Chapter 4
Data Preparation and Processing

4.1 Introduction

This chapter first comprises an overview about the available data, data characteristics, the source of data and the preparation procedure with explanations. Then, the trend of change will be analysed by means of temporal mapping through Landsat images at different times. The amount of urban sprawl will be measured and predicted for forthcoming years.

4.2 Data Acquisition and Data Collection

In this research, various sorts of data such as multi-spectral and temporal satellite images, a set of environmental, terrestrial attributes, and socioeconomic data were gathered. A temporal coverage of Landsat imagery from different sensors was collected. This temporal coverage includes satellite images of MSS, TM, and ETM^+ within the past 27 years. These satellite images were acquired through the Earth Science Data Interface of the Global Land Cover Facility, and also, the Earth Resources Observation & Science Centre (EROS) of US Geological Survey. A set of high resolution aerial photos of the study area were gathered in order to check ground control points. These satellite images were employed to extract land use and land cover maps. Also, the other collected data included demographic details of Tehran's metropolitan area, extracted through the last accomplished available demography statistics. This sociological information was downloaded from the webpage of the Iranian statistic centre. Additionally, a geodatabase of environmental and urban features such as topography, hydrology, building blocks, transport network, farming land and prepared land use maps was gathered through several sources (e.g. Tehran GIS centre and other affiliated organisations). These data were stored in different scales. A brief description of the utilised data is demonstrated in Table 4.1.

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Table 4.1 A description of the utilized data in detail

Type of dataset	Resolution/ scale	Source
Landsat images (MSS, TM, ETM+)	30 m	EROS
Geodatabase of existing features (e.g. transport network, streams, airports, administrative divisions, etc.)	1:25,000 1:50,000	Statistical centre of Iran, National Cartographic Centre (NCC), Iranian Space Agency (ISA)
Land use map	1:50,000	Tehran GIS centre
Digital elevation model	30 m	Tehran GIS centre
Demography data	1:50,000	Statistical centre of Iran

4.3 Data Processing

The prepared geodatabase of urban features and environmental elements that were collected through multiple sources had to be matched in terms of a geodetic reference system, scale and file format. ESRI Shapefile was chosen as the base file format and all the data were converted to this format. Topographic data, after preparation and missed data corrections, were converted to a digital elevation model (DEM). A set of topographic factors such as slope, aspect, and hillshade was produced, and all the gathered data were imported into the geodatabase.

Remotely sensed imagery is a generally recognised crucial source for land use change monitoring. The aforementioned satellite images were collected and stored on a hard drive in order to do signal processing and remote sensing analysis to achieve land use/cover maps. Therefore, after a preview of on-hand images and the removal of cloudy ones, a combination of images were produced for temporal analysis. A regular set of 10-year stage images of 1986, 1996, 2006 was chosen, and the gathered demography and socioeconomic data were converted to spatially explicit data with the aim of compatibility with other geodatabase datasets. The gathered data were controlled in terms of quality and certainty (e.g. data georeferencing). However, it should be noted that in this section this procedure is simply touched upon.

4.4 Temporal Land Use Map Extraction Through Remote Sensing

The prepared land use maps of 1986, 1996, and 2006 were obtained through the Tehran GIS centre. After a comparison with the actual situation of Landsat satellite images, some misclassifications were found in the maps. Hence, it was vital to update these land use maps with the Landsat images and also the aerial photos to achieve more accurate land use maps. These maps were classified into six categories such as open land, agricultural land, water bodies, industrial area, residential area and public parks.

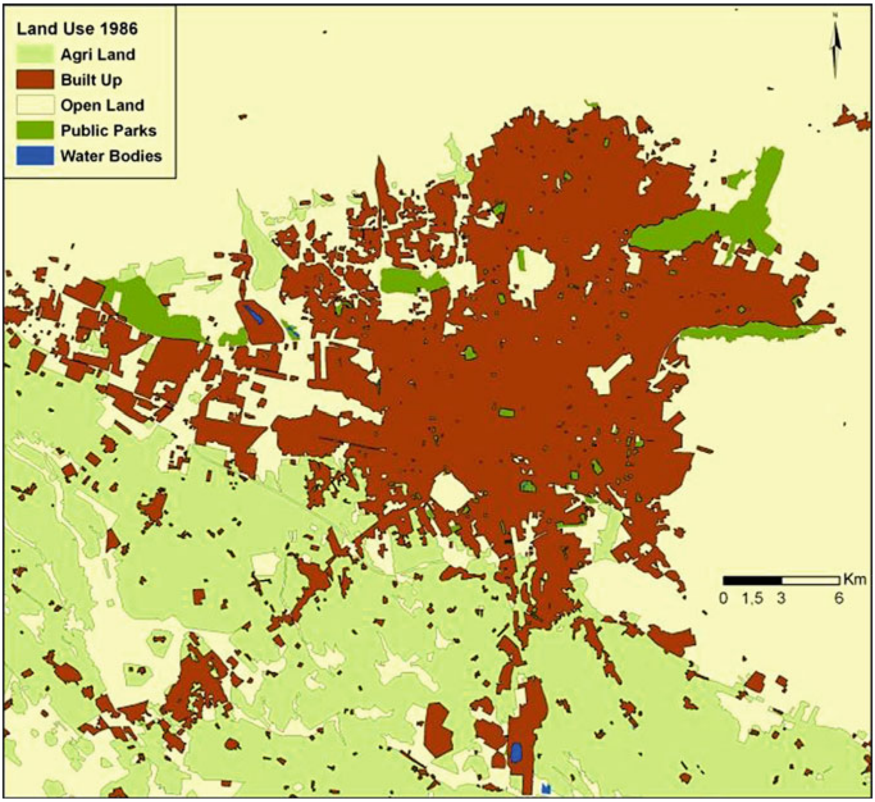

Fig. 4.1 Final extracted land use map of 1986

The finalised land use maps were eventually produced by overlaying remote sensing data, prepared land use maps, implementing various remote sensing techniques. These maps are the source maps of this research which are shown in Figs. 4.1, 4.2 and 4.3. The accuracy assessment process was done through Kappa index calculation. The accuracy of these maps was significant, since they are intended to be utilised as the base input files for simulation. Moreover, the six classes mentioned above were summarized into five categories by combining residential and industrial areas into the built-up class. This process avoided more possible complications arising from the discovery of industrialised zones, and reduced the computation process.

4.5 Temporal Mapping and Changes Visualisation

The prepared land use maps are shown in Figs. 4.1, 4.2, and 4.3. These maps demonstrate the land use pattern of the study area. This temporal mapping onstrates that Tehran is a centralised city with outward expansion. These maps

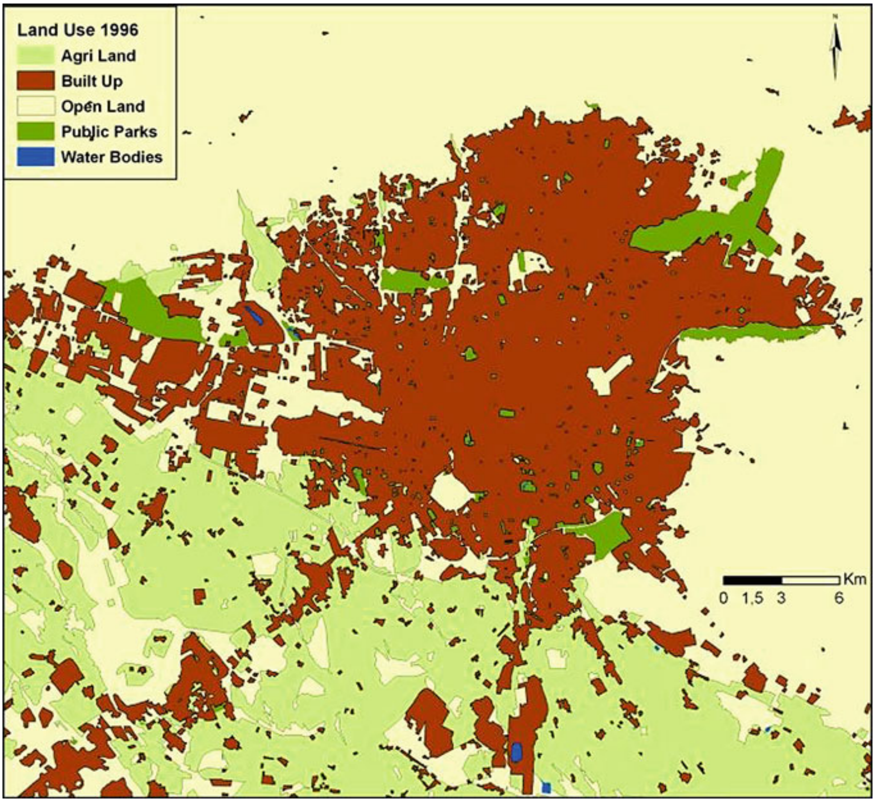

Fig. 4.2 Final extracted land use map of 1996

show that the changes have taken place mainly in north-west towards the south-eastern part of the border (anti-clockwise). In fact, high mountains in the northern and eastern parts of the city do not allow for more expansion; however, some expansion is still taking place.

Finally, the prepared land use maps of 1986, 1996, and 2006 were stored in the created geodatabase.

4.6 Evaluation of Change Trends

This temporal land cover mapping allows us to track the quantity and location of changes. The area of each land class was retrieved and imported to Table 4.2. The quantity of each land category in different years is shown in this table. Obviously, the trend towards the expansion of built-up areas over agricultural lands and open lands has been closely monitored; however, a nominal attempt to extend the

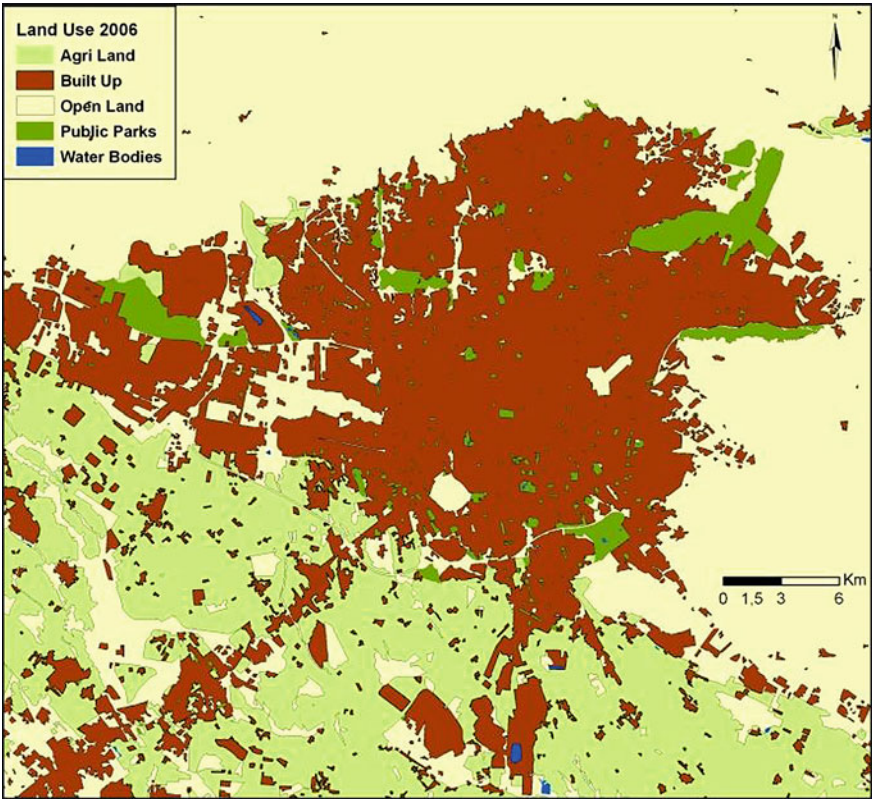

Fig. 4.3 Final extracted land use map of 2006

number of public parks and green leisure areas has been pursued by the municipality.

The results in Table 4.2 and Fig. 4.4 show that the percentage of built-up areas has been accelerating from 24 to 28%, up to 32%. This trend has resulted in the reduction of the farming area and open lands at a rate of 24 and 50%; 22 and 47%; and 21 and 44%, respectively. Consequently the mass of open lands and

Table 4.2 Land use type portions during the past 20 years

Land use type	Area 1986 (ha)	Area 1996 (ha)	Area 2006 (ha)
Agricultural land	45,174	41,172	40,005
Built-up	44,772	53,056	59,095
Open land	92,276	87,305	81,741
Public park	4,076	4,744	5,394
Water bodies	102	123	165

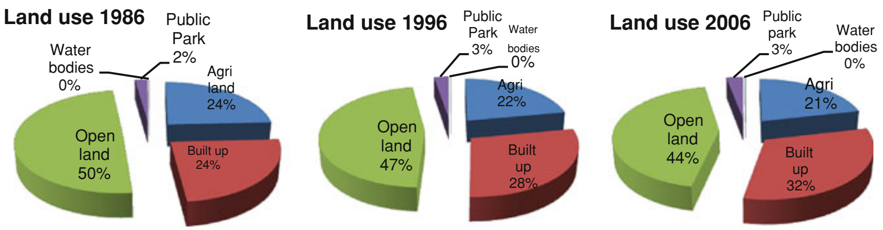

Fig. 4.4 Measurement of land use change between 1986 and 2006

agriculture have suffered on account of urban development. Despite this fast growing urban sprawl the fact remains that in some districts of Tehran, the height of buildings generally is not particularly high; however, the potential for vertical growth in the metropolis remains a real possibility.

Although, this study is not an attempt to measure high-rise built-up development, but it is a fact, nonetheless, that the cityscape is becoming higher in construction. This phenomenon is being driven by the growing need for more urban accommodation and business outlets, which is more affordable for residents and developers. Yet through this third dimension of vertical urban expansion the possibilities of further land change occurrence are minimalised. Again, it should be stressed that this trend towards vertical built-up expansion is not the intention of this research, but might be of interest to urban managers for future consideration.

According to Table 4.3, significantly about 4,000 ha of agricultural fields and more than 5,000 ha of open lands were taken over for urban development between 1986 and 1996. This records an increase in the quantity of built-up areas to around 8,300 ha in total. During this 10-year period, between 1996 and 2006, nearly 6,000 ha of agricultural fields and open land areas were converted to built-up development. This extensive city sprawl is one of the consequences of large migrations towards this metropolis, to meet the needs of the massive influx of people. Additionally, during this 20-year period (1986–2006), approximately 10,000 ha of open land area, along with 5,000 ha of agricultural fields, were converted into built-up areas. This represents an 8% increase in urban built-up environment at the expense of natural land, revealing a growth in urban development from 24% in 1986 to 32% in 2006.

Table 4.3 Quantification of changes between 1986 and 2006 in terms of hectares

	1986	1996	2006	1986–1996	1996–2006	1986–2006
Agricultural land	45,174	41,172	40,005	−4,002	−1,167	−5,169
Built-up	44,772	53,056	59,095	8,284	6,039	14,323
Open land	9,2276	87,305	81,741	−4,971	−5,564	−10,535
Public park	4,076	4,744	5,394	668	650	1,318
Water bodies	102	123	165	21	42	63

4.7 Measuring Change and Sprawl

The acquisition and conversion of farming land and open land on the fringe of cities into built-up areas is, by definition, urban sprawl. It is the aim of this thesis to measure the extent of this phenomenon.

Therefore, in order to predict the extent of this change in these fringe areas, previous occurred and anticipated values of change need to be taken into account. In academic terms and according to Torrens and Alberti (2000).

> Sprawl is a highly contentious issue—neither its determinants nor its characteristics are fully understood.

In recent years, researchers have performed conceptual investigations of the sprawl phenomenon, such as its characteristics, causes, and potential controls. A variety of methods to provide a better understanding of urban growth have been discovered by respective experts to measure sprawl. Theoretical discussions on the subject of sprawl have created a wealth of discussion around the matter. Urban sprawl is a practical, real world issue of considerable concern. Therefore, the sense of urgency that prevails with regard to the sprawl problem, creates an extreme need for more theoretical discussion to improve current methodologies (Torrens and Alberti 2000).

According to Table 4.2, within 20 years, around 14,000 ha of built-up area have been constructed by destroying roughly 50,000 ha of farming area, as well as 11,000 ha of open lands, which could have been used to expand green spaces or farming development.

Although urban expansion brought expectations of more public parks and green areas, no such increase of parkland has been observed.

An increase in the number of parks and green spaces for the Tehran metropolis, to especially combat air pollution, would seem of prior importance, thus urban planners need to take this issue into account. In fact, air pollution accounts for a number of deaths per year. From a landscape planner's aspect, a balance between urban development and the creation of green space should be a priority. However, it seems the municipality of this metropolis was not able to create new green spaces within the second period (i.e. 1996–2006).

4.8 Socio-Demographic Changes

Tehran has been confronted with various socio-demographic changes within recent decades. These changes have been caused mainly by three considerable conditions: first, change in governmental policy over family structure and childbirth numbers following the 1979 revolution; second, the population lost during the Iran-Iraq war, which encouraged people to support this loss; and thirdly, the mass of migration from other cities to Tehran to find work, to study and secure a better

Table 4.4 Tehran city, province and study area population details

	1966	1976	1986	1996	2006
Tehran city population	2,980,041	4,530,223	6,042,584	6,758,845	7,797,520
Study area population	2,981,047	4,580,515	6,257,713	7,024,295	8,154,691
Tehran province population	3,455,537	5,313,143	8,095,124	1,0343,965	13,413,348
Country population	25,788,722	33,708,744	49,445,010	60,055,488	70,472,846
Tehran city share of province (%)	86.20	85.30	74.60	65.30	58.10
Tehran province share of country (%)	13.40	15.80	16.40	17.20	19.00

standard of living. Altogether, these conditions have created significant urban pressures within Tehran to accommodate these socio-demographic changes.

According to Table 4.4, there are some significant conclusions which can be deduced as follows:

1. The population of Tehran city has been growing exponentially since 1966.
2. The population of Tehran province, within the country as a whole, has been increasing, proven by the mass migration towards this province from other provinces.
3. The population share of Tehran city, as of Tehran province, has been decreasing significantly, which means the majority of migrants tend to settle in suburban areas and, moreover, nearby cities have been developing even more quickly than Tehran (see Fig. 4.5).
4. The overview determines that nearby cities are housing a huge and growing number of provincial inhabitants, and their proximity to the metropolitan core is becoming increasingly less, i.e. this trend can cause a continuous homogeneous metropolis with many complications.

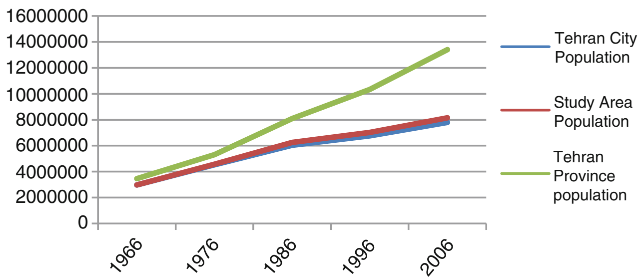

Fig. 4.5 Population growth in Tehran city in comparison with the metropolitan area

Table 4.5 Population density per area unit

Year	Residents population (Person)	Occupied area (ha)	Construction per capita (Person/ha)
1986	6,257,713	44,772	139.7
1996	7,024,295	53,056	132.4
2006	8,154,691	59,095	138.0

4.9 Measuring Per Capita Construction

Construction per capita is an often reported and commonly compared statistic for measuring the number of domestic residents in a city. Population density is the measurement of the number per unit area. It is commonly represented as people per hectare/square kilometre, which is consequent simply by dividing the total area population (i.e. those who have settled in a region) by region area. This calculation implements a straightforward mathematical method which is given in Eq. 4.1.

$$Construction\ per\ capita\ (Person/ha) = \frac{\text{Residents population (Person)}}{\text{Builtup Area (ha)}} \tag{4.1}$$

Equation 4.1 was executed to obtain this index for the past. The mean value of the three past periods was used to predict this index for forthcoming periods (see Table 4.5). Thus, by means of this index, as well as predicted population, the quantity of developed lands for the future can be determined, which is shown in Sect. 4.10.

4.10 Estimation of Change Demand

The quantity of change demand can be calculated through two possible ways: by retrieving via the Markov chain model, or through the extrapolation of statistical demographic data.

- *Markov chain model*: This model is able to predict the next status of change according to the previous status; therefore, a transition area matrix is produced by this model indicating the amount of change between existing categories. Table 4.6 presents the anticipated amount of change for the forthcoming period, which is in this example 2016. This matrix indicates that approximately 1,605 ha of agricultural land will be replaced by built-up areas by 2016. The same table for 2026 has been produced.
- *Statistical extrapolation*: The other possible method to predict land change demand is to calculate the index of construction per capita for the future. Then, the average value of this index can be calculated to input the equation, to incorporate the predicted population for 2016, 2026 as provided by the Iranian statistic centre. The index was calculated in Sect. 4.9 for the previous time points (i.e. 1986, 1996, and 2006). Hence, it is feasible to predict the anticipated amount of change, the

Table 4.6 Transition areas matrix of the Markov model for 2016 in terms of hectare

	Agricultural lands	Built-up	Open lands	Public parks	Water bodies
Agricultural lands	37,424	1,605	871	69	9
Built-up	214	58,326	324	206	2
Open lands	1,175	4,702	75,355	448	26
Public parks	10	47	35	5,290	7
Water bodies	4	2	0	1	158

Table 4.7 Statistical extrapolation of construction per capita index for 2016 and 2026

Year	Residents population (Person)	Occupied area (ha)	Construction per capita (Person/ha)
1986	6,257,713	44,772	139.77
1996	7,024,295	53,056	132.39
2006	8,154,691	59,095	137.99
2016	9,940,964	72,711	136.72
2026	11,553,771	84,508	136.72

assumption being to input the average construction per capita index for the next steps (i.e. 2016, 2026). Therefore, population was statistically predicted to obtain the expected amount of change. This means that change was quantified by this technique. In Table 4.7, the estimated amount of resident population in the study area, and construction per capita index are shown. In fact, the demand of change for the built-up class alone can be projected through this method, whereas the area of the other existing classes could not be estimated in this way. Thus, the Markov model is able to predict quantity of change for each particular land type.

4.11 Summary

In this chapter, the process of preparing the utilised data has been explained and also, a temporal mapping of land use change in the study area represented. The quantity of change has been analysed statistically and, therefore, the urban sprawl accordingly measured. In addition, socio-economic changes within the selected time periods have been taken into consideration.

As a final point, the forthcoming changes have been estimated through two different scenarios to be employed in the change allocation process.

Reference

Torrens PM, Alberti M (2000) Measuring Sprawl, CASA Working Papers (27). Centre for Advanced Spatial Analysis (UCL), London, UK