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Sustainability: An Effective Approach for Land Use Management - Application to Gaza City

By

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ABESTRACT

The current understanding of the causes of land-use change is dominated by simplifications, which in turn, underline many environment-development policies that led to unsustainable situation in Gaza City. Therefore, this research aims at establishing an integrated land-use management framework for Gaza city based on cause-effect relationship within sustainability context. It also aims at establishing a prediction model for the relationship between the most influential socio-economic, environmental and institutional indicators that had shaped the current land-use status of the city for the period 1967-2003. The methodology presented in this research work, offers opportunities to simulate the future demand of the different land-uses based upon actual land-use conditions and other determinant factors. The determinant variables of land-use changes have been identified and prioritized using statistical analysis and Artificial Neural Network (ANN). The results were compared with other statistical techniques and expert opinions. ANN prediction model helped in drawing scenarios for future development. Combinations of socio-economic, environmental and institutional variables in addition to the actual land use for the last four years are used as a basis of land-use change explanations and modeling. These pathways indicate that land-use policies and projections for the future must not only capture the population indicators as the only drivers for land-use change but also account for the specific human resource development indicators and urban-environmental conditions. This recognition requires moving beyond some of the simplifications that persist in much of the current understanding of the causes of land-use change and its driving forces. The analysis of the local expert's opinions provide evidence support the conclusion that the simple answers found in population growth, poverty and infrastructure rarely provide an adequate explanations of land-use changes. Rather, social responses follow from changing economic conditions, mediated by institutional factors are the real causes for land-use changes in Gaza. Therefore integration of socio-economic, institutional and environmental factors as well as recognition of the increasing role of policies is required to meet the future challenges and moving towards sustainability.

Keywords: Land-use management; Sustainability; Modeling; Artificial Neural Network; Socio-economic; Environment; Gaza; Palestine

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LIST OF ABBREVIATIONS

ANN	Artificial Neural Network
BZU	Birzeit University
CPC	Central Planning Committee
DPSIR	Driving force-Pressure-State-Impact-Response
DSR	Driving force-State-Response
EEA	European Environmental Agency
EPD	Environmental Planning Directorate
FAO	Food and Agriculture Organization
GIE	Gaza Industrial Estate
HPC	Higher Planning Commission
ICLEI	International Council for Local Environmental Initiatives
IUCN	International Union for the Conservation of Nature
LPC	The Local Planning Committees
LU	Land Use
LUCC	Land Use and Cover Change
MA	Multi-agent
MCA	Multi-criteria analysis
MCA	Multi-Criteria Analysis
MEnA	Ministry of Environmental Affairs
MLR	Multiple-Linear Regression
MOJ	Ministry of Justice
MOLG	Ministry of Justice
MOPIC	Ministry of planning and International Cooperation
PCBS	Palestinian Central Bureau of Statistics
PNA	Palestinian National Authority
PSR	Pressure-State-Response
PWA	Palestinian Water Authority
SD	Sustainable Development
SEEI	Socio-Economic, environmental and institutional indicators
SQS	Status Quo Scenario
TDS	Total Dissolved Solids
UN	United Nations
UNDP	United Nation Development Program
UNEP	United Nations Environment Program
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNRWA	United Nations Relief and Works Agency
WHO	World Health Organization
WSSD	World Summit on Sustainable Development

GENERAL INTRODUCTION

GENERAL INTRODUCTION

Land is scarce in the Palestinian territories, particularly in Gaza Strip where the population pressure is high and land-uses are changing rapidly. The changes in land-use are usually associated with negative environmental impacts mostly in urban areas compared with rural areas. The land-use changes, mostly, are represented in an intense land-use conversion from agriculture to residential areas and infrastructure facilities. This expansion of urban areas has led also to intensive generation of waste resulting in deterioration of the limited natural resources. Consequently, an environmental dilemma may occur in the foreseen future. Sustainability of urban land-use management in Gaza Strip is a challenge. It requires new concepts and approaches if management should be based on concrete objective and scientific findings (Al-Agha, 1997; Enshasi, 2000).

Several studies investigated different frameworks for Land-use management in many cities of the developing countries (Verburg et al., 1999; de Koning et al., 1999; Veldkamp et al., 2001; Whitfored et al., 2001; Alshuwaikhat, 2002; Pauleit et al., 2004; Weber, 2003; Veldkamp and Verburg, 2004). However, few studies combined integrated Land-use management with sustainability concept.

Since 1994 the responsibility for Land-use planning was transferred to the Palestinians according to Oslo Agreement in 1993. From that time Gaza city started to be the administrative capital of about one million inhabitants living in the Gaza Strip and attracted most of the Palestinian returnees from Diaspora. Since that time, Gaza has shown tremendous increase in its population and change in Land-use. These changes were combined with increased pressure on natural resources such as land and water and increased demand on infrastructure and services for the existing and new the urbanized areas (MOPIC, 1998).

The research is based on a case study of the Land-use in Gaza City as an example of the Palestinian cities. Gaza City is the major city of the Gaza Strip and it is the highest populated city in Palestine with about 400,000 inhabitants (PCBS, 2003). Also Gaza city is one of the most populated cities in the Middle East with a density of 13,970 persons/km^2 compared to Amman-Jordan and Beirut- Lebanon which have 12,500 and 10,700 persons/km^2 respectively at the mid of the year 2003 (PCSB, 2003; DOS, 2003; Beirut Municipality, 2003).

Research Problem

Gaza city has a continuous rapid changes in its land-uses mainly expansion of its built-up area, which has grown more than double its size in the last 37 years, it increased from 15.2 to 32.6 km^2. These changes in land-use were ineffectively managed with inability of the local institutions to mange this rapid urban expansion in a sustainable manner. Consequently, the current land-use practices in Gaza have been characterized by inadequate management approaches that lacks comprehensive and integrated land-use management framework which balance the relations between high demand on land for urban development activities and environmental protection (EPD, 1996; Al-Agha, 1997; Enshasi, 2000; UNEP, 2003). The use to which land is put at present is too much left to the decision of the owners of that land (EPD, 1996; MOPIC, 1998; EQA, 2003). As a result many developments emerge which are not compatible with natural environment, detrimental to natural resources, or conflict with the existing land-uses in their surroundings. UNEP (2003) identified the environmental impacts that resulted from lack of integrated land-use management as:

- Fragmentation of planning powers and responsibilities;
- Further deterioration of the existing environmental service infrastructure such as water and sewerage system;
- Unsustainable exploitation of natural resources mainly water resources;
- Degradation of the vegetation cover.

Yet the sustainability approach for land-use management in Palestine is still poorly documented by the local institutions. In addition there is weakness in integrating the socio-economic factors and environmental impacts into land-use management at policy-making level.

Research Objectives

The research aims at achieving the following objectives:

- To establish integrated land-use management framework for Gaza city based on cause-effect relationship within sustainability context.
- To establish a prediction model for the relationship between the most influential socio-economic, environmental and institutional indicators, that had shaped the current status of the land-use in the city for the period 1967-2003. This prediction model is the basis for drawing scenarios for future development.
- To develop recommendations for sustainable land-use management.

Constrains and Limitations

The complexity of the land-use system is usually an impediment, where many factors increase the unpredictability of the system. Hence, modeling cause-effect relationships of land-use management towards sustainability needs complete and accurate data on local, regional and national levels. It has to consider that the problems linked to sustainability of land-use management cannot be treated at the local level alone. For any integrated land-use management framework, it is necessary to measure, anticipate, and link land-use dynamics and their consequences in different levels. Therefore, land-use management should not ignore the regional, national and international factors that influence the land-use changes in the city. However, due to the limitation of data and information on the interactions between the city and the regional level, the research scope has been limited to explore the indicators related to the city within its boundaries. Since this is the first attempt to introduce a scientific method of analyzing and modeling the land-use changes and its environmental impacts of one of the Palestinian cities, this concept would need more exercises and applications in case of full information at different levels are exist.

The Need for Sustainability approach

Since the establishment of the Palestinian National Authority (PNA) in 1995, the Environmental Planning Directorate (EPD) at the Ministry of Planning called for integrated land-use planning framework (EPD, 1996) based on scientific approaches that can ensure the present development don not threaten the surrounding land sue on the short and long term. The problem of inadequate land-use management has also been one of the hot issues in discussions between Gaza Municipality and donor countries. The later is aiming at support the municipality to formulate a sustainable land-use management framework that meets the needs of present population and ensure the optimal use of natural resources mainly the land and water (World Bank, 2002b; Gaza Municipality, 2003). However this attempt is still suspended due to the political situation since the year 2000. Therefore the municipality urges for pioneer studies based on scientific approaches to develop a holistic multidisciplinary integrated approach for urban management that helps the city to move towards sustainable urban land-uses similar to many cities in the neighboring countries.

Research Methodology

The methodology followed in this research consists of four steps, which are conceptual framework, data collection, data analysis and modeling. Since the main focus of this research is on introducing integrated approach to sustainable urban growth management, the methodology followed here is built on analysis of the case study of selected Gaza city as follows:

- Development of conceptual framework based mainly on the sustainability framework including the most appropriate indicators related to socio-economic, pollution pressure, environmental and institutional aspects.
- Validation of the proposed conceptual framework with expert opinion and existing successful frameworks for sustainable land-use management.
- Application of the conceptual framework to Gaza city including description of each indicator based on literature review and several discussions with professionals in this field.
- Data collection on Gaza city in relation to its historical development, socio-economic, environmental, institutional and land-use changes. Sources of data used in the research include national government reports, master plans, aerial photos, municipal records and reports and other scientific researches. This includes also the experts opinion and judgment collected through questionnaire.

- Data analysis by using statistical analysis that will be employed to discover the most influential indicators that contributed land-use changes of the city.
- Modeling the interaction between the land-use categories and the most influential indicators using the artificial neural network prediction model.
- Prediction for future based on different scenarios and different models to explore viable solutions and potential remedies to the situation in the city .

Document Layout

The research is divided into five chapters. The first chapter presents the related literature on land-use and sustainability concept. The second chapter presents the conceptual framework for examining and modeling urban land-use drivers, pressures and impacts. The third chapter focuses on the description of the studied area and examines the historical development and possible indicators of land-use of Gaza city. The forth chapter focuses on data analysis and modeling the relationship between land-use and the most influential indicators and factors that have shaped the evolving state of land-use. The optimal model is used for future prediction of the land-use demand based on status-quo and sustainability scenarios. The research ended with conclusion and recommendations including directions for future research.

CHAPTER ONE

LAND-USE MANAGEMENT AND SUSTAINABILITY APPROACH

1 Land-use Management and Sustainability Approach

1.1 Introduction

Several international research projects have been initiated during the past two decades for the purpose of studying the land-use changes in response to the population growth and its consequences for the quality of life and the environment. These researches including for example, the International Geosphere-Biosphere Project and the land-use and Cover Change (LUCC) program (Messerli, 1997). These projects have indicated the need to construct an updated and accurate database concerning land-use changes, their meaning, their pace and the explanatory factors prompting their appearance (Mather, 1999). This goal has become more urgent as a result of the cumulative effects of inaccurate data on the ability to forecast the consequences of current trends.

This chapter, therefore focuses on analysis of land-use management and sustainability approach including the most related and credited definitions of these concepts in order to establish a link between them. It also includes development of sustainable land-use indicators' framework, including socio-economic, environmental and institutional indicators, as well as the indicators' selection criteria that developed by different scholars and international organizations. This chapter also provides the most recent modeling approaches for the land-use changes and its environmental impacts in the context of sustainability. Such information is essential for a better understanding of the sustainability of urban development processes. It considered as platform for establishing conceptual framework that intends to analyze and model the land-use changes into sustainability context.

1.2 Land-use Management

Land-use management could mean different things to different people. It varies from country to country and from time to time according to their understanding of land-use definition and the management process. Land-use management could include several concepts such as; land-use analyses, projection and modeling, assess the environmental implications at various temporal and spatial scales. Turner II et al. (1993) argued that land-use management needs complete and exact quantitative data that describing where, when and how change occurs. Wilson et. al. (2003) defined urban land-use as the way on how tc develop the land, which includes residential, commercial and industrial land-uses that resul in a built-up area. Thinh et al. (2002) defined the urban land-use structures (urban form) as ε framework of spatial relations between lands with differing uses and hence are alsc expressions of a spatial configuration of functions.

Herbert and Thomas (1997) in Liu and Philnn (2003) defined the cities as physica concentrations of population and housing, population or dwelling densities are measurabl criteria in delimiting the extent of urban development. Therefore they defined urban land- use management as a continuous process that control the physical concentration of peopl and buildings in space and over time. Liu and Philnn (2003) agreed at that definition anc argue that it is appropriate to use population and/or housing densities as criteria to delimi urban areas.

The focus of the authors here is defining urban areas from spatially perspective as an are with high population and building's density. Most of the scholars suggest a threshold alon the population-size continuum of settlements at which a village becomes a city, althoug this threshold varies significantly in space and over time. For instance, in severa Scandinavian countries, including Denmark and Sweden, any settlement that has more thar 200 inhabitants is classified as urban in the national census" (Herbert and Thomas, 1997). Ir the United States, urban areas comprise core census block groups or blocks that have ε population density of at least 1000 inhabitants per square mile and surrounding censu blocks that have an overall density of at least 500 people per square mile (US Censu Bureau, 2000). In Canada, an urban area should have a minimum population concentratior of 1000 and a population density of at least 400 persons per square kilometer based on the previous census population counts (Statistics Canada, 1996). In Palestine, land-use that classify as urban areas that have a least 10,000 inhabitants within defined boundaries and living in a continues geographical area without considering the density (PCBS, 2003).

It is obvious that from the different definitions that the authors are focusing on the physical dimension of land-use management and few try to integrate the social, institutional and environmental dimensions of the urban areas into the management process. A unifying hypothesis that links researchers from different disciplines is that, land-use changes have to be studied in order to obtain better understand of causes and consequences of these changes and to explore the extent and location of future land-use changes. Hence, land-use should be studied as one of the most important social processes and having enormous impact on the environment at local, regional and global scales in order to achieve sustainable land-use (Geist and Lambin 2002 in Nagendra et. al., 2004).

The contradiction between the need of urban development and the conservation of natural resource is bound to become more and more intensive, and urban land-use has to be controlled and managed efficiently in order to keep the balance and realize sustainable development. Therefore, land-use management aims at directing the land-use changes to a sustainable manner by supporting the land-users and policy makers in their decisions towards effective and optimal use of land resources.

1.3 Sustainability Approach

Sustainability approach to land-use management required better understanding of both concepts from different scholars and recognized international organizations. Therefore, the most related definition has been selected and critically reviewed in order to establish a frame of reference for sustainable urban land-use.

Sustainable concept itself came into prominence in 1980, when it was introduced by the International Union for the Conservation of Nature (IUCN) in the framework of the World Conservation Strategy, with "the overall aim of achieving sustainable development through the conservation of living resources" (IUCN, UNDP and WWF 1980). The United Nations Environment Program (UNEP) has since articulated and popularized the concept, which has been more recently defined by the World Commission on Environment and Development (the Brundtland Commission) as "development which meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987). Clearly the Brundtland statement has a strong people-centered ethical stance, concentrating on the satisfaction of human needs (not human wants), rather than for example, on protection of the environment in general. Therefore the conclusions of the Brundtland's report brought a new dimension into the environmental debate.

The International Council for Local Environmental Initiatives ICLEI (1994) provides more practical and local interpretation of sustainable development, which is helpful to apply the concept in urban areas: "Sustainable development is development that delivers basic environmental, social and economic services to all residents of a community without threatening the viability of the natural, built and social systems upon which the delivery of these services depends" (ICLEI, 1994).

The Agenda 21 and Rio Declaration are the main outputs of the United Nations Conference on Environment and Development UNCED held in 1992, stressed on integrating the land-use activities with sustainable development (UN, 1992).

Aalborg Charter published 1994 was adopted by the participants at the European Conference on Sustainable Towns. The Charter supported Agenda 21 principles, and to contribute to the setting up of The Fifth Action Program for the Environment of the European Union. Charter's section 1.9, concerning sustainable urban mobility focused on the following issues.

- Cities and towns shall strive to improve accessibility and sustain social welfare and urban lifestyles with less transport.
- It is imperative for a sustainable city to reduce enforced mobility and stop promoting and supporting the unnecessary use of motorized vehicles.
- Give priority to ecologically sound means of transport (in particular walking, cycling, public transport) and make a combination of these means the center of our planning efforts.
- Motorized individual means of urban transport ought to have the subsidiary function of facilitating access to local services and maintaining the economic activity of the city.
- United Nations (1996) focused on urban land-use development as a multidimensional process to achieve a higher quality of life for all people. It considered the economic development, social development and environmental protection as interdependent and mutually reinforcing components of sustainable development.
- The most recent United Nations World Summit on Sustainable Development (WSSD), held in Johannesburg in August 2002 recalled for adopting Agenda 21 at the local levels. In its Plan of Implementation, it focused on integrating socio-economic, environmental and institutional dimensions into land-use management (Seyfang Gill, 2003).

Sustainability has become a leading target of scientific research and policy agenda (Lopez-Ridaura, 2002). Thus Sustainable development is a much broader concept than environmental protection (Ravetz, 2000). It implies a concern for future generations and for the long-term health and integrity of the environment. It embraces concern for the quality of life (not just income growth), for equity between people in the present (including the poverty alleviation), for inter-generational equity (people in the future deserve an environment which is at least as good as the one we currently enjoy, if not better), and for the social, health and ethical dimensions of human welfare. It also implies that further development should only take place as long as it is within the carrying capacity of natural and human systems. Clearly, addressing the sustainable development agenda provides new challenges for urban policy integration within holistic frameworks. Therefore sustainable development should be investigated from its four dimensions environmental dimension (Sage, 1994; Turner, 1993), social dimension (Brown and Jacobson, 1987), economic dimension (Lopez-Ridaura, 2002; Ravetz, 2000), Institutional dimension and Geo-political dimension (Bouma, 2002).

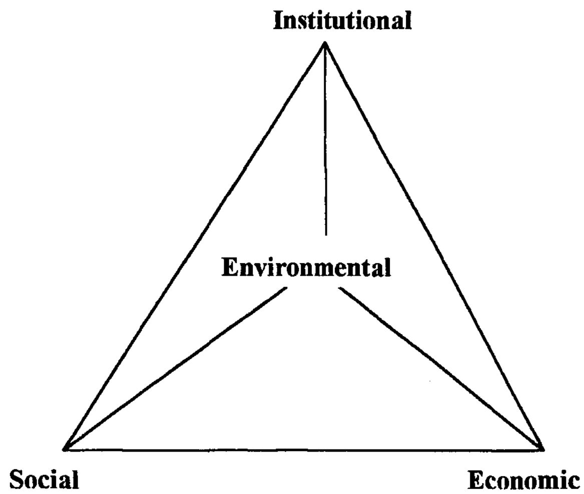
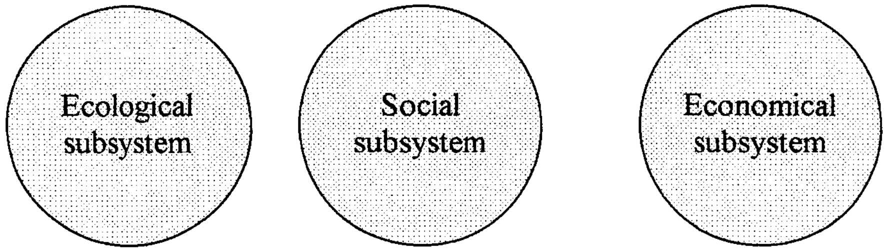


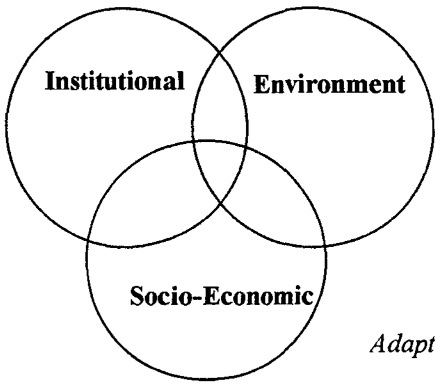
Figure 1.1 The Four Dimensions of Sustainability

Adopted from Spangenberg, 1995

To achieve sustainability, coordination across social, cultural, economic and environmental areas are required (Lele, 1991; Sheng, 1995). That cooperation, coordination, recognition, are not necessarily present, nor perhaps possible, in government thinking, policy or practice. That may be identified as one of the barriers to achieve sustainability (MAF, 1993). Figure 1.2 is representing the interaction and integration between the three sustainability dimensions with the political influence as external factor. Tabara (2002) argued that, the most usual and pivotal sets of notations in which the concept of sustainability revolves are the concepts of needs, natural ecosystems, and systems integration. Therefore, he defined sustainable development as the adaptative processes of progressive integration between the ecological, social and economical subsystems.



Unsustainable Development



Adapted from (Tabara, 2002)

Sustainable Development

Figure 1.2 Sustainable Development concepts

ten Brink (1991), considered the concept of sustainable development is a political rather than a scientific concept. He argued that if policy-makers want to make rational choices concerning sustainable development, they have to define this concept and formulate verifiable ecological objectives, and moreover they will need to possess adequate economic and ecological information. Political conditions and history are very important when studying urban Land-use changes and sustainable land management (Bouma, 2002). This could be refer to visible impacts on involved organizations and institutions; involvement into decision-making; legislative and fiscal framework.

Lele (1991) explained that his understanding of sustainability is thus more complex since it is based on causal interrelationships between urban poverty and environmental degradation which involve not only quality of environment but also technology, consumption patterns and ultimately culture and values in various regions of the world. Being applied to urban development, this definition of SD is to encompass three basic ideas:

- The idea of cost-effective development using nontraditional economic criteria;
- The idea of self-reliant development based on local political initiative, within natural resource constraints; and

- The idea of appropriate technologies and planning techniques in the management of resources such as land, water and energy.

The above issues are of course interrelated and overlaps between them exist in any approach. The breadth and complexity of the sustainability dilemma makes it useful to examine certain dimensions and components of SD separately.

The concept of sustainability shows many facets. Ecologists, environmentalists, agronomists, sociologists, economists and politicians use it with different connotations. In addition, the sustainability of land management systems varies in space, according to climate, soil, technology and societal conditions. Because of its complexity, sustainability is difficult to measure directly and requires the use of appropriate indicators for assessment. A good indicator is free of bias, sensitive to temporal changes and spatial variability, predictive and referenced to threshold values (Zinck and Farshad, 1995). To embrace the whole width of sustainability, several methods and techniques should be used concurrently, including land evaluation and co-evolutionary, retrospective and knowledge-based approaches. It is, however, at the application level that major constraints arise.

1.3.1 Sustainability Approach for Land-use Management

In their definition of sustainable land-use management, FAO (1993) clearly focused on agricultural production. This can be a choice, but land-use management has broader implications than agricultural production alone. It should be recognized that FAO (1993) defines sustainable land management and not sustainability as such. Emphasis is, therefore, on action and not on conceptual definitions, which is an attractive approach because land managers are key figures in realizing sustainable land-use systems (Doran, 2001).

Even though a management scheme may be sustainable from an agro-ecological point of view, it can be economically unsustainable or social unacceptable. This should certainly be considered but it is unwise to not explore various land-use management options (Bouma, 2001). The sustainability debate has shown that economic, social and environmental concerns need to be seen and solved in the context of each other (Haberl, Wackernagel, and Wrbka, 2004).

Attempt by Barredo and Demicheli (2003) in order to respond to the idea of sustainability, they argue that urban areas have to maintain an internal equilibrium balance between economic activity, population growth, infrastructure and services, pollution, waste, noise etc. in such a way that the urban system and its dynamics evolve in harmony, internally limiting, as much as is possible, impacts on the natural environment. Ravetz (2000) defined sustainable urban development by the actions that bring urban environmental sustainability together with urban development. Hence it is the actions, which guide the urban development towards sustainability.

Dumanskia and Pieri (2000) argued that sustainable management of the land resource is more important than land supply for development. However, land degradation and mismanagement are threatening our opportunities and flexibility for increased services from the land, requiring increased investment in soil conservation and even rehabilitation and reclamation. Sustainable land management and the choice of feasible and cost effective management options is hampered by the lack of available indicators for monitoring how land is being managed, the impacts of policies and programs on land management choices, and the impacts of different management scenarios (cause-effect relationships).

Kirkby (1995) shows that there is no contradiction between the two ideas, both sustainability and development of land-use are rational and enlightened concepts. To ensure the sustainability of land-use management, it is necessary to adopt management framework for any future urban development in order to avoid possible environmental problems. One of the difficulties to mange the repaid land-use changes is to forecast locations for future development. Local authorities are usually applying land-use management tools to define and restrict future land-uses. In France, these tools are the plan d'occupation du sol (POS) or the schéma directeur d'aménagement et d'urbanisme (SDAU) or more applied tools like the zone d'aménagement concertée (ZAC). These tools are associated with cities strategic planning decisions depending both on the use of all pieces of land adjacent to actual urban areas and on the restriction of some land-uses which impact may be harmful to sustainable development (Weber, 2002).

A sustainable land-use management system must satisfy a large variety of requirements, including technological feasibility, economic viability, political desirability, administrative manageability, social acceptability, and environmental soundness. Real world conditions at policy-making levels need to be substantially improved to achieve sustainable land management (Zinck and Farshad, 1995).

Hence, sustainable land-use management is neither static nor it imply a fixed spatial perspective. In order to develop an operable framework, it is necessary to define a time scale and a distinctive space. Time-series procedures offer some possibilities for steady surveys of and a distinctive space. Time-series procedures offer some possibilities for steady surveys of land cover changes. The articulation between statistical approaches (supervised classification and post-processing) and potential modeling capacities provides some support in decision-making documents to elaborate future monitoring scenarios. Regarding sustainability issues, this kind of approach may offer useful information on possible exposed land-use categories towards increasing urbanization (Weber and Puissant, 2003).

Verburg et al. (1999a) concluded that there is a need for new fields of research adding up to a better understanding of land-use change and its drivers. Understandings of land-use drivers will enable scientists to support the evaluation of land-use policies and associated impacts.

UNEP (2003) concluded that sustainable development in Palestine should be based on the integration between three the pillars which are social, economic and environmental factors. At present, land-use planning in the Occupied Palestinian Territories is driven by Israeli security considerations, with environmental concern playing minor role, in spite of the importance of the environmental conditions for long-term human health and well being for the citizens.

1.3.2 Concluding Remarks

Search of the available literature uncovered very few references combining analysis of land-use management with sustainability indicators that are both quantitative and integrated. However, a substantial number of references deal with sustainability and urban land-use management either (i) in an qualitatively manner but typically without the use of indicators, or (ii) in a quantitative manner, but solely dealing with certain environmental or spatially aspects.

It is obvious that there are wind ranges of definitions given by experts and international organizations for the terms land-use management and sustainable development. These definitions are fragmented and incomplete to present the rich picture of combining both concepts of urban land-use and sustainable development. Therefore it is essentially to establish a link between both ideas in order to be able to set a reference frame for defining the sustainable land-use management.

Linking both ideas should take into consideration the different dimensions of the sustainable development, which are economic, social, environmental and institutional. These dimensions

The proposed definition on sustainable land-use management is *the management of land-use changes that responds to the development needs for the present generations in environmental friendly, socially accepted, economical feasible and institutionally sound ways incorporated together in an integrated manner. It will not compromise the abilities for the future generations to meet their own needs.*

Therefore Sustainable land-uses management combines policies, and activities aimed at integrating socio-economic principles with environmental concerns. In order to make this definition applicable, there is a need to define its dimensions. These dimensions are considered as pillars for achieving sustainable land-use management, which are socio-economic driving forces, pollutions sources, environmental impacts and institutional response. In addition there is a need to establish an integrated sustainability indicator based system that translate these dimensions into measurable indicators.

1.4 Development of Sustainable Land-use Management Indicators

Interest in sustainable land-use has prompted a search for suitable indicators that might complement or supplant the traditional measures of urban management. Indicators are considered as a requirement to the implementation of the sustainability concepts (Hansen, 1996). By using indicators, sustainable land-use management could be tested and evaluated. As recommended by Agenda 21 and Rio Declaration of the United Nations Conference on Environment and Development UNCED (1992), set of related indicators helps in assessing the progress towards sustainability. Therefore indicators must be elaborated and validated according to scientific approaches (Bockstaller and Girardin, 2003)

The 1992 Earth Summit recognized the important role that indicators can play in helping countries to make informed decisions concerning sustainable development. This recognition is articulated in Chapter 40 of Agenda 21 (UN, 1992) which calls on countries at the national level, as well as local, governmental and non-governmental organizations to develop and identify indicators of sustainable development that can provide a solid basis for decision-making at all levels. Moreover, Agenda 21 specifically calls for the harmonization of efforts to develop sustainable land-use development indicators at the regional and local levels, including the incorporation of a suitable set of these indicators in common and regularly updated.

1.4.1 Sustainability Indicators

Indicators can provide crucial information and guidance, directly or indirectly, for decision-making in a variety of ways. They can translate physical and social science knowledge into manageable units of information that can facilitate the decision-making process. Sustainable land-use indicators can help to measure and calibrate progress towards sustainable development goals. They can provide an early warning, sounding the alarm in time to prevent economic, social and environmental damage (UN, 1996).

RESCUE (2002) distinguished two types of sustainability indicators. "Firstly, the predictive indicator which provides direct information on the future state and development of relevant socioeconomic and environmental variables. This information constitutes the basis for anticipatory planning and management. The predictive power is based on mathematical models of the man-environment system. The second type is the retrospective indicator. This type includes the traditional policy evaluation and historical trend indicators. They provide information about the effectiveness of existing policies or about autonomous developments, respectively. From these indicators decision-makers may learn and improve policy effectiveness. In this way, retrospective indicators may provide indirect information about future sustainability. They are usually quantified by a combination of measured data and reference values (e.g., historical situations, economic targets, health standards).

Therefore, sustainability indicators aim at monitoring key aspects of society–nature interaction in order to generate information needed to document the current state and the history leading up to it. Moreover, they are useful to communicate complex sustainability problems within the scientific community, to policy-makers and the broad public (Haberal et al., 20004)

Stewart (1993) discussed of current thinking on indicators of sustainable development. He proposes that indicators are tools for tracking progress towards sustainable development, measuring its success and identifying the selection of alternative choices to facilitate a more substantial form of development.

Within the context of major land-uses such as agriculture, the indicators of sustainability must be framed within the social and economic conditions of the society in question. Whereas an indicator is used to measure changes in key attributes, usually over time, a threshold provides a baseline against which sustainability can be assessed. A direct measure of sustainability using indicators is difficult, and indirect measures or surrogates may be easier to establish. The human development index (HDI) is a more complete indicator taking into account various welfare statistics. After discussing these indicators, they are integrated into a discussion on sustainable development (BZU, 1998; 2000).

Henderson (1994) examines the potential for the UN fourth development decade to produce more realistic indicators of development. She suggests that "the already important work by socially concerned economists, statisticians and sociologists of the past years should be used to ensure greater government accountability and to improve the overall quality of life of its citizens.

"It is well recognized that measures of gross national product (hereafter GNP) do not reflect all features of societal developments that are relevant from a welfare theoretical point of view. Corrections of GNP or substitute income-based measures (such as 'Sustainable Income') have been proposed for decades. It is argued that rather than correcting GNP or seeking one-dimensional substitutes, policy-making might - in the short term - be served best by the provision of a (small but relevant and consistent) set of indicators for environmental quality and/or (un)sustainability. Meanwhile economic research should lead to better methods for valuing costs of elimination and/or environmental damage" (Opschoor, 1991).

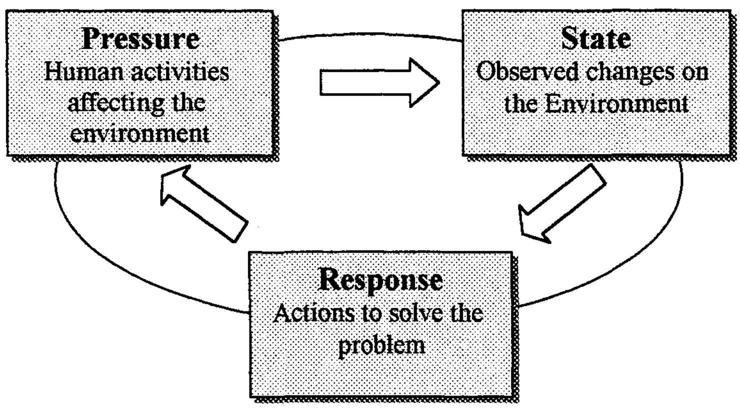
Many strategies have been proposed to reach sustainable development. Many of these strategies aim at one type of problem - preventing environmental deterioration - while ignoring the importance of economic or social goals (Ravetz, 2000). In addition, while political decisions are at the heart of the choices to be made, most researchers seem to consider sustainable development as a mere technical problem (de Graaf, 1996).

Article by Henderson (1994), reviews the current debate about new indicators of wealth and progress and how the meaning of development is changing. The goal of sustainable development is to clarify the confusion of means (i.e. the current obsession with economic growth) with truly evolutionary human development as the ends to be pursued within the ecological tolerances of the planet. The article also reviews the debate about overhauling national accounts as provided for in Agenda 21 and how best to augment such 'scorecards' with additional indicators of overall progress and quality of life. A historical overview of the social indicators movement is combined with a discussion of newer indicators of environmental costs & benefits.

Kaufmann and Cleveland (1995) argue that the sustainability of land-use systems can be understood by integrating concepts and indicators proposed by social and natural scientists. Sustainability is based on the balance between the ever-changing types and quantities of environmental life support used by society, and the long-run ability of natural ecosystems to provide life support. This balance can be evaluated by criteria that combine the strengths of social indicators, which measure the economic and technical factors that determine the use of life support, and natural science indicators, which model the long run ecological effects of using life support.

1.4.2 Framework for Developing Sustainability Indicators

The usefulness of indicators can be increased by putting them in an appropriate context or framework. The first attempt to develop such a framework is the so-called Pressure-State-Response (PSR) model. The PSR model was developed in the 1970s by the Canadian statistician organization, and subsequently adopted by the OECD (1993).



Source: UNCSD, 1996

Figure 1.3. Pressure-State-Response (PSR) model

The PSR model developed by OECD considers that activities of human system exert " pressures" on the environment and affect the quality and quantity of natural resources "state", society responds to these changes through environmental, land-use, awareness and sectorial policies " response". The PSR model integrates the cause- effect relationship. It helps decision makers and the public to observe the linkages between the human and the natural resources systems and to undertake the proper policy interventions. The PSR model provides a classification into indicators of environmental pressures, indicators of environmental conditions (state) and indicators of societal responses (OECD, 1993). Bayfield and Crabtree (1998) Criticized the PSR model because of its limitations when applied to sustainable development context. They argued that PSR model failed tc incorporate the links between economic activity and environmental change.

The limitations of the PSR model led the United Nations Commission on sustainabl Development (CSD) to develop a Driving Force-State- Response DSR model with primar modification. It extended the category of pressures to the more general driving forces Hence, the socio- economic dimensions were added to the framework.

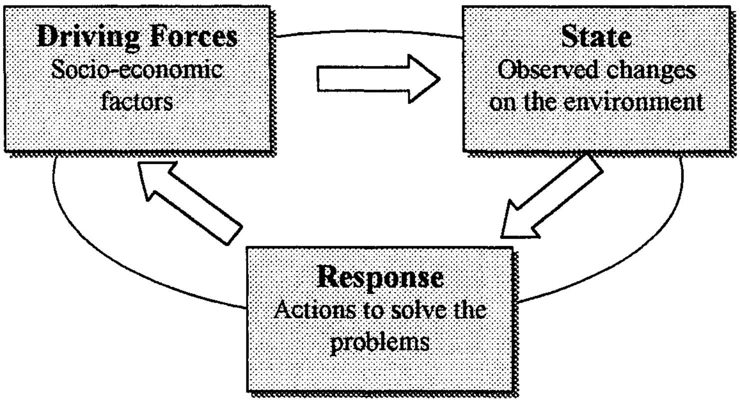
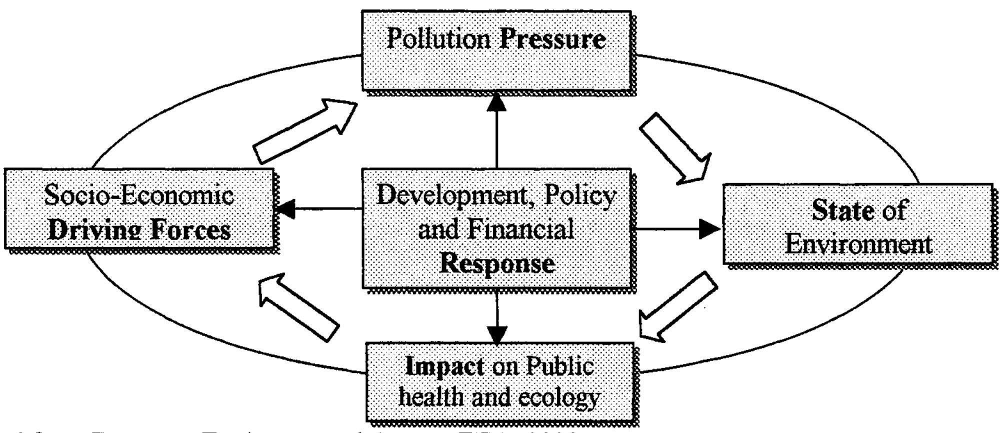


Figure 1.4. Driving forces-State-Response (PSR) model

RESCUE (2002) criticized both PSR and DSR indicator frameworks because both tend tc miss the complex interactions and interrelations between the different indicators and topics related to sustainability. The research team in RESCUE project argued that the inadequacies of PSR and DSR lead to oversimplification of the sustainability concept.

The European Environmental Agency (EEA, 1999; 2002) of the European Commission through the indicator community has developed the Driving force-Pressure-State-Impact-Response (DPSIR) model shown in Figure 1.5.



Adapted from European Environmental Agency EEA, 1999.

Figure1.5. Driving forces-Pressure-State-Impact-Response model

Driving forces (D) represent major social, demographic and economic developments in societies and the corresponding changes in lifestyles. Demographic development may be regarded as a primary driving force whose effects are translated through related land-use changes, urban expansion and industry and agriculture developments.

Pressure indicators describe the variables, which directly cause (or may cause) environmental problems. Examples: waste generation included solid, hazardous waste and wastewater.

State indicators show the current condition of the environment.

Impact indicators describe the ultimate effects of changes of state Examples: groundwater, air, soil and marine pollution.

Response indicators demonstrate the efforts of society (i.e. politicians, decision-makers) to solve the problems. Examples: provision of services such as development of water, wastewater and road networks. It includes also polices, regulation, enforcement and public investment for infrastructure development.

1.4.3 Criteria for Selecting Sustainability Indicators

During the research work of RESCUE (2002) to prepare an analytical sustainable framework of Brownfield regeneration in France, Germany, Poland and United Kingdom, Researches and experts from the four European countries developed criteria for selecting sustainability indicators. The research team identified the criteria for sustainability indicators as follows:

- Indicators that are relevant for land-use management (Dimopoulos, 1999; Verburg, et al., 2001; Veldkamp, and Verburg, 2004).
- Indicators must be measurable in qualitative or quantitative terms; indicators can be surveyed in a suitable frequency with respect to fast availability, limited number, fungible costs for present and future enquiry (OECD, 1997; Hamblin, 1998; Rubio and Bochet, 1998; Woodhouse et al., 2000);
- Indicators must be easy to understand and interpret (Mitchell and McDonald, 1995; Hamblin, 1998; Rubio and Bochet, 1998);

- Indicators are horizontally comparable (between regions or nations) and vertically compatible (nation – region – municipality) over a certain period; (Zinck and Farshad, 1995; Hamblin, 1998).
- Indicators are relevant for planning and political decisions, i.e. they can be influenced by political decision makers or planners; they are suitable to serve as basis for political decisions (Ten Brink et al., 1991; Guijt, 1996 (in Rigby et al., 2000); OECD, 1997; Rubio and Bochet, 1998; Woodhouse et al., 2000).
- Indicators describe trends and changes, they assess trends with regard to sustainability. They should cover the sustainability dimensions (Ten Brink et al., 1991; Hamblin, 1998).
- Indicators are generally comprehensible, logical, scientifically meaningful, specific, reliable, communicable, valid and optimally inaccurate (Pieri et al., 1995).
- Indicators aggregate data to volumes that can be processed, neither too abstract nor too detailed (Hamblin, 1998; Rubio and Bochet, 1998)
- Indicators are precautionary and not reactive (early warning function).

It is obvious that the proposed criteria are built on a wined range consensus of experts from four European countries. It is not claimed that they are complete, however, they can help in selected the indicators in a subjective and scientific manner that needed to develop the integrated indicators' framework. Therefore, these criteria will be helpful when selecting the indicators for the conceptual framework for sustainable land-use management in Gaza.

1.4.4 Validation of Sustainability Indicators

Validation of indicators can be done as part of the modeling process of the most determining factors for land-use changes. This could be easy when using a historical data on the expansion of urban land-use as a dependent variable and the possible determining indicators as independent variables. Multi-criteria and sensitivity analysis considered as useful tools to validate the list of influential indicators (Dimopoulos, 1999). However other scientist do not propose any validation method in case of well founded indicators, the indicators are directly relevant to the subject and if it is tested and used by the end users (Bockstaller and Girardin, 2003)

1.4.5 Identifying the Sustainable Land-use Indicators

Accepting the premise that sustainability is a society–nature interaction means that we must observe societies, natural systems, and their interaction over time and answer the following:

(1) Which changes do socio-economic activities cause in natural systems?

(2) Which socio-economic forces drive these changes, and how can they be influenced?

(3) How do changes in natural systems impact on society?

(4) How, if at all, can society cope with the changes it has set in motion?

These issues have always been the focus of academic researches as well as social and economic debates because land-use changes entails impacts and conflicts in socio-economic aspect, and serious pollution pressure, negative impacts on environmental sustainability and institutional measure to solve the problems (Haberl et al., 2004).

Based on the proposed definition of the sustainable land-use explained in section 1.2.3 it is found that there are four main groups of indicators investigated by most of the experts and scholars in this domain.

1.4.5.1 Socio-Economic Driving Forces Indicators

Urban land-use changes are driven by population growth, social and economic development (Bourne, 1996; Geist and Lambin 2002 in Nagendra et. al., 2004). Bouma, (2002) considered socio-economic and political conditions as very important factors when defining land quality and sustainable land-use management.

Turner et al. (1993) argued that population, economy and demographic factors would be likely determinants of land-use and considered the most important elements for urban expansion. Population increases may lead to an absolute need for space, but the actual increase of the true urban area is determined by the economy. Some case studies show that population increases are correlated with urban growth.

Dumanski and Pieri (2000) confirmed that the economic and social indicators are already in regular use as land-use driving forces to support decision making at global, national and sub-national levels. They found that indicators are common instruments for monitoring progress towards some larger objectives. For example, economic indicators, such as GDP, distribution of employment, etc., are used regularly to monitor performance of national and local economies. Similarly, access to social services, literacy rates, etc., are used fo comparative assessments of social development. On the environmental side, indicators ar available for monitoring and reporting on air and water quality. However, indicators whic can be used to monitor change in land quality are still not available, and because we canno monitor land quality, we are not in a strong position to take appropriate action on lan related issues such as land degradation.

The driving forces for land-use changes are differ according to the different geographica context. For example, Kombe (2003) studied land-use in the city of Dar es-Salaam Tanzania, he demonstrated that urbanization in poverty is the key factor underpinning an catalyzing changes in land-use, land transactions, increased rural–urban immigration and th overall transformation of land-use in the periphery areas. Unregulated periphery lan development has given rise to complex organic urban structures which predominantl expanding horizontally. While Hasse and Lathrop, (2003) studied land-use in New Jersey a the United States and he found that the phenomenon of sprawling urban development is on of the major forces driving land-use change. Yeh and Wu, (1996) concluded that, urban lan development in capitalist societies is driven by a market mechanism, in which individual and enterprises are the main actors and their locational choices are constrained an motivated by the capitalist production mode of profit-making.

Ewing (1994) found that there are other externalities of urban land-use changes have raise extensive concerns such as various governmental policies on land-use changes an management.

(Weber, 2002) found that it is important to better understanding the driving forces an processes of urban changes because of the dissemination of such habitats around centra cities mainly out of official planning sectors, without legal existence (and consequentl without legal access to city services and without environmental conservation rules, etc.).

Recently, Verburg et al. (2003) showed that the driving factors that influence the magnitud and extent of land-use change are often related to the functioning of local and nationa markets, policy and demographic conditions. Veldkamp and Verburg (2004) supported th idea that land-use change is driven by the interaction in space and time between biophysica and human dimensions.

Vledcamp and Lambin et al., (2001), found that initial efforts aimed at modeling land-us change have focused primarily on biophysical attributes (e.g. altitude, slope or soil type given a good availability of such data. Incorporation of data on a wide range of socio-economic drivers of change is however required. Most case studies highlight for instance the important role of policies in driving land-use changes e.g. international environmental treaties such as the Kyoto Protocol may drive significant changes in land-use in the future. Incorporation of social, political and economic factors is however hampered by a lack of spatially explicit data and by methodological difficulties in linking social and natural data. For example, the relevant spatial units for biophysical processes may be very different from the spatial units of decision making by actors. Proxy variables, which are easier to measure spatially (e.g. distances to a road or a town), are often used for deeper underlying driving forces (e.g. influence of markets). This shift from driving forces to proximate causes, for data convenience, might obscure causality. Subtle land-cover or land-use modifications, e.g. related to changes in cropping patterns, input use or tree density of forests, also need to be taken into account in addition to the more easily measurable land-cover conversions. Moreover, land-use change models need to account other variables such as land management technologies, infrastructures or land-use policies.

Case studies reviewed by Lambin et al., (2001) support the conclusion that neither population nor poverty alone constitute the sole and major underlying causes of land cover changes worldwide. Rather, people's responses to economic opportunities, as mediated by institutional factors, drive land-cover changes. Opportunities and constrains for new land-uses are created by local as well as national markets and policies. Various human-environment conditions react to and reshape the impacts of drivers differently, leading to specific pathways of land-use change. It is precisely that these combinations that need to be conceptualized and used as the basis of land change explanations and models. These pathways founds the authors indicates that land-use policies and projections of the future role of land-use change in Earth System dynamics must not only capture the complex socio-economic and biophysical drivers of land-use change but also account for the specific human-environment conditions under which the drivers of change operate. This recognition requires moving beyond some of the simplifications that persist in much of the current understanding of the causes of land-use and land-cover change. This does not preclude the development of a conceptually-based, land change science. Rather, it calls for advances that capture the generic qualities of both socio-economic and biophysical drivers as well as the place-based, human-environment conditions that direct land-use and land-cover change.

Integration of natural and social sciences as well as recognition of the increasing role of global factors is required to meet the challenge.

Weber and Puissant (2003) studied urbanization process in the Mediterranean region where pre-urban cities and new urban settlements have been established. The authors focused their study on the city of Tunisia and found that the major factor of urbanization in the region have risen over the past decades. The authors argued that several cities rapidly became regional centers or international nodes according to economic and political pressures and urbanization causes land cover changes, which can lead to deeper social, economic and environmental changes.

1.4.5.2 Environmental Impacts Indicators

Scientists, planners and researchers have paid much more attention to the issues related to land-use changes (Bounfour and Lambin, 1999; Weber and Puissant, 2003). The major urban environmental problems facing most cities in the developing countries include high rate of population growth, inadequate infrastructure and services, over-crowding, lack of land-use planning and control for environmental management, lack of integration between human settlement planning and housing development planning processes (UNEP, 1999).

More than simply a demographic phenomenon, rapid urbanization is one of the most significant processes affecting the cities and shaping their future. The result is a radical transformation in the structure of cities, accompanied by complex social, economic and environmental changes. While the benefits of economic growth are not distributed equitably, its negative consequences are spread at a planetary scale, with special emphasis on the urban environment. Three issues emerge as particularly critical: water supply and sanitation; solid waste management and energy/transport, creating increasing development challenges in dense urban areas (Al-Agha, 1997).

Recently, a study by EEA (2002) produced comparative information on urban development in selected European cities between 1950 and 1990 based on the interpretation of satellite imagery and aerial photographs. The study provided clearly evidence for the strong growth of urban areas across Europe, resulting in loss of farmland and natural areas in the surrounding countryside, whilst the creation of green spaces within urban areas did not match the speed of urban growth.

Research by Pauleit et al. (2004) has demonstrated the important environmental parameters such as surface temperatures, storm-water run-off and carbon sequestration. These parameters are directly affected by land cover features such as building density and the provision of green spaces. He studied also the densification of urban areas that is promoted by the compact city model and its negative impact on their environmental quality. In isolation, changes may be small and have little effect on the urban environment, however, it is hypothesized that over longer periods of time, they may significantly alter the urban fabric and negatively affect its environmental quality. Al-Agha, (1997) identified the main consequences in these impacts as unsuitable land-use, air pollution, ground water quality, hazardous waste, soil salinity, coastal and sea water pollution, high electricity voltage, depletion of natural resources, increase of natural and man made risks, urban sprawl, noise pollution, and other negative environmental and social effects.

In Palestine, environmental problems are dominated by the absolute need to better manage limited natural resources to meet the needs of its population. This population is not only growing at a rate of 4.2% annually but also is adopting new life styles and consumption patterns, which are more environmentally demanding (Enshassi, 2000). In the other hand the geographic fragmentation of the Palestinian areas are strongly hampers a comprehensive environmental planning. Moreover, mismanagement, over utilization of natural resources and conflicts over land-use cause very serious environmental problems (MEnA, 1999). Scattering of environmental activities among many players with no proper legislation or mandate and with the absence of a single coordinating institution also contributed greatly to the present environmental degradation in Palestine. The last problem has partly been resolved through the establishment of Ministry of Environmental Affairs (MEnA), in August 1998 as a central environmental planning and coordinating body, responsible for environmental standards, supervision and environmental monitoring in Palestine.

Rapid population and urbanization growth particularly in Gaza led to land transformation from agricultural to residential uses that resulted looses of productive agricultural lands and increase waste generation (Gaza Municipality, 2003). The outcome was an environmental damage that is still affecting public health and threatening the limited natural resources. Furthermore, the municipal services were not only inadequate but consistently deteriorating as well, with no planning or significant investments. All this lead to a situation that part of the Palestinian cities' population, particularly inside the refugee camps, have become accustomed to living with environmental standards that are far below human dignity. For instance, the insufficient wastewater network's coverage has led part of the residence t discharge wastewater directly to the sea or dispose it into underground cesspits. Thi happened without any kind of treatment, resulted in pollution of groundwater, soil an seawater which all danger the public Health (MEnA, 1999).

The increase traffic volume in the high densely urban areas led to increase of pollutants i the air such as sulphur and nitrogen dioxides, volatile chlorinated and aromati hydrocarbons (MEnA, 1999). Also the amount of solid waste has been significantl increased and dumped among the urban areas without any sanitary treatment which cause additional environmental and health threats. Therefore, the environmental situation in th Gaza cities is in a disastrous state and is deteriorating further. The situation has reached stage that is threatening to health and is below the international standards. When thi situation is compared with the high environmental standards of Israel and the standards c Jordan, the contrast becomes even more revealing and further frustrating. Therefor Environmental conditions in Palestine particularly in Gaza are considered to be among th worst in the Middle East. Serious environmental problems exist in several sectors, e.g water, wastewater, and solid waste (Enshassi, 2000).

1.4.5.3 Public sector management of urban land-use and development

Mubarak (2004) argues that governmental policies and inefficient urban planning practice have encouraged the transformation of the peripheral landscape into unchecked land sub divisions by land developers and individuals.

The public sector usually provides two types of urban services; benefactory services an regulatory services. Benefactory services are provided to sustain or improve the condition of living in cities. Benefactory services include: basic infrastructure services such as wate supply, garbage collection and disposal; amenities such as educational facilities, librarie recreation and cultural facilities; and services that address problems such as povert unemployment and blight. Regulatory services enforce restrictions on all kinds of behavic to ensure the maintenance of law and order and for the protection of the general public. Th ability of the public sector to meet the service needs of growing cities depends to a larg extent on their management capacity. Management capacity is a factor of both resource available for management and the development of appropriate institutional structure an practices in management. Funding for development intervention is usually extracted in th form of taxes, user chargers, levies and fines. Institutional building for urban land-us management is usually focused on establishing an inter-organizational management setup. The unique nature of urban management means that it is usually carried out by several government agencies, with each overseeing an aspect of the process.

In Palestine, during the period of occupation (1967-1993), the Palestinian influence on physical planning was very limited. According to the Oslo I Agreement signed in 1993, the responsibility for planning was conditionally transferred to the PNA. This would, for the first time in modern history, give the Palestinians the power to initiate, prepare, amend and abrogate their own physical plans at national, regional and local level. At the present time only rudimentary governmental planning institutions were functioning. Neither national, regional nor any other form of overall planning existed and only the largest municipalities had something resembling planning units such as Gaza, Ramallah, Nablus and Hebron Municipalities. However, these were far below the technical and administrative requirements of modern planning institutions needed to cope with the enormous task of planning for the rebuilding and development of Palestine (MOPIC, 1998).

1.4.6 Concluding Remarks

In order to understand the problems of the current situation of the land-use management, it is essential to develop a framework for indicators that integrates the different set of indicators related to sustainable land-use. It is found that sustainability framework that developed by United Nations organizations based on integrating socio-economic, environmental and institutional is the most well established framework that covers the whole dimensions of sustainable land-use management. This framework for the selection and development of indicators is essential for organizing and expressing the complexities and interrelationships encompassed by sustainable land-use management dimensions. Ultimately, the choice of a framework and a core set of indicators must meet the needs and priorities of Gaza city. The selection of the indicators' framework should be based on credited criteria to ensure the correctness and appropriateness of the intended indicators for sustainable land-use in Gaza.

Land-uses changes in Gaza city had driven by a mixture of different factors mainly geo-political and socio-economic factors (MOPIC, 1998). It should be noted that so far there is no attempt was made to provide comprehensive coverage of land-use management in Palestine, such as national or local sustainability approach.

Validation of the selected indicators can be done within the modeling process by using multi-criteria and sensitivity analysis. The selected groups of indicator will be used as an input for urban land-use modeling, therefore, the deferent existing models have to be reviewed and critically analyzed in order to defined the most appropriate modeling approach and tools.

1.5 Models for Sustainable Land-use Management

Since land-use change occurred due to mainly rapid urbanization, it requires scientific and objective knowledge based on elaborated a multidisciplinary framework. This knowledge is highly crucial for analyzing and modeling land-use changes for more efficient management practices. Understanding the urban growth within the land-use system is a prerequisite for modeling and forecasting future trends of land-use change and its environmental impacts. Hence, the aim of modeling is to abstract and represent the entity being studied. Modeling can be conceptual, symbolic or mathematical, depending on the purposes of the specific application. In the domain of land-use, modeling can be utilized for analyzing, evaluating, forecasting and simulating land-use systems to support decision-making. From the perspective of spatial science, modeling must take both the spatial and temporal dimensions of land-use into account. Theoretical background on modeling land-use can provide a guideline for selecting the suitable modeling methods among the currently available.

1.5.1 Conceptual Framework for Modeling Land-uses

The construction of multidisciplinary and integrated conceptual framework model is extremely important management tool for sustainable urban land-use (Bella et al., 1994). Such a conceptual framework model would allow for a more scientific-based choice of indicators and for developing the appropriate tools to evaluate the multi-dimensional aspects of urban land-use. This framework should be subjected to critical review to ensure that it meets crucial expectations. It directs research toward useful indicators of change rather than precise predictions.

Brang et al. (2002) defined the conceptual framework as a graphical representation of the real world by using diagrams that illustrate the interactions between different elements that translated into a list of indicators. It is orientating and integrating research efforts. Therefore conceptual models are very important in during the problem analysis and identify the possible indicators and their relations.

Pickup and Stafford-Smith (1993) argued that one of the land-use problems is the lack of a conceptual framework within the process of approaching sustainable land management. Therefore it plays an important role in linking and incorporating a critical set of sustainability indicators.

Niu, et al., (1993) concluded that, future research utilizing conceptual framework should not only foster the development of appropriate methodologies for the comparative evaluation of sustainable development at different levels, but also offer insights to appropriate decision makers at various levels regarding available options and alternative actions for the healthy development of their respective societies.

1.5.2 Land-use Change Models

Land-use change models are tools for understanding and explaining the causes and consequences of land-use dynamics.

Several models have been developed to simulate the behaviour of individuals and the up scaling of this behaviour, in order to relate it to changes in the land pattern (Berger, 2001; Parker et al., 2003). A variety of modeling approaches are used for exploratory analysis of land-use change. These include: (a) stochastic models based on transition matrices (Maxwell et al., 2000), Markov chains (Butcher, 1999; Brown et al., 2000); (b) optimization models (Riebsame et al., 1994) including a variety of socio-economic models focusing on supply and demand (Waddell, 2000), multiple goal linear programming (Huizing, 1992), and input–output analysis, possibly linked to spatial agro-ecological zones (Fischer and Sun, 2001); (c) dynamic, process-based simulation models (Stephenne and Lambin, 2001) including cellular automata (White et al., 2000; Jenerette and Wu, 2001; Messina and Walsh, 2001; van der Veen and Otter, 2001); and agent-based models (Ligtenberg et al., 2001; Otter et al., 2001; Parker et al., 2002) that represent both stochastic modelling and dynamic process-based simulation; and (e) empirical modeling approaches (Agarwal et al., 2002). Use of empirical models is particularly widespread for land-use change modeling. Empirical models provide a mechanism for exploratory analysis of detailed case studies and can help to identify the key driving variables behind land cover and land-use changes (Turner et al., 1993). Empirical models are also readily developed for a particular geographic place at a specific time from historical and geographic data describing socio-economic and environmental conditions. Typically, empirical approaches use regression methods to quantify models from data that describe the spatial and historic distribution of land-use changes. There are many examples of empirical models of land-use change based on regression (de Koning et al., 1998; Wear and Bolstad, 1998; Verburg et al., 1999; Mertens and Lambin, 2000; Pijanowskia et al., 2000; Pontius et al., 2001; Serneels and Lambin, 2001; Theobald and Hobbs, 1998). Verburg et al. (2004) review some of the concepts underpinning models of land-use change and identify a number of general limitations of empirical models. These include a relatively low degree of explanation, short time periods for study and small sample sizes (Veldkamp and Fresco, 1997).

Land-use change modeling, especially if done in a spatially-explicit, integrated and multi-scale manner, is an important technique for the projection of alternative pathways into the future, for conducting experiments that test our understanding of key processes in land-use changes. Land-use change models should represent part of the complexity of land-use systems. They offer the possibility to test the sensitivity of land-use patterns to changes in selected variables. They also allow testing of the stability of linked social and ecological systems, through scenario building (Veldkamp and Lambin, 2001). Verburg et al. (2004b) also note that cross-sectional analysis of actual land-use patterns can result in more stable explanations of land-use patterns; this is because cross-sectional data integrate the history of land-use changes and causes of change and reduce inherent variability.

Description and modeling of land systems highly depends on the data availability and quality. With recent advances in land-use modeling research, "the discrepancy of data types between human and biophysical disciplines are obvious" (Veldkamp et al., 2001). Researchers in the social sciences traditionally study individual behaviour at the micro-level, "some of them using qualitative and others using the quantitative models of microeconomics and social psychology" (Fox et al., 2002). Physical scientists, geographers and ecologists focus more on land at the macro-scale, through remote sensing and GIS, and using macro-properties of social organization in order to identify social factors connected to the macro-scale patterns (Verburg et al., 2002). "Due to the poor connections between spatially explicit land studies and the socio-economic approaches there is a general poverty in real integrated human-environmental approaches" (Nagendra et. al., 2004). Two empirical approaches to get more insight in the coupled human-environmental system by means of statistical modeling are presented by Aspinall (2004) and Kok (2004). Both approaches demonstrate the need to address these issues in a multi-scale approach in order to be able to separate the socio-economic drivers of land-use change and its environmental impacts.

Osaragi and Kurisaki (2000) argue that without a scientific understanding of the system under study implies a certain degree of uncertainty due to the numerous unknown factors involved. This may result in risky decision-making in urban development planning and management. Wrong decision-making may cause severe economic and environmental losses, or even lead to large disasters. As a consequence, scientific decision-making has been the pursuit of urban development planning and management that is highly dependent on the reasonable understanding of the objects involved. Understanding needs modeling to analyze the complex relationships involved in the decision-making; it also needs an understanding of the properties of the problems being studied. Therefore a prerequisite to the development of realistic models of land-use change is the identification of the most important drivers of change (Veldkamp and Lambin, 2001)

Van-den-Bergh and Nijkamp (1991) examined the implications of ecologically sustainable economic development for integrated dynamic modeling. After a concise discussion of sustainable development it is suggested that five concepts are central to it: intergenerational equity, the regional scale, multiple use, long-term uncertainty, and economic-ecological integration. The discussion of each of these issues is focused on the implications for model elements and uses. Thereby, old ideas are reviewed and new ones are proposed. The aim is not to come up with a rigid framework for dealing with sustainable development but rather to suggest which alternatives are available to deal with the central concepts, although in a section on economic-ecological integration general requirements for dynamic economic-ecological models are mentioned explicitly in order to offer a general frame of reference. These requirements are fairly general and may be taken up in ensuing discussions of the methodological aspects related to sustainable development." (Van-den-Bergh and Nijkamp, 1991)

These urban models may well describe elements within an urban system in a micro-view, but for modeling urban expansion, they neglect to describe the relationship between the driving forces and urban expansion (Li et al., 2002). For example, in developing regions, how is population increase and economic growth, as the driving force for urban growth, related to the extent of urban expansion? These models concentrate on estimates of location of new urban cells, but overlook the effect of the population and economy as an aggregative way for urban expansion in the macro views. Due to micro-views, they are usually highly data-intensive, and data assembly has been a laborious and time-consuming process in practical applications, which may be disadvantageous for building operational simulation models. It would therefore be very useful to build a simple macro model that could simulate urban expansion in various situations based on overall population increases together with economic factors, instead of on some detailed intra-urban factors such as urban land-use, employment, life expectancy, illiteracy rate, etc.

Verburg et al. (1999) argued that modeling land-use change is a function of its biophysical and socio-economic driving forces provides insights into the extent and location of land-use changes and its effects. Therefore he and his colleagues developed a spatially explicit multi-scale approach to the Conversion of Land-use and its Effects (CLUE) modeling framework, which used for the quantitative multi-scale description of land-use dynamics. It is based on the empirical description of the biophysical and socio-economic drivers of land-use at different aggregation levels, using a system analytical approach for the characterization of agro-ecosystems (Veldkamp and Verburg, 2004). Sub-national changes in land-use following changes in the national demand for agricultural commodities are modeled on the basis of complex interactions in time and space and the competition between alternative land-uses (de Koning et al. 1999).

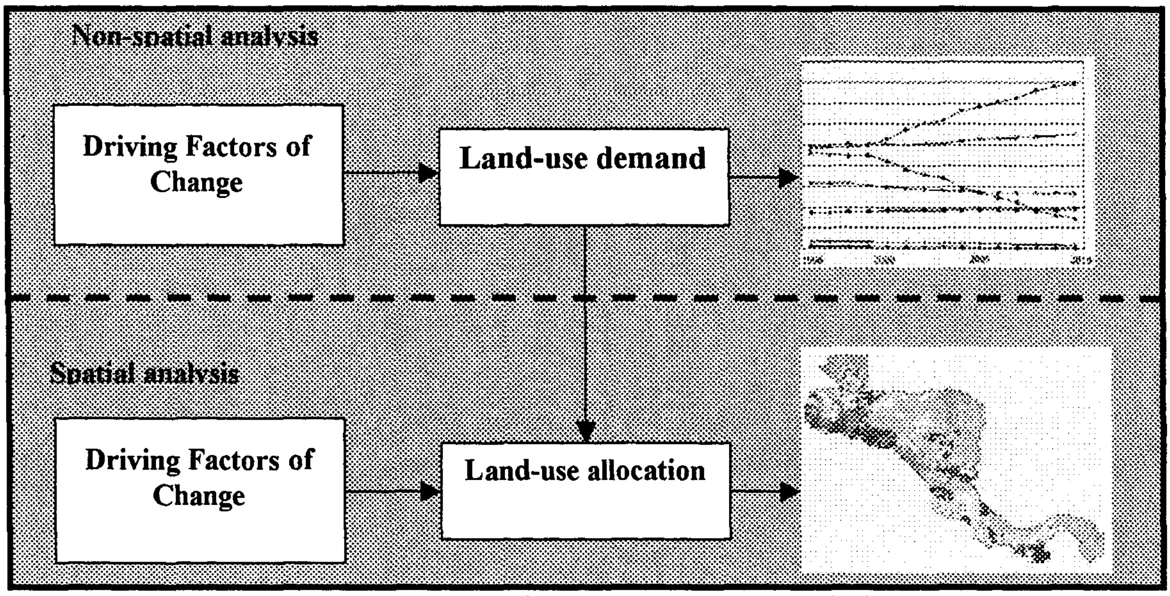


Figure 1.6. General structure of the CLUE modeling framework (Source: www.cluemodel.nl)

The CLUE modeling framework is a dynamic spatially explicit simulation methodology, which uses actual and historical land-use patterns in relation to biophysical and socio-economic determinants for the exploration of land-use changes in the near future (Verburg et al., 1999; Verburg et al., 2002). The model was first applied to Costa Rica (Veldkamp and Fresco, 1996), while recently the methodology was being tested for countries in Central-Andean America and Asia, showing different land-use change patterns (Verburg et al., 1999a; 1999b). The authors of CLUE argue that the full validation of the model is complicated because time series of land-use development at sufficiently high spatial detail are often lacking.

Wilson et al., 2003 argued that when modeling land-use changes, therefore, we are looking at the patterns of development on the landscape, rather than referring to relative differences in the density of development or population (i.e., ''urban'' as distinguished from ''suburban'' or ''rural'').

1.5.3 Environmental impact modeling

Land-use change models are often used as inputs in environmental impact studies (Veldkamp and Verburg, 2004). Most commonly the land-use change is used as an input of a model to calculate environmental process impacts such as pollution, emissions, rainfall run-off, losses of vegetation, etc. The problem with such assessments is they are often mono-disciplinary, static and present only a limited number of alternatives. Furthermore, the time horizon is usually fixed and the long-term dynamics of human-environmental systems are ignored. This special issue demonstrates four developments that can lead to improved human-environmental impact assessments.

- Analyzing the system properties in a biophysical and socio-economic context at multiple scales (Kok, 2004; Aspinall, 2004).
- Integrating spatially explicit land-use change models in integrated assessment models (de Nijs et al., 2004 ; Solecki; Oliveri, 2004).
- Visualization and quantification of the effects of land-use change, to support land-users and policy makers in their decisions (Stoorvogel et al., 2004).
- Modeling of the actual decision making process with agent-based modeling (Evans and Kelley, 2004; Huigen, 2004; Ligtenberg et al., 2004).

A fifth almost unexplored possibility is to incorporate dynamic feedbacks between changing land-use and changing environment and vice versa. Such dynamic feedbacks between the social and biophysical model components are still rare. Some first experiments have been made where different rates of change in land-use have different biophysical impacts and feedbacks (Schoorl and Veldkamp, 2001; Ducrot et al., 2004). The need for this coupling is clear and links between (micro to macro) agent-based and (macro to micro) empirical models are needed (Verburg et al., 2004). This will hopefully lead to more dynamic scenarios that facilitate the identification of mechanisms for better governance and decision-making.

Van Pelt, M.J.F. 1993 examined how the concept of ecological sustainability may affect project appraisal for developing countries. He proposed that three criteria should be applied efficiency, equity and ecological sustainability. Operationalization of the sustainability criterion requires that policy-makers set targets for natural resource use. Moreover, they need to address new trade-offs, for instance between short-term income objectives (efficiency) and long-term environmental objectives (sustainability). The new issues raised by the sustainability criterion require a review of the applicability of project appraisal methods. Cost-benefit analysis (CBA) has been used most frequently, but its usefulness in sustainability-oriented project appraisal is shown to be limited. Despite some methodological problems, multi-criteria analysis (MCA) should be regarded as an appropriate alternative or complementary appraisal tool. MCA does not require monitorization of effects, nor does it exclusively focus on efficiency measurement. These advantages apply particularly to developing countries where the data base is weak, economic activities are directly dependent on natural resources, and distribution concerns are strong. MCA may be applied to, inter alia, the estimation of scores on the sustainability criterion, and to the integrated evaluation of scores on the three key criteria.

1.5.3.1 Spatial and Statistics Modeling Tools

When modeling land-use changes, therefore, we are looking for the appropriate modeling tools that could give acceptable results in analysis and predicting the available data (Wilson et. al. (2003). Traditional statistical models, e.g. Markov chain analysis, multiple regression analysis, principal component analysis, factor analysis and logistic regression, have been used in interpreting socio-economic activities (Theobald and Hobbs, 1998; Wu and Yeh, 1997; Wu, 2000b; Lopez et al., 2001). Lopez et al. (2001) report a model for predicting land cover and land-use change in the urban fringe. They conclude that the most powerful use of the Markov transition matrices seems to be at the descriptive rather than the predictive level. Linear regression between urban and population growth offered a more robust prediction of urban land-use changes. Wu and Yeh (1997) apply logistic regression for modeling land development patterns in Guangzhou between 1978 and 1992, based on a series of aerial photographs. They found that the major determinants of land development have changed: from distance from the city center to closeness to the city center; from proximity to inter-city highways to proximity to city streets; and from more related to less related to the physical condition of the sites etc. This demonstrates that various factors are changing their roles in the process of land development. This research has shown that logistic regression has a stronger capacity for interpreting urban development based on the probability of land conservation. Awad and Aboul-Ela (2003) found that Monte-Carlo Simulation technique is suitable for solution of non-linear programming problems in residential land-use planning.

However, traditional statistics are criticized as being ineffective in modeling spatial and temporal data. The major reason is that spatial and temporal data often violate basic assumptions such as the normal distribution, appropriate error structure of the variables, independence of variables, and model linearity. Taking into account environmental, socio-economic and cultural variables aspects of land-use process processes, relationships between the variables may be very complex. Statistical method, such as logistic regression, may have some limitations when variables interact on a complex way. They are invalid when spatial variables correlate with each other and have difficulties in handling poor and noisy data (Li and Yeh, 2002).

Two alternatives are frequently adopted. One is incorporating spatial sampling into traditional analysis (Gobin et al., 2001). The other is developing new statistics based on spatial relationships such as spatial dependence and spatial heterogeneity. New methods for analyzing spatial (and space-time) data include spatial data analysis (Griffith and Layne, 1999; Haining, 1990), spatial econometrics (Anselin, 1988), local spatial analysis (Ord and Getis, 1995) and geographically weighted regression (GWR) (Fotheringham et al., 2000). Satellite imagery is increasingly used elsewhere to assess urbanization by measuring land-use and land cover change for whole cities and city regions (Alberti et al., 2002; Jürgens, 2003). Attempts have also been made to develop spatially explicit models of urban land-use and cover change (Verburg et al., 1999; EEA, 2002; Parker et al., 2002; Herold et al., 2004). However, there is still a scarcity of models to predict the environmental consequences of this change such as increased surface runoff and pollutant emissions into the atmosphere, water and soil (Alberti and Waddell, 2000; Weng, 2001). Remote sensing techniques for measuring urban areas and estimating urban population have been used since the 1950s (De Bruijn, 1991; Bocco and Sanchez, 1995). One of the main basic theoretical approaches behind has been the allometric growth model that relates population data to the corresponding urban area. The procedure can be reverted to compute population from remotely-sensed urban areas (Henderson and Xia, 1997).

1.5.3.2 Agent-based modeling

Multi-agent (MA) systems are designed as a collection of interacting autonomous agents, each having their own capacities and goals but related to a common environment. This interaction can involve communication, i.e. the passing of information from one agent to another.

An agent-based model is one in which the basic unit of activity is the agent. Usually, agents explicitly represent actors in the situation being modeled, often at the individual level. Agents are autonomous in that they are capable of effective independent action, and their activity is directed towards the achievement of defined tasks or goals. They share an environment through agent communication and interaction, and they make decisions that tie behaviour to the environment.

From the perspective of modeling, multi-agents also have attractive features (White and Engelen, (2000): (1) as a tool to implement self-organizing theory such as a straightforward way of representing spatial entities or actors having relatively complex properties or behaviors; (2) an easy way to capture directly the interactive properties of many natural and human systems, as well as the complex system behavior that emerges from this interaction. Agent-based simulation is ideally suited to exploring the implications of non-linearity in system behavior and also lends itself to models that are readily scalable in scope and level. The approach is useful for examining the relationship between micro-level behavior and macro outcomes. Multi-agent models can locate agents and other resources of the environment in space and thus include the effects of space on the behavior of the agents and the effects of the agents on the environment (Frank, 2000).

Consequently, current applications of MA models mainly focus on abstracted theoretical research or micro-behavior simulation. There is no report that MA has been applied solely for understanding urban growth on a certain scale. However, it can be inferred that MA are an ideal tool for understanding decision-making complexity of urban growth at a micro scale, such as a residential area in certain city (Benenson, 1998).

MA models simulate decision-making by individual agents of land-use change explicitly addressing interactions among individuals (Evans and Kelley, 2004). The explicit attention for interactions between agents makes it possible for this type of models to simulate emergent properties of systems. If the decision rules of the agents are set such that they sufficiently look like human decision-making they can simulate behaviour at the meso-level of social organization, i.e. the behaviour of in-homogeneous groups of actors. This specia issue demonstrates the current progress of several multi-agent models (Huigen, 2004; Evans and Kelley, 2004 ; Ligtenberg et al., 2004). Most of the current models are only able tc simulate very simplified, hypothetical landscapes, as the number of interacting agents anc variety of factors that need to be taken into account, is still too large to make comprehensive models (Parker et al., 2003). The papers in this issue demonstrate that realistic applications of multi-agent model are starting to develop. Especially model validation of agent-basec models is still a largely unexplored terrain of research. Some first attempts for agent-basec and empirical approaches are presented by Evans and Kelley (2004).

1.5.3.3 ANN-based modeling

An artificial neural network (ANN) is a system composed of many simple processing elements operating in parallel, whose function is determined by network structure connection strengths, and the processing performed at computing elements or nodes. The development of a neural network model requires the specification of a "network topology", a learning paradigm and a learning algorithm. Unlike the more commonly used analytica methods, the ANN is not dependent on particular functional relationships, makes nc assumptions regarding the distributional properties of the data. This independence makes the ANN a potentially powerful modeling tool for exploring nonlinear complex problems (Olden and Jackson, 2001; Mas, et al., 2004). According to published literature on ANN various applications, its strength lies in its ability to handle non-linear functions, to perform model-free function estimation, to learn from data relationships that are not otherwise known and, to generalize to unseen situations. ANNs have been shown to be universal and highly flexible function approximators or any data. Therefore, ANNs make powerful tools for models, especially when the underlying data relationships are unknown (Corne et al., 1999; Mas, et al., 2004).

The use of neural networks has increased substantially over the last several years because of the advances in computing performance (Skapura, 1995) and the increased availability of powerful and flexible ANN software. Recent ANN applications include transport planning and land-use interaction (Rodrigue, 1997; Shmueli, 1998), remote sensing (Atkinson & Tatnall, 1997), image classification and analysis (Skidmore et al., 1997), spatia interpolation (Rigol et al., 2001), land cover classification (Brown, Lusch, & Duda, 1998 Foody, 2002), urban change and land cover transformation (Veldkamp and lambin, 2001

Pijanowskia et al., 2002). Shmueli (1998) used an ANN model to test whether or not there is a connection between socio-economic and demographic variables and travel activities. Kropp (1998) applied a self-organizing map (SOM) by using ANN model to classify 171 cities into four categories and assess their sensitivity to change. As a form of non-linear dimension reduction, SOM successfully provided an effective tool to identify cities that are susceptible to perturbations of human-nature interactions. Rodrigue (1997) provided an overview of a parallel transportation/land-use modeling environment and concluded that parallel distributed processing offers a new methodology to represent the relational structure between elements of a transportation/land-use system and thus helps to model these systems. He also considered that sequential urban modeling does not represent complex urban dynamics well, and he proposed a parallel network (back-propagation algorithm) model to simulate the spatial process and spatial pattern of integrated transport/land-use system.

Pijanowskia et al. (2002) and Mas et al., (2004) integrated ANN and GIS to forecast land-use change, where GIS is used to develop the spatial predictor variables. Four phases were followed in their researches: (1) design of the network and of inputs from historical data; (2) network training using a subset of inputs; (3) testing the neural network using the full data set of the inputs; and (4) using the information from the neural network to forecast changes. They concluded that ANN constitutes a powerful alternative in spatial land-use change processes modeling, when more conventional models obtain poor performance. However, it is probably impossible to develop models of land-use processes, which present a high power of prediction because these processes depend upon very diverse factors from environmental to socio-economic and cultural that are changing over time. They recommended ANN model for future prediction that helps the environmental planners and managers to develop policies aimed at controlling the adverse ecological and social effects of land-use changes.

1.5.4 Validation Methods of Model Performance

The majority of the large number of existing land use models lack a proper validation, often because of data problems (Kok et al., 2001). Validation of land-use change predictions is only possible by using historical land-use changes (Verburg, 1999). This allows the evaluation of both the stability of the statistical relationships between land-use and its determining factors as well as means to validate the allocation algorithm of the used models. As input for the yearly changes in demand for any study area as a whole, a linear interpolation of land-use change in a certain period of time should be used. Most biophysical determining factors can be assumed constant during the validation period. This is not the case for the demographic and socio-economic conditions. For the validation of the model performance, Verburg (1999) proposes to calculate correlations between the observed and modeled changes of land-use. If the correlation between observed and modeled patterns ranged between 0.76 and 0.98, the pattern is well matched. The high correlations can partly be explained by the relatively small changes in land-use during the validation period. This comparison of observed and modeled changes in land-use in certain period of time therefore provides a better measure of model performance.

Aspinall (2004) argued that model validation and testing must also address the issue of a lack of temporal invariance in relationships with drivers of change and the influence of this on models. A standard approach to model validation and testing is to develop a model based on the change over one period t_0- t_1 and to use the model to predict the pattern of change after another independent period t_1-t_2 The model is then tested by comparing the predicted change with the observed change at time t_2: This approach may work if the modeling is confined to a period within which the drivers do not change. For example, a model developed for the period 1980–1990 for the study area described in this paper could be used to predict land-use change between 1990 and 2000, and then be tested with observed data for 2000. Because these dates are all within one period, this analysis may be appropriate. If, however, a model was developed for change between 1995 and 2005 and used to predict change between 2005 and 2015, this may provide an unreliable validation since two different sets of drivers of change may have operated during the period between 2005 and 2015. A problem in this regard is that it is often not known when specific drivers change. Hence, A proper validation not only requires a second independent data set, it should be preceded by model calibration, which calls for an additional data set (Kok et al., 2001).

1.6 Conclusion

Sustainable land-use management aims at integrating socio-economic, environmental and institutional factors into one framework that leads to formulate the appropriate policies and activities. Developing indicators framework is essential tool for tracking progress towards sustainable land-use. The selection of these indicators should be based on objective criteria and well-designed conceptual framework.

The researches done until now for developing a conceptual framework for modeling sustainable land-use management are still fragmented and incomplete attempts. Most of the reviewed researched focused on investigation the tools for special modeling of urban land-use rather than analyzing the interaction between factors that effecting the changes of urban land-use. Very few scholars described the relationship between the driving forces, environmental impacts and urban expansion in one framework.

Therefore, for the efficient analysis of land-use change problems, it is essential to establish a conceptual integrated framework that aims at achieving sustainable land-use management. It is essential to look for the appropriate modeling approaches and tools that could give acceptable results in analysis and predicting the available data. Traditional statistical models such as multiple regression analysis, principal component analysis and factor analysis have been very successful in interpreting socio-economic activities. However, traditional statistics are criticized as being ineffective in modeling spatial and temporal data. Attempts have also been made to develop spatially explicit models of land-use and land cover change by using several tools such as satellite imagery, aerial photography, GIS, remote sensing, agent-based modeling and ANN based modeling.

CHAPTER TWO

CONCEPTUAL INTEGRATED MODEL FOR SUSTAINABLE LAND-USE MANAGEMENT FOR GAZA CITY

2 Conceptual Integrated Model for Sustainable Land-use Management for Gaza City

2.1 Introduction

Based on the research problem and the literature review, land-use management is a crucial issue for the cities in Palestine, particularly in a densely populated area such as Gaza City, where undergoing rapid urban development is being dominated the land-use changes of the city. Because of land is considered as limited resource in Gaza, thus there is a need for better management of land-uses. Therefore, an integrated model based on cause-effect framework for modeling the relationship between socio-economic, environmental and institutional driving forces with land-use changes is introduced in this chapter. This model is used as a tool for better understanding the consequences of land-use changes aiming at achieving sustainable land-use management.

The proposed model expected to contribute to the design, exploration and evaluation of land-use options at the local level. Specifically, its objectives are to develop methodologies for exploratory land-use analysis and to evaluate these for generating options for policy formulation. The model strategy was to develop an operational methodology and corresponding system for quantitative land-use management at the local level.

The most related indicators to the land-use management have been selected based on sustainability approach and presented in Table 2.1. Consequently, underlying factors behind the changes in land-use will evolve through the interplay of different aspects of the conceptual framework.

2.2 Description of the Conceptual Integrated Model

The proposed conceptual model seeks to integrate the main socio-economic, environmen and institutional factors in explicit, interactive and holistic approach for better land-us management. The model requires historical development data and information on the land use changes versus socio-economic, institutional and environmental aspects. Each dimensio is considered as an element within an integrated system. Therefore the reference framewor for the integrated model is based on sustainability approach. The conceptual framewor shown in Figure 2.1 is built on four main interactive components. Each component consist of number of indicators that have been selected according to their importance and relevanc to the land-use management (see section 1.4.3).

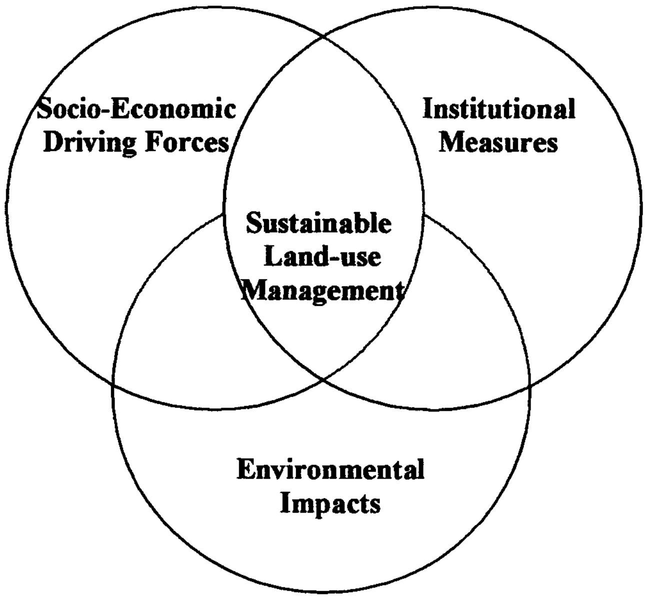


Figure 2.1. Conceptual Framework for the Sustainable Land-use management Model

Sustainable land-use management must be based on three integrated dimensions, which ar strengthening socio-economic, controlling pollution pressures and remediation of th environmental impacts, and enhance capacity building for local institutions.

Socio-economic dimension of the sustainability approach is considering the overall stabilit of socio-economic aspects of the people (Brown and Jacobson, 1987; Veldkamp et al., 2001 Pauleit et al., 2004). Land-use management process is socially desirable when it meets th actual as well as the expected future needs of the communities and individuals. It has also t consider the aspect of increase the development chances for future generations. Socia acceptance will be supported by an overall increase of living standards and welfare and by distribution pattern of benefits that reduces poverty and increases social stability in terms o income, health, education and access to public services. Economic sustainability needs a supportive environment, in particular with respect to institutions and markets. The economical policies are providing stability for the area economy and for the local society. The economical sustainability requires a clear and reliable rules, e.g. about taxes, environmental and social standards. It needs access to information, free movement of goods, co-operation between partners, physical infrastructure and political support.

Pollution pressure and the environmental impacts of the sustainability approach means that negative environmental impacts emitting from the city should be reduced stepwise mainly groundwater pollution and waste generation. Hence, the overall environmental state is improving in the long-term view of the city. In addition, the use of renewable resources is not exceeding their regeneration rate and that the consumption of non-renewable resources is decreasing in a short to medium term perspective.

Institutional measures for sustainable land-use management are based on improving the institutional ability to manage the development process in a sustainable manner even when the conditions are changing over time. The institutional measures would be able to cope with short, medium and long-term interests and to provide tools for the mediation between the different sustainability dimensions. In addition, it has to provide tools for good flow of information between all relevant actors in order to facilitate a transparent and participatory planning process. Participation has to be institutionalized in order to give the stakeholders the opportunity to take part in administrative decision processes.

Policies at the local level have great importance in driving land-use changes. Policies, which based on deep understanding of the pervious and current situation of land-use change and its drivers, have great impact on sustainability of land-uses. Land-use policies must not only capture the complex socio-economic and biophysical drivers of land-use change but also account for specific human-environment conditions under which the drivers of change operate (Lambie et al., 2001). However, it was difficult to quantify the policies and list them in the indicator's list.

Geopolitical influence at the national level has its impacts on the local levels. Geopolitical stability is driver for progressing towards sustainability. Moreover, it could facilitate the regional cooperation for development and environmental protection.

International influences have also considered as part of the driving forces of land-use change. For instance international donors, either governments or organizations, are supporting the local development. Their support for projects like roads and housing construction, has mainly contributed to the changes in the city's land-use. Another example environmental treaty such as the Kyoto Protocol may drive significant changes in land-use in the future.

2.3 Possible Indicators for the Sustainable Land-use Model

The related indicators to sustainable land-use management have been selected based on the available technical studies, expert's opinions and scientific criteria mentioned in section 1.4.3. They capture all dimensions for the sustainability framework, which can indicate whether the city is becoming more or less sustainable. Thirty indicators have been locally and international recognized as main indicators for sustainable land-use management. Researchers from different international research centers identified most of these indicators in addition to other indicator such as policies and biophysical indicators (Turner et al., 1995; Bourne, 1996; Musters et al., 1998; Wilbanks and Kates, 1999; Lambin et al., 2001; Weber and Puissant, 2003; Veldkamp and Verburg, 2004). Biophysical indicators also play an important role in shaping the land-uses of the city, however, it is not included in the list of possible indicators due to the lack of data on most of them. The data as geopolitical and international influence are incomplete or even not exist. As a result, Table 2.1 presents the thirty possible indicators that used in the conceptual framework.

Table 2.1 Possible indicators used in the proposed conceptual framework.

	Socio-economic Driving Forces Indicators	Code
	Demographical	
1	Population rate of growth	PG
2	Percentage of population under the age of 19 years	P19
3	Percentage of population living in Refugee camp	PC
4	Population density	PD
	Health	
5	Fertility rate	FR
6	Infant mortality rate	IM
7	Life expectancy	LE
	Educational	
8	Percentage of students from the total population	ST
9	Illiteracy rate	IR
	Access to public services	
10	Percentage of households connected to water network	HW
11	Percentage of households connected to wastewater network	HWW
12	Percentage of households connected to electrical network	HE
	Economic and employment	
13	Percentage of labor forces	LF
14	Unemployment rate	UE
15	Per capita GDP	GDP
16	Poverty rate	PR
	Environmental Indicators	
17	Amounts of Solid waste	SW
18	Groundwater Abstraction	GWA
19	Ground water quality (total dissolved solids-TDS)	TDS
20	Percentage of households use cesspits for wastewater discharge	WWC
21	Percentage of households discharge their wastewater to the sea	WWS
22	Number of motor vehicles	CAR
23	Electrical consumption	EC
	Institutional Measures	
	Infrastructure Development	
24	Road network Development	RND
25	Water network Development	WND
26	Sewer network development	SND
	Provision of public services	
27	Establish new schools	NS
28	Establish new health facilities	NH
29	Establish new public parks	NP
	Fund Raising	
30	Fund from local and external sources for development	FUND
	Land-use categories	
	Urban areas	
31	Residential/commercial areas	RES
32	Road areas	ROD
33	Industrial areas	IND
34	Recreational areas and public parks	REC
	Agriculture areas	
35	Agricultural and open spaces	AGR

2.3.1 Socio-Economic Driving Forces

Palestinian Central Bureau of Statistical (PCBS) and United Nations Development Program (UNDP) have identified a long list of socio-economic indicators including demographic, educational, health, economic and other related indicators (PCBS, 2002; UNDP, 2002). The main demographical indicators have been identified are; population number, population rate of growth, percentage of population under 19 years and percentage of population living in refugee camps (UNCTAD, 2002). The possible health indicators could be presented by three main indicators, which are fertility rate, infant mortality rate and life expectancy. Two main educational indicators have been identified which are illiteracy rate and percentage of students at all educational levels. Only five economic representative indicators have been selected which are: labour forces, unemployment, GDP, poverty rate, cars per households, municipal revenues and expenditures for development (UNCTAD, 2002). Access to public services indicators also have been identified such as the percentages of households connected to water, wastewater and electrical networks are consider as important indicators for urban land-use.

Demographical Indicators

Population growth rate

Population provides an important contextual reference on sustainable land-use management for decision makers looking at the interrelationships between people, resources, environment and development (UN, 1996). Changes in population growth rate could play an important role in reducing poverty, achieving economic progress, improving environmental protection, and moving to more sustainable consumption and production. Urbanization has become a dominant trend in the growth and distribution of the population. In the other hand, rapid population growth can lead to unsustainable living conditions and increased pressure on the environment, especially in the areas suffering scarcity and limited natural resources.

The annual population rate of growth refers to the annual ratio of increase in population number which equal to the (birth rate minus death rate) + (migration rate). It is often calculated from the known population figures according to the following formula:

Annual population rate of growth = $\{(Pt - Pt\text{-}1) / Pt\text{-}1\} * 100$

Where P_t is the population number in certain year and P_{t-1} is the population number of in the previous year.

Percentage of the population under the age of 19 years:

It reflects the ration of the young people who are belongs to age category under 19 year to the total population of the city. This indicator is widely used in order to present the demographical structure of the society and explain other indicators such as dependency ratio and labour forces (BZU, 1998; 2000). The increase of this category of population demands increase in all social infrastructure such as educational and health facilities.

Population density

Population density is almost universally taken to be an indicator of land-use changes (Qadeer, 2004, UNDP, 2002). It measures the ration number of population per land area unit, usually square kilometer). As the population density increase, the pressure on land increase in parallel resulting in more land being put to residential use and loosing more agricultural lands and open spaces. Therefore MOPIC (1998) considered the population density among the most important indicators for land-use management in Gaza.

Percentage of population living in the refugee camp:

This refers to the percentage of the population living within the jurisdiction of the refugee camp determined by the responsible agency UNRWA. The limited area of the refugee camp combined with population growth made it worth to investigate the relation of this indicator with land use changes. This indicator has been used by the international organizations for studying the future urban land-uses (UNDP, 2002; UNRWA, 2004)

Health Indicators

Rapid urban growth can outstrip society's capacity to protect the environment and provide health care services. Air and water pollution in urban areas are associated with excess morbidity and mortality, while overcrowding and inadequate housing contribute to respiratory and other diseases. Total fertility rate, infant mortality rate and life expectancy are the core health indicators related to sustainable land-use management. These indicators are widely accepted and have been available and in use for some time (UN, 1996).

Total fertility rate

Total Fertility rate (among women 15–49 years old) is defined by PCBS as the average number of children that would be born alive to a woman during her life-time. This indicator is related directly to the increase of population number and the educational level of the society especially the women. It also connected to the health situation and family planning programs adopted by the Ministry of Health (PCBS, 2003). More stable levels of fertility can have a considerable positive impact on quality of management of urban areas and resource utilization (UN, 1996).

Infant mortality rate:

It reflects the ratio of the deaths among infants under one year old in a given year per every 1,000 live births. This indicator would provide information on the level of mortality, health status and level of health care in the area, as well as effectiveness of preventive care and attention paid to the health of the mother and child.

Life expectancy at birth:

According to WHO definition, life expectancy refers to the number of years a newborn infant would live if prevailing patterns of age specific mortality rates at the time of birth were to stay the same throughout the child's life. An increase of life expectancy means direct increase in the total population and increase of the old people category. This increase required more facilities and health care to the old people.

Educational Indicators

Education, as a lifelong process, is widely accepted as a fundamental prerequisite for the achieving sustainable development. It cuts across all areas of Agenda 21, being a particularly critical element in meeting basic human needs, and in achieving equity, capacity building, access to information, and strengthening scientific knowledge. Education is also recognized as a means of changing consumption and production patterns to a more sustainable path (UN, 1996). Education, in all levels, is regarded as a process by which human beings and societies can reach their full potential. There is a close association between the illiteracy rates and the persistence of poverty irrespective of the level of a country's development. It is vital to increase the number of educated people to achieve the goals of building a more sustainable society. In this way, people are better equipped to participate in decision-making that adequately and successfully addresses environment and development issues (UN, 1996).

Percentage of students in all educational levels

This percentage presents all students at all educational levels (elementary, intermediate, secondary and university levels). The increase of this percentage means increase of the demand on classrooms and additional educational facilities, which means additional funds should be allocated to the educational sector and more lands should be devoted for this purpose. These figures obtained from the different educational providers such as ministry of education, UNRWA and local universities.

Illiteracy rate

According the definition from UNESCO (2000), This indicator refers to the proportion of the population that has the ability to understand and use written information in daily activities to develop one's knowledge potential. It includes capability to understand texts, various types of documents and arithmetic operations. Low levels of literacy affect an individual's ability to find a job and to perform well in that job, and are likely to lead to lower paying jobs, reinforcing inequities that may have contributed to the low literacy skills in the first place. Literacy levels also have an impact on an individual's ability to participate in society and culture. Assessing illiteracy rates offers a measure of the effectiveness of education systems.

2.3.2 Access to Public Services

Three indicators have been used to assess the percentage of households connected to the domestic water, wastewater and electricity networks. These percentages are reflecting the legal connections to the total number of households within the city. Usually these indicators reflect the wealthy of the city's population and directly connected to the economical indicators such as employment and poverty rate. In addition they indicate the abilities of the local institutions to provide public services.

2.3.3 Economic Indicators

The search for sustainability for land-use requires information on labour forces, unemployment rate, per capita GDP, poverty rate, expenditures for development of the basic facilities and infrastructure (UNCTAD, 2002). These selected indicators are well known and commonly used measures at local and national levels. They reflect the important issues of the local economic performance.

Labour forces

Labour force represents all those employed including people above 15 years and below 65 years, during the reference period, were in paid employment or self-employed and unemployed who are currently seeking work. It is calculated as a percentage of the total population. This indicator would provide information on the type of positions held by persons belonging to target groups to help determine whether all people have access to employment opportunities.

Unemployment rate

According to International Labour Organization (ILO) and PCBS, this indicator refers to all people above 15 years and below 65 years who did not work at all during the reference week, who were not absent from a job and were available for work and actively seeking a job during the reference week. Persons who worked in Israel and were absent from work due to closer are considered unemployment. Increase of unemployment rate has a strong relation with increase in poverty rate, which led to decrease of quality and quantity of urban development (Naqib, 2003; PCBS, 2003; World Bank, 2002a). Higher unemployment rates in Gaza are attributed the weaker capacity of the economy in Gaza to provide job opportunities

Per Capita GDP- Rate of Growth:

Per capita Gross Domestic Product (GDP) is a standard measure of basic economic growth (UN, 1996). Per capita GDP of Gaza region is calculated according to purchasing power and converted to US dollars to equalize purchasing power to currency of the region. The UNDP has used purchasing power parity for international GDP comparisons. These comparisons will be more accurate than comparisons based on exchanged rates, which are extremely unstable. Per capita GDP was calculated by dividing the total GDP for the region by the population of region during that year. It was difficult to calculate the GDP per capita for one city alone; therefore we used the per capita GDP for the whole Gaza Strip to be representative indicator. Per capita GDP has significant impacts on the overall wealthy and family income of the Palestinian People during the last years. It is noticed that high per capita GDP is correlated to better living standers, which related to expenditure and consumption of the Palestinian families (UNCTAD, 2002; BZU, 200; 2002).

Percentage of population living under poverty line:

Refers to the percentage of the population living below the specified poverty line. PCBS (2002) and MOPIC (2002) identified poverty as "the absence of the minimum standards of income or resources to meet basic needs of food and housing as the ability to maintain the minimum living standards". This includes tow poverty lines according to the spending patterns of the families. The first is termed "deep poverty line which was calculated to reflect a budget for food, clothing and housing. The second adds other necessities including health care, education, transportation and housekeeping supplies. Since expenditure levels better reflects the population's needs, and help to specify the poverty in Palestine, PCBS used the monthly expenditure level rather than using the monthly income. Therefore, High poverty rates are resulted from many several socio-economic factors and affected the overall living standers and their expenditure to improve their living conditions.

2.3.4 Environmental Indicators (pollution pressure and environmental impacts)

The Environmental indicators examine the impacts on land-use changes on land and water resources including solid waste, groundwater abstraction, water salinity and wastewater discharge. These environmental indicators are becoming dominant issues in studying land-use management (UN, 1996).

Total amount of collected solid waste

This represents the annual collected amounts of solid waste from all neighborhoods within the city. The collection responsibility is divided between three bodies (1) the environmental section of the municipality whose solid waste collectors work within the boundary of the city except the refugee camp. (2) Private contractors who hired by the municipality to collect the solid waste from certain location for a certain period of time. (3) UNRWA who is responsible for collecting the solid waste from inside the refugee camp. Solid waste normally consists of domestic waste, construction debris, industrial waste and medical waste. The collected amounts of solid waste from Gaza city are dumped in many random dumpsites, which located within the residential areas. Some of it transferred to the municipal landfill far away from the residential areas. These dumpsites cause soil contamination and its latchet infiltrated into ground water depending on the vulnerability of the soil at that area. An increase of these amounts of solid waste are posing additional pressure on the environment and contribute to more pollution of soil and groundwater as well as its odors which threaten the public health of the city's population.

Groundwater abstraction

It refers to the cumulative annual amounts of groundwater that have been pumped from the groundwater aquifer by the municipal water wells and agricultural wells either for domestic, agriculture or other uses. The increase of groundwater abstraction is direct result of increase in population and urban areas combined with increase in economical activities. It also followed the changes of the family's life style and their consumption patterns. The overexploitation of the groundwater has leading to many causes of irreversible saltwater intrusion especially in the coastal areas as well as rapid depletion of groundwater levels (EQA, 2003). Water resources management is crucial issue for land-use sustainability in Palestine where suffering from shortage of this natural resource.

Groundwater quality represented by total dissolved solids (TDS)

Groundwater quality deterioration from land-use conflicts is underlying the sustainable management of water resources and threatening the public health (EQA, 2003). Uncontrolled expansion of urban areas is one of the causes for the deterioration of water quality. Urban areas, including buildings and roads, considered as impervious surface, therefore, less rain is able to infiltrate the soil and run off increase (Reilly et al., 2004). In addition to other pollution sources such as solid waste, sewage, chemicals, etc. These urbanization-associated water quality impacts makes it clear that land-use planning and integration of best management practices could be mitigate water pollution and preserve water quality. TDS reflects the quality of the freshwater and consists to the total weight of all salts that are dissolved in a given volume of water expressed in milligrams per liter (mg/l). These salts in TDS consist mainly from Calcium, Magnesium, Potassium, Sodium, Carbonates, Bicarbonates, Chlorides, sulfates, and Phosphates and other solids (WHO, 2004). The lower the TDS level in the water, the more efficiently human body's cells actually get hydrated by the water that you drink. The higher the TDS levels in the water, the greater the probability of harmful contaminants that can pose health risks or hinder the absorption of water molecules on the cellular level. World Health Organization WHO (2004) identified the acceptable drinking water that containing TDS concentrations below 1000 mg/liter.

Percentage of households using cesspits for wastewater discharge

It is the ratio of total number of households who are not connected to the wastewater network and using cesspits or boreholes to discharge their sewage. This is a usual behavior in the newly developed areas, in the periphery areas as well as certain sited of urban areas, which are still not served by sewer network. These cesspits serve one household or a building with many households. This phenomenon is increasing rapidly due to insufficient wastewater coverage and its environmental impacts stay for long time (EQA, 2003). This system allows the row wastewater to percolate through soil directly to the groundwater causing serious pollution to the soil and groundwater.

Percentage of households discharge their wastewater directly or indirectly to the sea

It is the ratio of the total number of households who are not connected to the wastewater network and discharge their sewage directly to the sea. This happened in areas without wastewater network coverage and located close to the seashore. Wastewater is one of the major bacterial pollution sources of the seashore that threatens the public health as well as its negative impacts on the development coastal areas as recreational and tourism area (MOH, 2002).

Number of motor vehicles and transportation

This indicator represents both fuel consumption, as one of the main energy source, and environmental pollution. Motor vehicles emission is one of the major air pollution in the cities. Vehicle emissions along the city's roads in were found to be dangerous to human health based on studies conducted by the national environmental board (UNCSD 1997). Higher number of cars has its implication to the land-use by expanding the existing road network and establishing spaces for parking purposes. Sustainability requires attention to number of vehicles, fuel and alternative models of transportation (Arij, 2002). Efficient air quality monitoring system and policies for pollution control are among the measures for sustainability of the city.

Electrical consumption

This indicator represents the annual amounts of the electrical consumption by the citizens for different uses (domestic, commercial and industrial). Electrical consumption in the urbanized areas is related to the growth of the socio-economic indicators. Sustainability requires conserving energy and searching for alternative energy sources especially the renewable energy sources

2.3.5 Institutional indicators

The institutional measures for land-use management are represented by three main integrated categories that related to services, policies and funds.

- The public sector provides services in order to sustain or improve the conditions of the city such as water supply, wastewater and roads. It also provides amenities such as educational facilities, health facilities and public parks (Gaza Municipality, 2002).
- Local institutions also adopt and implement the land-use policies and regulation for the different land-uses. Policies and regulations are important factors for land-use management if they are based on deep analysis of the current situation. The enforcement of these regulations is also important in order to control the land-use changes.
- They also raise funds for development either from local or external sources. The main portion of these funds is devoted to maintain, operate and develop the city's infrastructure facilities such as water, wastewater, electricity and roads networks.

Developing water network

This indicator represents the annual expansion of the water network within the city's boundaries and rehabilitation of the existing network. It reflects the ability for the local institutions to meet the accelerated demand on water supply. Palestinian Water Authority (PWA) related this indicator to population increase, poverty rate and funds for water network development. Rehabilitation of the existing network would raise the efficiency of the network and reduce the losses of water.

Developing wastewater network

Similarly to the development of water network, the expansion and rehabilitation of the wastewater network are prerequisites for sustainability of land-use management. It aims to minimize the environmental pollution caused by improper wastewater discharging.

Developing road network

The expansion of urban areas requires parallel expansion to the road network. Fo sustainability of the city, the roads network shall be planned in efficient way that fulfill th needs for newly developed areas with environmentally sound design.

Developing health and educational facilities

Health and educational facilities need to be developed in terms of quantity and quality. I refers to the expansion of the areas devoted for these facilities in addition to the developmen of its capacity in terms of equipment and staff. Sustainability of these facilities is a important factor for the overall sustainability (UNESCO, 2003)

Funds for development

According to the Municipal treasurer, this indicator represents all local and externa revenues. Municipal local revenues are collected by the municipal treasury section from th city citizens and institutions as taxis and fees. The external funds that obtained from dono countries and international institutions either directly to the municipality or through th national government and allocated for specific development projects. This budget were spen to implement large-scale projects in the city such as establishment or rehabilitation of roads electrical network, water network, sewage network, public institutions, environmenta programs, and other construction projects. Each project has its budge and spent according t specific items and time schedule. Funds availability can ensure the sustainability of servic delivery and maintain the continuity of the development process.

2.4 Land-use categories

Spatial and statistical information on land-use changes have great values to the land-us planners and mangers. They provide the baseline for classification of land-uses. Based o these information Gaza land use can by divided into five categories which are residential roads, industrial, recreational and agricultural areas.

Residential areas

PCBS (2000b) defined it as the areas mainly covered by residential buildings; despite o whether they are actually occupied or temporarily vacant. Included in residential lands ar commercial areas that usually occupied the ground floors of the residential buildings in the main streets. It also includes the areas for public buildings such as governmental ministries, schools, hospitals, health clinics and other social facilities.

Road areas

This category of land-use includes lands used for public roads, including paved and unpaved streets as well as public parking lots along the roads (PCBS 2000b). It also included the areas devoted for public railway. Planned and efficient road system has great influence on the sustainability of land uses.

Industrial areas

It represents that land that allocated for manufacturing activities including small, medium and large-scale industries. These areas could be found inside the urban areas or in separate locations away from the residential areas. Industrial development can contribute to sustainability if it is planned on environmental-friendly bases and economical viability.

Recreational areas and public parks

This relates to land-used for purposes of recreation, e.g. sports fields, major playgrounds, public parks and green areas. Public beaches along the seashore are also considered under this land-user category (PCBS, 2002c; 2003).

Agricultural areas

According to PCBS (2000b) this refers to the major classes of land-use on agricultural holdings. Agricultural land includes land under scattered cultivated lands and permanently uncultivated land. Most of the agricultural lands are located around the city and at the peripheries. Replacement of vegetation by more impermeable structures like buildings and roads contributes to several environmental problems and will obviously alter the ecology of the city. Whitford et al. (2001) identified four environmental impacts of losses of agricultural and green areas which are increase temperature, decrease water run-off, lower amounts of absorbed carbon dioxide and lower biodiversity. Vegetation cover has its direct impact on the sustainability of the city and minimizing its negative ecological effects.

2.5 Conclusion

Understanding the different indicators and factors that drive the changes of land-use is prerequisite for modeling and forecasting future trends of land-use changes and its impact Therefore this understanding must be based on integrated conceptual framework fo modeling cause-effect relationship. The proposed conceptual framework is based a scientif approach that study the cause-effect relationship between the most influential indicators th selected based on the sustainability dimensions which are socio-economic, environment and institutional. The geopolitical dimension and national policies are important factors t be integrated into the proposed approach, however it is found to be difficult to translate them into quantitative indicators.

The application of this integrated management approach on Gaza city aiming at achievir sustainable land-use management. In order to make this approach applicable, 16 possib indicators have been chosen to present the socio-economic conditions of the Gaza city and possible indicators are representing the environmental dimensions of land-use changes. Th institutional response to land-use changes were represented by the infrastructure and publ service provision and funds for development.

The proposed conceptual model would provide decision-makers and planners wi integrated process for land use management. It would be helpful tool for other Palestinia cities to develop their own conceptual framework based on the sustainability interrelate components.

CHAPTER THREE
DESCRIPTION OF THE STUDY AREA

3 Description of the Study Area

3.1 Introduction

According to the conceptual framework illustrated in chapter two, sustainability approach requires understanding of the interrelated components of the socio-economic, environmental and institutional indicators. Therefore this chapter focuses on the description and the characteristics of Gaza City as a case study in the developments of land-use change indicators and its causes. This chapter provides also details on the socio-economic, environmental and institutional indicators as part of the cause-effect relationship with land-use changes. These indicators will serve as an input to the prediction model developed in the next chapter.

Data on land-use was derived using aerial photographs for Gaza city at different years and some old maps. In addition, annual data on the new urban areas have been calculated from the municipal records for building licenses. The socio-economic data has been collected from PCBS, Gaza municipality and other relevant institutions. The environmental impact indicators have been collected from different institutions such as Environment Authority, Ministry of Agriculture, Water Authority, etc.

3.2 Geographical Location

Gaza City is situated in a strategic location on the trade routes between Asia and Africa, between the desert in the South and the Mediterranean climate in the North. It is located at the north part of Gaza Strip (34°-longitude and 31°-latitude) (Figure 3.1). The total surface area of the city is about 45.353 km^2, which is about 12% of the total area of the Gaza Strip. The city consists of 17 neighborhoods, varying in characters, that have formed in different periods and are inhabited by residents of different income groups (Gaza Municipality, 2000).

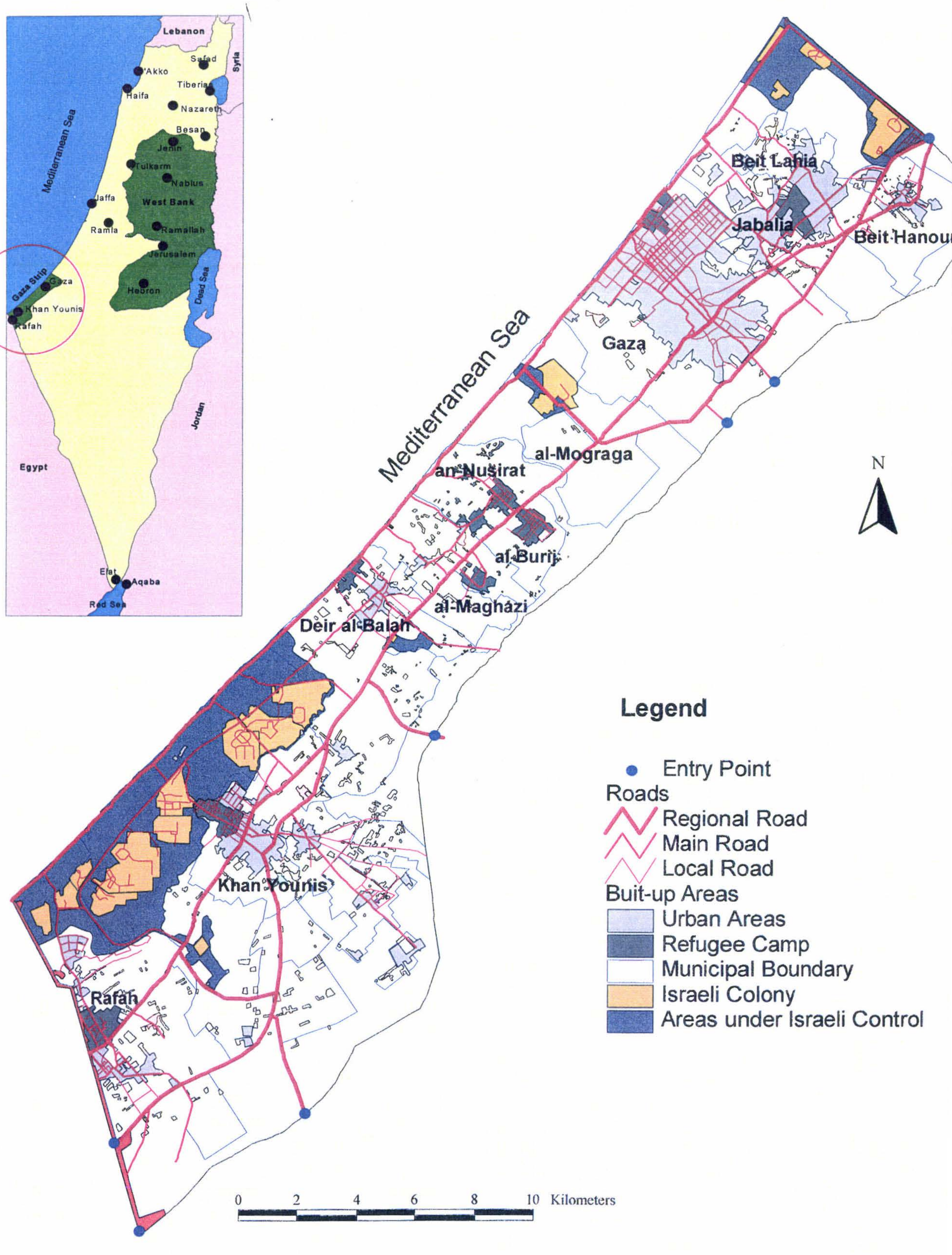
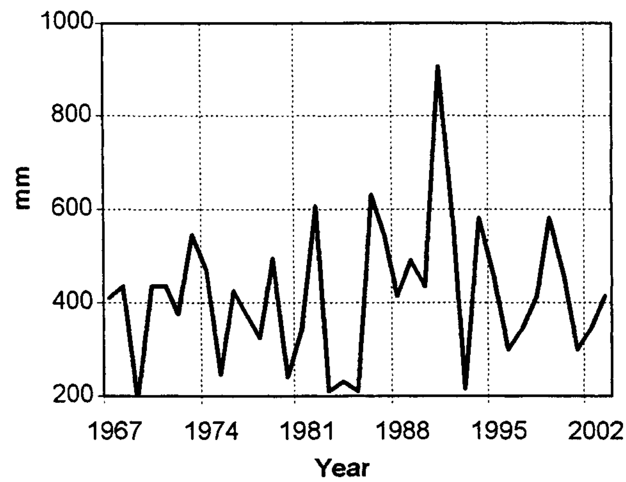


Figure 3.1 Location Map of Gaza City

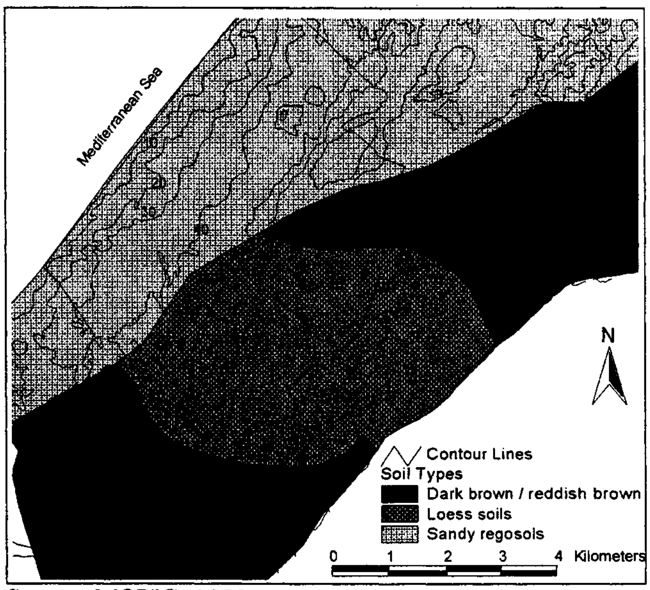
3.3 Physical Conditions

Gaza city lies within the Mediterranean climatic zone. This zone is characterized by winter rain and summer drought. Rainfall is limited to the winter and spring months, mostly between October and April. The annual average annual rainfall is 350 - 400 mm, while the overall annual average rainfall in the West Bank is between 450-500 mm, (ARIJ, 1997; Arij, 2001). The average temperature ranges from 20-32°C in summer to 6-13°C in winter. The daily relative humidity fluctuates between 65% in the daytime and 85% at night in the summer and between 60% and 80% in the winter (PEnA, 1994). The area of Gaza city is essentially a foreshore plain gradually sloping westwards.



Source: Metrological Station-Gaza City

Figure 3.2 Annual Rainfall in Gaza



Source: MOPIC, 1998

Figure 3.3 Soil/Topography of the Gaza city

The city covers an area of relatively flat topography, lying at an elevation of 30 – 40 meters above the sea level. The highest part is Al-Muntar, which rises to a highest of 65 meters and lies some 4 km from the sea. The core of the city occupies a hill in a region 3 km away from the sea and rises some 15 – 20 meters above the surrounding land. Most of the town's soil is composed of coastal sand dunes (Loess soils and Sandy regosols) however, Calcaric soil (Radish brown) which is available in the agricultural areas mainly the citrus plantation areas located to the East-north and Southeast edges of the city.

3.4 Historical Development of Gaza City

Land-use of Gaza city was greatly affected by other factors much stronger than the physica planning system such as political complications and regional conflicts (Mahrouq, 2001 Therefore a historical review of the urban growth and development will serve as background for understanding the current land-use characteristics.

Historical development for the land-use of Gaza city can only be studied with the region context. Therefore this historical review will highlight to the major changes in the situatio of the city. Nine main stages have characterized the current land-use of the city. Each stag has its characteristics and has different policies and regulation. These stages are Ottoman period (before 1917), British mandate (1918-1948), the Egyptian administration (1949 1967), The Israeli occupation in four stages (1968-1973), (1973-1980), (1980-1987), (1987 1994), the first Palestinian Intifada (1987-1994), the establishment of the Palestinia Authority (1995-2000) and the second Intifada (2001-now).

3.4.1 Ottoman Period (1517-1917)

The city fell to the Ottomans Turks in the 13^{th} to the 15^{th} century (1517-1917) and becom part of the Ottoman Empire. The city was surrounded by fence with seven gates. In thi period, Ottoman Turks cut the first railway line in the region, connecting Turkey throug Syria and North Africa through Egypt passing at the center of Gaza City. At the end of thi period main streets have been constructed and new city boundary has been drown of an are about 11 km^2.

3.4.2 British Mandate Period (1918 – 1947)

Following World War I, Gaza became part of the British mandate for Palestine. During thi period new legislation and regulations have been adopted. Later new plans wer implemented to expand the old city towards the west, the north and the south. The majo part of this expansion is the establishment of the Northern and Southern Rima neighborhoods with a regular grid overlapping the existing line structure.

During this period the city boundaries were drown in the year 1936 based on field surve and maps with coordinate system with a total area of 3300 hectares. The urban structure i Gaza city is the cluster development around the center of the Old City, linear toward the eas and grid toward the west. The built-up area of the city expanded from 200 hectares, whic is the area of the old city to more than 366 hectares (MOPIC, 1998). This expansion of th

Gaza urban area has a significant impact on decrease of the agricultural lands by more than 160 hectares.

Physical planning systems during the British mandate:

The modern physical planning system in Palestine was early established during the British mandate period at the beginning of the 20th century. Several ordinances consequently laid down the basis of this system from 1921 to 1948. Information and communications technologies and data sources were very simple and all work done manually (Mahrouq, 1995). The planning process went on a traditional slow fashion depending on the fundamental doctrine of the period: "survey-Analysis-Plan" (Coon, 1991). In 1936, the British authorities published The British Mandate Law - "City, Village and Building Act, 1936, under Planning Law No 28" which remains the legal basis for physical planning in Gaza. According to MOPIC (1998) three levels of planning administrations are defined under this law as follows:

- The Central Planning Committee (CPC) has in terms of regional planning the authority to issue, amend and approve cities plans.
- The District Planning Committees (DPC) has the authority to review objections to regional plans and to exercise the role of the Local Planning Committee (LPC) in areas not subject to the jurisdiction of the LPC.
- The Local Planning Committees (LPCs) are through their jurisdiction over local planning, parcellation and issuing of building permits, responsible for complying with regional plans and their regulations and guidelines.

All the three committees including the municipal council members were appointed directly by the British commander.

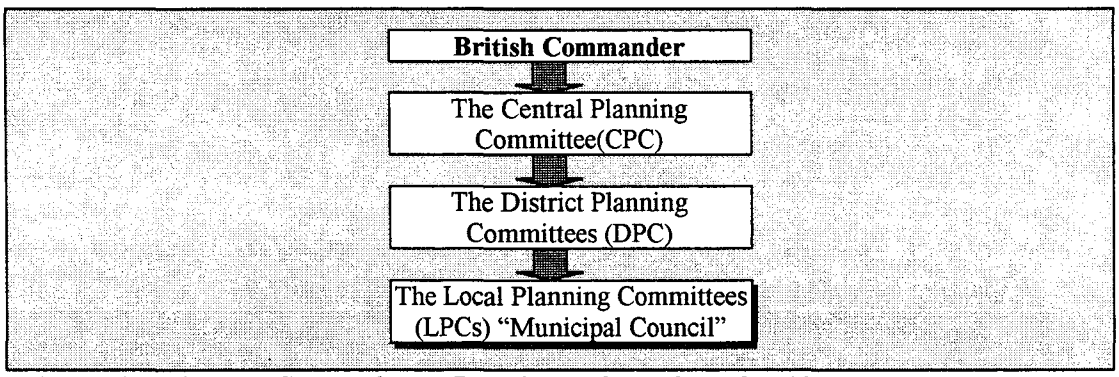


Figure 3.4 Planning System during British mandate adopted in 1936

3.4.3 The Egyptian Administration (1948 – 1967)

After the first Arab-Israel-war in 1948, Egyptian administration took control over Gaza Strip. As a result of this war, massive movement occurred during the period between April and August 1948. Thousands of Palestinian refugees from different Palestinian villages and cities arrived in Gaza, increasing the population of the city by 300% (MOPIC, 1998). Therefore the United Nations Relief and Works Agency UNRWA established the Beach Camp, at the northern part of the city, on 74.7 hectares (less than one square kilometer) to accommodate around 23,000 refugees. The refugees initially lived in tents later replaced by mud brick shelters in the early 1950s, and with cement block shelters with asbestos roof in the 1960s (UNRWA, 2004).

The second Arab Israeli war in 1956 resulted of Israeli occupation to Gaza Strip until March 1957 when the Israelis withdraw from Gaza under the United Nations pressure. During the year (1956-1957) a huge destruction happened to the city's infrastructure. Re-development of infrastructure had been started after the Egyptian administration returned back to Gaza in 1957. However, Gaza Strip was a district and separate entity within the regional development policy of Egypt, never having the opportunity of being included within the framework of the Egyptian schemes (Mahfal, 1987). The Egyptian administration started to distribute some of the governmental lands in the city to the governmental employees in order to encourage the urban development. The built-up area had expanded from 1,000 Hectares to 1,530 Hectares including the refugee camp area.

Physical planning systems during the Egyptian Administration (1948 – 1967)

During the Egyptian administration period, the Ministry of Interior appointed General Commander who has a military power and responsible for the central planning committee which continues its duties according to the British low in the previous periods.

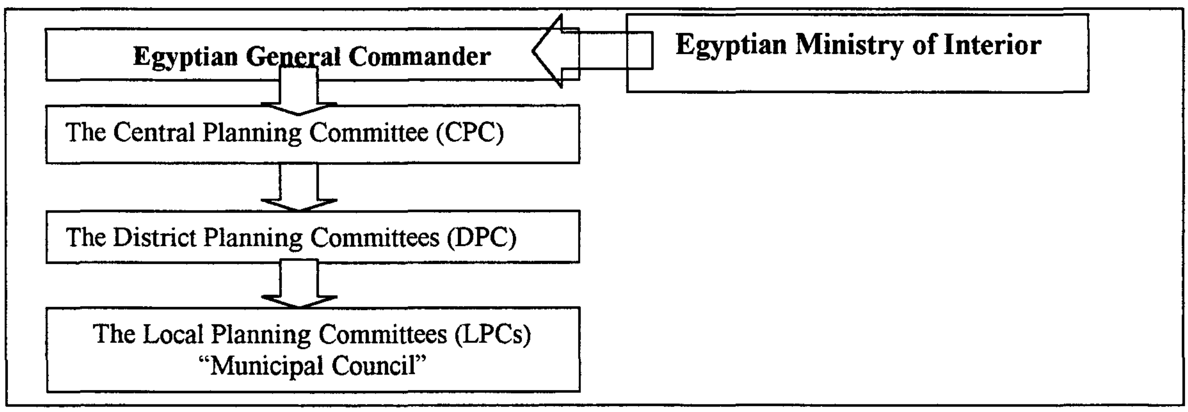
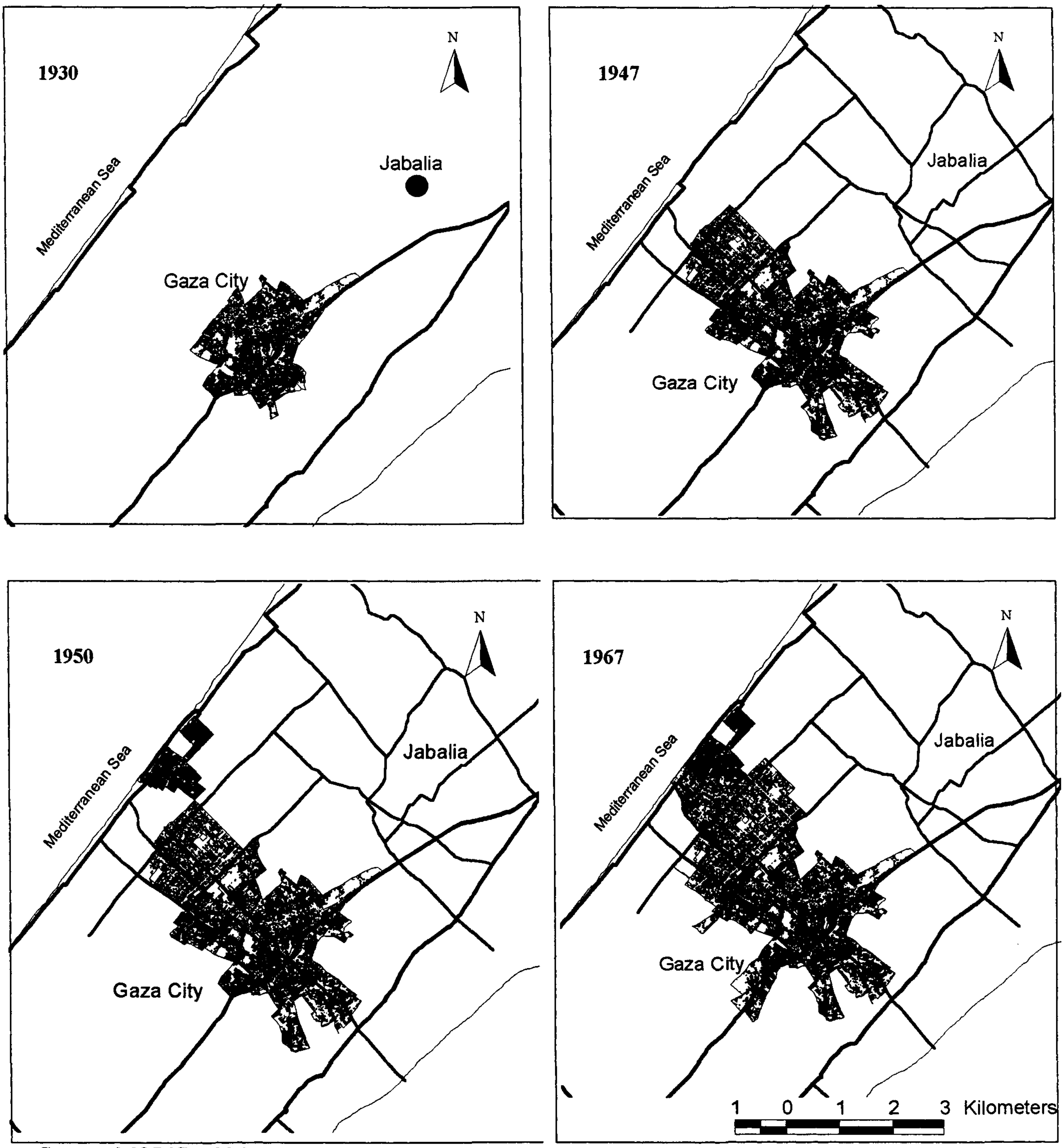


Figure 3.5 Planning System during Egyptian Administration 1948-1967

Figure 3.6 summarized the urban development for the period 1930-1947



Source: MOPIC, 1996

Figure 3.6 Planning System during the Egyptian Administration Period 1948-1967

3.4.4 Israeli Occupation 1967-1973.

As a result of the second Arab-Israeli war, Israeli forces occupied Gaza Strip and the West Bank. During Israeli occupation, Palestinians were not allowed to participate in any form of planning duties, which was entirely controlled by the Israeli military forces. By the year 1973 the population had increased from 118,000 to 127,200 inhabitants with 2.9 rate of growth (ISD, 1980).

In 1971, the Israeli authorities demolished more than 2,000 shelters to widen the roads inside the Beach camp for military reasons and about 8000 refugees forced to move out of the camp (Municipality of Gaza, 1981). The boundaries of the city continued at the same area as it was drawn during the British mandate (UNRWA, 2003). The built-up area of Gaza City increased from 1,530 hectares in 1967 to be 1,600 hectares with housing density more than 10,000 inhabitants per square kilometer. The urban development during this period considered as insignificant due to poverty, unemployment and poor living conditions at the first six years of the Israeli occupation. In this period Gaza had serious deficiencies in housing and infrastructure and an inadequate sewage system that has contributed to serious problems of hygiene and public health.

3.4.5 Israeli Occupation (1973- 1980)

This period has noticed dramatic changes in urban structure of the city. The Israeli military authorities had established the neighborhood of Sheikh Radwan to the north of the city to evacuate the Beach camp and resettle the refugees whose houses were demolished by the Israeli occupation forces, in the first stage. In the second stage, anyone else who wanted to move from the Beach camp to Sheikh Radwan Neighborhood had to demolish his house in order to obtain a house there. The project was started in 1973 and continued at different stages. The residents, at first did not take interest since this process harms their case as refugees. However, as a result of the increase in the population, and because the house which the head of the family got in the 1950s remained as it was, some of people moved to Sheikh Radwan. At the beginning, the Gaza Municipality refused to provide services for the few residents who settled there. Later, in 1976, project (A) was implemented; the Israeli occupation forces distribute pre-made houses, which consisted of two rooms, a kitchen and utilities. After that, they modified their policy and followed the "build your own house" plan. They offered the head of the family 250 square meters of land, and the head of the family built his house according to his own desire. Sheikh Radwan project (A) was completed in 1973. It contains 1,000 housing units, a shopping center, a school, a mosque, and a clinic. In October 1978, the implementation of Sheikh Radwan project (B) started. It expanded to the east and to the north of the previous project. The land was distributed was divided into small parcels with 250 square meters. Thus, the project would absorb around 2,200 families. This project is considered an extension of Nassr and Northern Rimal neighborhoods. The project was completed, especially in the eastern part, by the end of the 1980s and the beginning of the 1990s.

In the other hand The Israeli occupation established Nitzarim Colony in 1974 to the Southwest of the city. This colony built on around 1.6 km2 and limited the expansion of the southern part of the city.

3.4.6 Israeli Occupation 1980-1987

This period characterized with more economic development since the number of employees inside Israel has been increased and more commercial exchange between Gaza and Israel has been noticed. This economical development has its impacts on the urban growth of the city, which led to expand the built-up areas from North, East and South edges of the city. However the annual rate of growth for population stay within the rage of 3.0% which increase the total population from about 160,000 to 200,000 inhabitants in 1980 and 1987 consequently. The unemployment rate has decreased to around 8.2, which was the lowest rate registered in the modern history of Gaza. Also GDP has noticed an increase by 62 percent of the GDP recorder in 1968. The educational facilities had also noticed significant changes since establishment of the Islamic University.

The urban development also noticed a new establishment of housing project in Salah Khalaf Street to the Northern edge of the city. The area of this project has reached 70 hectares where 22,000 inhabitants have settled within the area of this project and around.

3.4.7 The First Palestinian Popular Intifada 1987-1994

The Palestinian first Intifada was erupted on December1997 and continued for seven years. This period characterized by difficult situation in all aspects of life. Curfews and border closure had direct impacts on the socio-economic aspects mainly employment and education. For instance the employment increased from 8.0 to 32 percent in the years 1980, 1993. In addition the Israeli military forces closed most of the educational institutions and did not allow for implementation of any development projects. For these resaeon there was insignificant urban development recorded.

Physical planning systems during the Israeli Occupation (1967-1994):

During this period the urban planning was entirely controlled by Israeli military commanders. The Palestinians were not allowed to participate in any forms of planning. However, during this period many large-scale projects have been implemented such as expansion of the electrical and water networks which supplied by Israeli companies. In 1970 Israeli military commander from the Israeli interior affairs chaired the municipality of Gaza. The three committees for planning were also chaired by Israeli commanders who have the right to impose roles and regulations that have military purposes and objectives.

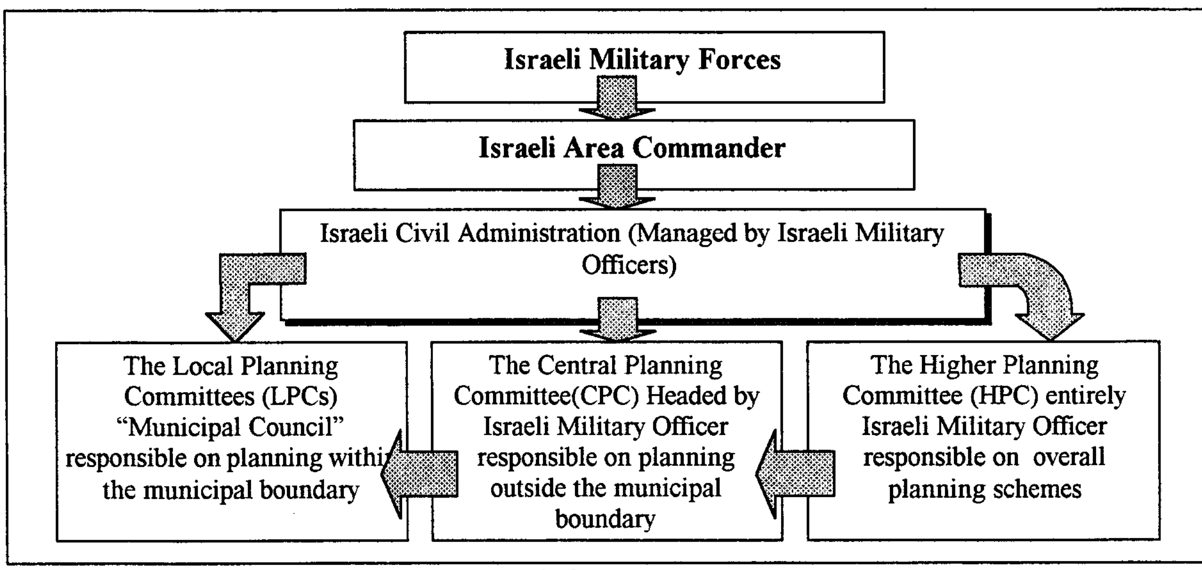
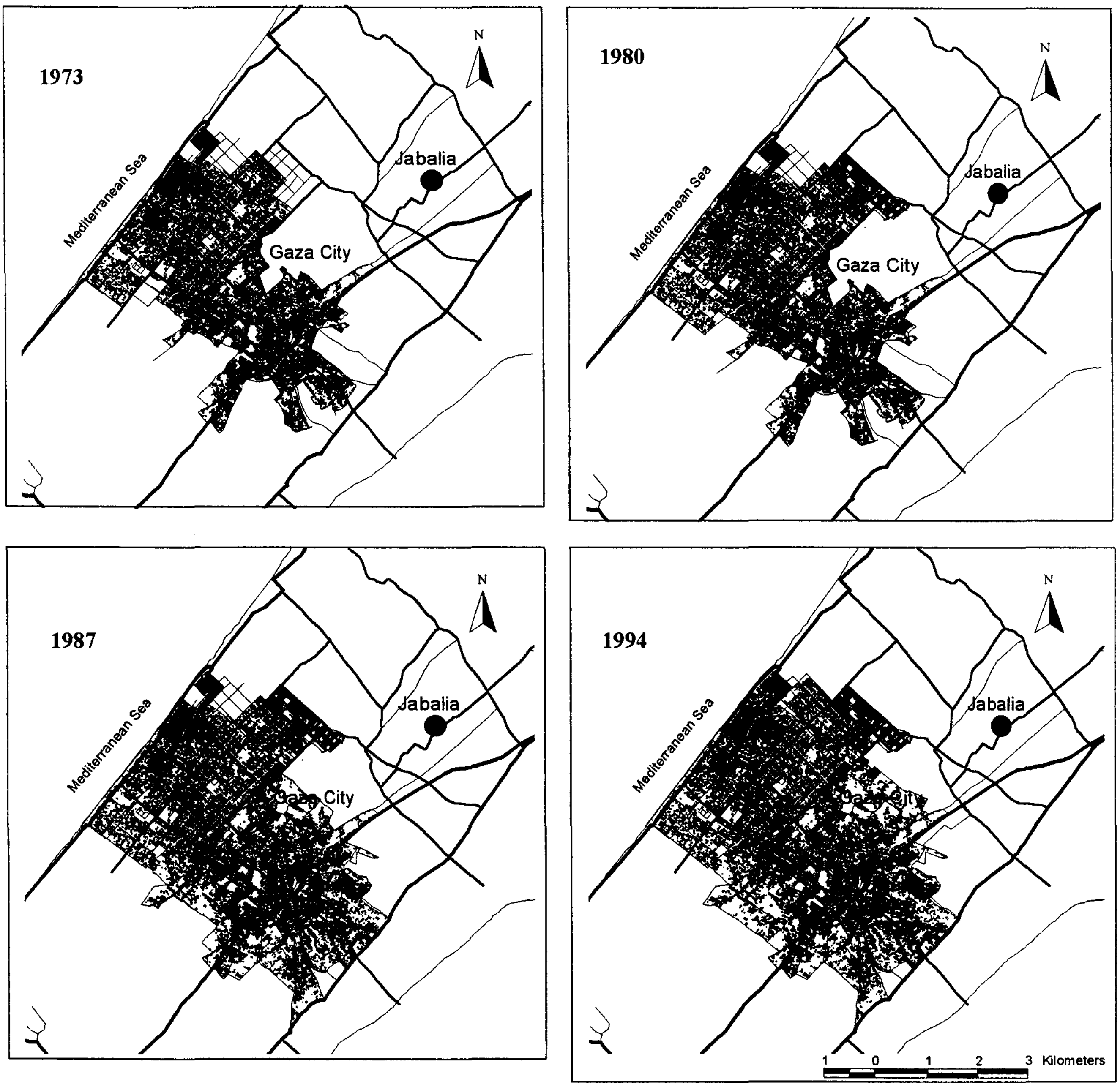


Figure 3.7 Planning System during Israeli Occupation 1967-1994

Figure 3.8 summarized the urban development of Gaza City during the period of Israeli Occupation (1967-1994).



Source: MOPIC, 1996

Figure 3.8 Urban Development of Gaza City (1973-1994)

3.4.8 Palestinian National Authority (1994- 2000)

The peace process between the PLO and the Israel in the early 1990's led to the foundatioı of the Palestinian National Authority (PNA) in 1994. A political stability has been th characteristics of this period, which encourage the investment in infrastructure an development projects. Therefore it is noticed that continues increase in the urban areas wit a very high annual rates about 3.4 percent for the last ten years. Most of the urba expansions are for residential purposes to accommodate the increase in population, th returnees of Palestinian families from Diaspora and establishment of governmenta ministries and institution.

In 1995 Gaza city experienced a massive urban growth mainly construction of 126 multi story buildings. This type of buildings never exists before in the city. In addition to tw large-scale residential projects have been implemented which are Al-Awda and Tel AlHawa. At the end of this period the total urban area was about 3147 hectare accommodating around 40,000 inhabitants with a density of 127 inhabitants per hectare.

3.4.9 The second Palestinian Intifada (2000- 2004)

The second Palestinian Intifada erupted in October 2000 protesting the difficult situation i the last period and against the Israeli policies, which increased the closures and people' movement restrictions.

Physical planning System during the Palestinian Authority period

According to the Oslo-I-Agreement signed in 1993, the responsibility for planning wa conditionally transferred to the PNA. This would, for the first time in modern history, giv the Palestinians the power to initiate, prepare and amend their own physical plans at a levels. At this time only rudimentary governmental planning institutions were functioning Most of the previous laws and regulations remained applicable in the West Bank and Gaza The PNA has directed immense efforts towards the improvement of planning activity in th Palestinian areas on the local, regional and national levels. In this regard, considerabl amount of funds has been allocated towards the capacity building in the various fields o planning. Consequently, the PNA through the Ministry of Planning and International Co operation (MOPIC) took the initiative and the responsibility for overall developmen planning.

A proposal for a Palestinian Planning and Building Act is being prepared by the MOLG, Ministry of Justice MOJ and MOPIC. Until the new law has been approved, the British Mandate Law - "City, Village and Building Act, 1936, under Planning Law No 28" remains the legal basis for physical planning in Gaza Governorates. Under the law three levels of planning administrations are defined:

- The Higher Planning Commission (HPC) headed by the president of the Palestinian Authority and several ministers as members. The role of this commission is overall planning policies and approval of planning lows and regulations. The commission has the mandate to approve the plans for cities that prepared by CPC and LPC.
- The Central Planning Committee (CPC) has the authority to issue regulations for regional planning, approve plans and amend and expand planning boundaries of the cities. PNA appoints members to the CPC, which is chaired by the MOLG representative and the other ministries representatives are members.
- Gaza LPC is responsible for local planning, land parcellation and issuing of building permits. It has the mandate to adopt the regional plans and their regulations and guidelines to their localities.

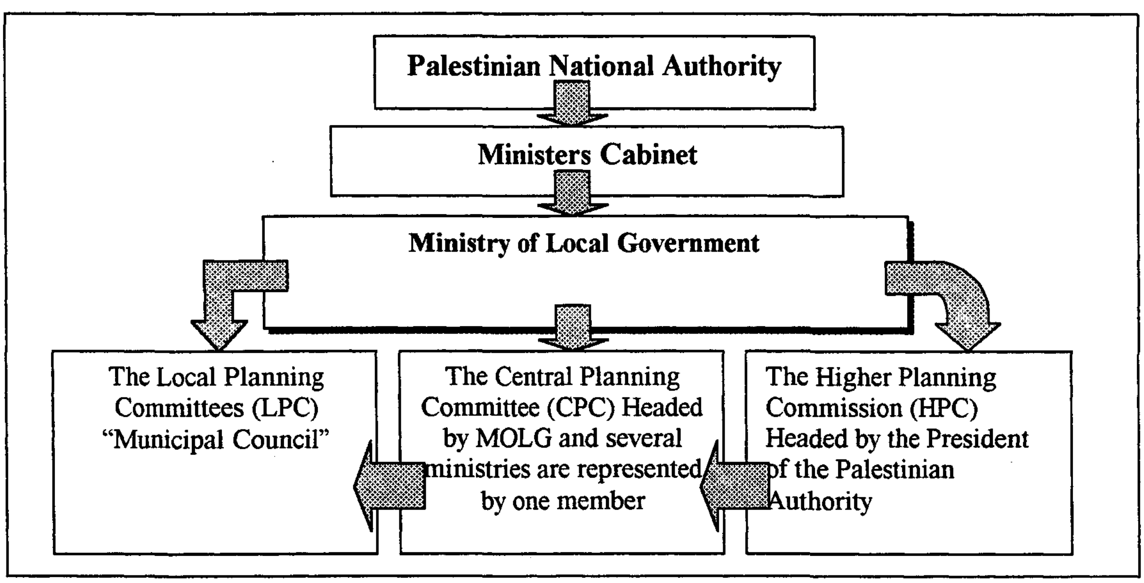


Figure 3.9 Planning system during the Palestinian Authority adopted in 1995

3.4.10 Summery of the historical development of Gaza City

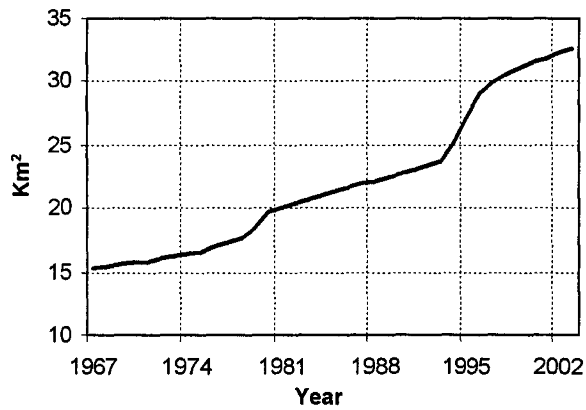
During the last three decades Gaza city experienced land-use changes, which characterize by continues expansion of the built-up area over the agricultural lands mainly for residenti purposes. Several socio-economic and political factors had influenced these changes. Th following table is summarizing the changes of the main urban development includin residential, commercial and roads areas.

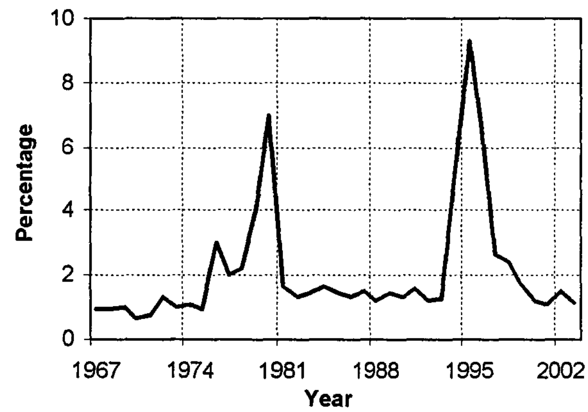
Table 3.1 Summery of the historical development of Gaza City

Period	Main Urban land-use Developments	Total built-up area of Gaza City (in km2)
Ottoman period (1517-1918)	Construction of the railway and the main street of the city	2.00
British Mandate (1918-1948)	Grid system for the new built-up areas. Expansion of the city's boundary. New urban regulation and construction low.	3.66
Egyptian Period (1948-1967)	Establishment of the Beach refugee camp for more than 23,000 refugees. Expansion the city from north and east.	15.28
Israeli Occupation Period (1967-1973)	Urban land-use planning controlled by Israeli military forces with little development has noticed.	16.16
Israeli Occupation Period (1973-1980)	Establishment of Sheikh Radwan Neighborhood, which started with 2200 housing unite. Establishment of Israeli colony to the southwest of the city.	19.73
Israeli Occupation Period (1980-1987)	Expansion of the city from all directions with different patterns.	21.87
Israeli Occupation Period (1987-1994)	Little development has been noticed with random development.	24.92
Palestinian Authority Establishment (1994-2003)	Massive urban growth especially multi-story buildings and boom in infrastructure development all over the city. Establishment of Al-Awda and Tal-AlHawa areas	32.65

3.5 Land-use Categories in Gaza City

Land-use changes can be traced from the historical development of the city during the last three decades. Currently Gaza city has around 32.6 square kilometers of built-up areas mainly residential, commercial and road areas. Figures 3.10 and 3.11 show that there are two periods with high urban rate of growth. In 1978 due to the establishment of Sheikh Radwan neighborhood and in 1995 due to the construction boom at the beginning of the establishment of the Palestinian Authority.





Source: Municipal Records

Figure 3.10 Built-up areas (1967-2003)

Figure 3.11 Urban Growth Rate (1967-2003)

It is clear that the residential and roads areas are increasing very rapidly among the other land-uses. While the industrial areas increased with a slow growth rate. There are no significant changes noticed in recreational areas, which means that these areas had no major development compared to the of the city's population increase during the last three decades.

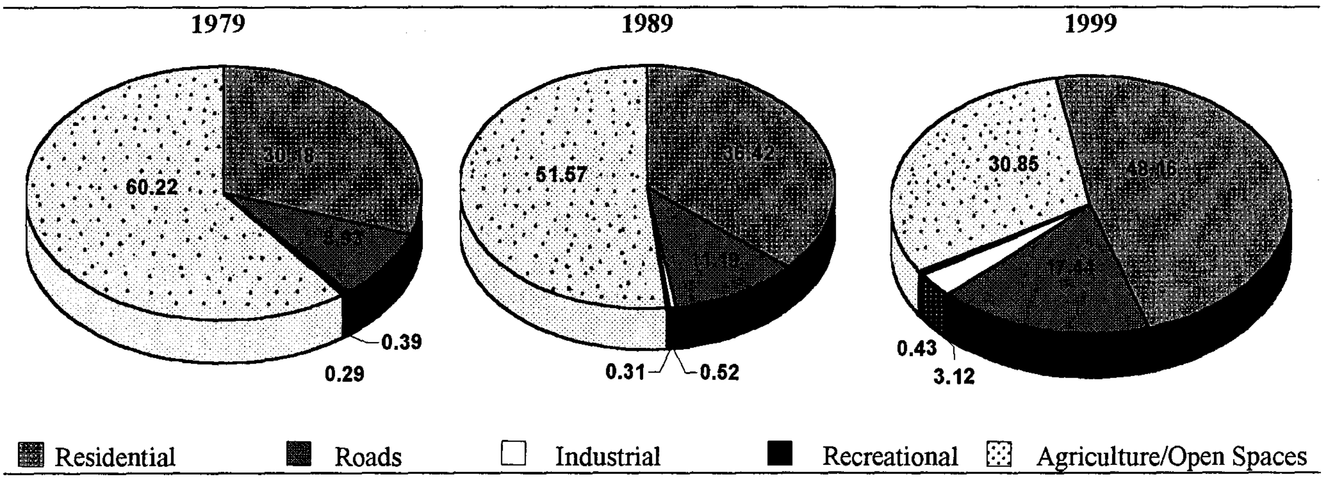


Figure 3.12 Land-use Changes (in percent) for the years 1979, 1989 and 1999

Figure 3.12 shows that the residential areas have been increased by 18% during the period 1979-1999. While the recreational areas including the public parks have increased by only 0.13% which considered as insignificant increase.

Land-use map presented in Figure 3.13 indicated that the residential areas have the major portion among the other land-uses. It is clear the lowest surface area among the other land-use categories is the recreational and industrial areas, both occupied less than 0.5% of the city's area. **See the aerial photo of the city (Annex 1)**

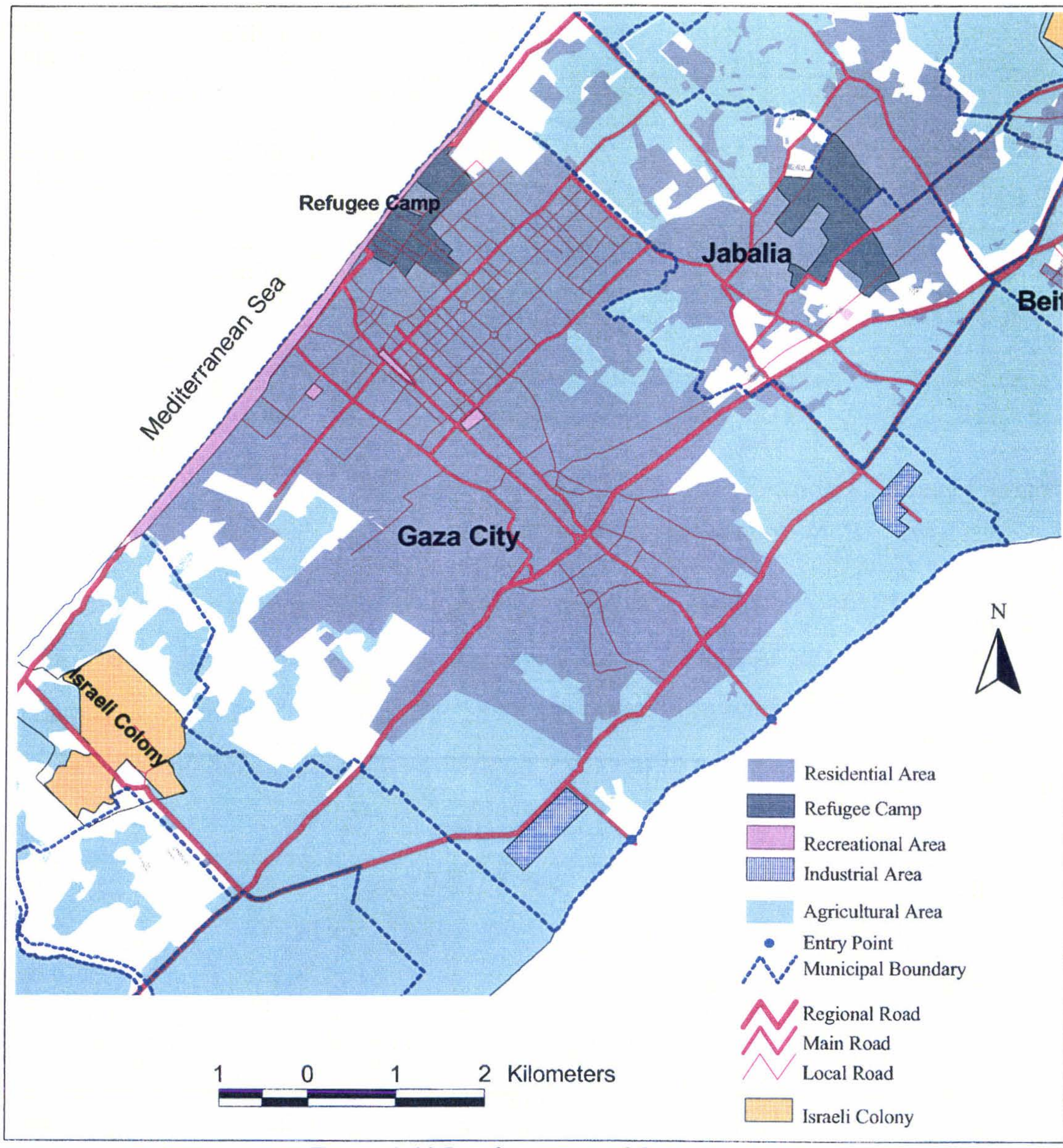


Figure 3.13 Land-use map of Gaza City in 1999

3.5.1 Residential Areas

Residential areas have been categorized according to the aerial photos of Gaza taken in different years (1979, 1986, 1994, and 1999). Also the municipal records and its geographical information system had been used to extract the three categories of the housing density (high, medium and low) that characterized the residential areas.

- Residential areas with high housing density, which has more than 20,000 inhabitants per square kilometer, are living in around 2,850 housing units. This category includes the refugee camp and the old city of Gaza.
- Residential areas with medium housing density have a density around 15,000 inhabitants per square kilometer. It has an average of 2800 housing units per square kilometer.
- Residential areas with low housing density have density less than 10,000 inhabitants per square kilometer. It has an average of 700 housing units per square kilometer.

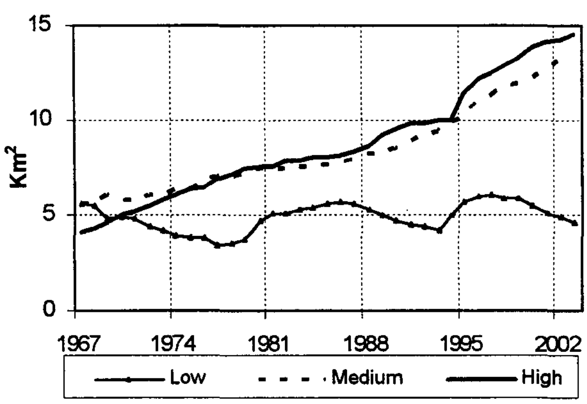


Figure 3.14 Areas of Different Housing Densities within the residential areas (1967-2003)

According to collected data from the municipality of Gaza, the residential areas with low density around 5.0 km^2. While the residential areas with medium-density were increased by 7.7 km^2 during the last 37 years, hence this category of land-use occupied around 40 percent of the total built-up area of the city.

Figure 3.15 shows that during the period 1980-2000 there are significant changes in the three housing densities with the residential areas. During this period, the municipality had approved many plans for land-use conversion from agriculture to residential purposes. This conversion was made under the demand pressure for housing units to accommodate the natural population increase and the Palestinian returnees from Diaspora.

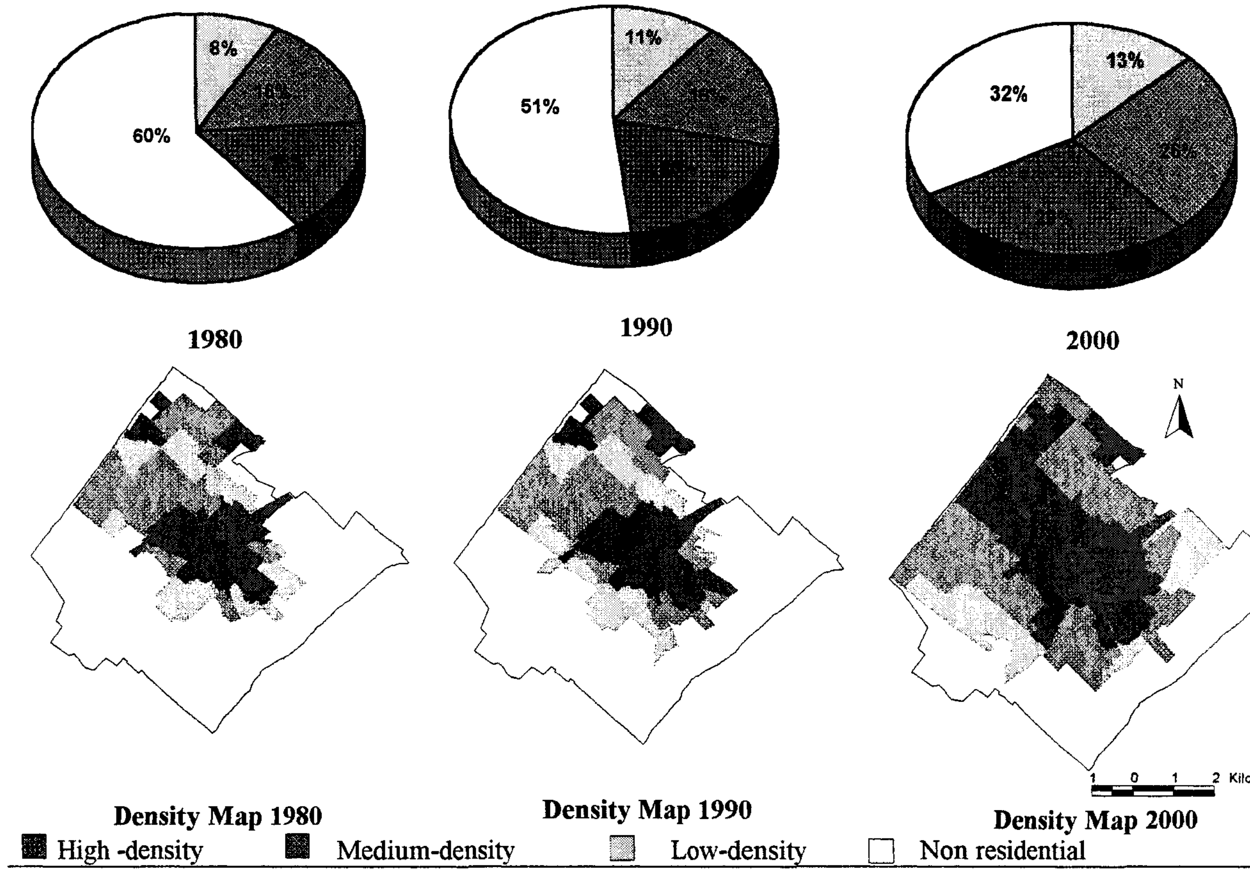
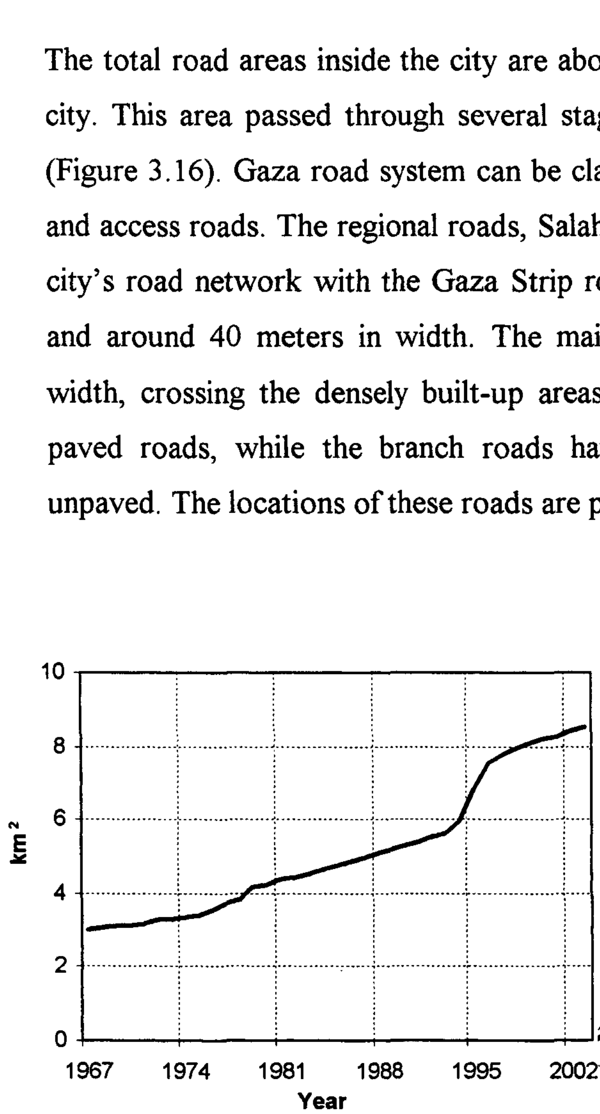


Figure 3.15 Housing Densities in the Residential Areas

PCBS study (2003) of Gaza housing pattern shows most of the population have not changed their homes throughout the years, while a great part live in units added to their parents' homes. This trend of high-density seems to continue in the future, which means that most of the city's built-up area will be transformed to high-density area. The municipal geographical information system showed that in the year 1999, the city possesses about 64,700 housing units, about 50% of the units are consists of one to two-story buildings, about 35% of three to four-story buildings and only 15% of five-story buildings and higher.

3.5.2 Road Areas

The total road areas inside the city are about 8.2 km^2, which is 20% of the total area of the city. This area passed through several stages of development throughout the last 37 years (Figure 3.16). Gaza road system can be classified into four categories: Regional, main, local and access roads. The regional roads, Salah Al-Deen and the coastal road, are connecting the city's road network with the Gaza Strip road system. Each of them has a length of 6.2 km and around 40 meters in width. The main and local roads have around 16-30 meters in width, crossing the densely built-up areas of the city and the majority of these roads are paved roads, while the branch roads have a width of less than 10 meters and mostly unpaved. The locations of these roads are presented in Figure 3.17.



Source: Gaza Municipality, 1981; 2003; PCBS, 2003

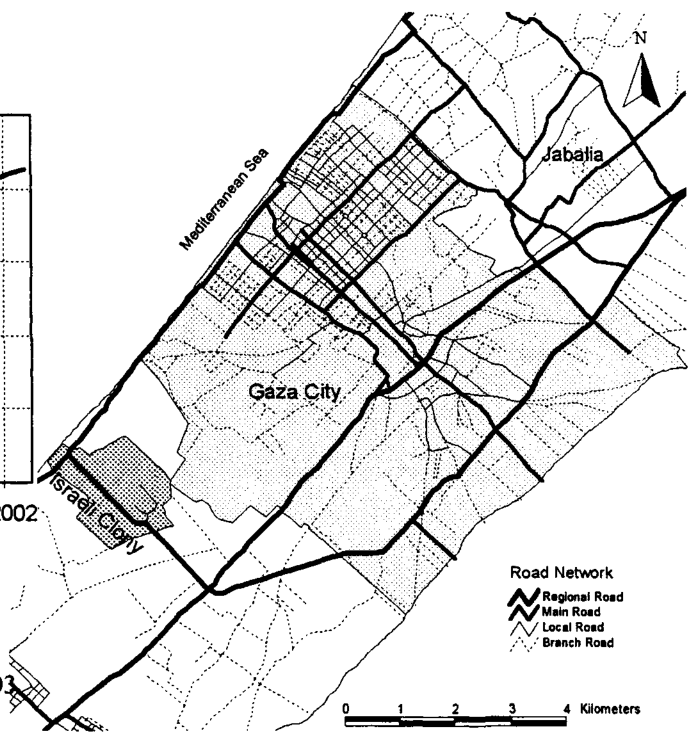


Figure 3.16 Road Areas (1967-2003)

Figure 3.17 Road Network Map (1999)

The main railway crossing the city from north to south and follows the alignment parallel to Salah El-Deen Street and intersects at two points. Since 1974 this railway was not functioning while the major parts of this railway disappeared and have been taken from it place.

3.5.3 Industrial Areas

Gaza city has around 60% of the total industrial establishments in the Gaza Strip. The largest industrial location exists in the Southern-East edge of the city, called Gaza Industrial Estate (GIE), which established in 1996. The GIE, has an area of 48.5 hectares close to Al-Mentar Commercial Border Crossing. Various industrial establishments, mainly tiles manufacturing, are distributed within the city's neighborhoods.

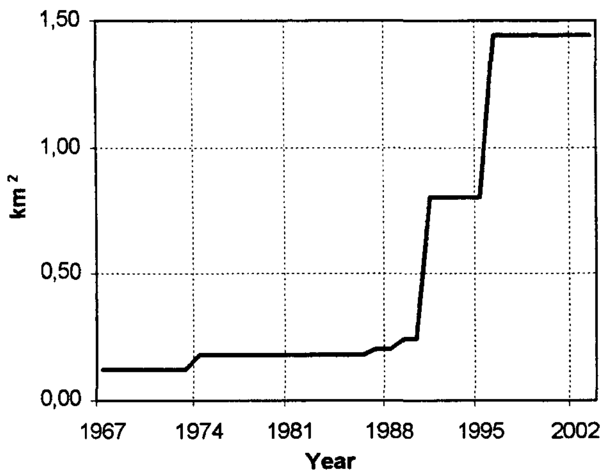
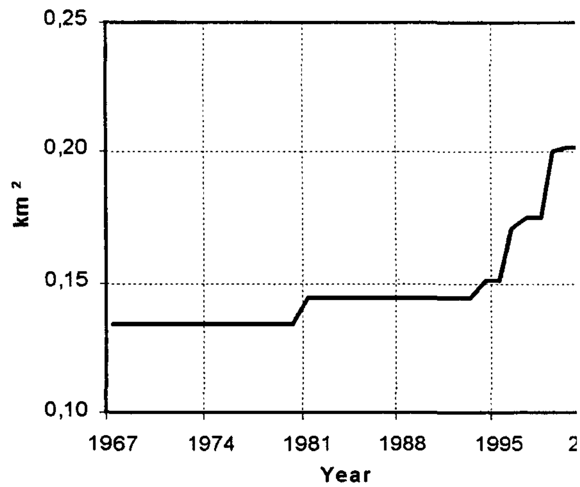


Figure 3.18 Industrial Areas (1967-2003)



Source: Municipal Records

Figure 3.19 Recreational Areas

3.5.4 Recreational Areas

The most common recreational places in Gaza are the beach area and public parks. Beach area is suffering from pollution problems such as row sewage flow to the sea, solid waste dumping, in addition to the lack of facilities and erosion of beach areas. In Gaza there are 12 small-scale public parks with total areas of 9.0 hectares. Most of the public parks exists in the city had been established after 1994. Very few sport areas exist in the city with limited and poor facilities.

3.5.5 Agricultural Lands

The agricultural lands of Gaza city are limited and scarce. The uncontrolled expansion of the residential areas, the rarity of water for irrigation, and the Israeli constrains on exporting agricultural products led to decrease in the city's agricultural lands. Gaza experiences a fragmented agricultural land due to the system of ownership inheritance and parcellation of land among the family members. The majority of agricultural lands, about 75%, consist of parcels less than one hectare (MOPIC, 1998). The traditional crops like citrus trees are being replaced by other crops. Therefore, only 5 percent of the employed labour force in Gaza is still working in the agricultural sector. Figure 3.20 shows that during the last 37 years it is noticed that more than 1250 hectares from agricultural lands has been replaced by urban development. The largest land-use conversion activities happened in Gaza was between the years 1995-1998. Around 321 hectares, located mostly in the southern and eastern edges of the city, were converted to residential purposes. Figure 3.21 shows that the agricultural lands decreased from around 30 km^2 to around 13km^2.

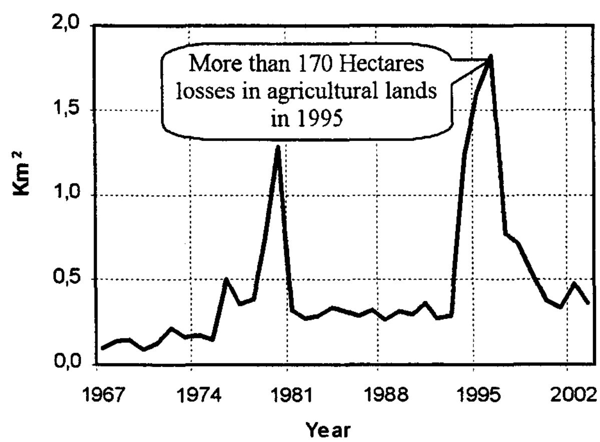


Figure 3.20 Annual losses in Agricultural lands

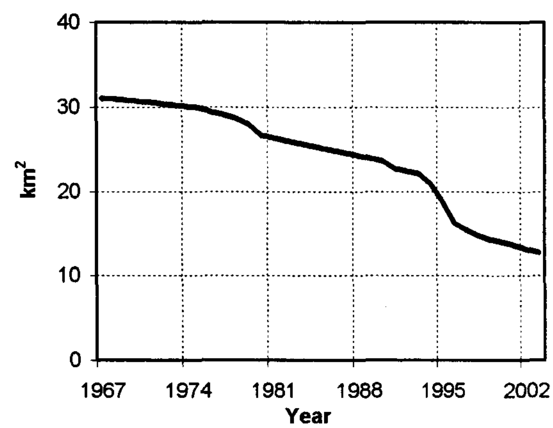


Figure 3.21 Areas for agricultural lands

3.6 Socio-Economic Indicators:

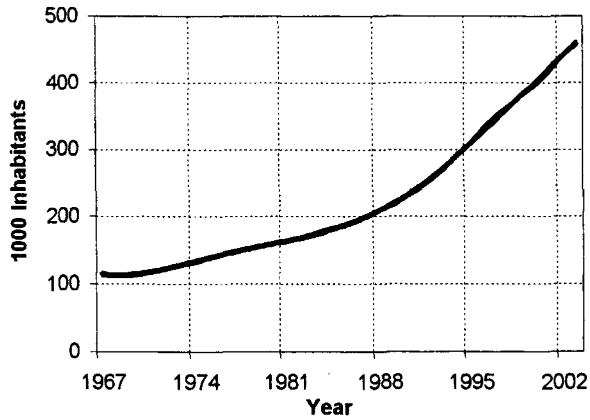
A combination of 18 possible socio-economic indicators were identified in section 1.4.5 and section 2.3. Data on socio-economic indicators have been obtained from different sources as follows:

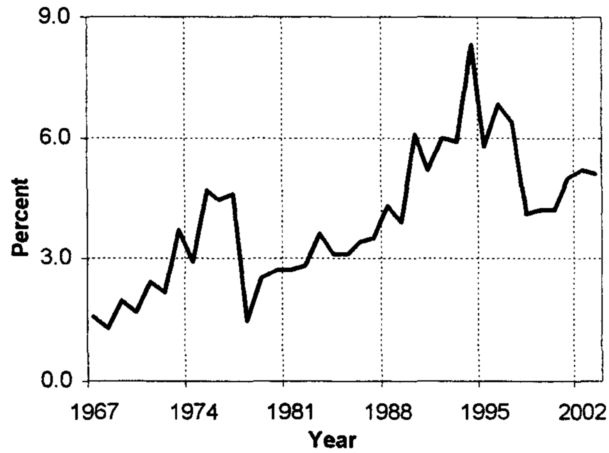
- Demographical data from 1967 to 1993 was obtained from the Israel Central Bureau of Statistics. It published an annual-base book titled "Statistical Abstract of Israel". It included database on the socio-economic situation of the cities in Gaza Strip. The methodology of data collection was based on sample survey, therefore, the data described as high quality data with overall accuracy more than 90% (ICBS, 1992).
- Demographical data from 1994 to 2004 was obtained from the Palestinian Central Bureau of Statistics (PCBS) and published in annual-base under "Statistical Abstract of Palestine". The collected data are based on the 1997 census and the annual reports based on sample survey.
- Reports published locally by the international organization based in Gaza City such as UNRWA, UNDP, UNESCO and FAFO-Norway.
- Unpublished reports done by the municipality of Gaza for each sector mainly the provision of public services such as water, wastewater, roads, etc.
- Locally published reports by local institutions such as; ministries of health, education, planning and local governments.

A limited number of unrealistic figures had been appeared during the data collection, therefore it required special treatment by the experts from PCBS using trend analysis (See Annex 2).

3.6.1 Population

Gaza population has increased from 112,000 inhabitants in 1967 to about 461,000 inhabitants in the year 2003 (Figure 3.22). This makes Gaza the largest city in the Palestinian territories (PCBS, 2000). Figure 3.23 shows that the average rate of population growth during the last 37 years is about 3.7%. This rate exceeds the average rate of growth for the whole of the Palestine and higher than growth rates in the neighboring countries e.g. in Egypt 2.3, in Jordan 3.2, and in Saudi Arabia 3.1 percent (World Bank, 2002b). This increases explained by high rate within the period 1994-1999 when a significant number of Palestinian families had returned from Diaspora. The extent of returnees to Gaza city appears to be greater than the other cities of the Palestine. The phenomenon is seen to be the result of Gaza's position as the temporarily administrative capital of the Palestinian Authority. This rate of growth declined during the recent years due to many factors such as the Israelis restrictions on the number of returnees and decline in the fertility rates.





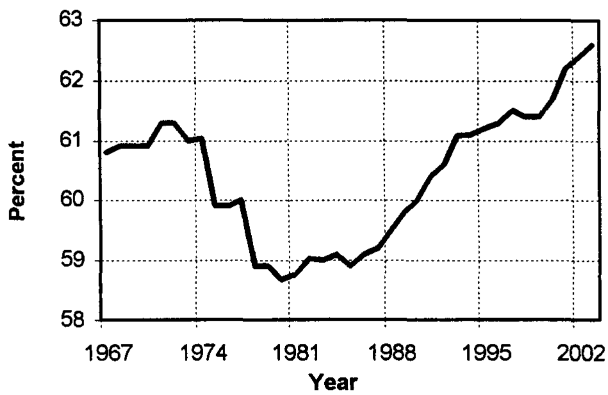
Source: ICBS, 1982; 1992; PCSB, 1997; 2001; 2003

Figure 3.22 Population Number (1967-2003)

Figure 3.23 Population Growth Rate (1967-2003)

The average household size in Gaza city is about 7.0 persons, which higher than household size in Ramallah in the West Bank 6.1 (PCBS, 2002), in Amman-Jordan 6.0 persons. (Khawaja and Tiltnes 2002) and considerably higher for Tel-Aviv city in Israel with 3.0 persons (ICBS 2002). Extended households are more common in the Gaza than in the other areas of Palestine, and more common in refugee camps than elsewhere.

The composition by age tends towards the predominance of the younger age about 51% of the population is 14 years or younger. As much as 18.5% of the Gaza residents are under the age of 4 years. Moreover, Gaza has a higher average number of children per adult household members in comparison with average figures for Palestine. The large proportion of population under 19 years old has been significantly reduce the size of the available work force.



Source: ICBS, 1982; 1992; PCSB, 1997; 2001; 2003

Figure 3.24 Percentages of Population under the age of 19 years

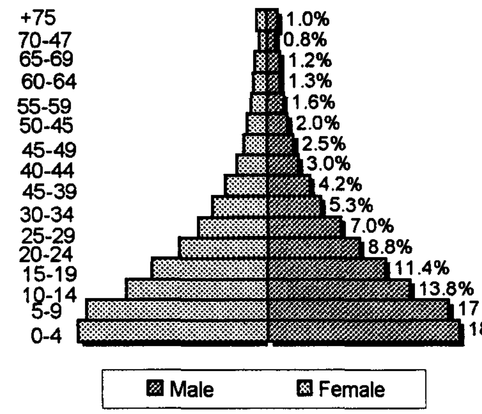
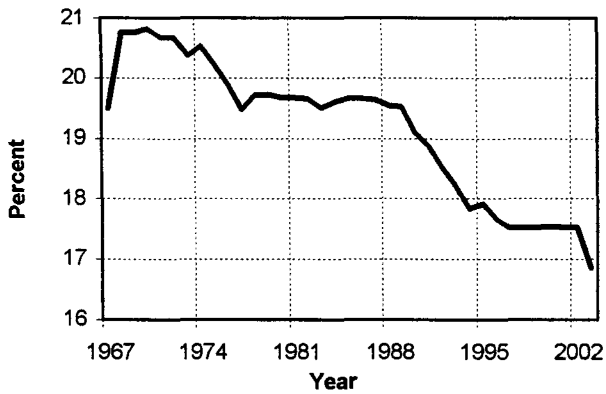


Figure 3.25 Population Pyramid, 2000

Population Living in the Refugee Camp

It is a unique situation that more than 17 percent of the city's population are living in densely and crowded refugee camp. Most who fled to the Gaza as a result of the Israeli occupation and destruction to their original villages in 1948, about 75,876 inhabitants, are currently living in the Beach camp with a total area of 0.7 km^2 (UNRWA, 2002). This has made the population density for this camp as one of the highest in the world (more than 100,000 inhabitants per square kilometer). This density reflects on the other aspects; the shelters are crowded, schools and classrooms are also crowded as more than 7000 additional pupils are registered in UNRWA schools every year.

Despite the continuously increased in camp's population, the percentage of the camp's population from the city's population are decreasing from 21% in the year 1969 to 17% in the year 2003. This decrease has many reasons mainly due to the significant number of the refugees, around 64000 inhabitants, who had moved to new homes in the neighborhoods around the camp (UNRWA, 2002).



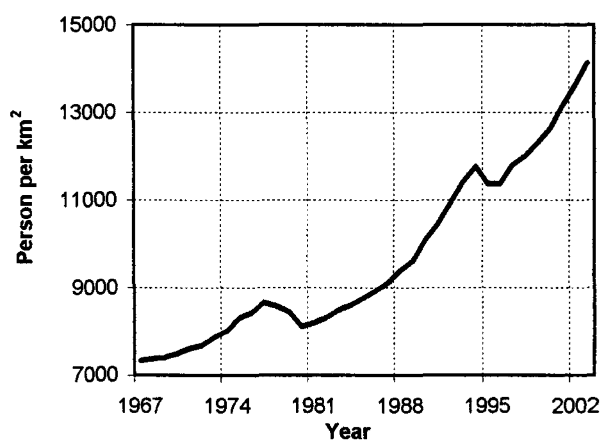
Source: UNRWA, 2004; PCBS, 1997; 2003

Figure 3.26 Percentage of Population Living in the Refugee Camp

Figure 3.27 Location Map for the Refugee Camp

Population density

The over all population density of Gaza city is about 13,970 persons/km^2. Compared to Amman-Jordan, which have 12,500 persons/km^2, Gaza is the most populated city in the Middle East. (PCSB, 2004; DOS, 2004). The highest population density within the city can be found in the refugee camp followed by Sabra and Shijaia neighborhoods where the population density exceeds 40,000 persons/km^2 **(see annex 1 for population density map)**

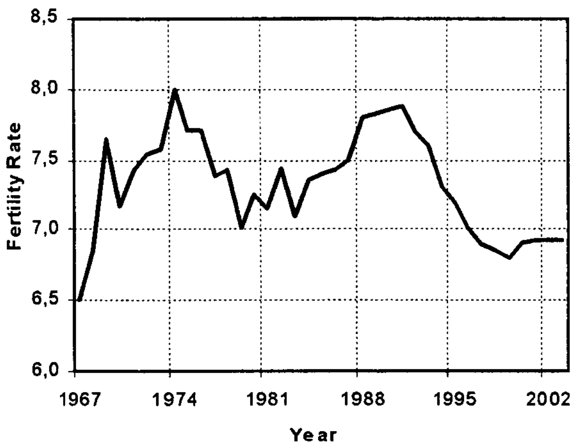


Sources: ICBS, 1982; 1992; PCSB, 1997; 2001; 2003

Figure 3.28 Population Density (1967-2003)

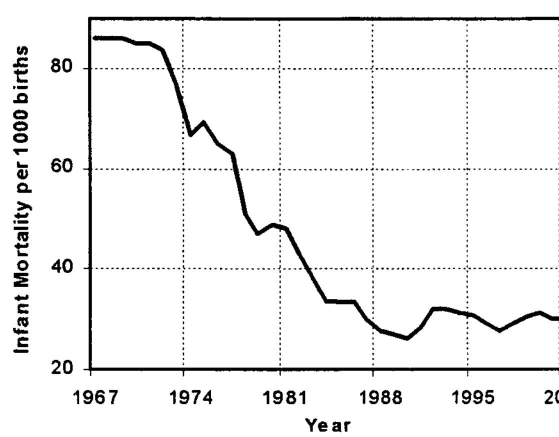
3.6.2 Health indicators

Since the establishment of the Palestinian Authority in 1994, the health status of Gaza population has been improved as a result of many factors including: economic development, improvement in water, sewage and sanitation systems and improvement in educational standards as well as improvement of the quality of health services. The basic infrastructure of preventive and primary health care services has been developed substantially since the establishment of Ministry of Health. Hospital services development has also been substantial with acceptable hospital facilities, equipment and staffing. UNRWA services also developed and expanded its free of charge services to all the refugees in Gaza City around 250,000 inhabitants (UNRWA, 2002). As a result of that infant mortality rate has declined from 82 per thousand live births in 1967 to 27 per thousand live births in the year 2000. Although Ministry of Health and UNRWA had initiated many programs for family planning and health education in their maternity and child centers, the fertility rate however, remains high around 7-8 Childers per each women aged 16-49 years. The infant mortality rates have dropped from about 32 per thousand in 1994 to about 27 per thousand in the year 2000 (see Figures 3.29 and 3.30). The rapid drop in the mortality rate reflects the more satisfactory level of health services as more modern medical techniques and facilities become available. The same reasons are behind the increase of the life expectancy to reach about 71 years in the year 2000 (Figure 3.31).



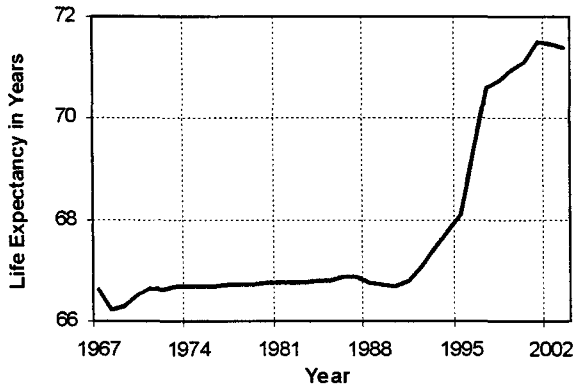
Source: MOH, 2002

Figure3.29 Fertility Rate



Source: MOH, 2002

Figure 3.30 Infant Mortality Rate



Source: MOH, 2002

Figure 3.31 Life Expectancy

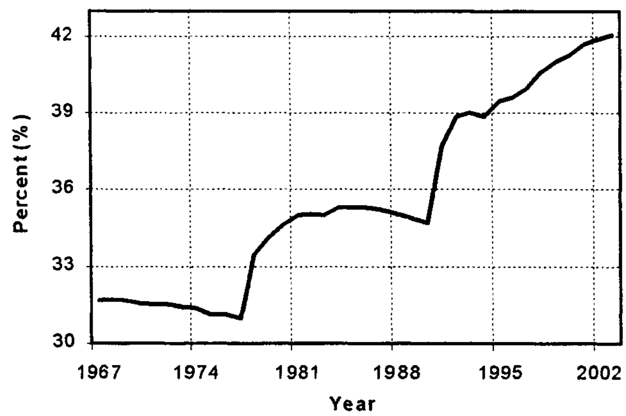
3.6.3 Educational Indicators:

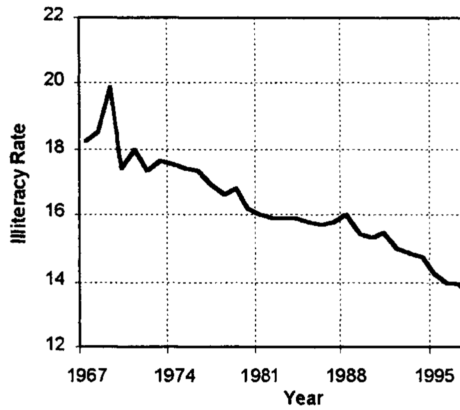
The population's educational level is of wide economic significance. Firstly, it affects the extent of the population's participation in economic activities, since a higher educational level leads to a tendency to participate in the workforces; secondly, it finds expression in the quality of manpower. It is noticed that a rise in the population's educational level has taken place. Educational system in Gaza operates within three frameworks: private, governmental and UNRWA establishments. Private and UNRWA schools are only for the first two levels elementary and intermediate for students aged 7-14 years. In the other hand, the governmental schools are covering the three levels elementary, intermediate and secondary levels for students 7-18 years. It is appear from Figure 3.32 that the percentage of students is increasing rapidly from 31 percent to 41 percent during the last 37 years. The annual growth over this period in the size of the education enrolment i.e. the total number of pupils in elementary, intermediate and secondary levels, was higher to the natural rate growth of the city's total population and stood at about 6.5%. The increase in the number of classrooms was higher than the previous period due to the big investment from the donor countries in the educational sector.

The Palestinian universities at Gaza city developed rapidly in terms of building areas, professors and students during this period. The increase was clear in the number of students and number of the universities staff. The PNA helped the university to develop their facilities and capacities.

The development of the educational system had influenced the reduction in the illiteracy rate among the city's population. It decreased from 18% in 1967 to less than 13% in 2003

(Figure 3.33). This percentage considered slightly low compared to the neighboring Arab countries like Egypt 17% and Jordan 14% (UNESCO, 2003).





Source: Ministry of Education, 2003

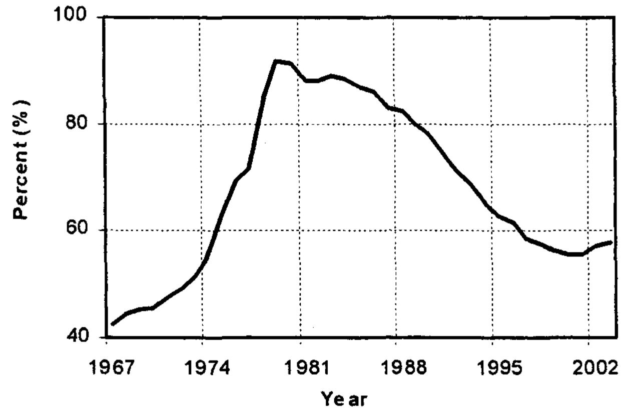
Figure 3.32 Percentage of Students in all Educational Levels

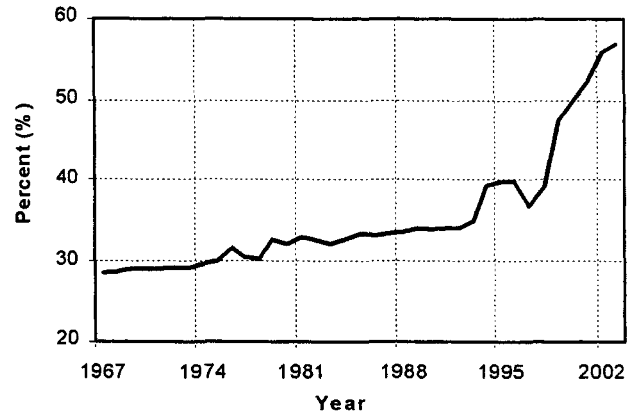
Figure 3.33 Illiteracy Rate

3.6.4 Access to public services

Households connected to water and wastewater network

Reliable figures on water coverage by neighborhood are difficult to determine because some municipal water is not metered. The procedure used to determine the percentage of population that served by piped water supply is combination of population figures from the municipal geographical information system with the number of water meters in different neighborhoods. Figure 3.34 shows that, the average metered water coverage for all Gaza city in the year 2000 is likely to be around 60.0 percent. Six neighborhoods were below the average, while eleven neighborhoods were higher than the average of the city. The water section at the municipality reported that the average monthly demand for new water connection was 118 applications. Figure 3.35 presents the percentage of households connected to the wastewater network, which has decreased to reach 55% in the year 2003.





Source: Gaza Municipality, 2000; 2002; 2003

Figure 3.34 Percentage of Households Connected to Water Network

Figure 3.35 Percentage of Households Connected to Wastewater Network

In the other hand, the number of households connected to the wastewater network increased from 6000 connections in 1967 to about 34,150 connections in 2003. This means that 56.8 percent of the households are currently connected to the sewer network. Figure 3.35 shows continuous increase in this percentage over time, especially for the recent period 1996 to 2003.

Households connected to electrical network

The percentage of households connected to electrical network has been decreased due to the fact that many households are sharing one connection. Therefore it is found that the rate of increase in electrical connection are lower that the rate of growth in households. It is found that only 70 percent of households have legal connections, while the other 30 percent having sub-connection from their relatives.

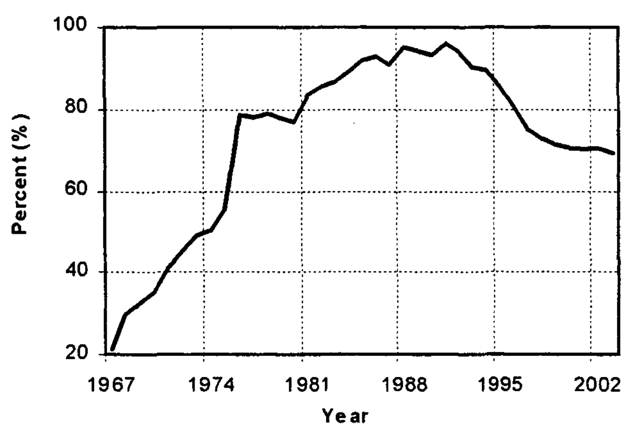


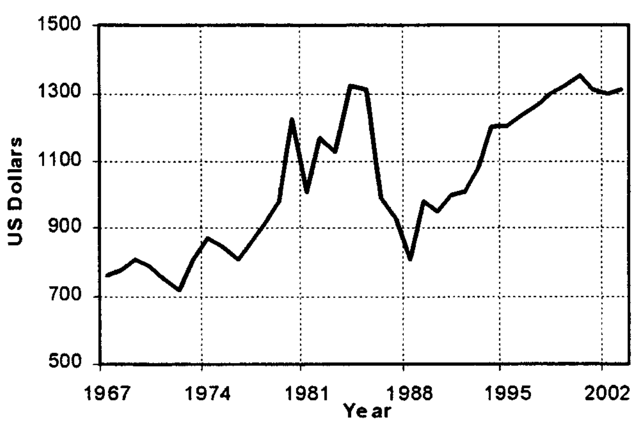
Figure 3.36 Percentage of Households Connected to Electrical Network

3.6.5 Economic Indicators:

Economic development in the Gaza can be evaluated through many indicators that influenced by regional, national and global factors. Among several indicators identified by BZU (2000), only four indicators have been considered as possible influential indicators on land-use change of Gaza. These indicators are; per capita GDP, labour forces, unemployment rate and poverty rate.

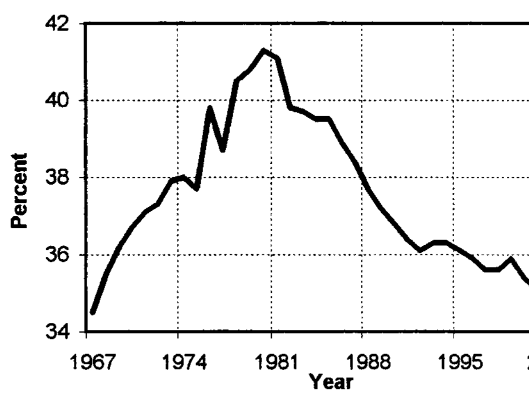
Per Capita GDP

A number of studies asserted that the Palestinian economy has weakened considerably over the period 1994-2003, affecting negatively the standard of living for most, if not all, Palestinians in the Gaza Strip. According to the office of the United Nations Special Coordinator in Palestine the real per capita GDP declined by 36.2 percent between 1992 and 1996 (UNSCO, 2002). There are several explanations for this trend mainly the dramatic drop in the remittances from Palestinian workers in Israel and other countries. Such remittances constituted a substantial 25.0 percent of the national GDP in 1992 declining to 8.0 percent three years later (Pedersen and Hooper, 1998). This development highlights the vulnerability of the Palestinian economy to political instability in the region. In the year 2000, per capita GDP in Gaza reached 1300 US Dollars (Figure 3.37) while it is around 1640 USD in Amman- Jordan and 4360 in Beirut- Lebanon.



Source: Pedersen and Hooper, 1998; PCBS, 2002a

Figure 3.37 Per Capita GDP for Gaza Strip



Source: ICBS, 1982; UNCTAD, 2002; PCBS, 2(

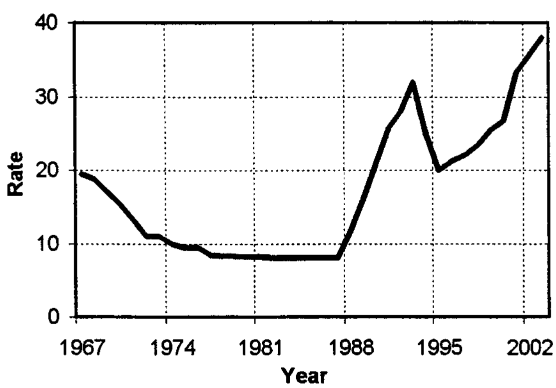
Figure 3.38 Percentage of Labour Forc(

Labour forces

The total Gaza's labor force numbers in the year 2000 is about 140,000 workers, or around 36% of the total population. The labour force is variable depending on the population's age composition and employment rates. Data on labour forces shows that around 35% of the total population are counted as labour forces. Several factors appear to have combined to explain these figures. Firstly, the participation of women in the labour force has remained low due to the high fertility rates, limited number of women get university education, and traditional social limitations. Secondly, the proportion of students of the ages 14 to 25 years has increased in recent years and has led to a drop in their participation in economic activities.

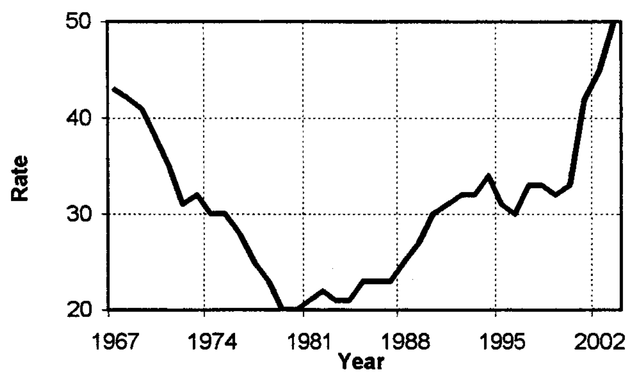
Unemployment rate

The most important factor in the economic well being of the Palestinian households is access to employment. During the fourth neighborhood of 1995, almost 20 percent of the labour forces were unemployed. The unemployment rate was continuously increased since 1996 standing at around one third of the labour force (Pedersen and Hooper 1998).



Source: BZU, 1998; 2000; *PCBS, 2002a*

Figure 3.39 Unemployment rate



Source: UNCTAD, 2002; PCBS, 2002a ; PCBS, 2003

Figure 3.40 Poverty Rate

Poverty rate:

The combined effect of less work opportunities and lower paid jobs is worsened living conditions and increase poverty rate. A recent study indicates that there has been a substantial deterioration of living standards over the years 1987-2003. Based on expenditure data from the Palestinian Central Bureau of Statistics, it was estimated that in 1995 about 30 percent of the Gaza population lived under poverty threshold (Shaban, 1997; PCBS 2002b;

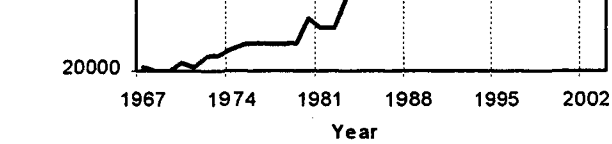
World Bank 2002a). The poverty rate was higher among refugee camp residents than other areas of the city. UNSCO (2002) states that the "continuous declines in the real household expenditures during 1996 and 2000 have probably increased the incidence and severity of poverty rates. Poverty has climbed from an already high level of 31% before the year 2000 to 40% in the year 2002 (UNSCO, 2002; World Bank 2002a). Poverty has been found to vary dramatically among the city's neighborhoods. The share of the population living in poverty in the Gaza Strip is more than twice as high as in the West Bank (World Bank 2000; 2001). The World Bank (2002a) has estimated that two-thirds of the 'new poor', those who have become poor since October 2000.

3.7 Environment Indicators

Based on explanations in sections 1.4.5.2 and 2.3.4, there are seven possible environmental indicators which are; annual amounts of solid waste, percentage of households use cesspits for wastewater discharge, percentage of households discharge their wastewater directly to the sea, number of motor vehicles, electrical consumption, annual groundwater consumption, and domestic water salinity. The following are the detailed description of each indicator.

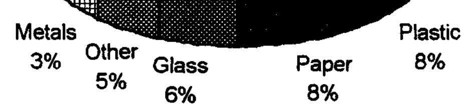
3.7.1 Annual Amounts of Solid Waste

The Municipality of Gaza and UNRWA are sharing the responsibility for collecting, transporting and dumping the city's solid waste. The municipality collected an average of 131,000 tons per year from 16 neighborhoods of the city while UNRWA is responsible for solid waste collection from the Beach camp with around 5,400 tons per year. The majority of the city's neighborhoods are nearly served by solid waste collection services. Only three neighborhoods appeared to be less served than the others. Beach camp has the lowest solid waste collection service at only 40% coverage followed by Daraj and Sabra served at about 60%. Part of the reason for low coverage in these areas is the higher population density in these areas.



Source: Gaza Municipality, 2003; UNRWA, 2003; UNEP, 2003

Figure 3.41. Annual Collected Amounts of Solid Waste



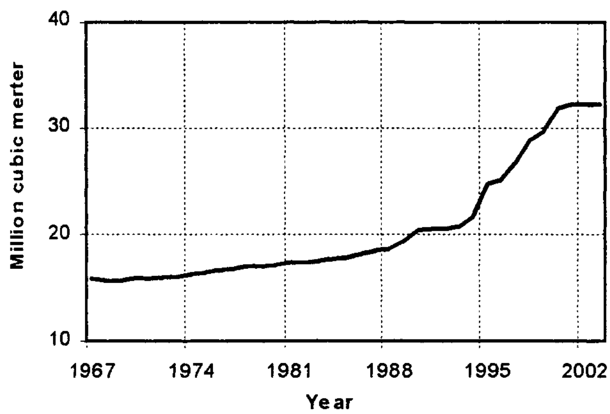
Source: UNRWA, 2003; UNEP, 2003

Figure 3.42. Composition of the Municipal Solid Waste

The municipality is responsible for daily operation of the landfill Southeast t the city. The landfill has an area of 13 hectares and received 500 tons/day mainly organic material (Domestic solid waste) as it appears in Figure 3.42. Currently the access of the landfill site, been difficult or impossible, as a result of partial or full closer, therefore the municipality is using temporal sites inside the residential areas, which has negative impact on the public health (UNEP, 2003).

3.7.2 Ground Water Abstraction

As shown in the Figure 3.43, the abstracted water quantities from the municipal water wells are increasing very rapidly for the last three decades. During this period there were serious restrictions on the drilling new wells and on the abstracted quantities. The network system efficiency, consumption over abstraction is considered as low as 57 percents. There are many two main reasons behind this low percentage, which are the losses in the network and the illegal connections. Both quantities can't be measured or estimated correctly.



Source: Gaza Municipality, 2003

Figure 3.43. Annual Ground Water Abstraction

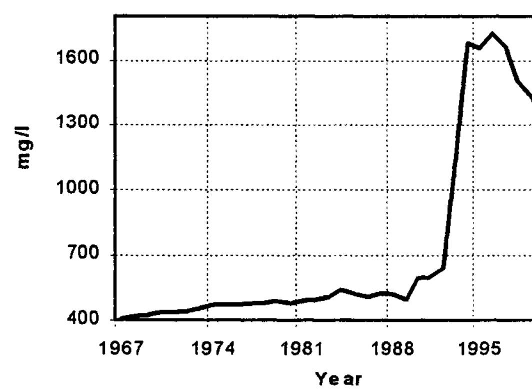


Figure 3.44. Domestic Water Salinity (T

3.7.3 Groundwater Pollution

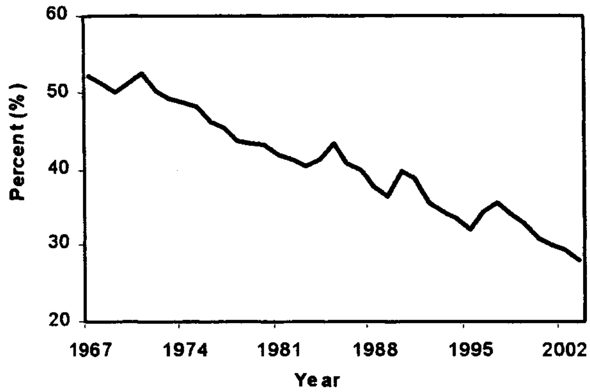
Water quality in Gaza Strip in general is a problem of great concern, since the quality is deteriorating very rapidly as a result of continuous over abstraction and pollution factors. The salinity of the water varies from place to place within the city. With exceptions of the costal part of Gaza where the salinity is higher close to the coastal area, the tests of ground water quality in Shikh Ajleen area, has a chloride content of 1200 mg/l. The recommended maximum value by the World Health Organization (WHO) is 250 mg/l.

The nitrate (NO_3) concentration is considerably high, the maximum value found is 290 mg/l, but the average is 115 mg/l. WHO recommended the upper value should no exceed 50.0 mg/L. The main reason for the high nitrate concentration is the pollution from the use of fertilizers in agriculture and pollution from untreated domestic wastewater. Florid (F_l) concentration is also high, it has values ranging between 0.8-3.8 mg/l throughout the whole Gaza. WHO recommended upper value is 1.5 mg/l. Currently, around 35 percent of Gaza households are using water purification devices for or buy purified water for drinking water and cooking purposes. A higher number of high-income households use a filter than low-income households.

The deteriorated of water quality in Gaza is represented mainly by the salinity of groundwater which exceeds up to five times the maximum norm recommended by the WHO. This could be explained by two main reasons; groundwater over-abstraction and the seawater intrusion. Figure 3.44 represents the average total dissolved solids (TDS) values calculated from a total of 18 municipal wells. It is noticeable that the TDS after 1994 has increased rapidly to exceed the WHO maximum allowable TDS for drinking water which is 1000mg/l. Rehabilitation of water wells by increasing its depth or by construction new water wells in 1996-2000 led to decrease TDS values.

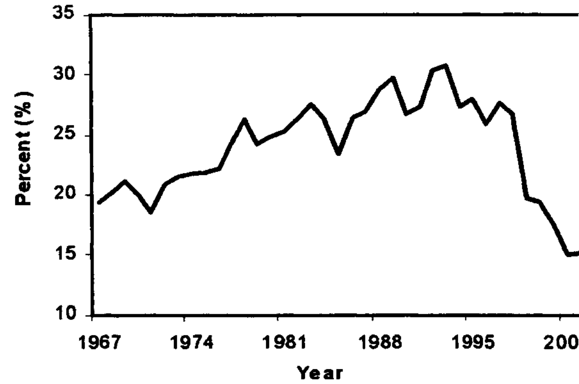
3.7.4 Wastewater Conveyance and Treatment

According to the municipal records there are around 28 percent of the total households are not connected to the wastewater network and using cesspits constructed near their homes to discharge their wastewater (Figure 3.45). Most of these households are located in areas lack of basic infrastructure such as wastewater network and paved roads. Sabra and Tofah neighborhoods are among these areas. Around 15 percent of households who dispose the wastewater are discharging their wastewater directly to the sea, these areas mostly located close to the sea shore and not covered by the sewer system such as parts of the Beach camp and Sheikh Ajleen neighborhood (Figure 3.46). The decrease of these figures in the recent years are related to the improvements of the wastewater conveyance system e.g. expansion of the wastewater network and developing wastewater treatment facilities.



Source: Gaza Municipality, 2003; UNRWA, 2004

Figure 3.45 Percentage of households use cesspits to discharge their wastewater



Source: Gaza Municipality, 2003; UNRWA, 2004

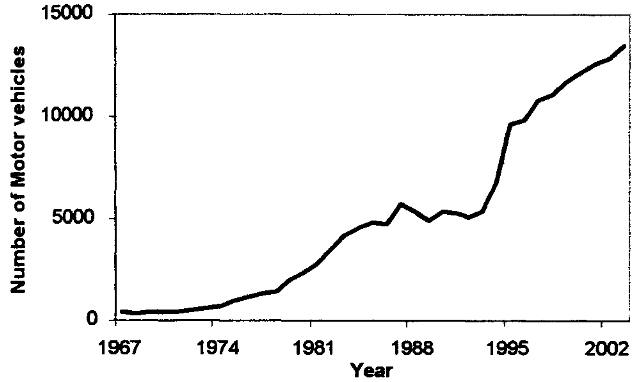
Figure 3.46 Percentage of households discharge their wastewater to the s

Gaza wastewater treatment plant, which located to the Southwest of the city, received around 27,600m³/day in the year 1994 and increased to 35,000m³/day, 47,000m³/day and 50,000m³/day by the years 1998, 2000 and 2003 respectively. This inflow significantly exceeds the WWTP capacity, which designed to receive 40,000m³ per day. There is no wastewater re-use locations, therefore the major amount of the treated wastewater were disposed to the sea.

3.7.5 Energy Consumption and Environmental Pollution

Number of motor vehicles

It is noticed a continuous increase in the number of the registered automobiles in the city. The rapid increased was noticed for the period 1995-2000. The ration of cars per households for the last four years is stable on 0.21 car per household which is very low compared to other cities such as Amman where it is around 0.7 and in Israel where there is 1.2 cars per households (PCBS, 2003).



Source: Abu Eisheh, 2001

Figure 3.47 Number of Cars

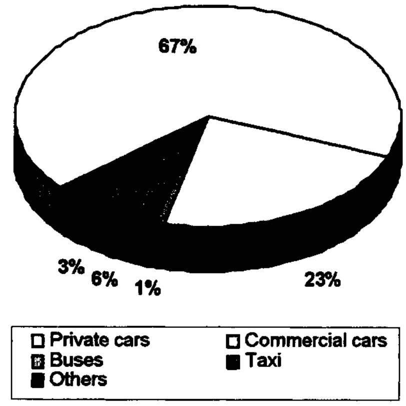
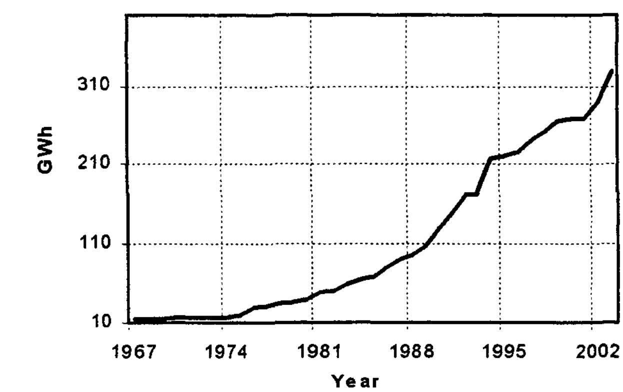


Figure 3.48 Types of Motor Vehicles,

Public transport is limited to the university students who came from all over the Gaza Strip to the four universities located in Gaza City. The buses are accounted less than 1.0 percent of the total motor vehicles (Figure 3.48), which belongs to five companies, were operated within the city serving more than 5,000 student per day. The most common public transport in Gaza is the share-taxi (vehicles with 7 passengers) transporting the passengers inside and outside the city.

Electrical consumption

The electrical consumption has been used as energy indicator since it is the main energy sources used in Gaza. Figure 3.49 presents the electrical consumption, which revealed that the electrical consumption had increased during the period (1994-2000) by more than 23 percent. This growth could be a result of the urban expansion of the city and establishment of new housing projects with multi-story buildings. Since 1994 the electrical network and its efficiency have been developed especially after construction the new power station about four kilometers to the south of the city.



Source: Gaza Electrical Company, 2003

Figure 3.49 Electrical Consumption

3.8 Institutional Measures

According to the indicators framework mentioned in sections 2.3.5 there are seven possible indicators representing the institutional measure that related to land-uses, which included infrastructure development, provision of public services and fund raising for development.

3.8.1 Provision of infrastructure facilities

Road Network Development

Three coverage indicators have been used in this analysis to gain a more accurate idea of the Municipality's road development. The first indicator is the surface road length per 10,000 inhabitants. Per capita road area in square meters based on road areas and neighborhood population is the second indicator, which provides a relatively good idea about the degree to which the actual population is being served by roads. The third indicator has been the road area as a percentage of the overall neighborhood area based on the unified neighborhood boundaries. These indicators provide an idea of how thoroughly the neighborhoods have been covered by roads and considering only the roads areas and not their conditions.

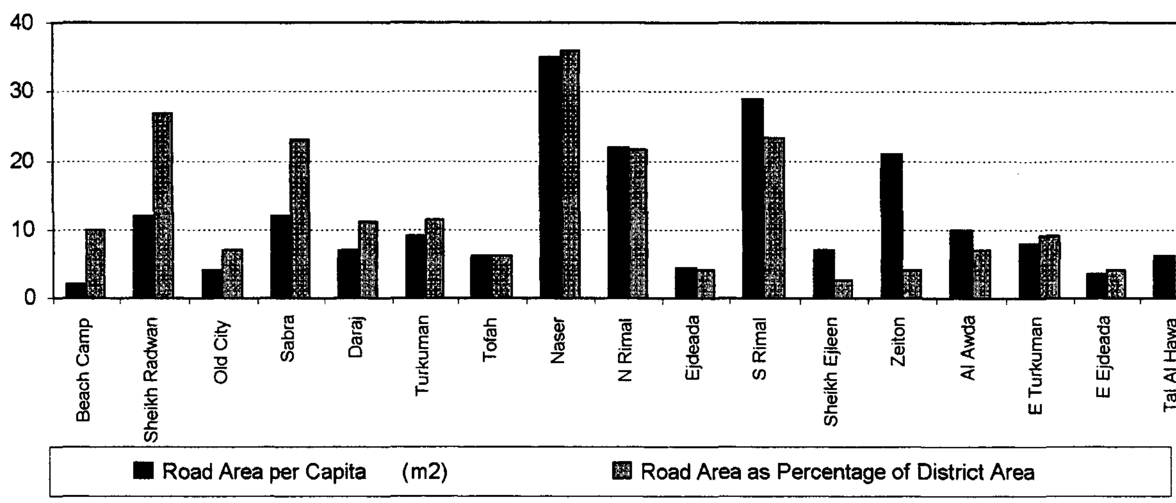
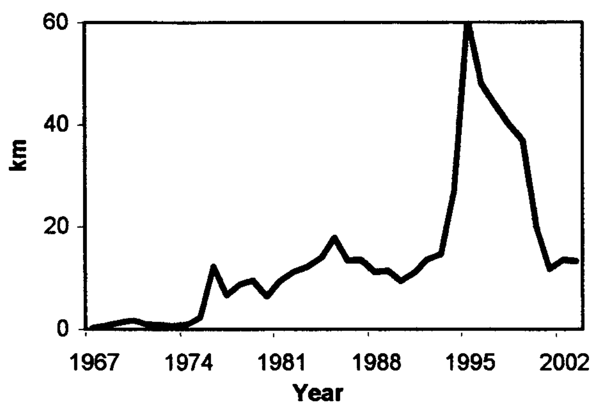


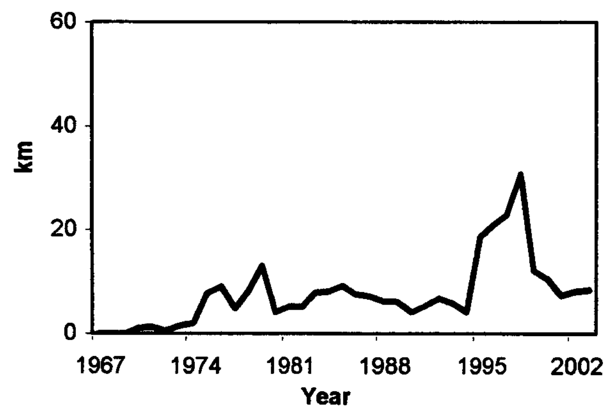
Figure 3.50 Road Coverage, 2000

As might be expected, the three upper-income zones of Nasser, Northern Rimal and Southern Rimal neighborhood have the highest roads coverage. Results from the two indicators presented in Figure 3.50 shows that Nasser neighborhood, for example, has both the highest per capita road area and the highest ratio of road area to neighborhood area. The results are representatively 34.5 m^2 per resident and 35.6% of the neighborhood area. The ratio of road area to neighborhood area is quite high and exceeds the urban planning target of 22-25% Specified by urban planning department. The fact that Northern and Southern of 22-25% Specified by urban planning department. The fact that Northern and Southern Rimal neighborhood are well supplied with roads may be one reason encouraged urban development in these areas. The second highest road area per capita is found in the Southern Rimal neighborhood at 29.3m^2/capita. While the second highest ration of road area to overall neighborhood area occurs in the Sheikh Radwan neighborhood at about 27%.

Water and Wastewater Networks Development

The significant development of the water and wastewater networks were occurred after the year 1994, since a significant external funds were allocated for expanding and rehabilitation of the existing network. Moreover, development of water and wastewater facilities such as water wells, pump station, wastewater treatment plant had been made possible by these funds. However it is noticed that the development of water network has given priority over wastewater network in terms of expansion the network.





Source: PADCO, 2000

Figure 3.51 Development of Water Network

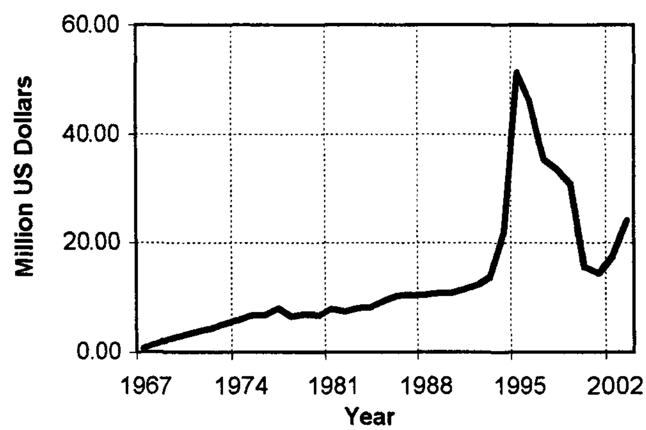
Figure 3.52 Development of Wastewater Network

3.8.2 Provision of Public Services (health, education and public parks)

During the recent period and after 1994, the PNA and UNRWA had constructed additional health and educational establishment that contribute to the improvement peoples' health and of overall living conditions (World Bank, 2002b). These services still need more development in terms of quantity and quality. Currently there are 122 governmental schools, 21 UNRWA schools and 4 private schools. Most of these schools are operating in two shifts, one in the morning and one in the afternoon. Moreover the classrooms are over crowded with more than 50 pupils in each classroom especially at UNRWA schools.

3.8.3 Funds for Development

Funds for development are coming from two different sources, local and external, were invested in development of infrastructure facilities such as electrical network, roads, water network, sewage networks, wastewater treatment facilities, and construction of public buildings. The majority of the funds for these investments are donated by the international community to the Palestinian authority. Figure 3.53 shows that the expenditures has slow increase until 1994. Upon the Palestinian Authority establishment in 1994 a significant budget have been investments in the Palestinian areas in general and in Gaza city in specific. The total investment from March 1994 to December 2003 reached 116 Million US Dollars. Despite this significant budge the rapid development rate was greater than the expended budgets, therefore the municipality still have long list of urgent infrastructure projects that need to meet the present urban growth and population increase.



Source: Gaza Municipality, 1981; 2000; 2003

Figure 3.53 Total Funds for Development

In its efforts to improve the financial situation, the municipality has started to implement incremental cost recovery principle based on the affordability of the citizens. Taking into consideration the difficult economical situation of the citizens. During the period 1994-2000 the municipality improved its financial system by implementing a computerized modified accrual accounting base instead of the cash based system used before. The municipal revenues composed of fees for water, building licenses, commercial, and fees for other services such as advertisement.

3.9 Conclusion

The political situation has greatly influenced the socio-economic conditions of Gaza population. Therefore, socio-economic conditions in Gaza did not led to progress in the overall development, because it did not achieve greater levels of independence and sustainability. It was marked by decline in the participation rates of men and women in the employment and per capita GDP rate of growth. This, in turn, led to decline in the living standards of Gaza people and cause a great pressure on the urban environment.

The environmental indicators had multi-dimensional implications and characterized by continuous deterioration. The increase the amount of the generated wastewater, increased abstraction of ground water, increase the density inside the city and increase the amounts of the annual solid waste are adding more pressure on the limited natural resources. Moreover, unplanned expansion of the residential areas on the account of agricultural lands and green areas had negatively affected the sustainability for land-uses.

The responses of the local authorities are not able to fulfill all the development requirements. At the policy level, the municipality is surviving towards finalizing the detailed plans for all the city's neighborhoods. However its response, besides being modest, is neither consistent nor sustainable as a result of political difficulties, Israeli closure polices, the institutionalized dependence on foreign assistant, and the lack of a mechanism for sustainable management.

CHAPTER FOUR

DATA ANALYSIS AND MODELING

4 Data Analysis and Modeling

4.1 Analysis Plan and Tools

The analysis plan followed in this chapter is designed to achieve two main objectives; firstly, selecting the most influential, socio-economic, environmental and institutional, indicators and secondly, modeling the relationship between these indicators and land-use changes. Several steps have been taken to achieve these objectives using different tools (Figure 4.1).

Firstly, a series of univariate analysis were undertaken to explore the data for each indicator alone. Non-normal distribution of the data, particularly in form of large skewness, can result serious errors in analysis and incorrect conclusions. Therefore, normality test has been performed for all indicators, hence, the results of this test will be the base for Bivariate and multivariate analysis. Slight deviation from normality typically did not have significant effect on the statistical analysis.

Secondly, Bivariate analysis has been employed to investigate the relationship between the land-use categories in one hand and the selected possible indicators in the other hand. The indicators that have significant relationship with land-uses were selected as determinant indicators. These determinant indicators were used as an input for the prediction model. The coefficient of determination (R-squared) are used to represent the proportion of common variation in the two variables (i.e., the "strength" or "magnitude" of the relationship). The results of the correlation matrix were compared with the expert's opinions that gathered from the results of the indicator-ranking questionnaire (Annex 3).

Thirdly, multivariate exploratory techniques mainly factor analysis were applied in this context to discover underlying determinant factors of the land-use changes in Gaza. Factor analysis also provides information on the relative relationships among variables. For example, variables that share positive factor loadings all relate to each other in the same direction. Therefore, factor analysis has been used to identify variables of interest, and then consider the absolute values of these indicators for a more concrete understanding of the meaningful relationships among these indicators.

Fourthly, data analysis and modeling using Artificial Neural Network (ANN) techniques aiming at developing reliable model for land-use prediction. ANN was developed to model the brain's interconnected system of neurons so that computers could be made to imitate the brain's ability to sort patterns and learn from trial and error (Bishop, 1995; Najjar et al., 1997; Haykin, 1998; Najjar and Zhang, 2000). In regression problems, when the objective is to predict the output variable value using given input variables, ANN can solve this problem by using multi-layer perceptron MLP with back propagation algorithm. Many researchers proved that ANN is a powerful tool that uses a machine learning approach to quantify and model complex behavior and patterns. ANN model can be used as a management tool for the prediction of land-use changes that could be use by land-use managers and planners towards better management of land resources.

Fifthly, modeling with multiple-linear regression (MLR), which is widely used for land-use modeling, has been used to model the relationship between several independent or predictor variables and each of land-use indicators as dependent variables. A multiple regression allows the simultaneous testing and modeling of multiple independent variables. The results of the MLR are compared with the results of ANN model based on the model's performance criteria.

Finally, prediction for the coming 15 years has been performed using the selected prediction model. The prediction was calculated based on two different scenarios. The first is status-quo scenario, which based on extrapolation of the recent developments. The second is the sustainability scenario that assumes socio-economic development with appropriate polices and regulations for improvement of the existing situation.

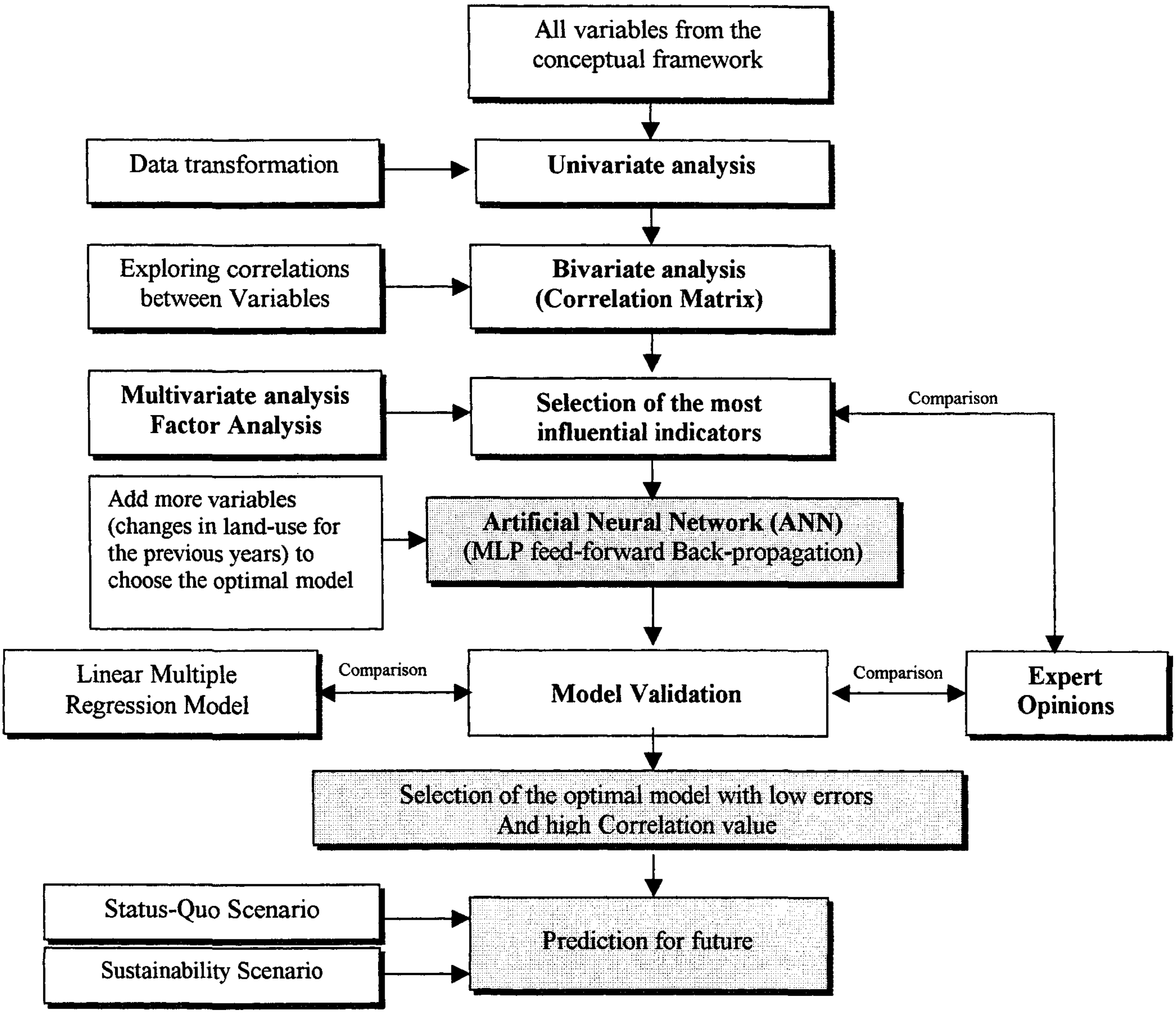


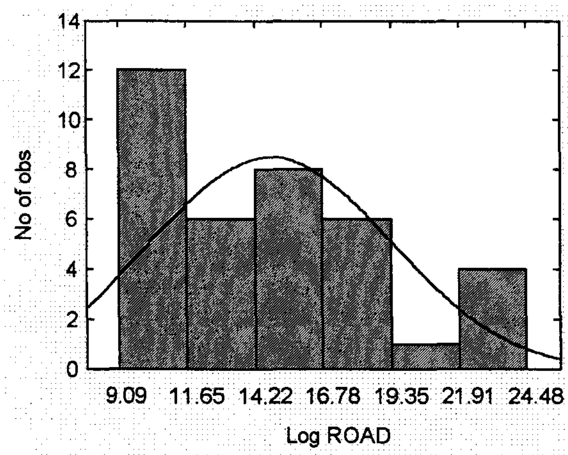
Figure 4.1: Analysis Plan and Methodology

4.2 Statistical Analysis

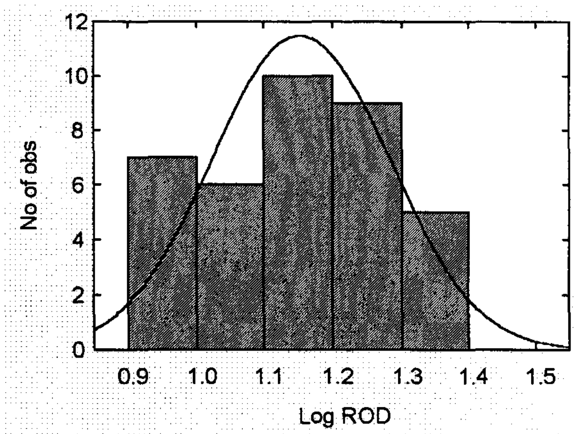
4.2.1 Univariate Analysis:

Univariate statistical tests assume a normal distribution of the given data. Therefore, normality test for each indicator has been performed using fitting empirical distribution (Kolmogorov-Smirnove test). It considered that if the p-value of the indicator is greater than 0.2 then the data for that indicator is normally distributed and there is no real evidence against the null hypothesis (Schafer, 1997). Results from normality test for all the variables gave evidences that most of the indicators have non-normal distribution with mostly a positive skewness. Data transformations have been performed using log (10) of the indicators values in order to minimize the skewness and produce a normally distributed data.

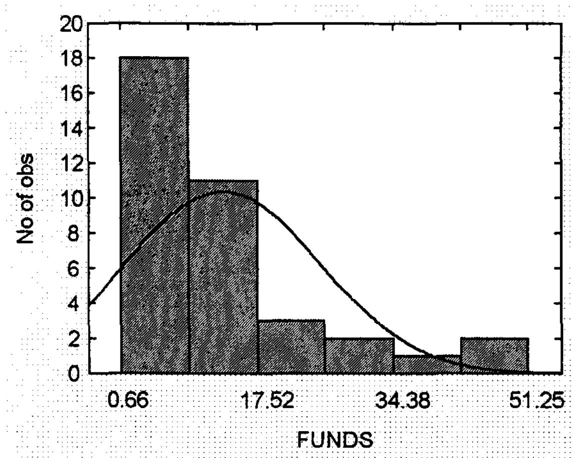
Figure 4.2 shows the data transformation for two indicators as an example of the procedure followed for all indicators.



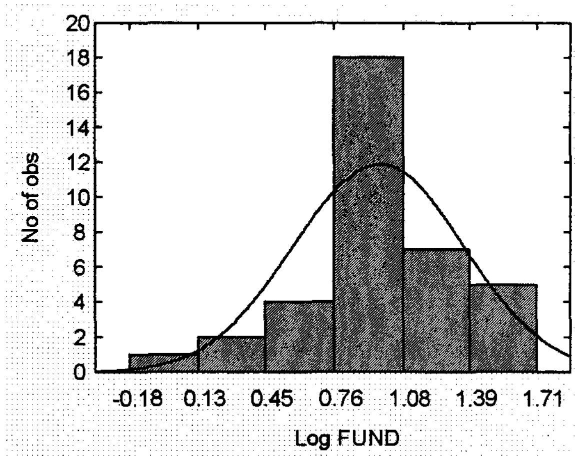
Data distribution on roads before transformation



Data distribution on roads after transformation



Data distribution on funds before transformation

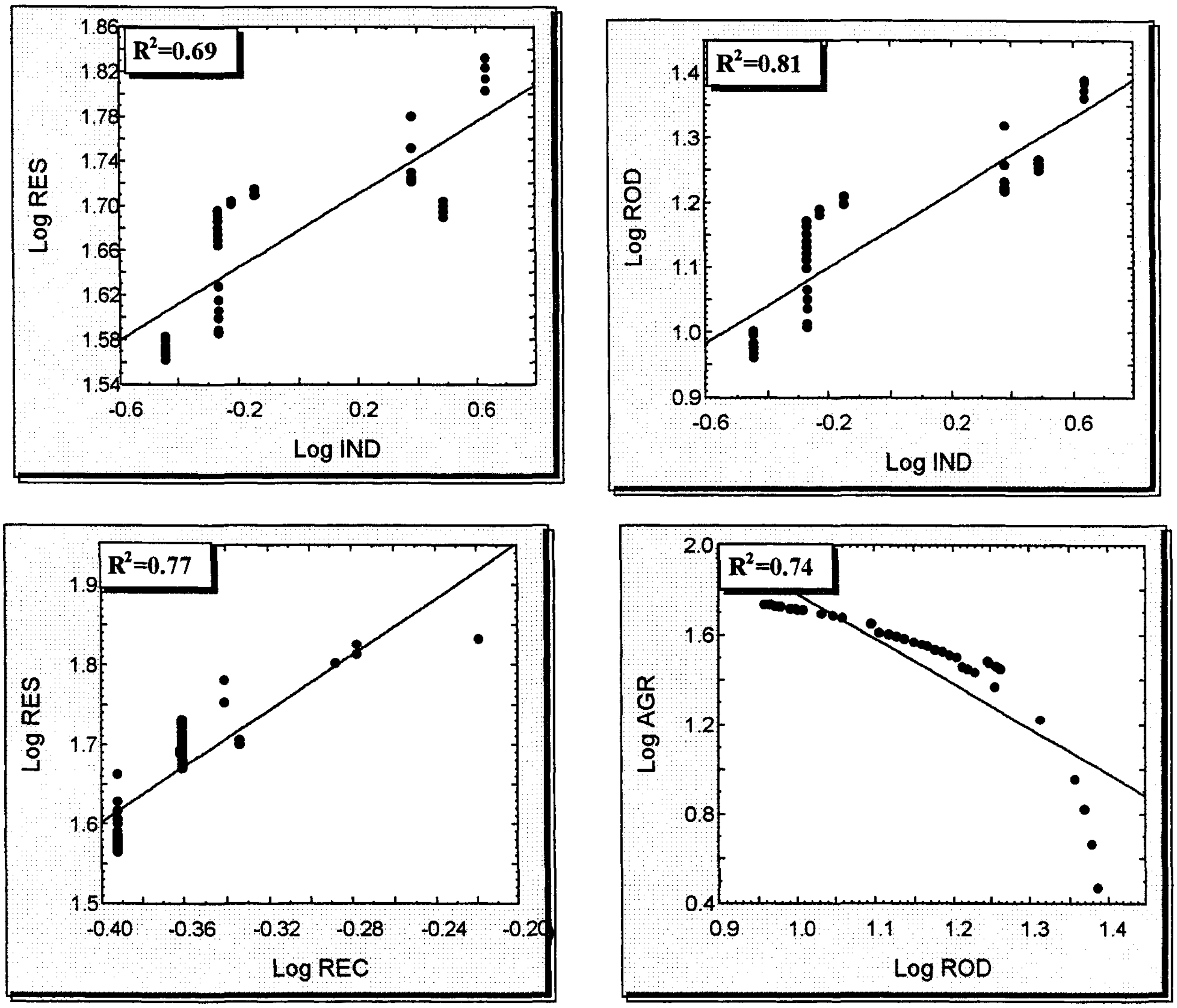


Data distribution on funds after transformation

Figure 4.2. Normality test and Data Transformation for the Roads and Funds Indicators

4.2.2 Bivariate Analysis:

A series of bivariate analysis have been taken to illustrate the relationship between each two indicators. Figure 4.3 presents the relationship between the areas used for residential and industrial purposes in one hand and the areas used for roads and agricultural purposes in the other hand. It is obvious that there is a moderate correlation between the residential areas and the industrial areas with R-square equal to 0.69, which could be explained by the rate of growth of the residential areas was higher than the growth of the industrial areas. The industrial development in Gaza was progressing in very slow steps due to the economical difficulties during the last 37 years. The high growth rate of land-use conversion from agriculture to residential purposes, due to the high demand on housing unites, led to decrease the areas for agricultural purposes. The road network expansion was in low rate of growth compared to rate of decrease in agricultural lands. The analysis shows that there is a moderate inverse correlation between expansion in areas for roads and the areas for agriculture uses.



RES: Residential Areas ROD: Roads IND: Industrial areas REC: Recreational areas AGR: Agricultureal areas

Figure 4.3. Bivariate analysis among land-use indicators

4.2.3 Correlation Between Variables

Correlation analysis was initially performed to select the determinant indicators that have significant relationships with the land-use categories. The most widely used type of correlation coefficient is person r, which presents the values of two variables that are correlated proportional to each other. The correlation is high if it is can be approximated by a straight line (sloped upward or downward). This line called the regression line or least squares line. Initially, 30 variables were selected for the bivariate correlation analysis. Table

4.1 shows the correlation between the land-use categories and the possible influential indicators.

Table 4.1. Correlation Matrix of land-use indicators and possible influential indicators

No.	SEEI Indictors	Land-use Indicators (LU)				
		RES	**ROD**	**IND**	**REC**	**AGR**
1	PG	**0.71**	**0.70**	0.20	-0.47	-0.61
2	**P19**	**0.95**	**0.95**	**-0.96**	**-0.74**	**-0.83**
3	PC	0.68	0.17	0.33	-0.11	0.05
4	**PD**	**-0.82**	**-0.81**	**-0.91**	-0.46	0.60
5	FR	-0.37	-0.38	-0.18	-0.72	0.63
6	IM	-0.27	-0.26	-0.37	0.14	0.04
7	LE	-0.50	-0.49	-0.65	-0.12	0.24
8	ST	-0.65	-0.65	**-0.79**	-0.22	0.38
9	IR	0.01	0.00	0.20	-0.47	0.31
10	HW	0.20	0.20	0.39	-0.24	0.10
11	**HWW**	**-0.72**	**-0.72**	**-0.82**	-0.30	0.47
12	HE	0.38	0.38	0.55	-0.04	-0.09
13	**LF**	**0.94**	**0.94**	**0.95**	**0.80**	**-0.87**
14	**UE**	**-0.86**	**-0.85**	**-0.94**	-0.51	0.65
15	GDP	-0.18	-0.17	-0.37	0.30	-0.14
16	**PR**	**-0.93**	**-0.93**	**-0.96**	**-0.70**	**0.80**
17	SW	-0.61	-0.60	**-0.75**	-0.21	0.35
18	**WWC**	**0.86**	**0.86**	**0.93**	0.52	-0.67
19	WWS	0.65	0.64	**0.75**	0.33	-0.50
20	CAR	-0.65	-0.64	**-0.78**	-0.25	0.39
21	EC	-0.66	-0.65	**-0.79**	-0.24	0.39
22	**GWA**	**0.74**	**0.74**	**0.78**	-0.21	0.48
23	**TDS**	**0.70**	**0.70**	**0.83**	0.27	-0.44
24	WND	0.22	0.22	0.39	-0.14	0.04
25	SND	0.15	0.14	0.33	-0.27	0.15
26	RND	0.12	0.12	0.30	-0.25	0.15
27	NS	-0.27	-0.27	-0.17	-0.60	0.46
28	NH	0.31	0.30	0.33	0.03	-0.17
29	NP	0.12	0.12	0.20	0.25	0.15
30	**FUND**	**0.81**	**0.81**	**0.91**	0.47	-0.60

Log (10) is used for all variables listed above (Significant correlation at $p < 0.01$)

It is obvious from the correlation matrix that there are 10 indicators have significant linear correlation with at least three of the land-use categories. These correlations vary from 0.7 to 0.95 in both directions (positive or negative correlations). These indicators are Log population under 19 years (P19), Log population density (PD), Log households connected to the wastewater (HWW), Log labour forces (LF), unemployment rate (UE), poverty rate (PR), households used cesspits for wastewater disposal (WWC), groundwater abstraction (GWA), groundwater salinity (TDS), and funds for development (FUND). Among these 10 indicators LF, PD and PR have strong correlation with all land-uses. Therefore these three indicators should be considered as the main driving forces behind land-use changes in Gaza.

The other 20 indicators have insignificant correlation with most of the land-use indicators. It doesn't mean that they have no contribution to the land-use changes but their contribution is low compared to the first 10 indicators. In order to establish a simple and not complicated model, the first 10 indicators that have significant correlation with the land-uses will be the main focus in the further analysis.

Changes in residential and road areas have significant negative linear correlations with Log population density, log the percentage of households connected to the wastewater network, Log unemployment rate and with Log poverty rate. This means that the decrease in the values of these four indicators cause the increase in the residential. The increase in unemployment and poverty rates hindered the development of the residential and road areas. In the other hand, residential and road areas have also significant positive linear correlations with Log population under 19 years, Log labour forces, Log wastewater disposed into cesspits, Log ground water abstraction, Log domestic water quality (TDS), and with log funds for development. The increase in population under 19 years and percentage of labour forces caused an increase of residential and road areas. This increase is residential and road areas will lead to increase the pressure on the environment, which presented by increase of ground water abstraction and more deterioration of domestic water quality.

The industrial areas have a significant negative correlation with nine indicators which are; Log population under 19 year, Log population density, Log percentage of students, Log households connected to wastewater network, Log unemployment rate, Log poverty rate, Log amounts of solid waste, Log number of cars and Log electrical consumption. The decreases of the values of these indicators were associated with increase of the industrial area. For instance, the decrease of the unemployment rate is associated with the increase of the industrial development opportunities. In the other side, the industrial areas have a positive correlation with six indicators, which are; Log labour forces, Log the percentage of households use cesspits for wastewater discharge, Log wastewater discharged to the sea, Log groundwater pollution and log funds for development. That's confirmed the fact that whenever increasing labour forces and funds for infrastructure development the industrial area will increase.

Changes in recreational areas have significant negative correlation with only two indicators, which are Log population under 19 years and Log poverty rate, while significant positive correlation with Log labour forces can be noticed. Since the recreational areas had the lowest percentages among the other land-use categories with little changes since 1967, therefore they had limited impacts on other indicators.

The changes in agricultural areas have also significant negative correlation with two indicators, which are, Log population under 19 years and Log labour forces. This result can be explained by the fact that these two indicators representing two categories of population who are not engaged in agricultural activities. While the Log poverty rate have a significant positive correlation with the agricultural areas. That's confirmed the fact that whenever increasing in poverty, the people shift to agricultural activities as alternative source of income.

Correlation matrix between the selected indicators

The correlation among the selected influential indicators is illustrated in table 4.2. It explores the inter-relationships among these indicators. The correlation coefficient (r) was calculated for each pair of variables in order to avoid using highly correlated variables (i.e. coefficient of correlation over 0.80) and to reduce the effect of muti-collinearity (Mas et al., 2004).

Table 4.2. Correlation Matrix among the influential indicators (Log values is used)

	P19	PD	HWW	LF	UE	PR	WWC	GWA	TDS	FUND
P19	**1.00**									
PD	0.57	**1.00**								
HWW	0.56	**0.72**	**1.00**							
LF	**-0.79**	-0.57	-0.50	**1.00**						
UE	**0.76**	**0.78**	0.60	**-0.81**	**1.00**					
PR	**0.80**	0.37	0.39	**-0.80**	**0.81**	**1.00**				
WWC	-0.40	**-0.76**	**-0.79**	0.41	-0.56	-0.19	**1.00**			
GWA	0.62	**0.76**	**0.80**	-0.60	**0.69**	0.41	**-0.79**	**1.00**		
TDS	0.61	**0.70**	**0.77**	-0.57	**0.66**	0.36	**-0.75**	**0.79**	**1.00**	
FUND	0.26	**0.72**	**0.70**	-0.19	0.33	-0.05	**-0.74**	**0.77**	**0.74**	**1.00**

Significant correlation at $p < 0.01$

The correlation matrix shown in Table 4.2 reveals that population density has significant correlations among all the 10 determinate indicators. This confirms the fact that the densely areas are associated with more socio-economic and environmental problems. Therefore population density is considered as the main driving force for land-use changes in Gaza. Also ground water abstraction has correlated significantly with other indicators, while funds for development has a moderate to low correlations with other indicators.

4.2.4 Multivariate Exploratory techniques - Factor Analysis

Factor analysis is a variable reduction procedure that allows one to explore the interrelationships among variables in a dataset (Stevens, 1996). Significant clusters of variables or factors are identified through optimally weighted linear combinations of observed variables that maximize the amount of explained variance. The main applications of factor analytic techniques are to reduce the number of the independent variables and to detect structure in the relationships between these variables, that is to classify variables. Factor analysis boils down a correlation matrix into a few major factors so that the variables within the same factor are more highly correlated with each other than with variables in the other factors. It is assumed that the observed variables are correlated or go together because they share one or more underlying causes. Factors that emerge in the analysis of change will show which variables tend to change together over time, and in which direction change takes place. Variables with factor loadings of 0.80 or greater are considered in interpreting each factor, with particular emphasis given to items with loadings greater than 0.80 (McDade & Adai, 2001). This analysis was performed for variables shown in table 4.2 by using STATISTICA software (Version 6.0) produced by Statsoft Inc., USA.

Factor analysis involves a two-step process. Initially, the elements are resolved into their principal components via principal components analysis. Determining the principal components requires transforming the data into orthogonal variables using the eigenvectors of the matrices of the original variables (Trost and Oberlender, 2003). Each principal component is a linear transformation of the original variables. Because the principal components are orthogonal, no interdependence or multi-collinearity exists in the transformed data. Once the principal components are determined, a factor rotation is performed. Factor rotation involves rotating the principal components about the axes of the original variables. The factor rotation preserves the orthogonality of the principal components, but a new transformation matrix is formed with each rotation. Different methods exist for performing factor rotations. A preferred method, known as the method of maximum variance (varimax normalized), results in a series of rotations wherein each rotation creates a new variable or factor such that the maximum remaining variance in the data is explained by that variable (Trost and Oberlender, 2003). An important consideration during factor analysis concerns the number of factors to resolve during the analysis. The number of factors can range from one to the total number of original variables, which are 10 factors. Typical rotational method using varimax normalized has been employed to obtain a clear pattern of loadings, that is, factors that are somehow clearly marked by high loadings for some variables and low loadings for others.

Several guidelines were followed to assist in determining how many factors to be included in the factor analysis. One of the most common guidelines is the minimum eigenvalue criterion. Essentially, this method involves ranking the eigenvalues of the principal components of all the variables from greatest to least, then counting the number of eigenvalues greater than one. Another important consideration in deciding the number of factors relates to the interpretability and meaningfulness of the resultant factor groups. In this sense, factor analysis can be as much an art as a science. The researchers utilized the minimum eigenvalue criterion as a starting point to determine the proper number of factors and then examined the changes resulting from increasing or decreasing the number of factors from the minimum eigenvalue starting point (Trost and Oberlender, 2003). Each change resulted in a slightly different arrangement of factor groups. Applying factor analysis to the data on Gaza city, with the 10 indicators resulted from the correlation matrix in table 4.1 and by using minimum eigenvalue method, it is noticed that only 2 factors were successfully extracted with eigenvalue more than 1.0. Table 4.3 presents these two factors with their eigenvalues and total variances.

Table 4.3. Eigenvalues using principle component extraction method

Factor No.	Eigenvalue	% of the Total variances	Cumulative Eigenvalue	Cumulative %
1	6.98	69.82	6.98	69.82
2	2.25	22.48	9.23	92.30

From the second column *(Eigenvalue)* of the table above, we find the variance on the new factors that were successively extracted. In the third column, these values are expressed as a percent of the total variance. As we can see, factor 1 accounts for 69.8 percent of the variance which means that Factor one explained more that 72 percent of the actual changes in land-use of Gaza city, factor 2 accounts around 22.5 percent. As expected, the sum of the eigenvalues is equal to the number of indicators. The first two eigenvalues cumulated around 92 percent of the total variance, while the other 8 factors explained less than 8 percent of the changes in the land-use areas.

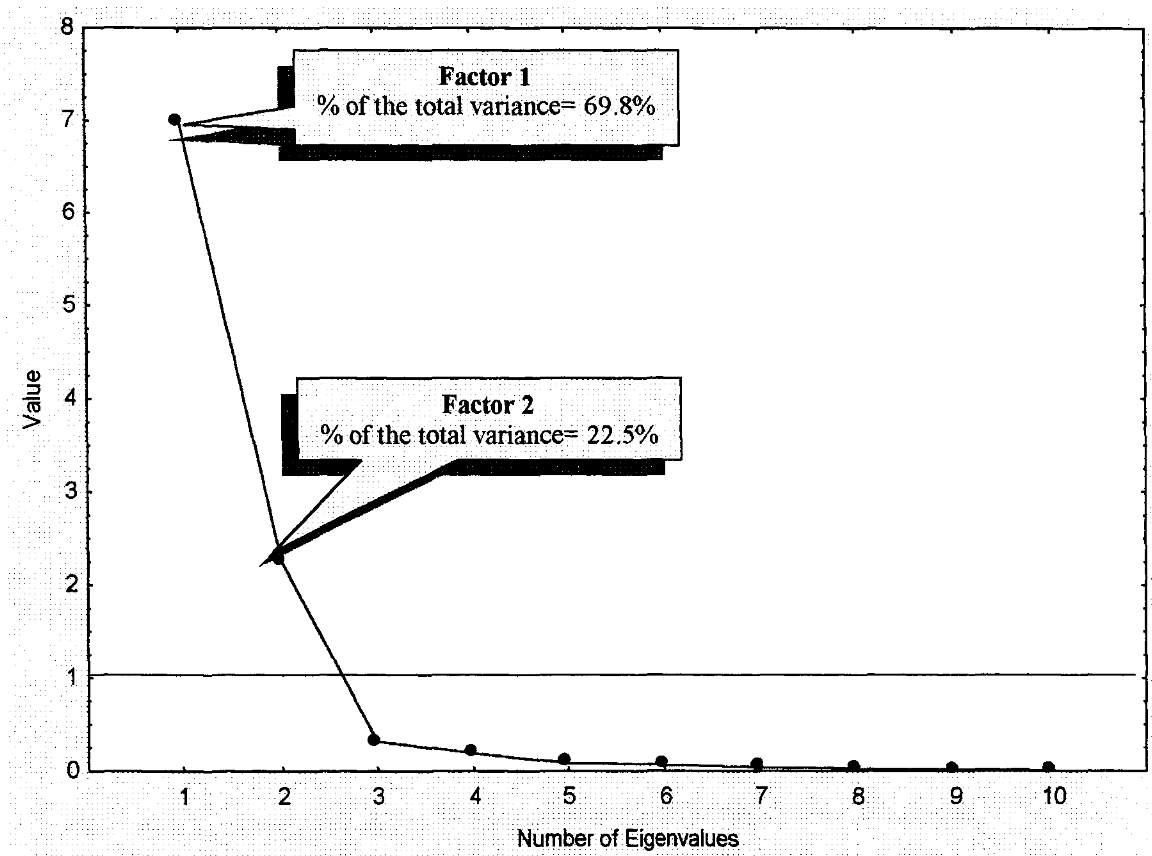


Figure 4.4. A line graph of the eigenvalues for factor analysis

Figure 4.4 presents a line graph of the eigenvalues in order to perform Cattell's scree test. The plot of eigevalues graph shown above has been "enhanced" to clarify the test. Based on Monte Carlo studies, Cattell suggests that the point where the continuous drop in eigenvalues levels off suggests the cutoff, where only random "noise" is being extracted by additional factors. In this case, that point would be at factor 2 (as indicated by the arrows). Therefore the approach employed in this analysis is in selecting only these two Factors with eigenvalues greater than 1 out of 10 factors.

Table 4.4 presents the rotated factor-loading matrix for the first two factors. It shows the relative influences of each indicator exhibits on each factor. It identifies the major contributing elements to each of the two factor groups. Titles can be given to each factor group based on the perceived relationships among the primary indicators in each factor.

Table 4.4. Factor Loadings Matrix

	Factor 1	Factor 2
Log P19	0.295	**0.909**
Log PD	**0.921**	0.354
Log HWW	**0.870**	0.340
Log LF	-0.256	**-0.931**
Log UE	0.412	**0.859**
Log PR	0.021	**0.982**
Log WWC	**-0.958**	-0.172
Log GWA	**0.892**	0.399
Log TDS	**0.868**	0.364
Log FUND	**0.934**	-0.068

Rotation method: Varimax normalized, Extraction: Principal components, (Marked loadings are >0.7)

Common factors were identified and the resulting factor loadings, shown in Table 4.3, represent the degree of correlation between an individual variable and a given factor. Values close to the -1 or +1 give an indication of stronger contribution of a variable to that factor. Within a factor, a positive loading indicates a direct association with the factor, while a negative loading indicates an inverse association. The first factor explains the highest proportion of observed variance in the dataset. The second factor accounts for the majority of variance not explained by factor 1, and so on.

Considering the first column of loading in the factor loadings matrix, shown in Table 4.3, indicates that this factor has a strong influence on the six indicators which are Log population density, Log households connected to wastewater network, Log households uses cesspits wastewater disposal, Log Groundwater abstraction, Log domestic water salinity and funds for development. It combined the social, environmental pressure and environmental impacts indicators. This factor is clearly identified the quality and quantity of the Gaza urban environment. Therefore it could be named as urban-environment management factor.

Considering the second column of factor loadings, it is clear that this factor has influence on four indicators and a moderate to weak influence on the remaining indicators. Since those four indicators focusing on human resource development indicators therefore this factor could be named as human resources development factor. This interpretation is consistent with the finding that this factor has a moderate effect on the other indicators due to the lower investment in the field of human resource development during the last 37 years. The slow improvement of the economical conditions in Gaza has insignificant impacts on development of social condition. These difficulties combined with the political instability in the area are hindering the efforts by the local institutions to minimize the pollution pressures nor they can provide remediation for the environmental negative impacts that threatening the public health.

The factor loadings shown in table 4.3 are represented by two-dimension scatter plot in Figure 4.5. Each indicator is represented as a point. It is clear that there are five indicators have high positive loadings at urban environmental management (factor 1). While there are three indicators have high positive loadings at human resource development factor (factor 2). Only one indicator of each factor has a negative loading.

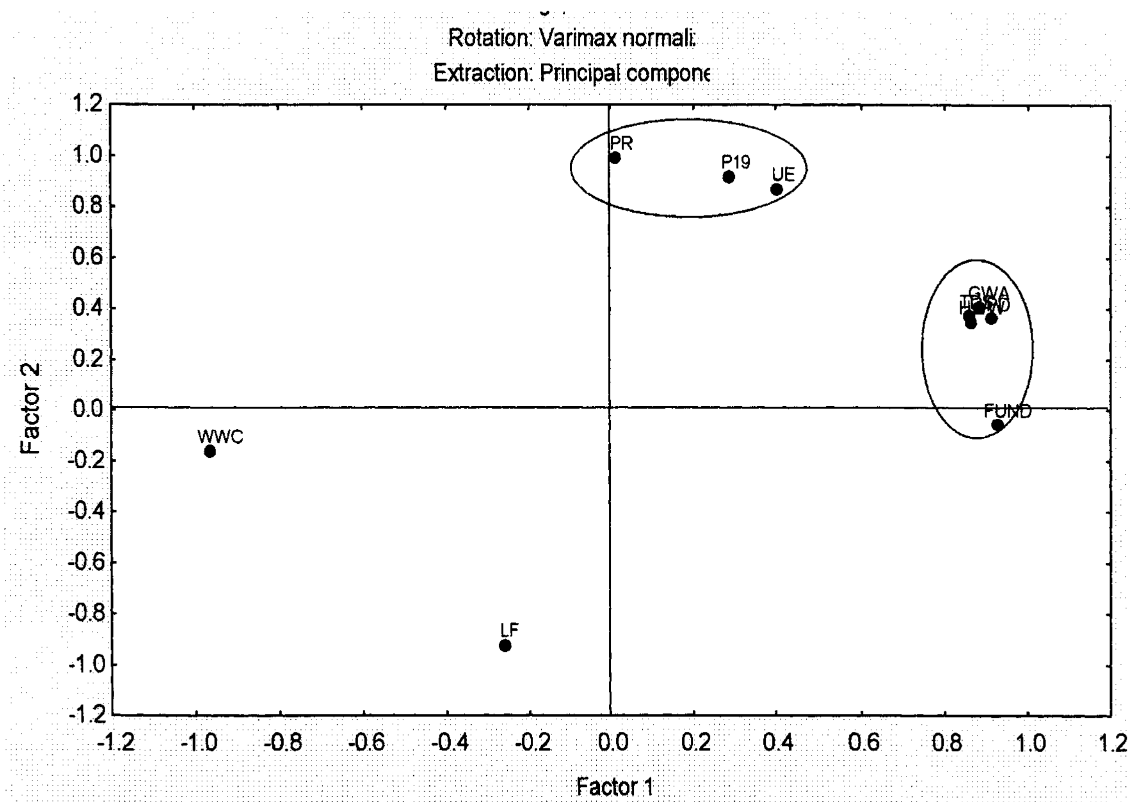


Figure 4.5. Plot of the two-Factor rotated solution for Factor 1 Vs. Factor 2

4.2.5 Comparison with Expert Opinions and Judgments

The comparison of the statistical results with expert's opinions has significant value in evaluating the current understanding of local experts to the influential indicators that is driving land-use changes in Gaza. Therefore 23 local experts were identified as sources for individual indicator-ranking information. Experts were chosen according to their knowledge in the field of land-use management as well as their professional ability to provide ranking for the identified socio-economic, environmental and institutional indicators. Each expert was asked to rank these indicators (30 indicators) in order of its relative importance and relevance to the land-use management in Gaza City. The results of expert's opinions were accomplished through the circulation of the indicators-based questionnaire (see Annex 3). The results of the questionnaire were averaged within each indicator, and a preliminary ranking was computed. Figure 4.6 shows that the overall agreement between expert's and the statistical results was only 47% of. The agreements were found in 14 indicators mainly population density, population under 19 years, unemployment rate, poverty rate and funds for development. In the other hand this analysis revealed that the environmental indicators were less estimated which resulted significant differences from the statistical analysis.

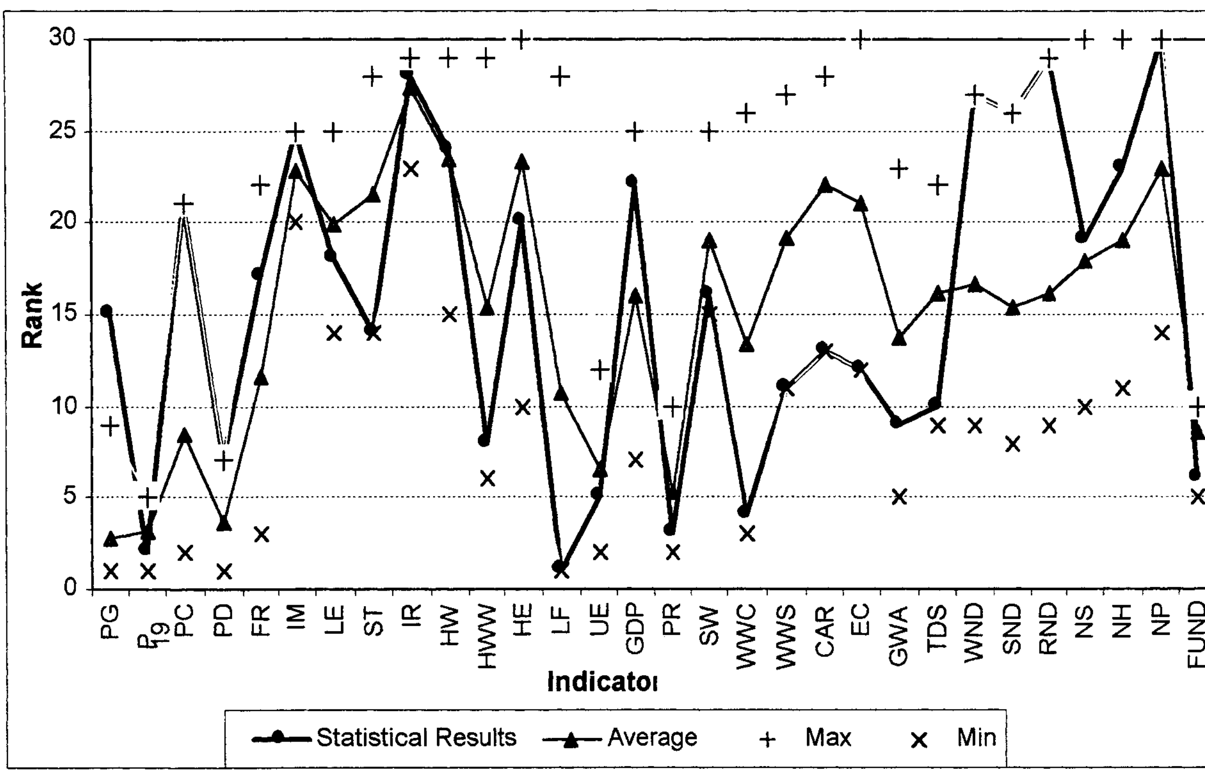


Figure 4.6. Experts Opinion Results versus Statistical Results

Despite the fact that the environmental dimension is recognized by the Palestinian Authority as one of the important pillar for sustainable development (EQA, 2003), It is obvious that the local experts are giving the environmental indicators low priority in land-use management.

4.2.6 Concluding Remarks

Univariate, bivariate and multivariate techniques have been used to investigate how socio-economic, environmental and institutional indicators are related to explain the land-use changes. Despite the fact that these statistical methods have several assumptions such as normal distribution of the data and linear relationships with the dependent variables, it was helpful in identifying the determinant indicators and factors that influence the changes in land-use of Gaza. The statistical analysis resulted with 10 indicates that have significant correlation with the different land-uses in Gaza and contributed by major role in shaping the land-uses for the last 37 years. The factor analysis resulted with two main underlying factors that driven the land-uses to unsustainable situation which are the management of urban-environment and human resource development. These two factors are influenced by the policies and actions that have been taken during the last 37 years. Local expert's opinion and judgment revealed that the environmental dimension is not taken into consideration during the preparation of land-use plans. The differences between statistical results and expert's opinion provide evidences on the subjectivity in land-use management and decision-making.

Therefore the statistical analysis compared to expert's opinions provide evidence support the conclusion that the simple answers found in population growth, poverty and infrastructure rarely provide an adequate understanding of land-use changes. Rather, individual and social responses follow from changing economic conditions, mediated by institutional factors. Opportunities and constrains for new land-use are created by markets policies, increasing influence by regional factors. Various urban-environment conditions react to and reshape of the impacts of drivers differently, leading to specific pathways of land-use change. It is precisely these combinations that need to be conceptualized and used as the basis of land change explanations and modeling. This conclusion agrees with Lambin et al., (2001) conclusion that supported by case-study evidences from different countries.

This conclusion makes it more complicated to the traditional statistical models to produce an accurate prediction model for the changes of land-uses that could deal with complex relations between the indicators and its underlying factors. In addition, the collected data on the selected indicators showed non-linear relationships and non-normal distribution. Therefore, the next stage of modeling requires advanced techniques that provides a non-linear function mapping of a set of input variables into the corresponding network output, without the requirement of having to specify the actual mathematical form of the relation between the input and output variables, it should has the versatility for modeling a wide range of complex non-linear phenomena.

4.3 Analysis and Modeling Using Artificial Neural Network (ANN)

ANN is a flexible mathematical structure that has certain performance characteristics resembling biological neural network of the human brain (Najjar et al., 1997; Mas et al., 2004, Kumar et al., 2004). ANN used here as analysis and predictor tool aims at exploring and modeling the relationship between the predictor variables (the determinant indicators, the inputs) and predicted variable (land-use indicators, the output), even if the relationship is very complex and not easy to articulate in the usual method of "correlations" or "differences between groups". Figure 4.7 shows a fundamental representation of an artificial neuron. The advantages of the artificial neural network ANN approach are: its ability to handle non-linear functions, to perform model-free function estimation, to learn from data relationships that are not otherwise known and, to generalize to unseen situations.

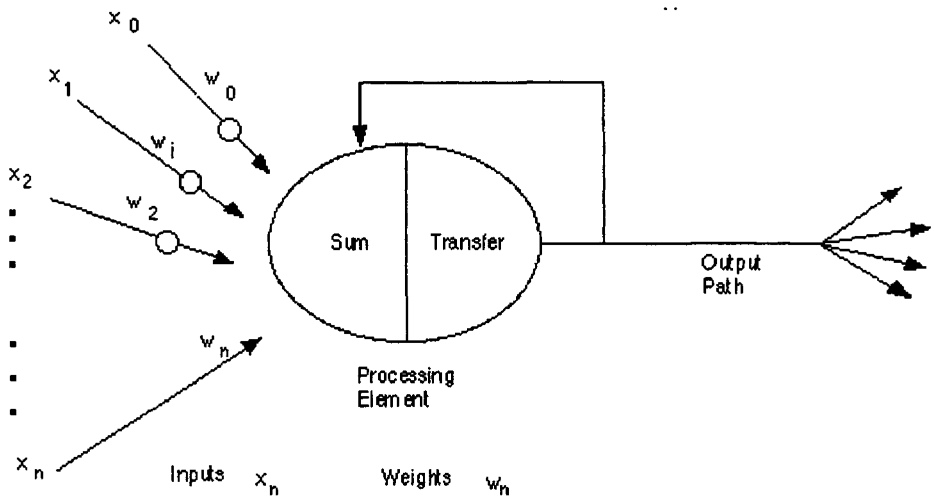


Figure 4.7. A Basic Artificial Neuron.

ANN composed a large number of interconnected processing elements or nodes, arranged in an input layer, one or more hidden layers an output layer and connection weights (Najjar and Zhang, 2000). Each hidden node *j* receives incoming signals from every node *i* in the previous layer which carried scaled (normalized) value Xi represented by the formula:

$$\overline{X}_i = \frac{X_i - X_{i(min)}}{X_{i(max)} - X_{i(min)}} \qquad (1)$$

Associated with each incoming signal (X_i) is a weight (W_{ij}). The net integral incoming signals (Net_j) to node j is the weighted sum of all incoming signals. A bias (TH_j) shown in the following equation is added to the function in order to make the output not very sensitive to any changes in the input.

$$Net_j = \sum_{i=1}^{n} \overline{X}_i W_{ij} + TH_j \tag{2}$$

The net incoming signals of a hidden node (*Net_J*) is transformed to an output (O_j)from the hidden node by using the non-linear transform function (*f*) which is typically a sigmoid function shown in Figure 4.8 (Najjar and Zhang, 2000; Kumar et al., 2004). This function then turns this number into a real output via some algorithm. It is this algorithm that takes the input and turns it into a zero or a one, a minus one or a one, or some other number.

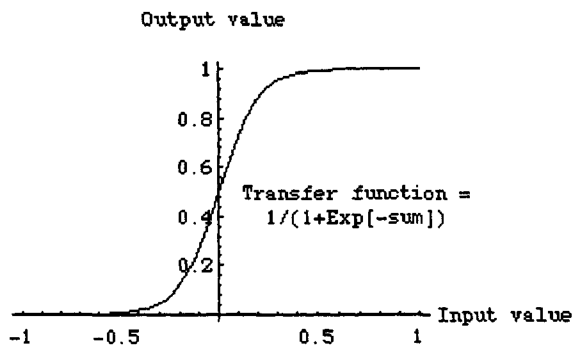


Figure 4.8. Sigmoid transfer function.

This transfer function also can scale the output or control its value via thresholds. The result of the transfer function is usually the direct output of the processing element (Hassoun, 1995). The sigmoid function is usually used as the activation function because of the convenient mathematical expression of its derivate which represented by the following form of equation:

$$O_j = f(Net_j) = \frac{1}{1 + e^{-Net_j}} \tag{3}$$

The output O_j passes as a signal to the output node (k). The net entering signal of an output node (Net_k)

$$Net_k = \sum_{i=1}^{n} \overline{X}_i W_{jk} + TH_k \tag{4}$$

The incoming signals of the output node (Net_k) is transformed using the sigmoid type function to scale the output ($\bar{O}_k$)

$$\bar{O}k = f(Net_k) = \frac{1}{1 + e^{-Net_k}} \tag{5}$$

The scaled output is de-scaled to produce the target output according to the following formula:

$$O_k = \overline{O}_k(O_{max(k)} - O_{min(k)}) + O_{min(k)} \quad (6)$$

Figure 4.9 shows the architecture of the three-layer feed forward ANN (q, n, s) with input variables: (x1, . ., xq), estimated output variables: (O1,..., Os), and Observed output variables (d1, . ., ds).

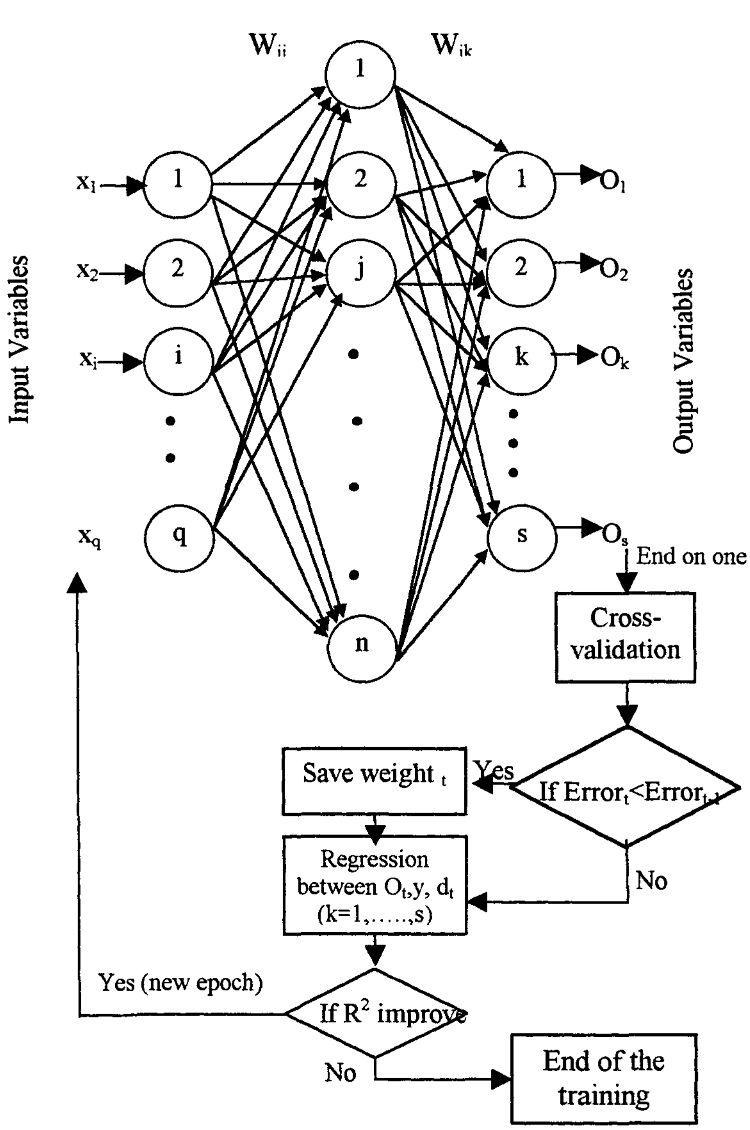


Figure 4.9. MLP architecture

The Multi-layer perceptron (MLP) is the most popular ANN architecture in use today (Rumelhart et al., 1986; Najjar and Zhang, 2000; Basheer and Hajmeer, 2000; Kumar et al., 2004). It assumes that the unknown function (land-use changes) is represented by a multi-layer, feed-forward network of sigmoid units. The MLP consists of three layers: input, hidden, and output. Thus it can identify relationships that are non-linear in nature. The feed forward error backpropagation learning algorithm is the famous procedure for training ANNs (Basheer and Hajmeer, 2000). The objective of the backpropagation training process is to adjust the weights of the network to minimize the average of square errors of the network, which approximates the model outputs to the target values with a selected error goal (Bishop, 1995).

The ANN software used in this study is TR-SEQ1. It is a three-layered ANN training program developed by Professor Yacoub Najjar from Kansas State University-USA (Najjar, 1999). The program capable of performing simultaneous sequential training and testing. It is a comprehensive, powerful and less time consuming package and characterized by intelligent problem solver that can guide step by step through the procedure of creating a verity of different networks and choosing the network with the best performance.

4.3.1 Selection of the output variables for land-use models

The output variables are fixed for all trained models, which are repressing the percentages of land-uses, divided into five sub-indicators which are residential (RES), roads (ROD), industrial (IND), recreational (REC) and agricultural (AGR) indicators. The output data have been divided into three subsets; training (60%), testing (20%) and validation (20%). The results of these models, hereafter, called land-use models.

4.3.2 Selection of the input variables for land-use models

A total of 20 combinations of input variables presented in four groups are investigated. Table 4.5 illustrates the each network configuration (number of input and neurons in hidden layer and number of iterations made for model development.

The first group consists of nine models with a combination of the $SEEI_{(t)}$ variables and additional land-use variables from the previous years $LU_{(t-1)}$, $LU_{(t-2)}$, …., $LU_{(t-7)}$.

The second group has four models with combination of SEEI variables from the previous 4 years {i.e. $SEEI_{(t)}$, $SEEI_{(t-1)}$,…. $SEEI_{(t-4)}$}.

The third group has three models with combination of additional variables from land-use variables $LU_{(t-1)}$, $LU_{(t-2)}$, $LU_{(t-3)}$and $SEEI_{(t)}$, $SEEI_{(t-1)}$, $SSEI_{(t-2)}$ and $SSEI_{(t-3)}$ variables.

The fourth group consists of five models with combination of $SEEI_{(t)}$, in addition to the changes in land-use expressed by $\Delta LU_{(t)}$. Additional $\Delta LU_{(t-1)}$, ……. , $\Delta LU_{(t-5)}$.

Table 4.5. Input Combinations for Land-use Models

Model no.	Input combinations	No. of inputs	Neurons in hidden layer	No. of iterations
	Group 1			
1	$SEEI_{(t)}$	10	1	100
2	$SEEI_{(t)}, LU_{(t-1)}$	15	1	300
3	$SEEI_{(t)}, LU_{(t-1)}, LU_{(t-2)}$	20	1	1000
4	$SEEI_{(t)}, LU_{(t-1)}, LU_{(t-2)}, LU_{(t-3)}$	25	2	100
5	$SEEI_{(t)}, \mathbf{LU_{(t-1)}, LU_{(t-2)}, LU_{(t-3)}, LU_{(t-4)}}$	**30**	**1**	**1400**
6	$SEEI_{(t)}, LU_{(t-1)}, LU_{(t-2)}, LU_{(t-3)}, LU_{(t-4)}, LU_{(t-5)}$	35	2	100
7	$SEEI_{(t)}, LU_{(t-1)}, LU_{(t-2)}, LU_{(t-3)}, LU_{(t-4)}, LU_{(t-5)}, LU_{(t-6)}$	40	2	100
8	$SEEI_{(t)}, LU_{(t-1)}, LU_{(t-2)}, LU_{(t-3)}, LU_{(t-4)}, LU_{(t-5)}, LU_{(t-6)}, LU_{(t-7)}$	45	2	100
	Group 2			
9	$SEEI_{(t)}, SEEI_{(t-1)}$	20	1	100
10	$SEEI_{(t)}, SEEI_{(t-1)}, SEEI_{(t-2)}$	30	1	1200
11	$SEEI_{(t)}, SEEI_{(t-1)}, SEEI_{(t-2)}, SEEI_{(t-3)},$	40	2	100
12	$SEEI_{(t)}, SEEI_{(t-1)}, SEEI_{(t-2)}, SEEI_{(t-3)}, SEEI_{(t-4)},$	50	2	100
	Group 3			
13	$SEEI_{(t)}, SEEI_{(t-1)}, LU_{(t-1)}$	25	1	1600
14	$SEEI_{(t)}, SEEI_{(t-1)}, SEEI_{(t-2)}, LU_{(t-1)}, LU_{(t-2)}$	40	2	100
15	$SEEI_{(t)}, SEEI_{(t-1)}, SEEI_{(t-2)}, SEEI_{(t-3)}, LU_{(t-1)}, LU_{(t-2)}, LU_{(t-3)}$	55	3	1800
	Group 4			
16	$SEEI_{(t)}, \Delta LU_{(t-1)}$	20	4	1100
17	$SEEI_{(t)}, \Delta LU_{(t-1)}, \Delta LU_{(t-2)}$	25	3	3000
18	$\mathbf{SEEI_{(t)}, \Delta LU_{(t-1)}, \Delta LU_{(t-2)}, \Delta LU_{(t-3)}}$	**30**	**1**	**100**
19	$SEEI_{(t)}, \Delta LU_{(t-1)}, \Delta LU_{(t-2)}, \Delta LU_{(t-3)}, \Delta LU_{(t-4)}$	35	3	3000
20	$SEEI_{(t)}, \Delta LU_{(t-1)}, \Delta LU_{(t-2)}, \Delta LU_{(t-3)}, \Delta LU_{(t-4)}, \Delta LU_{(t-5)}$	15	3	500

SEEI= *Socio-Economic, Environmental and Institutional (10 Indicators),*
LU= *Land-uses in percentages,*
$\mathbf{\Delta LU_{(t-1)}}$ = *Changes in land use* *and* ***t*** = *time*

The optimal ANN model's structure that resulted in minimum error and maximum efficiency during both training and testing was selected for validation. This experiment was done for developing MLPs; then, based on the performance of various trained MLPs with different input combinations, the best network were selected.

The data for each input combination were divided into a training set, a validation set, and a testing set. The training set consists of a set of examples used only for learning, (i.e. to fit the weights of the network). The validation set is a set used to adjust the network parameters such as network architecture (for example number of hidden layers and neurons, or number of training cycles). The test set is a set of examples used only to assess the generalization performance of a trained neural network, (external valuation). Hence, MLP was applied to the prediction of land-use areas in four phases: (1) design of the network and of inputs from historical data; (2) network training using a subset of inputs; (3) testing of the neural network using the full data set of the inputs; and (4) using the information from the neural network to forecast changes. To avoid over-training of the network (Skapura, 1995), the neural network was trained with a different set of data by changing the trained set of data in random order. Therefore about 60% of the investigated data set was chosen as training data set (i.e. 21 cases), while other 20% (i.e. 8 cases) chosen as cross-validation data set and the rest cases 20% (i.e. 8 cases) were chosen as testing data set. This procedure has been repeated several times with different data inputs. In order to select the optimal model, about 16 models have been produced. Each model used different data sets have a significant influence on the predicted flow.

ANN Model used successfully as an optimization tool in a number of case studies (Liong et al., 2001). ANN well suited to the task of selecting an appropriate combination of inputs to a model as it has the ability to search through large numbers of combinations, where interdependencies between variables may exist. The main steps in the optimization process, as shown in Figure 4.10, aims at determining the input variables, which have a significant influence on the predicted land-use changes. Consequently, the followed procedure analyzed different combinations of the influential socio-economic, environmental and institutional (SEEI) indicators in addition to the antecedent land-use values (i.e. $LU_{(t-1)}$, $LU_{(t-2)}$ .... $LU_{(t-n)}$ or the SEEI indicators for the previous years (i.e. $SEEI_{(t-1)}$, $SEEI_{(t-2)}$,....... $SEEI_{(t-n)}$. Input variables including combination of the data from pervious years on both LU and SEEI are also trained.

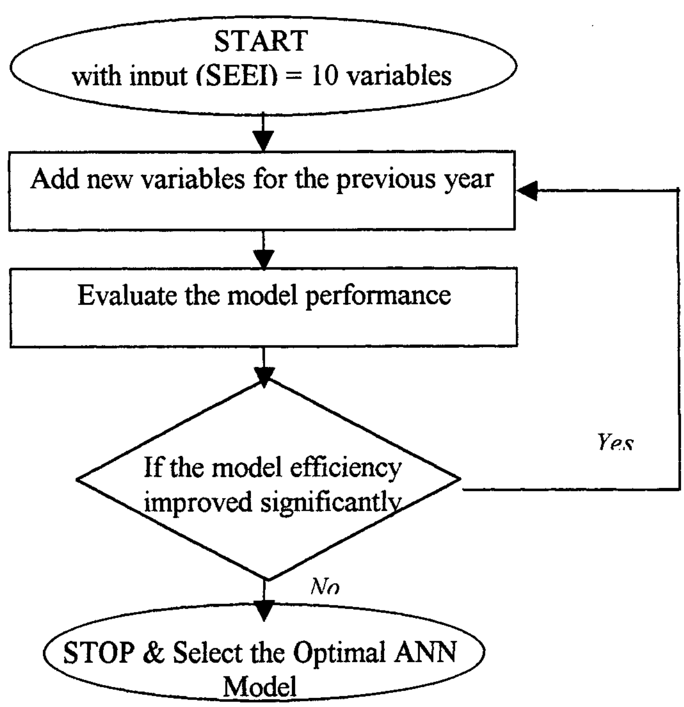


Figure 4.10 Selection procedures for the optimal ANN model

For the network structure identification, the current study employed a procedure of time-series of land-use changes. This procedure suggests training a network with minimum input variables initially (i.e. the 10 SEEI indicators with 37 data sets), and systematically increasing the input vector dimension by adding more variables from the previous year and training the new network. This procedure, though adding complexity to the model, considers the ability of additional input variable to capture any nonlinear residual dependencies.

The number of hidden neurons in the network, which is responsible for capturing the dynamic and complex relationship between various input and output variables, could be identified by various trials (Maier and Dandy, 2000). The trial-and-error procedure started with one hidden neurons initially, and the number of hidden neurons was increased up to 4 during the trails. The small number of hidden neurons refers to the limited number of observations. For each set of hidden neurons, the network was trained in batch mode to minimize the average-square error at the output layer. In order to check any over-fitting during training, a cross-validation was performed by keeping track of the efficiency of the fitted model. The training was stopped when there was no significant improvement in the model's efficiency, and the model was then tested for its generalization properties.

4.3.3 Evaluation Measures and Selection of the optimal ANN model

The selection process of the desired optimal network model is composed of two consecutive stages which indicate the values of efficiency. In the first stage, statistical accuracy measures such as coefficient of determination (R-square), Average Squared Error (ASE) and the Mean Absolute Relative Error (MARE) on both training and testing data sets to filter out the most promising optimal networks. The values of both ASE and MERE close to zero indicates a better performing model. The values of R^2 range from 0 to 1, with higher values close to 1 indicating better model performance. These statistical indicators can be expressed mathematically as shown in equations 4, 5 and 6. Statistically, an optimal network is defined as the one with the best overall accuracy measures. In the second stage, the predicted and actual outputs graphical responses for both training and testing sets for the selected most promising networks. Based on the overall graphical evaluation of each model's performance, the absolute optimal network can easily selected.

$$R^2 = 1 - \frac{\sum_{i=1}^{N}(Qt_i - \hat{Q}t_i)^2}{\sum_{i=1}^{N}(Qt_i - \overline{Q}t_i)^2} \tag{7}$$

$$ASE = \frac{\sum_{i=1}^{N}(Qt_i - \hat{Q}t_i)^2}{N} \tag{8}$$

$$MARE = \frac{\sum_{i=1}^{N}\left|\left(\frac{(\hat{Q}t_i - Qt_i)}{Qt_i}\right)\right|}{N} \times 100 \tag{9}$$

Where Qt_i *is the observed value,* $\hat{Q}t_i$ *is the Predicted value,* $\overline{Q}t_i$ *is the mean value and N is the total number of data sets.*

The performance of each model according to the input combinations and in terms of the R-square is presented in Table 4.6, where it can be observed that the model performance

Group 1

The model performance continues to increase significantly with the additional antecedent land-use information to the $SEEI_{(t)}$ variables. Note that a combination of time-series data on land-uses and $SEEI_{(t)}$ variables in the input vector significantly improve the performance among the inputs models in the first group. The performance of model (6) indicates that addition of antecedent land-use information for more than 4 year is not significant in the optimal input vector. The best performance was achieved for Model 5. This model has efficiency of 83% to 97% for the training data sets and 91 to 97% for validation data sets.

Group 2

Among the second group, the performances of the model 11 indicates that addition of antecedent SEEI information for more than 3 year did not significantly improve the performance of the model. Therefore, model 10 is best model among this group, however, this model has performance ranged between 71% to 83% , which is lower than the optimal model in group 1.

Group 3

Models 13, 14 and 15 in the third group presents the combination of additional variables from both land uses and SEEI indicators from the previous years. These additional inputs did not improve the model's performance significantly.

Group 4

Similar to the first group the model performance continues to improve for additional 4 years of changes in land use. Model (19) has better performance among the other models among this group, however, its results still lower than it found in the model number (5).

Table 4.6 Coefficients of the Determination (R^2) for the Training and Testing

Model Number	Training Data Subset					Testing Data Subset				
	RES	**ROD**	**IND**	**REC**	**AGR**	**RES**	**ROD**	**IND**	**REC**	**AGR**
Group 1										
1	0.43	0.55	0.58	0.25	0.56	0.45	0.63	0.77	0.23	0.57
2	0.69	0.82	0.85	0.53	0.85	0.72	0.79	0.84	0.52	0.77
3	0.82	0.92	0.76	0.73	0.89	0.75	0.81	0.80	0.68	0.81
4	0.87	0.93	0.83	0.76	0.92	0.88	0.90	0.87	0.78	0.86
5	**0.96**	**0.97**	**0.86**	**0.83**	**0.97**	**0.97**	**0.92**	**0.91**	**0.87**	**0.95**
6	0.94	0.97	0.84	0.73	0.96	0.87	0.90	0.81	0.70	0.88
7	0.92	0.91	0.86	0.80	0.96	0.84	0.85	0.79	0.63	0.81
8	0.89	0.87	0.86	0.76	0.82	0.78	0.82	0.75	0.60	0.76
Group 2										
9	0.75	0.79	0.71	0.68	0.74	0.72	0.75	0.70	0.70	0.66
10	0.81	0.83	0.78	0.71	0.78	0.79	0.81	0.77	0.71	0.76
11	0.64	0.71	0.73	0.53	0.62	0.61	0.70	0.70	0.52	0.62
12	0.52	0.45	0.43	0.32	0.35	0.50	0.41	0.41	0.32	0.35
Group 3										
13	0.75	0.74	0.63	0.65	0.71	0.70	0.71	0.73	0.68	0.69
14	0.89	0.87	0.88	0.81	0.83	0.85	0.84	0.82	0.73	0.77
15	0.64	0.56	0.57	0.48	0.54	0.59	0.52	0.56	0.45	0.61
Group 4										
16	0.57	0.76	0.73	0.41	0.75	0.60	0.67	0.73	0.40	0.65
17	0.70	0.83	0.64	0.62	0.77	0.72	0.69	0.68	0.55	0.69
18	0.73	0.83	0.71	0.63	0.81	0.76	0.78	0.75	0.67	0.74
19	0.83	0.86	0.74	0.71	0.85	0.85	0.80	0.79	0.75	0.83
20	0.81	0.79	0.69	0.61	0.81	0.75	0.78	0.69	0.59	0.77

Figure 4.11 compared the coefficient of coordination R^2 for all trained models. It is obvious that model (5) has the highest values of R-square in both training and testing phases among all the 20 models. According to the Table 4.5, the optimal ANN model was found at 1400 iterations and one neural at the hidden layer. This means that study of the land-use areas at any year (t) requires data on the 10 $SEEI_{(t)}$ indicators that identified in Table 4.2 and data on land-use areas for the previous four years.

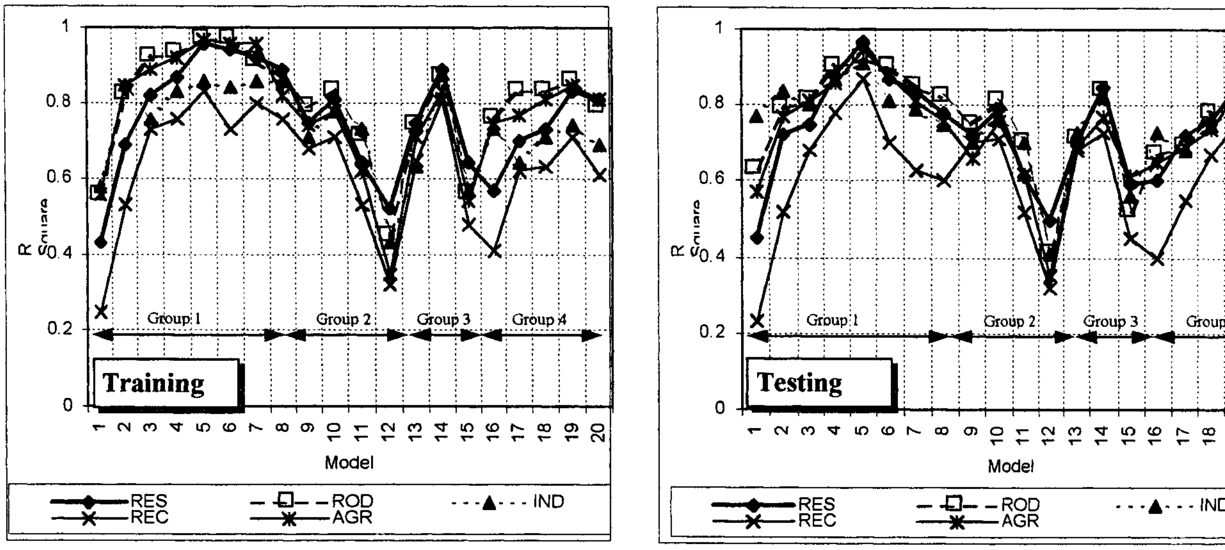


Figure 4.11. Coefficient of Determination (R2) for Training and Testing

The graphical comparison of the different models' performance is given in Figure 4.12. It is obvious between the developed ANN model 5 has close values of R-square in both training and testing phases. This clearly indicates the powerful function approximation features of the back-propagation in the multi-perceptron ANN method.

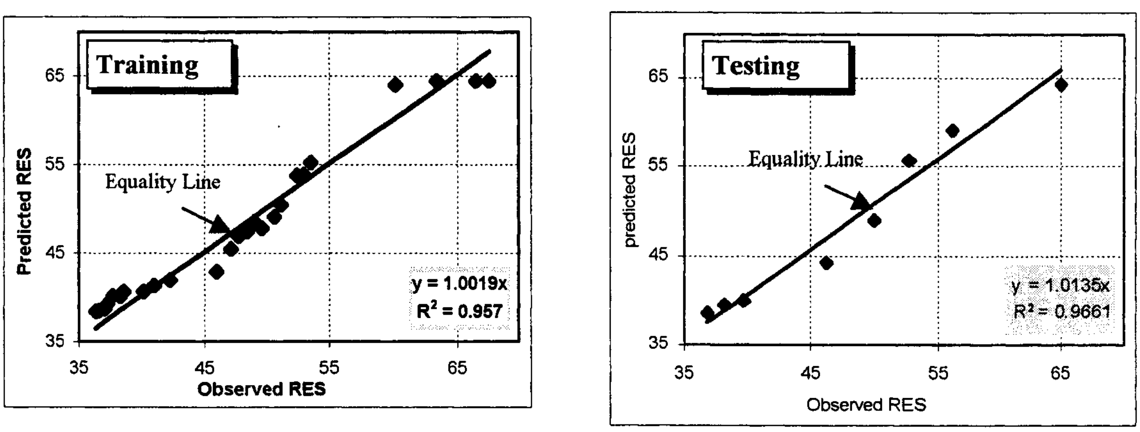


Figure 4.12 Observed versus Predicted Residential Areas (Training and Testing)

The average squared error (ASE) and the mean absolute relative error (MARE) for all land-use categories have been calculated and presented in Table 4.7 and Figure 4.13. The results confirmed the findings of the comparison between the observed and predicted percentages of land-use categories. It is obvious that the model 5 has the smallest values for both ASE and MARE.

Table 4.7 Statistical Accuracy Measures (Training and Testing)

Model	MARE (training)	MARE (testing)	ASE (Training)	ASE (Testing)
Group 1				
1	40.1	38.7	0.023	0.019
2	18.3	30.0	0.007	0.013
3	21.1	23.6	0.004	0.008
4	17.9	16.0	0.006	0.004
5	**14.9**	**10.2**	**0.003**	**0.002**
6	18.6	21.3	0.006	0.011
7	19.6	29.1	0.007	0.009
8	23.4	27.6	0.007	0.012
Group 2				
9	38.2	36.2	0.025	0.022
10	20.3	19.8	0.007	0.011
11	32.4	33.1	0.005	0.009
12	34.8	55.6	0.010	0.007
Group 3				
13	36.4	37.2	0.015	0.018
14	28.4	24.8	0.008	0.009
15	52.6	53.4	0.017	0.019
Group 4				
16	38.00	36.00	0.027	0.018
17	20.98	23.48	0.009	0.016
18	17.78	15.88	0.003	0.007
19	15.78	13.08	0.003	0.006
20	18.48	21.18	0.004	0.01

ASE =Average Squared Error and MARE = Mean Absolute Relative Error

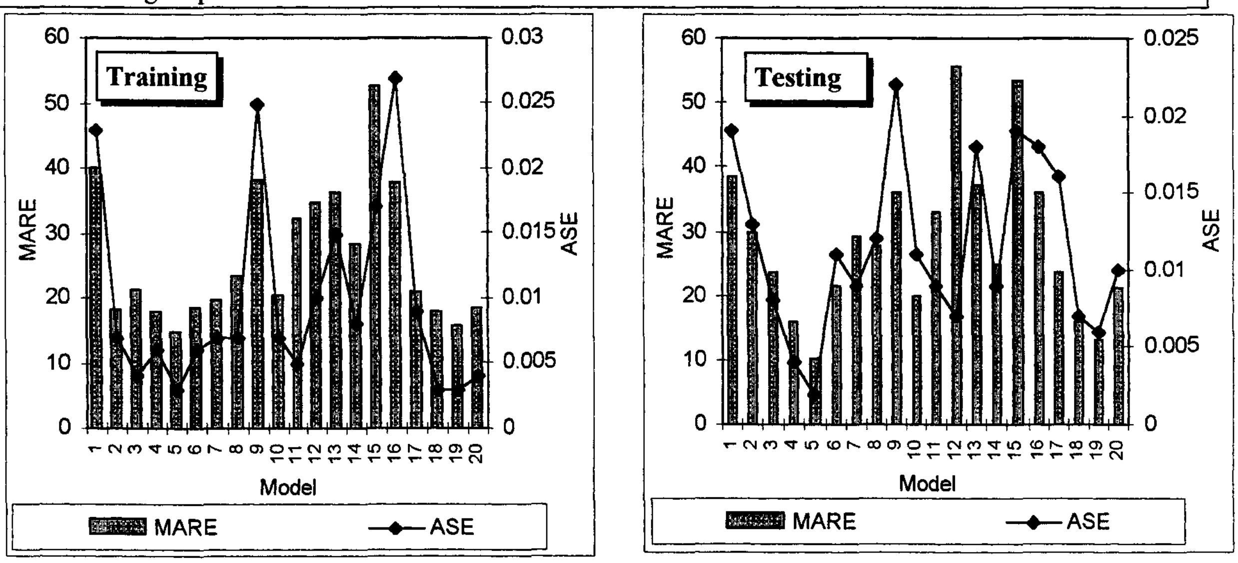


Figure 4.13. MARE and ASE (Model 5)

The optimal network found was MLP with 30 input predictive variables and one hidden node. This resulted a model that has a good performance for land-uses with average performance ratio of 93% and ASE of 0.003 (Figure 4.11). The input vector is represented by the 10 determinate factors and the land-use areas for the previous 4 years.

The land-use percentages model can be represented by the following compact form:

$$LU_{(t)} = ANN\{P19_{(t)}, PD_{(t)}, HWW_{(t)}, LF_{(t)}, UE_{(t)}, PR_{(t)}, WWC_{(t)}, GWA_{(t)}, TDS_{(t)}, FUND_{(t)}, LU_{(t-1)}, LU_{(t-2)}, LU_{(t-3)}, LU_{(t-4)}\} \quad ($$

Where $(LU)_t$ *is the Land-use areas at time (t) which is equal to the sum of (RES + ROD + IND + REC + AGR) at time (t).*

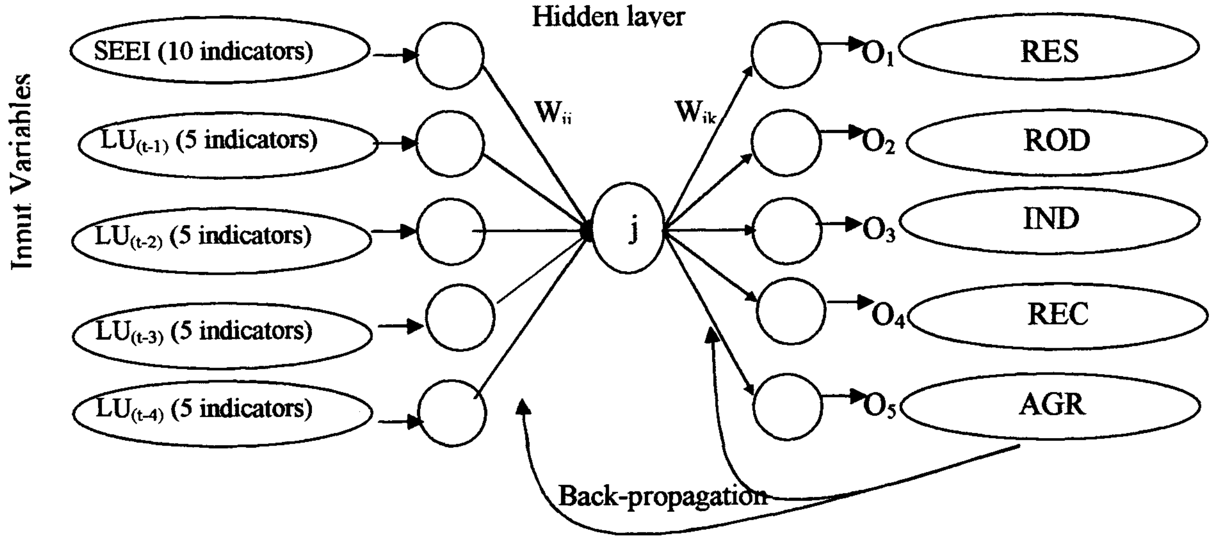


Figure 4.14. Schematic diagram for the optimal land-use percentages model (Model 5)

4.3.4 Model's Validation

For the validation of the model performance, the observed and modeled changes in land-use between 1967 and 2003 are compared at the different land-use categories. By comparing the observed and the predicted land-uses, for the validation data set, it was founded that the value of R^2 ranged between 0.91 and 0.97 for the five different land-use types. These high correlations can partially be explained by the relatively small changes in land-use among the validation data set. The comparison of measured and simulated changes in land-use between 1979 and 1994 provides a better measure of model performance.

Table 4.8 Statistical Accuracy Measures (Validation Data Subset)

Model	R-Square					Error	
	RES	**ROD**	**IND**	**REC**	**AGR**	**MARE**	**ASE**
Group 1							
1	0.50	0.72	0.84	0.23	0.56	41.3	0.025
2	0.71	0.76	0.88	0.57	0.56	25.5	0.012
3	0.76	0.76	0.89	0.57	0.56	24.2	0.008
4	0.96	0.88	0.90	0.76	0.87	17.4	0.007
5	**0.97**	**0.98**	**0.92**	**0.95**	**0.98**	**15.1**	**0.003**
6	0.74	0.83	0.72	0.60	0.78	19.3	0.008
7	0.74	0.81	0.72	0.58	0.74	20.2	0.009
8	0.72	0.80	0.73	0.58	0.73	23.2	0.012
Group 2							
9	0.74	0.73	0.68	0.70	0.56	39.9	0.023
10	0.80	0.78	0.76	0.71	0.76	21.4	0.014
11	0.62	0.69	0.67	0.48	0.60	36.2	0.009
12	0.48	0.41	0.41	0.32	0.31	37.7	0.010
Group 3							
13	0.68	0.70	0.61	0.66	0.63	37.5	0.015
14	0.82	0.81	0.73	0.76	0.78	30.7	0.009
15	0.58	0.52	0.30	0.41	0.51	55.6	0.019
Group 4							
16	0.68	0.72	0.56	0.33	0.31	62.2	0.028
17	0.73	0.75	0.43	0.38	0.32	61.4	0.019
18	0.79	0.81	0.62	0.41	0.33	55.3	0.009
19	0.89	0.87	0.73	0.43	0.33	42.1	0.007
20	0.082	0.87	0.54	0.41	0.30	51.2	0.007

Table 4.8, Figure 4.15 and Figure 4.16 present the results of the validation. For all land-use types and aggregation levels there are positive and significant correlations between measured and simulated land-use changes.

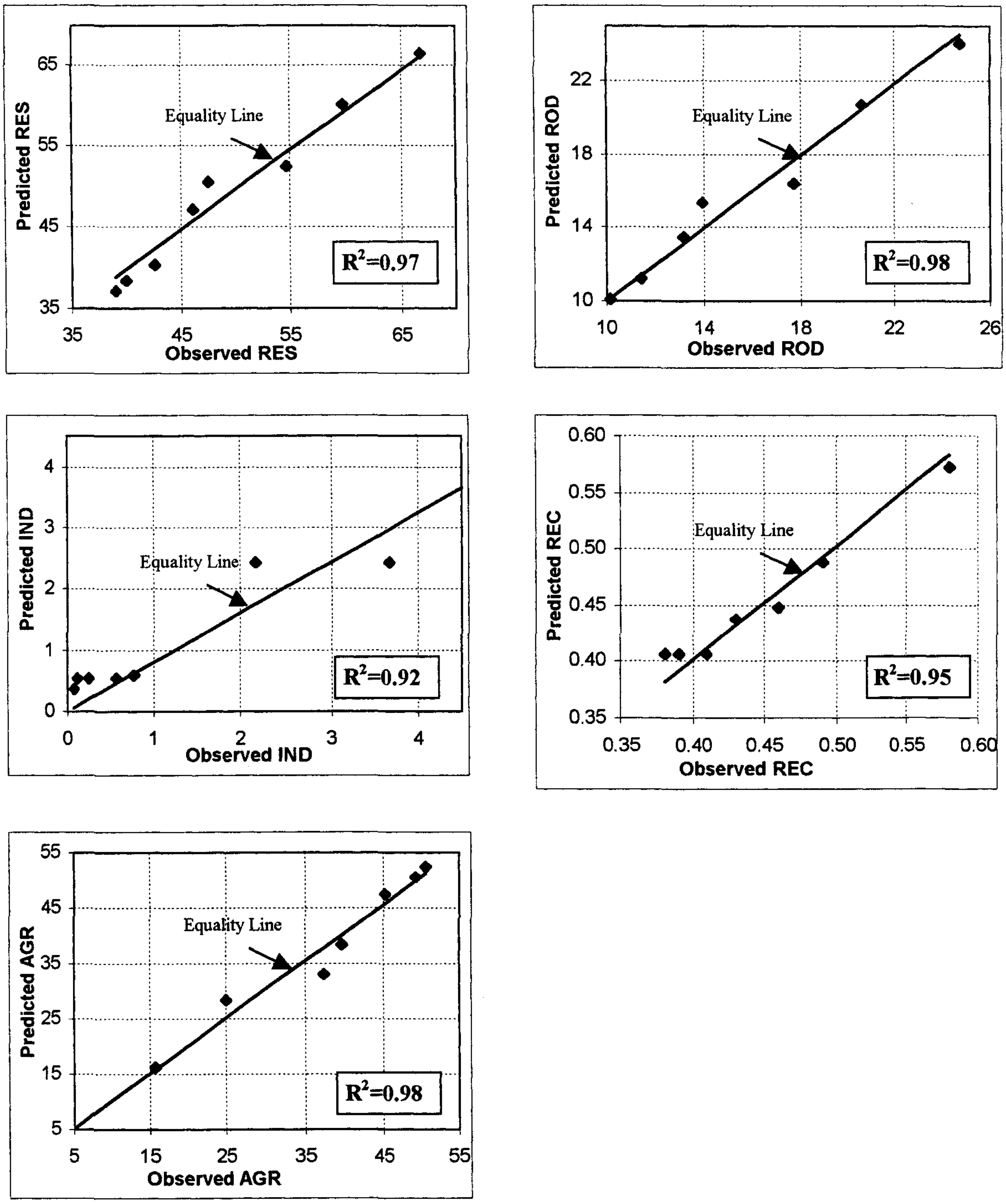


Figure 4.15. Observed versus Predicted Land-uses for Validation Data Subset (Model 5)

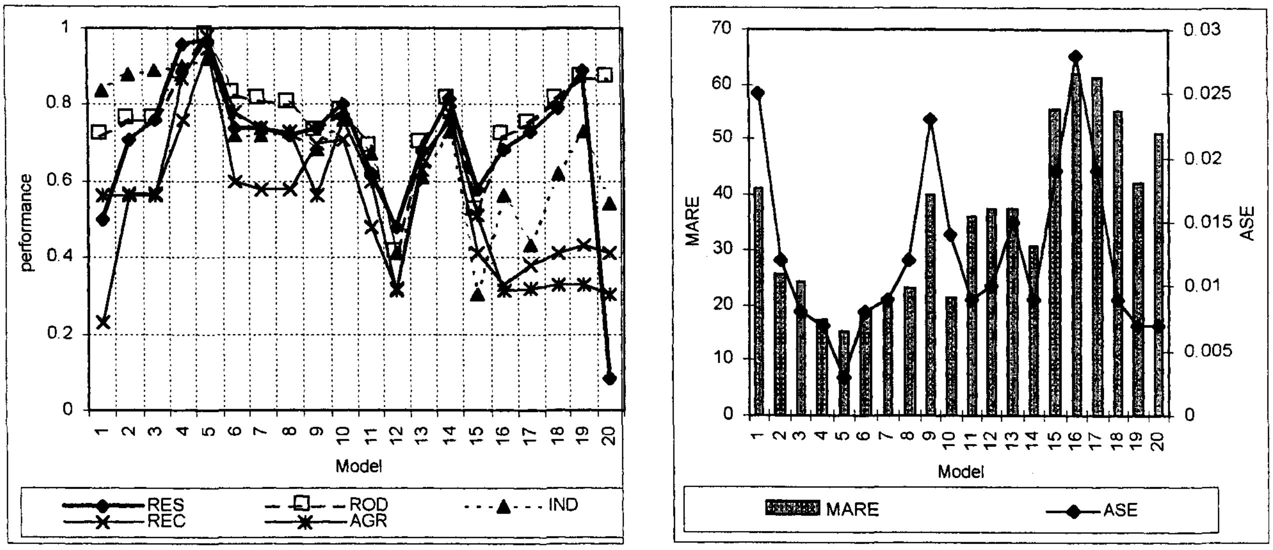


Figure 4.16. R2, MARE and ASE for Validation Data Subset (Model 5)

4.3.5 Sensitivity Analysis

Neural Networks offer an interesting ability to test the sensitivity and significance of the various input variables to produce the outputs. This can be carried out by manipulating the connection weights and biases of the designed Network (Hajmeer et al., 1997). This indicates which input variables are considered most important by that particular neural network model. Sensitivity analysis can give important insights into the usefulness of individual variables. It often identifies variables that have low significant effect on the accuracy of the network. Key variables that always of high sensitivity can improve model's performance significantly. Therefore sensitivity analysis is extremely useful because it rates variables according to the deterioration in modeling performance that occurs if that variable is no longer available to the model. It assigns a single rating value to each variable.

A rank 1.0 indicates that the model performance actually worsen if the variable is removed. A rank of 14.0 indicates that the variable has no positive effect on the model at all. It is frequently worth removing variables even with sensitivity somewhat above 1.0 and retraining the network. The high value of R-square give indication on making the variable "unavailable" either has no effect on the performance of the network.

Table 4.8 indicates the sensitivity of each variable reported separately for training and verification subsets. The consistency of the sensitivity ratings across the two subsets is a good initial cross check on the reliability of the sensitivity analysis. The basic sensitivity figures are; R-square, average square error and Ranking.

Table 4.9: Sensitivity Analysis for the Land-use Percentages Model

Model no.	**Input combinations**	**Training** R^2	ASE	**Validation** R^2	ASE	**Rank**
5.1	Model 5 without $P19_{(t)}$	0.71	0.011	0.69	0.012	3
5.2	Model 5 without $PD_{(t)}$	0.74	0.008	0.73	0.009	4
5.3	Model 5 without $HWW_{(t)}$	0.89	0.002	0.88	0.002	12
5.4	Model 5 without $LF_{(t)}$	0.88	0.002	0.87	0.003	11
5.5	Model 5 without $UE_{(t)}$	0.81	0.005	0.79	0.005	8
5.6	Model 5 without $PR_{(t)}$	0.77	0.006	0.76	0.006	5
5.7	Model 5 without $WWC_{(t)}$	0.85	0.004	0.86	0.005	14
5.8	Model 5 without $GWA_{(t)}$	0.79	0.005	0.76	0.006	6
5.9	Model 5 without TDS(t)	0.90	0.002	0.88	0.002	13
5.10	Model 5 without $FUND_{(t)}$	0.80	0.005	0.79	0.005	7
5.11	Model 5 without $LU_{(t-1)}$	0.67	0.015	0.68	0.016	1
5.12	Model 5 without $LU_{(t-2)}$	0.69	0.014	0.69	0.014	2
5.13	Model 5 without $LU_{(t-3)}$	0.84	0.004	0.84	0.005	9
5.14	Model 5 without $LU_{(t-4)}$	0.86	0.003	0.87	0.003	10

Tables 4.9 provides sensitivity ranking for variables included in the optimal model chosen which indicates that the land-uses for the previous two years in addition to the followed by percentage of population under 19 years, population density and poverty rate respectively are ranked as the first five important variables. The networks without these variables have a high error, indicating that the network performance deteriorates badly if they are not present. The variables groundwater abstraction, funds for development and unemployment rate have moderate importance to the network performance. While the other variables such as labour forces, percentage of households connected to the wastewater network, percentage of households using cesspits for wastewater disposal and groundwater pollution have less importance to the network performance compared to the other indicators included in the model. The final ranking of the input variables is presented in Table 4.10.

Table 4.10 Ranking for input indicators using ANN Sensitivity Analysis

Rank	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Indicator	$LU_{(t-1)}$	$LU_{(t-2)}$	$P19_{(t)}$	$PD_{(t)}$	$PR_{(t)}$	$GWA_{(t)}$	$FUND_{(t)}$

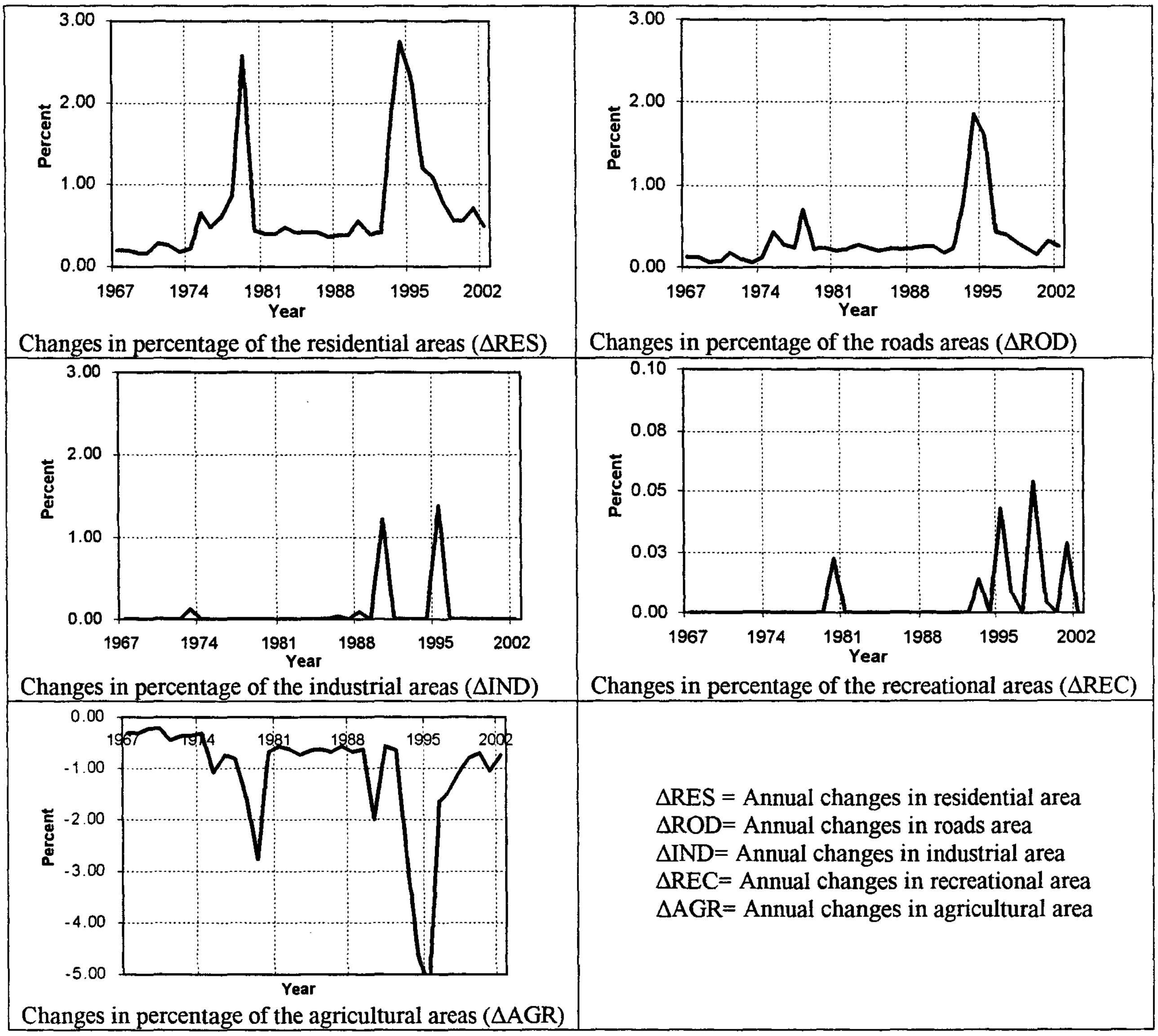
Rank	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Indicator	$UE_{(t)}$	$LU_{(t-3)}$	$LU_{(t-4)}$	$LF_{(t)}$	$HWW_{(t)}$	$TDS_{(t)}$	$WWC_{(t)}$

4.4 Alternative Output Variables for Land-use Change Modeling

Two alternative approaches of modeling land-use change ($\Delta LU_{(t)}$) have been developed. The first group of models considered all land-land use categories as output variables, while the second group has only three output indicators based on sensitivity analysis which explained below.

4.4.1 Modeling the land-use changes using output variables $\Delta LU_{(t)}$

The annual changes in land-use $\Delta LU_{(t)}$ which equals to $\{LU_{(t)} - LU_{(t-1)}\}$ are used as output variables represented by the annual changes in the percentages of residential, roads, industrial, recreational, and agricultural areas expressed by ΔRES + ΔROD + ΔIND + ΔREC + ΔAGR (Figure 4.17). The output models will be called hereinafter "Land-use change models".



Changes in percentage of the residential areas (ΔRES)

Changes in percentage of the roads areas (ΔROD)

Changes in percentage of the industrial areas (ΔIND)

Changes in percentage of the recreational areas (ΔREC)

Changes in percentage of the agricultural areas (ΔAGR)

ΔRES = Annual changes in residential area
ΔROD= Annual changes in roads area
ΔIND= Annual changes in industrial area
ΔREC= Annual changes in recreational area
ΔAGR= Annual changes in agricultural area

Figure 4.17 The output variables, Annual Land-use changes (ΔLU)

4.4.1.1 Selection of the input variables for land-use change models

Similar to the procedures followed in the previous land-use models, six models have been developed with different input combinations. The $SEEI_{(t)}$ variables and additional land-use variables from the previous years (i.e. $LU_{(t-1)}$, $LU_{(t-2)}$, ..., $LU_{(t-5)}$)are used as input variables in order to produce the land use change models (Table 4.11).

Table 4.11. Input Combinations for Land-use Change Models

Model no.	Input combinations	No. of Outputs	No. of inputs	Neurons in hidden layer	No. of iteratior
21	$SEEI_{(t)}$	5	10	1	100
22	$SEEI_{(t)}$, $LU_{(t-1)}$	5	15	3	3000
23	$SEEI_{(t)}$, $LU_{(t-1)}$, $LU_{(t-2)}$	5	20	3	3000
24	$SEEI_{(t)}$, $LU_{(t-1)}$, $LU_{(t-2)}$, $LU_{(t-3)}$	5	25	3	1400
25	$SEEI_{(t)}$, $LU_{(t-1)}$, $LU_{(t-2)}$, $LU_{(t-3)}$, $LU_{(t-4)}$	5	30	3	500
26	$SEEI_{(t)}$, $LU_{(t-1)}$, $LU_{(t-2)}$, $LU_{(t-3)}$, $LU_{(t-4)}$, $LU_{(t-5)}$	5	35	3	10000

***SEEI**= Socio-Economic, Environmental and Institutional Indicators,*
***LU**= Land-uses in percentages,* ***t** = time*

Coefficient of multiple determination (R^2) are obtained for both training and validation sets of the data as shown in Table 4.12. The search for the optimal model among this group of models requires a comparison between the values of R^2 and ASE in both training and validation sets.

Table 4.12 Coefficients of the Determination (R^2) for the Training and Testing

Model No.	Training Data Subset					Validation Data Subset				
	ΔRES	**ΔROD**	**ΔIND**	**ΔREC**	**ΔAGR**	**ΔRES**	**ΔROD**	**ΔIND**	**ΔREC**	**ΔAGR**
21	0.54	0.68	0.49	0.13	0.28	0.49	0.59	0.32	0.11	0.19
22	0.51	0.72	0.63	0.32	0.12	0.45	0.86	0.41	0.26	0.24
23	0.53	0.62	0.72	0.23	0.22	0.50	0.59	0.63	0.18	0.21
24	**0.63**	**0.71**	**0.75**	**0.36**	**0.41**	**0.6**	**0.74**	**0.71**	**0.36**	**0.42**
25	0.43	0.55	0.57	0.16	0.22	0.44	0.52	0.56	0.34	0.25
26	0.57	0.68	0.74	0.29	0.27	0.57	0.58	0.69	0.18	0.22

It is noticed that the value of R^2 in the 24th model has superior values compared to the other models in this group. Similarly, the accuracy measures of Average Squared Error (ASE) confirms the same result.

Table 4.13 Statistical Accuracy Measures for Land-use Change Models

Model No.	$ASE_{(Training)}$	$ASE_{(Validation)}$
21	0.001700	0.0095
22	0.000100	0.0077
23	0.000065	0.0033
24	**0.000048**	**0.0048**
25	0.000300	0.0058
26	0.000055	0.0100

It is obvious that the optimal land-use change model is the 24th model, which can be presented by the following compact form:

$$\Delta LU_{(t)} = ANN\{P19_{(t)}, PD_{(t)}, HWW_{(t)}, LF_{(t)}, UE_{(t)}, PR_{(t)}, WWC_{(t)}, GWA_{(t)}, TDS_{(t)}, FUND_{(t)}, LU_{(t-1)}, LU_{(t-2)}, LU_{(t-3)}\} \quad (10)$$

Where $\Delta LU_{(t)}$ is the Change in Land-use percentages at time (t) which is equal to the sum of (ΔRES + ΔROD + ΔIND + ΔREC + Δ AGR) at time (t).

P19 =The population of age under19 years	*PD= Population density*
HWW= Households connected to wastewater	*LE= Labour forces*
UE= Unemployment rate	*PR= Poverty rate*
WWC= Percentage of households using	*GWA= Ground water abstraction*
TDS= Total Dissolved Solids	*FUND= Funds for development*

To compare this result with the previous land-use model number 5, which presented in equation 9 (section 4.3.3), it is found that the value of R^2 for the land-use change model ($\Delta LU_{(t)}$) is lower than the value of R^2 for the land-use percentages model ($LU_{(t)}$). This might be explained by the minimal changes in the one or more of the output variables. Therefore sensitivity analysis was performed in order to choose the most important output indicators by that particular neural network model and disregard the output variables that have no positive effect on the model.

4.4.1.2 Sensitivity Analysis for Land-use Change Model

Sensitivity analysis used to identify the output variables that have low significant effect on the accuracy of the network, and key variables that always of high sensitivity and have significant improvement on the model performance. The ranks 1, 2 and 3 was given to the models when its performance actually worsen if the output variable is removed while the ranks of 4 and 5 indicates that the output variable has no positive effect on the model at all. The high value of R-square give indication on making the variable "unavailable" either has no effect on the performance of the network. The basic sensitivity figures are; R-square and average square error.

Table 4.14: Sensitivity Analysis for the Outputs of the Land-use Change Model

Model no.	Output variables	Training R^2	Training ASE	Validation R^2	Validation ASE	Rank
24.1	$\Delta LU_{(t)} - \Delta RES_{(t)}$	0.51	0.016	0.49	0.012	1
24.2	$\Delta LU_{(t)} - \Delta ROD_{(t)}$	0.64	0.008	0.63	0.009	2
24.3	$\Delta LU_{(t)} - \Delta IND_{(t)}$	0.99	0.002	0.98	0.0003	4
24.4	$\Delta LU_{(t)} - \Delta REC_{(t)}$	0.99	0.002	0.99	0.0002	5
24.5	$\Delta LU_{(t)} - \Delta AGR_{(t)}$	0.71	0.005	0.69	0.005	3

Tables 4.14 provides sensitivity ranking for the output variables included in the optimal model (Number 24) which indicates that the residential, roads and agricultural land-uses

respectively are ranked as the first three important output variables, the networks without these variables have a high error, indicating that the network performance deteriorates badly if they are not present. The changes in the percentages of recreational and industrial land uses have less importance to the network performance compared to the other indicators. Therefore the next step will try to re-build the previous models with the same procedure but only with the three output variables.

4.4.2 Modified Land-use Changes Model

Additional models could be generated without the two indicators ΔIND and ΔREC, hence, the output variables will be only three indicators which are; $\Delta RES_{(t)}$, $\Delta ROD_{(t)}$ and $\Delta AGR_{(t)}$. The same input variables for the previous land use change model have been use to generate six models shown in Table 4.15 in order to predict {ΔLU- (ΔIND +ΔREC)}.

Table 4.15. Input Combinations for Modified Land-use Change *Model*

Model no.	Input combinations	No. of Outputs	No. of inputs	Neurons in hidden layer	No. iterat
27	$SEEI_{(t)}$	3	10	1	10
28	$SEEI_{(t)}$, $LU_{(t-1)}$	3	15	3	11
29	**$SEEI_{(t)}$, $LU_{(t-1)}$, $LU_{(t-2)}$**	**3**	**20**	**2**	**30**
30	$SEEI_{(t)}$, $LU_{(t-1)}$, $LU_{(t-2)}$, $LU_{(t-3)}$	3	25	3	30
31	$SEEI_{(t)}$, $LU_{(t-1)}$, $LU_{(t-2)}$, $LU_{(t-3)}$, $LU_{(t-4)}$	3	30	3	50
32	$SEEI_{(t)}$, $LU_{(t-1)}$, $LU_{(t-2)}$, $LU_{(t-3)}$, $LU_{(t-4)}$, $LU_{(t-5)}$	3	35	4	14

SEEI*= Socio-Economic, Environmental and Institutional Indicators,*

LU*= Land-uses in percentages,* ***t*** *= time*

Coefficients of multiple-determination (R^2) are obtained for both training, testing and validation data sub-sets with 60%, 20% and 20% of the data respectively. Table 4.16 shows only the results of the training and validation subsets in order to compare the results with other models.

Table 4.16 Coefficients of the Determination (R^2) for the Training and Validation

Model No.	Training Data Subset			Validation Data Subset		
	ΔRES	**ΔROD**	**ΔAGR**	**ΔRES**	**ΔROD**	**ΔAGR**
27	0.91	0.92	0.97	0.90	0.92	0.97
28	0.97	0.99	0.97	0.93	0.96	0.97
29	**0.99**	**0.99**	**0.99**	**0.99**	**0.99**	**0.98**
30	0.99	0.98	0.99	0.99	0.97	0.98
31	0.99	0.99	0.99	0.99	0.98	0.98
32	0.99	0.99	0.98	0.99	0.97	0.97

It is noticed that the value of R^2 in the 29^{th} model has progressed than the other models performed. Similarly, the values of ASE confirm this same result (Table 4.17).

Table 4.17 Statistical Accuracy Measures (Training and validation)

Model	**ASE $_{(Training)}$**	**ASE $_{(Validation)}$**
27	0.001700	0.0095
28	0.00010	0.00077
29	**0.00006**	**0.00013**
30	0.00012	0.00016
31	0.00017	0.00067
32	0.00020	0.00190

***ASE** =Average Squared Error*

It is clear that the optimal model among this group is model number 29 and can be presented in the following compact form:

$$\{\Delta RES_{(t)}, \Delta ROD_{(t)}, \Delta AGR_{(t)}\} = ANN\{P19_{(t)}, PD_{(t)}, HWW_{(t)}, LF_{(t)}, UE_{(t)}, PR_{(t)}, WWC_{(t)}, GWA_{(t)}, TDS_{(t)}, FUND_{(t)}, LU_{(t-1)}, LU_{(t-2)}\} \quad \mathbf{(11)}$$

It is noticed that only previous two years in addition to the SEEI indicators can explain the changes in the major three categories of land-uses.

4.4.3 Concluding Remarks

Artificial neural network with multi-layer perceptron and Back-propagation learni algorithm offers a credible base for modeling land-use changes with different inp combinations. ANN gives the opportunity to compare the model's performance and sele the optimal model among each group of models based on certain criteria. It also trained wi different output variables in order to discover the phenomena of land use changes.

Among the 32 trained models there are three models that have successfully presented t land-uses and their changes in Gaza City. Theses models are differing in their input a output variables. The model of land use percentages $LU_{(t)}$ has many input variables (variables) and five output variables with high coefficient of coordination (R^2). The seco model, the land-use change model $\Delta LU_{(t)}$, has less input variables (25 variables) and le value of R^2. While the third one, the modified land-use change model, has only three outp variables and 20 input variables. This model has superior value of R^2 and low value of R error. Table 4.18 summarized the characteristics of the three models.

Table 4.18 Comparison between the successful models

Mode l No.	Output Variables	No. of Output	Input Variables	No. of Input	No. of Hidden Nodes	Average R^2 Validation data set	Avera ASE Valida data s
5	$LU_{(t)}$	5	$SEEI_{(t)}$, $LU_{(t-1)}$, $LU_{(t-2)}$, $LU_{(t-3)}$, $LU_{(t-4)}$	30	1	92.4	0.0(
24	$\Delta LU_{(t)}$	5	$SEEI_{(t)}$, $LU_{(t-1)}$, $LU_{(t-2)}$, $LU_{(t-3)}$	25	3	56.6	0.00
29	$\Delta RES_{(t)}$, $\Delta ROD_{(t)}$, $\Delta AGR_{(t)}$	3	$SEEI_{(t)}$, $LU_{(t-1)}$, $LU_{(t-2)}$	20	2	98.3	0.00(

Before using these models for land-use projection, ANN results should be compared wi other statistical models that have been used for land-use modeling for long time ago.

4.5 Multiple-Linear Regression (MLR) Statistical Test

Many researchers used multiple-linear regression (MLR) to predict land-use changes because they have the advantage of a well-defined mathematical basis as well as measures of how well a curve matches a given data set (Bishop, 1996; Veldkamp and Fresco, 1997b; Koning et al., 1999; Mas et al., 2004). MLR is found as a an appropriate statistical tool to determine the influence of independent variables on dependent variables, as it allows to examine the contribution of each independent variables to the regression model (Hair et al, 1998; Paudel and Thapa, 2004). It has a straightforward statistical test, with high ability to incorporate effects of each independent variable on dependent variable. MLR analysis can be generally represented in the form of

$$Y = C + B_1X_1 + B_2X_2 + \cdots + B_nX_n + e$$

Where Y is the total estimated one of the land-use categories, and X_1, X_2, ... , X_n are measures of distinguishable variables that may help in estimating Y, C is the estimated constant, and B_1, B_2, ..., B_n are the coefficients estimated by regression analysis, given the availability of some relevant data, and e is the remaining unexplained noise in the data (the error).

The performance of the model can be evaluated through the coefficient of determination (R^2) and the adjusted coefficient of determination (adjusted R^2) can describe the proportion of the total variance in the observed data that can be explained by the model. Both indices indicate the degree to which the models explain variation for each land-use category. The values of R^2 that close to 1.0, when comparing the predictions and observations, indicates the goodness of fit of the land-use prediction models. Usually there is substantial variation of the observed points around the fitted regression line. The deviation of a particular point from the regression line (its predicted value) is called the residual value. The smaller the variability of the residual values around the regression line relative to the overall variability, the better is our prediction. Statistical tests using the selected model were performed for ANOVA (F test), for significance test of the regression coefficient, and for multicollinearity.

4.5.1 Application of MLR

MLR was performed using (STATISTICA for windows 6.0) to develop the predictio models of land-use changes from the same set of variables used in ANN-model (section 4.6.2 and 4.6.3). Five models were resulted that relates one dependent variable of land-us categories to the other independent variables. The result of the regression analysis usin normalized variables shown in Table 4.19.

Table 4.19 Coefficients (B) Estimated by the Regression Analysis

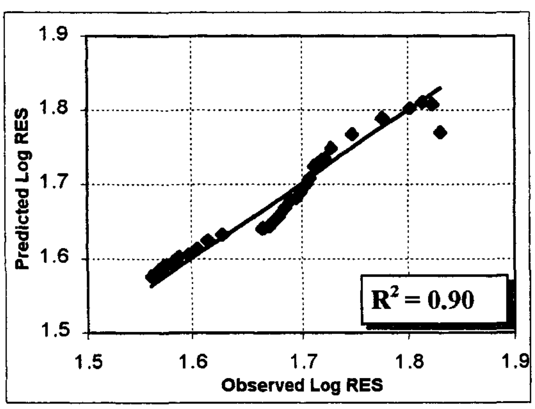
	Log RES	Log ROD	Log IND	Log REC	Log AGR
Intercept (C)	**1.106**	**0.240**	**-5.582**	**-0.926**	**6.301**
Log P19	-0.020	-0.051	2.122	0.197	-1.838
Log PD	0.076	0.117	0.173	0.050	-0.337
Log HWW	0.095	0.160	0.523	0.090	-0.727
Log LF	-0.159	-0.182	0.110	-0.088	0.324
Log UE	0.007	0.011	-0.023	0.003	-0.010
Log PR	0.033	0.044	0.104	0.045	-0.300
Log WWC	-0.111	-0.182	-0.306	-0.066	0.482
Log GWA	0.048	0.080	0.363	0.045	-0.360
Log TDS	-0.001	0.001	0.095	-0.004	0.008
Log FUND	0.005	0.007	0.069	-0.002	0.017
Log RES-1	0.038	0.049	-0.096	-0.028	0.241
Log ROD-1	0.033	0.048	0.072	0.001	0.006
Log IND-1	0.003	0.006	0.027	-0.001	-0.001
Log REC-1	0.002	0.001	0.079	-0.040	0.087
Log AGR-1	0.010	0.018	0.000	0.013	-0.076
Log RES-2	0.042	0.062	-0.048	-0.009	0.146
Log ROD-2	0.036	0.055	0.076	0.010	-0.043
Log IND-2	0.002	0.005	0.038	0.001	-0.014
Log REC-2	0.032	0.057	0.338	0.032	-0.130
Log ARG-2	0.006	0.008	-0.021	0.005	-0.035
Log RES-3	0.050	0.076	-0.017	0.002	0.070
Log ROD-3	0.040	0.062	0.072	0.015	-0.079
Log IND-3	0.003	0.007	0.061	0.003	-0.033
Log REC-3	0.049	0.076	0.186	0.023	-0.068
Log AGR-3	0.001	-0.002	-0.044	-0.001	0.001
Log RES-4	0.069	0.104	0.039	0.010	-0.079
Log ROD-4	0.049	0.076	0.083	0.019	-0.144
Log IND-4	0.005	0.011	0.096	0.005	-0.061
Log REC-4	0.128	0.186	0.360	0.048	-0.577
Log AGR-4	-0.009	-0.017	-0.075	-0.004	0.068

The R-square value was ranged between (0.75 to 0.91) and the adjusted R-square value was ranged between (0.54 – 0.35). These values shows the total variation in land-use categories that can be explained by the models. As the p-values were less than 0.01 in all models, the regression models are statistically significant.

Table 4. 20 Results of the Regression Models

Dependent Variable	R	R-Square	Adjusted R-Square	Standard Error of estimate:
RES	0.95	0.90	0.54	0.102
ROD	0.92	0.86	0.35	0.554
IND	0.92	0.91	0.40	0.155
REC	0.86	0.75	0.46	0.082
AGR	0.89	0.79	0.37	0.573

The plot of predicted Log (RES) versus observed Log (RES), as an example of the other land-use categories, shown in Figure 4.18 presents the high linear correlation with R^2 equal 0.90. The scatter plot of the regression residual versus predicted Log (RES) shows that there is no special pattern or trend in this distribution. They are normally distributed around zero. T-test was done to check if any statistically significant differences existed between the actual and predicted values for the five land-use models. The probability of the actual t-value was less than tabulated with df = 32. Therefore there are no statistically significant difference exists between the actual and predicted values for the different land-uses models.



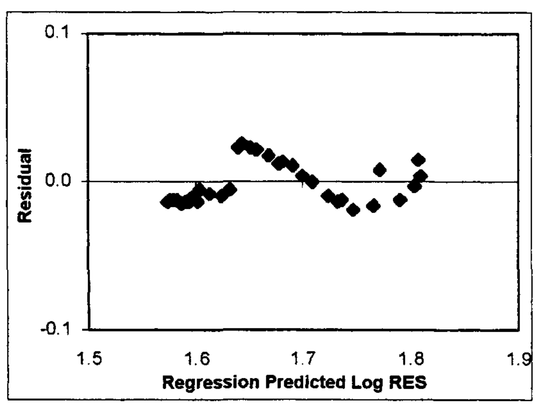


Figure 4.18. Multiple Linear Regression (Dependent Variable is RES)

4.5.2 Concluding Remarks

The ANN approach is a generic technique for mapping the relationship between the input and outputs without the need to know the details of these relations. The proposed approac becomes more explicit and can be adopted for prediction land-use changes in the Palestinia cities. In order to compare the performance of the ANN model developed, a multiple linea regression (MLR) techniques to develop a viable regression-based-model. The resulte MLR model produced R-square ranged from (0.75 to 0.91) for the five land-use categorie These values are lower than the values of R-square resulted from ANN models in all it phases (training, testing and verification).

Despite the wide use of MLR for modeling and analysis, some researchers and scholar describe the disadvantages of MLR as: (1) it has no specific, or clearly defined, approac that will help to select the optimal model that best fits the historical data to a give application (Garza and Rouhana, 1995; Bode, 2000); (2) the variables influencing th dependent variable must be reviewed in advance and it is also difficult to use a large numbe of input variables (Bode J., 2000, Kim, et al., 2004).

The artificial neural network ANN model is a very promising technique that has significar capabilities to model land-use data. The results of ANN mode show that it is a ration approach that can be used effectively in prediction land-use changes in the Palestinian citie where many factors involved. For future prediction it is required to develop sever scenarios that depends on certain assumptions. These scenarios can be differ from place t place, however, it should be based on realistic and achievable assumptions.

4.6 Prediction for Future

Prediction for future is an effective approach for better management and decision-making especially if done in an integrated manner using the appropriate models. Land-use prediction models provide valuable information on the system's behaviour under a range of conditions. Modeling is an important technique for the projection of alternative pathways into the future. It requires better understanding for the previous and the current situation and realistic assumption for future. Therefore, two different scenarios were formulated based on trend analysis for the indicators under the study. These scenarios are; status quo scenario and sustainability scenario. Each scenario is based on a set of assumptions made by the local institutions (see EPD, 1996; MOPIC, 1998).

4.6.1 Status Quo Scenario (SQS)

- SQS is based on extrapolation of the trends at the last four years. It is assumed that there are no significant changes will take place in the socio-economic, environmental nor in the institutional situation. It assumes also that there are no major changes in the current policies for land-use planning. The political situation assumed to remain without major developments for the coming 10 years. Hence, there will be slow peace process and the power of the local institution will remain limited. There will be slow progress in institutional capacity building and appropriate legal and regulatory system.

Main Assumptions:

- It is assumed that the population rate of growth will slowly decline from 5.0 in the year 2005 to 4.5 in the year 2015. Therefore, the total population of the city assumed to increase from 508,000 inhabitants in 2005 to reach over than 756,660 inhabitants in 2015. The percentage of population under 19 years assumed to be around 61.8%. The population density assumed to increase at the same previous trends to reach around 19,218 inhabitants per km^2.

- According to the present trends, the percentage of households connected to the wastewater network within the city will increase slowly from 57.7% in the year 2005 to 63.7% in 2015. This increase considered as insignificant change compared to the population growth.

- It is assumed that there are no significant improvements in labour forces and unemployment rate. The labour forces will slightly increase from 34.4% in the year 2005 to 35.9% in the year 2015. Insignificant decrease (around 1.8%) in unemployment rate is assumed for the coming 10 years. Similarly, insignificant improvement in the poverty rate is assumed (from 49.7% to 41.6%).
- The assumed little improvement in the public services mainly wastewater networks could reduce the percentage of households using cesspit for discharge their wastewater by 6.3%. This little improvement will not solve the problem of soil and groundwater pollution caused by the remaining large number of households using cesspits.
- External funds are coming forward reluctantly and at slow paces. Private investors are limiting themselves to invest in small housing projects. The funds for development, either it come from local or external sources, assumed to increase by one million US Dollars per year. These funds will not be enough to finance major infrastructure project within the city.
- The environmental pressures and negative environmental impacts will continue with the same trend without major improvements to regulate, mitigate or remediation of these problems.

Table 4.21 summarized the developments of the socio-economic, environmental an institutional indicators based on status quo scenario.

Table 4.21 SEEI Indicators – Status Quo Scenario

Year	2000	2005	2010	2015
P19	61.7%	62.5%	61.9%	61.8%
PD	12643	14661	16573	19218
HWW	49.8%	57.7%	60.8%	63.7%
LF	35.4%	34.9%	35.4%	35.9%
UE	26.7%	38.1%	37.3%	36.3%
PR	33.0%	49.7%	44.5%	41.6%
WWC	30.8%	28.1%	24.9%	21.8%
GWA (k m^3/year)	31.920	34.800	41.300	53.550
TDS (mg/l)	1314	1410	1580	1850
FUND (Million $ US)	15.5	24.4	27.9	32.0

4.6.2 Sustainability Scenario

The sustainability scenario is necessary to explore viable solutions and potential remedies to the situation in the city. Sustainability scenario is assumed prosperous development of the socio-economic, environmental and institutional situations. It assumes major changes in the current policies for land-use planning in order to respond at the socio-economic and environmental challenges. Rapidly progressing in the peace process and political stability will have positive impact on the overall development. Therefore, it is assumed significant developments in the economical production sectors (industrial, agriculture, construction, tourism, etc). Consequently, decisions on investment in water, power, seaport, regional highways, industrial zones and other major projects are made legally on the basis of consideration of socio-economic development and regional cooperation. Polices at different administrative levels will be directed at development of welfare and quality of life. Consequently, development funds will be directed towards the social sectors such as health, education, environmental hygiene, recreation, etc. Environmental policies to manage the natural resources are properly designed and implemented for the log-term, therefore, the expansion of random urban development at the expense of agricultural and green areas will be minimized.

Main Assumptions:

- The assumed development in health and educational facilities will encourage the decrease of population growth and fertility rate. Hence, the population growth rate will continuously decrease to reach 2.8 in the year 2015 which puts much lower pressure on land and gives more time and opportunity for balanced development. Therefore the total population in the year 2015 assumed to be 730,000 inhabitants. The percentage of population under 19 years old will also assume to decrease by 4.4%. The population density will stay at a constant rate, however, these densities assumed to be well-distributed among the city's neighborhoods.

- The percentage of households connected to wastewater network and facilities assumed to be more than 81.0% of the total households living in the city. This development has its impact on minimizing the negative environmental impacts caused by inappropriate wastewater disposal methods.

- The economical development will play an important role in decreasing th unemployment poverty rate. It is assumed that the unemployment and poverty rate wi reach the lowest levels (20.9% and 19.5% respectively) for the year 2015.
- An increase in external and local funds for infrastructure development will encourage th private sector to investment in large-scale projects. These development projects wi create sustainable jobs and alleviate poverty rates.
- The local institutions will cooperate to regulate and mitigate the environmental pressure and their negative impacts. Hence, the limited natural resources will properly managed.

Table 4.22 summarized the development of the socio-economic, environmental an institutional indicators based on status quo scenario.

Table 4.22 SEEI Indicators- Sustainability Scenario

Year	2000	2005	2010	2015
P19	61.7%	61.6%	59.2%	57.2%
PD	12643	14369	15024	15712
HWW	49.8%	60.0%	70.0%	81.0%
LF	35.4%	35.6%	38.0%	42.4%
UE	26.7%	33.0%	25.8%	20.9%
PR	33.0%	44.0%	27.0%	19.5%
WWC	30.8%	23.1%	12.5%	6.2%
GWA (km^3/year)	31.9	33.0	39.3	47.4
TDS (mg/l)	1315	1257	1092	1025
FUND (Million $ US)	15.469	35.6	52.4	64.7

4.6.3 The Scenario's Results

The sets of assumptions used as input for the two scenarios have been processed so as t simulate the ten SEEI indicators for the years 2005, 2010, 20015 and 2020. Therefore th output of the scenarios consists of SEEI description, as shown below.

It is clear from the diagrams in Figure 4.19 that there are differences between the tw scenarios. The main differences appear in the poverty rate, unemployment rate an environmental indicators. These indicators are be affected by the overall development an considered as the main driving forces for sustainability of Gaza natural resources.

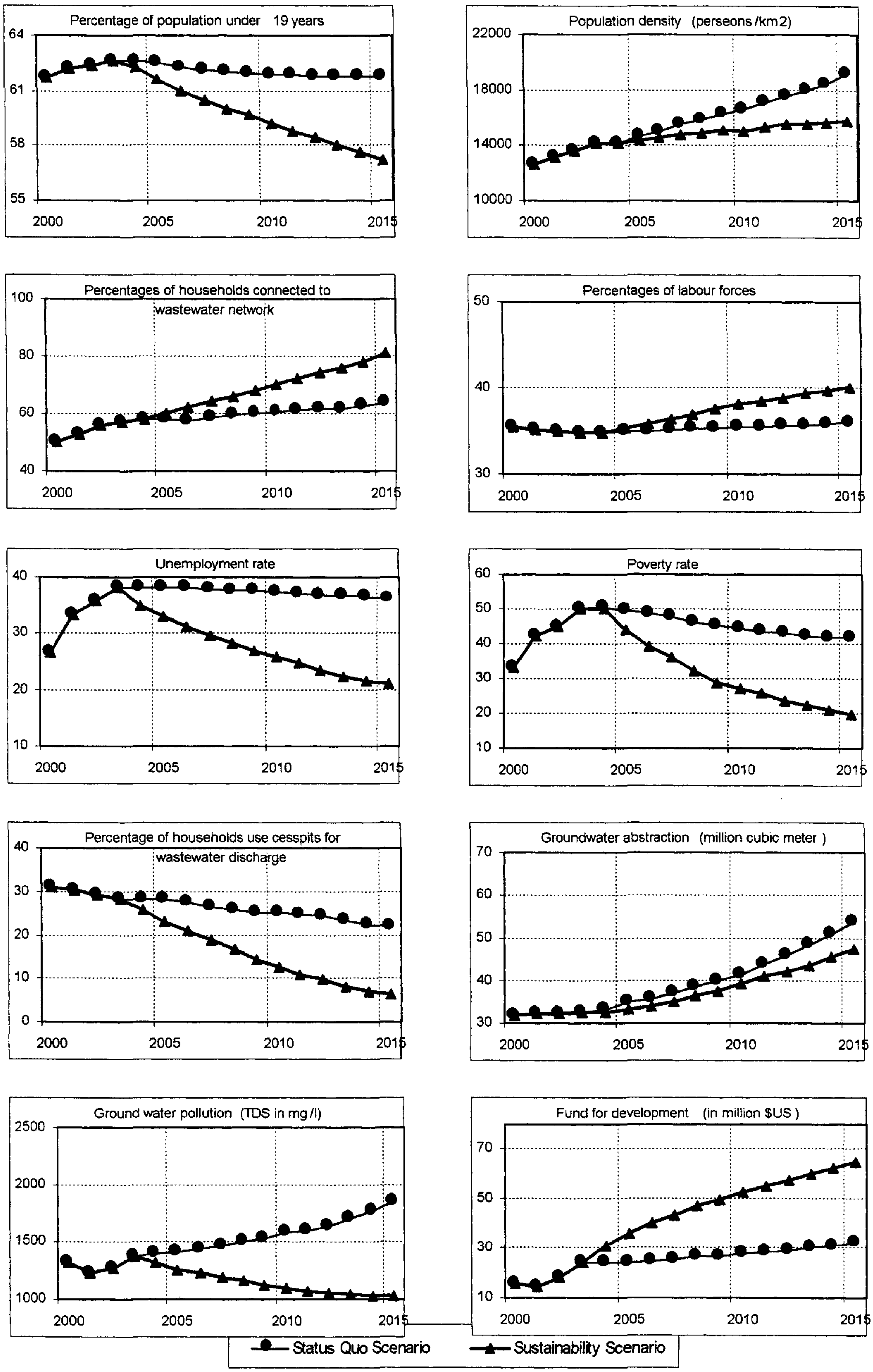


Figure 4.19 Prediction of the SEEI indicators based on Status Quo and Sustainability scenario

4.6.4 Land-use Prediction Using ANN Models

An attempt was made to assess the likely impact of the two scenarios on the use of land b the year 2015 using the three different models that presented in Table 4.18 (section 4.4.3). was estimated the additional required expansions of residential, infrastructure, industrial an recreational areas, and how much agricultural land will be remained. The optimal ANN based models, given in formulas 9, 10 and 11, have been applied to predict the land-us changes and land demands for both SQS and sustainability scenarios.

4.6.4.1 Status Quo Scenario

Using land use percentage model ($LU_{(t)}$)

Using the land use percentage model, which has five outputs, 30 input variables and or hidden node, for land use prediction. The output of each year will be input for predicting th land-use demands for the next year. For instance, the ANN model will predict $LU_{(t+1}$ therefore, the input data will be the simulated socio-economic, environmental, institution for year *(t)* and data on the land-uses for the previous four years {e.g., $LU_{(t)}$, $LU_{(t-1)}$, $LU_{(t-}$ and $LU_{(t-3)}$} where *t* is the time expressed by one year. The new output $LU_{(t+1)}$ together wit $LU_{(t)}$, $LU_{(t-1)}$, $LU_{(t-2)}$ will be used as an input to predicted $LU_{(t+2)}$. Table 4.23 presents th demands for different land-uses in terms of areas need until the year 2015. The mod resulted with around 65% of the city's area to be for residential areas and 23% for roac purposes. It also resulted with no significant changes in the industrial and recreational area A reduction of about 15% in the agricultural areas could happen by the year 2015.

Table 4.23 Status Quo Scenario Using Land-use Percentage Model

	2005		2010		2015	
Land-use	**Area (km²)**	**%**	**Area (km²)**	**%**	**Area (km²)**	**%**
RES	25.4	**54.8%**	28.0	**60.4%**	30.1	**65.0%**
ROD	8.6	**18.5%**	9.7	**20.9%**	10.7	**23.0%**
IND	1.5	**3.2%**	1.6	**3.5%**	1. 8	**3.8%**
REC	0.2	**0.5%**	0.2	**0.5%**	0.2	**0.5%**
AGR	10.7	**23.0%**	6.8	**14.7%**	3.6	**7.7%**

Using Land-use Change Model ($\Delta LU_{(t)}$)

The land use change model, which has five outputs, 30 input variables and three hidden nodes, is used for land use prediction under SQS. The model formula was $\{\Delta LU_{(t)} = ANN\ (SEEI_{(t)}, LU_{(t-1)}, LU_{(t-2)}, LU_{(t-3)})\}$. The model resulted with around 70% of the city area would be devoted for residential purposes while no agricultural land would be left within the city by the year 2015.

Table 4.24 Status Quo Scenario using land-use Change Model

	2005		**2010**		**2015**	
Land-use	**Area (km²)**	**%**	**Area (km²)**	**%**	**Area (km²)**	**%**
RES	25.0	**53.9**	27.9	**60.2**	32.4	**69.9**
ROD	9.0	**19.5**	10.3	**22.2**	12.0	**25.8**
IND	1.5	**3.1**	1.5	**3.3**	1.6	**3.5**
REC	0.2	**0.5**	0.3	**0.6**	0.3	**0.7**
AGR	10.6	**23.0**	6.3	**13.7**	0.0	**0.1**

Using the Modified Land-use Change Model ($\Delta LU_{(t)} - \Delta REC_{(t)} - \Delta IND_{(t)}$)

The modified land-use change model has three outputs, 25 input variables and two hidden nodes was used for land use prediction based on SQS. The model formula was $\{\Delta LU_{(t)} = ANN\ (SEEI_{(t)}, LU_{(t-1)}, LU_{(t-2)}, LU_{(t-3)})\}$. The future demand of industrial and recreational areas have been assumed to be as the current trend, therefore, there are no major changes in theses percentages, while 10% of the city's area would remain for agricultural lands.

Table 4.25 Status Quo Scenario using the Modified Land-use Change Model

	2005		**2010**		**2015**	
Land-use	**Area (km²)**	**%**	**Area (km²)**	**%**	**Area (km²)**	**%**
RES	24.9	**53.8**	27.5	**59.4**	30.3	**65.5**
ROD	8.8	**18.9**	9.4	**20.4**	9.7	**20.9**
IND	1.4	**3.1**	1.4	**3.1**	1.4	**3.1**
REC	0.2	**0.5**	0.2	**0.5**	0.2	**0.5**
AGR	11.0	**24.0**	7.7	**16.7**	4.8	**10.3**

Comparison Between the Three Models Based on SQS

Figure 4.20 provides a comparison between the results of the three models based on SQS. I is obvious that the land-use percentages model has the lowest percentage (64%) fo residential area, while the land-use change model has the highest percentage (69%) fo residential areas. The agricultural areas occupied around 10% of the city's area by the yea 2015 according to the modified land use change model while it disappeared according to th land-use change model. The three models agreed that the industrial and recreational area remain as they are today with no major changes in their areas.

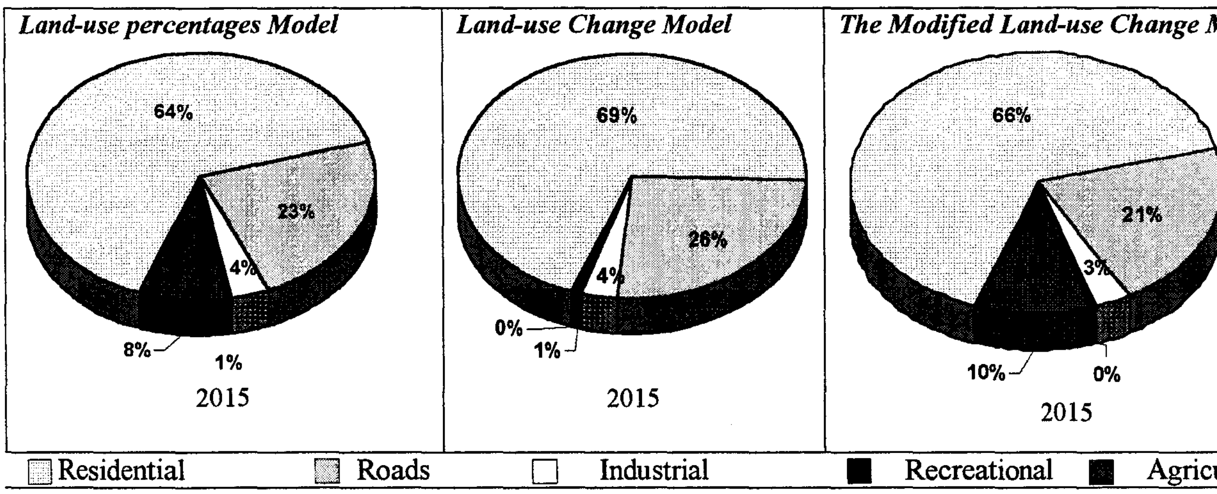


Figure 4.20 SQS Prediction for the year 2015 using three different ANN models

4.6.4.2 Sustainability Scenario

Based on assumptions of the sustainability scenario, effective policies and socio-economi development programs assumed to be the main driving forces for land-use optimization Therefore significant increases in the areas of the different land-uses would occur in order t achieve sustainable land-use. The expansion of these areas would be the basis for socio economic sustainability (i.e. food security, poverty alleviation, reduction of th unemployment rate, etc.). By applying the land-use percentages model, it appears that littl development in the industrial and recreational areas would happen. Table 4.26 shows th areas allocated for the different land-uses for the years 2005, 2010 and 2015.

Table 4.26 Sustainability Scenario According to the Land-use Percentages Model

Land-use	2005 Area (km²)	%	2010 Area (km²)	%	2015 Area (km²)	%
RES	23.8	**51.4**	25.3	**54.7**	26.7	**57.6**
ROD	9.2	**19.8**	10.2	**21.9**	11.5	**24.8**
IND	1.5	**3.3**	1.8	**3.8**	2.1	**4.5**
REC	0.3	**0.6**	0.4	**0.9**	0.6	**1.4**
AGR	11.5	**24.9**	8.7	**18.7**	5.5	**11.9**

Applying the land-use change model on the sustainability scenario gives different results especially for the residential areas which would increase from 52.5% in the year 2005 to 62.8% in the year 2015. The industrial and recreational areas have no significant expansion in their areas.

Table 4.27 Sustainability Scenario According to the Land-use Change Model

Land-use	2005 Area (km²)	%	2010 Area (km²)	%	2015 Area (km²)	%
RES	23.8	**52.5**	24.8	**57.2**	25.7	**62.8**
ROD	8.9	**19.2**	9.5	**21.4**	10.1	**24.5**
IND	1.5	**3.2**	1.5	**3.3**	1.6	**3.5**
REC	0.2	**0.5**	0.3	**0.6**	0.3	**0.7**
AGR	11.4	**24.6**	8.1	**17.6**	4.0	**8.6**

Different results have been obtained by applying the modified land-use change model especially in the industrial and recreational areas. These two land-use categories have been assumed to increase significantly while the residential area's increase is more realistic according to the assumption that the population growth would be decreased by 2.2%. The model resulted with no agricultural areas would be remain within the city's area. Table 4.28 presents the predicted percentages and areas for the different land-uses under this model.

Table 4.28 Sustainability Scenario According to the Modified Land-use Change Model

Land-use	2005 Area (km²)	%	2010 Area (km²)	%	2015 Area (km²)	%
RES	24.2	**52.1**	26.4	**57.0**	28.0	**60.5**
ROD	8.8	**18.9**	10.2	**21.9**	11.9	**25.7**
IND	1.4	**3.1**	2.9	**6.2**	4.7	**10.1**
REC	0.4	**0.9**	1.2	**2.6**	1.7	**3.7**
AGR	11.6	**25.0**	5.7	**12.3**	0.0	**0.0**

Comparison Between the Three Models Based to Sustainability Scenario

The difference between the three models prediction are clearly presented by Figure 4.21. The modified land-use change model offers the opportunity to assume the recreational and industrial areas, which could be affected directly by the land use policies. However this model assumed that the agricultural areas would disappear from the city and replaced by development projects for different purposes.

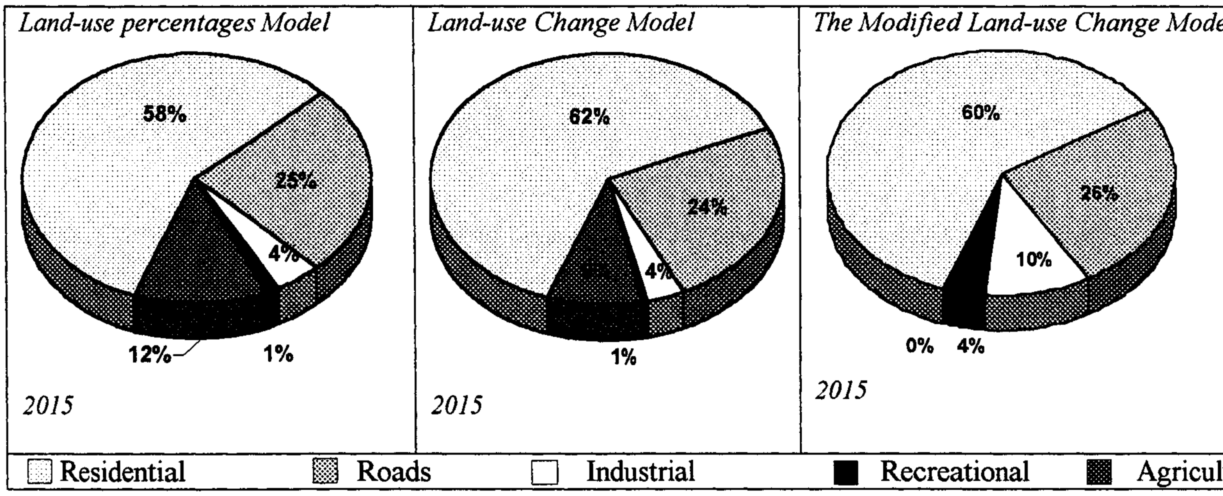


Figure 4.21 Sustainability Scenario Prediction for the year 2015 based on the three models

The three models give the opportunities for the land-use planners and decision-makers to formulate the land-use policies that would change the land-use management towards more sustainable. They can also decide on the appropriate sustainability approach that could be adopted in the future.

4.6.5 Comparison Between the Two Scenarios

The changes of the different land-uses are predicted and presented in terms of percentages for each type of land-use. Figures 4.22, 4.23 and 4.24 show the comparison between the two scenarios according to the prediction resulted from the three models. The sustainable scenario assumed a significant development in all land-use categories to accommodate the new development in their related sectors. In the opposite, the status quo scenario assumed that the existing trend is continue for the coming years with little development in the five land-use categories.

Results of the land use percentages model (MODEL # 5) Using the formula $LU_{(t)} = ANN \{ SEEI_{(t)}, LU_{(t-1)}, LU_{(t-2)}, LU_{(t-3)}, LU_{(t-4)} \}$

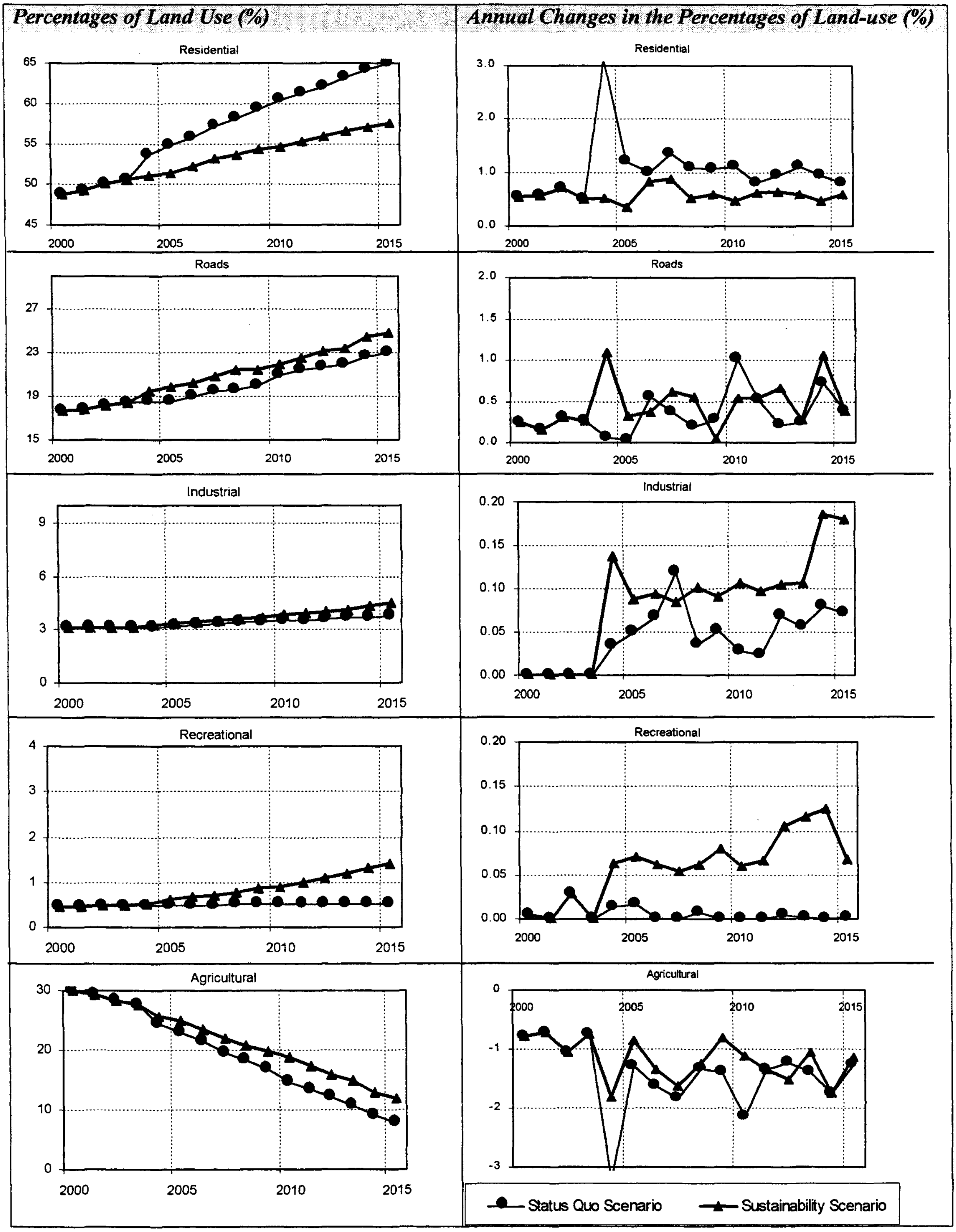


Figure 4.22 Predicting Land-use Demand based on Land-use Percentages Model

Results of the land use change model (MODEL # 24) Using the formula $\Delta LU_{(t)} = ANN\ \{\ SEEI_{(t)}, LU_{(t-1)}, LU_{(t-2)}, LU_{(t-3)}\}$

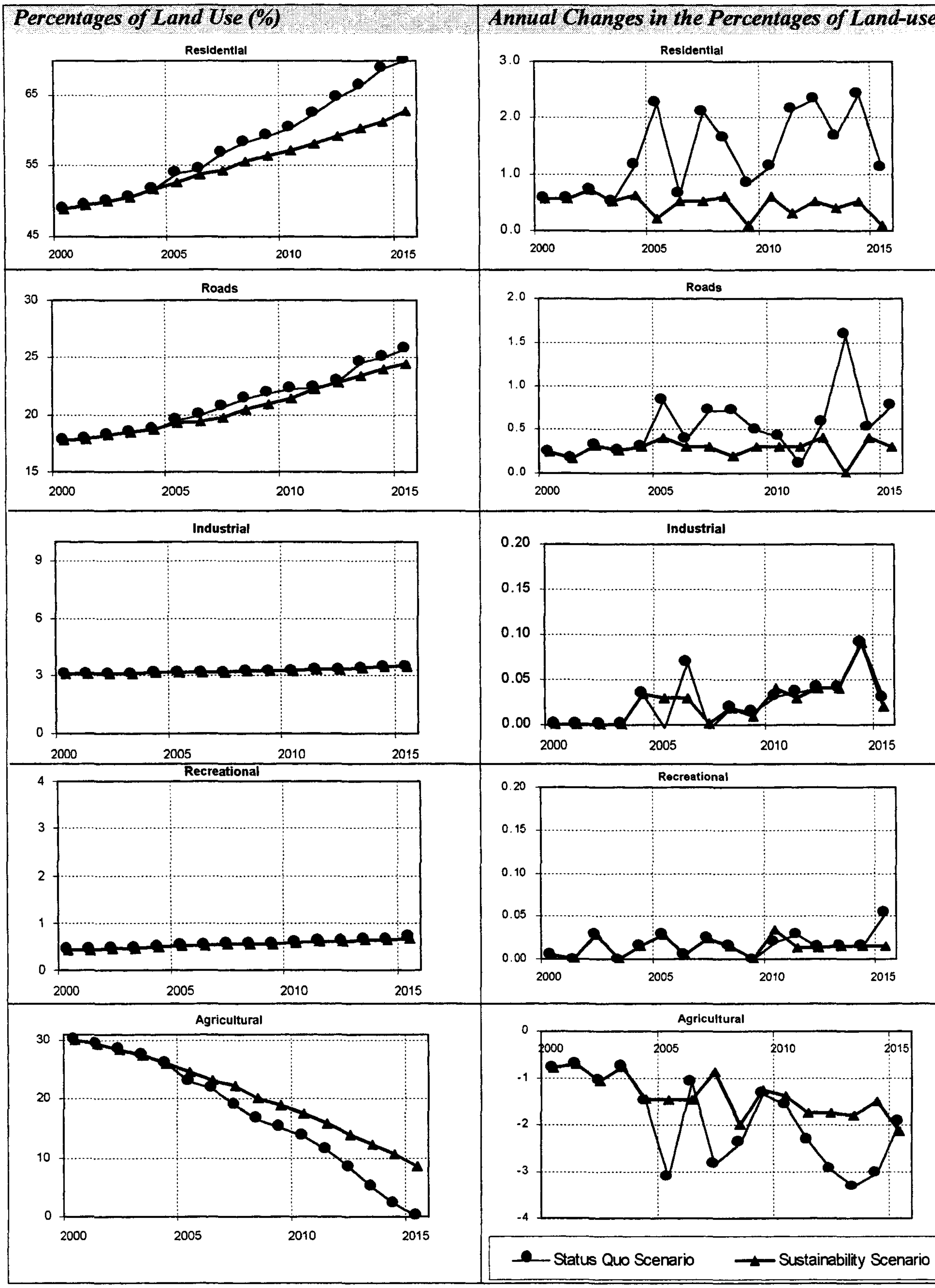


Figure 4.23 Predicting Land-use Demand based on Land-use Change Model

Results of the land use change model (MODEL # 29) Using the formula

$$\Delta RES_{(t)} + \Delta ROD_{(t)} + \Delta AGR_{(t)} = ANN\ \{\ SEEI_{(t)},\ LU_{(t-1)}\ ,\ LU_{(t-2)}\}$$

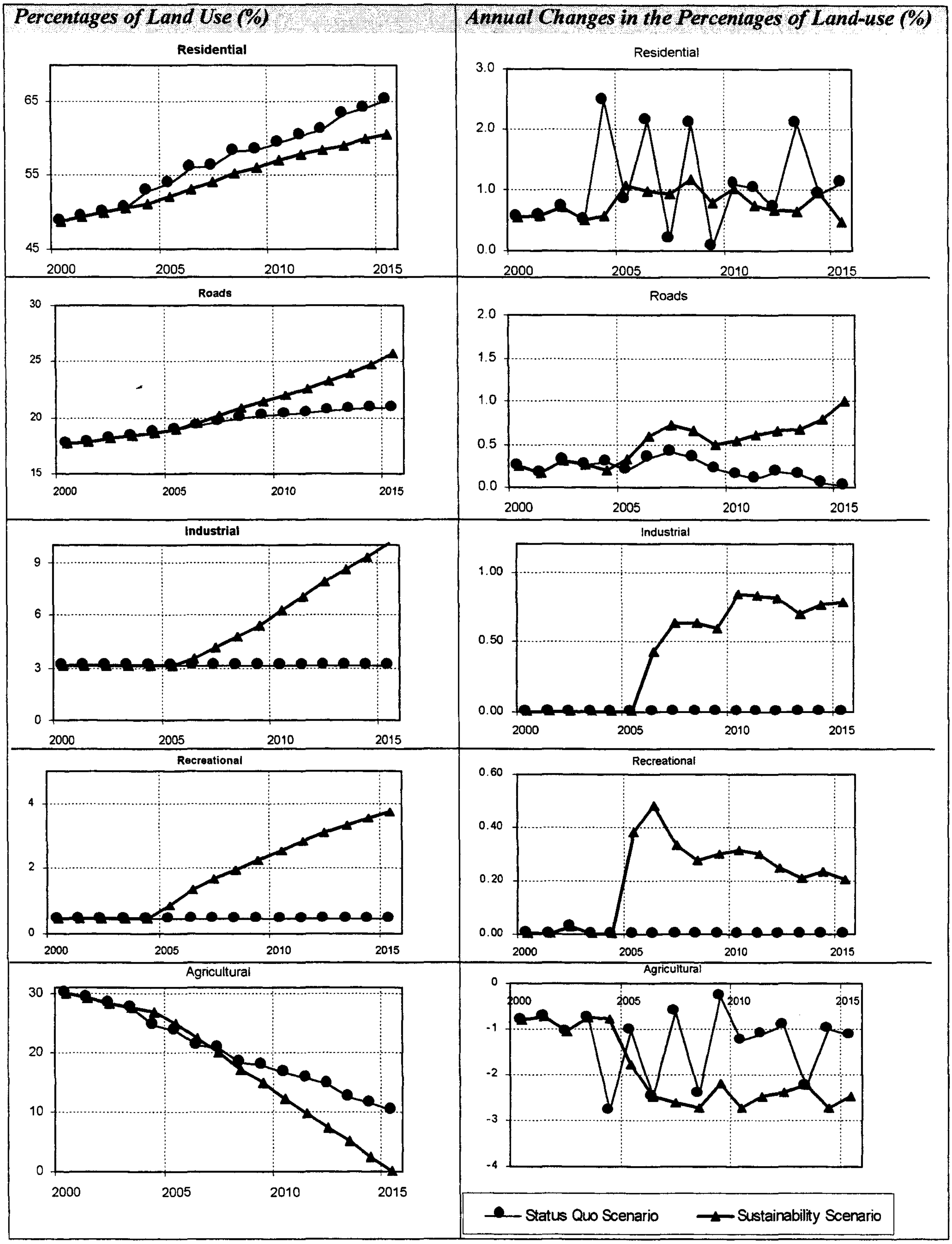


Figure 4.24 Predicting Land-use Demand based on The Modified Land-use Change Model

4.6.6 Spatial arrangements for the predicted land-use demands

The two scenarios as presented and evaluated in the previous sections have shown that much rural and agricultural lands will decreased to be developed for residential, infrastructure, recreational facilities and industrial establishments. It is also learned that sustainability scenario requires more land contributes to over all sustainable development than the status quo scenario. There are limited directions of city's urban expansion; therefore any development should search for the optimal use of land. The only expansion for the residential areas could be from the south part of the city while the industrial development could be at the same location of the existing industrial sites. The spatial land-uses (Figure 4.25) were prepared and extrapolating opportunities and trends taking into account the output data to the prediction models. The presented map is an attempt to indicate the best possible locations of the proposed development arrangement. The infrastructure networks and facilities shown and designation such as industrial zones may eventually change in size according to the results of the models, but its still needs environmental impact assessment and further feasibility studies.

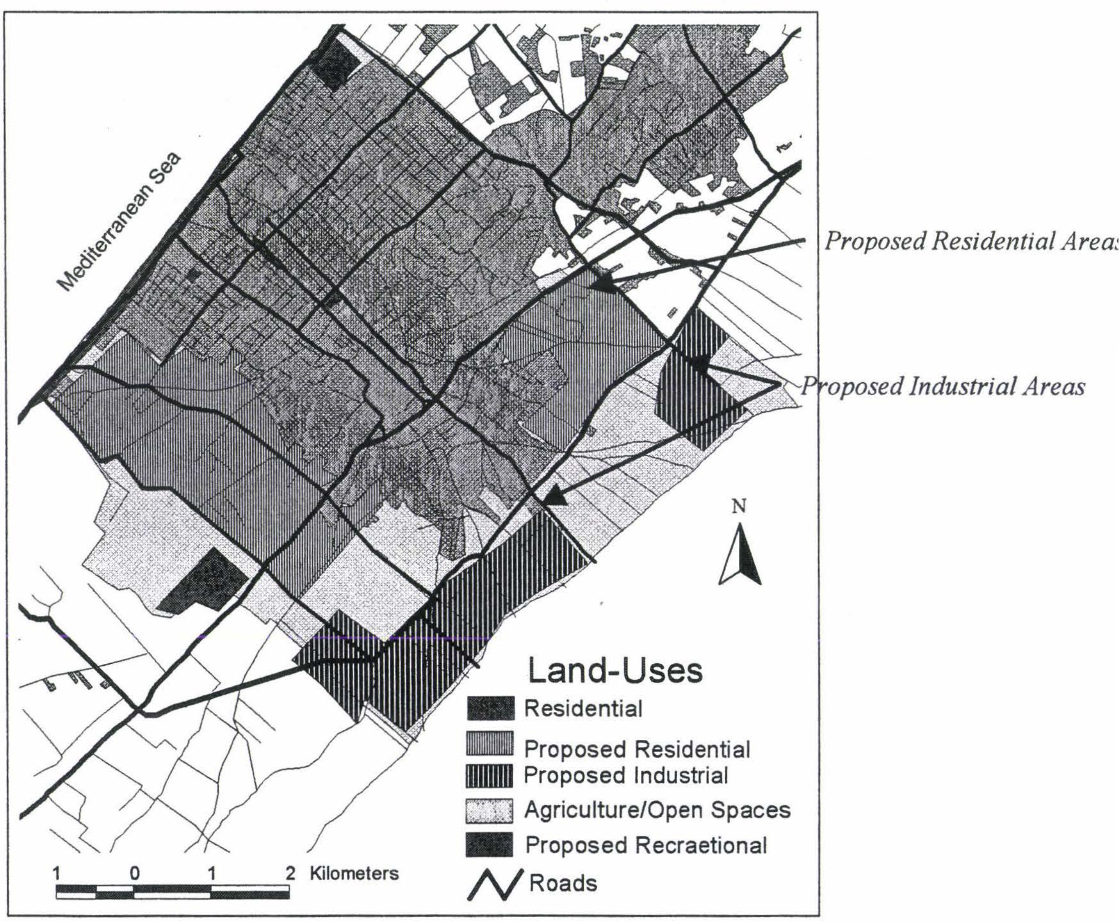


Figure 4.25 Proposed Spatial Arrangement

4.6.7 Concluding Remarks

The application of the artificial neural network (ANN) models proved a generic technique for mapping the relationship and predicting the land-use changes in Gaza. The approach followed for constructing the ANN model was based on socio-economic, environmental and institutional (SEEI) determinants in addition to time-series for land-uses data. Three optimal ANN models were found as a function of SEEI data for one year and the historical changes in the identified five land-use categories. The three models have different input and output combinations.

For additional validation of the selected models, a comparison with other used models such as multiple-linear regression model. The comparison clearly indicates the progressively performance of ANN model in terms of producing models with high correlation between actual and predicted values. In addition ANN model was developed with less efforts than that required for the development of regression model.

ANN models were applied to predict the future land-use demands based on two different scenarios, which are status-quo-scenario and sustainability scenario. The status quo scenario, with no overall view on development and no intervention from the Palestinian Authority, would be predominantly take place in case of minor changes in the socio-economic and political situation. The prediction for future under sustainability scenario indicates that choices could be made for better land-use management. This can be realized by reviewing the current policies and put in effective the most efficient policies for sustainability of land-use. For instance, setting priorities for poverty alleviation, unemployment reduction, water sustainability, landscaped open spaces development, establishment of industrial areas with environmental considerations, etc.

Therefore, ANN model can be easily used as land-use predictive tool for planners to assess the potential impact of the socio-economic determinants on land-use demands. Therefore, the ANN approach is a very promising technique that has significant capabilities to model land-use changes. Its results are rational, accurate, and feasible to use it efficiently by local land-use planners and decision-makers.

GENERAL CONCLUSION AND RECOMMENDATIONS

General Conclusion and Recommendations

Conclusion

In this research, a sustainability approach for land-use management has been developed based on cause-effect relationship. The sustainability approach gives insight into the management of land-use as a function of the complex interaction of a large number of socio-economic, environmental and institutional factors. The effectiveness of such an approach depends on finding the non-traditional ways of dealing with land-use management. The methodology presented in this research work, offers opportunities to simulate the future demand of land-use changes based upon actual land-use conditions and other determinant factors.

The determinant variables of land-use changes have been identified and prioritized using multi-criteria analysis with Artificial Neural Network (ANN) compared with other statistical techniques and expert opinion. The main findings of these analysis techniques are:

- Population group under the age of 19 years old followed by population density, access to wastewater network, percentage of labour forces, unemployment rate and poverty rate are the most socio-economic driving forces for land-use change.
- Percentages of households use cesspits for wastewater discharge, and ground water abstraction are the main pressing environmental pollution sources that associated with land-use changes. The salinity of domestic water is the most representative variable of the environmental impacts of land-use changes.
- Policies, regulations and funds allocated for development are the most institutional measure that affects the land-use changes.

These combinations of socio-economic, environmental and institutional variables in addition to the actual land-use for the last two to four years are used as a basis of land-use change explanations and modeling. These pathways indicate that land-use policies and projections of the future role of land-use change in Gaza City must not only capture the population growth as the only driver for land-use change but also account for the specific human resource and urban-environment conditions. This recognition requires moving beyond some of the simplifications that persist in much of the current understanding of the causes of land-use change and its driving forces. This does not preclude the development of a conceptually based, land change science. Rather, it calls for advances that capture the generic qualities both socio-economic and institutional drivers as well as the environmental conditions th affect and effect on land-use changes. Integration of these factors as well as recognition the increasing role of policies is required to meet the challenges.

The analysis of expert's opinions provide evidence support the conclusion that the simp answers found in population growth, poverty, and infrastructure rarely provide an adequa understanding of land-use changes. Rather, individual and social responses follow fro changing economic conditions, mediated by institutional factors. Opportunities a constrains for new land-use are created by markets policies, increasing influence by region factors. Various urban-environment conditions react to and reshape of the impacts of drive differently, leading to specific pathways of land-use change. It is precisely the combinations that need to be conceptualized and used as the basis of land chan explanations and modeling.

The approach of ANN-based model appears to offer great potential for studies of land-u change. It makes it feasible to construct multiple models for several datasets and to choo the optimal model among them based on certain performance criteria. ANN model can developed and used for assessing the influence of different driving forces on land-u changes. It has potential for analyzing different views of the causes of land-use change a give a future prediction of these changes. These predictions are very helpful for bett decision-making on land-use demands. Multiple-linear regression (MLR) has be developed for comparison purposes with the results of ANN model. It was obvious th ANN model has a better performance than the MLR model. In fact, the linear nature MLR model estimator makes it inadequate to provide good prognostics for a variabl characterized by a highly nonlinear data. On the other hand, the ANN model is a nonline mapping tool, which potentially is more suitable for land-use changes prediction. It offers flexible alternative and standard software can be used to construct intricate multi-purpo non-linear solutions. This method has no limitations in the form of fixed assumptions formal constraints and reasonable models can be developed on small data sets, through t addition of controlled random noise to the input patterns.

Scenarios of land-use demand aimed to explore possible future for land-uses under a set simple conditions and assumptions. The development of two scenarios revealed that in ord to achieve sustainability in land-use management, the socio-economic and institution development should be complied with the appropriate development policies. The developments would encourage the decline of population growth, re-planning of high urban densities, extend the wastewater network to cover all the city, Reduces unemployment rate and alleviate the poverty rates.

Expected impacts of research output on land-use management

The differences between the research results and expert opinion about the significance of land-use related indicators revealed that there is a need to develop new approaches that based on scientific findings. The proposed land-use management approach will assist land-use managers to gain better knowledge and understanding about the actual urban land-use driving forces, pollution pressures and environmental impacts. It will enable the public sector to better deal with the challenges of managing urban land-use changes in a sustainable manner. For scientists and policy-makers the results would help to understand, anticipate and possibly prevent the adverse effects of land-use changes, by focusing policies on those locations that are most threatened. The proposed approach intended to move the local government to more preventive role rather than responding to the problems after they occurred.

Recommendations for improving land-use management

Integrated land-use management in Gaza should be based on sustainability approach tha takes into consideration the three dimensions of sustainability, which are social, economic and environment. This requires understandings of land-use drivers that will enable planner and decision-makers to support the evaluation of land-use policies and associated impacts. I is recommended that polices and regulations at different administrative levels should b directed towards sustainability of human resource development and urban-environment That can be made through:

- Encourage the decrease of population growth and fertility rates. Hence, th population growth rate would continuously decrease to reach 2.8 in the year 201 which puts much lower pressure on land and gives more time and opportunity fo balanced development.
- The population density should be harmonized and well distributed among the city' neighborhoods by applying the sustainability approach on the district level.
- The percentage of households connected to wastewater network and facilities shoul be increased to more than 90% of the total households living in the city. Thi development would minimize the negative environmental impacts caused b inappropriate wastewater disposal methods.
- Decisions on investment in water, power, seaport, regional highways, industri zones and other major projects should be started immediately on the basis o consideration of socio-economic development and regional cooperation. Thes developments will play an important role in decreasing the unemployment povert rate.
- Development funds, local and external, should be directed towards the social sector such as health, education, environmental hygiene, recreation, etc.
- The local institutions should cooperate to regulate and mitigate the environment pressures and their negative impacts, mainly determine measures to stop pollution o groundwater resources. Environmental impact assessment would be an effective too for environmental protection before establishing any of any development project especially the industrial establishments.

- Considering the increase in population number of the city by the year 2015, the predicted land-use demand calls for expansion of the recreational and industrial areas. This expansion will give more opportunities for the city to accommodate the development in industrial and recreational facilities that will drive the land-use of the city to more sustainable situation.
- Incentives for investors should be designed to attract more investors especially in the industrial sector.

Recommended directions for future research

- The following research fields are recommended for future land-use management in the Palestine:
- Coupling land-use change models with biophysical models, allowing for multi-level interactions and feedback. Such coupled models can be used as decision support systems for policy formulation.
- Integration of spatial and empirical land-use modeling based on multi-criteria evaluation is still to be developed. The special modeling should be based on new modern technologies such as, remote sensing, satellite images, etc. These technologies could provide a spatially explicit, integrated and multi-scale evaluation for the current land-use changes. This approach could provide new techniques for the projection of alternative pathways into the future.
- Future researches are needed on applying the sustainability-modeling approach to other areas in Palestine where a random development occurred.

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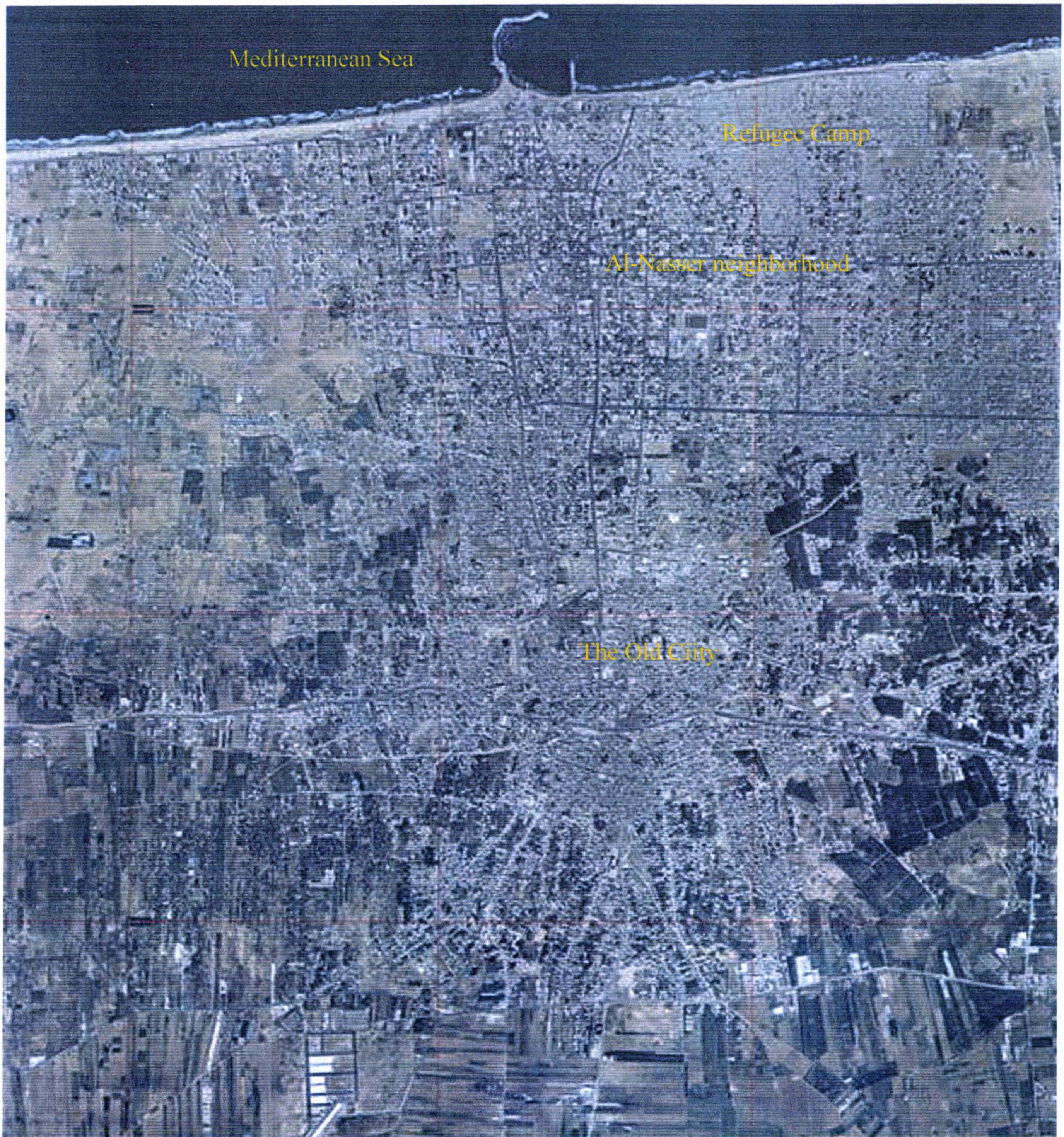
ANNEXES

ANNEX 1

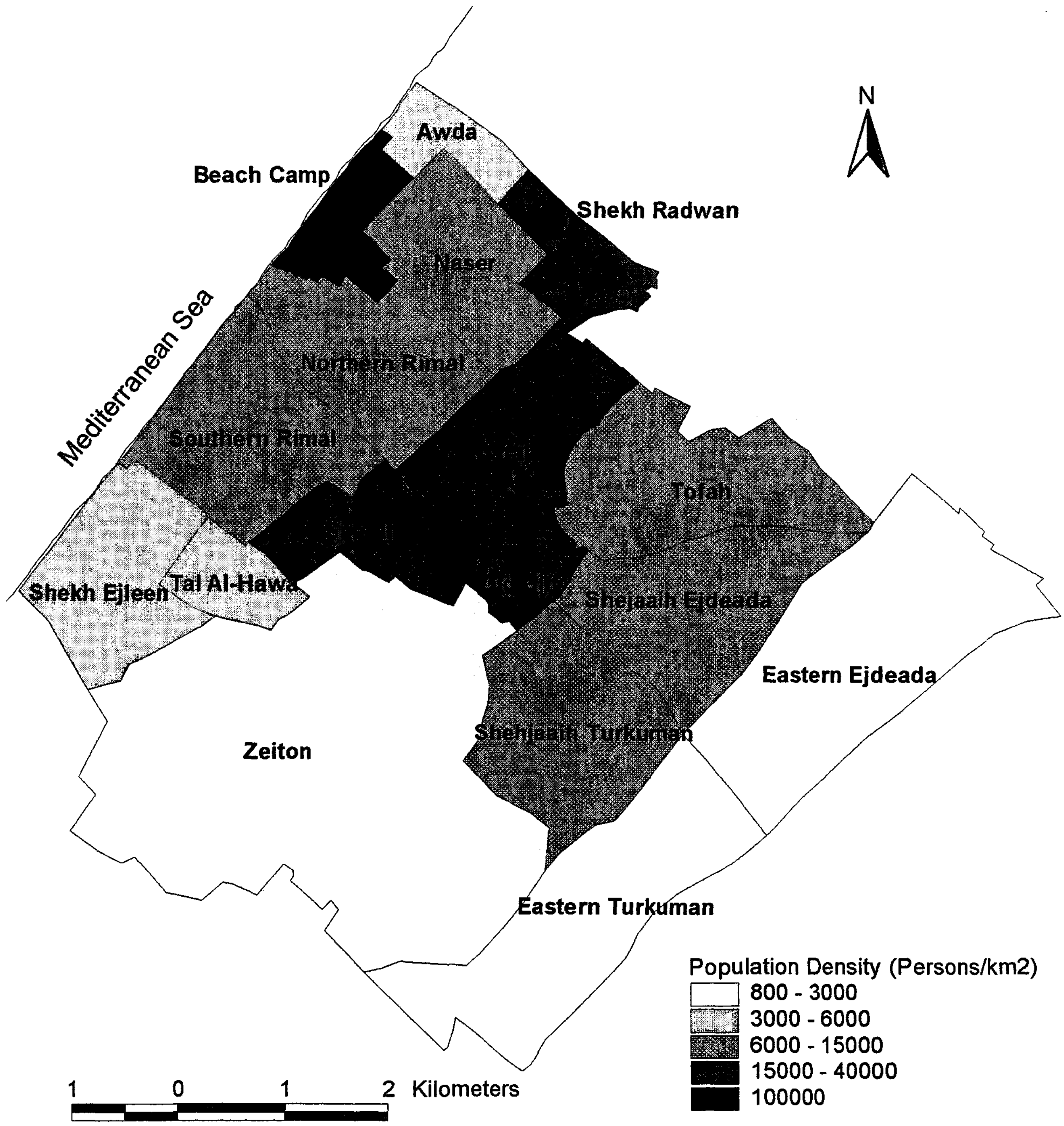
Aerial Photos of Gaza City, 1999



Aerial Photo of The Beach Camp , May 1999

Aerial Photo of Al-Nasser neighborhood , May 1999.

ANNEX 1.2. Population Density Map, 1999.



ANNEX 2

Data on Socio-economic, environmental and institutional indicators

Year	P19	PD	HWW	LF	UE	PR	WWC	GWA	TDS	FUND
1967	60.8	7330	28.5	**34.5**	**19.5**	43.0	52.1	15.8	410.0	0.7
1968	60.9	**7376**	28.6	**35.5**	18.8	42.0	51.2	**15.7**	**415.0**	1.5
1969	60.9	7403	28.9	36.2	17.0	41.0	50.0	15.7	425.0	2.4
1970	60.9	7480	28.8	36.7	15.3	38.0	51.2	15.8	434.0	**3.1**
1971	61.3	7607	29.0	37.1	13.3	35.0	52.4	15.9	439.0	3.7
1972	61.3	7672	29.1	37.3	11.0	31.0	50.1	16.0	448.0	4.4
1973	**61.0**	**7872**	**29.2**	37.9	**11.0**	32.0	49.2	16.1	454.0	5.2
1974	**61.0**	8015	29.6	38.0	**10.0**	30.0	**48.7**	16.2	467.0	5.9
1975	59.9	8316	29.8	37.7	9.4	30.0	**48.3**	16.4	471.0	**6.7**
1976	59.9	8429	31.7	39.8	9.5	28.0	46.1	**16.6**	**468.0**	6.8
1977	60.0	8648	30.3	**38.7**	8.5	25.0	45.5	16.8	479.0	8.0
1978	58.9	8585	30.1	40.5	8.3	23.0	43.6	16.9	480.0	6.5
1979	58.9	8449	32.5	40.8	8.3	20.0	43.3	17.0	488.0	6.9
1980	58.7	8109	32.0	41.3	8.2	**20.0**	43.1	17.1	482.0	6.7
1981	58.8	8196	32.9	41.1	8.2	21.0	41.8	17.3	487.0	7.8
1982	**59.0**	8314	32.5	39.8	8.0	22.0	41.2	17.4	498.0	7.4
1983	**59.0**	8492	32.1	39.7	**8.0**	21.0	40.4	17.6	508.0	7.9
1984	59.1	8608	**32.7**	39.5	**8.0**	21.0	41.1	17.8	543.0	**8.2**
1985	58.9	8750	33.3	39.5	8.0	23.0	43.3	18.0	525.0	9.3
1986	59.1	8926	33.0	38.9	**8.0**	23.0	40.6	18.2	510.0	10.2
1987	59.2	9103	33.3	**38.4**	**8.0**	23.0	39.8	18.4	521.0	10.4
1988	59.5	**9383**	33.6	37.7	11.7	25.0	37.6	18.7	520.0	10.3
1989	59.8	9610	34.0	37.2	16.1	27.0	36.3	19.5	500.1	10.8
1990	60.0	10067	33.8	36.8	21.0	30.0	39.5	20.3	595.1	10.7
1991	60.4	10421	34.0	36.4	25.8	31.0	38.7	20.6	603.2	11.4
1992	60.6	10919	34.0	36.1	28.1	32.0	35.7	20.6	636.2	12.2
1993	61.1	11416	34.8	36.3	32.0	32.0	34.4	20.8	1100.0	13.9
1994	61.1	11748	39.2	36.3	25.0	34.0	33.5	21.7	1680.0	21.9
1995	61.2	11367	39.8	36.1	20.0	31.0	32.2	24.7	1650.4	51.2
1996	61.3	11376	39.7	35.9	21.2	30.0	34.3	25.1	1720.3	46.0
1997	61.5	11789	36.8	35.6	22.0	33.0	35.6	26.8	1660.0	35.3
1998	61.4	11984	39.3	35.6	23.4	33.0	34.0	28.8	1502.0	33.6
1999	61.4	12277	47.4	35.9	25.5	32.0	32.9	29.7	1426.7	30.8
2000	61.7	12643	49.8	35.4	26.7	33.0	30.8	31.9	1314.7	15.5
2001	62.2	13127	52.4	35.1	33.3	42.0	30.1	32.2	1083.0	14.4
2002	62.4	13595	55.8	34.9	35.6	45.0	29.2	32.2	1259.0	17.7
2003	62.6	14133	56.8	34.7	38.0	50.0	28.1	32.3	1370.0	24.0

Bold figures are the missing data, which calculated by using trend analysis done by PCBS.

PG	Population growth rate (%)
P19	Percentage of population under the age of 19 years
HWW	Percentage of households connected to the wastewater network
LF	Percentage of Labour forces from the total population
UE	Percentage of unemployment from the labour forces
PR	Poverty rate (percentage of population living under poverty threshold)
WWC	Percentage of Population use cesspits for wastewater discharge
GWA	Groundwater abstraction (million cubic meters)
TDS	Total dissolve solids for Groundwater pollution (mg/l)
FUND	Total funds for development (Million US Dollars)

ANNEX 3

Experts Opinion and Judgment [1]

Questionnaire on Land-use Management

This questionnaire has been prepared as part of the research work on **Sustainability An Effective approach for Land-use management- application to Gaza.** The research is undertaken as part of the requirements for PhD program at Lille University for Science and Technology - France.

The research aims at establishing of an integrated land use management approach for Gaza city based on cause-effect relationship within sustainability context. The research will also investigate the most influential indicators that had shaped the evolving the current status of the land-use in the city for the period 1967-2003. The importance of this investigation is that it tackles the whole cycle of sustainability for land use management based on scientific approaches.

The indicators used in this research were divided into five categories, which are: socio-economic driving forces, environmental impacts and institutional measures. Artificial Neural Network (ANN) and other statistical techniques were used to produce the prediction model. These results will be compared with expert opinion resulted from this questionnaire.

The results of this questionnaire have very important value for this research in order to formulate sustainable land-use management approach. Therefore, the ranks that you will give to each indicator should reflect the correlation of this indicator and land use management (i.e. its importance in land use management).

Mohammed Eila

PhD Student

Lille University for Science and Technology

1 This Questionnaire has been distributed to 23 experts and professionals from different local Palestinian institutions.

Part I: General Information

Name: ....

Academic Background ....

Occupation: ....

Institute/Organization: ....

Years of experience in land use issues: ....

Part II

Could you please rank the following indicators from 1 to 32. The first rank will be given to the most important indicators (i.e. no. 1 in given to the most important indicator while no. 3 is given to the indicator that has the lowest importance in land use management).

You can skip the indicator/s that you fell it should nit be included in the model.

INDICATORS	RANK
Socio-economic Driving Forces Indicators	
Population rate of growth	
Percentage of population under 19 years	
Percentage of population living in Refugee camp	
Population density	
Fertility rate	
Infant mortality rate	
Life expectancy	
Percentage of students from the total population	
Illiteracy rate	
Percentage of households connected to water network	
Percentage of households to wastewater network	
Percentage of households connected to electrical network	
Labor forces	
Unemployment	
Per capita GDP	

Poverty rate	
Environmental Indicators	
Amounts of Solid waste	
Groundwater Abstraction	
Ground water quality (total dissolved solids-TDS)	
Percentage of households use cesspits for wastewater discharge	
Percentage of households discharge their wastewater to the sea	
Number of motor vehicles	
Electrical consumption	
Land Use Management Measures	
Road network Development	
Water network Development	
Sewer network development	
Establish new schools	
Establish new health facilities	
Establish new public parks	
Fund from local and external sources for development	

Comments:

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