CELLULAR AUTOMATA FOR POPULATION GROWTH PREDICTION: TRIPOLI-LIBYA CASE

by

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ABSTRACT

Due to obstruction in the national plan of urbanization in Tripoli (Libya) and population growth, serious problems have emerged in the form of random settlements, overcrowding and poor infrastructure. After more than two decades of inertia, the government has created a national plan in order to resolve the problems, hence it has enforced the demolition of some zones and modified other (irregularly built) ones, however the process is extremely costly. This research introduces a solution through cellular automata (CA) model to predict growth trends; size of residential, industrial and utilities areas; and to project future population. The model is implemented using digitized land use maps of Tripoli to indicate each areas as group of cells to predict their growth. The model incorporates two types of fuzzy rules bases, the first of which is based on the inputs population and area, and the second of which is based on the three inputs of population, area and density. The population prediction is performed using three scenarios, namely decreasing, fixed and increasing growth rates, such that all possibilities of growth are covered. In addition, the residential area prediction is performed based on two cases: normal density and low density. The former is introduced since new areas tend to have more open spaces and bigger houses. Furthermore, the model considers the growth of the industrial areas to be slower than that of residential areas. The model is developed and validated for the period of 1980 to 2010. The prediction is performed for thirty years from 2010 to 2040. In addition to the CA model, a regression model is developed and tested on the three growth scenarios for the same period (30 years). The prediction results are very close for 2040 in terms of population. The model incorporates the introduction of public services areas that are distributed equally on the growth areas, which occupy about 15-20% of the total area. This model can help the government to develop areas in a proper way and controls the expansion to have well layout and planned of the city, improving people’s standard of living sustainably, while protecting the environment with better planning.

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DECLARATION

I certify that the effort in this thesis has not previously been submitted for a degree nor has it been submitted as part of requirements for a degree. I also certify that the work in this thesis has been written by me. Any help that I have received in my research work and the preparation of the thesis itself has been duly acknowledged and referenced.

Signature of Student:

Adel Zidan

December 2014, London

CHAPTER 1: INTRODUCTION

1.1 Background

The world population has been increasing drastically since 1900, and particularly since the mid-twentieth century, making population growth (and the attendant pressures it places on limited resources) a critical issue for governments worldwide. Prior to the emergence of advanced human civilizations (10,000 BP), it is estimated that the human population did not exceed ten million (Population Bulletin, 1991), due to the tiny growth rate (which was nearly zero) attributable to the birth rate almost equalling the death rate. After the establishment of sedentary civilizations the death rate declined and the population began a relatively steady growth. It is estimated that by 1650 the world population was 500 million, and by 1800 it had reached one billion. More extensive documentary evidence exists from the nineteenth century onwards, making estimates more accurate; by 1930 the population was estimated to be two billion, and only thirty years later it was three billion, reaching four billion by 1975 and five billion by 1987. Clearly at current rates the global population growth is increasing exponentially, now easily increasing by over one billion in a decade (Population Bulletin, 1991).

Data concerning population, growth rate and city planning is essential in order to develop appropriate plans to accommodate this growth to obviate any uncontrolled growth, which has a negative impact on communities, especially in developing countries. Furthermore, while the most fundamental concern of such management is to enable life to continue, people increasingly have aspirational lifestyles (including increasingly in the developing world) that require ever increasing resources, and governments are expected to provide a civilized and modern life which includes infrastructure, housing and healthcare systems, while on the broader level it is increasingly acknowledged that the consumer ideal in its current form is unsustainable.

With regard to city planning, the main challenge faced by municipal authorities in many developing countries is random settlements. The most famous examples of such dwellings are the slums of Mumbai or Brazilian favelas, but in fact slum-level housing is not necessarily implied by unplanned and random settlements; people can build high-quality housing in an ad hoc (and unofficial or illegal manner) and whole communities can grow in this way, presenting the main problem for municipal authorities arising from population growth in the developing world. To solve these problems governments must have advanced spatial planning to meet popular demands for resources in an economically and environmentally sustainable way.

This research introduces a model that helps to predict the population and size of area required for these inhabitants, enabling the correct and optimal planning of the area in advance, which is the ideal way in which to plan and build modern cities, improving quality of life and protecting the environment as well as achieving sustainable development.

To understand the urban growth process, dynamic models of cellular automata are used to simulate this movement because of the advantages of this method, including transition rules, pixels, neighbourhood and states help to realization the process, predict the expansion in cities and draw shapes of cities beside satellite images to recognize changes over time (Al-Kheder et al, 2007).

There is combined model which includes cellular automata and fuzzy logic (FCM) used to simulate complicated dynamic systems which contain time and area, determining the situation of each cell by recognizing population growth model as a transition function which encompasses birth, death and emigration rates, ignoring the environmental diversity in each cell. This model shows better results than other two models of population, wherein emigration is neglected and the birth rate and death rate are fixed (Ramirez and Diaz, 2008).

1.2 Motivations

The main objective of this research is to develop a model that can support the process of urban planning by guiding the urban growth towards formal urban development and all benefits behind that such as helping governments to save money and time, protecting the environment and contributing to implement decision by using advanced techniques, as well as enabling governments to set short- and long-term plans. Controlling the growth and directing it in the appropriate direction at the right time, preventing any random building and promoting a fair distribution of services to the population, all contributes to improving everyone's quality of life.

Knowing the likely size and nature of growth in the future, governments can estimate the required budget for each project and modify projects depending on budgets available in a space of time, in addition to achieving projects' completion in order of priority (e.g. an acute housing crisis is prioritised over a long-term industrial development plan). This model enables governments to choose between alternative projects in the case that one of them fails to pass environmental impact assessment (EIA).

1.3 Aim and Objectives

The aim of this research is to develop a system which can predict future population growth with regard to residential and industrial areas. The objectives that follow from this aim are:

1. Several software, programming and theories involved in constructing the model, such as Matlab, image processing and Cellular Automata (CA).
2. Collecting the necessary data for this research, including land use maps of Tripoli city, its population, size of area, and the growth rate for different years.
3. Dealing with the maps by reading, resizing and digitizing them using the appropriate programs for that.
4. Designing an initial model to have a basic conceptualisation of how it works; in this model, only residential areas could be considered.
5. Developing the initial model by allowing the industrial areas to expand if it met the conditions for that and adding fuzzy logic file to improve the prediction made in three scenarios (prediction with declining growth rate, prediction with fixed growth rate and prediction with increasing growth rate), also made in two phases: one considering the predicted residential area having the same population density, and the other considering a different population density. The predictions were made for thirty years (2010-2040).
6. Testing the model by applying it on an old map for same thirty-year period (1980-2010) and comparing the gained results from the model with the real data in 2010.

7. Using a well-known equation to prediction the future population by calculation, as well as applying it in three scenarios (This equation is the main method for population prediction).
8. Comparing results from the model with the calculation for the three scenarios and both phases.

1.4 Scope of Study

The main study area is Tripoli, the capital of city of Libya, located in north-western Libya on the Mediterranean shore. It had a population of about 1,600,000 people in 2010 and an area of about 800 km^2.

Tripoli is a major economic centre with many government offices, and an important industrial zone in the production of oil (Libya wasproducing3 million barrels a day in the 1970s, although the industry and country have progressed erratically over the decades due to the international political situation). Increasing oil prices and the locus of national political and economic activity in Tripoli made it the destination for internal migration and immigration into Libya; the former is more significant, and almost the whole population of the Tripolitania region is now concentrated in the city, contributing significantly to the increased congestion and rapid population expansion, most of which is beyond the control of the competent authorities due to the problems of Tripoli such as crowding, traffic jams, slow movement and many environmental issues.

1.5 Challenges

The challenges are divided into personal and technical. The personal challenges are related to my background, particularly my initial lack of experience in software and design. I considered myself to be an ordinary computer user but after extensive research (including reviewing many papers and attending some training courses) and application of software design and application while conducting this study I came to understand the field.

The technical challenges regarding the poverty of existing data, and the difficulties of accessing it under the previous Libyan regime, caused me to face significant problems in getting maps and data about Tripoli to produce the model. I was able to ascertain from the documentary record that the regime was essentially careless about the national plans and it covertly tolerated the random sprawl, despite the ample availability of spacious land for proper urban planning. Only 12% of the area of Libya is populated and the gross domestic product (GDP) is 75 billion USD annually. Given that the population of Libya is smaller than six million and the country has very low population density, and that the nation has abundant financial resources relative to its population, it is astonishing that a complete lack of urban planning is manifest in the country.

Another difficulty or challenge faced me while collecting data was the amorphous nature of Tripoli's municipal boundaries due to the erratic and capricious diktats of the former regime; the eastern and western areas of Tripoli in particular frequently alternated between being part of the main municipality of being considered rural administrative zones. The constant fluctuation in what constitutes 'Tripoli' (as conceptualised for official purposes) renders it highly complex to analyse the city longitudinally in terms of population, land size and density over time.

1.5 Original Contributions to Knowledge

This research contributes to knowledge by introducing a model that predicts the expansion trends of cities and the size of this expansion in residential and industrial areas and population accurately, which can be used as a basis for national plans and improving cities.

This research has undergone several stages to achieve maximum effectiveness. At first the land use map of Tripoli was read, resized and changed to greyscale to ease its processing using Matlab, then image processing was applied to change the image to numbers, then was taken to Excel where divided into matrices each one has hundred column and hundred row after that changing the numbers in each pixel which are indicating degree of colour to numbers indicating the different sectors on the map (e.g. residential, industrial and military use), then the map was transcribed to Matlab and stacked together for the application of cellular automata (CA) model, which allows the expansion of residential and industrial areas to be charted based on certain parameters and the behaviour of neighbouring cells. Important factors that will control and direct the growth were taken into account when the model was being designed, such as natural constraints (e.g. sea, rivers and terrain) and administrative policies (e.g. protected areas, pubic parks and recreational facilities), as well as the population growth rate.

In order to obtain better results fuzzy logic files were added to the model, one of which has the two inputs of population and area, with the output of expansion; and the second of which has the three inputs of population, area and density, with the output of expansion. The first fuzzy file is used in stage one of the model, when the density is the same in the new residential areas predicted, and the second fuzzy file is used when there is different density in the new residential area predicted.

The model's prediction of residential and industrial areas' size and population is calculated by multiplying the density with the predicted residential area. The model runs in three cases (decreasing, constant and increasing growth rate) and two phases (same population density and different population density). The prediction period used in this study is thirty years, but this could be longer or shorter depending on user requirements.

The public services sector (i.e. schools, hospitals, military bases, and commercial and sports areas) will be added to the final map of 2040, and these areas will occupy rough 20% of the total city area, as in 2010. To evaluate the model the validation model is made of exact parameters and conditions for a period of thirty years. Also, from 1980 to 2010 the results were excellent in terms of population and residential and industrial areas' size.

1.6 Thesis Layout

Chapter one in this thesis talks about the research briefly, the main idea of the research and the justification of the aim and objectives. The research strategy to achieve the results as well as the challenges faced and problems solved by the research have been outlined with regard to the study context and existing literature.

Chapter two illustrates some previous studies in the same field of this research which have been reviewed to understand theories and use them effectively to produce results with high accuracy and other useful information including population growth, urban planning and using cellular automata in prediction growth to get a clear idea about the research.

Chapter three presents the contextual information about Libya in general and Tripoli in particular, with reference to its population growth and needs and historical factors. Tripoli is described in terms of its location, size and population Tripoli along with the history of urban planning in the city.

Chapter four is the theories and tools used to achieve this research and information about these tools, which are cellular automata, image processing and fuzzy logic, as well as the rules and the use of cellular automata, to give an idea about the research how it works because the research initially uses cellular automata model to predict residential, industrial areas and population in future.

Chapter five shows the initial cellular automata model and the validation model designed to test the model. It was primarily designed to test a period of thirty years. The results were encouraging, and this chapter also presents the equation used to predict the population and its results to compare between the model results and calculation results.

Chapter six presents the main model used for prediction and the gained results and figures show the growth in terms of residential and industrial areas and the size of the population for the three scenarios, namely decreasing growth rate, constant growth rate and increasing growth rate. The model is also used for two phases: the prediction of residential area having the same density and with different density for the new predicted residential area.

Chapter seven is the final chapter which illustrates the stages that the research has undergone and outlines the improvements made in accuracy. It gives suggestions for future improvements to the model, including factors pertaining to a wider range of sectors such as planning, economy, policy, social as well as the population growth. The structure of the thesis is presented in Figure 1.1.

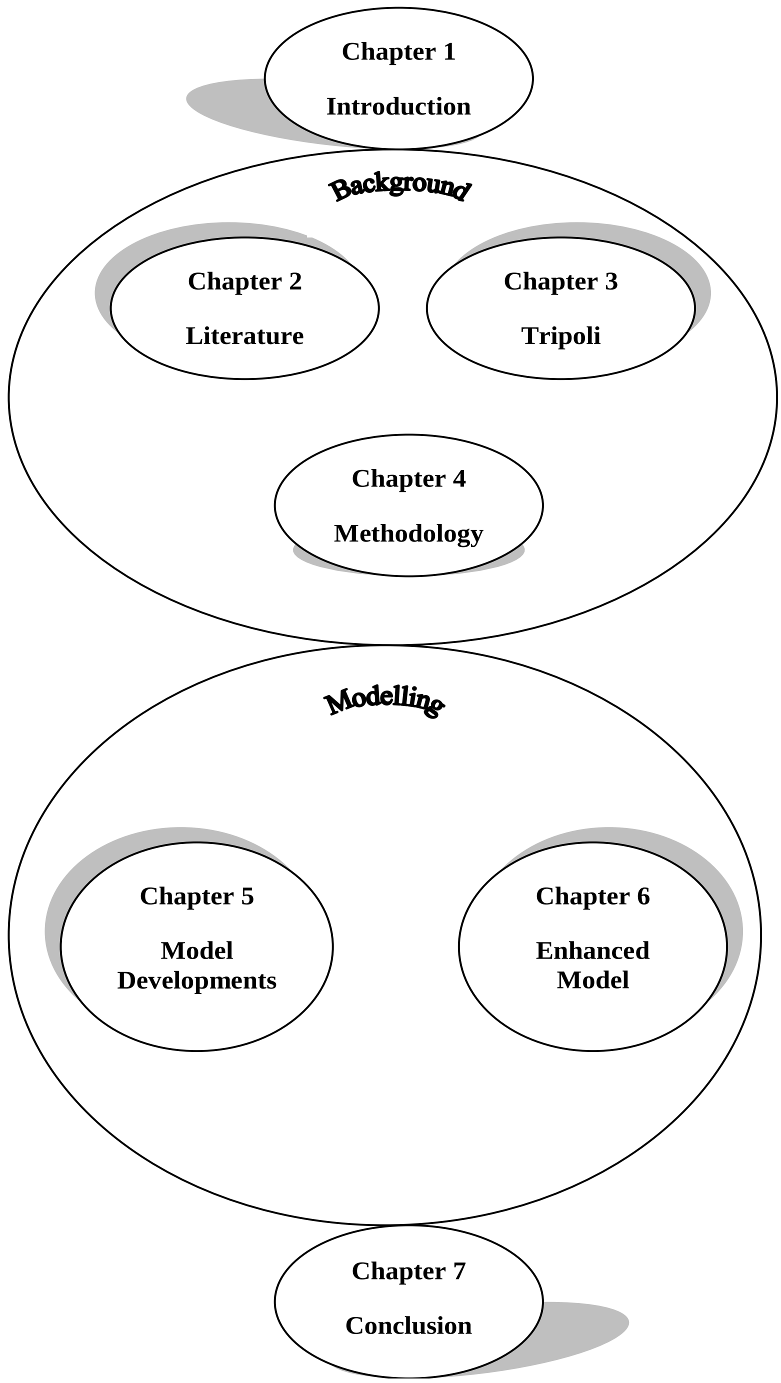

Figure 1.1: Thesis structure

1.7 Author's Publications

Several papers related to this research have been published and presented at international and internal conferences:

1. Zidan, A. and Abbod, M. (2012), Geographical Information Systems Data Modeling for Urban Planning. RESCON 2012, Brunel University, June 2012.
2. Zidan, A. and Abbod, M. (2013), Geographical Information Systems Data Modelling for Urban Planning. RESCON 2013, Brunel University, June 2013.
3. Zidan, A. and Abbod, M. (2014), A Cellular Automata Model to Predict the Growth Trends in Tripoli-Libya. Published on GSCIT 2014, Sousse, Tunisia, June 2014.

CHAPTER 2: LITERATURE REVIEW

2.1. Introduction

Rural-urban immigration is mainly caused by spontaneous pressures such as increasing national population, greater employment opportunities in cities, and improved access to healthcare and education amenities in cities. Often this is exacerbated by failures of government distribution of such facilities. The growth of urban populations in relative and absolute terms has both positive and negative implications, the former can be alleviated or prevented (respectively) by appropriate planning. Both the advantages and disadvantages are multiple and depend on many contextual factors. For example, advantages can include easier and more cost-effective service provision by governments to citizens and concentration of the workforce (and thus reduced infrastructural investment), which attracts direct foreign investment; conversely, urban population concentration exacerbates pressure of amenities and infrastructural facilities, and has potentially adverse economic impacts such as increasing the price of land, housing and goods, along with environmental degradation. Over recent years, various attempts have been made to achieve sustainable development and solve people's problems regarding housing and public services while protecting the environment and preserving natural resources, as explored in this chapter.

2.2. Population

One of the most pressing global problems is vast and increasing population growth, especially in the developing countries, along with the spread of aspirational lifestyles. In 2009 the world population numbered approximately 7.1 billion, of whom 50%lived in urban areas (United Nations Department of Economic and Social Affairs [UNDESA], 2009). This creates huge negative impacts on the environment, natural rescores and the global climate due to growth sprawl and increasing use of natural rescores and production of pollution (air, water, terrestrial, noise and visual) already being expressed in increasing species extinction.

Governments and international organisations are seeking methods to deal with these dilemmas and balancing between population increase and conservation of natural resources while trying to minimise the destruction, at the same time attempting to find solutions that can enable governments to predict and manage growth. As part of such efforts many programmes and software have been used effectively. In recent decades cellular automata were widely used and deemed to be successful models to preserve the environment while enhancing people's lives.

2.3 Population Growth

In these paragraphs discussion about the issue of population growth with examples from different places of the world to illustrate that the issue became worldwide problem.

By the beginning of the 20th century, the population of Colombia was about 4 million inhabitants. By the 50 it had already reached 12 million, and about 40 million by 1990. The global population growth rate during the 20th century has been an estimated 2% annually during the 1940s, peaking at 3.4% in 1950, then slowly declining to 2% by the mid-1970s and stabilizing at the end of 1990 at 1.6% annually(Mason et al, 2002). A study by the US Forest Service estimates that 10% of the forests in the south of the country could disappear within 50 years due to urbanization. The population growth in 13 southern states from Texas to Virginia may cause the loss of 23 million of 200 million acres of forests in the south (80 million hectares).Because the majority (90%) of forests are privately owned in the southern US (usually by corporations), it is impossible for the US political system to prevent deforestation and the consequent ecological disaster due to its avowal of unfettered corporatism (Mason et al, 2002).

As well as a major general increase in population, significant changes in the distribution of population have occurred. In the nineteenth century the population of the Russian Empire increased by 3.5 times, but regionally the population of New Russia increased 8.5 times, the Urals 4.5 times, Siberia 6.5 times and the area of the Don Cossacks 15.5 times. The degree of urbanization in different across regions varies considerably, with particular concentration in the two metropolitan provinces of St. Petersburg and Moscow, where the townspeople comprised three-quarters of the population (Feshbach, 2002).

Canada has a population of 33.3 million people, which gives it a very low population density of approximately 3 pop/km². However, the population is very unevenly distributed. Most of the country has population densities of around 1 pop/km². The northern half is largely uninhabited. Huge territories, including Newfoundland, Prince Edward Island, Yukon and the north accumulate over 3% of the total population. Conversely, there are two foci of densely populated population: the Great Lakes and the surroundings of Vancouver. The provinces of Alberta, and Manitoba Saskatchewan in the centre of the country contain over 6% of the population. A similar build-up exists for the Atlantic provinces of Nova Scotia and New Brunswick. The Canadian population has very small growth (about 0.8% per annum), despite a migration balance of 5%. The population is moderately aged; about 16% of the population is under 15 years old, 69% are between 15 and 65, and 16% are over 65 (Hathout, 2002).

New York City became a major global metropolis and the gateway of immigration to the US during the nineteenth century. Successive mass immigrations (mainly from Europe) have made it a densely populated city with an increasingly antiquated infrastructure and rising costs of living, yet people continue to flock to the City. For the year ending July 1, 2013, an incursion of outsiders combined with continuing decline in the loss of emigrants to other states caused the population of the City of New York to increase by over 61,000, topping the eight million mark for the first time (Robertsmarch, 2014). The environmental impact of population growth in California, which is one of the most populous states in the US, include adverse impacts on air quality. According to the Office of Statistics, the population of California recorded at the end of 2013 was 37,253,956 (Cramer, 2000).

Mega cities are more typical in the developing world, particularly Asia. This can clearly be exhibited in Pakistan, where there has been a manifest overcrowding problem in Karachi since the Partition of India in 1947. According to the census of 1998, the total population was nearly 9 million, but in 2010 it had increased to 13 million. Poverty is the main driver of this urban growth, whereby impoverished rural residents flock to the city and large families are the norm as a security for old age. The World Health Organization has cautioned that if birth rate does not stabilise in Karachi within the next ten years, the city will become the most populated city in the world, based on linear regression model, with anticipated exacerbation of unemployment, health, housing and terrorism problems (Abbas and Muhammad, 2010).

More than half of the world's population live in urban areas, and by 2000 approximately 2.9 billion people were living in urban areas. The UN estimates that 4.9 billion will be living in cities by 2030, with the most dramatic growth (60%) expected in Asian cities, those in China, India, Pakistan, Vietnam and Bangladesh (McGee, 2001). This creates challenges for maintaining quality environment and sustainable development all over the world. Using optimal polynomial functions to fit historical trajectories regarding population dynamics, comprehensive forecasts of population growth between 2010 and 2030 have been carried out and investigated. If population increases according to past patterns, by 2030 the world total population reach 7.94 to 8.33 billion; the annual growth will decline in the forecast period. Global total population will not further increase during the period 2050-2060 and will not cross a limit of 9.5 billion in the future (Zhang, 2010).

Using a monocentric city model, growth control is shown to have a negative effect on population growth. The model suggests that adequate policies of birth control are dependent on the policies of neighbouring counties. Spatial analysis has been used to explore the relationship between population growth and unemployment (Li, 2006). Agglomeration economies are significant in relation to the degree of congestion as a result of population density. The increasing population in the cities of the US has given rise to unemployment.

Although China has controlled its population growth, it remains the most populated country in the world and is facing problems of unemployment, illiteracy and health discrepancies. These problems are also caused due to high rate of shifts from rural to urban areas in search of better living and educational opportunities, explaining a new concept of demographic dividend that talks about rise in the state of economic growth and its relation with the rising share of working age people while holding the concept of population neutralism. Planned birth policy results in a decreasing fertility rate which has caused a tremendous slow down in the increase in population, converting the immediate problem of population growth to a future problem of population ageing (Zhang, 2008).

2.4 Urban Planning

Urban planning in general refers to the efficient use of land and transport planning, in an effort to make places of human settlement more habitable and efficient in relation to their environment. The discipline explores a very wide range of aspects of the built and social environments of urbanized municipalities and communities, illustrating the significance of health policies in relation to the urban planning in the recent decades.

The relationship between urban planning design and health equity is more important in the cities with low socio-economic status. There are a wide range of planning and design processes that include landscape architecture, infrastructure, urban planning and transport planning. The resultant environment after all these reforms has vital role in the provision of health services. Urban planning and design processes affect health equity by shaping physical urban environments; this can further facilitate the availability of sufficient housing and basic communications, access to the other benefits of urban life on the basis of equality, quality living standards, and an urban environment that promote outdoor physical activity (Smit et al, 2011).

One aspect of urban planning that is likely to be a key global concern in the future years is solid waste management. Scientists and environmental activists are of the view that the scale of human activities due to urbanization in the African cities is leading to negative health and environmental impacts. Due to poor governance factors (e.g. corruption) that are rife throughout Africa, urban planning initiatives have generally failed throughout the continent, despite the noteworthy spiritual, economic and cultural value placed on the development of Africa by the international community (Demanya, 2007; Rydin et al, 2012).

Despite being one of the richest cities in the world in the richest nation, New York City continues to have numerous problems due to urbanization and urban planning solutions to resolve the problems of housing, health provision, and improvement in public transport have met with limited success, despite the city being a pioneer of such disciplines since the nineteenth century. There continues to be socioeconomic inequality related to urban planning, and poverty and the poor health outcomes are strongly associated with ethnic minorities; criminal activities, urbanization, and use of drugs all associated with minority groups, partly due to immigrant issues and also due to the lack of appropriate planning and provision for such groups (Friedan, 2001). However, the problems of Western cities are essentially the problems of over-burdening inherently developed systems; in developing countries the situation is complicated by the fact that no such pre-existing systems are in place. Cities in South America and South Asia for example, while they may have a historic core, actually represent slum dwellings sprawling over vast areas rather than cities in the traditional sense. Due to the acute problem of population growth and urban expansion in India, family planning strategies are aggressively pursued as a damage limitation measure. The rate of population growth in slum areas is higher than in cities due to lower education and access to necessary family planning services (Speizer et al, 2012).

The efforts made within the last few years towards spatial planning in the UK area part of sustainable development in cities, such as urban housing schemes, traffic management and the improvement of health services. It must be noted here that due to the net increase in the overall population of the UK, a shortage of public transport has been observed within cities and intercity travel is relatively long and overcrowded. Because of unemployment and inflation, personal vehicles are not affordable to every individual. For this reason, the government is planning to improve the system of public transport; more roads are being constructed along with underpasses. In addition, global climatic changes have affected the quality of air in the UK; smog in the area is a big problem caused by pollution due to toxic waste (Fischer, 2007).

Developing countries such as Pakistan are facing grave problems of over-population, unemployment, and inflation. In these chaotic situations, the international institutions like the IMF, the WHO and the World Bank issue developmental loans for the improvement of living conditions, but corruption and the crippling cost of financing causes the price of services to escalate beyond the reach of the common man. Furthermore, urban planning has been found to be particularly susceptible to corruption in developing countries, especially in the construction industry (Hasan, 2011).

During the twentieth century there were many urban models in use, but recent economic and political models underlining new urban places have outgrown them. A powerful tool for promoting change is visualization and conceptualization, to bring not only incremental improvement but also to combine existing infrastructure with the new one (Lopes and Lindström, 2012).

2.5 Using Cellular Automata to Predict Growth

A cellular automata (CA) model was designed for urban growth to simulate the process of urbanization in a hypothetical region. This model consists of a set of rules that describe the spatial interaction of cells and a set of parameters that lead to explore different urban forms. Furthermore, different results of the model can be evaluated throughout fractal analysis and the estimation of the fractal dimension. A significant connection is noticed between the parameters of the model and the value of the fractal dimension, and some important factors were used into the model to make it applicable in the examination of real urban patterns: landscape constraints, transportation network, protected areas and physical geography (Apostolos, 2010).

Cities are recognized as complex systems; a fuzzy cellular automata urban growth model can be helpful to handle these complexities (Al-Ahmadia et al, 2008). Dynamic urban expansion models are useful tools to understand the urbanization process and there are several socio-economic indicators which affect the urban expansion (Wuet al, 2010). A CA model of land cover change is great method to provide protection of environmentally sensitive areas and urban growth projections (Mitsova, and Wang, 2011).Population growth is one of the most important engines of change in any urban system and determines the shape of the cities in future for that this factor must be the initial part of any model (Mavroudi, 2007).

A number of factors contribute to the challenges of spatial planning and urban policy in mega-cities, including rapid population shifts, less organized urban areas, and a lack of data with which to monitor urban growth and land use change. To support sustainable development in cities, CA model is used to predict how growth trend will continue in the future (Shafizadeh, Moghadam and Helbich, 2013). The benefits of using CA models is that they not only offer an understanding of the urban growth development, but also give realizations of many potential growth scenarios to which urban regions could be subjected in the future. The traditional concentric zone model was based on the concept that the growth of a city radiates from a central core to form a series of concentric zones of a range of land uses. According to this (sector) theory, patterns of urban land use were affected by the road networks leading out from the city centre. However, both the concentric zone theory and sector theory assumed that the city grew around only one nucleus, whereas the multiple-nuclei theory suggested that urban growth in big cities took place around multiple nuclei. The combination of GIS and CA is the method to achieve better action on the process and form of urban dynamics simulation and modelling rather than traditional models (Maithani, 2010).

Two satellite images of Tehran, the capital city of Iran, for two different years were used as the initial data layers to study the changes in urban patterns of this city. Using CA setting the logistic regression functions as transition functions important factors affecting the urban growth were selected (i.e. distance from rural centres, distance from agricultural centres, distance from urban centres and neighbourhood effects). up to 75% accuracy of urban growth patterns can be predicted by using combination of optimization techniques with CA model (Khalilnia, Ghaemirad and Abbaspour, 2013).

To simulate the urban growth over the last three decades for Indianapolis city, urban growth simulation for an artificial city was done, with urban sprawl determinants such as the size and shape of neighbourhood besides examine different types of constraints on urban growth simulation being assessed. The results showed that circular neighbourhoods have easier but faster urban growth compared to nine-cell neighbourhoods. The definition of CA rules is a critical phase in simulating the urban growth pattern in close behaviour to existing growth, including running the developed CA simulation over a classified remote sensor historical image in a developed GIS tool. A set of crisp rules were defined and calibrated based on real urban growth pattern. The percentage of accuracy was excellent, reaching an average accuracy of more than 80%, although the need to amend CA growth rules over time was stated, to go with the growth pattern changes to achieve accurate simulation (Alkheder and Shan, 2005).

Combining CA with system dynamic and applying it for Beijing after testing the model for period from 1991 to 2004 enabled prediction of the city expansion to 2020 (Heet et al, 2006). Using cellular automata to simplify the complicated process of urban planning system is far better than traditional modelling methods; (Ghafari, Saadatian and Salleh, 2012). Nairobi is projected to cover all the area around the city, with the loss of vital resource land (Mundia and Aniya, 2007). Old maps and two satellite images for Jiangning were used to trace the changes in the city, including the loss of agricultural land, then CA was implemented to predict the change in future (Chang-Qing, 2006). CA is the best way to address cities' sophisticated growth procedure, the CA has simple roles to ease the complex and give prediction close to actual cities. Coupling GIS tool and remote sensing data with CA to get cities' true simulation of the future urban expansion (Ai-Ageili, Mouhoub and Piwowar, 2013).

In France, the management of urban growth depends upon the housing policies that are designed by municipalities by the department of region or the state. Like many parts of the world, sustainable development in urban areas is crucial. In order to manage these problems, the urban planners use varieties of tools as conceptual models, computer aided drafting and geographic information system. As these are traditional tools and have lost their efficiency, new strategies have been developed by researchers. CA describes heterogeneity of the produced results and envisages an interesting debate regarding growth management and territorial intelligence (Phillipe et al, 2012). CA model was used to predict growth in urban areas in a project estimating regional effects of urbanization on San Francisco Bay. The specifications of the model involve a wide range of data sources, such as road networks, and topography. In addition, self-modification was allowed in the control parameters of the model, whereby the CA acclimatises itself to all the generated conditions, especially during stagnation and rapid growth. The model was designed for accumulation of probabilistic estimates that are based on Monte Carlo methods (Clarke and Hoppen, 2012).

In Philippines, it is essential to monitor and forecast land use and change in order to design urban planning, resource allocation, agricultural mapping, and conservation. Studies about land change provide insights for comprehensive policy making and guiding governments and private institutions. Presenting a model of CA with two dimensions using Markov chains for numerical stimulation of land change in Camiguin (an island in the Philippines) comprising fifty years revealed that wooded areas are at risk of disappearing (Beltran and David, 2010).

2.6 Summary

There is no doubt that more advanced technology increases accuracy of results in any fields. Authorities must focus and spend more on research to improve programmes and models and make them touch the reality because that will help to solve problems and potential to work in advance by predicting population growth and the size of land they need then possibility to guide the growth to the right place and achieve the fundamental goals of providing quality of life and protecting the environment. One of the most important criteria that measure the development level of countries is Planning Systems. Planning approaches are different from one country to another because there are several factors that affecting the planning system, including social, economic, cultural and topography factors. The most successful planning systems are those that meet the wishes of the people and contribute to facilitate ways of life and keep up with population growth.

CHAPTER 3: TRIPOLI CITY

3.1. Introduction

Libya has undergone many natural and human disasters over the last century, causing the death, mass internment and migration of the population (e.g. colonisation, wars, drought and desertification), all of which inhibit population growth. This chapter presents a summary of the most important stages of the history of Libya in terms of the population and population growth rate, and the city of Tripoli in terms of urban planning.

3.2. Libya

Libya is a North African country of the Southern Mediterranean. It is bordered by Egypt on the east, Sudan on the south-east, Chad and Niger on the south, Algeria on the west, and Tunisia on the north-west. Libya extends over an area of 1,759,540 km^2, making it the 17^{th} largest country in the world in terms of area (Figure 3.1).

The Libyan coast is the longest of any African country on the Mediterranean shore, with a length of 1,770 kilometres. It has a Mediterranean climate, with moderate spring and autumn, hot and dry summers and relatively cold winters, with semi-desert in the northeast, arid desert in the south, and a temperate mountainous region (Green Mountain) where summer temperatures do not exceed 30°C (Urban Planning Agency, 2007).

The area of modern Libya was inhabited by an indigenous Libo tribe for thousands of years and later by Berbers, but its documented history stems from the Mediterranean civilizations. Minoan colonists from Cretein the eighth century BCE established five Greek cities (Abanntaboles) in Cyrenaica (Seranaike), which were the most prosperous cities in Africa in that era, but prior to the Roman conquest the region was dominated by the Carthaginian civilization, which arose from Phoenician settlers. Following the collapse of the Roman Empire, the Vandals occupied Libya in the fifth century CE, before the resumption of Roman rule under the Byzantines in the sixth century prior to the Arab-Islamic incursion. Numerous quasi-independent

Muslim dynasties followed, the most important of which were the Aghlabids, the Fatamids and their Amazigh (Berber) vassas the Ziriun.

Figure 3.1: Map of Libya

From 1551 Libya was under the authority of successive Ottoman regimes. From 1551 to 1711 it was under the First Covenant. In 1711, Ahmed Al-Qura Manley led a popular revolution to overthrow the Ottoman prefecture, founding the Qara dynasty, which ruled autonomously (while acknowledging the nominal authority of the Ottomans) until 1835. Yusuf Pasha is considered the most significant ruler of this family. An ambitious ruler, he emphasized the sovereignty of Libya's territorial waters, and he levied tax on the waters of the Mediterranean from all nations, including Britain, France Italy and the US. Libya's strong naval fleet and the role of Tripoli as an international terminus of trade made it relatively prestigious among the North African polities. Due to Ottoman reforms and centralization from 1835 to 1911the province came under more direct control from the Sublime Porte, and this witnessed some infrastructural development. In 1911the Italians invaded Libya and subjugated the native population. After WWII a provisional administration under British control led to the establishment of the United Kingdom of Libya in 1951, a federal system of hereditary constitutional monarchy under the rule of King Idris.

The discovery of significant oil reserves in 1959 immediately transformed Libya from one of the poorest countries in the world to one of the wealthiest.

Libya's main natural resources are petroleum, natural gas and gypsum. The main source of national income is oil and gas exports. The oil reserves in Libya comprise about 41.5 billion barrels, making it the leading African country in terms of oil. Oil accounts for about 94% of the proceeds from Libya of foreign exchange and 60% of government revenue, comprising 30% of GDP. Libya produced 1.6 million barrels of oil per day in 2010. The most important industries are the production of iron and steel, cement and building materials, caustic soda, urea fertilizer and other petrochemical industries. The most important agricultural products are barley, wheat, tomatoes, potatoes, olives, vegetables, fruits and meat. The Libyan government subsidises the prices of basic food commodities, fuel and electricity, and education and health services are provided for free (Ali, 1998).

Arabic is the official language spoken by the vast majority of the population. English is used as the medium of instruction in Colleges of Applied Sciences, and it is widely used in the business sector. Some minority languages are spoken in provincial villages. The majority of the population is Muslim (97%); 3% belong to other religions, most of whom are expatriates. The majority are Sunni Muslims following Maliki jurisprudence, with an Ibadi minority mainly located in the Nafusa Mountains (Urban Planning Agency, 2007).

3.3. Population Growth in Libya

Libya is a country with a vast area and a small population, but most of the population density is around the coastal areas: approximately 90% of the population live in only 10% of the country, with about 88% in the major cities of Tripoli and Benghazi alone. Thus, population density in these cities is high, while it is very low in other areas. The total population of Libya is about 6.5 million (2012), of whom 27.7% are under the age of 15 (World Bank, 2012).

Population growth in Libya has witnessed instability through the stages of development of the state, with upward and downward trends. Although statistical analysis of data for the rate of population growth during the period 1954 to 1984 shows tremendous population growth, this unexpectedly tailed off after 1984 (Table 3.1). The average annual population growth rate in Libya from 1954 to 2006 shows in Table 3.2.

Table 3.1: Libyan population, 1954-2006

Year	Population
1954	1,089,000
1964	1,564,000
1973	2,249,000
1984	3,643,000
1995	4,405,000
2006	5,658,000

Table 3.2: Libyan population growth rate, 1954-2006

Year	Average Annual Growth Rate
1954-1964	3.8%
1964-1973	3.4%
1973-1984	4.2%
1984-1995	2.9%
1995-2006	1.8%

There are no fixed international standards to determine the proportion of the natural growth of each country; population growth is related to available natural resources and other environmental considerations in addition to human development. Population policies developed by the relevant national authorities are based on existing information to attempt to control the growth process in line with overall development plans; thus it is fundamentally a question of balance, ensuring that the population is neither too large nor too low, to maintain sustainable socio-economic development relative to the human population in a geographical and state context (Alshrief, 2010).

3.4. Tripoli

Tripoli is the capital and largest city of Libya. Its population approximately two million, and the broader Tripolitania region in north-western Libya is relatively populous. It has always been a maritime city, being established by the Phoenicians in the seventh century BCE, becoming an important Mediterranean entrepôt and a nexus for the Sub-Saharan trade. Although the greatest cultural impacts on Tripoli in antiquity were from the Phoenicians and the Romans, its name derives from the Greeks, reflecting that it emerged from an amalgam of three smaller towns, and to this day it is distinguished by distinct areas (Figure 3.2). Since that time Tripoli has always been an urban and commercial centre linking Africa with the Mediterranean, making it a prize for successive invaders.

Figure 3.2: Map of Tripoli

3.5. Urban Planning in Tripoli

3.5.1. Second Ottoman Era (1835-1911)

Modern urban planning began in Tripoli during the second Ottoman era (1835-1911), reflecting the modernising reforms undertaken throughout the Ottoman provinces. These included the farmyard care system, the provision of water taps to the public, erecting a telegraph system among the major regions, some landscaping, and municipal reforms to improve urban planning and specialized construction operations, particularly to plan urban growth beyond the traditional medina walls (which included the abolition of the city gates in Tripoli in 1881).

The Ottoman administration also established several buildings belonging to facilities outside the city walls, such as hospitals, camps and public buildings (e.g. the School of Islamic Arts and Trades), as well as street lighting (Ali, 1998). This stage in the management of municipalities can be considered sophisticated, with the provision of services by basic urban planning carried out by the municipalities to organize and direct the development, with the issuance of building permits, and specifying any legislation dealing with various aspects of urban planning with assigning responsibility for construction.

3.5.2. Era of Italian Colonialism and the British Administration (1911-1952)

Urban planning was launched by the Italian colonial administration with a view to providing for an Italian colonist population, with no regard for the indigenous heritage (although the kitsch neoclassical architecture of the colonists could be linked to Libya’s past as a key Roman province, it was intended as a projection of European imperial power). The first activity of the Italians in regard to urban planning was to superficially map the ancient city of Tripoli in 1918, identifying two planning basis of the linear main streets and multi-storey buildings in central areas. This height was specified for the streets same as the main city of Rome in order to maintain the line of buildings roof, buildings in this street at the same level and not determined on the density or on the street width, yet practically to maintain the entry of light or sunlight. The buildings on the Avenue of Omar Mukhtar are a good model for this system. In other areas the height was restricted to only two floors. Furthermore, designated city parks were marked out.

One of the main applications of the new approaches to urban planning was the removal of the old city walls overlooking the harbour and the south-western coast. This was replaced by a fences to protect the city from the ring road surrounding the old city of Tripoli, as the railway extended to the port (Ali, 1998).

3.5.3. Era of the Kingdom of Libya (1952-1969)

With the booming Libyan economy due to the availability of huge reserves of gas and oil and high prices, Tripoli received a big movement in construction and infrastructure, developing a number of excellent facilities at the regional level, notably Tripoli International Fair, Tripoli International Airport and the Port of Tripoli, and a large road network was created, linking all parts of the country, with the delivery of electricity to all villages despite the vast area of the country.

Numerous large-scale projects were built in Tripoli and the infrastructure witnessed significant improvement and introduced long-term and short-term plans consisting of national plans for urban and sustainable development. The first generation plan was put into action in 1968 and was scheduled to continue to 1980. The plan achieved many targets in terms of the planned expansion of the city, controlling growth and building public facilities where needed (Urban Planning Agency, 2007).

3.5.4. Tripoli after 1969

In the early years following the Green Revolution in 1969 the implementation of the first-generation plan continued into the mid-seventies, at which point the government disregarded it as a result of changing interests, and city growth was stalled while the population continued to increase. The government applied monoculture as a form of national planning, whereby all state facilities and public services were concentrated in the capital Tripoli, which encouraged a lot of people to migrate there, further increasing pressure on the infrastructure and resources and causing an increase in the cost of living (Table 3.3). This delayed the age of marriage and increased unemployment, decreasing the economic as well as physical growth of Tripoli and increasing pollution (exacerbated by the lack of road planning and construction). The government also established some military camps within and around the city of Tripoli and prevented people from building homes near these camps, which negatively affected the process of population expansion in some places.

People were consequently forced to build houses in open areas beyond the control of the municipal authorities and random settlements emerged analogous in function to the favelas and slum dwellings of impoverished nations. These settlements lack the basics of infrastructure, and are not connected to public water and sewage networks. Each house has a private well water supply, and black tanks for sewage. When the government later decided to implement the third-generation plan, many areas were forcibly demolished at great expense to owners and the authorities. The lack of planning and the chaotic nature of government decisions have made urban planning a fantasy in Libya; decisions are erratic and uncoordinated. In recently years the government decided to set up a green belt around the centre of the city of Tripoli in order to reduce the pollution and make it an outlet for the city. Consequently many areas were demolished to link this belt, but no trees have been planted thus far, with the result that the only achievement has been the destruction of buildings and a reversion to desert. Figure 3.3 shows the shape of Tripoli city in 1980, where Figure 3.4 illustrates how the city expanded and its shape in 2010.

Table 3.3: Population and average growth rate in Tripoli, 1980-2010

Year	Population	Average Growth Rate
1970-1980	784,000	9.5%
1980-1990	997,000	1.9%
1990-2000	1,100,000	1.8%
2000-2010	1,600,000	2%

Figure 3.3: City of Tripoli Map, 1980

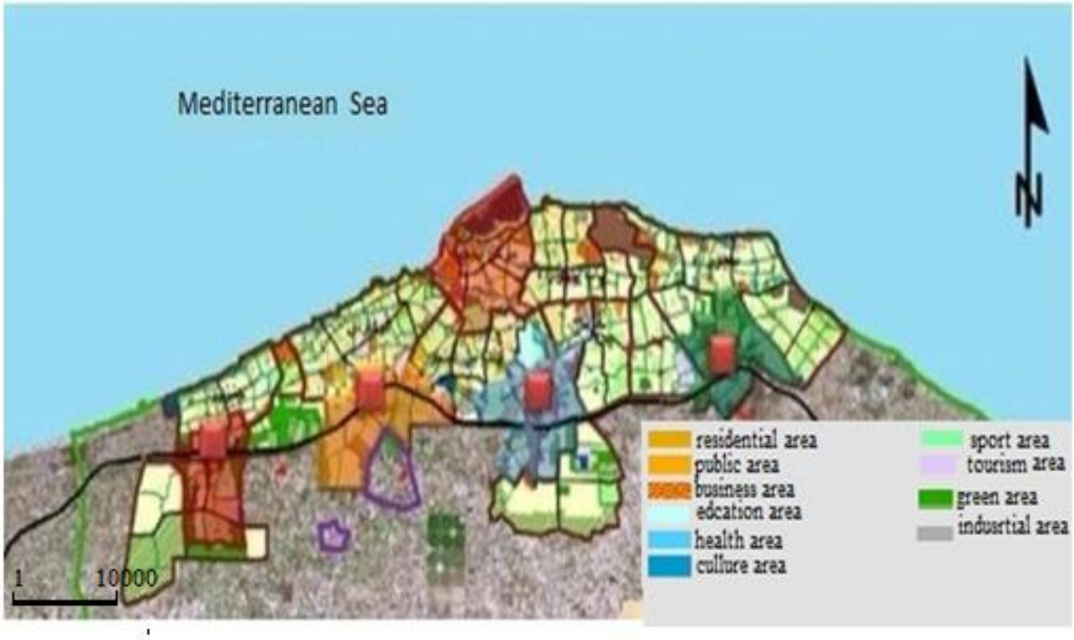

Figure 3.4: City of Tripoli Map, 2010

3.6. Summary

Planning patterns and measuring growth rates is very important for each country to predict future growth and prepare appropriate plans for sustainable development, avoiding any mistakes due to lack of data. The competent authorities of planning work to achieve sustainable development through the implementation of various development projects. Governments must pay more attention for archiving data and using advanced technology because that reflects positively on people and societies.

CHAPTER 4: METHODOLOGY

4.1. Introduction

In the scientific field, tools help to reach accurate results. Tools come in many forms, the most general of which are theories, some of which are flexible and can be used in multiple areas, and which can be adapted and developed in response to empirical testing. This chapter explains the theoretical paradigm that underlies this research and the methods used to answer the research question.

This chapter presents the theories that were used in this research to achieve the aim of the research. Image processing is used to change maps to digital image preparing them for cellular automata model. This chapter also gives some information about cellular automata (CA) types, rules and the use of it, and quick review on fuzzy logic which is used into the model as step of improvement.

4.2. Image Processing

Image processing can be understood as the type of signal processing for which the input is an image. This may include video frame or photograph. On the other hand, the output of image processing can be a set of parameters or characteristics about the image or an image itself. It is important to notice that with technological advancement, the technique of image processing has been revolutionised and most image processing methods incorporate the technique of treating image as two dimensional. Optical and analogue image processing are available, but the most widely deployed technique nowadays is digital image processing. The proceeding paper incorporates brief yet thorough summaries of given researches. These summaries may significantly help in analysing and understanding the concept as well as different techniques which are used in image processing.

Technological advancements have brought dramatic changes in the lives of people. The advanced and modern techniques are playing an incredible and inevitable role in facilitating data processing, collection and acquisition. All of these features have inevitably contributed to the improvement of society. Deep and thorough analysis of the research has revealed that the accessibility of large amounts of information enables the efficient transfer of rich information, particularly through maps. Indeed, the problem faced in modern cartography is to exclude the huge volume of rich data possible due to the overcapacity of cartographic products; surplus data can undermine communication and the understanding of information. City maps, which are essential for urban planning, face a real dilemma in this regard as they must show comprehensive information (e.g. regarding electrical, water, sewage and road infrastructure, existing and planned structures, topography, drainage factors etc.) while remaining comprehensible and functional. In such situations, technological developments have dramatically facilitated overcoming the complexity issues of city maps, including digital image processing.

Novel approach may significantly assist its users in determining graphical load. This approach is based on dual stage map image processing. It is important to notice that this approach uses various tools, including statistical image filters and wavelet transform. All of these features enable users to acquire incredible complexity of images, resulting in integrated and sustainable construction practices (Ciolkosz-Styk, 2007).

Image processing and GIS for hydrothermal alteration mapping have been undertaken for the Baguio district of the Philippines (Carranza and Hale, 1999). It was demonstrated that the presence of hydrothermally transformed rocks may significantly deceive the occurrence of hydrothermal mineral deposits. After considering this situation, the project managers of different projects like reconnaissance mineral exploration have aimed to draw pictures of hydrothermally altered rocks. It has been evaluated from the thorough analysis of this mapping, hydrothermal alteration can be acquired by utilising satellite imaginary techniques. It is due to the fact that some minerals show spectral features or characteristics, hence resulting in adequate and appropriate mapping. It is important to notice that this technique of image processing is successfully mapping the hydrothermal zones in the areas of semi-arid and arid regions. On the other hand, in the humid regions, high vegetation density has incredibly restricted the integrity of image processing techniques.

Some of the most prominent techniques of mapping hydrothermally altered zones include integration of ground data and processing of Land sat TM images, both of which have inevitably facilitated project managers' mineral exploration projects to have clear and obvious maps of the mines. These techniques utilise two-band ratio images as an input of PC (principle components) analysis. This technique plays a major role in mapping each modified mineral into separate principle components as "mineral images" (Carranza and Hale, 1999). This technique also offers digitised ground data which is utilised for training pixels for different areas, including water areas, urban areas and alteration zones. Therefore, it can be stated that this image processing method indispensably allows the project personnel to have clear and evident pictures and map of hydrothermally transformed zones. It is due to the fact that the mineral images of PC, digital elevation model (DEM) and the training pixels are utilised in an organized arrangement in order to map such zones which are hydrothermally altered. The recognized or identified hydrothermally transformed zones can easily be acquired from the classified image (Carranza and Hale, 1999).

With the passage of time, dramatic migration has been observed from rural to urban areas in Palladam Taluk, Tamil Nadu. One of the major reasons behind this migration may include infrastructure facilities as well as job opportunities (Usha and Anitha, 2012). It has been evaluated from the analysis of this area that this migration has incredibly transformed the urban cities or areas. Extensive migration of people in urban areas has increased the issues and problems in these areas, like climatic issues, uncontrolled development, loss of prime agricultural lands, wildlife habitat, destruction of important wetlands etc. In this situation, it is necessary for the concerned authorities to have adequate and accurate land use data, in order to minimise or control these issues. In this regard, various researches and studies have been conducted, in order to have integrated and detailed land use maps (Usha and Anitha, 2012). In the year 1972, the layer of land use map was digitised in Quantum GIS (QGIS) software environment by heads-up digitization method (Usha and Anitha, 2012). Afterwards, in the year 2011, the layers of land-use map were established by controlled arrangement of technique called satellite imagery. In this imaging technique, the training site was established by referring advanced space borne thermal emission and reflection radiometer (ASTER) satellite imaginary, along with the collaboration of global positioning system (GPS). It is important to notice that all of these features and elements coordinate in QGIS environment. Finally, the classified or resultant image is transformed into vector format. Recent results and findings accumulated from this image processing technique show that the land use significantly changed between 1972 and 2011,as represented and compared in map or geographical formats (Usha and Anitha, 2012).

To analyse and recognise the urban texture using image processing techniques, various techniques and methods have been introduced in order to examine the environmental design of individual buildings. All of these techniques have been used to measure or analyse different features of building designs including sound, light, heat etc. Unfortunately, those techniques were not efficient enough to examine all of those features. In this situation, image processing techniques were emerged as one of the greatest alternatives. It has been evaluated that image processing techniques play an incredible and indispensable role in examining the environmental consequences. Digital elevation model (DEM) can be considered as one of the greatest techniques of image processing which helps in analysing and evaluating the conditions of urban regions. Another technique or method of image processing is to analyse urban areas through the application of filters (Ratti and Richens, 1999).

Another model to analyse and evaluate the environmental effects of urban texture is the raster-based urban model, which is very helpful in understanding and analysing the design and planning of urban areas. In addition to this, it is also recognised that digital elevation model (DEM) can also be used with synthetic aperture radar (SAR) and semi-automatic digital photogrammetry techniques can also be used for the development of advanced and useful image-based urban models. All of these image processing techniques may incredibly improve and enhance design and planning of urban texture (Ratti and Richens, 1999).

In the past decades, aerial imagery was mainly obtained using monochrome films. Its utilisation in the applications of remote sensing and analysis of GIS was limited by its high spatial resolution and limited spectral information. It has been observed that this image processing technique is important but often underutilised resource. It is important to notice that the conventional classification of grey-level aerial photos is mainly dependent on digitising and visual interpretation, in order to assess land cover classifications that can be utilised in global positioning systems (Biediger, 2012). This technique is time-consuming and not highly reliable. In this regard, various researches and studies have been conducted on the utilisation of digital image processing techniques and methods, in order to facilitate heads up digitising and visual interpretation of grey-level imagery. This is due to the fact that current remote sensing software packages have restricted operations with respect to classifying aerial photos, mainly black and white. There are many different methods of image processing like principal components analysis, texture analysis, in order to improve and enhance unsupervised and supervised classification algorithms to offer a support for digitising land cover types in GIS (Biediger, 2012).

One problematic area for image processing of urban areas is plants, which are dynamic (i.e. growing or being trimmed etc.) and non-linear. Plants have great significance in maintaining environmental equilibrium in urban areas and they are of great aesthetic value to human communities. The mapping of urban green areas may considerably help to sustain environmental integrity and enable the concerned authorities to ensure protection of the environment through effective management.

Different remote sensing technologies inevitably help in acquiring accurate and detailed information about land use for further planning and management. Remote sensing data technology is a strong technique for the development of thematic maps. Moreover, there are various satellites which play a vital role in providing image data. One of the major examples of the data which offers very high resolution (VHR) may include Quick Bird and Ikonos. It is quite noticeable that both of them have entirely dissimilar characteristics (Misakova, 2007).

In this research the process is

Step 1. Read the map into Matlab, adjust the size and change it from coloured to grey map to facilitate dealing with it.

Step 2. Digitize the map using image processing which mean changing it to numbers (Figure 4.1)

Step 3. Transfer the image to Excel and divided into matrices 100*100 each then replace the numbers in each pixel by numbers indicating particular sectors (e.g. residential, industrial and agricultural areas). Figure 4.2, shows part of the map (100*100) after changing the numbers which is figure 4.1, vertical and horizontal numbers refer to pixel's numbers.

Step 4. Redraw the complete image again in Matlab.

Step 5. Apply the model which used for prediction. Figure 4.3 shows the structure of whole process.

OK401 fx 225

K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE
201	201	201	201	201	201	201	201	201	201	201	201	201	201	201	201	201	201	201	201	201
201	201	201	201	201	201	201	201	201	201	201	201	201	201	201	201	201	201	201	201	201
201	201	201	201	201	201	201	201	201	201	201	201	201	201	201	201	201	201	201	201	201
207	212	209	202	202	208	208	208	204	201	204	208	208	208	204	201	203	208	203	202	207
159	106	139	202	194	149	146	146	187	206	175	144	146	144	179	204	191	149	192	196	152
40	3	18	132	183	38	19	19	71	196	121	24	18	17	127	213	144	31	144	186	39
38	145	66	44	167	20	94	95	18	163	105	38	106	101	161	211	104	0	98	198	117
133	215	160	88	160	34	183	197	50	139	105	81	210	203	202	202	79	47	73	202	203
178	208	207	195	169	31	164	164	30	146	107	48	133	128	182	193	48	117	51	187	211
188	165	95	118	161	15	23	26	38	190	107	2	6	6	148	176	35	175	37	166	212
190	128	0	32	148	25	62	2	131	211	101	51	136	131	186	140	43	162	41	135	213
166	194	141	41	142	36	173	60	75	208	100	80	206	199	209	106	3	14	3	103	214
105	218	159	35	142	36	190	144	27	188	101	84	216	210	207	66	49	98	52	59	210
13	70	20	32	152	34	186	188	30	133	110	5	23	18	89	45	139	206	142	41	194
77	0	33	158	179	73	189	205	106	107	131	43	46	44	97	71	177	207	178	72	183
196	189	194	200	200	197	201	201	198	198	199	196	196	196	198	197	200	201	200	197	200
201	201	201	201	201	201	201	201	201	201	201	201	201	201	201	201	201	201	201	201	201
201	201	201	201	201	201	201	201	201	201	201	201	201	201	201	201	201	201	201	201	201
201	201	201	201	201	201	201	201	201	201	201	201	201	201	201	201	201	201	201	201	201
201	201	201	201	201	201	201	201	201	201	201	201	201	201	201	201	201	201	201	201	201
202	203	201	201	202	202	201	201	202	203	203	203	202	202	203	203	203	201	202	203	203
195	189	200	202	195	191	201	201	190	186	187	186	192	190	186	186	187	198	190	186	186
132	76	189	207	144	110	203	200	99	59	65	59	116	103	59	60	67	175	98	60	58
61	0	160	213	115	62	204	199	79	24	2	27	99	51	19	32	38	168	44	20	32
42	31	129	213	117	65	203	201	200	158	40	174	198	49	134	204	199	197	44	140	206

Figure 4.1: Digitized image

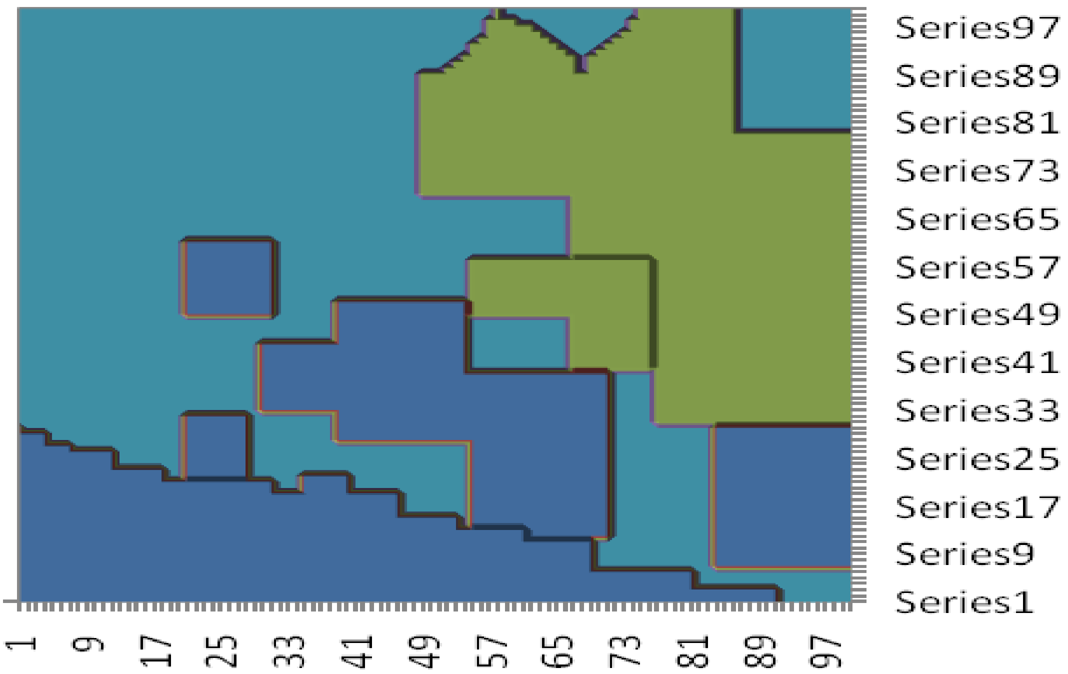

Figure 4.2: Image after changing numbers

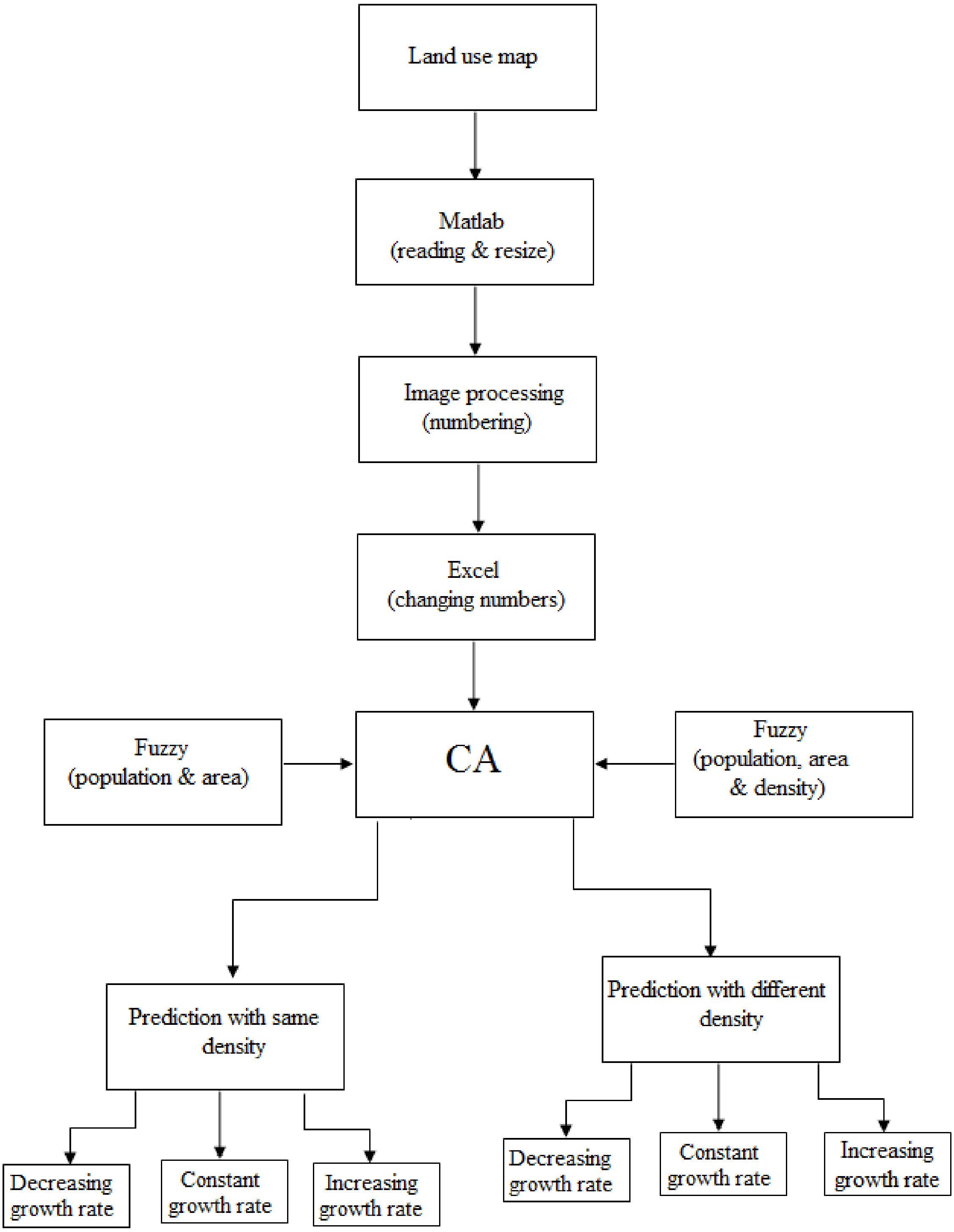

Figure 4.3: Model flowchart

4.3. Cellular Automata

The simplest definition for cellular automata (CA) is a group of cells in changeable states depending on neighbouring cells state and the cells themselves. The main varieties of CA are elementary, reversible and totalistic (Shinozakiet al, 2012).

The concept of CA is considered to be a discrete model, which is mainly studied in certain specialized fields, including computability theory, physics, designing and planning, intricate science, mathematics and in the modelling of microbiology (Shinozakiet al, 2012). Keeping its applications in the aforementioned fields into keen considerations, it is safe to posit the acute significance and necessity of the concept. In addition to this, it has also been observed that the cellular automata are also named as cellular spaces. They are also named as iterative arrays as well as well-defined cellular structures (Duanet al, 2012). It has been also found that the entire process of cellular automation significantly consists of a regular grid consisted of cells. Each of these grids is effectively comprised of a finite and limited number of states. These states are related to on and off as well, which is in complete contrast to a coupled map lattice (Tsormpatzoglou and Karafyllidis, 2012).

4.3.1. Classifications of Complexity

One-dimensional cellular automation is found to exist on an infinite horizontal array comprised of cells. Moreover, in this part, a comprehensive discussion about the one-dimensional cellular automata is presented (Schiff, 2011). Different square cells are considered to be limited to around two possible states in each cell, named white and black. The rules that are related to cellular automata are considered to be effectively related to the determination as well as identification of the specialized pattern of infinite arrangement of the black as well as white cells (Steeb, 2011).

It has also been found that the rules pertaining to cellular automata are specifically updated and based on the technique of nearest neighbour scheme (Shinozakiet al, 2012). This effectively means that if it is significant that the determination of the state in a cell is done having a position p and with time step t + 1, then it is important that cells with position states p – 1(cell on left of cell p), p and p + 1(cell on right of cell p) in the time step t is done. Here, it is significant to understand that the eight possible patterns related to white and black cells is done and therefore, the state at a time t + 1 at the position p is taken to be white or it is chosen to be black (Blecicet al, 2012).

4.3.2. Rules of the Cellular Automata

- *Collecting Evidences*

The rules of CA may be effectively understood through the process of analysing three major steps. The first part is related to the determination of appropriate neighbourhood of the cell (Steeb, 2011). The second part is linked to the collection of cellular changes as the evidences to form input configurations. Moreover, the third step aims at constructing a comprehensive decision tree. This tree will be effective for the purpose of extracting the rules of CA. Evidence is basically defined as a comprehensive method for the purpose of collecting evidences. These evidences are usually found in pairs where the first component indicates the neighbourhood of the cell and the other component is the next cell at a given time (Blecicet al, 2012).

- *Decision of a Neighbourhood*

It has been observed that there are a number of different candidates involved in the process of finding a suitable candidate (Steeb, 2011) due to the fact that the necessary conditions for the purpose of determining the selection of the neighbourhood is effectively related to the cell-state transitions that are considered to be uniquely examined. In addition to this, it is preferable that the entire process of the determination of the neighbourhood must not contain redundant spaces that are considered to be relevant to a number of different changes in the states comprised within the cells (Zagoris and Pratikakis, 2012). Moreover, it is also significant that the neighbourhood must be analysed through the process of putting a neighbourhood as the entire square of the radius. It is critical that the radius must be chosen to be unity (Amorim, et al, 2012).

- *Classification of Conditions*

The third significant step is related to the classification of the conditions (Avolio et al, 2012). It has been observed that if the rules of the discussion are significantly classified from the arbitrary evidences, it may be that their forms have different relations between the neighbourhood as well as the next immediate state of the cell. The following figure gives an insight about three different rules that are significantly constructed by a number of three different evidences (Amorimet al, 2012).

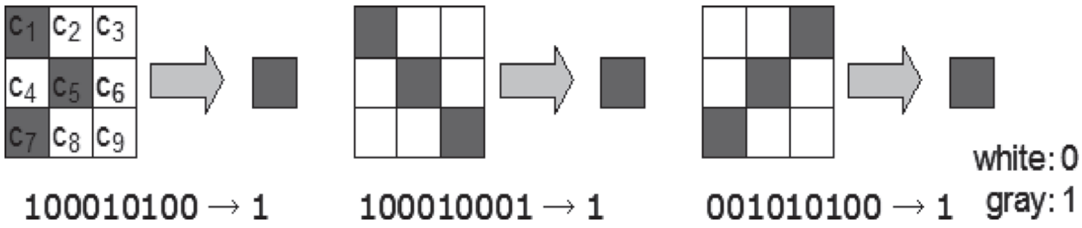

Figure 4.4: CA rules constructed by evidences. Source: Maeda and Sakama (2006)

- *Building of Decision Trees*

Certain rules that are necessary to understand the scenario also include the building of a decision tree (Garzon, 2012). If a cell has a neighbourhood defined as St, a decision tree may effectively return to the next immediate state of the cell. This configuration may be defined as St+1 as a significant output (Avolioet al, 2012). It has been observed that once a decision tree is built successfully then it may have the effective ability to classify the evidences from the entire Enhanced Voronoi Diagram (EVD). It has also been estimated that a population may effectively include a population that consists of around ten individuals that significantly represent the condition trees (Zagoris and Pratikakis, 2012).

4.3.3. Uses of Cellular Automata

- *Image Processing*

It has been observed that there are a number of different uses and applications of cell automata. It is considered to have acute significance in the field of image processing as well. The model of cell automata is considered to have significance in terms of effectively defining the filtering of the digital images (Duanet al, 2012). Each pixel in the entire region of CA modelling may be effectively demonstrated by the triplet (i, j, k). Here, it is significant to understand that the entire image may then be considered as the one that has a particular state of configuration of the entire cellular automation. The cellular space here is defined as the n x n array, which is then effectively defined by the entire image. In addition to this, it has also been observed that each site in the array is found to significantly correspond to a pixel (Tsormpatzoglou and Karafyllidis, 2012).

- *Forest Fires*

Another significant example is related to the spreading of the fire in the homogenous as well as inhomogeneous forests. Furthermore, it has also been observed that a comprehensive model for the forest fires will be incorporated for the purpose of predicting the extent of the spreading of fire in the homogenous as well as inhomogeneous forests (Steeb, 2011). The CA model for it may be significantly productive for the purpose of incorporating certain parameters which include weather conditions as well as land topography. This application of cellular automata is due to the intense impacts of forest fires. These impacts are huge and also there is a constant demand for a number of different effective tools that are used to manage as well as fight these fires (Duanet al, 2012).

- *Settlement Patterns*

The significant aspect of cellular automata is also effectively related to the settlement patterns. In this application, it has been found that the technique of cellular automata and its algorithm is used for the purpose of making significant predictions. These predictions are effectively associated to the development of a rural countryside (Blecicet al, 2012). This model is largely similar to that of the forest fire model. However, in this application, it has been found that the entire area here is evidently broken up into a grid of environmental factors. These are found to be related to the major roads as well as land topography (Tsormpatzoglou and Karafyllidis, 2012). These factors were also used to create a number of different states that can be easily contained in each cell. In this application, two prominent scenarios were employed. The first one is effectively related to the static set of rules and the other one is concerned with the various rules that are effectively changed as the policies of the region are changed (Zagoris and Pratikakis, 2012).

In this research the digitized map is integrated into the CA model (Appendix 1), which is a set of neighbouring cells influencing each other to predict the future growth in terms of direction and speed. The model parameters will determine whether there is a chance to expand or not.

4.3.4. Cellular Automata used in this Research

The elementary CA type and the Moore neighbourhood form which involve nine cells the cell itself and eight neighbour cells were used in designing the model of this research whereas examine cells which are represent area that able to develop whether can be developed and become either new residential or industrial areas depending on cell's location, parameters and population growth rate. The cells examination is repeating many times depending on duration which set for the model.

4.4. Fuzzy Logic

In 1965, Professor Lotfi A. Zadeh proposed the theory of fuzzy logic (FL), a form of data processing that approximates rather than being exact and fixed (Europe Gets into Fuzzy Logic, 1991). FL is particularly useful to deal with data because it simulates human control logic and has been widely applied in control systems. It can be integrated into anything from tiny simple products to big and complicated control systems. Artificial intelligence has seen particularly effective use of fuzzy logic and tangible applications built with FL include computers, washing machines, automatic cleaners, improving fuel consumption for vehicles, controlling of underground trains, and systems for early earthquakes prediction (Zadeh, 1987). To obtain high accuracy, two fuzzy logic files have been used at different stages in this research: the first file consists of two inputs, population and area each one has three variables which gives nine rules; and the second has three inputs (Figure 4.6), namely population, area and density also each of them has three variables to sum up with 27 rules, Figure 4.7 shows graphical presentation of the fuzzy rules.

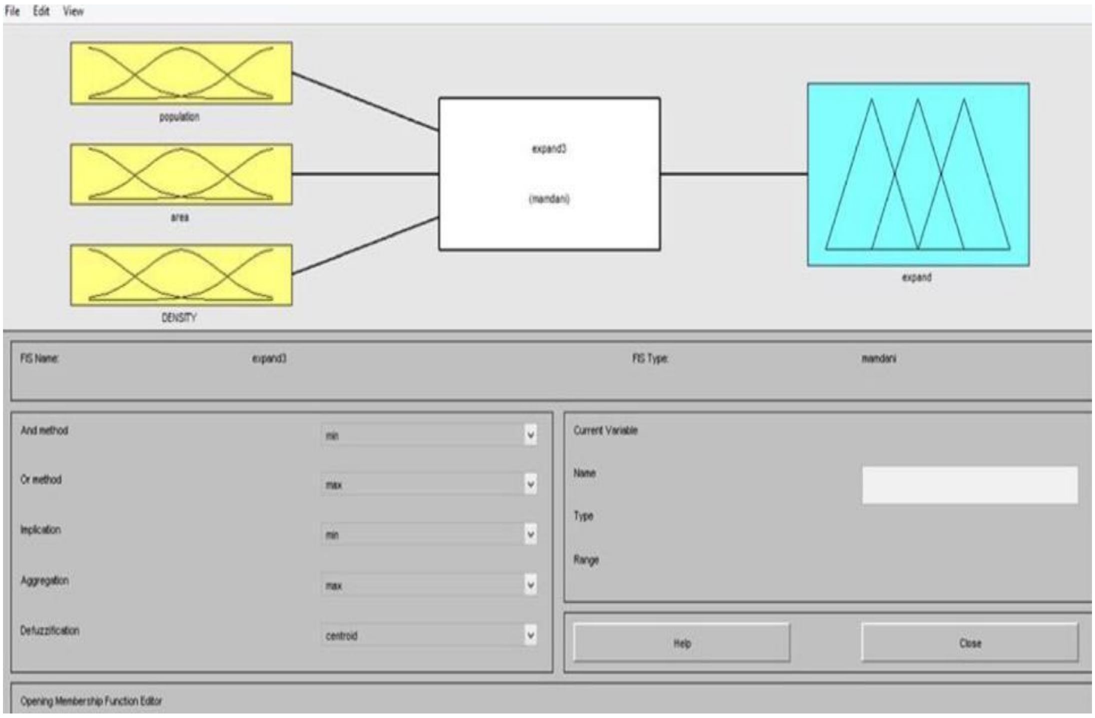

Figure 4.5: Fuzzy logic model GUI

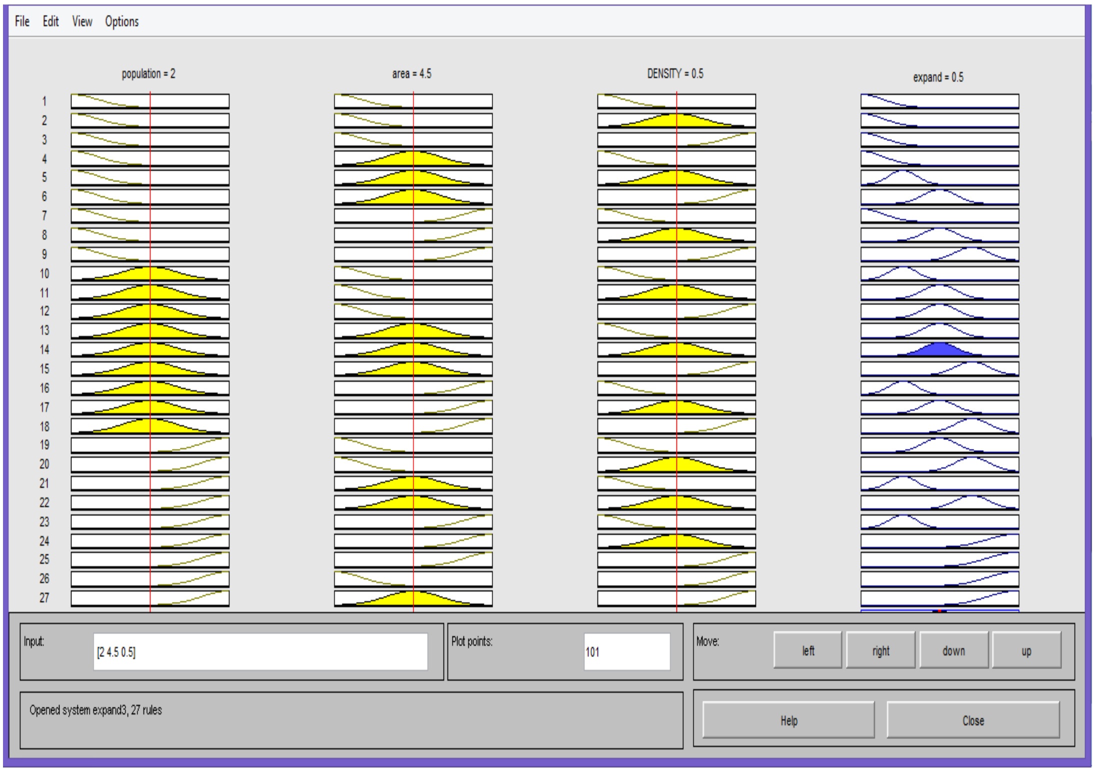

Figure 4.6: Graphical presentation of the fuzzy rules

4.5. Summary

Theories consulting from of extensive studies of the facts and phenomena provide a logic vision to the reality. Theories translate consistent relationships between specific variables in order to identify and predict what will undergo changes. The scientific theories help researchers to achieve their targets easier. It is very important to improve theories that to make them applicable for various areas and give better results.

CHAPTER 5: MODEL DEVELOPMENT

5.1 Introduction

There are several factors that impact on the population growth positively or negatively. While more dramatic instances of factors causing a drop in population include natural disasters (famines, epidemics, diseases, floods and earthquakes) and wars, these have a minimal net effect on global population growth (as explained in chapter one, population continued to increase exponentially during the mid-twentieth century, despite the Second World War and the population attrition in the Soviet Union and the People's Republic of China). The most influential factor is in fact fertility rate, which relates to social and economic issues (e.g. income considerations in family planning, unplanned pregnancies and birth control, issues traditionally subject to religious injunctions).

With regard to infrastructure, the economic factor is perplexing. Naturally civic municipalities seek economic development by attracting industrial and commercial investment, but in doing so migrants are attracted to locate in such areas (seeking employment), thus exacerbating demographic pressure on existing resources. This also has long-term effects such as increasing the fertility rate (due to the presence of more people and more families), and economic development accompanied by improved access to healthcare reduce death rates.

This chapter presents the existing population growth in Libya and Tripoli, then the equation used to predict the future population and its results for Tripoli, after which the CA model designed to predict the population and size of residential and industrial areas in future is explained. Finally, the model is examined for the accuracy of its results.

5.2 Regression Model

In the contemporary history of Libya numerous demographic disasters have affected the population, including long years of drought years and more particularly the Italian invasion and occupation (1911-1943), during which approximately half of the native population perished or emigrated to escape mass internment in Italian concentration camps. Libya became relatively prosperous after the discovery of oil, and from the 1960s onwards many Libyan émigrés returned to the country (mainly from neighbouring countries in North Africa). This spurred population growth until the beginning of the 1980s when the implementation of the National Plan (particularly the Second Generation Plan) was stopped by the Government, partly due to the deteriorating international situation (e.g. the decline of the alliance with Egypt from the late Nasserite period and international ostracism by the Reagan Administration during the 1980s). Consequently, the capital city (Tripoli) became overcrowded, causing a significant inflation of house prices, with knock-on effects of delaying the age of marriage and consequently reducing the fertility rate, ultimately producing a sharp drop in the rate of population growth. This brief sketch of recent history indicates that the population growth rate in Tripoli has been erratic and volatile compared to normal city contexts.

Population prediction for the next thirty years (2010-2040) was calculated using the classic equation shown below (eq 5.1) (Alshrief, 2010), which is widely used and which has been found to give very accurate results as long as the inputs (i.e. present population and growth rate) are accurate. The calculation in three scenarios of the growth rate (constant, increasing and decreasing) considers 2% to be the constant scenario, because that was average growth rate for the last decade, whereas 0.2% will be added every ten years in the increasing scenario (2.2%, 2.4%, 2.6%), and same value 0.2% will be deducted every decade in the decreasing scenario (1.8%, 1.6%, 1.4%). Normally changes in population growth rate are very small every year, and significant fluctuations are rare, which is why only 0.2% was chosen to change the growth rate in both decreasing and increasing scenarios (Alshrief, 2010).

$$P2 = P1 \times (1 + i)^{n} \text{........................} \quad (5.1)$$

where p2 is predicted population, p1 is current population, i is the growth rate, and n is number of years.

784.000 people were living in Tripoli in 1980, thus: for the constant scenario, 2,898,200 people will be living in Tripoli in 2040; for the decreasing scenario in 2040 the prediction is 2,575,800; and the prediction in increasing scenario is

3,259,100. The minimum population in Tripoli in 2040 as predicted will not be below 2,575,800 and it will not exceed 3,259,100 (Table 5.1).

Table 5.1 Tripoli population prediction & growth rate

Year	Decreasing		Constant		Increasing	
	Population	Annual Growth rate	Population	Annual Growth rate	Population	Annual Growth rate
1980	784,000	4.2%	784,000	4.2%	784,000	4.2%
1990	975,000	2.9%	975,000	2.9%	975,000	2.9%
2000	1,100,000	1.8%	1,100,000	1.8%	1,100,000	1.8%
2010	1,600,000	2%	1,600,000	2%	1,600,000	2%
2020	1,912,500	1.8%	1,950,400	2%	1,989,000	2.2%
2030	2,241,500	1.6%	2,377,500	2%	2,521,300	2.4%
2040	2,575,800	1.4%	2,898,200	2%	3,259,100	2.6%

5.3 Cellular Automata Model

This model is designed to make maps as group of cells, each of which cells is affected by its neighbours, thus data can be transferred from one cell to others. Each cell contains a number, and these numbers represent a particular sector on the map(the maps used in this model are land use maps); for example, all residential areas have a signifying number which is two, as do all industrial has number five and business areas has number three. Another number in the model refers to the open area or zone able to grow which is eight, located around the existing city. This area is currently either totally or partly empty, indicating that it is a potential area for growth or development. The model also has parameters which determine the right time for expansion or growth.

Where there is cell with the number indicating an area that is able to develop or an open area (eight), and this is surrounded by cells whose numbering designates a particular speciality e.g. residential (two), the open area will thus be determined by the parameters to be a new area of the surrounding type (i.e. the model will determine the open area to be a zone of future residential development(nine)) (Figure 5.1). If the parameters do not determine an immediate change, then the cell will change in subsequent iterations or when it has a chance to change.

Every six iterations equal one year and each cell equal approximately 13m^2. The model can be adjusted at any time and can be made longer or shorter, depending on the authorities' plans, and it is applicable for any city or village in the world. At the same time, the model will accept if a city or village has natural obstacles (mountains, rivers and slopes) where the city cannot grow, moreover another option that can be added into the model is popular preferences (e.g. people love to live near the sea, while growth tends to be faster in areas with cheaper land). The actual growth rates from 1980 to 2010 have been added to the model to get better results.

The model predicts growth trends, population growth and the size of land needed to develop every year, which gives the competent authorities opportunity to make short- and long-term plans as well as to calculate the budget and choose the perfect project for each region. Also, more importantly, they can plan for sustainability, protecting the environment and economic stability.

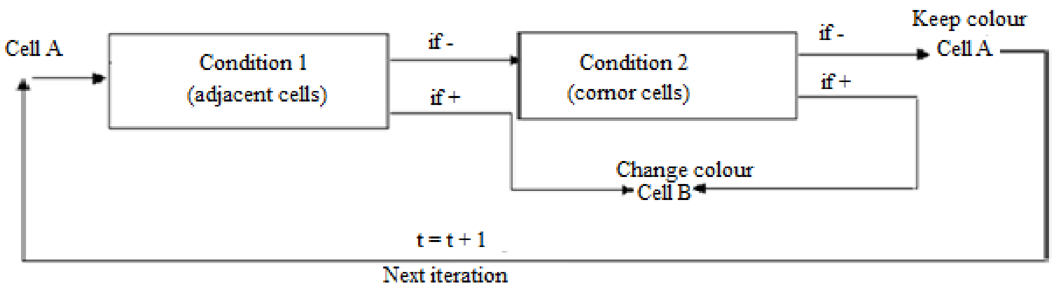

Figure 5.1: Model block diagram

5.4 Model Validation

To make sure that the model works correctly the land use map of Tripoli for the year 1980 (Figure 5.2) is integrated into the model (Figure 5.3) and tested for a period of thirty years (1980-2010), the same duration as the prediction model (2010-2040) with the same parameters. The parameters can accelerate and delay urban expansion and are linked to the growth rates. The model works on residential and industrial areas (Figure 5.4) and predicts the growth of both areas, but the industrial areas grow more slowly than the residential area, the main factors in this process are parameters and iterations whereby the parameters for residential areas are 1.3 for the adjacent cells and 1.7 for the corner cells; and 1 for adjacent cells and 3 for corner cells for the industrial area. The reason for separate measurements is to avoid growing diagonally and illogically; in terms of iterations the residential areas can grow every iteration whereas the industrial area can expand once every five iterations.

The results gained from this test were very close to the real data in Tripoli in 2010 in terms of the city's size of residential area (Figure 5.6) and population (Figure 5.5). The population of Tripoli in 1980 was 784,000 and size of the city was 225.3 km^2, increasing to 1,600,000 and 790.9 km^2 respectively by 2010. This is even more remarkable when one considers the lack of cohesion in urban planning in Tripoli during the same period, thus inspiring great confidence in the model.

In 2010 population density in Tripoli was 2600 pop/km^2, which is considered relatively high compared to the size of the country; 88% of Libya is empty, which makes it clear that the government comprehensively failed to develop Tripoli properly, thus undermining the environment and society. The natural consequence has been ad hoc urban sprawl, accentuated by local cultural traditions. In Libya, when children get married they typically build small apartments above their parents' houses to save on buying a house or land, thus the expansion is more vertical than horizontal. This is reinforced by the lack of loans or programmes of house-building that would help mitigate the challenges faced by young people seeking a home. The digitized maps (Figures 5.7 - 5.9) show the expansion of the residential and industrial areas after applying the model in 1990, 2000 and 2010 in Tripoli city.

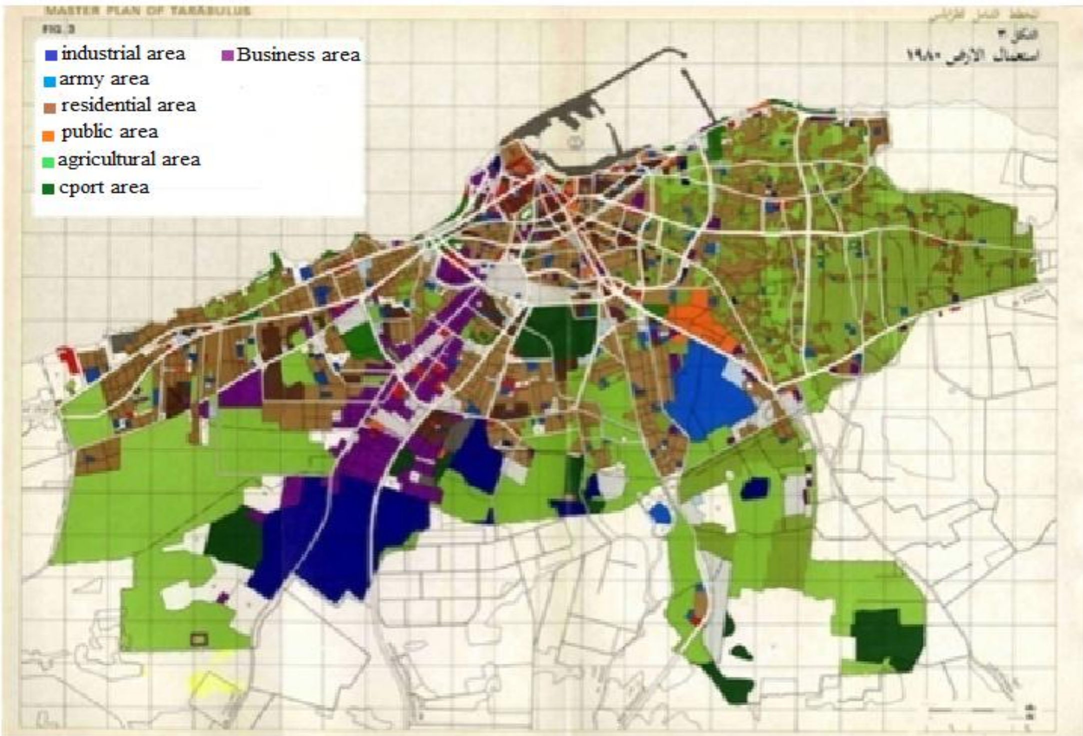

Figure 5.2: Tripoli land use map in 1980

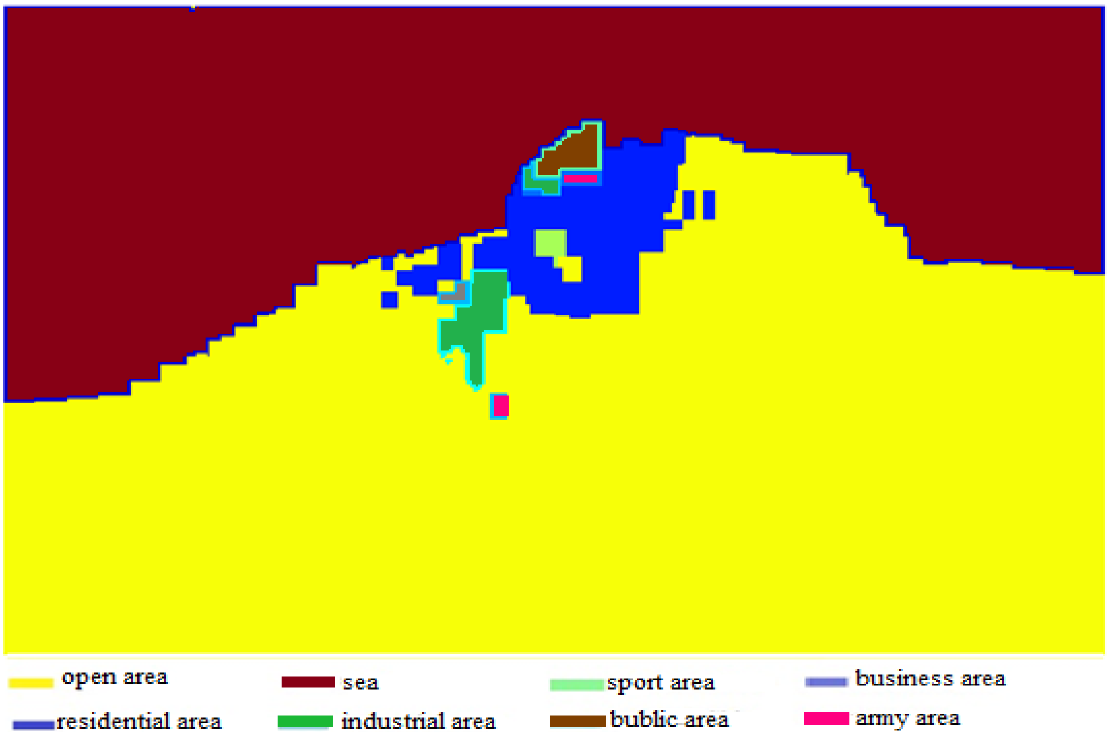

Figure 5.3: Digitized Tripoli land use map of 1980

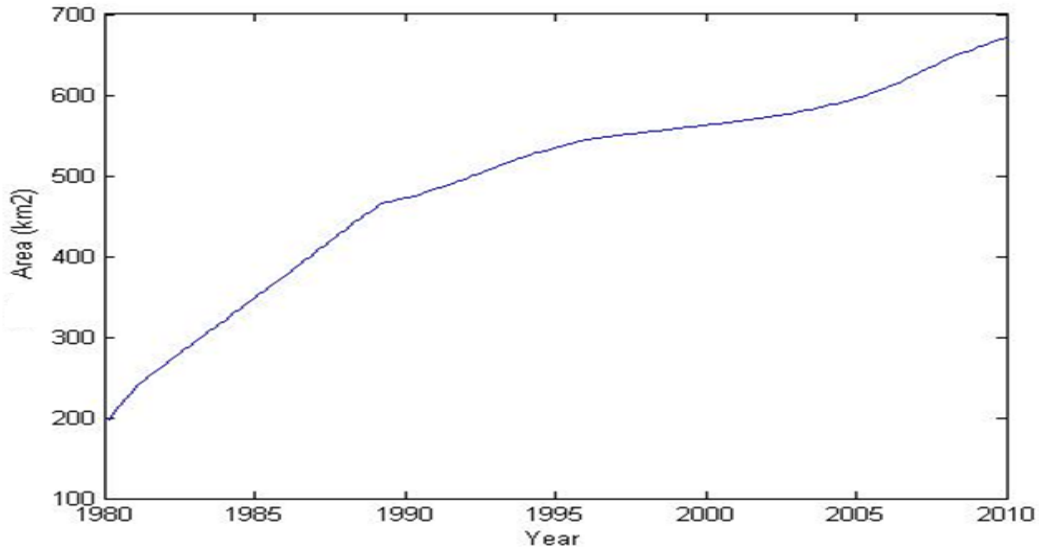

Figure 5.4: Residential and industrial areas

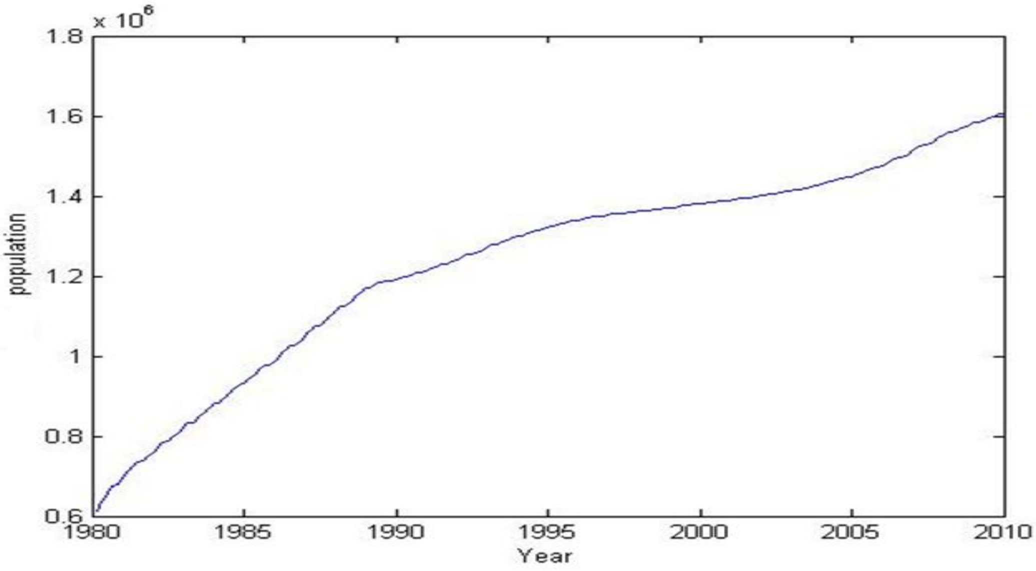

Figure 5.5: Population

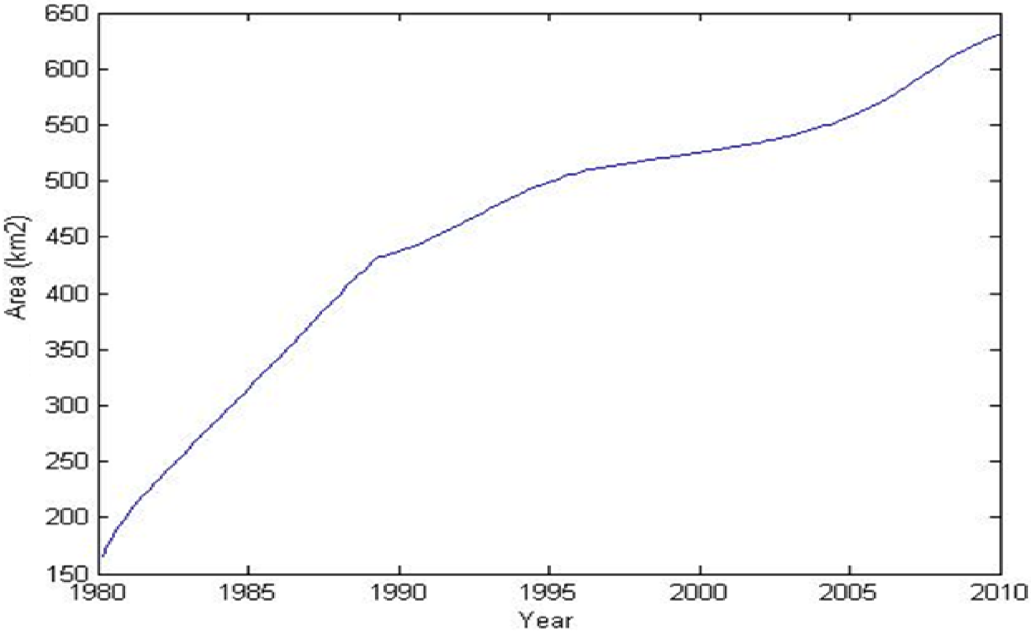

Figure 5.6: Residential area

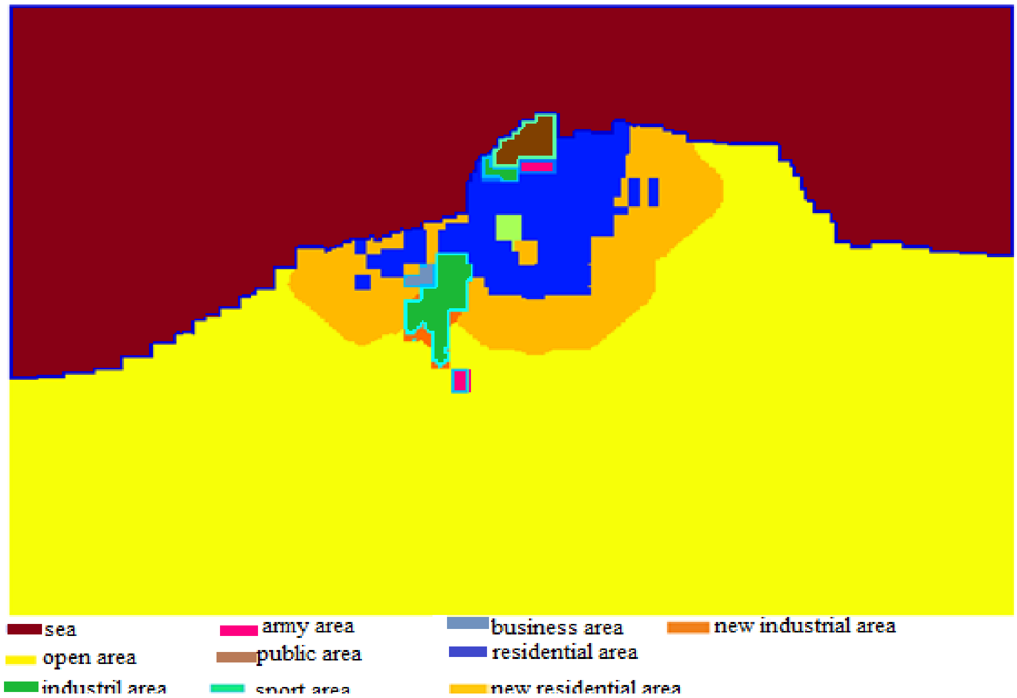

Figure 5.7: Expanded Tripoli map (1980 to 1990) by model

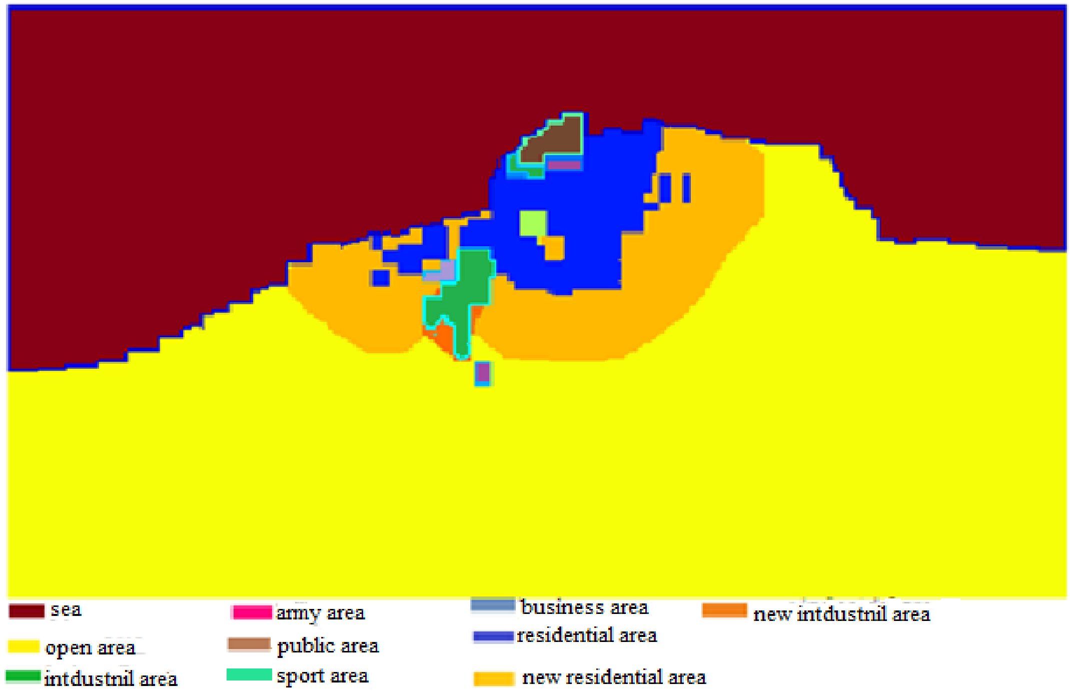

Figure 5.8: Expanded Tripoli map (1980 to 2000) by model

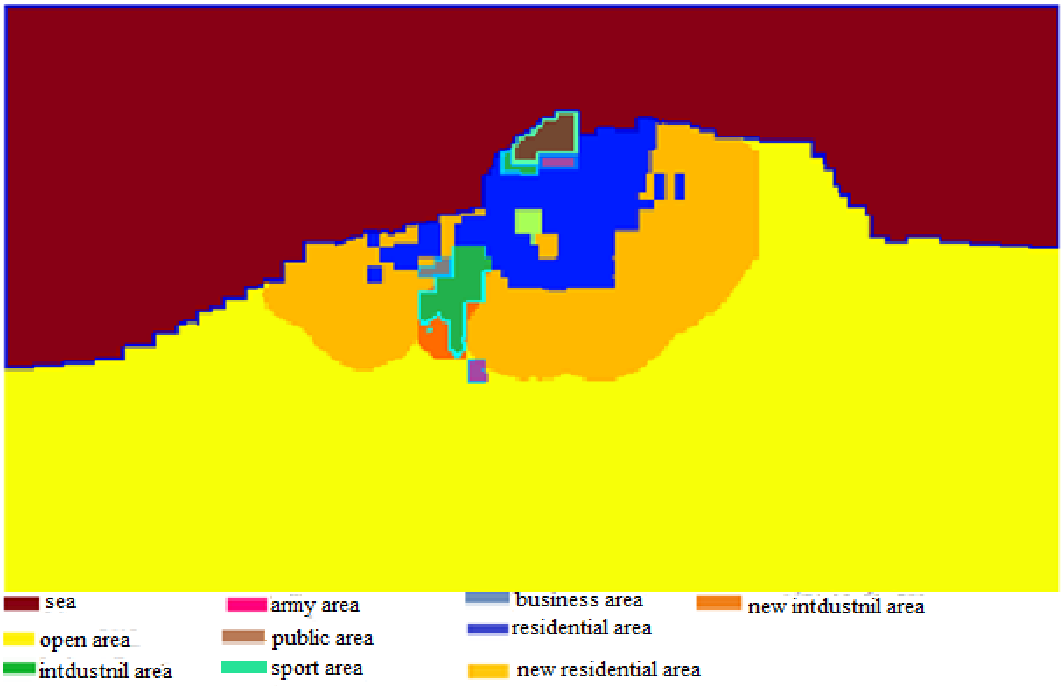

Figure 5.9: Expanded Tripoli map (1980 to 2010) by model

5.5 Summary

It is very important to utilise the remarkable advanced technology available nowadays to solve real and pressing problems to improve people's quality of life. In urban planning there are many technologies to help organise, plan and control urban expansion. This model showed high accuracy and it can be relied upon for future predictions, therefore we can know the growth trends and particularly which places grow faster, which will enable authorities to plan appropriately in advance and avoid random expansion, as well as minimising damage to the environment.

Our responsibility toward our planet to maintain the nature resources and protect it from destruction so that the coming generations can enjoy these resources. Urban sprawl (chiefly housing/residential) has negative impacts on forests, squanders water, causes pollution and ultimately exacerbates global warming. All of these structural problems inherent in modern human life can be mitigated by using technology to predict and manage population growth and needs squared with the space needed for them in future, potentially enabling growth to be diverted or allocated to places where it causes minimum disruption and using the minimum of natural resources.

CHAPTER 6: ENHANCED MODEL

6.1 Introduction

The use of technology in areas that benefit humanity has become necessary as well as convenient due to critical problems faced at this time in history. Technological techniques provide highly accurate results with significant reliability. In this case, such techniques can enable accurate prediction of population increase and thus enable proper urban planning and management of public services.

This research predicts the population growth, growth trends and the size of land requiring development to give the competent authorities the potential to plan appropriately and avoid any uncontrolled growth, as well as to stop environmental destruction. Therefore, using advanced technology can contribute to improve the circumstances of people's lives and establish long and short-term plans for existing and future generations.

This chapter illustrates the mechanisms of the model action and shows the predicted results when density is the same over the city and when it is different in the east and west sides. Each of these stages consists of three scenarios: in case of population growth decline, the other case is fixed and increasing population growth also explains the fuzzy rules used in the model. Finally, the results are discussed with regard to validation of the model and its prediction of different phases and scenarios.

6.2 Model Developments

This model is designed to predict population growth, the size of land needed for the population and to indicate which areas are able to become new residential areas faster than other areas, depending on factors such as whether the area is open and allows to the city to expand, proximity to existing residential zone and presence or absence of contraindications either natural (mountains, rivers etc.) or man-made (including environmental protection legislation).

Additionally, this model predicts the expansion of industrial areas. The reason why only residential and industrial areas were chosen for growth prediction using this model is that residential areas are the fastest growing and the main issue for Tripoli city, and industrial zones have particular needs such as high voltage power supply and ample water, along with proximity to major roads and railway networks to ports or airports, especially if products are for export. Industrial zones are also abhorrent to residential areas (e.g. industrial zones are normally located in areas where prevailing winds can push gaseous emissions away from homes), yet the model does not allow the industrial areas to grow as fast as the residential. After five iterations the existing industrial has an expansion, but the greater increase in residential areas has the net result that after the first ten years it becomes preferable to establish a new industrial area than to expand an existing one to minimize the infrastructural costs on existing networks.

The model predicts the population growth and industrial expansion for the next 30 years from 2010 to 2040. This model comprises two phases, predicting the growth with equal population density over the city and with different density. Each phase contains three scenarios: decreasing, constant, and increasing population growth rate.

Public service areas (schools, hospitals, government utilities, business, army, sport and leisure areas) will be added to the final city map. This area consistently occupied about 20% of the total city area from 1980 to 2010, thus this area is anticipated to spread in tandem with the population it serves.

The map used in this model is a land use map of Tripoli that shows different sectors of the city in 2010 (Figure 6.1), digitized for the application of the model.

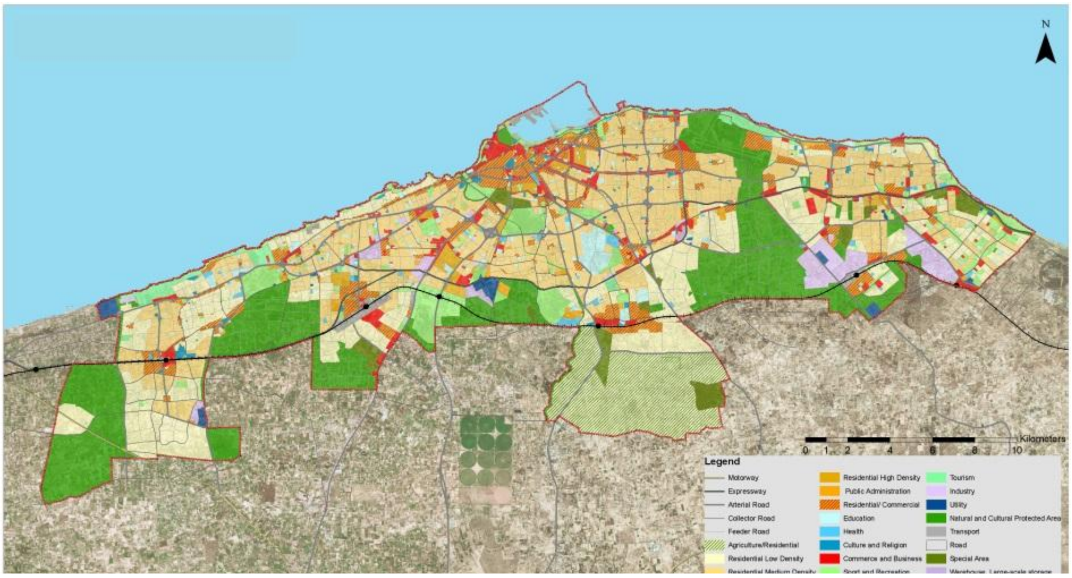

Figure 6.1: Tripoli land use map in 2010

6.3 Population Growth

This is the first stage of the model (Figure 6.2) where the density is same in the population prediction and it is equal the population density in 2010 (2600 pop/km^2). To obtain accurate results a fuzzy logic file was used with population input (Figure 6.3) has three variables which are representing the three scenarios of population growth rate and area input (Figure 6.4) also has three variables which are representing the number of cells around the cell being tested. The output is expansion (Figure 6.5) ranges from zero to one which is representing the expand whether big or small, using Gaussian function and nine rules (Table 6.1). The block diagram below explains the fuzzy file role in the model, and the table shows the fuzzy rule base. The other figures show population, area and expand function plots.

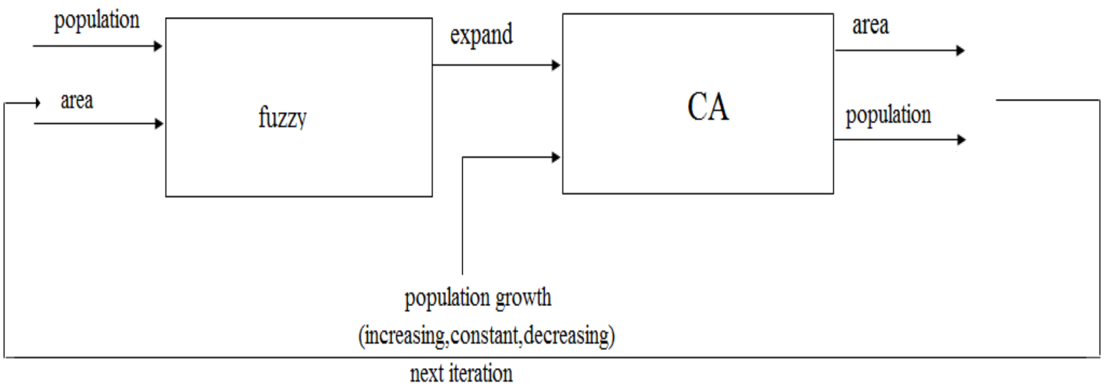

Figure 6.2: Fuzzy logic-CA model block diagram

Table 6.1: Fuzzy logic rule base

Area \ Population	Small	Medium	High
Small	Small	Small-Medium	Medium
Medium	Small-Medium	Medium	Medium-High
High	Medium	Medium-High	High

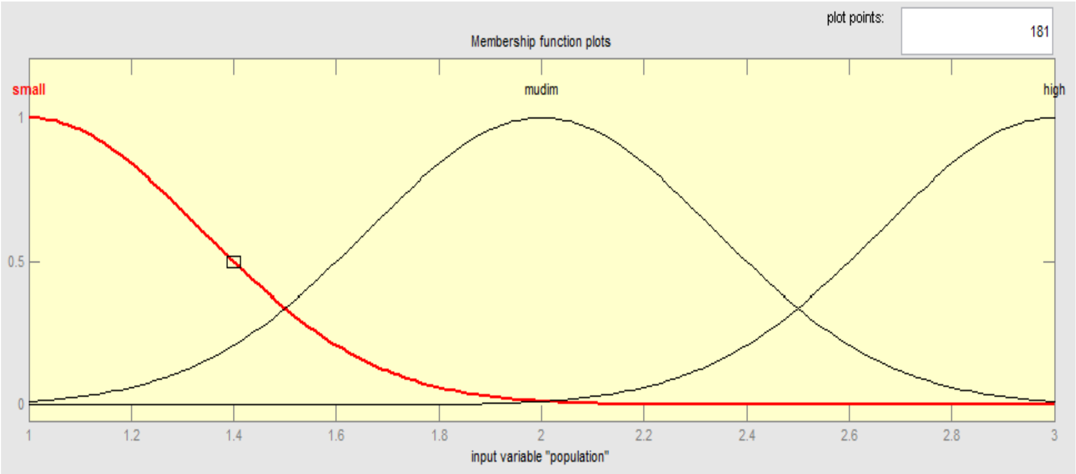

Figure 6.3: Population membership function plots

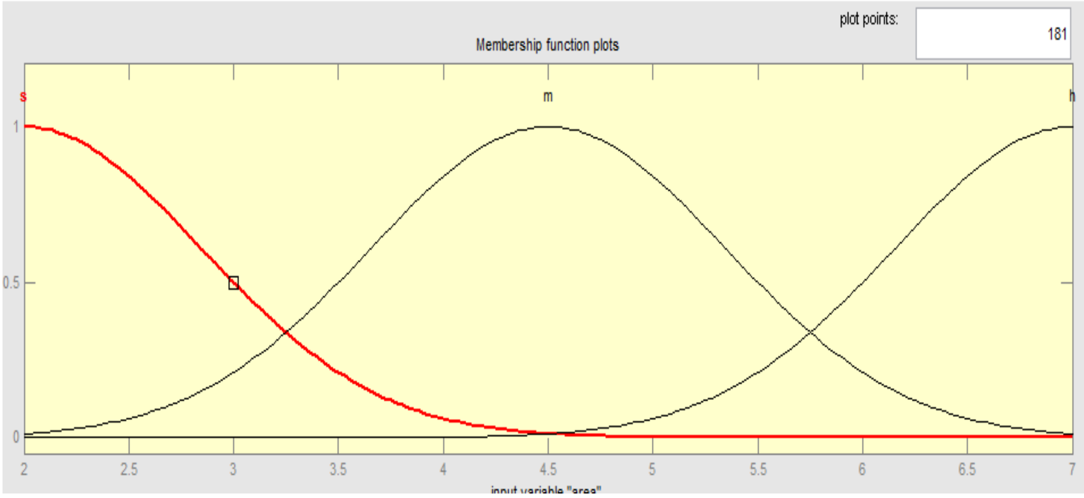

Figure 6.4: Area membership function plots

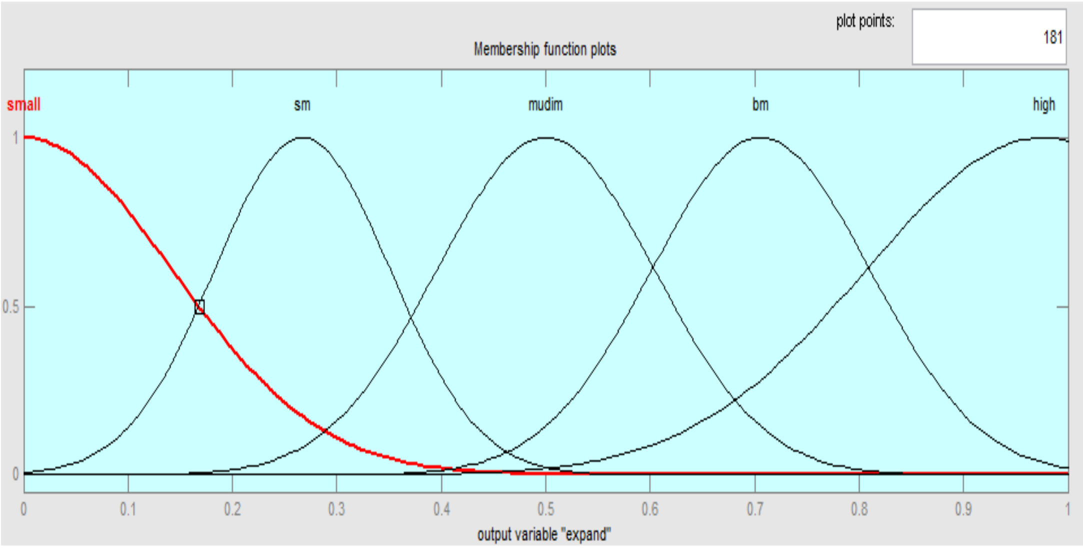

Figure 6.5: Expansion membership function plots

6.3.1 Declining Growth Scenario

The initial map used in all scenarios and both phases is the digitized land use map of Tripoli (Figure 6.6). For this scenario the growth rate is -0.2% every ten years (2% then 1.8% then 1.6%). Figure 6.7 shows the increase in residential and industrial over the thirty years; there is a sharp increase in the first few years then more regular growth until the end of the first decade, after which point the increase slows due to the growth rate declining. Figure 6.8 shows the increase in population that happens every ten years. There is also a significant growth in the beginning because of the increase in residential areas.

Figure 6.9 illustrates the expansion in residential areas in 2020, 2030 and 2040. The shape of the expansion is broadly similar to the previous figure. Figure 6.10 clarifies the industrial expansion for the same period it can be seen that expansion for approximately five years abruptly stops when the residential area arrives at the industrial area, after which there is a jump in 2030 due to the new industrial area suggested which is big enough to meet population needs for many years, thus no new expansion is necessary during the period from 2030 to 2040. Finally, Figures 6.11-6.13 show the increase of residential and industrial zones on the map in 2020, 2030 and 2040, and Table 6.2 compares the differences of these sizes and the population between 2010 and 2040.

Table 6.2: Declining growth scenario results

	Green Area (km^2)	Public Facilities Area (km^2)	Army Area (km^2)	Sport Facilities Area (km^2)	Industrial Area (km^2)	Residential Area (km^2)	Total Area (km^2)	Population
2010	180.6	22.7	18.5	22.6	43.6	515.1	803.1	1,619,200
2040	180.6	53.9	40.6	38.1	60.4	644.5	1,018	2,178,200

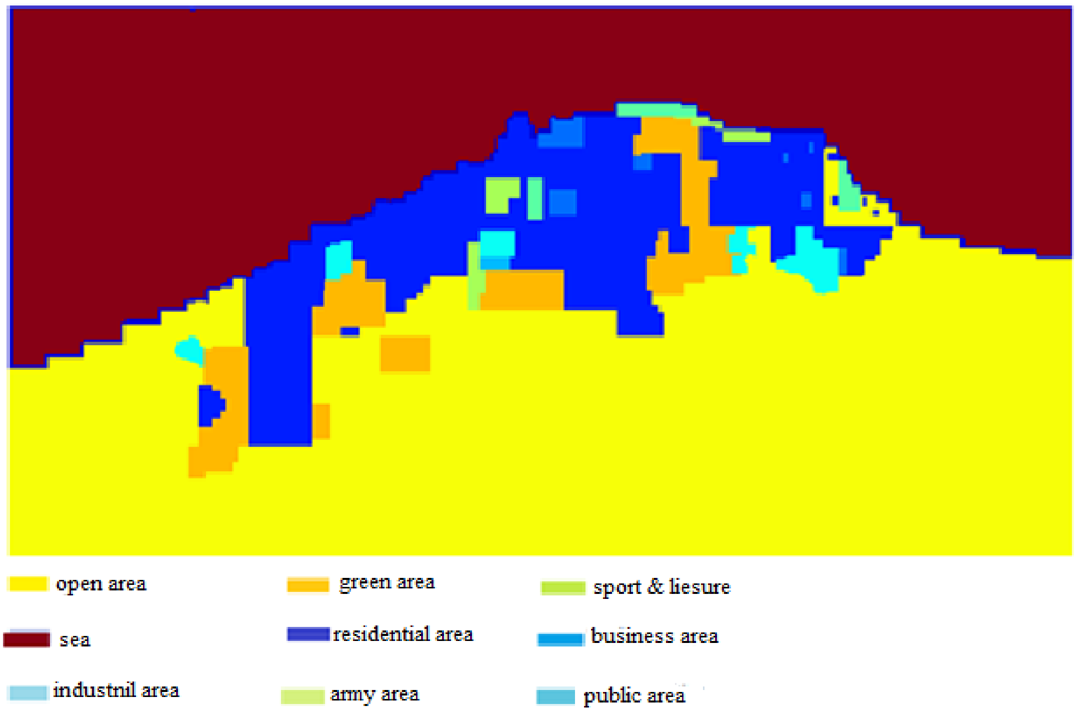

Figure 6.6: Tripoli digitized map of 2010

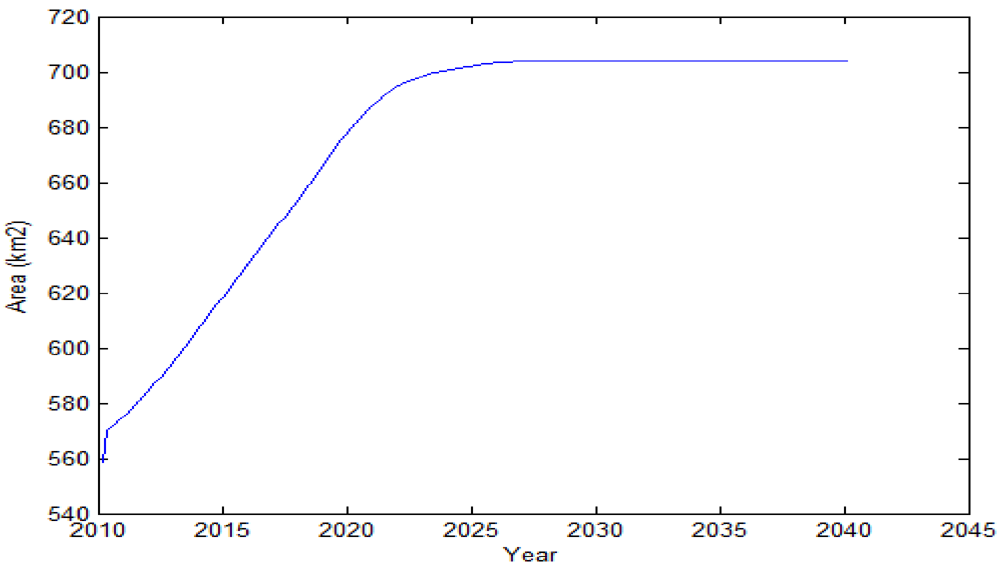

Figure 6.7: Declining growth residential &industrial areas

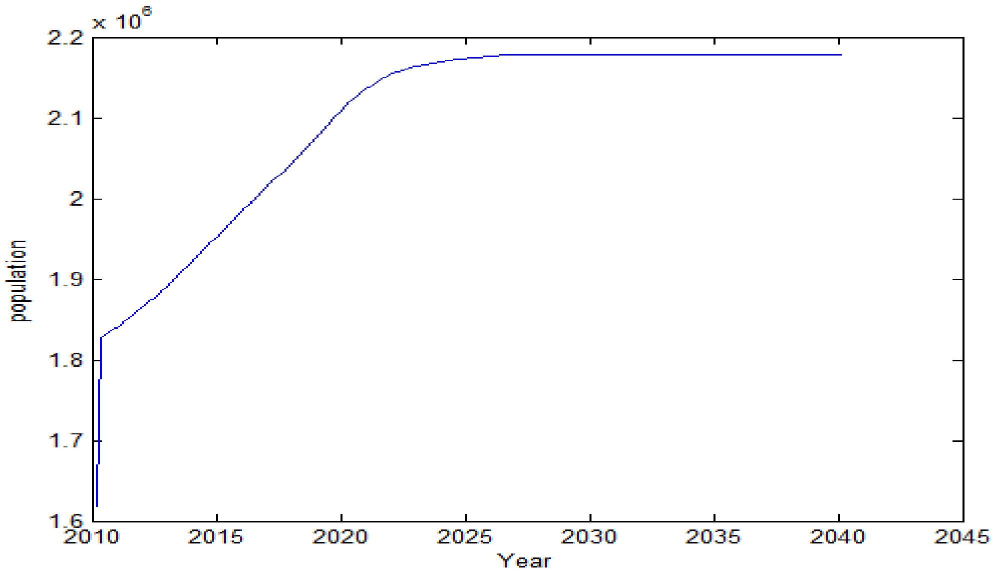

Figure 6.8: Declining growth total population

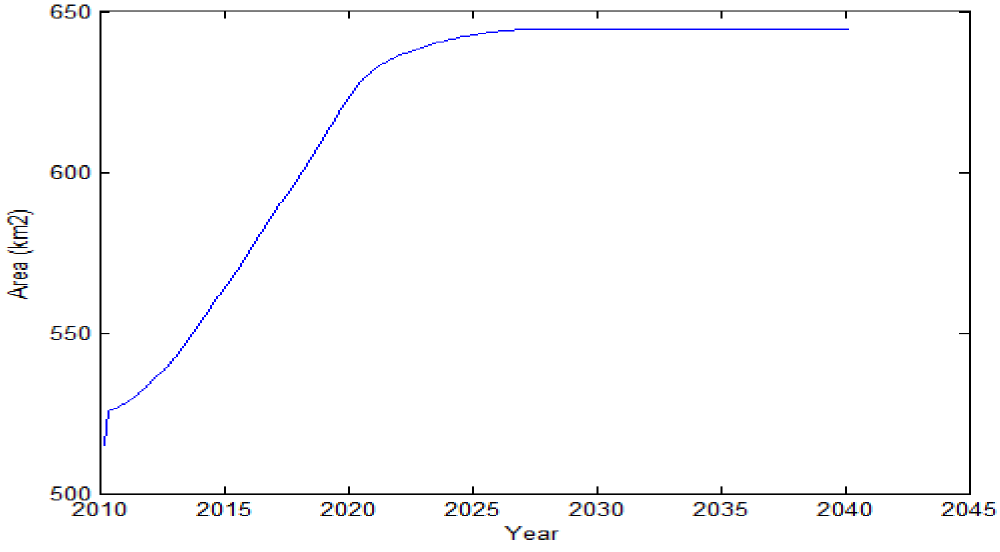

Figure 6.9: Declining growth residential area

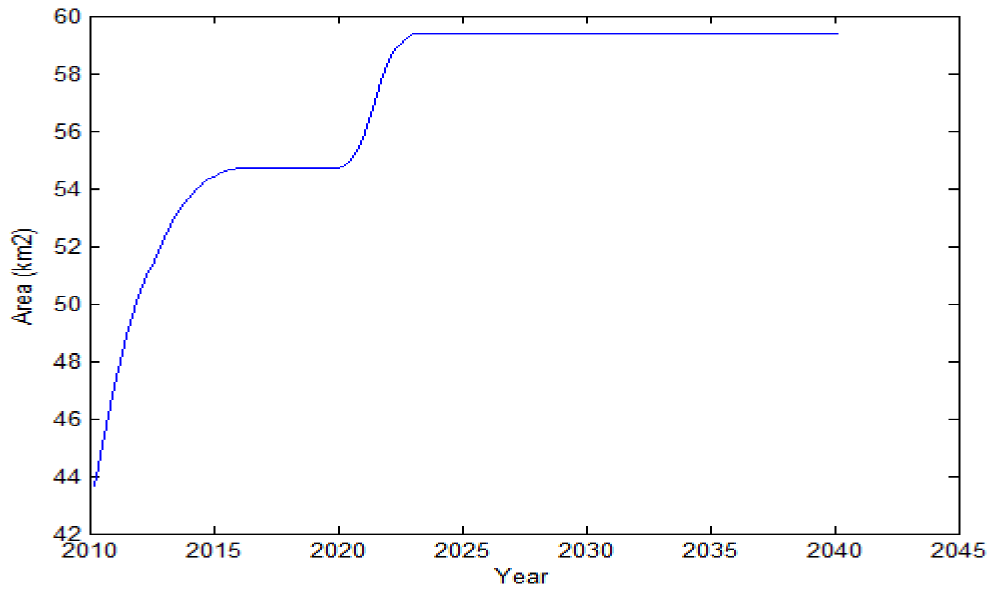

Figure 6.10: Declining growth industrial area

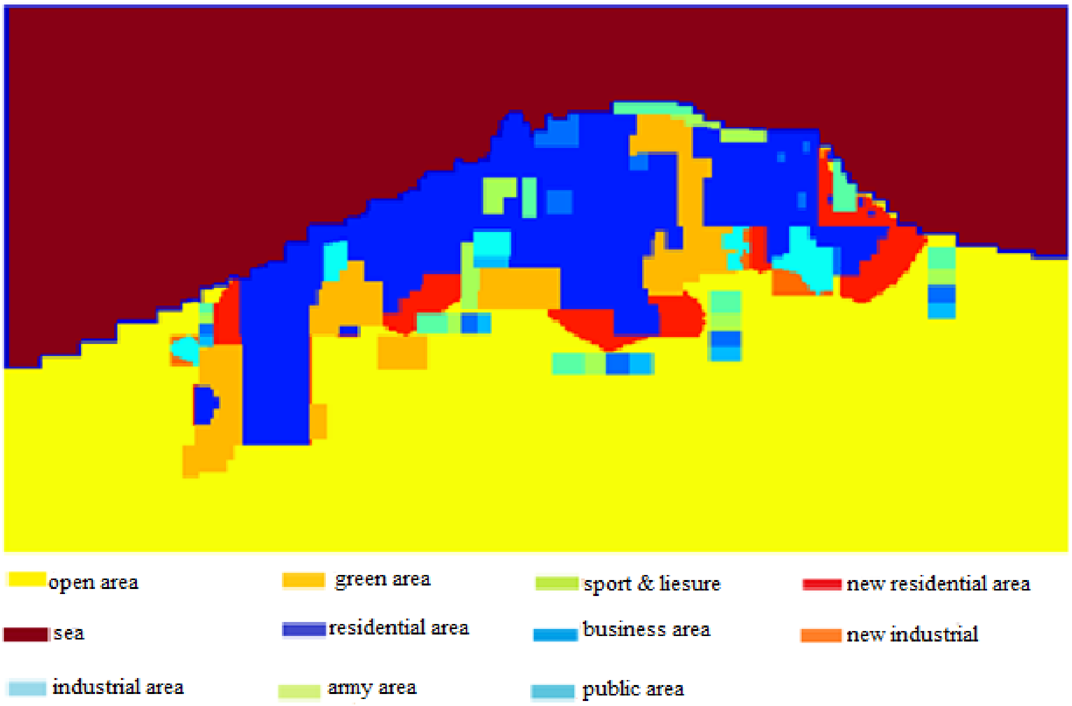

Figure 6.11: Declining growth Tripoli map in 2020

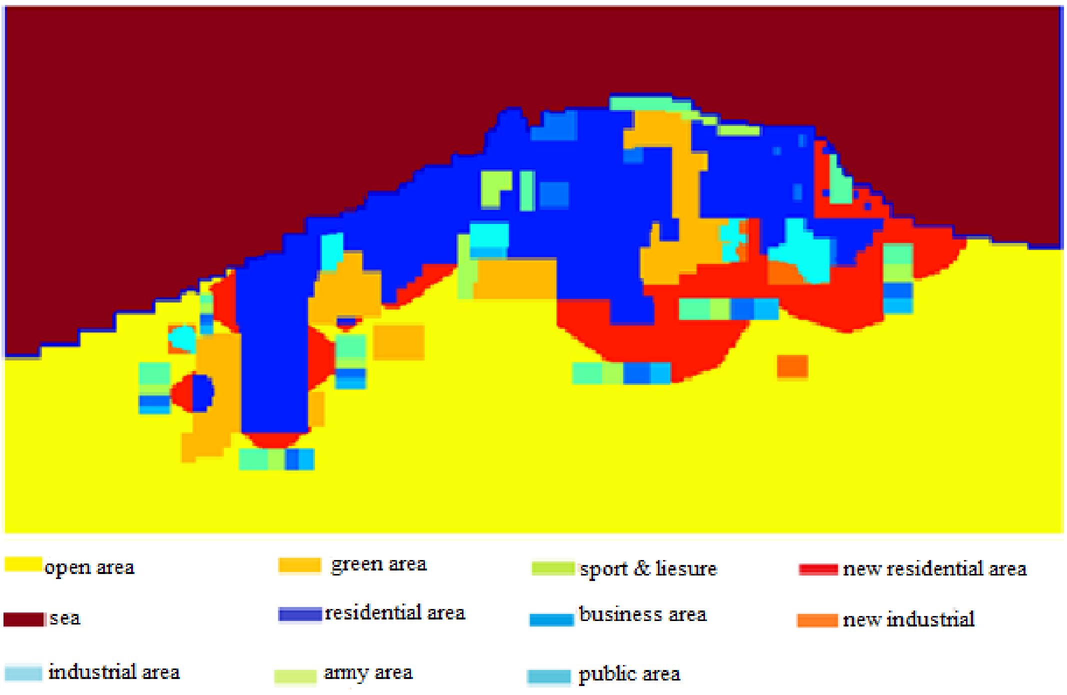

Figure 6.12: Declining growth Tripoli map in 2030

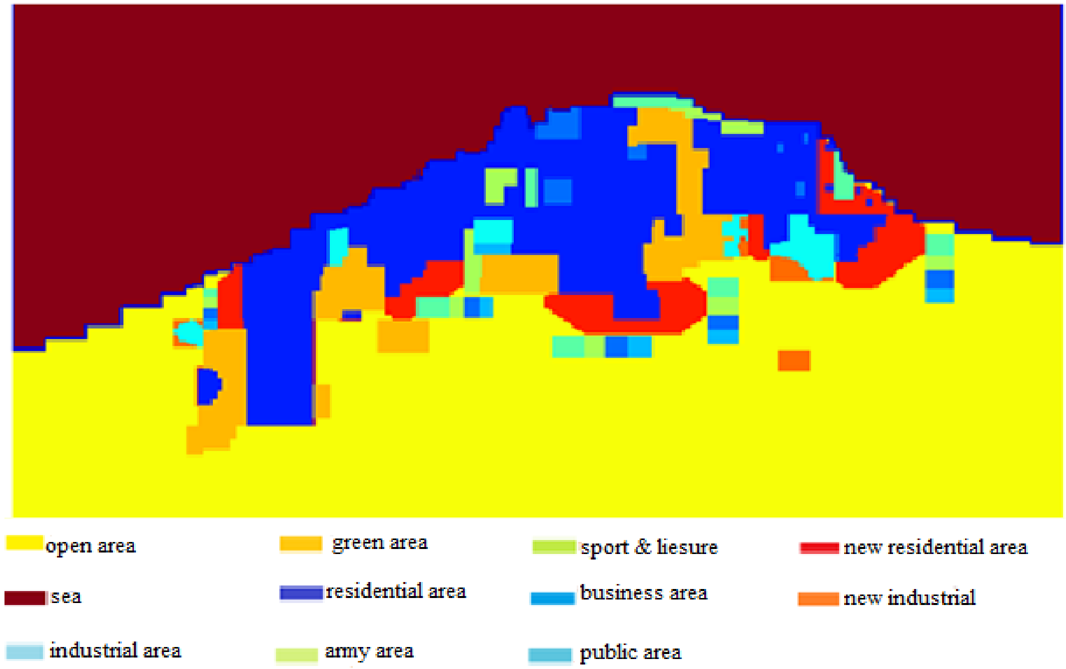

Figure 6.13: Declining growth Tripoli map in 2040

6.3.2 Fixed Growth Scenario

The population growth rate is fixed in this scenario at 2% for the thirty years. Figure 6.14 presents the increase in residential and industrial areas. It is clear that there is a steady rise for thirty years. Figure 6.15 indicates the population growth in thirty years from these figures it is noticeable their rapid surge in first years then a more constant increase in subsequent years. Figure 6.16 shows the ascending expansion of residential areas in 2020, 2030 and 2040 and Figure 6.17 explains the industrial area expansion over thirty years. The form of expansion is illustrated by Figures 6.18-6.20. Table 6.3 shows the results of this scenario in 2040 for population and the difference between many areas in 2010 and 2040. The curves illustrate the increase of population and the expansion of residential and industrial areas for the same period. The predictive calculation of population growth results in 2,898,200.

Table 6.3: Fixed growth scenario result

	Green Area (km^2)	Public Facilities Area (km^2)	Army Area (km^2)	Sport Facilities Area (km^2)	Industrial Area (km^2)	Residential Area (km^2)	Total Area (km^2)	Population
2010	180.6	22.7	18.5	22.6	43.6	515.1	803.1	1,619,200
2040	180.6	65.5	60.1	44	88.4	855.3	1,293.9	2,885,900

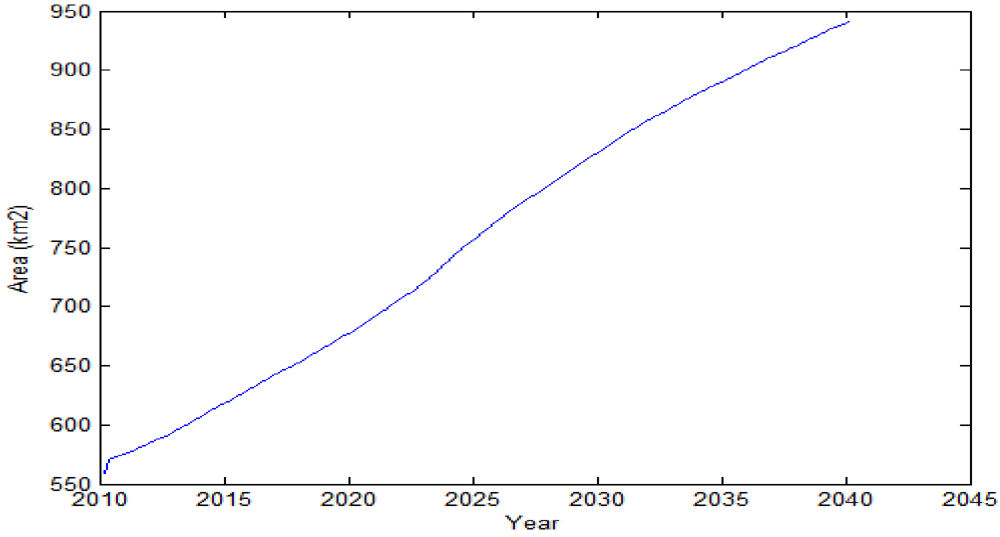

Figure 6.14: Fixed growth residential and industrial areas

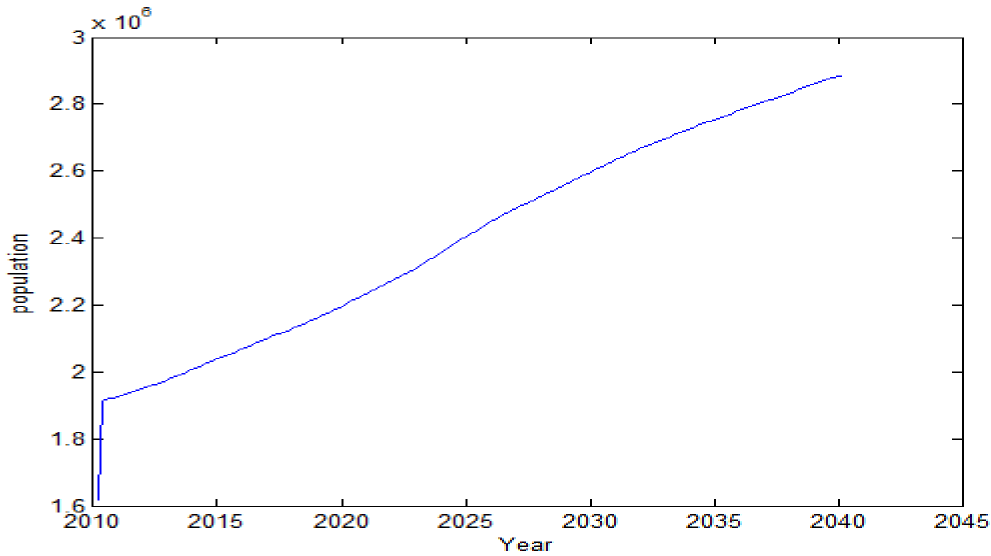

Figure 6.15: Fixed growth total population

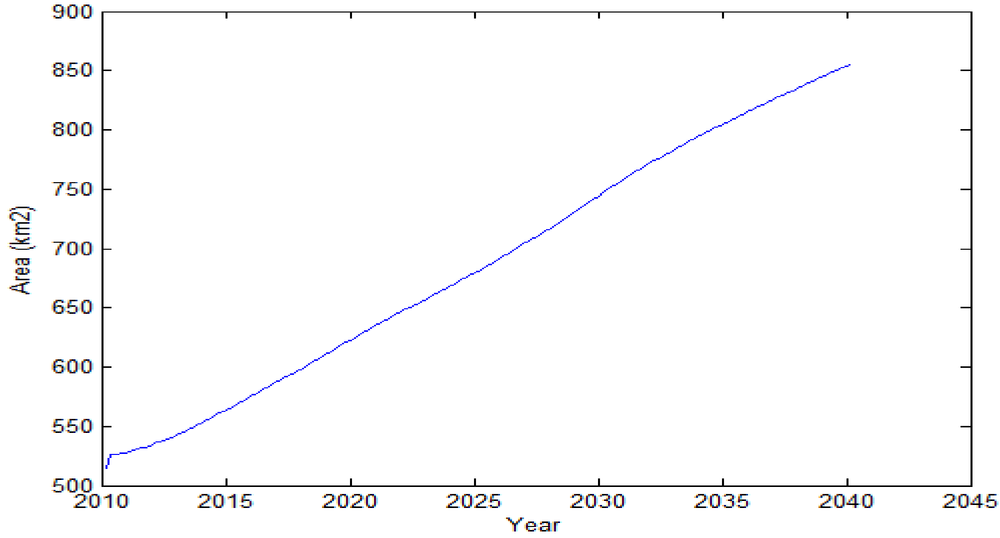

Figure 6.16: Fixed growth residential area

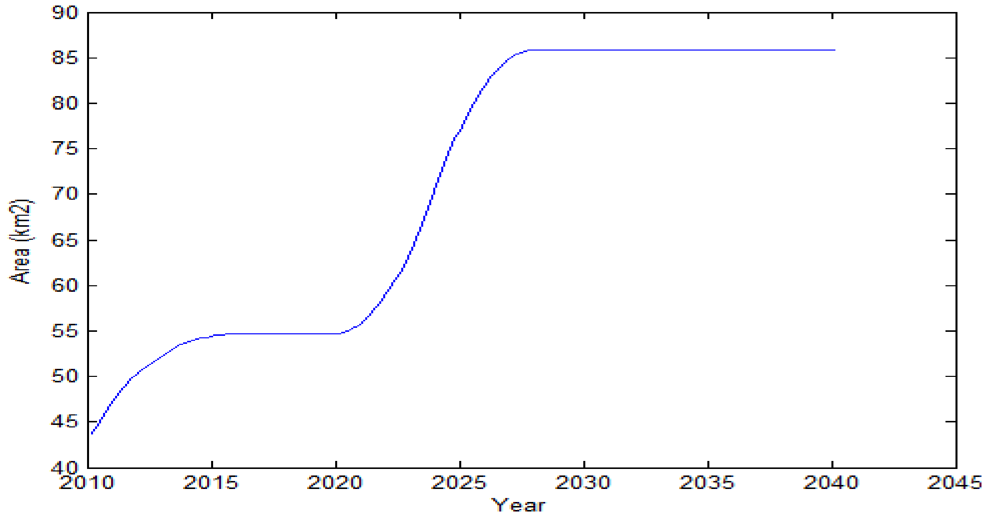

Figure 6.17: Fixed growth industrial area

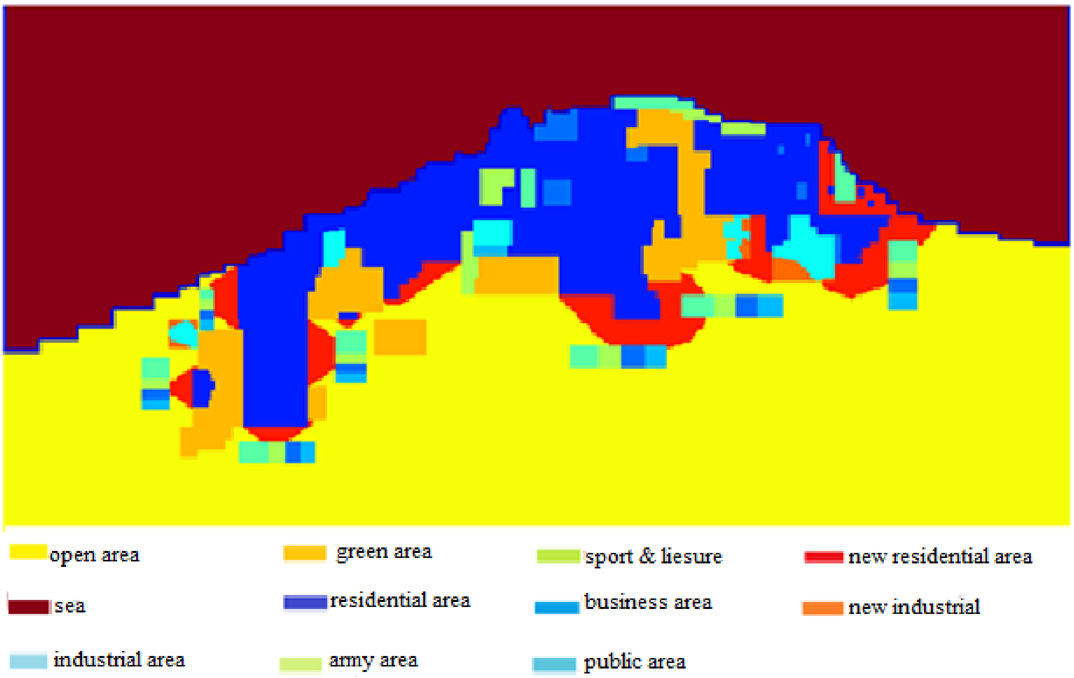

Figure 6.18: Fixed growth Tripoli map in 2020

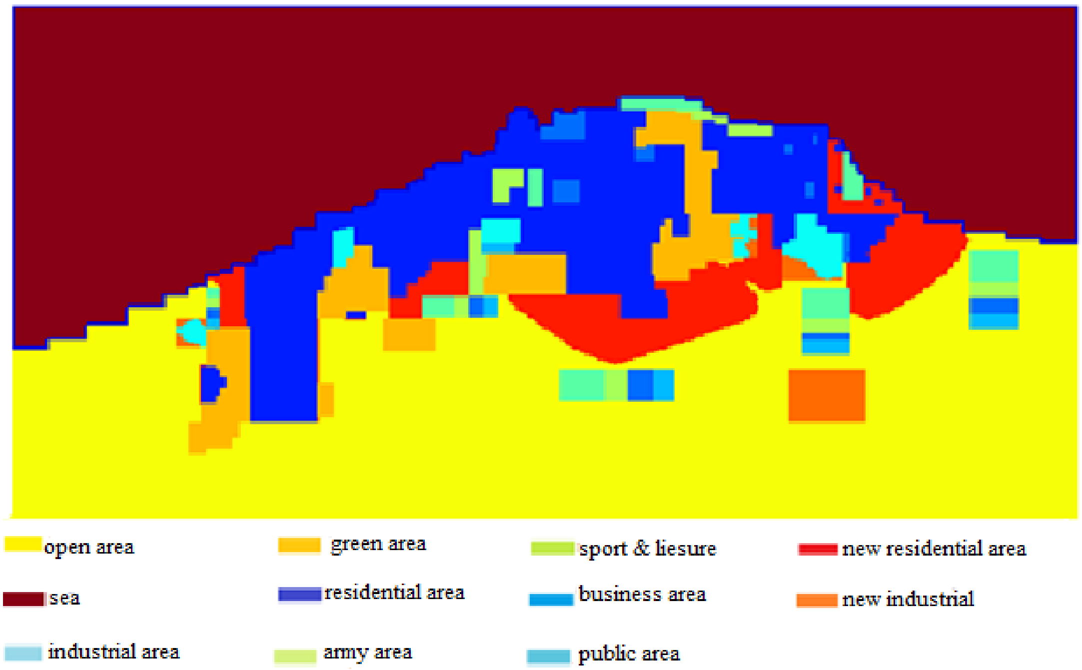

Figure 6.19: Fixed growth Tripoli map in 2030

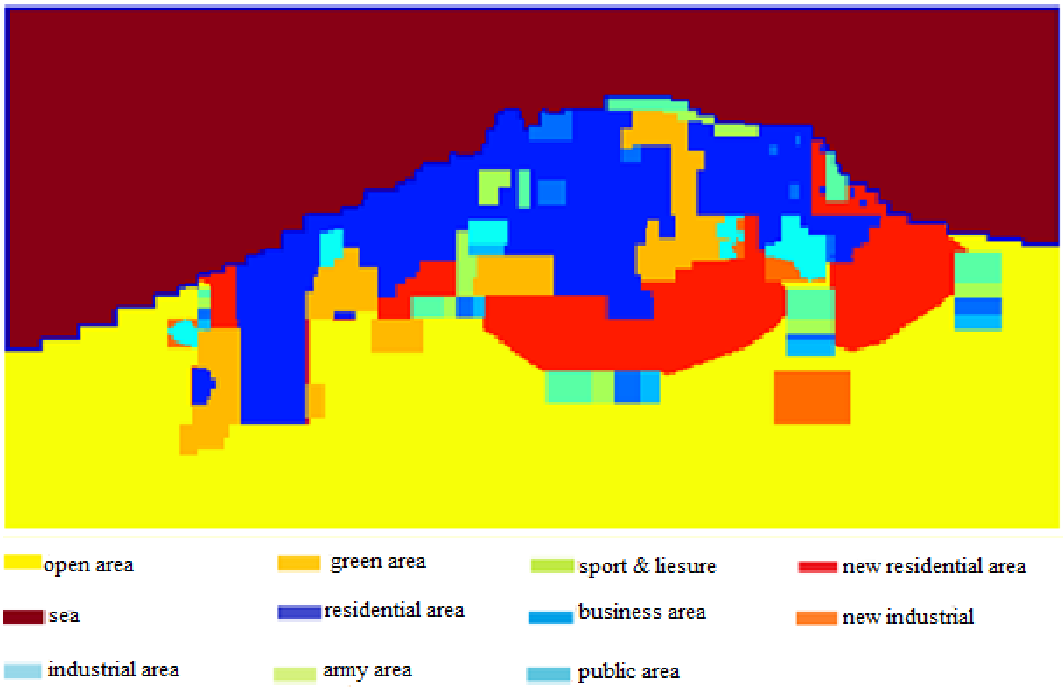

Figure 6.20: Fixed growth Tripoli map in 2040

6.3.3 Increasing Growth Scenario

In this case the growth rate goes up by 0.2% every decade (2% then 2.2% then 2.4%). Figure 6.21 displays the change in residential and industrial zones in 2020, 2030 and 2040. It can be seen that there is rapid expansion over the three decades. Figure 6.22 demonstrates the corresponding rise of population with the sharpest rise during the initial years then a more steady increase. Figure 6.23 shows a constant increase in the residential area over the thirty years, and Figure 6.24 shows the increase in the existing industrial areas' size in the beginning, then the appearance of new industrial areas during the second decade. Finally, Figures 6.25- 6.27 show the shape of the growth. The results are similar to those of the previous scenarios with the exception of the different sizes of residential and industrial areas and number of population. The calculation for the population prediction is 3,259,100 in 2040. Table 6.4 indicates the variety of zone sizes in 2010 and 2040.

Table 6.4: Increasing growth scenario results

	Green Area (km^2)	Public Facilities Area (km^2)	Army Area (km^2)	Sport Facilities Area (km^2)	Industrial Area (km^2)	Residential Area (km^2)	Total Area (km^2)	Population
2010	180.6	22.7	18.5	22.6	43.6	515.1	803.1	1,619,200
2040	180.6	65.5	60.1	44	95	890	1,335.2	3,002,900

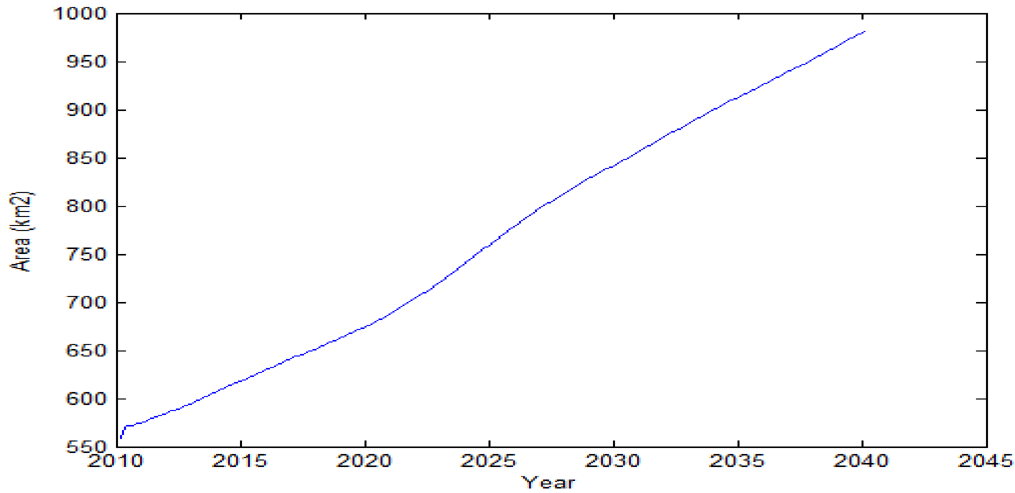

Figure 6.21: Increasing growth residential and industrial areas

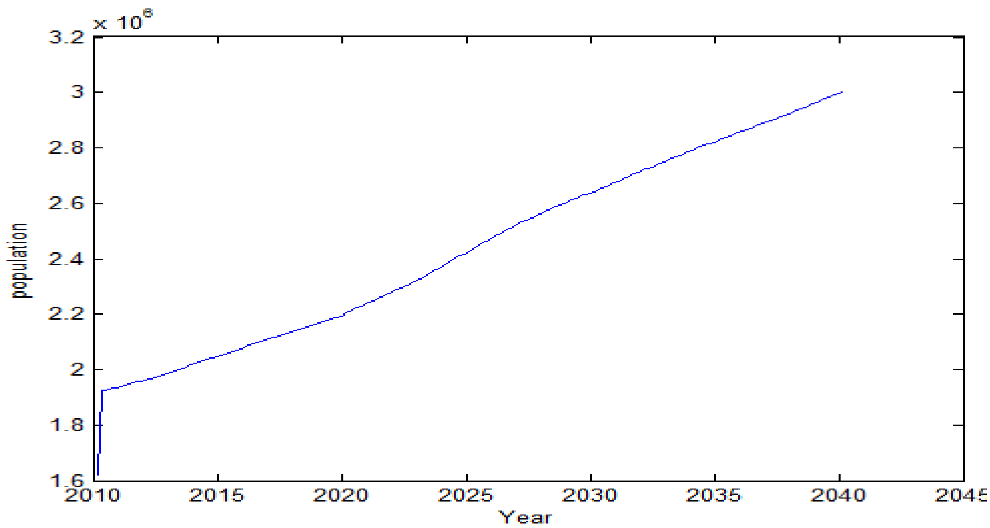

Figure 6.22: Increasing growth total population

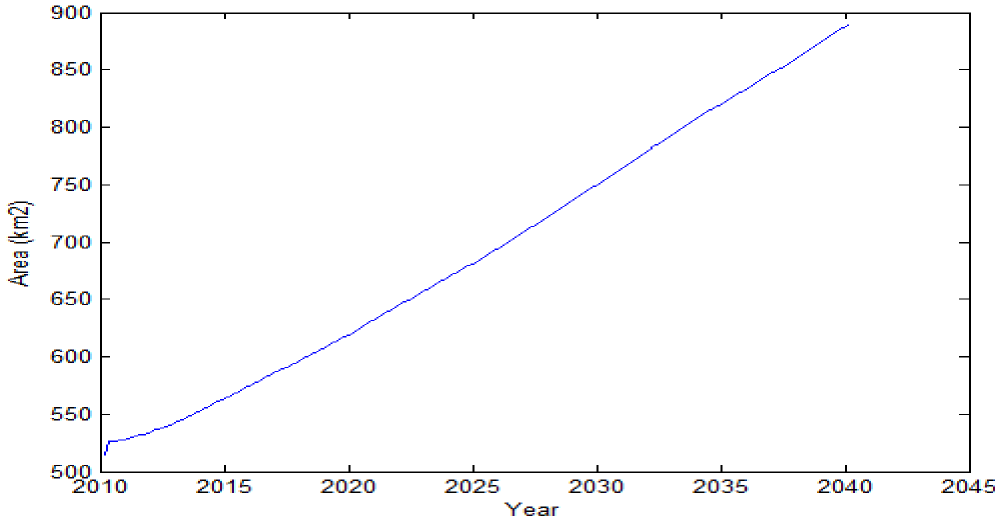

Figure 6.23: Increasing growth residential area

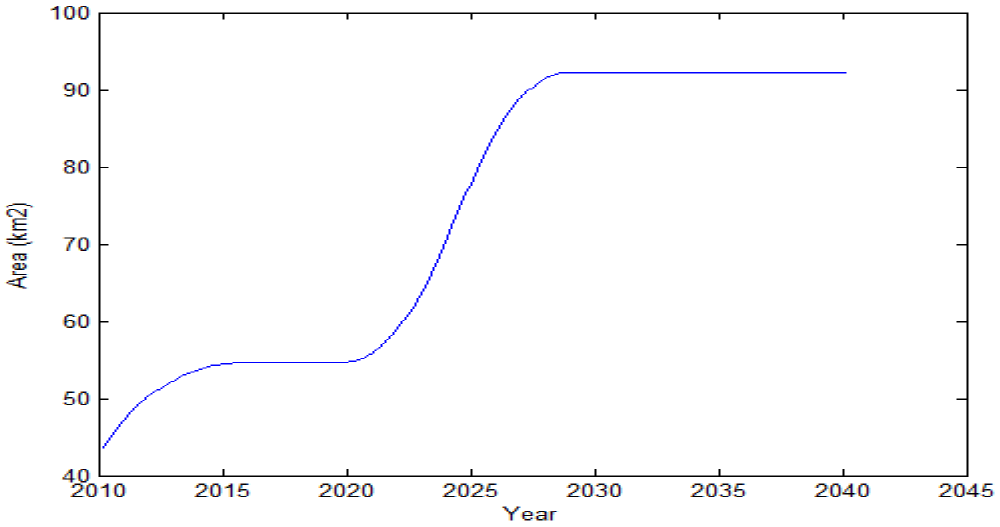

Figure 6.24: Increasing growth industrial area

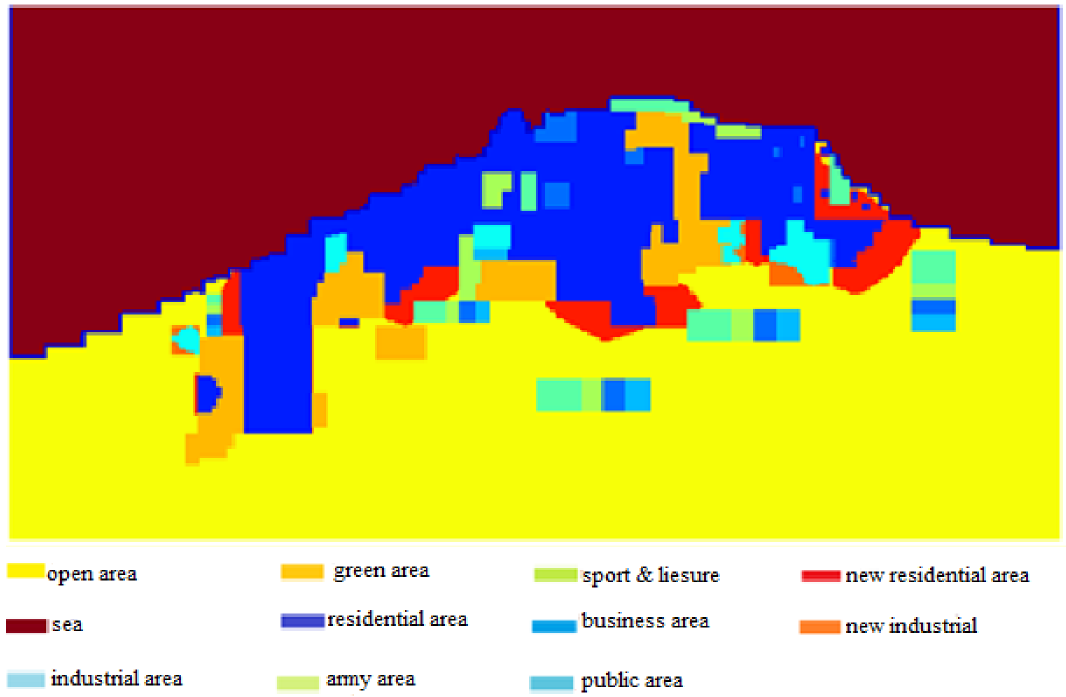

Figure 6.25: Increasing growth Tripoli map in 2020

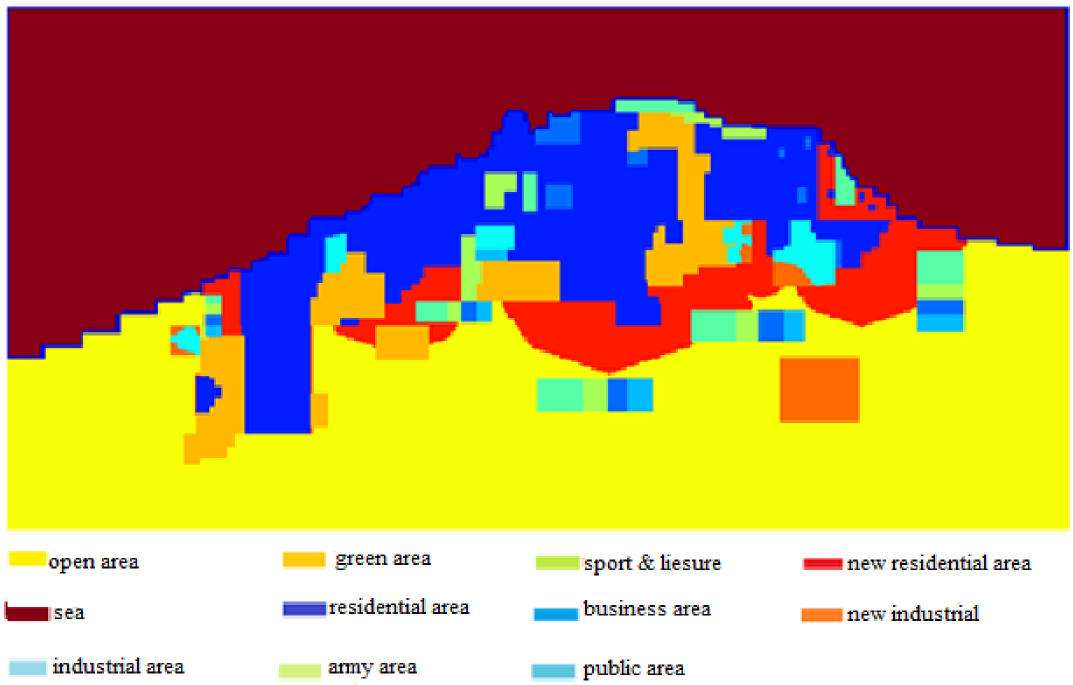

Figure 6.26: Increasing growth Tripoli map in 2030

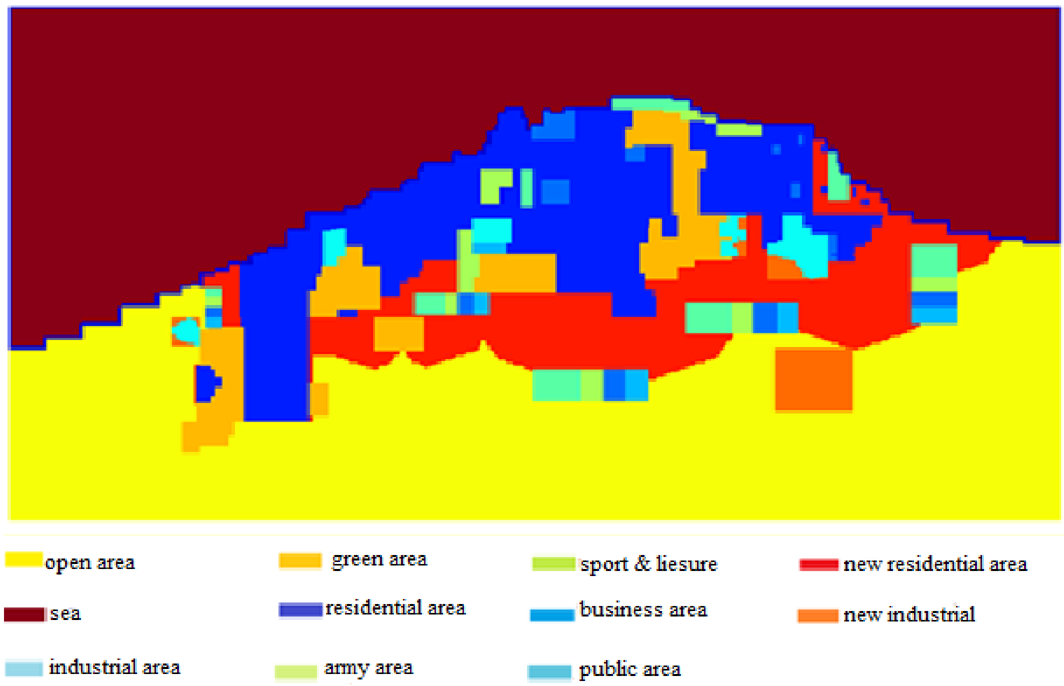

Figure 6.27: Increasing growth Tripoli map in 2040

6.4 Enhanced Model with Population Density

At this stage the predicted population takes account of different densities within the city, with lower density in the west and south-west of Tripoli because of relatively high land prices, related to the availability of potable groundwater (there is no public water network and every house has its own well; this dimension does not apply to other parts of the city, however the area is approximately 8 km from the city centre). Conversely, the east and south-east of Tripoli have higher density, largely due to government construction of residential complexes from late 2010.

In this phase a fuzzy logic file is used with three inputs: population (Figure 6.29) ranging between one and three; area (Figure 6.30) from two to seven; and density (Figure 6.31) from zero to one. Using Gaussian function with 27 rules (Table 6.5) the output is expanded (Figure 6.32) with the range of zero to one.

The difference in the density of the predicted population through the model can be achieved by giving command that at a certain point on the map (almost the middle) the area before this point which is in west of Tripoli has low density and after it the density is high. This phase also made of three scenarios. The block diagram below clarifies the fuzzy file role in the model (Figure 6.28), while the table elucidates the fuzzy rule base. The other figures explain the population, area and density and expand function plots.

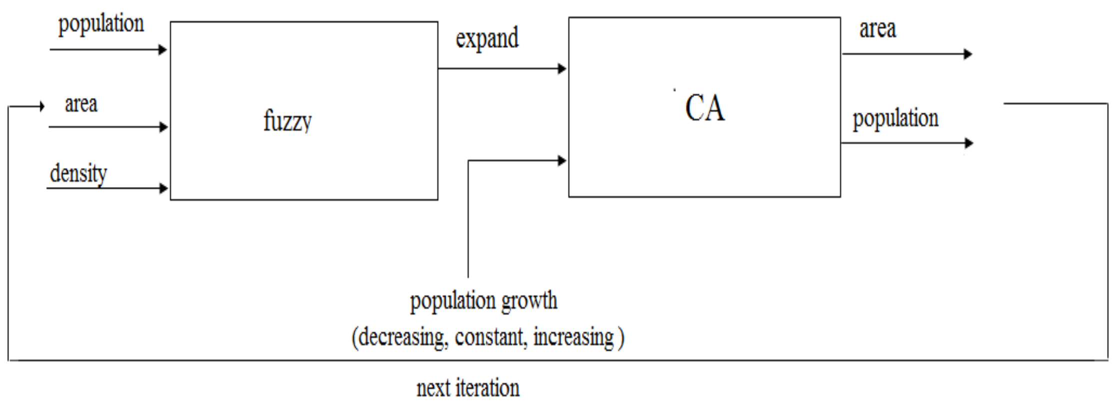

Figure 6.28: Enhanced model block diagram

Table 6.5: Fuzzy logic rule base with population density

Rule	Population	Area	Density	Expand
1	Small	Small	Small	Small
2	Small	Small	Medium	Small
3	Small	Small	High	Small
4	Small	Medium	Small	Small
5	Small	Medium	Medium	Small-Medium
6	Small	Medium	High	Medium
7	Small	Big	Small	Small
8	Small	Big	Medium	Medium
9	Small	Big	High	Medium-Big
10	Medium	Small	Small	Small-Medium
11	Medium	Small	Medium	Medium
12	Medium	Small	High	Medium
13	Medium	Medium	Small	Medium
14	Medium	Medium	Medium	Medium
15	Medium	Medium	High	Medium-High
16	Medium	Big	Small	Medium-Big
17	Medium	Big	Medium	Medium
18	Medium	Big	High	Medium-High
19	High	Small	Small	Small-High
20	High	Small	Medium	Medium
21	High	Small	High	High
22	High	Medium	Small	Medium
23	High	Medium	Medium	Medium-High
24	High	Medium	High	High
25	High	Big	Small	Small-High
26	High	Big	Medium	High
27	High	Big	High	High

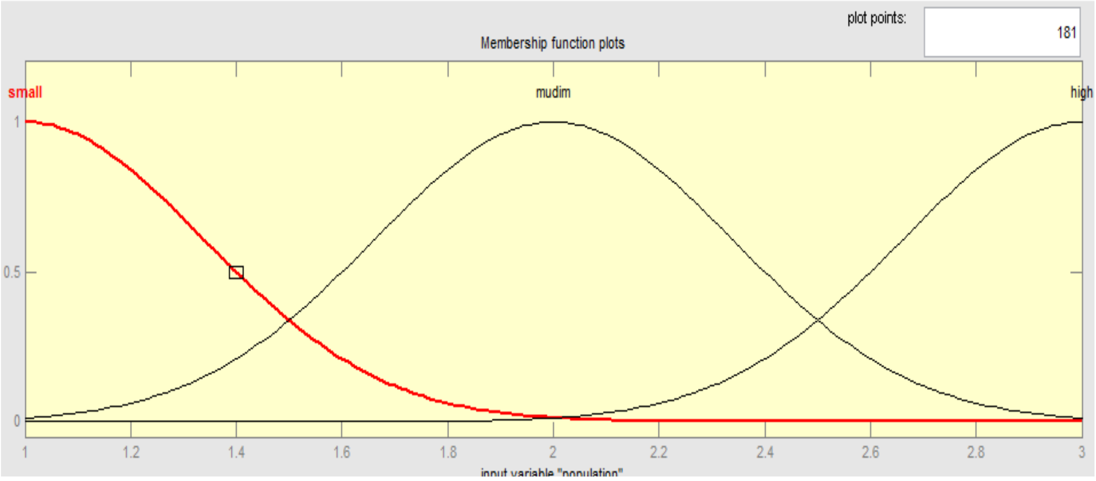

Figure 6.29: Population membership function plots

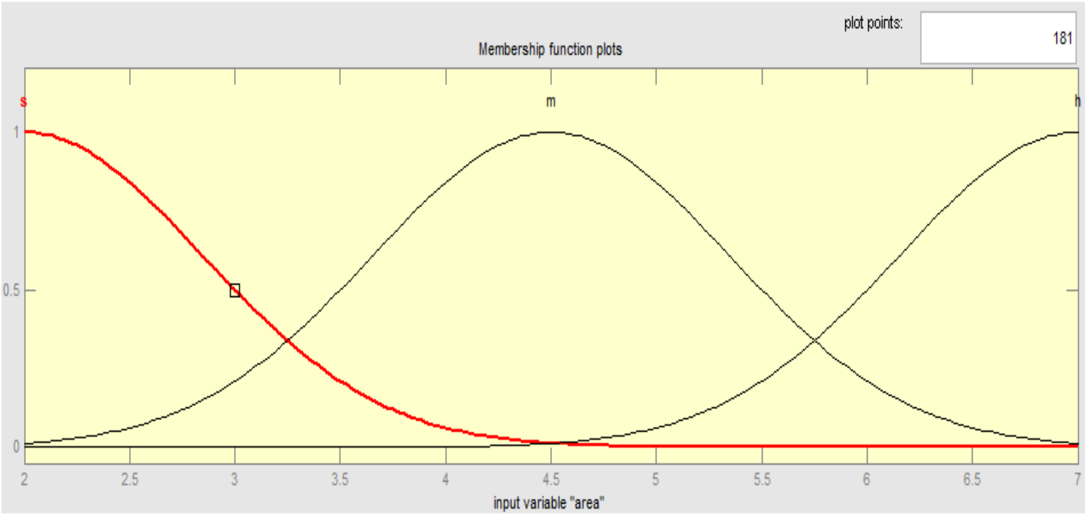

Figure 6.30: Area membership function plots

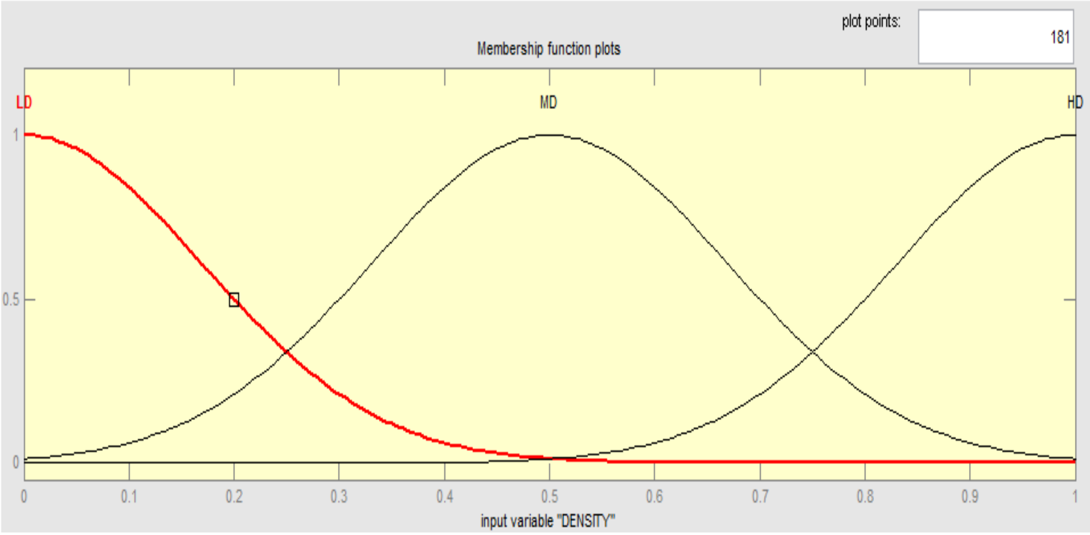

Figure 6.31: Area membership function plots

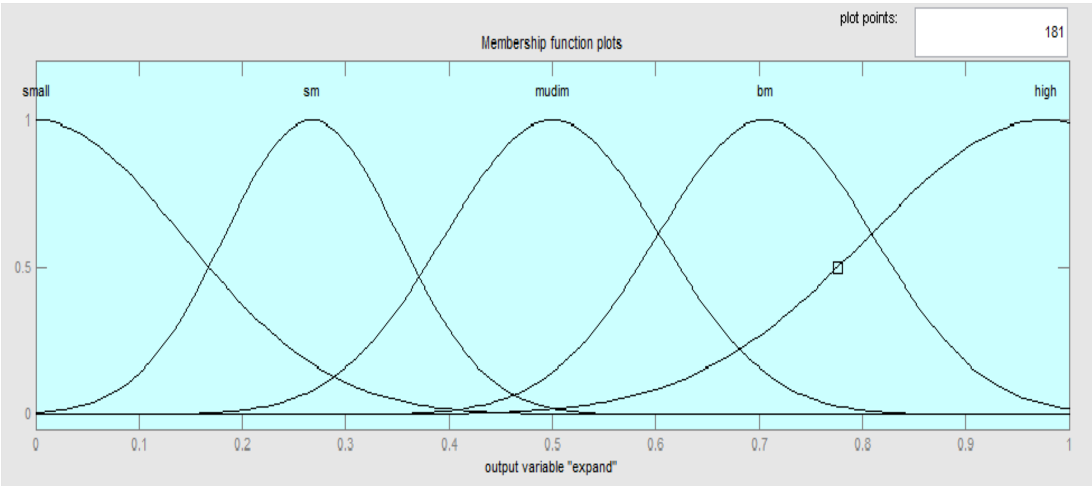

Figure 6.32: Expansion membership function plots

6.4.1 Declining Growth Scenario

The difference between this scenario and the previous decline in growth is the density. In this one, the population prediction for the eastern part of the city is higher than that for the western part and the size of residential area is larger in the east. Figure 6.35 illustrates the expansion in residential and industrial areas every ten years, Figure 6.36 shows the growth in population in 2020, 2030 and 2040, and Figure 6.37 shows the increase in residential areas over the same period. Figure 6.38 explains the expansion in the industrial area over the thirty years and Figures 6.39-6.41 clarify the places of the new residential and industrial areas during the period

2010-2040. The Table 6.6 makes clear the growth in many areas in 2040 and how they were in 2010. The predicted result for this scenario by calculation is 2,575,000.

Table 6.6: Declining growth scenario results

	Green Area (km^2)	Public Facilities Area (km^2)	Army Area (km^2)	Sport Facilities Area (km^2)	Industrial Area (km^2)	Residential Area (km^2)	Total Area (km^2)	Population
2010	180.6	22.7	18.5	22.6	43.6	515.1	803.1	1,619,200
2040	180.6	51.0	43.5	43.3	60.4	695.9	1,002.7	2,535,500

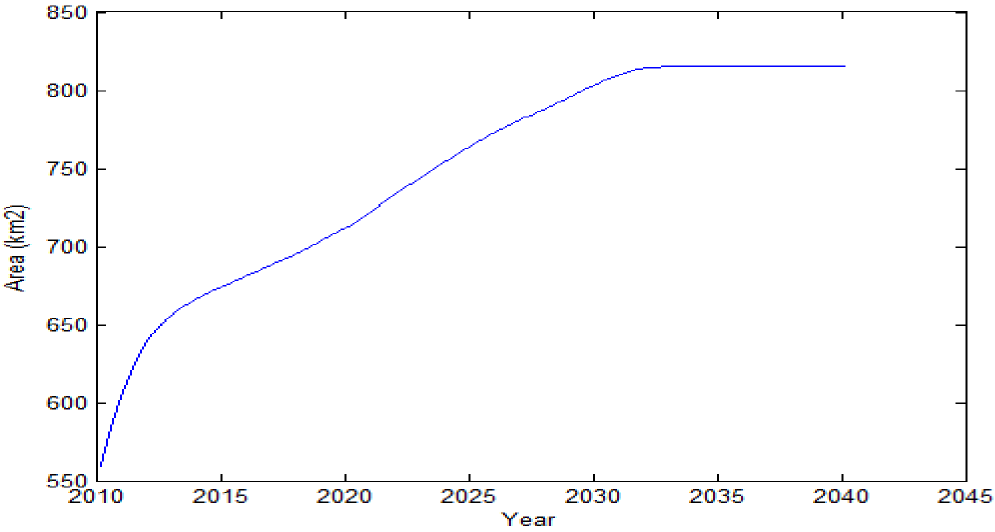

Figure 6.33: Declining growth residential and industrial areas

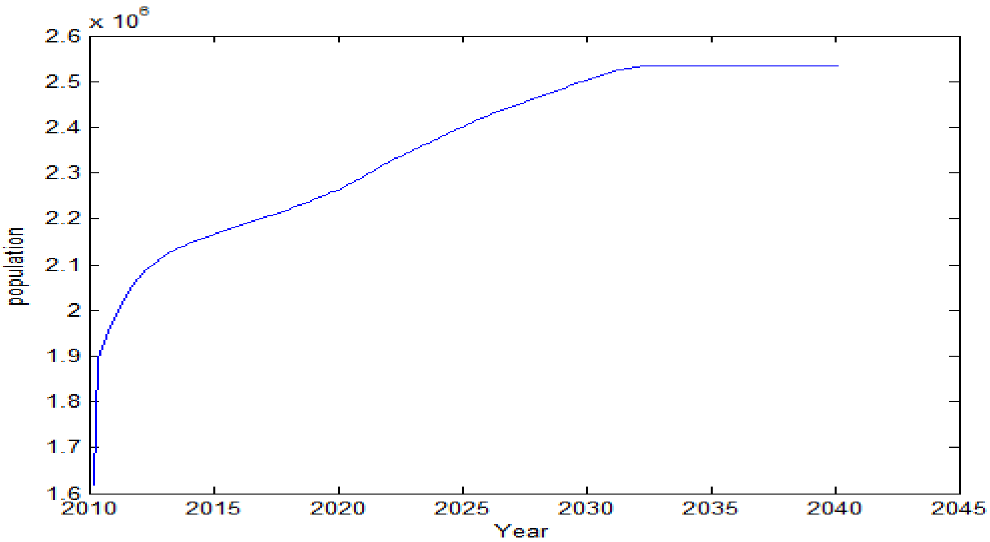

Figure 6.34: Declining growth total population

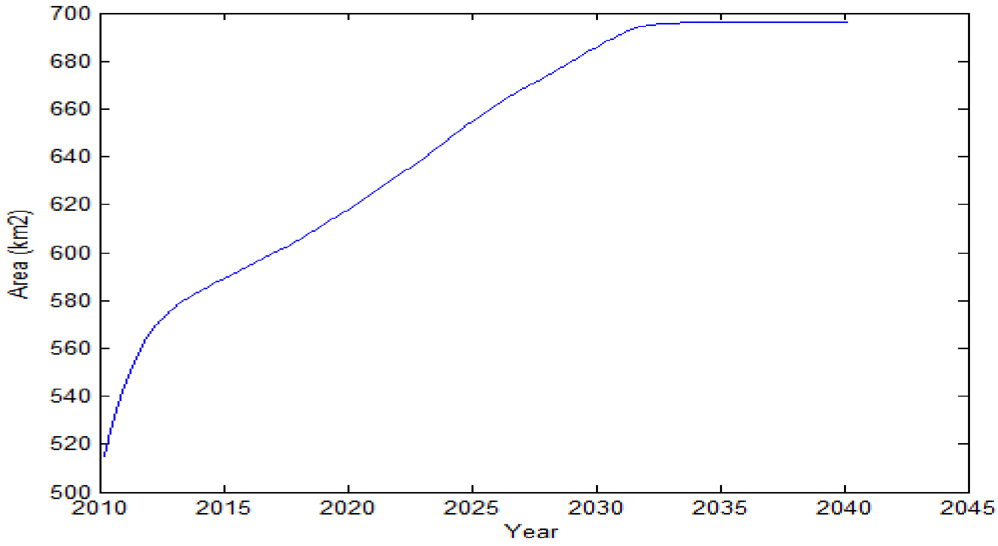

Figure 6.35: Declining growth residential area

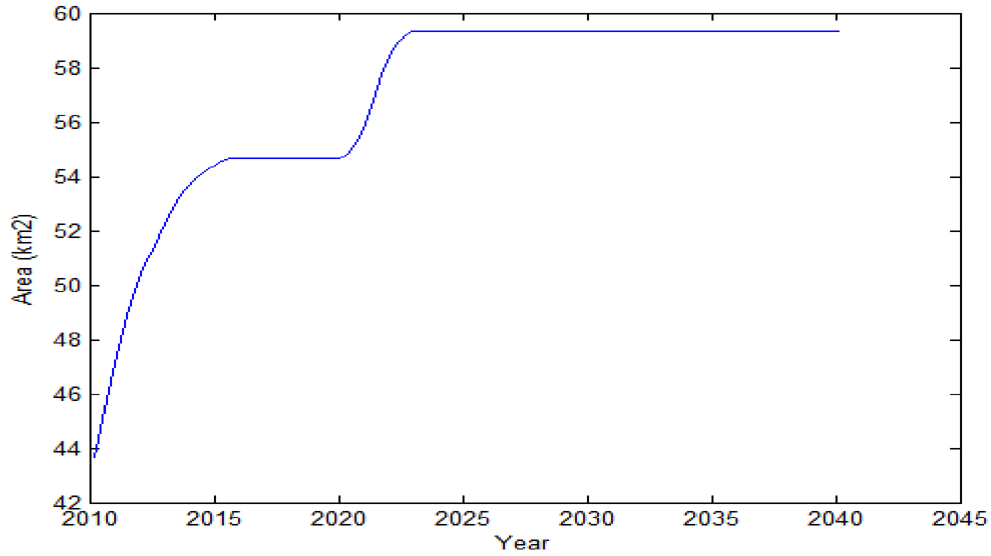

Figure 6.36: Declining growth industrial area

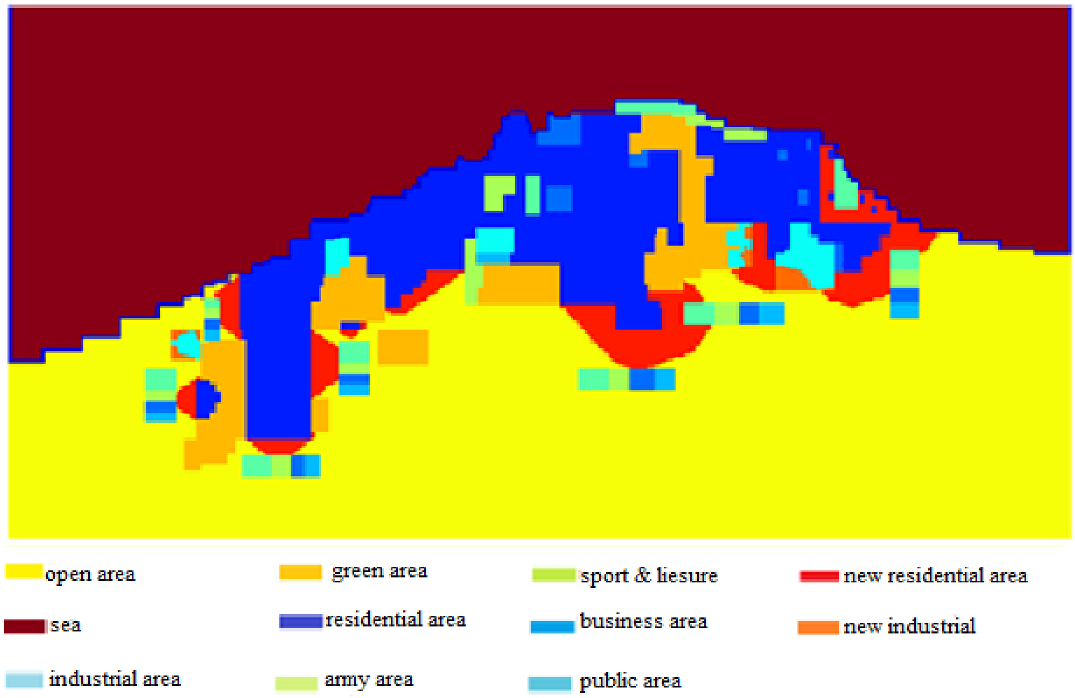

Figure 6.37: Declining growth Tripoli map in 2020

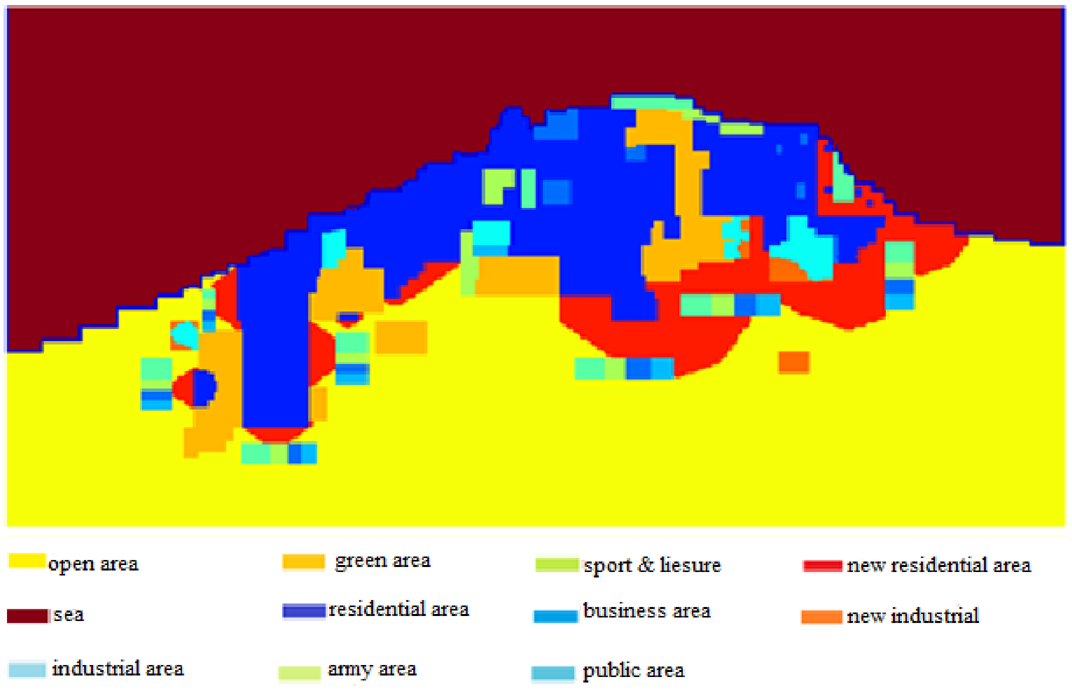

Figure 6.38: Declining growth Tripoli map in 2030

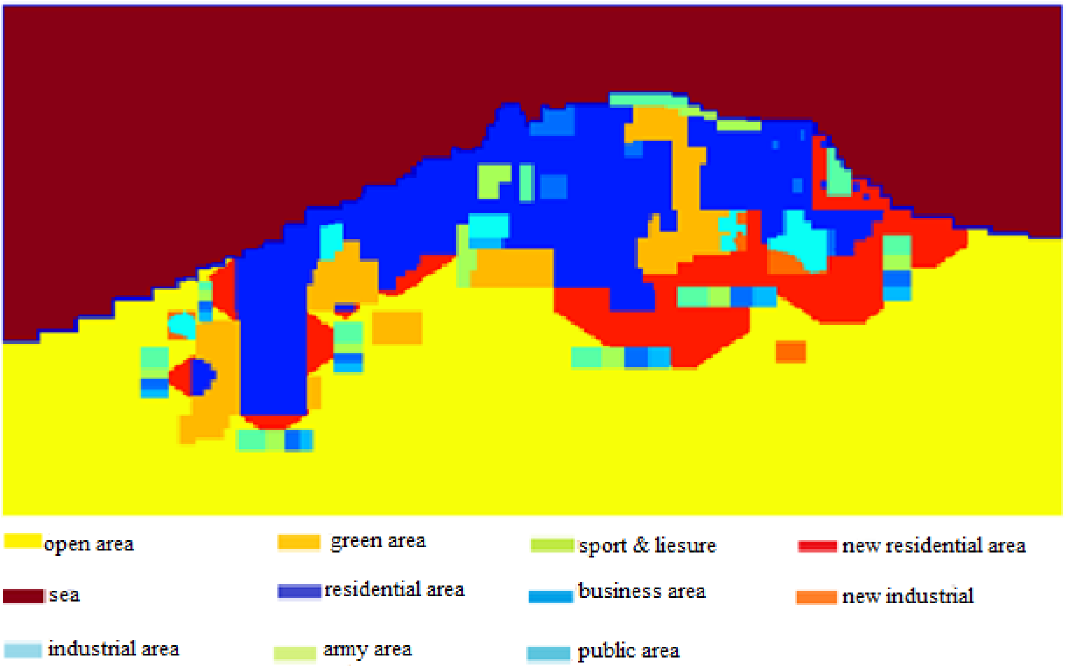

Figure 6.39: Declining growth Tripoli map in 2040

6.4.2. Fixed Growth Scenario

The population growth rate is constant throughout the period of future prediction. The gained results of this scenario are shown in the following figures and tables. Figure 6.40 presents the change in residential and industrial areas over the three decades. It seems that the increase at beginning of first decade is faster than in other years. Figure 6.41shows the rise in population in 2020, 2030 and 2040; there is remarkable accord with the previous figures, with a large initial increase followed by moderate increase for the remainder of the period. Figure 6.42 illustrates the expansion in residential zones steadily throughout the whole period, and Figure 6.43 demonstrates the rise of industrial zones with small increases in the first ten years then a noticeable increase during the second decade due to the suggestion of new industrial areas. Figures 6.44 – 6.46 expand the map.

In 2040 the total population in Tripoli city is 2,898,200 by calculation; Table 6.7 shows the change in different zones between 2010 and 2040.

Table 6.7: Fixed growth scenario results

	Green Area (km^2)	Public Facilities Area (km^2)	Army Area (km^2)	Sport Facilities Area (km^2)	Industrial Area (km^2)	Residential Area (km^2)	Total Area (km^2)	Population
2010	180.6	22.7	18.5	22.6	43.6	515.1	803.1	1,619,200
2040	180.6	51.0	43.5	43.3	67.15	778.4	1,164.0	2,818,500

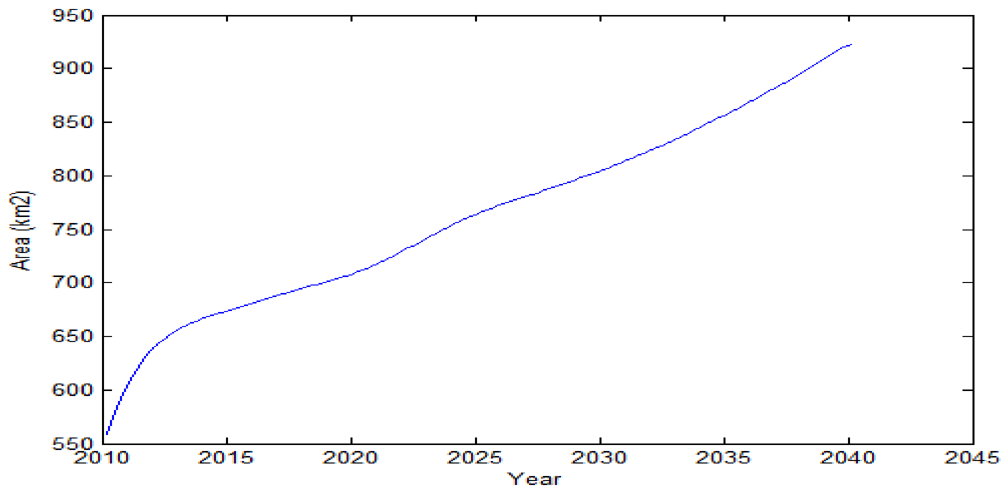

Figure 6.40: Fixed growth residential and industrial areas

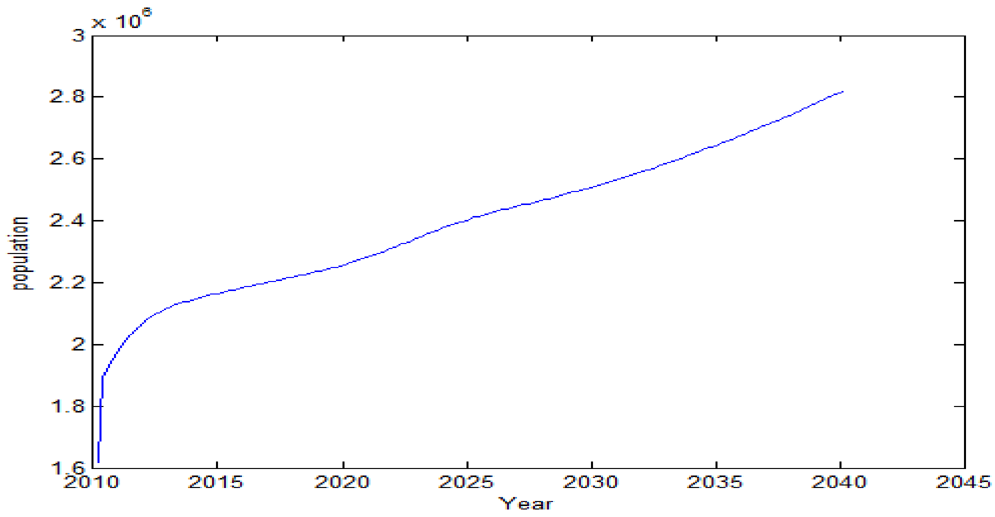

Figure 6.41: Fixed growth total population

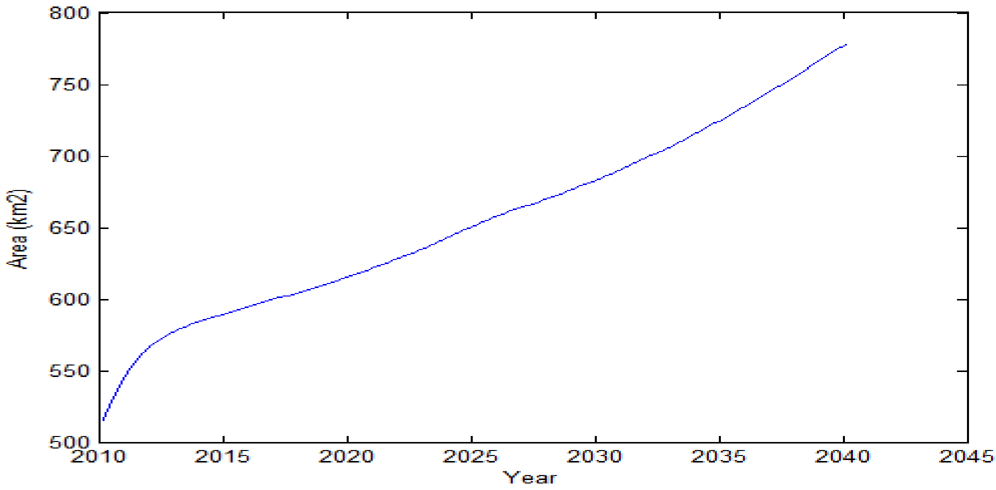

Figure 6.42: Fixed growth residential area

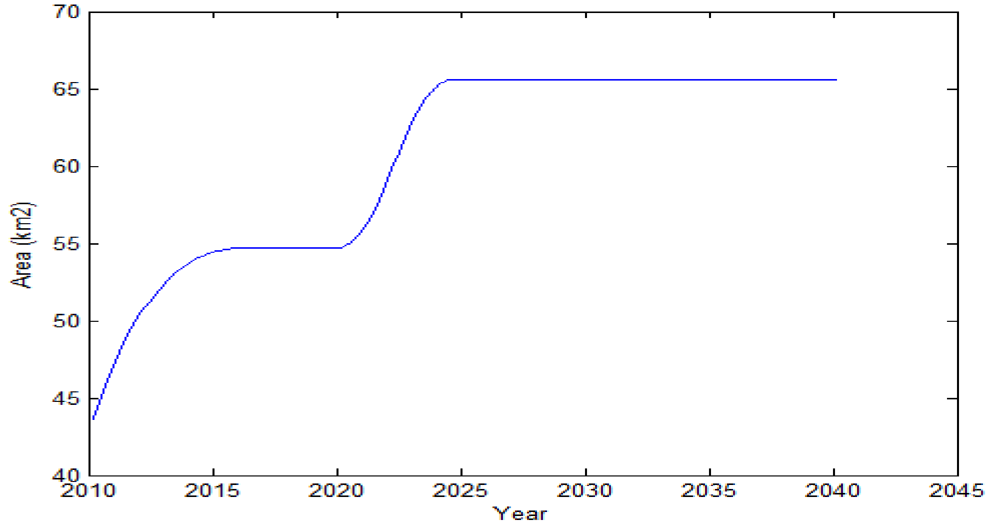

Figure 6.43: Fixed growth industrial area

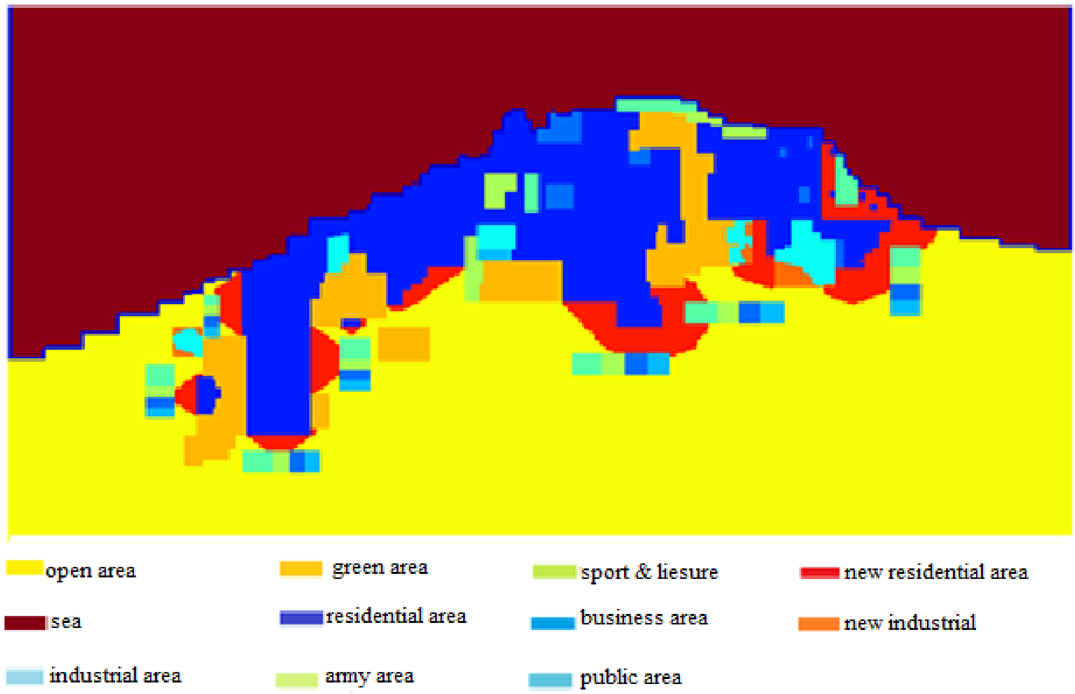

Figure 6.44: Fixed growth Tripoli map in 2020

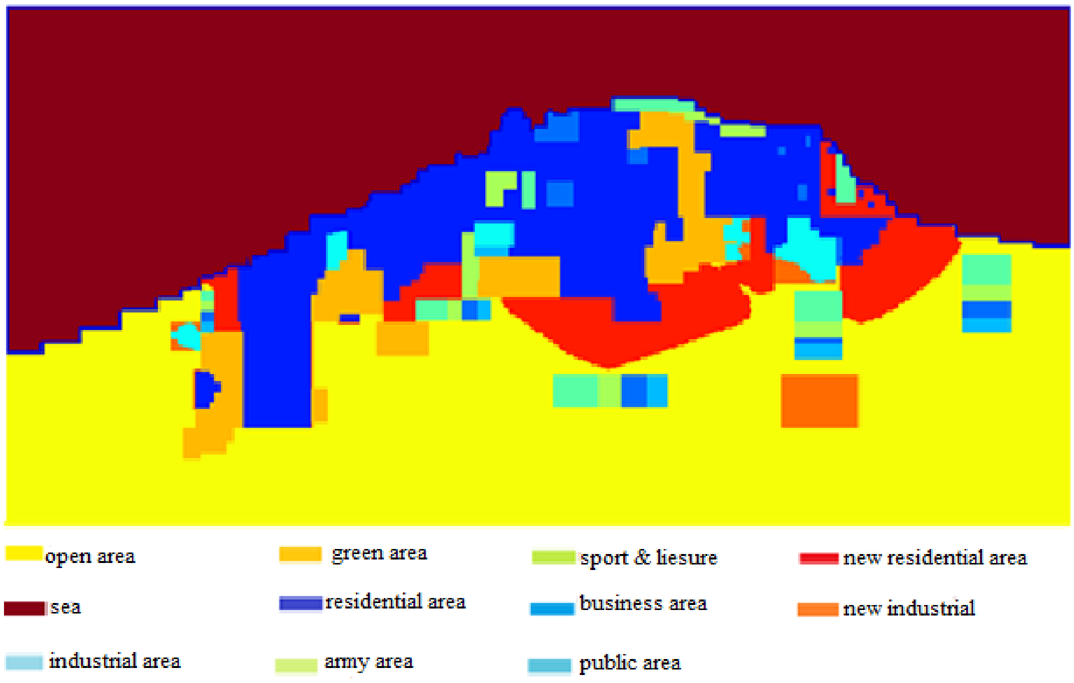

Figure 6.45: Fixed growth Tripoli map in 2030

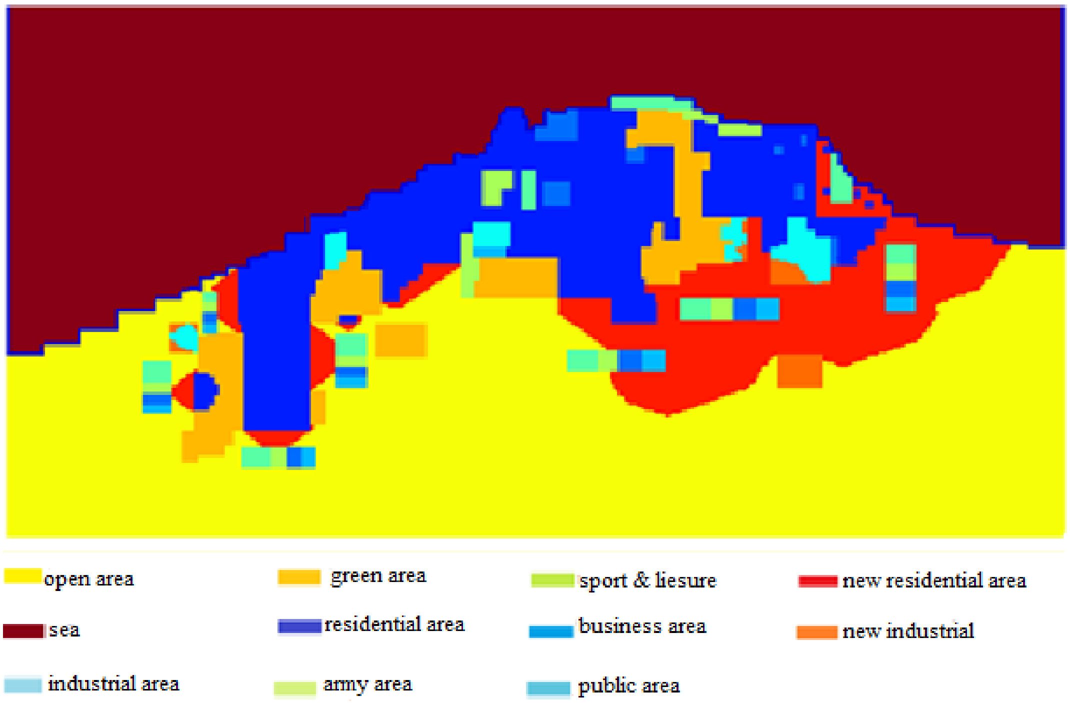

Figure 6.46: Fixed growth Tripoli map in 2040

6.4.3Increasing Growth Scenario

In this scenario the growth rate is increasing every decade by 0.002, as usually the growth increases or decreases gradually, changing significantly only in exceptional circumstances. Figure 6.47 shows the increase in residential and industrial areas over the thirty years, Figure 6.48 shows the increase in population every ten years, Figure 6.49 illustrates the expansion in residential areas in 2020, 2030 and 2040 and Figure 6.50 clarifies the expansion in industrial areas for the same period. Finally, Figures 6.51 – 6.53 map the increase of residential and industrial areas in 2020, 2030 and 2040. The population prediction by calculation 3,259,100 in 2040. Table 6.8 demonstrates the sizes of several zones in Tripoli city in 2010 and 2040.

Table 6.8: Increasing growth scenario results

	Green Area (km^2)	Public Facilities Area (km^2)	Army Area (km^2)	Sport Facilities Area (km^2)	Industrial Area (km^2)	Residential Area (km^2)	Total Area (km^2)	Population
2010	180.6	22.7	18.5	22.6	43.6	515.1	803.1	1,619,200
2040	180.6	70.5	49.3	49.2	95.07	786.9	1,231.5	3,043,700

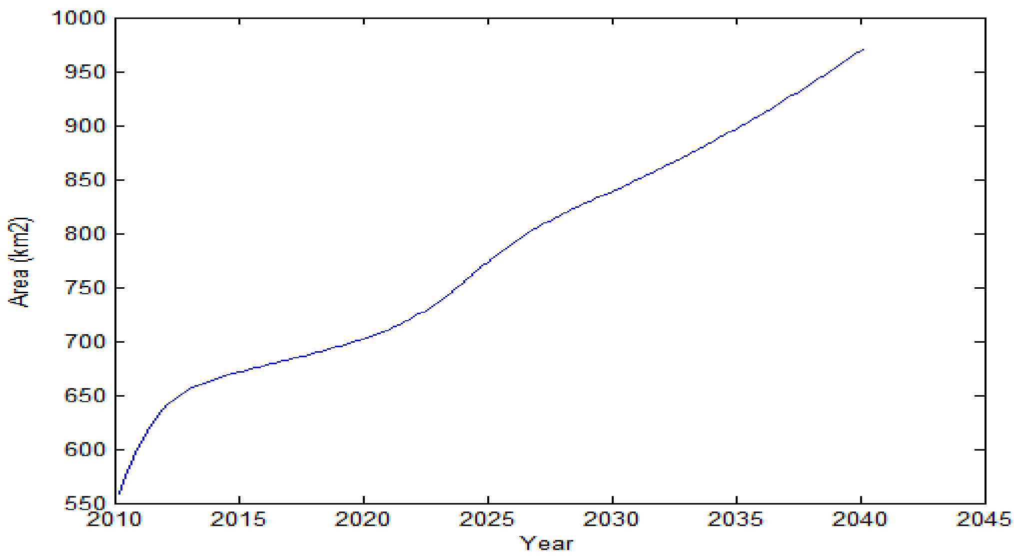

Figure 6.47: Increasing growth residential and industrial areas

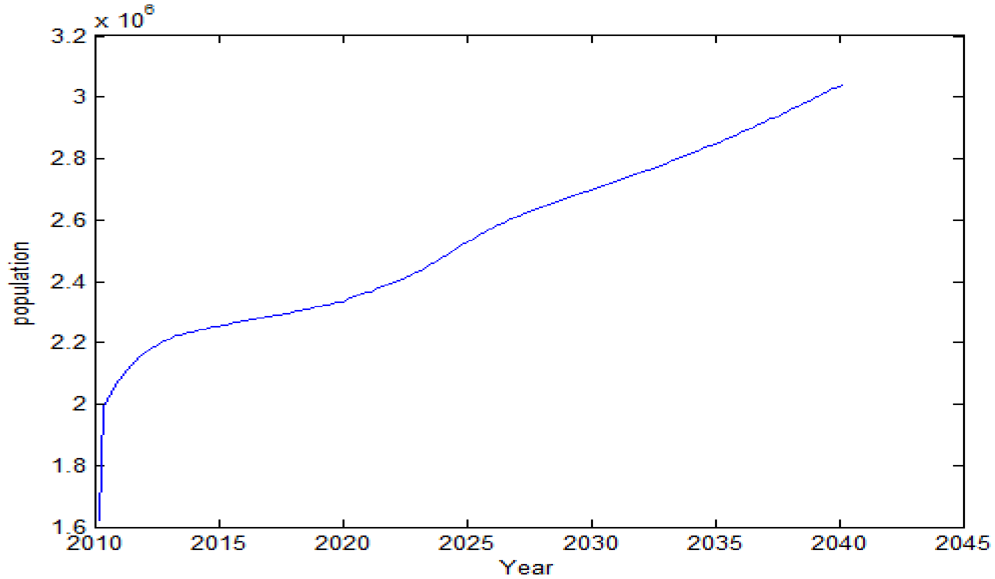

Figure 6.48: Increasing growth total population

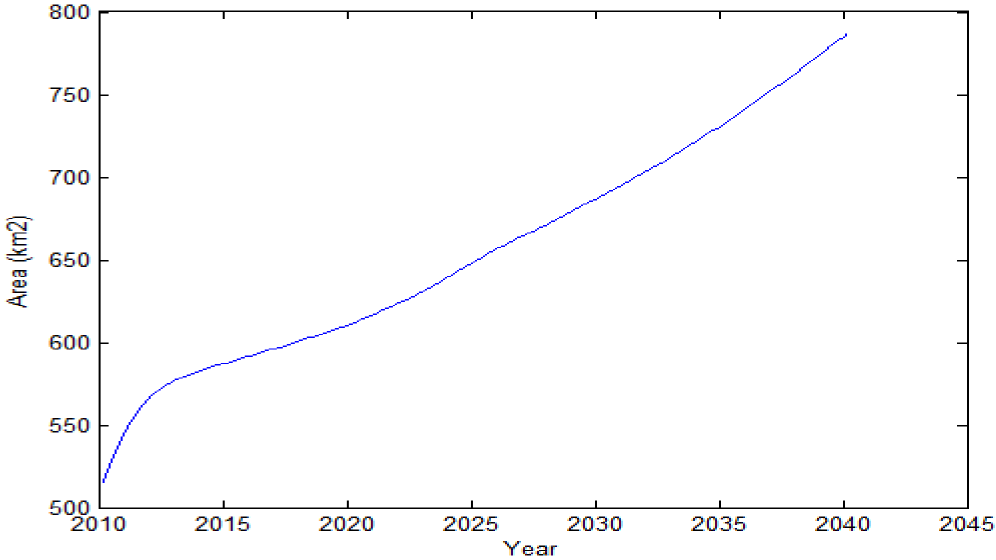

Figure 6.49: Increasing growth residential area

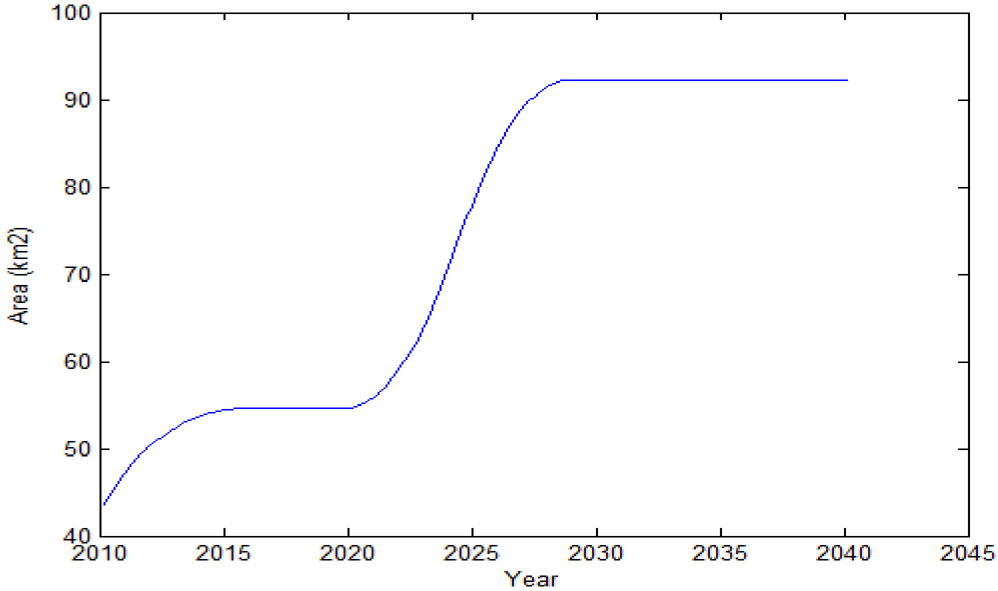

Figure 6.50: Increasing growth industrial area

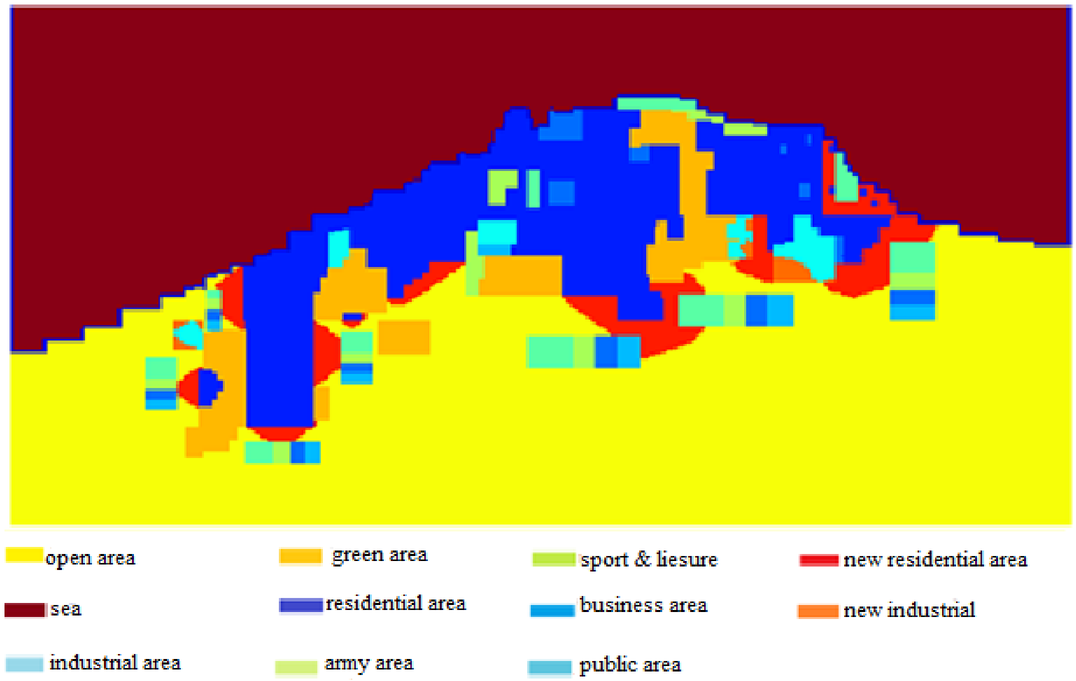

Figure 6.51: Increasing growth Tripoli map in 2020

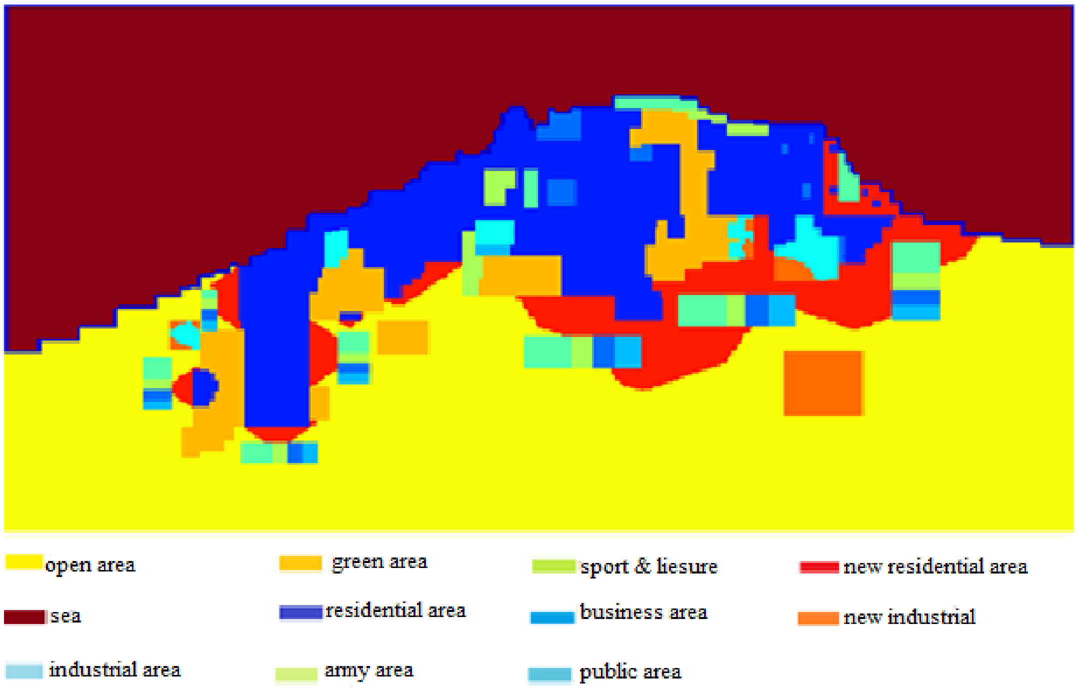

Figure 6.52: Increasing growth Tripoli map in 2030

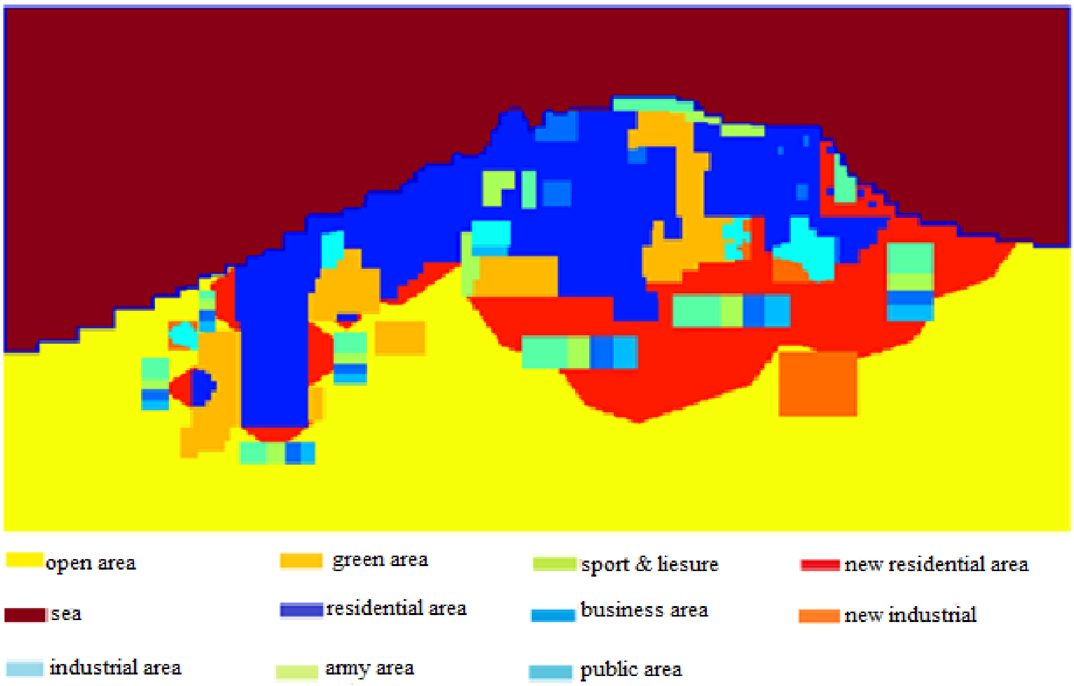

Figure 6.53: Increasing growth Tripoli map in 2040

6.5 Results Discussion

From the tables below it is noticeable that prediction by the validation model is very close to the actual population and size of land (total, residential and industrial), which gives strong proof that the model is efficacious and its results can be relied upon for future prediction and making proper plans. From the future prediction we can observe that the constant scenario in both phases with the same and different densities produced almost the same calculation prediction, whereas the different density phase was closer to the calculation prediction than the other phase except when the constant scenario is opposite (Table 6.9).

In the period between 1980 to 2010 the population almost doubled; as shown in Table 6.10, the total area increased about three times and the residential expanded roughly four times, yet minor expansion occurred happened in the industrial area, largely because national policies and the volatile position of Libya in international trade (e.g. it was intermittently subject to various sanctions) did not favour industrial development.

It seems that areas with the same density are larger than areas with different densities (Table 6.11), which can be explained by higher density areas being intrinsically smaller than lower density areas. For the industrial areas there is no big difference between the same and different density in the three scenarios.

Table 6.9: Population prediction by model and calculation in 2040

Scenario	Prediction with fixed density	Prediction with different density	Prediction using the regression model
Decreasing	2,178,200	2,535,500	2,575,000
Constant	2,885,900	2,818,500	2,898,200
Increasing	3,002,900	3,043,700	3,259,100

Table 6.10: Population and area prediction using the regression model (1980-2010)

	1980	2010	Regression model 2010
Population	784,000	1,600,000	1,619,200
Total area (km^2)	225.3	790.9	803.1
Residential area (km^2)	156.0	509	515.1
Industrial area (km^2)	30.0	41.5	43.6

Table 6.11: Prediction of total, residential and industrial areas in 2040

	Same density			Different density		
	Decreasing scenario	Constant scenario	Increasing scenario	Decreasing scenario	Constant scenario	Increasing scenario
Total area (km^2)	1,018	1,293,9	1,335,2	1,002,7	1,164	1,231,5
Residential area (km^2)	644.5	855.3	890.0	695.9	778.4	786.9
Industrial area (km^2)	60.4	88.4	95.0	60.4	67.15	95.07

6.6 Summary

The results of this research were very encouraging to utilize a technology with great potential benefits for sustainable socioeconomic development. The results indicate that the residential area is the most rapidly expanding in Tripoli during the two stages and the three scenarios; therefore the government must concentrate on this area and prepare in advance for suitable density residential areas and appropriate infrastructure to avoid overcrowding.

Industrial areas are also increasing but much less markedly and in a smaller total area, but this is more subject to the future directions and policies of Libyan administrations. If a significant effort were made to develop industry in Libya after the current instability has passed then Tripoli would be a key location for industrial expansion due to being the capital city, the port city and the largest city in Libya, thus a greater proportion of the city would be for industrial use.

CHAPTER 7: CONCLUSIONS AND FUTURE WORK

7.1 Conclusions

There is no doubt that all inventions and progress in human history, including civilization itself, arose as solutions to the problems people faced. For instance, medicine was invented to treat diseases, transportation to facilitate travel and electricity to perform arduous labour previously performed by the mechanical action of human or animal muscle power. The unique problem of the current point in human development is that the strain exerted by the human population on natural resources and ecosystems is no longer sustainable, due to the intrinsically high population and to the aspiration lifestyle sought by people worldwide.

Modern technology makes it easier and faster to accomplish many tasks with greater cost efficiency, therefore governments should use such tools in all fields in order to develop their countries sustainably and mitigate the impending environmental disaster. This research, essentially a work in electronic and computer engineering, must be seen in the wider context of addressing the global conundrum of how to achieve sustainable economic growth. Thus the applications of the research findings go far beyond the rudimentary data provided for the city of Tripoli.

However, this research is of immediate utility and benefits to the particular city context of Tripoli, which faces acute urban planning problems due to decades of neglect and confusion, which have resulted in random settlements, overcrowding, pollution, a lack of public facilities and poor infrastructure. This thesis can be used to predict trends of population increase and urban expansion by zone, enabling municipal planners to prepare appropriate infrastructure and to ultimately provide sustainable expansion for Tripoli and an improvement in the standard and quality of life for its inhabitants.

When the Libyan government decided to reactivate the dormant national plans it was faced by larger problems because of the erratic layout of existing zones within the wider framework of the city (e.g. the merging of industrial and residential areas). It was thus necessary to remove some areas in total and partly in other places; such urban renovation is much more expensive than proper planning from the outset. Furthermore, the destruction of unplanned structures was as chaotic as the situation that had precipitated them; the government simply destroyed unauthorised structures without building new well planned areas and relocation sites. While the people affected were paid compensation indemnity, this action strongly contributed to increasing the price of houses and land across the city and exacerbated the housing shortage.

The most immediate aim of this research was to help the government by giving it a tool to anticipate future population trends and the size and location of residential and industrial areas, subsequently allowing it to plan in advance for sustainable and coordinated infrastructure development. This research has passed several stages of improvements and developments until it reached a high degree of accuracy and satisfaction. The initial theoretical analysis reviewed many papers talking about theories and tools later used in this research to understand their mechanisms, in order to achieve the research aim and objectives. The practical part was larger and more complex, beginning with land use maps of Tripoli city and rendering them applicable for the model designed to predict the future expansion of the city.

Maps were resized and transliterated in numerical forms between Matlab and Excel, being digitized by image processing prior to establishing the basic model for residential growth only, followed by adding the possibility of expanding the industrial zone. The industrial zone is perhaps the most difficult to anticipate because it has been affected by Libya’s erratic political fortunes over the last century. If the Libyan government were to invest in industrial development in future (which can be anticipated given the scramble for economic diversification among other countries dependent on oil exports, such as the countries of the GCC and Nigeria), this would entail more long-term development and serious investment in infrastructure (electrical, road, rail and port). Thus in practical terms this model is highly effective for residential expansion planning, but extra dimensions must be considered for industrial expansion.

To get more accurate results generally, fuzzy logic files have been added to the model. Population density is uniform initially for the new predicted areas, but in the second phase the density would be different in the new areas predicted, with high density in some places and low in others due to several factors, including land prices, water availability and proximity to the city centre. This research provides an opportunity to know the size of residential area and the population occupying this region in both high or low density in addition to industrial area size in future. All of this could lead the government to develop short- and long-term plans for the future to improve people's standard of living. We hope that this research can contribute to the improvement of people's lives and lead the expansion of cities on the basis of correct urban planning, enabling them to grow sustainably.

The future challenge is to persuade governments to apply this model more widely; it is believed that the accuracy of the results are strong enough to persuade governments to adopt this model in putting the future plans for urban expansion, but for government personnel not familiar with computer science this may require a leap of faith.

7.2 Future Work

All research is capable of improvement for certain applications, and this research can be improved over time and for other places; it is flexible enough to accept significant adjustments.

- There are several factors affecting the implementation of national plans and size of projects in countries, one of the most important of which is the fundamental factor of the national economy, which essentially determines projects' size and duration. Some countries allocate a large part of their budgets to urban expansion while others aim to decentralise and disperse their urban populations. A third group of countries outsource the whole problem of urban planning to private companies (under planning authority regulations).

- In developing countries governments are still held accountable for providing people with houses, public services and infrastructure. Nations with relatively strong economies can build large projects within reasonable time periods while impoverished countries are forced to reduce the size of the projects and wait longer for delivery due to lack of funding, therefore the prediction for new residential and industrial areas will be dependent on national economic potential. We believe that the model would be improved by including this factor.

- The second factor that determines the size of projects and time needed for completion is national policy; some countries consider agricultural production to be the main source of national income, thus such countries prefer to have areas with high population density rather than devoting agricultural areas to residential use, to protect their agricultural production. Other countries focus on industrial production, subsequently the expansion of industrial areas in these countries (and the provision of infrastructure to industry) is prioritised over residential development (and possibly public health). Non-industrial countries often have a mixture of residential and industrial areas, typically with factory workers living close to work. Taking this factor into account would improve the results obtained from the model.

- The third factor that influences the expansion of cities is the social factor of popular demand. It is noticeable that in some cities where residents have more aspirational lifestyle, property near natural beauty (e.g. the sea or hillside regions) is preferable. Considering popular demand according to social desires and natural factors specific to cities would improve the performance of the model.

- Cellular Automata is widely use in medicine because the similarity of CA and cells in human body for that it will be useful to adapt and implement the improved form in medicine into this field.

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APPENDIX

Appendix 1

```
File  Edit  Text  Go  Cell  Tools  Debug  Desktop  Window  Help
Stack: Base
1.0  1.1

        for i=2:m-1
            if xx(i,j)==8;
                kk1=0;
                kk2=0;
                rr1=0;
                rr2=0;
                %adjucent
                if (xx(i,j-1)==2)|(xx(i,j-1)==11),  rr1=rr1+x2(i,j-1); kk1=kk1+1; end;
                if (xx(i-1,j)==2)|(xx(i-1,j)==11),  rr1=rr1+x2(i-1,j); kk1=kk1+1; end;
                if (xx(i+1,j)==2)|(xx(i+1,j)==11),  rr1=rr1+x2(i+1,j); kk1=kk1+1; end;
                if (xx(i,j+1)==2)|(xx(i,j+1)==11),  rr1=rr1+x2(i,j+1); kk1=kk1+1; end;
                % corners
                if (xx(i-1,j-1)==2)|(xx(i-1,j-1)==11),  rr2=rr2+x2(i-1,j-1); kk2=kk2+1; end;
                if (xx(i-1,j+1)==2)|(xx(i-1,j+1)==11),  rr2=rr2+x2(i-1,j+1); kk2=kk2+1; end;
                if (xx(i+1,j+1)==2)|(xx(i+1,j+1)==11),  rr2=rr2+x2(i+1,j+1); kk2=kk2+1; end;
                if (xx(i+1,j-1)==2)|(xx(i+1,j-1)==11),  rr2=rr2+x2(i+1,j-1); kk2=kk2+1; end;
                kks=kk1+kk2;
                rrs=rr1+rr2;
                if kk1>7 kk1=7; end;
                if kks>7 kks=7; end;
                if kk1<1 kk1=1; end;
                if kks<1 kks=1; end;
                % density selection
                if j>400 density=med_density; else density = low_density; end;
                if rr1>3/factor;
                    x1(i,j)=11;
                    rc=1+rc;
                    pc=pc+density;
                    pred1=evalfis([pop_g rr1*factor density],rb_fis);
                    %disp([1 pop_g rr1 pred1]);
                    x2(i,j)=pred1;
                else
```