Regardless of decline in relative importance of agriculture production in Egyptian Economy in terms of contribution to the GDP and employment, in still plays a vital role in feeding the population while providing income to the rural population(Tellioglu et al. 2017). **Figure 3** shows the major sectors contributing to Egyptian GDP (2006-2016), where agriculture clearly shows a downtrend.

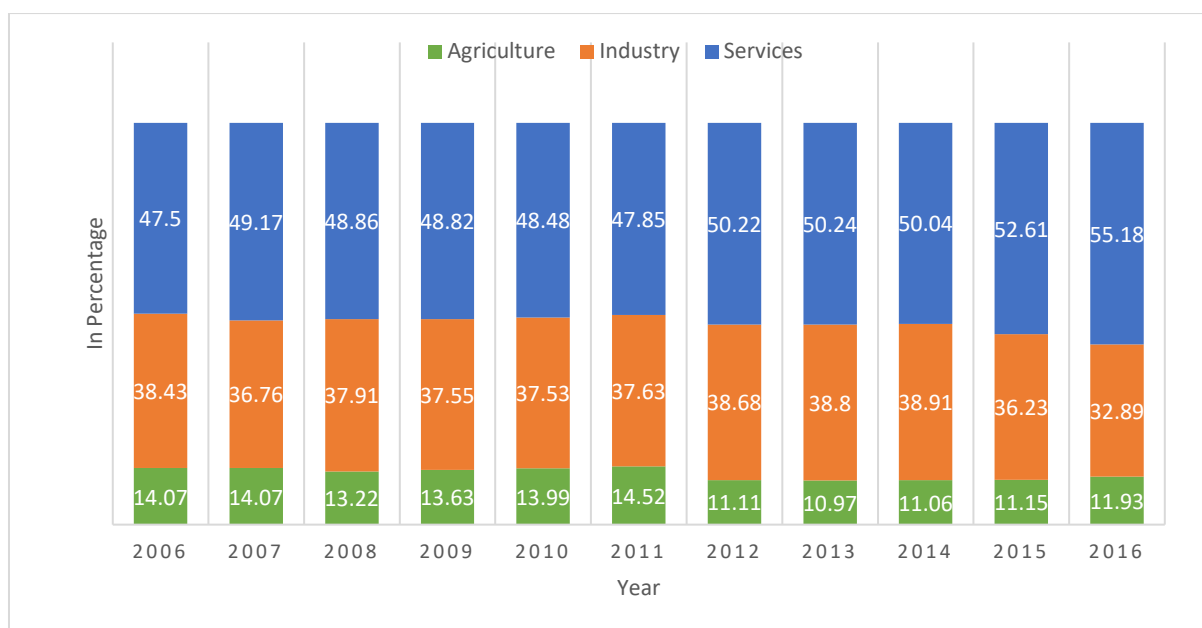


Figure 1 Distribution of gross domestic product (GDP) across economic sectors of Egypt (2006 - 2016) (Source - World Bank 2018)

Contribution of agriculture to the GDP of Egyptian Economy was 11.7% in 2017 (World Bank 2018). Egypt's agricultural system is labour demanding and it employs 24.83% of the total labour force of Egypt during 2017. Even though the agricultural system of Egypt is labour intensive, the labour's efficiency increased by just around 1 percent which is calculated as agriculture value added per labour in constant 2010 US dollars (Tellioglu et al. 2017). **Figure 4** below shows the role of agriculture in economy of Egypt.

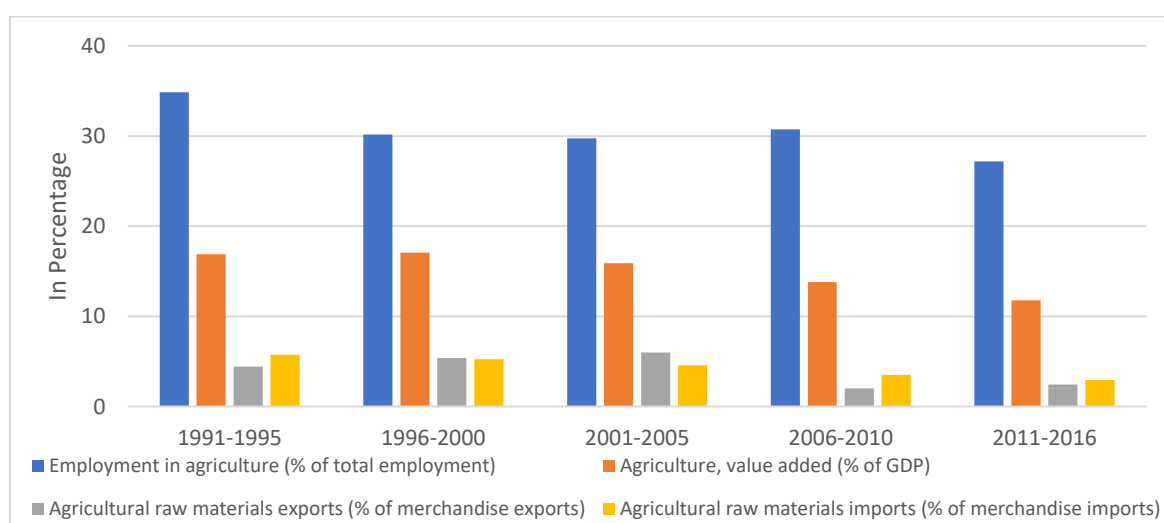


Figure 2 Role of Agriculture in Egyptian Economy (Source - World Bank 2018)

The Egyptian agricultural system transformed from being exported oriented in ancient times to import oriented in recent times, due to decreasing export and increasing import. Egypt also known as the “wheat basket” of the world is the largest wheat importer across the globe. Other than fruits and starchy roots (**Figure. 3**), Egypt consumes more than its produces and as a result its net import exceeds 50% of its total food consumption (WFP and CAPMAS 2013) (Tellioglu et al. 2017). This resulted in the rise of agricultural trade deficit in last two decades growing to \$10.8 Billion in 2014 from \$2.3 Billion in 1994 (Tellioglu et al. 2017).

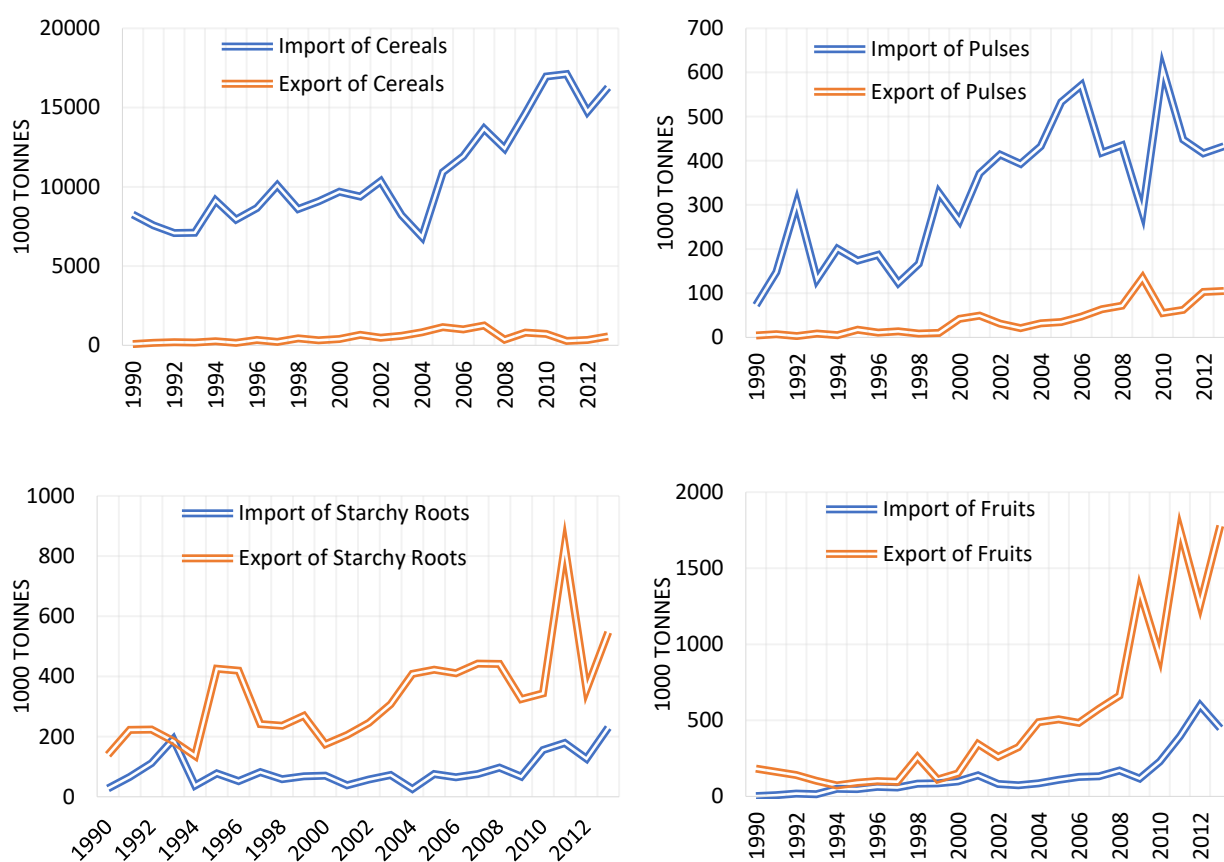


Figure 3 Import and Export of main food commodity groups in Egypt (1990-2013) (Source: Food Balance Sheets - Knoema.Com 2018)

Also, due to Egypt’s unique geographic feature, agriculture mostly takes place near the valley of River Nile and its delta and most of the Egyptian population (nearly 95%) resides in and around River Nile Delta (Alfiky et al. 2012). With rapid increase in urban population in recent years (Worldometers 2018), this may also pose another threat to Egypt’s food production, since urbanisation usually takes place on agricultural

lands which will result in decrease in food production. This is a growing concern for Egypt and its economy since there is descending trend in production of cereals and pulses far lower than their level of consumption (Tellioglu et al. 2017) in addition to its vulnerability to fluctuation in rate of currency exchange, global food price, change in climatic conditions etc.

2.2 Food Security

Food is a basic necessity for human's survival on planet earth. Food security is an uphill challenge faced by the world due to rapid growth of global population. In last one hundred years, the global population has increased by nearly 5 times; from 1.6 billion in 1900 it has reached 7.6 billion in 2018 as per recent estimates of United Nations (Worldometers 2018) as can be seen in **Figure 1** below. As of 2018, 54.9% of the total global population are residing in urban areas resulting in expansion of urban areas across the globe(Worldometers 2018). With the present growth rate of nearly 1.1%, we will have to feed a population nearly 9 billion by the year 2050, estimating an increase in food demand by 60% compared to present day (Breene 2016) . Hence, United Nations in 2015 has set 'Zero Hunger' as its second goal out of the seventeen Sustainable Development Goals to achieve the growing demand of food across the globe aiming to eradicate food poverty and hunger by achieving food security, improved nutrition and promoting sustainable agriculture by 2030.

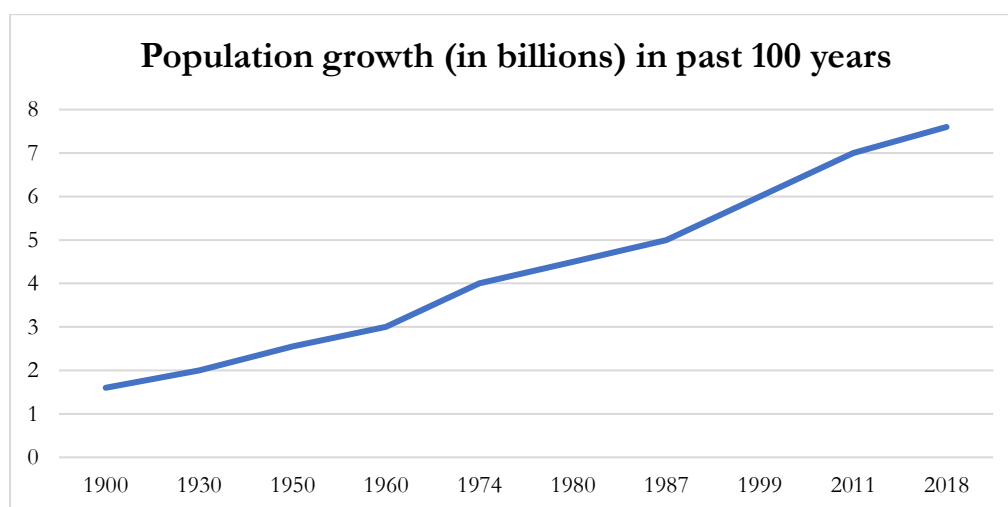


Figure 4 Rapid growth of population in past 100 years. (Source: Worldometers 2018)

In the 1970's the world faced one of the most severe food crisis from 1972-75 which resulted in death of nearly 2 million people mostly in Africa and Asia (Gerlach 2015). The roots of this food crisis were characterised by a major El Nino event, followed by high demand of food from Soviet Union later leading to energy crisis and economic crisis (Gerlach 2015). United Nations responded to the crisis by organising the first World Food Conference in Rome, 1974 where the term 'food security' first evolved. 'stable food supply to assure international access' (Gross et al. 2000) was set as the major priority to achieve food security in this conference for developing international policies to combat the world food crisis and hunger (Gerlach 2015). The World Food Conference, 1974 mainly emphasised on three main agendas all related to food supply (UNSPECIFIED 1974). The key agendas were to set up an international funding to enhance production; creating reserve stocks of food produce and increase in food aid; and establishing an institutional framework among the members for smooth implementation of all mandates (UNSPECIFIED 1974). In the 1980's, the green revolution across the globe resulted in growth of food production which enhanced the food availability. However, this didn't eradicate food crisis and famines. Thus, FAO and World Bank further expanded the concept of food security encompassing both "physical and economic access to food supplies"(Gross et al. 2000). Focus was shifted from food supply to access to food supplies at all times for all the people (FAO 2003). Later at World Food Summit (WFS), 1996 defined food security as a multi-dimensional concept which was widely accepted considers four important dimensions such as food availability, accessibility, usability and stability. The definition approved by the World Food Summit 1996 remains the most accepted definitions till date (Simon 2012). In 2001, the state of food insecurity, refined the definition of WFS, 1996 by including term 'social' in the WFS definition which is as follows "Food security, at the individual, household, national, regional and global levels [is achieved] when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life".

Food poverty and hunger remain a significant threat to a growing economy; where and when the individuals become a part of the consequential chain of demands and need to gather food for nourishment and ultimately a healthy life. Inefficiency to acquire food will lead to hunger and further affecting the vital

organs of the body and further affecting the vital organs of the body and immune system. Under the chronic malnourished state, individuals are incapable of obtaining sustenance, and this will constrain the welfare and growth of the economy. (United Nations 2015). With nearly 815 million people at such state across the globe (WFP 2017), sustainable development remains a distant dream because without human development, it is not possible to achieve other sustainable development goals such as gender equality, education, health etc. This remains a grave concern for many countries especially in Asia and Africa which faces huge food poverty issues. As per FAO, 2015 data, we can see in **Figure** below that nearly 90% of the people suffering from food insecurity in the world are from Asia and Africa.

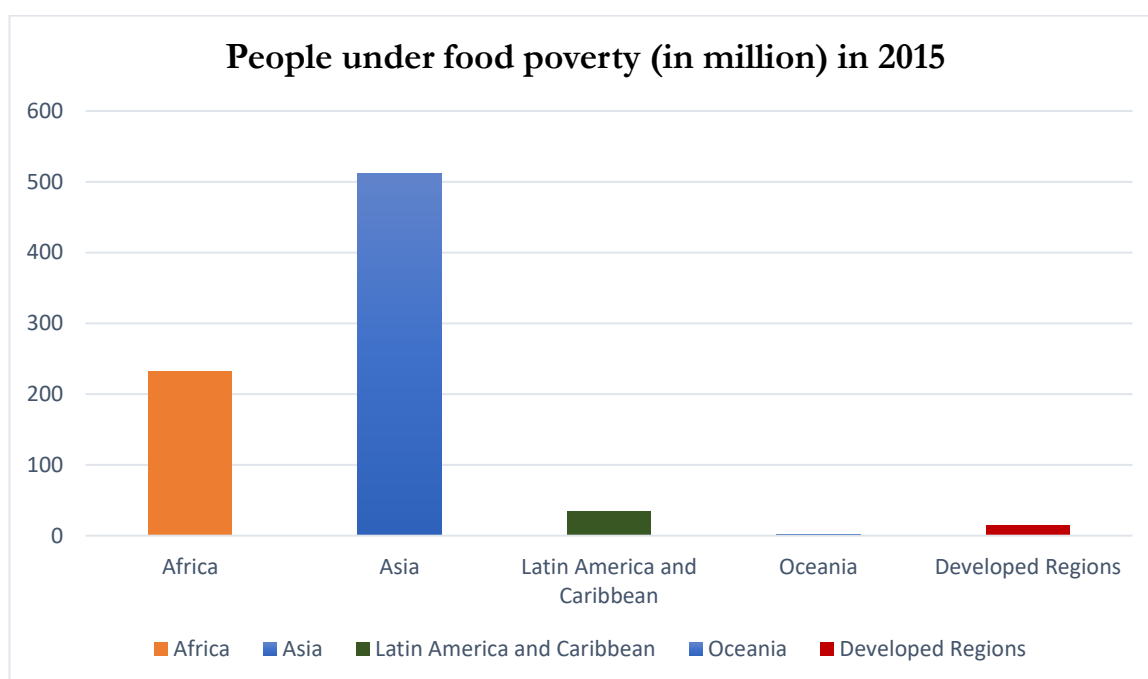


Figure 5 People under food poverty in 2017 (Source: FAO 2015)

In this research work, the aspect of food availability in terms of food production is being mainly considered to understand the aspect of food production and its importance for having food security.

2.3 Urbanisation and its impacts

Increase of people living in the cities and town can be derived as urbanisation. This concept evolved during the industrial revolution resulting in growth of industries and jobs in various sectors(The Open University 2016). The global trend of urbanisation has been ever increasing since its inception. Growth of

job opportunities due to industrialisation resulted in migration of people from rural to urban areas. Urbanisation resulted in increase in urban population finally overtaking rural population in the year 2008 (Urbanisation 2015). Urbanisation is now a common sight in developing countries across Asia and Africa. Areas in the cities where deprived and poor people resides are given many names such as slums, barrios, shantytowns etc (Urbanisation 2015).

Urbanisation is becoming a global phenomenon in 21st century. Urbanisation also has various effects which impacts everyone in negative ways. Deprived area suffers from poor and unhygienic living conditions with no proper access to daily basic needs such as water, sanitation etc. This results in pollution in various forms affecting the environment like waste pollution, air pollution and water pollution. (The Open University 2016). Spread of urbanisation results in urban sprawl covering areas near a growing city with people migrating and staying in this city fringes making it more compact. This results in loss of vegetation and pollution of natural resources at site having various environmental disadvantages (Guida-Johnson et al.).

2.4 Land-Use/Land-Cover Change and its analysis

Land cover can be defined as physical characteristics covering the surface of the earth such as grassland, woodland, water barren land etc (OECD 2005a). Land Use can be defined as the usage of land by humans for carrying out their socio-economic activities such as agricultural, industrial, residential, urban rural etc (OECD 2005b). Though land cover and land use are different in terms of definition, they are interlinked and affects one another, hence often used together as one term. Also, change in either may not be the consequence of the other (Riebsame et al. 1994). Change in landcover usually takes place due to two forces at play - nature and humans and not necessarily indicate land degradation (Riebsame et al. 1994).

Growth of population results in growth of basic needs such as habitat, food consumption and other livelihood activities, acting as the driving force of creating demand for land resource. This generates changes in the land cover over the earth surface cause by land use change due to the growth of population (De Rosa et al. 2016). Due to population growth, human and economic development activities took place

which resulted in industrialisation followed by green revolution driving land cover changes in massive scale such as deforestation, desertification, conversion of swamps into urban areas etc. across the globe resulting in number of environmental degradation such as biodiversity loss, reduction in source of carbon storage, conversion of swamps to urban lands etc (De Rosa et al. 2016). These land use change causes various impact environmental and social impacts at large scale leading to increase in greenhouse gas emitting activities resulting in climate change and global warming (Cooper et al. 2002).

Land Cover (LC) and Land Use (LU) are the two most basic elements to understand and characterise various changes on the earth surface induced by nature and humans. Greenhouse gas emissions and land use changes due to agriculture and urbanisation are considered the two major factors which results in climate change (Cooper et al. 2002). Both the terms Land Use (LU) and Land Cover (LC) are often interlinked and combined as one term by researchers to understand the effect of one over the other and to interpret various impacts of Anthropocene activities on environmental modification across the globe (Pelorosso et al. 2009). Topographical surveys and other conventional methods are used to check LULC changes but its application is very limited and time consuming to cover larger surface. Hence, to monitor land-cover of large surface area, remote sensing using satellite imagery is the only feasible and advanced technology available to human kind at present times to assess and detect LULC changes over a period of time (Stow et al. 2002). However, analysing LU/LC changes to assess environmental impacts had long been neglected and undervalued by researchers (Lindeijer 2000) as an important tool to calculate and assess various environmental anomalies caused by human activities and also carry out economic analysis and assessment (Banse et al. 2008) (Hertel et al. 2009).

Researchers now uses LU/LC analysis methods for detection change in land use to analyse, assess and understand - dynamics of forest cover and forest precipitation (Da Ponte et al. 2017); forest loss due to urban expansion (Salghuna et al. 2018); urban growth (Jiang et al. 2007) and urban sprawl (El Garouani et al. 2017), its impact on agriculture areas (A. A. Shalaby et al. 2012; A. Shalaby et al. 2015) etc. With

improvement in satellite technology, LU/LC has become a tool that can be used for research purposes in multi-disciplinary areas.

2.5 Application of Geospatial Technologies for studying and assessing environment

Geospatial technologies can be defined as the combination/set of all the technologies used to collect, store and process geographic data to analyse and understand various features on the Earth Surface (Dempsey 2014). These technologies of data acquisition of earth's surface have evolved over the years. The art of drawing map can be traced back to prehistoric times which further evolved as a subject in itself called cartography and map making in the early 19th century. Later, after the invention of photography during the 19th century, aerial photographs captured by cameras attached to hot-air balloons, pigeons etc (American Association For the Advancement of Science 2008). After the invention of aeroplane in the 20th century use of aerial photography accelerated for making maps and collecting information during the second world war (American Association For the Advancement of Science 2008). During the cold war in the 1960's, interpretation of photographs took a new turn after the launch of satellite and start of the CORONA program (Baumann 2009). Arrival of modern computer systems in 1970's, storage of satellite images became possible, followed by development of software to process and analyse these images digitally gave a new dimension to "the science and art of photographic interpretation" creating a new field of study called geographic information system GIS (American Association For the Advancement of Science 2008). GIS gave the special ability to store and compile various complex geospatial data (information of a precise location on earth's surface) into a set of thematic layer of maps making it easier for humans to analyse these complex set of data in one platform and be able to communicate it to a large audience in a simpler form (American Association For the Advancement of Science 2008). Growth of geospatial technologies has seen its application in a varied sector such as - study of natural resources, environmental monitoring and conservation, weather forecast, disaster management etc.

The common set of geospatial technologies used to study various earth's features are as follows:

- a. **Global Positioning System GPS:** A satellite-based geo-positioning system used to determine location of anything at a given time with the help of satellite signals received (Van der Spek et al. 2009).
- b. **Remote Sensing:** It can be defined as the science of obtaining information about any object, location or area without being in contact with them (through aircraft or satellites) (National Ocean and Atmospheric Administration, USA 2018).
- c. **Geographic Information Systems GIS:** Geography (location) and data (attributes) can be regarded as the two key data types of this geospatial technology. One of the pioneer researcher in the field of GIS, Prof. Dueker, defined GIS as follows - “A geographic information system is a special case of information systems where the database consists of observations on spatially distributed features, activities or events, which are definable in space as points, lines, or areas. A geographic information system manipulates data about these points, lines, and areas to retrieve data for ad hoc queries and analyses” (Kenneth Dueker, Portland State University, 1979).

Concept of GIS and Remote Sensing would be discussed further to have a broader understanding of its concepts and its application for this thesis.

2.5.1 Remote Sensing – The technology and its use

Remote Sensing as defined above the science of acquiring information about any object (its shape, size, location or area) without being in contact with them through aircraft (aerial photography) or satellites (sensors) (National Ocean and Atmospheric Administration, USA 2018). This process comprises of various steps and can be broken down into 7 simple steps (Samarakoon 2017) as shown in **Figure 6** below.

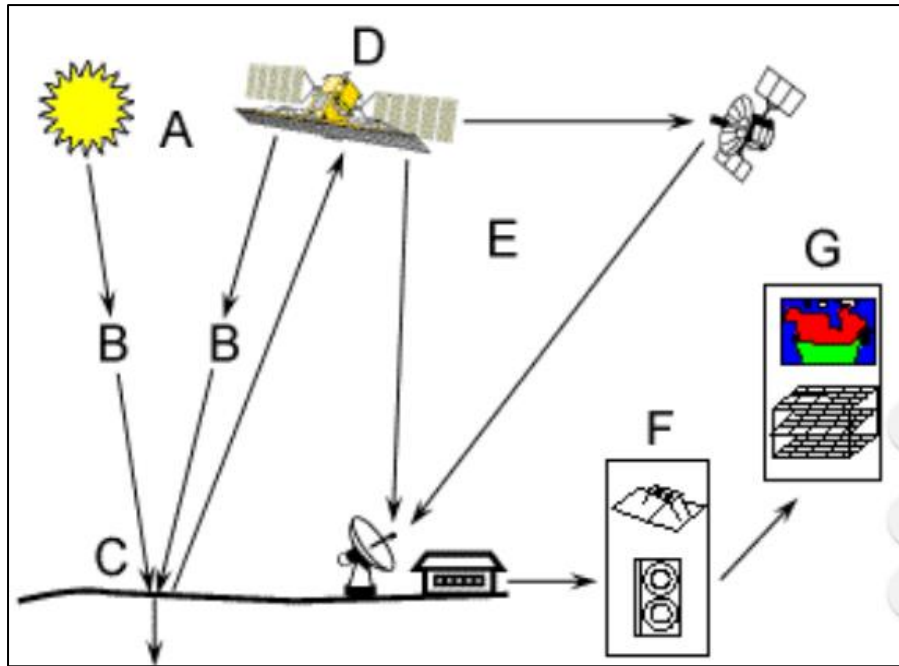


Figure 6 Process of Remote Sensing (Source: Samarakoon)

- Illumination** from the energy source provides the required electromagnetic energy to target the object or area of interest.
- Radiated** energy from the energy source travels through the atmosphere (interacting with the atmosphere) to the target. This process can take place more than once due to travelling of energy from target to the sensor.
- Both the energy and the target have its own properties. The energy travelling from the source through the atmosphere **interacts** with the target based on their properties.
- After interaction, the energy is **emitted** (scattered) back from the target. This emission has electromagnetic radiation which needs to be collected and recorded with the help of **sensors**.
- Recorded energy is transmitted (in electronic form) to a **receiving and processing** station. The received data is then processed into an image form which can be either a hardcopy or in a digital format.
- The image is then analysed to **extract information** about the target for further **interpretation**.
- The final component of the process of remote sensing is **application of this information** from the data (image) for revealing new information and assisting in solving problems

The data collected is used by researchers and scientists to monitor various processes on the earth's surface. The best part of this technology is its ability to cover large area at a given point of time; capacity of the sensors to collect images from the non-visible spectrum and transmission of these data's in a short period of time (Lloyd 2010).

The sensors used in the satellites are the most important component for carrying out the remote sensing process. Each object on the surface of the earth transmits energy in varied nature (Liu et al. 2016). Sensors acquire these energy variations as information of each objects in the form of electromagnetic spectrum (as seen in **Figure 7**) helping them to create images of the objects on Earth's Surface. Unlike human eyes, sensors are capable of detecting energy variations beyond visible range of electromagnetic spectrum. (Baumann 2010)

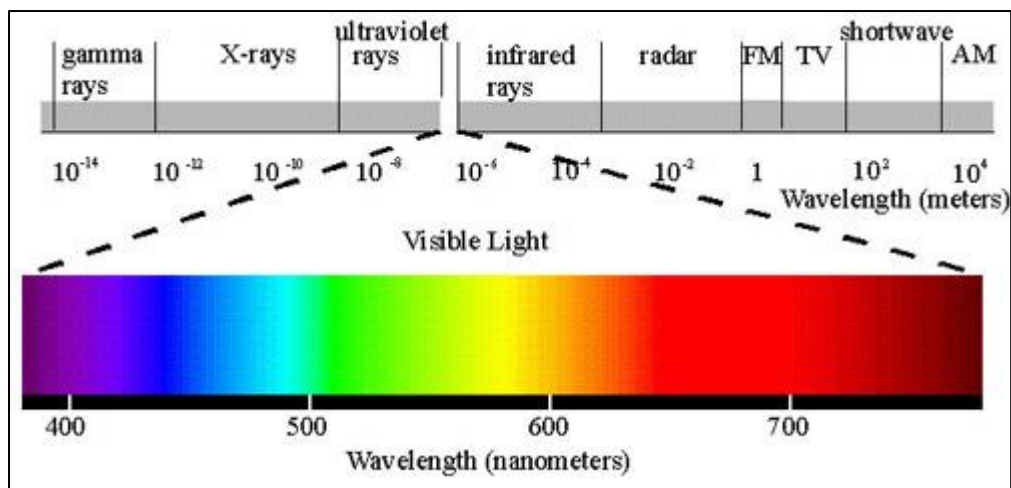


Figure 7 Electromagnetic Spectrum (Satellite Imaging Corp 2018)

There are four sensor characteristics which usually affects the quality satellite image depending on the specification of the platform and the sensor namely - spatial Resolution, spectral characteristics, temporal resolution and radiometric resolution (Liang et al. 2012). First three characteristics are the most relevant with respect to our study and will be discussed further.

Spatial resolution describes the pixel size of a satellite image i.e. the measurement of the smallest feature on the earth that can be determined by the sensor of the satellite. Higher spatial resolution represents

better image quality because of the ability of sensor to visualise minute details of an object on the earth surface (**Figure 8**) (Liang et al. 2012).

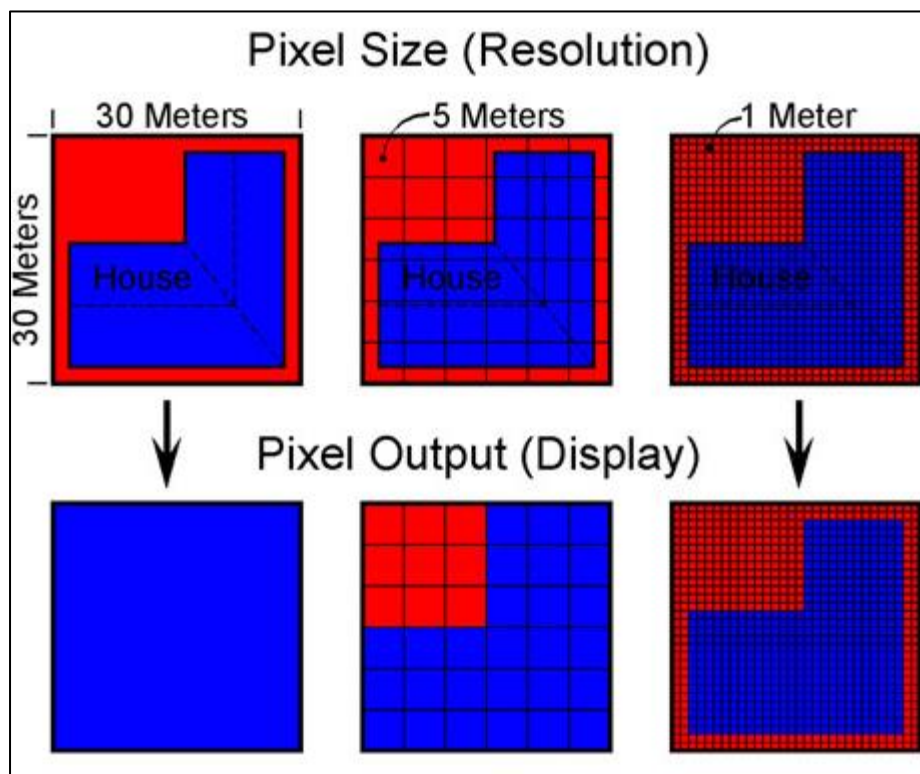


Figure 8 Spatial Resolution (Source: Satellite Imaging Corp 2018)

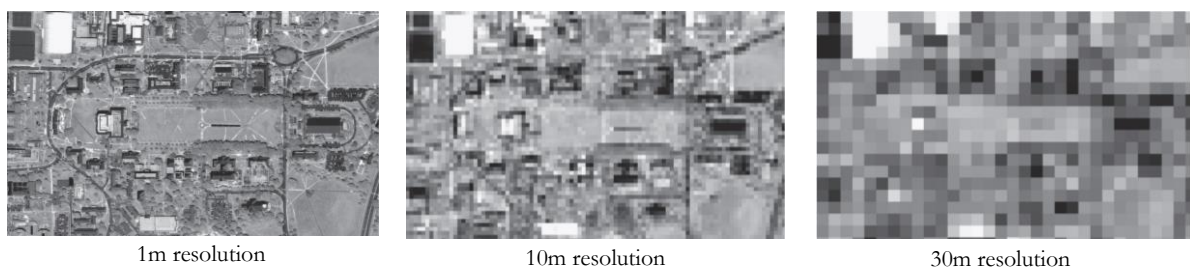


Figure 9 Different pixel resolution of the same image (Source: Liang et al. 2012)

Spectral resolution can be specified as the number and the width of spectral bands in a sensor used to collect the radiance reflected from earth's surface. Along with the number of bands, width of a band and its position in the electromagnetic spectrum is also important to determine better quality of a satellite image (Liang et al. 2012; Satellite Imaging Corp 2018). Combination of spectral bands results in several colour composite images. These bands when combined in certain ways helps in identifying specific features

from Earth's surface like agriculture, forests, urban areas etc (**Figure 9**). This is one of the most important factor to take into consideration for detecting change in earth's features over a period of time (Turner et al. 2007). Agriculture and vegetation monitoring is another aspect of using remote sensing techniques where understanding the concept of spectral resolution is very important. Leaves from plants contains chlorophyll and possess biochemical and biophysical attributes which are specific to each plant (Wang et al. 2013). This property helps in determining reflectance of plants, as their spectral signatures differ from each other. The spectral signatures of vegetations are clearly detected in the following spectrum regions – visible, near-infrared and shortwave. (Wang et al. 2013).

Some of the common band combinations that can be applied to Landsat images and be displayed as red, green, blue (RGB):

Temporal resolution is described as the measurement of number of times (frequency) a sensor revisits the same area on surface of Earth. This depends on various factors such as the design of the sensor, its orbit pattern, viewing angle and distance/altitude from Earth's surface (Liang et al. 2012). This is another important aspect used for carrying out time series land-use/land-cover classification. Most of the multi-temporal/time-series LU/LC detection studies conducted are mostly derived from spectral-temporal information (Zhai et al. 2018) due to the un-availability of data with better spatial resolution until recently.

Landsat was the first satellite program introduced by USGS for studying the surface of the Earth launched its first satellite Landsat 1 in 1972 with two image sensors MSS and RBV (Baumann 2009). There is an open access to the images from Landsat till date. Over the last 40 years, various sensors have been added (refer to **Table 1** below) in subsequent Landsat Satellite series with advancement in technologies and need for various purposes.

Table 1 Sensors and bands in Landsat Satellites (Source -USGS 2018)

Sensors	Satellite (s)	Bands	Resolutions (meters)	Scene Size
Multispectral Scanner (MSS)	Landsat 1-3	Band 4-7 - spectral	60	

	Landsat 4-5	Band 1-4 - spectral	60	170 km (north-south) x 185 km (east-west)
Thematic Mapper (TM)	Landsat 4-5	Bands 1-5, and 7 - Spectral Band 8 - thermal	30 30	170 km (north-south) x 183 km (east-west)
Enhanced Thematic Mapper Plus (ETM+)	Landsat 7	Bands 1-5, and 7 - Spectral Band 8 - panchromatic	30 15	170 km (north-south) x 183 km (east-west)
Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS)	Landsat 8	Bands 1 to 7 and 9 - spectral Band 8 - panchromatic Band 10 and 11 - thermal	30 15 30	170 km (north-south) x 183 km (east-west)

2.5.2 GIS and Image processing

GIS is a tool used for analysing and manipulating geographic data. Before the advent of GIS software, analysing vector and raster data needed separate software. GIS made it became easier to process raster and vector data on the same platform. Satellite images are usually taken from an altitude. Electromagnetic spectrum while passing through the earth's atmosphere, faces various hindrance and sometimes gets scattered or absorbed. Further there are also other factors such as cloud cover, pollution etc. which might affect the quality of the data collected. Hence, satellite images require corrections and restoration processes for improving the quality of satellite data (Prudyus et al. 2015).

There are various methods used for interpreting satellite images which are categorised into two categories pixel-based classification and object-based classification. Under pixel-based classification there are two techniques – unsupervised and supervised image classification. The two methods under pixel-based classification are mostly used for classifying satellite images as until recently high-resolution data were not easily available (GIS Geography 2014)

Unsupervised classification is the most basic technique for image classification. For performing this classification, one doesn't need to know the pixel size of the image or create any training samples. As a first step, the software creates cluster based on the properties of pixels. These clusters are generated by using clustering algorithm such as K-means and ISODATA. After the clusters are generated, each cluster are identified into groups/classes as per the requirement of the user (GIS Geography 2014)

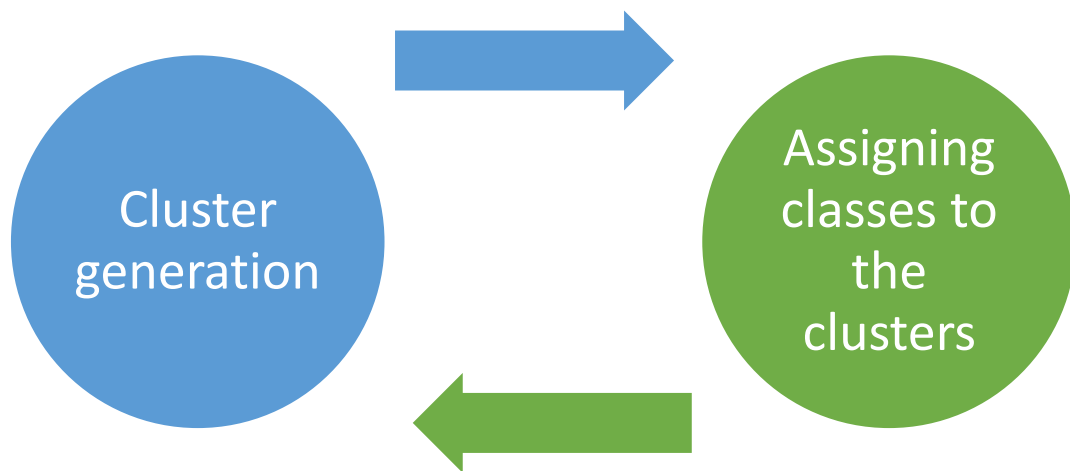


Figure 10 Steps of unsupervised classification (Source: GIS Geography 2014)

Supervised classification is the advanced version of unsupervised classification. Here, the analyst must have prior information about the land cover classes of the study area for developing training samples. User with prior information about the land-cover creates spectral signatures using polygon tool in the training sets. Once the training samples are created, the software classifies the image based on the defined training sets. Maximum likelihood and minimum-distance classification are the most commonly used algorithms for carrying out supervised classifications (GIS Geography 2014).

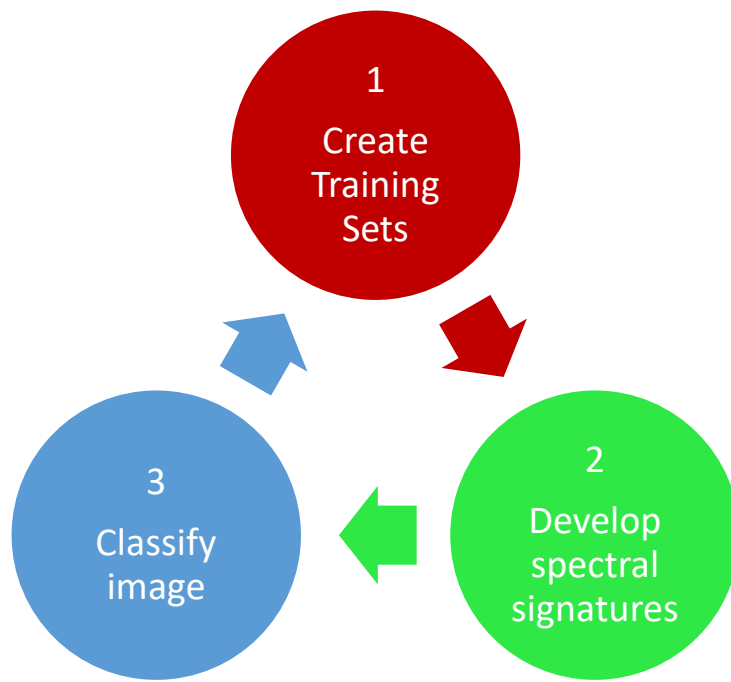


Figure 11 Steps of supervised classification (Source: GIS Geography 2014)

3. Methodology

3.1 Research Design

3. In this chapter we will address the various methods that will be applied to design this research in order to answer the research questions set in the introduction. Research work for this thesis will follow a set of procedures keeping in mind the overarching aim of this thesis. **Table 3** below divides the research work into following sections:

Table 2 Research Design (Prepared by Author)

	Research Question	Objectives	Steps	Methods
RQ1	What is the rate of change of agricultural areas to urban settlements Gharbia and in Menoufia governorate of the middle Nile Delta region (due to change of land-use patterns in last 20 years since 1997?	Detect the rate of urbanization in Gharbia and in Al- Menoufia using GIS and Remote Sensing in past 20 years	<ul style="list-style-type: none"> • Collection of data about both the governorates – historical, statistical etc. • Download satellite data for the same month for each year - 1988, 2003 and 2018 • Process and classify the satellite data • Create LU/LC map 	<ul style="list-style-type: none"> • Literature Review • Satellite data Collection • Image processing and enhancement • Hybrid classification
		Develop a LU/LC map of the study for the year 1988, 2003 and 2018		
		Identify and define the pattern of urbanization.		
RQ2	What are the factors of urbanisation on the Nile Delta region and its effects on the agriculture system (food security) of Egypt?	Identify and analyse the major factors along with urbanisation affecting the food security (food production) of Egypt	<ul style="list-style-type: none"> • Literature review about the major factors leading to urbanisation in Egypt – historical, statistical, policies etc. • Literature review about 	<ul style="list-style-type: none"> • Literature Review and analysis • Statistical data Collection • Policy Analysis

		Understand the effects of urbanisation on the agricultural system of Egypt	the effects of urbanisation on agriculture system (food production and security) of Egypt	
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3.2 Study Area

To address RQ1, the study area is Gharbia and Menoufia - two adjacent governorates located in the central part of the Nile Delta region towards the north of Egypt. Menoufia is located to the south of Gharbia and to the north of Cairo and Gharbia is situated 90km north of Cairo. Rural population dominates urban population in both Gharbia and Menoufia. Agriculture is the most common activity in both the governorates due to its fertile land and proximity to River Nile. Gharbia governorate is known for cotton cultivation and its textile industry, while Menoufia is famous for production of maize, wheat and cotton along with vegetables like green beans and potatoes which are largely exported (Gharbia Governorate 2018; Menoufia Governorate 2018). Nile Delta region of Egypt the study area for RQ2.

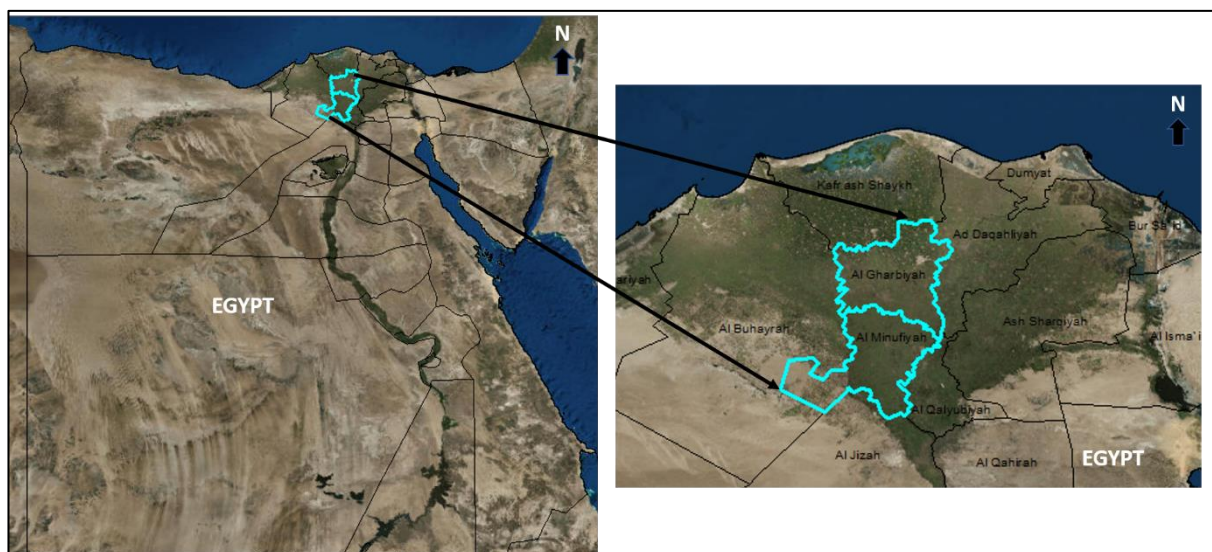


Figure 12 Study Area - Gharbia and Menoufia Governorates

Table 3 Demographic details of study area (Source: CAPMAS 2015)

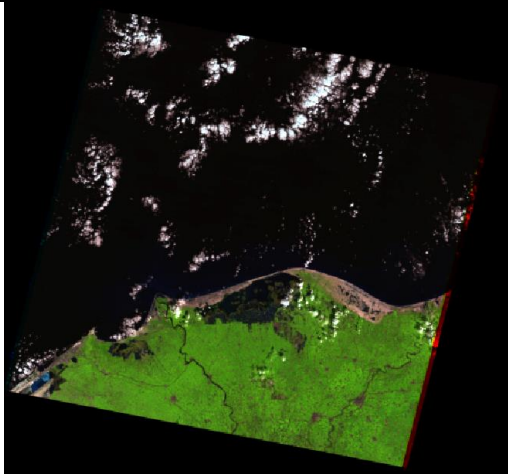
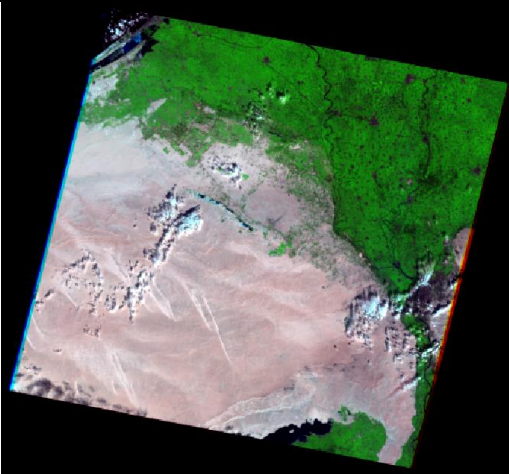
	Gharbia Governorate	Menoufia Governorate
Area	1942 sq. km	2499.3 sq. km
Total Population (2015)	4751 865	3941 293
Urban Population (2015)	1427 235	812833
Rural Population (2015)	3324 630	3128 460
Population Density (2015)	2447	1577

3.3 Data Collection

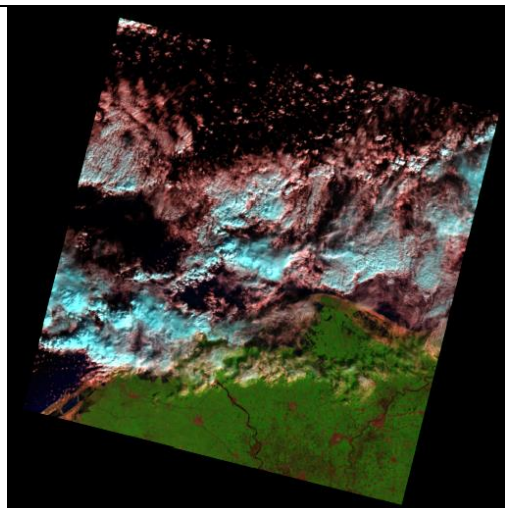
3.3.1 Satellite Data

For carrying out this research work and answer RQ 1, various LANDSAT 5 and LANDSAT 8 satellite images were acquired from USGS Earth Explorer website (**Table 4**). From the literature review conducted, it was evident that agriculture in Egypt takes place in three cropping seasons – winter, summer and nilii (kharif s season) (Abdel Meguid 2017). Winter is the season where most of the cereals are grown in Egypt and hence been considered for our study period (EI-Sherif 1997; Harb et al. 2015). Satellite images (**Table** below) were chosen from the month of January.

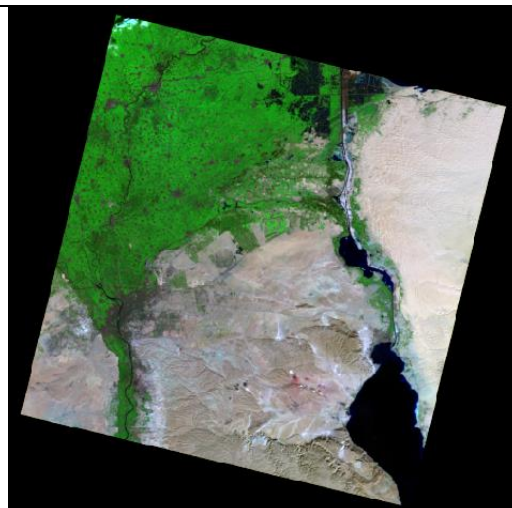
Table 4 Satellite images for carrying out research work

Satellite - LANDSAT_5; ; Sensor – TM; Month – January; Year - 1997	
 <p>LT05_L1TP_177038_19970102_20180209_01_T1</p>	 <p>LT05_L1TP_177039_19970102_20180209_01_T1</p>

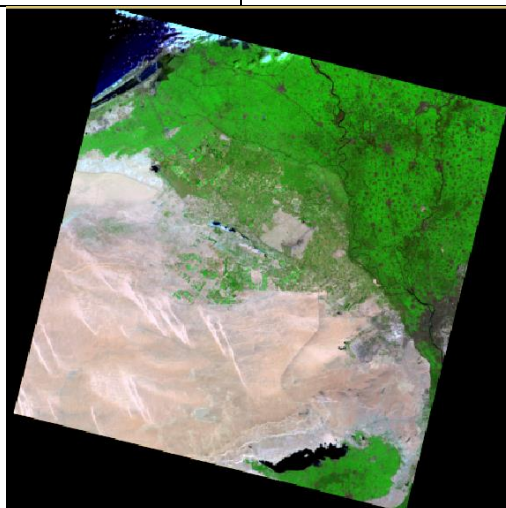
Satellite - LANDSAT_8; Sensor - OLI_TIRS; Month – January; Year - 2017



LC08_L1TP_177038_20170109_20170311_01_T1



LC08_L1TP_176039_20170102_20170312_01_T1



LC08_L1TP_177039_20170109_20170311_01_T1

Table 5 Characteristics of Landsat images used

Dates	1997/01/07	1997/01/02	2017/01/09	2017/01/02	2017/01/09
Satellite	LANDSAT 5	LANDSAT 5	LANDSAT 8	LANDSAT 8	LANDSAT 8
Sensor ID	TM	TM	OLI TIRS	OLI TIRS	OLI TIRS
Spatial resolution, m	30	30	30	30	30
Path number	177	177	177	176	177
Row number	038	039	038	039	039
Projection	UTM	UTM	UTM	UTM	UTM
Datum	WGS84	WGS84	WGS84	WGS84	WGS84
UTM Zone	36	36	36	36	36

3.3.2 Literature Review

Literature review was conducted with the purpose of understanding what kind of research work was already carried out about the effects of urbanisation on agriculture and food security of Egypt and to identify the major factors affecting the food security (food production) of Egypt in order to answer RQ1 and RQ2.

Literature review was carried out in the following way:

- The author searched for relevant academic literature in four databases (LUB Search – Lund University’s database of academic literature, Ebsco, Science Direct, JSTOR). Author also searched Google for relevant grey literature. All the literature that were collected was in English as the author doesn’t understand Arabic.
- Keywords were used to find relevant literature about the topic.
 - Land Use Change ‘and’ Nile Delta
 - Egypt ‘and’ Food Security
 - Nile Delta ‘and’ Food Security
 - Urbanisation ‘and’ Nile Delta
 - Urbanisation ‘and’ Nile Delta ‘and’ Food Security
 - Urbanisation ‘and’ Agriculture ‘and’ Egypt
 - Urbanisation ‘and’ Egypt ‘and’ Food Security
- After identification of relevant literature, they were reviewed and analysed as mentioned in data analysis section.

3.4 Data Analysis Methods

3.4.1 Image preparation, processing, classification and accuracy assessment

- a. Satellite image preparation - For analysing and classifying a raw satellite image the basic step that needs to be done is stacking up (composite) all the single band images of a satellite to get the multi-spectral image which will be used for visual analysis (ArcGIS Desktop 2018).

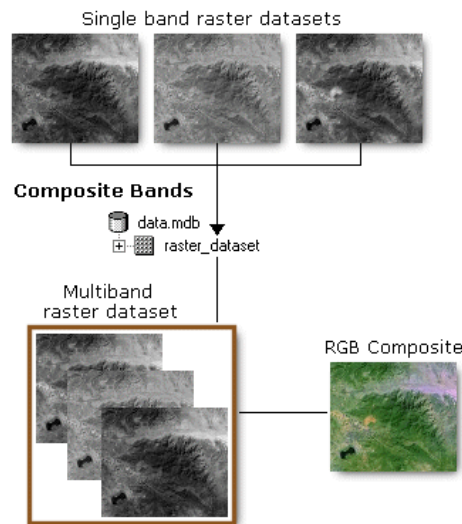


Figure 13 Concept of stacking (composite) layers (Source: (ArcGIS Desktop 2018))

- b. Mosaic: After stacking of all the single bands to get a multi-spectral image, the images obtained were required to be merged (mosaiced) as the author used two tiles from 1997 and three tiles from 2017 as seen in **Table 4**. Since the mosaiced tiles covers nearly the entire Nile Delta region, the mosaiced image was clipped to the study region as shown in **Figure 14** below.

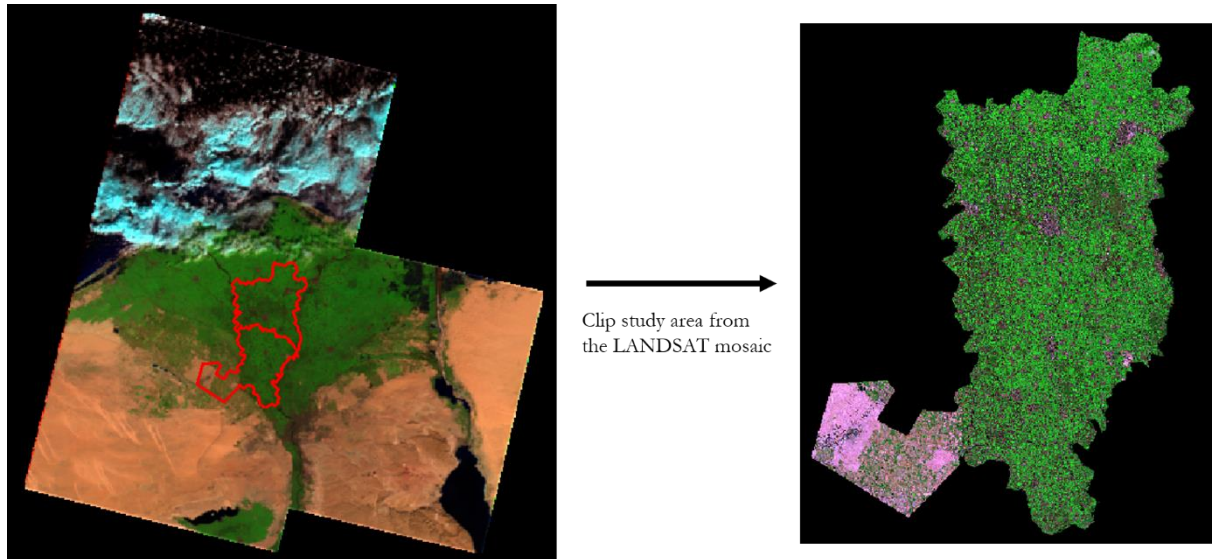


Figure 14 Clipping the study area using ArcGIS

c. Classification: As discussed previously in literature review, although there are various methods available for image classification, supervised and unsupervised classification are broadly used by researchers to conduct change detection. For carrying out image classification, number of training sampling points are usually required (Lu et al. 2007). Performing time-series LU/LC detection can be difficult due to the requirement of large number of training samples, which may also affect the accuracy of the image. Hence, the author adopted to apply the hybrid or combined classification (combination of both unsupervised and supervised classification methods) technique for carrying out time series detection of middle Nile Delta Region. The concept of applying this method is described in **Figure 15** below. There are a couple of examples of researchers using this method for image classification such as Zaki et al. 2011 conducted LU/LC change study in Northeast of Cairo using hybrid classification method yielding result with high accuracy. A multi-temporal LU/LC change study of the Kahramanmaraş city in Turkey was conducted by Alphan et al. 2009 using hybrid classification with high accuracy results.

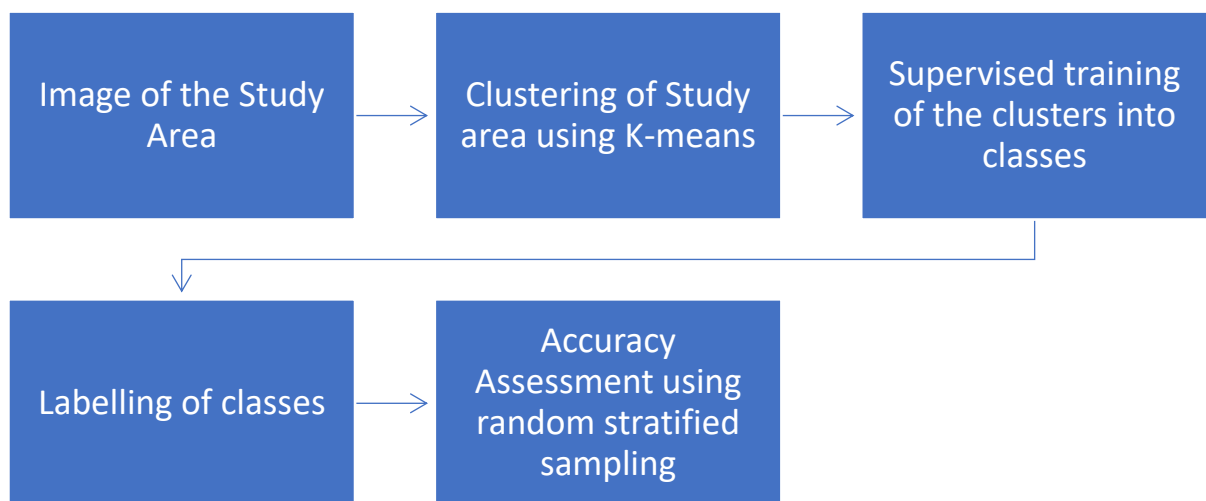


Figure 15 Hybrid or combined classification (combination of both unsupervised and supervised classification methods) applied for change detection study

- d. Group of classes: After conducting literature review about detection of LU/LC classification in Nile Delta region, following 4 classes - agriculture, urban, water and barren were finalised to assess the LU/LC change detection in the study area considering a similar research conducted by Hegazy et al. 2015 in the Nile Delta Region.
- e. Accuracy Assessment: To check the accuracy of the classification done, method of stratified random sampling was used. As suggested by (Congalton 1991), the thumb rule is to collect a minimum of 50 samples for each land use class to assess accuracy. A total of 200 samples were selected for each image classification. The simple formula used to calculate classification accuracy is: $(\text{Number of Agreements} / \text{Total number of Reference Points})$ (Chuvieco et al. 2009). As per Chuvieco et al. 2009, following this formula might result in errors as few of the number of agreements were obtained by chance. Hence, Chuvieco et al. 2009 suggested performing of Kappa statistics analysis for removing any effects from random factors and assess the actual agreement.

The complete process to be followed to carry out land-use classification can be described in a flow chart below.

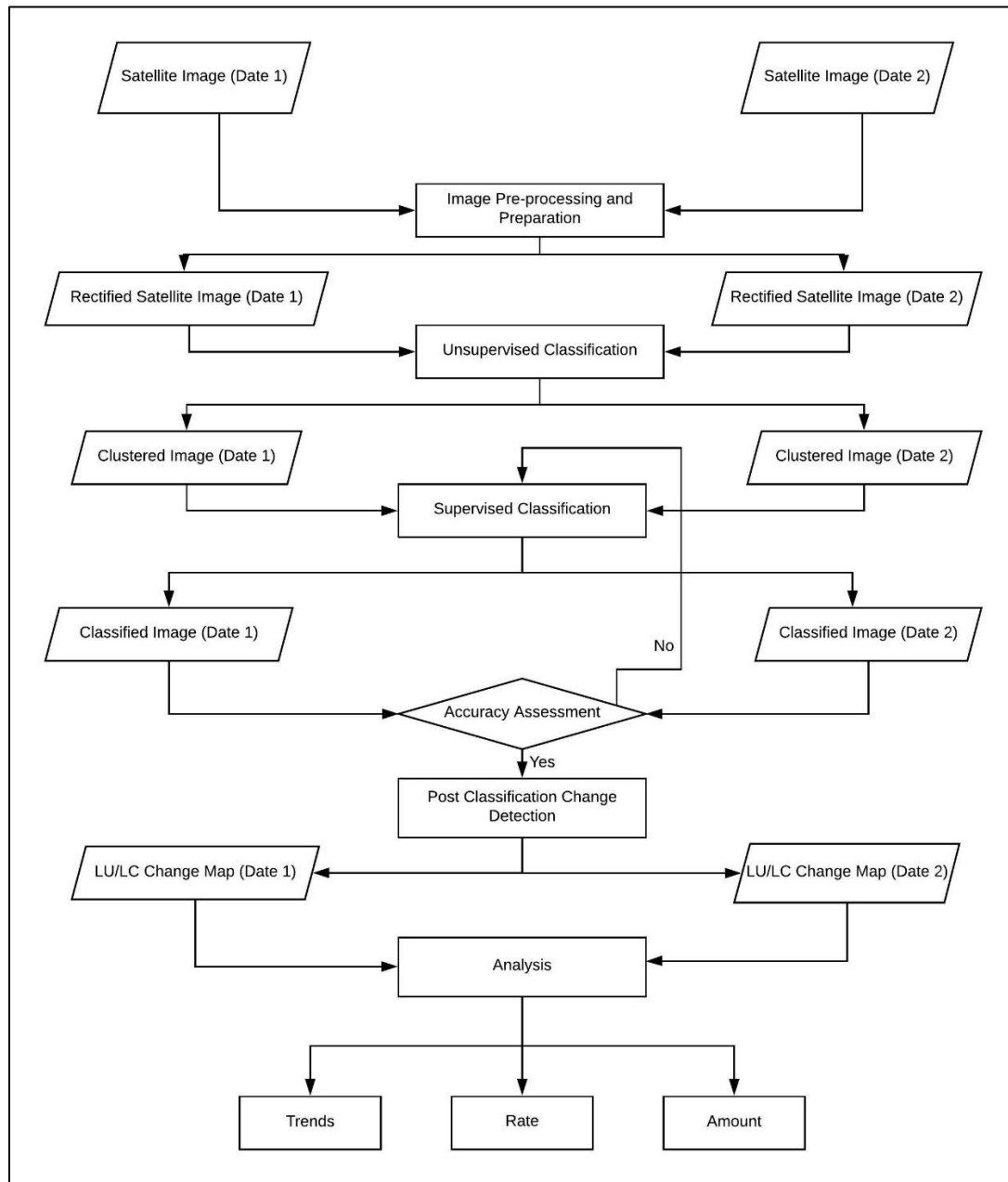


Figure 16 Classification Process Followed

3.4.2 Literature analysis

After completion of collection of relevant literature, the author read all the articles and research papers taking notes from each of them for the thesis. Each literature was analysed for its contents to create themes/topics and code them to various factors affecting food security of Egypt.

4. Results and Analysis

This chapter interprets the results obtained from the analysis of maps using geospatial technologies to answer along with relevant literature as mentioned in the methodology to answer RQ1. For rese

4.1 Analysis of the Land Use/Land Cover change (RQ1)

The main aim of carrying LU/LC change analysis was to understand the impact of urbanisation on the study area. Aim of this analysis was to understand if the land use change of the study area during (1997-2017) has affected the food security of Egypt, especially in the rate of change agricultural lands into urban areas. The study area, as mentioned in the chapter 3, habitats mostly rural population which indulges mostly in agricultural activities. Decrease in agricultural might affect their livelihood and the food productivity of the region. The other main goal of this RQ was to create a LU/LC thematic map which would be used as the foundation for future research in the study area. The maps below (**Figure 17-18**) are obtained as a result of the classification of the satellite images to detect the the Land Use/Land Cover in the study region.

Accuracy is an important aspect of every research studies conducted for better usage of its information in further studies and decision-making processes. Analysis without a quantitative statement of its accuracy is often not accepted by researchers. Anderson et al. 1976 suggested that accuracy in between 85-90% is usually the standard accuracy for conducting a LU/LC study. The land use/land cover classification done through the methods mentioned in chapter 3 yielded an accuracy of 89.00% for 1997 and 84.00% for 2017 (**Table 6**). Due to expansion in urban areas as well as agricultural lands in the study area in 2017 compared to 1997, there was often confusion in the spectral signatures of pixels between classes of agricultural areas, urban areas, and barren land. This resulted in lower accuracy of 2017 land use classification compared to 1997.

Table 6 Statistics of Accuracy Assessment (Source -Author)

Year	Accuracy Totals
1997 Kappa (K^{\wedge}) Statistics	0.8533
1997 Classification Accuracy	89.00%
2017 Kappa (K^{\wedge}) Statistics	0.7867
2017 Classification Accuracy	84.00%

- a. Change in agricultural areas: In the study area, the area for cultivation increased in the last to decades with addition of new agricultural lands through land reclamation in the desert fringes of Nile Delta. The observed change in agricultural area, in the last two decades was 6.10% adding nearly 252.77 sq.km of agricultural lands (**Table 7, Figure 19**). The agricultural cover in the study region increased from 2071.15 sq.km in 1997 to 2197.59 sq.km in 2017 (**Table**.
- b. Urbanisation: Urban areas play a vital role in the study area because of the dependency of the major population on agriculture for their livelihood. Sizes of the cities and urban areas increased by 21.19% from 1192.56 sq.km in 1997 to 1445.33 sq.km in 2017 (**Table 7, Figure 19**). This may pose future threat to the rural population of the region
- c. Surface Water: Water from the River Nile passes by the city on both the sides. However, surface water within the region showed a decreasing trend by 25.70% (**Table 8, Figure 22**). This can also be due to the increase in water stress on the region with increase in population and urban growth followed by land reclamation in the desert fringes of the study area.
- d. Barren Lands: The most positive trend analysed by the study was the decrease in the area of barren lands by 63.52% (**Table 8, Figure 22**) which is mostly due to the various land reclamation projects that can be seen towards the south-west region on the study area. Most of the reclaimed areas might still needs further development for being suitable to cultivate.

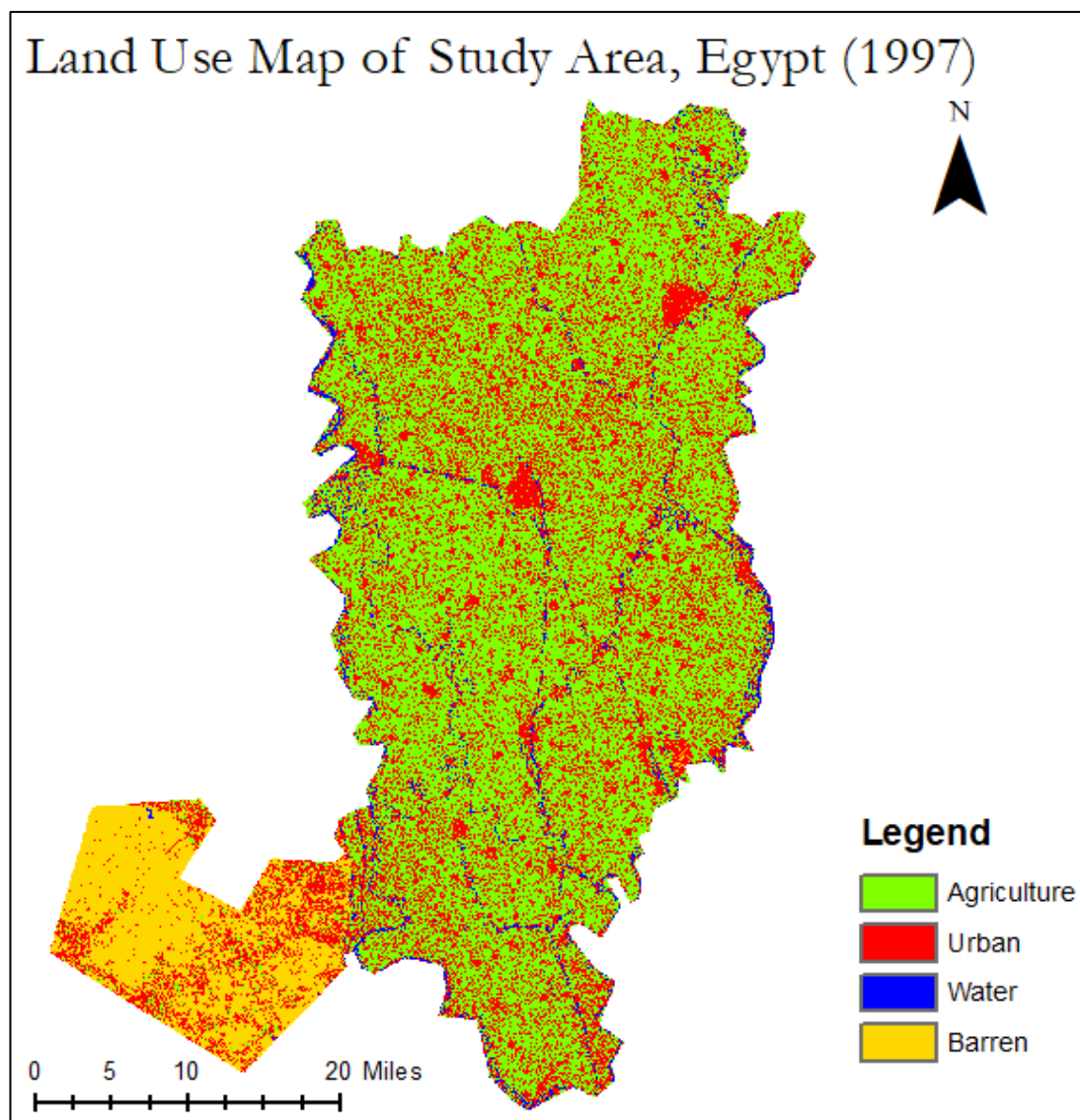


Figure 17 Land Use classification map of 1997 (Prepared by Author)

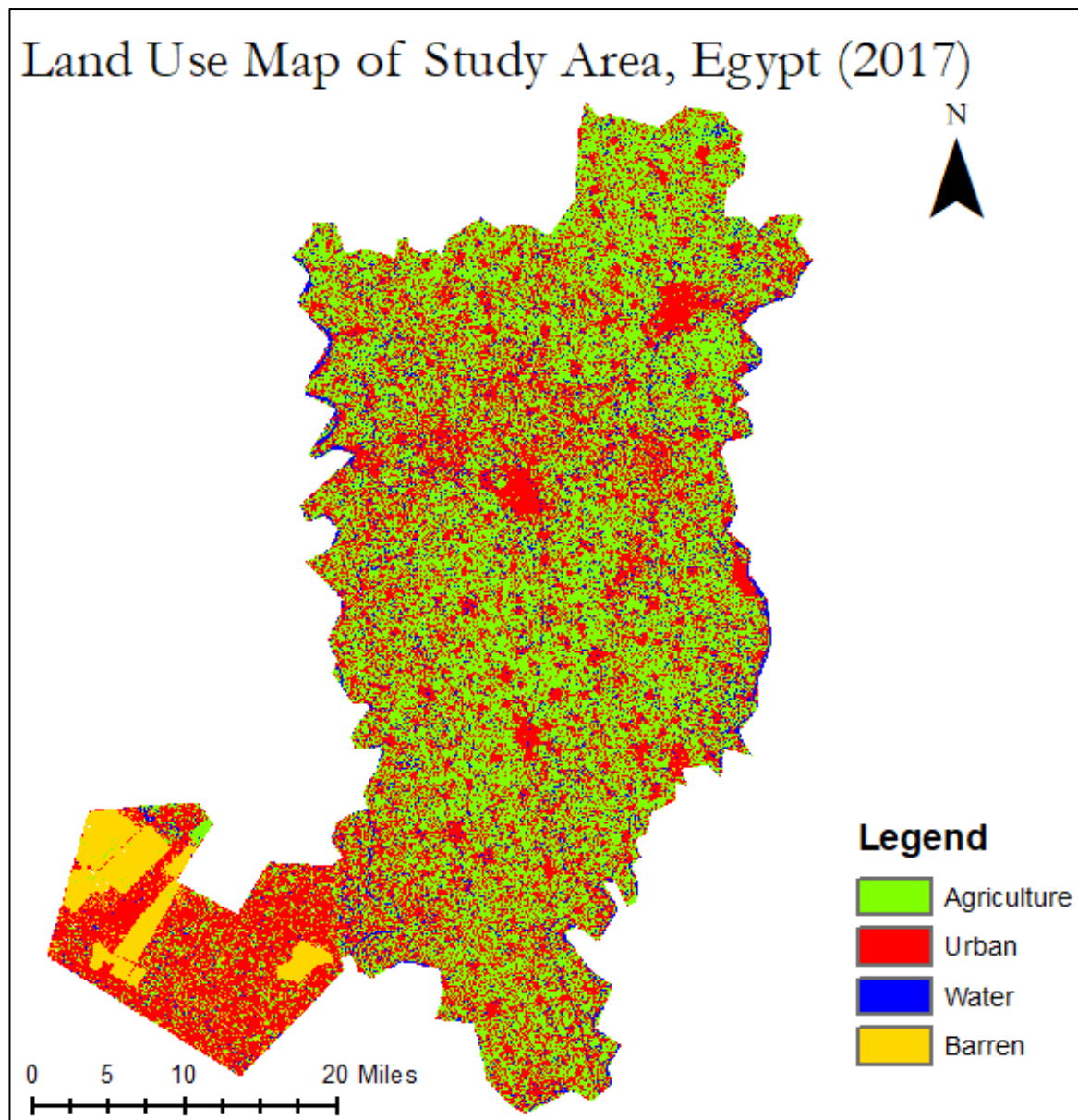


Figure 18 Land Use classification map of 2017 (Prepared by Author)

Observed land cover changes in the study region in area (sq.km) and percentage is shown in **Table 7** and **Figure 19** showcasing yearly averages of change of each class. **Figure 20** and **21** explains the proportion of each land class during the study period. **Table 8** along with **Figure 22** explains the change in the land use patterns of the study area in past 20 years from 1997-2017. The data obtained is explained using **Tables** and graphs for better interpretation of the results to the reader.

Table 7 LU/LC Statistics of the Study Area (Calculations by Author)

	Units	1997	2017
Agriculture	Area in sq.km	2071.15	2197.59
	% of Total Land	49.69206	52.73369
Urban	Area in sq.km	1192.56	1445.33
	% of Total Land	28.61249	34.68235
Water	Area in sq.km	514.47	382.232
	% of Total Land	12.34342	9.172095
Barren	Area in sq.km	389.79	142.184
	% of Total Land	9.352035	3.411868

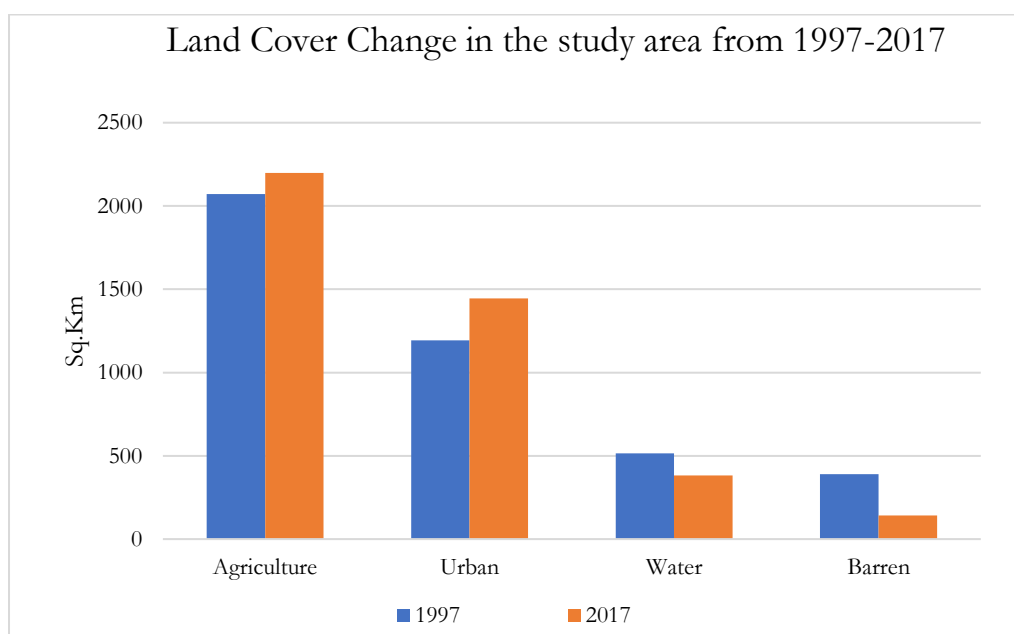


Figure 19 Land Cover Change in study area (1997-2017) (Calculations by Author)

Proportions of each class to the whole studied area in 1997

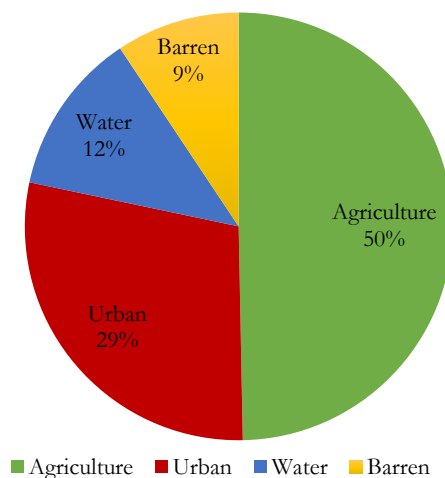


Figure 20 Proportion of each land class in 1997 based on LU Classification (Calculations by Author)

Proportions of each class to the whole studied area in 2017

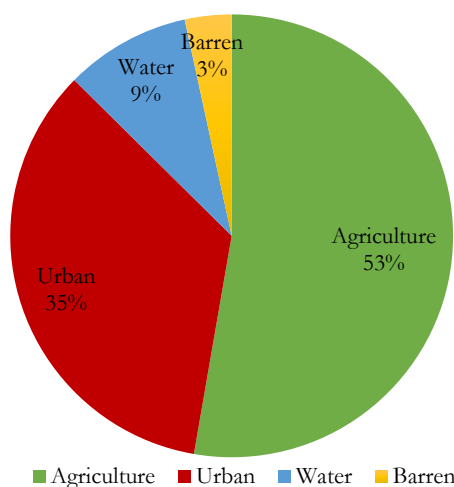


Figure 21 Proportion of each class in 2017 based on LU Classification (Calculations by Author)

Table 8 Changes in LU/LC of Study Area, 1997-2017 (Calculations by Author)

	Units	Change between (1997-2017)
Agriculture	Change in Sq.km	126.44

	% Change	6.10
Urban	Change in Sq.km	252.77
	% Change	21.19
Water	Change in Sq.km	-132.238
	% Change	-25.70
Barren	Change in Sq.km	-247.606
	% Change	-63.52

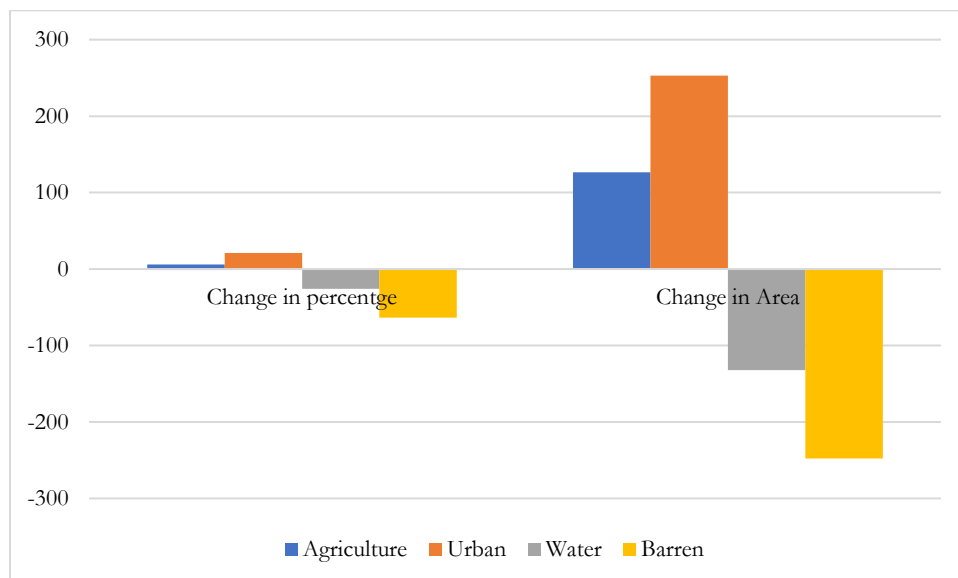


Figure 22 Change in Land Use Patterns (between 1997-2017) (Calculations by Author)

It was observed through the study of land use classification, that the pattern of urbanisation was seen over agricultural lands rather than the area of desert fringes in the southwest region of the study area. This is a vital point to note because the existing agricultural lands are a result of sediment deposition by the Nile river since ancient times which made the Nile Delta fertile in nature. Whereas, all the land reclamation is happening in desert fringes, which will require time to be develop fertile nature. Hence, losing the fertile land to urbanisation can be non-renewable in

nature which might affect the pattern of agricultural production due to decrease in fertile land cover.

5. Discussion

Literature review about urbanisation and its effects on Egyptian agricultural resulted in various topics which results in urbanisation and affects the food security of Egypt. However, since the topic of urbanisation is vast and inter-disciplinary in nature, the themes for discussion were narrowed down to the major factors of urbanisation affecting agriculture in Egypt, relating to RQ1 and RQ2 which will be discussed below.

5.1 Cause of urbanisation and its implication on Egypt's agriculture

Egypt's population growing at a rate of 2-3%, has resulted in becoming the most populous country in the MENA region. Egypt's population has grown by four times since 1952 from 21.2 million (Julia Zinkina et al. 2013) to 93 million in 2018 (CAPMAS 2018). Egypt's went through trends of modernisation due to diversification of the Egypt's economy through industrialisation in the 19th century (Julia Zinkina et al. 2013). Economic development and growth in population are natural contributors of urbanisation (A. A. Shalaby et al. 2012). For Egypt the beginning of industrialisation was cotton production, due to its important role in British Industrial revolution. Fertile Nile delta was suitable for cotton farming, making Egypt the supplier of cotton to British textile industry. This resulted in change in agriculture practices in Egypt from small scale farming to large scale farming, resulting in growth of capitalist system. This resulted in migrations of rural workforce to urban areas in large number during the 1970's (Bent 2015; CPAS 2018).

Egypt faces high population density owing to its unique geographic feature of Nile Delta which occupies just 4% of Egypt's total area, while accommodating 96% of its population. This results in a decreasing trend of land availability per capita, 0.029 ha/person in 2014, which is one of the lowest in the world. (World Bank 2015). Moreover, nearly 40% of Egypt's industries are located in the Nile. This creates a straining effect on the limited available resource land and water (Zaghloul et al. 2011).

Overpopulation followed by transition of national economy to industrial economy resulted in urbanisation and desertification. As a result, there is a decreasing trend in cultivated areas in the Middle Nile Delta region comprising a major agriculture zone of Egypt (**Figure**) (Zaghloul et al. 2011).

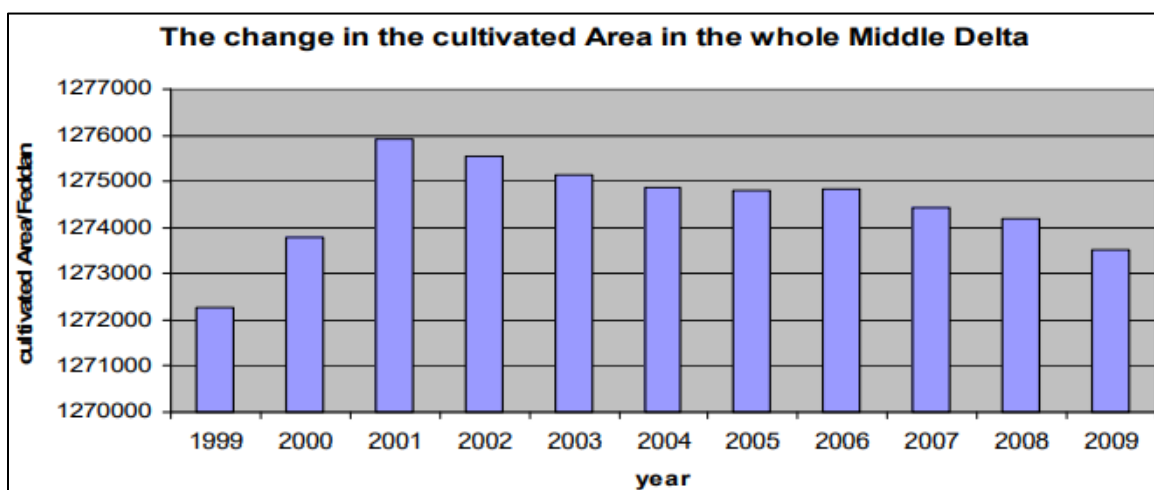


Figure 23 Decrease in cultivated area in Middle Nile Delta Region (Image Source - Zaghloul et al. 2011)

There is also an increase in informal urbanization which exceeds the reported area of loss of agricultural land which is further affected by rise in the sea-level, leading to a loss of nearly 10 percent of the fertile area in the valley and the Nile delta region (Redeker et al. 2014). It is estimated with present growth of population and urban expansion rates, by the year 2100, urban encroachment may result in land use change between 12,500 to 25,000 sq.km in the Nile Delta region (Redeker et al. 2014). Furthermore, if the urban growth follows the trend of urbanisation of last two decades, it is estimated that the entire fertile area of Nile delta will be lost in less than 120 years (Redeker et al. 2014). Also, as per the UN Convention to Combat Desertification, Egypt is suffering from high rates of desertification, losing 34 hectares of land on a daily basis, which is the highest in the world. The impact of urbanisation is estimated to be 5 times more than the impact of climate change on the Nile delta region. (Redeker et al. 2014).

Egyptian Government has tried to undertake various measures to combat this growing problem such as (building Law 119/08) under the General Organization of Physical Planning (GOPP) at

the Ministry of Housing and UN Habitat; the “desert green” project of land reclamation from desert areas since the late 1990’s (Werr 2015;Redeker et al. 2014). All such initiatives have failed to deliver on its objectives while costing huge amount of public money due to lack of institutional capacities and experts, reliable budget and weaker project planning and implementation strategies (Redeker et al. 2014). Experts consider desert land-reclamation as highly vulnerable process with deep environmental problems and high probability of failure (Attwa et al. 2017) followed by huge cost requirement.

A report by Cairoobserver, stated various loopholes in government policies resulting in disastrous output of urban encroachment in Nile Delta region. There are various factors leading to urban growth encroaching arable lands which are intertwined with each other. Lack of governance, followed by gap in implementation of national policies and housing policies, improper laws for land ownership and zoning are some of them. Raise of taxes on farming and lifting up of farmers subsidies followed by increase in policies to import wheat at nominal rates has resulted in degradation of the agricultural economy and production. Cost of modern farming equipment and supplies has increased also making it less accessible to the farmers (Cairoobserver 2015). As a consequence, there has been a decreasing trend of agricultural employment followed by lower contribution of agriculture to countries GDP (refer to figure 3 and 4).

Wheat import policies and dependence on imported wheat has also been considered as one of the biggest contributors to urban encroachment. Value of arable lands are hence, decreasing for carrying out agricultural activities, making farmers even poorer. However, these arable lands are far more valuable if converted to urban areas due to high demand of built-up areas, increasing its worth ten times more. This is mainly caused by increase in population leading to high demand of land for building habitation (Cairoobserver 2012).

6. Conclusion

The aim of this research work was to assess the growth of urban areas in middle Nile Delta region of Egypt and its potential impacts with the purpose to add to the knowledge gap about urban growth in this region of Nile Delta, due to lack of research literature and importance of this region to Egypt from agriculture perspective. To achieve the research objective of this thesis two research questions were developed **RQ1 - What is the rate of change of agricultural areas to urban settlements Gharbia and in Menoufia governorate of the middle Nile Delta region due to change of land-use patterns in last 20 years since 1997? RQ2 - What are the factors of urbanisation on the Nile Delta region and its effects on the agriculture system (food security) of Egypt?**

To address the first research question, a land use/land cover classification map was developed with the help of geospatial technologies for a period of 20 years from 1997 to 2017. From the study it was evident that there was a decrease in agricultural areas and surface water due to increasing urban areas in the study region. This established the impacts of urban encroachment in the study region.

To address the second research question, a comprehensive literature review was carried out to understand the major factors leading to encroachment of arable lands to be converted to urban areas in the Nile delta region. The major factors were discussed in chapter 5.

Egypt, located in the semi-arid region, depends on river Nile to fulfil all its needs. Moreover, 95% of the total population of Egypt resides in the Nile Delta and its valley making it the lifeline of Egypt. Human activities resulting in various impacts might affect Egypt's source of water posing as a huge risk for country's development. Based on the results from this research work following recommendation measures might help in tackling the growing problem.

1. There is a vital requirement to be less dependent on importing wheat and other cereals, rather being more self-sufficient. There are two advantages in following this recommendation – a) increase in the value of arable lands for carrying out agriculture with better economic outputs from the produce; b) Less vulnerability to the fluctuating global food prices and rate of currency exchange, resulting in minimisation of fiscal deficit as result of less dependency on food import and being more self-sufficient.
2. Need to design implementable and sustainable urban models based on population density for being able to accommodate maximum number of people in a lesser amount of land area catering the need of Egypt's high population density helping to save more arable land to feed the masses.
3. There is an urgent need to work for strong socioeconomic development, followed by education and capacity building. This will create expert human resources with better skills and expertise to tackle the ongoing problem of improper planning and implementation of project and policies along with climate change demands.
4. Practice of urban agriculture and rooftop farming adding to the urban greenery, followed by creation of jobs and increase in food production, leading to minimisation of intensive agriculture practices creating less pollution.

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GIS Software Used

ERDAS Imagine 2018 (trial version for 30 days)

ArcGIS 10.2

GIS Data Sources

The U.S. Geological Survey the Earth Explorer. <https://earthexplorer.usgs.gov/> Accessed March 05, 2018