Designing and Implementing a GIS-based Cadastral Database for Land Administration in the City of Asmara, Eritrea.

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DECLARATION

The work described in this thesis was carried out in the Faculty of Science and Agriculture, School of Applied Environmental Science, Discipline of Geography.

This study represents my own original work. Where use has been made of the work of others it is duly acknowledged in the text.

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ABSTRACT

The knowledge and application of land information and GIS in Eritrea are very limited and as a result there is a shortage of sufficient, reliable, up-to-date and modern land information for decision-making. This study aimed to develop and design a GIS-based cadastral database for land administration in the city of Asmara, Eritrea.

The two components of the cadastral data, the spatial and non-spatial were collected and processed in a GIS environment. GIS-based cadastral data was created to store the data. A recently acquired IKONOS image and existing Auto CAD data were the main sources of data for the study. Geo-rectification, conversion, building of topology, spatial adjustment, and digitizing were used for creating the parcels and roads of Asmara city. A key of relation was created to link both the spatial and non-spatial components of the cadastre.

The study used illustrated practical examples to show how GIS-based cadastral data could support land administration as practiced by the different divisions of the Municipal Office of Asmara city. The importance and usage of the cadastral database for urban planners and property valuators were detailed.

Spatial and network analysis were used to develop bands for creating a banded property appraisal system for assessing the service catchment areas of hospitals and the only fire station. Further, a location allocation model was also developed to recommend suitable sites for new fire stations in the city of Asmara.

It is recommended that the Municipal Office of Asmara adopts the designed GIS-based database. It is also recommended there the major cities in Eritrea follow similar methodology to design and implement cadastre database for their administration.

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ASCII	American Standard Code for Information Interchange
AUTO CAD	Automated Computer Aided Design
CBD	Central Business District
CIDA	Canada International Development Aid
DOE	Department of Environment
EELPA	Eritrea Electric Light Power Authority
ESRI	Environmental Systems Research Institute
FAO	Food and Agriculture Organization of the UN
FIG	Féderation International des Géomètres
GCP	Ground Control Point
GIS	Geographic Information Systems
GPS	Global Positioning Systems
MIE	Ministry of Information Eritrea
MLWE	Ministry of Land Water and Environment
NEMP-E	National Environmental Management Plan of Eritrea
DXF	Drawing Interchange File
PID	Parcel Identification
RS	Remote Sensing
TIN	Triangulated Irregular Network
UN	United Nations
UN-Habitat	United Nations Human Settlements Program
UNDP	United Nations Development Program
UNFPA	United Nations Population Fund
USAID	United States Agency for International Development
UTM	Universal Transverse Marcater
WGS84	World Geodetic System, 1984

CHAPTER 1: INTRODUCTION

1.1 General Introduction

Land and its resources have been the base of wealth for most societies since the beginning of civilization. However, the management of such land and resources has seen many and varied approaches and systems. At present and in the near future, there are two phenomena that threaten human well-being: the growth of the world population and the destruction of our natural resources; the two are inter-related (Henssen, 1990). Monitoring these problems and preventing future deterioration of the resources call for a just and efficient land administration in general (Dunkerley, 1983).

Eritrea Land Proclamation No. 58/1994 inspires the present study; this land proclamation is expected to make allocation of land for urban public services, commercial and residential purposes, so as to improve the quality of urban life. This means that government should do everything necessary to provide optimal access to land for all kinds of uses in a fair and equitable manner. This implies that for all kinds of activities, suitable land should be made available, and such land should be located and provided with the required infrastructure, public services and with security of tenure.

In order to promote this notion, there is a need to improve the efficiency of land administration in Eritrea. One of the necessary components of such improvement of land administration is obviously the provision of land information. A special kind of land information is the one that deals with land tenure, land use and land distribution and is called cadastre. It is also the basis for many parcel-oriented information systems and activities (FIG, 1995).

A cadastre is an administrative device, which shows the relationship of man-to-land, formed by a right or stewardship, and which must answer the questions of who, how, where and how much (Dale and McLaughlin, 1988).

Until recently the collection and compilation of cadastral data and the publication of a printed map was a costly and time-consuming procedure. The amount of data involved, and the accuracy and detail required for these maps of localized areas was difficult and often too costly to draft. Quantitative spatial analysis was often extremely difficult to attempt within the units delineated on the map without collecting new data for the specific purpose in hand. Municipal offices have been identified as some of the most important groups of users of cadastral data (Volkwyn, 1998), more specifically, cadastral data has been found to have applicability in a number of planning functions. They can be used in zoning, land use, transportation, economic development planning, site selection, and land suitability analysis (Budic, 1994).

While the term cadastre and cadastral system are used interchangeably in the literature, the term cadastre tends to refer to the actual cadastral data, whereas the cadastral system is the actual cadastral data and the collection of organizations and procedures that are associated with the cadastral data.

1.2 Problem Statement

A review of the cadastral and land information systems in Asmara city reveals that decision makers are not presently obtaining sufficient information from these systems to make informed decisions. A proper land information system in Eritrea is almost non-existent. The available one is not reliable for use in decision-making as it is handled manually and not supported by up-to-date cadastral parcel coverages. The registration of ownership rights to land in an accurate and timely manner can be a very difficult and elusive process. The difficulty in locating records of properties, their values and exact locations and their ownerships is a real problem throughout the country, especially in the city of Asmara Municipal Office. It is, therefore, difficult to tax property equitably and equally difficult, if not impossible to fund, locate, repair and upgrade infrastructure and public services.

In Asmara city a property tax is levied based on the area of the land parcel, this means that properties, which are well-developed with full access to urban amenities are charged the same tax compared to properties, which are situated at less serviced locations of the city. This system lacks both horizontal and vertical equity in taxation among properties.

It is not uncommon in the city of Asmara to find places where the roads are often unsurfaced and get flooded regularly. It is also not uncommon to find areas with the bare minimum of basic services and utilities provision, as a result the quality of urban environment and urban quality of life are deteriorated.

A major problem in the administration of land in Asmara city is a lack of up-to-date land information. Without an efficient cadastral system it is difficult to know where a property is located, who owns it, and its value; as a result it is difficult to tax property fairly, efficiently, and effectively. Without an adequate tax base it is difficult, if not impossible, to fund essential infrastructure and services. It is obvious that, if a city administrators and planners do not know the location and state of all existing infrastructure, and services, it would be difficult to repair, and upgrade them. Other consequence of a poor land information system in Asmara city is the inability to undertake city planning and acquire land for public services purpose.

1.3 Aims and Objectives of the Study

1.3.1 Aim

This study is concerned with urban Land Information Systems for enhancing the efficiency of urban land administration. The aim is to design and implement a GIS-based cadastral database for urban land administration in the city of Asmara.

1.3.2 Objectives

In meeting the overall aim of the study numerous objectives were set. The objectives are as follows:

- To review the existing cadastral data and investigate a means of developing a digital cadastral database.
- To develop a GIS-based cadastral database.
- To develop a banded property taxation system using the designed cadastral database for the city of Asmara
- To delineate the catchment areas of hospitals and the fire station in Asmara city.
- To identify suitable location for new fire stations in Asmara city.

1.4 Limitations of the Study

This study has been constrained by time and the available spatial data.

1.5 Structure of Thesis

The study is structured in six chapters. Chapter two reviews the literature explored with regard to the development and uses of land information systems (thus cadastral systems). Chapter three provides a description of the study area. Chapter four presents a description of the materials and methods used to achieve the objectives of the study. Chapter five deals with the procedures of applying the designed digital cadastral database for land administration, property taxation and hospital and fire station services planning. The research findings are also discussed in this chapter. Chapter six concludes the study and puts forward relevant recommendations regarding the results of the study.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

This chapter presents the literature explored in relation to the central problem that motivated this study, and in relation to its objectives. Literature is reviewed about urban land administration and the development of digital cadastral databases. The uses of GIS-based cadastral data for enhancing property taxation systems and public service planning are also reviewed.

2.2 Land

Land is the foundation of all forms of human activity; from it we obtain the food we eat, the shelter we need, the space to work, and the room to relax (Dale and McLaughlin, 1988). Land is man's most valuable resource. It is indeed much more than this: it is the means of life without which he could never have existed and on which his continued existence and progress depend (Barnard, 1953). Balchin *et al.* (1988) added that land is an economic commodity, which, like capital and labour, is needed for the production process, and that people and all kind of social and economic activities, need land. Kivell (1993) noted that land possesses a number of specific characteristics that makes land different from other commodities; such important characteristics of land are:

1. No cost of creation: Land can be considered as a free gift of nature. The cost of developing land to make it suitable for urban development, and the installation of services make the price of urban land significantly higher than raw land.
2. Fixed supply: Land can be intensified through change, for example through constructions, it can be changed from one use to another.
3. Immobile: Land is permanent it cannot be moved. Accessibility can be changed through road developments and transport opportunities. That makes land demand more flexible, and may result in changing land use patterns (Kivell, 1993).

2.2.1 Urban Land

Urban land is among the most valuable economic and social resources of any nation. The cities of the Third World are growing at an unprecedented rate because of rural-urban migration and high urban population growth rates. The UN-Habitat report states that, by the end of the 20^{th} century human kind will be crossing a threshold where over 50% of the population lives in urban areas (UN-Habitat, 1996). Urban areas are, in general, defined as being based on size and employment structure. The history of the development of cities goes back a long way to the cities in Egypt, Ancient Greece, and the Roman Empire (Roger *et al.*, 1992).

Urban land is the scene of considerable growth and transformation process; this results from the conversion of land from rural uses to urban uses and transformations from one urban use and ownership to another (Dunkerley, 1983). The dynamic nature of urban land makes cities throughout the world the scene of complex social and economic processes (Meyer, 1994). Thus, urban land cannot be properly managed without an adequate system for the measurement and recording of the boundaries of parcels, and the registration of all legal rights and relations related to each parcel thus without an adequate cadastral system (Doebele, 1985).

2.2.2 Urban Land Administration

There are many definitions of 'Land administration' mainly caused by a different understanding of the word 'administration'. Land administration is sometimes defined as 'the process of regulating land and property development and the use and conservation of the land, gathering of revenues from the land through sales, leasing and use of land' (Dale and McLaren, 1999). It is also defined as the process of determining, recording and disseminating information on ownership, value and use of land and its associated resources (UN, 1996). Gazdzicki (1998) noted that a good land administration system produces a number of benefits: guarantee of ownership and security of tenure, support for land and property tax, provision of security for credit, developing and monitoring land markets, protecting state land, reduction in land disputes, facilitating rural land reform, improving urban planning and infrastructural development, supporting environmental management, and producing statistical data.

In most of the Third World countries land needs to be carefully managed if it is to be properly used and if waste is to be avoided. Land administration in general entails decision-making and the implementation of decisions about land. Land administration may also involve making fundamental policy decisions about the nature and extent of investments in the land. It also includes the routine operational decisions made each day by land administrators such as surveyors, valuers and land registrars (McLaughlin and Nichols, 1989).

Land and the way governments deal with the land are issues of major importance in the development of society. The global objectives combating urban poverty and enhancing sustainable settlement are closely related to the land issue (UNDP 1992). According to the plan of action, strengthening legal frameworks for urban land administration and land ownership is strongly recommended, for the following reasons:

1. To facilitate access to land for the urban and rural poor;
2. To create efficient and accessible land markets;
3. To establish appropriate forms of land tenure that provide security; and
4. To facilitate public services (UNDP, 1992).

Ting and Williamson (1998) noted that, land administration is likely influenced by society's changing priorities. As society and its priorities are dynamic and its relationship with land is dynamic, so too must the land administration system be dynamic. Thus, modern land information systems that are capable of maintaining the dynamic nature of the relationship are essential for land administration.

2.3 Land Information Systems

The basic resource in all decision-making is information. LIS includes the acquisition and assembly of data, their processing, storage, and maintenance, and their retrieval, analysis and dissemination (Dale and McLaughlin, 1988). Several formal definitions of land information systems have been proposed. Best known is the one adopted by Féderation International des Géomètres (FIG): a land information system is a tool for legal, administrative and economic decision-making and an aid for planning and development which consists on the one hand of a database containing spatially referenced land-related data for a defined area, and on the other hand, of procedures and techniques for the systematic collection, updating, processing and distribution of the data (FIG, 1990).

There is a growing need all over the world for land information as a base for planning, development and control of land resources. In most Third World countries, there is a growing demand for better land information and development controls (Tukestra, 1998). For better land management and urban development control, detailed information about land use, who owns the land, who occupies which land, and what is the pattern of land use is required. In some cities in less developed countries as much as 75 percent of development may take place in the informal sector without planning control and with no adequate public services or the provision of suitable access to the land (Harriss, 1989). Under such circumstances, the land information is needed to guide urban infrastructure development. Such land information must be updated rapidly and continuously if the development is to be controlled. Land records, therefore, are of great concern to all governments, and formulation of land policy, and its execution, may in large measure depend on the effectiveness of land information. The availability of land is the key to human existence, and its distribution and effective use are of vital importance (Simpson, 1976).

Anderson (1981), observes that land information system is an aid in the planning and development for the maintenance and improvement of the standard of living. The usefulness of land information system depends upon its accuracy, completeness and accessibility, and also upon the extent to which the system is designed for the benefit of the user, rather than producer of the information. Dale and McLaughlin (1988) list four categories of LIS: environmental information, infrastructural information cadastral information, and socio-economic information.

2.4 The Cadastre

The cadastre is one of the types of land information systems and is simply described as a methodically arranged public inventory of data concerning properties within a jurisdiction, based on a survey of their boundaries (Henssen, 1995). From a database perspective a cadastre is a land information system where information is referenced to unique, well-defined units of land normally referred to as land parcels. The outline of these land parcels are normally shown in large-scale maps, are linked to textual land title registers and provide a spatial reference for other spatial or non-spatial related data (Marwick, 1997).

More specifically, the Féderation International des Géomètres (FIG) defines the cadastre as: "a parcel based and up-to-date land information system containing a record of interests in the land (for example rights, restrictions and responsibilities). It usually includes a geometric description of land parcels linked to other records describing the nature of the interests, and often the value of the parcel and its improvements" (FIG, 1995).

Parcel-based land information system is the simplest, most efficient way of representing land information. Much of human life, activities and properties have meaningful links with specific pieces of land. Ownership, occupancy, lease, and mortgage, are central to the whole sphere of economic activities, the question of who disposes of the land and has rights to the land is, therefore, of vital importance (Henssen, 1990). Henssen (1990) also argues that the most natural way to determine and locate a population is by reference to its dwelling sites that can be defined through the parcel numbers; enterprises can be located in the same way. Parcel-based land information is required in a wide variety of activities. Frequently, users range from existing or prospective landowners to lawyers, surveyors, valuators, real estate managers, and agencies at all levels of government

2.4.1 Types of Cadastre

Parcel-based land information systems may be classified according to the information they contain or the primary purposes for which they have been developed. Dale and McLaughlin (1988) identify three categories of cadastre:

1. A juridical cadastre: that serves as a legally recognized record of land tenure

(Williamson, 1997).

2. A fiscal cadastre: primarily developed for property valuation. It is an inventory of land parcels that provides the information necessary to determine the value of each parcel and the tax due on it (Dillinger, 1986).
3. A multi-purpose cadastre: that encompasses both the juridical and the fiscal cadastre with the addition of other parcel-based information. The multi-purpose cadastre is defined as a large-scale, community-oriented land information system designed to serve both public and private organizations and individual citizens (Oliver, 1985).

2.4.2 Historical Perspective of Cadastre

The origin of fiscal cadastres that support a system of land valuation, and land tax can be traced to Egyptian times (Dale and McLaughlin, 1988). On the other hand juridical cadastres, information systems that underpin the legal registration of land in support of land transactions are far more resent. It was not until the 1870s, when Napoleon Bonaparte established the first modern cadastral system by ordering the creations of maps and cadastral records that eventually established the foundation of the European cadastre (Roger *et al.,* 1992). In the 18th and 19th centuries, the cadastre was used in continental Europe for taxation and fiscal purposes (Williamson, 1997). Cadastral systems have evolved beyond their primary purposes to provide the basis for general land administration systems (Ting and Williamson, 1999). It is now recognized that an effective cadastral system is the basis for an efficient real estate market and fundamental for an efficient system of sustainable land use management (UNDP, 1992).

The cadastral systems have evolved from a tool for wealth resource to indispensable tools that manage the scarce resource and environmental concerns of the public. In modern times, as Enemark (1997) explained, with the advent of GIS and other elements of information technology, the use of the term cadastre is evolving for planning as well.

2.4.3 Cadastral System Components

The literature often uses the terms cadastre, cadastral system, cadastral data and cadastral map interchangeably. It is not always sufficiently clear whether the authors are referring to the entire cadastral system or specific cadastral components. The model presented by FIG (1995) (see Appendix A) indicates that the cadastral system consists of a number of components such as land register, maps, and survey data.

FIG (1995) describes a cadastral system as containing a record of legal interests in a land parcel and a geometric description of that land parcel. Eden (1988) describes these two components of a cadastral system using the terminology of spatial data, and textual data. In defining the domain of cadastral systems, Henssen (1995) uses the term 'land recording' to describe the two complimentary components of land register and the cadastral map. Henssen (1995) defines a cadastral map as: "the outlines of the property and the parcel identifier normally are shown on large scale maps which, together with registers, may show for each separate property the nature, size, value and legal rights associated with the parcel." Henssen (1995) also defines a land registration as: "the process of official recording of rights in land through deeds or as title on properties. It means that there is an official record (land register) of rights on land or deeds concerning changes in the legal situation of defined units of land."

Generally, cadastre consists of two main entities: the cadastral register and the cadastral map. Historically as described above the purpose for the establishment of the cadastre was for land tax purposes, rather than for the property market, and planning and monitoring urban land development. Recently, cadastral reform has resulted in the computerization of both the cadastral maps and registers. Fundamental to this study is the development and designing of the cadastral map.

2.4.4 Importance of Cadastre

A cadastre may be established for fiscal purposes (for example valuation and equitable taxation), legal purposes (conveyance), to assist in the management of land and land use (for example for planning and other administrative purposes), and enables sustainable development and environmental protection (FIG, 1995). Due to the character of its detailed land information, the cadastral system can be served as a basic land registration system, which is accessible to different governmental and private organizations. In this project, the designed cadastral system not only serves the fiscal and legal requirements, but also can apply the general urban planning for example allocation of safety institutions, using public sector allocation model.

From the renaissance until the late nineteenth century the cadastral map was, in many areas, an established adjunct to effective government monitoring and control of land (Baigent and Kain, 1992). A number of uses to which cadastral maps have been put by state agencies, including evaluation and management to estate land resources, land reclamation, land redistribution and enclosure has been reported (Baingent and Kain, 1992).

In addition to the functions associated with land tenure, the purpose of the cadastral systems as necessary infrastructure to assist in the management of land and land use, to enable sustainable development and environmental improvement has been stressed by Enemark (1997). Specifically, Enemark (1997) presents a concept to support the different business infrastructure component to support the different business systems in the area of land administration. Enemark (1997) cites these systems as:

1. Land Tenure Systems: to secure legal rights to land;
2. Land Value System: to levy tax on market value of land;
3. Land Use Control: to enable land use planning; and
4. Land Development System: to enable regulation of land development.

In urban areas, the cadastral system is essential to support an active land market by permitting land to be bought, sold, mortgaged and leased efficiently, effectively, quickly and at low cost. The cadastre is essential for efficient management of cities and permits land/property tax to be raised thereby supporting a wide range of urban services, and allowing the efficient management and delivery of local government services (Williamson, 1997).

2.5 Geographic Information System

GIS is a special class of information systems that keep track of not only events, activities, and things, but also of where these events, activities, and things happen or exist (Medyckj and Hearnshaw, 1993). GIS, in its simplest form, is information that relates to specific location (Abel *et al.*, 1994).

GIS has been variously defined in many ways and by many people including Burrough (1986), Aronoff (1989), Huxbold (1991), Healey (1991), and Goodchild *et al.*, (2001). But in Chrisman (1997) one of the most general definitions which was developed by consensus among 30 specialists could be found: GIS "A system of hardware, software, data, people, organization and institutional arrangements for collecting, storing, analyzing, and disseminating information about areas of the earth."

GIS applications involve several domains of knowledge, DoE (1987). Urban planning, route optimization, public utility network management, demography, cartography, agriculture, natural resources administration, costal monitoring, fire and epidemic control are some of the applications of GIS listed by Aronoff, (1989).

2.5.1 Analytical Functions of GIS

It is the ability to analyse geographical patterns and relations, which differentiates GIS from other computer systems, such as those used for computer cartography, computer aided design, remote sensing and database management (Maguire, 1991). The analytical functionality of a GIS provides information for the support of decision-making. The role of GIS is to manage spatial data and produce reports and maps for use within the model. In effect, the system serves as a zoning assistant, allowing the user to interact with the spatial decision supporting system (Armstrong *et al.*, 1990).

Poor location decisions in facilities siting may result from a variety of factors, the most common of which are uninformed land use planners. However, recent advances in GIS provide decision makers with efficient tools with which to organize and structure the spatial decision making process (Densham, 1991).

2.5.1.1 Network Analysis

A network analysis in a GIS is often related to finding solutions to transport problems. In general a network is a system of interconnected linear features through which resources are transported or communication is achieved (Lombard *et al.*, 1993). One major application of network analysis is found in transportation planning, where the issue might be to find paths corresponding to certain criteria, like finding the shortest or least cost path between two or more locations, or to find all locations within a given travel cost from a specific origin (Zhan, 1997).

2.5.2 Database Management Systems (DBMS)

Central in a GIS is the database management system (DBMS), a database management system provides a number of functions to create, edit, manipulate and analyse spatial and non-spatial data in the application of a GIS. A database is a collection of one more data files stored in a structured manner, such that interrelationships which exist between different items, or sets of data, can be utilized by the DBMS software for manipulation and retrieval purposes (Healey, 1991). A geographic database is a critical part of an operational GIS; this is because of the cost of the impact of a geographic database on all analysis, modeling, and decision making activities (Date, 1995). Its completeness and accuracy affects all the applications it supports. For best results, the database should be organized to efficiently serve one or more application and be maintained by a set of well-documented and well-administered procedures.

2.5.2.1 Database Design

A database is designed to serve the needs of a group of users for different applications. The goal of the designed database is to serve Municipal Office in their daily activities for example assessment, transportation planning and maintenance, public safety, planning and zoning, utility planning and service allocation, disaster planning and response, economic development plan, and natural resources management (Dangermond *et al.*, 1986).

As discussed earlier cadastral data consist of two basic types of data: spatial data and non-spatial data. Each of these data types has specific characteristics, and each has different requirements for efficient data collection, storage and display. The spatial cadastral data contains boundary lines and property parcel polygons, each with unique identifiers. The non-spatial cadastral data includes additional information about property parcels. The term unique identifier refers to a unique number that is used by the computer systems to reference either a spatial feature and/or its relative attribute/non-spatial information (Gatrell, 1991).

Goodchild *et al.* (2001) proposed five broad stages for the development of a database:

1. Conceptual: user needs and requirements, feasibility evaluation;
2. Design: system design and database design;
3. Development: acquisition hardware, software and data;
4. Operation: system installation, data conversion, development of application; and
5. Audit; evaluation for improvement and expansion.

The conceptual model or logical design is the user's view of the interrelationships between data sets stored in the database. The relationship database model is widely used, and is based on a number of fundamental concepts including entity sets, attributes, domains, relationship sets and mappings. In relational systems, all data are represented in tables (relations) of rows and columns; each row represents the data of an individual entity set.

Database can be classified according to the way they store and manipulate data. According Zeiler (1999), there are three types of database used in a GIS today: Relational Database Management Systems, Object-Oriented Database Management Systems, and Object-Relational Database Management Systems.

Codd 1970 defined a series of rules for the efficient and effective design of database table structures. The heart of Codd's idea was that the best relational databases are made up of simple, stable tables that follow four principles:

1. Only one value is in each cell at the intersection of row and column;

2. All values in a column are about the same subject;
3. Each row is unique; and
4. There is at least one unique value of the relation thus key of relation.

2.6 GIS-based Cadastral Databases for Municipal Offices

Much of the day-to-day work of Municipal Offices involves cadastral map of the city. The information on these maps is constantly changing, requiring the maps to be modified or completely redrawn to keep current (Larsson, 1991). This is very expensive, labour and time consuming process to do manually. Antenucci (1991) explains the basic function of GIS as the following: "One of the most frequently utilized capabilities of GIS is its ability to store maps digitally and update information on an on-going basis."

Development in information technology has made the automation of spatial and non-spatial database possible, and the automated databases have proven to be cost-effective, and more efficient, compared with manual registration systems (Dale and McLaughlin, 1988). Moreover, an increasingly useful application of GIS in cadastral systems, which provide up-to-date records of land tenure, land values and land use in both textual and graphic formats, stimulated the importance of cadastral system. With GIS all the information stored in a multitude of maps, paper tabular files, computerized database and large lists of names and the interrelations of the numerous features and their characteristics analyzed as related to a given problem (Chou, 1997).

2.7 Cadastral GIS for Property Taxation

Property taxes are compulsory charges or levies, which relate specifically to ownership, occupation or development of land and buildings (McCluskey *et al.*, 1998). They are mostly levied on capital value or annual rental value and are collected for use by municipal offices. Their effects are both fiscal (revenue generation) and regulatory (encouraging property development and/or discouraging land speculation).

In order to raise financial resources to provide infrastructure and services, the municipal offices (public sector) typically charges the user for the services rendered (Davey, 1993).

The main aim of any property rating system is to raise revenue for provision of services by the urban authority (Konyimbih, 2001). Thus property tax is related to the benefits received; these benefits are in the form of provision and accessibility to the public services in general. Davey (1993) outlines the main reasons for charging property as to attain rational use of limited financial resource, generate financial resources to cover incurred costs to the society, and maintain equality among the municipal citizenry.

Out of the revenue collected by Municipal Offices the property rates is the best candidate due to the special inherent characteristics of landed property. According to Nsamba-Gayiiya (2001) these special characteristics include: fixity in supply (within certain limits), fixity in location, permanence (within broad limits), and visibility.

Much as property taxation is appreciated as an attractive and promising option for financing municipal offices operations and for providing municipal office with access to a broad and expanding tax base, unfortunately the performance and productivity of the property tax systems in most countries are still below their potential. Mou (1996) asserted that, "...one of the most lucrative yet least tapped sources of tax revenue to support urban government in Africa is property tax" (Mou, 1996). Further Mou (1996), explain the reasons for the dismal performance are many and varied, but they can be summarized as follows:

1. Poor coverage, many properties are out of the tax net;
2. Inaccurate valuation and inflexible bases;
3. Critical shortage of professionals;
4. Unwillingness of urban residents to make contribution through the property rates for non-existent or poor quality services;
5. Lack of transparency and accountability; and
6. Lack of efficient land information systems.

Most African countries have serious problems in respect of the capacity to properly assess properties for property taxation purposes. Lack of professional land information is stated as a serious problem in Kenya (Olima, 2000) and Tanzania (Masunu, 2001). The condition is the same in other East Africa countries.

Bahl, (1998) noted that to effectively administer the property tax, municipal offices must carry out the following tasks:

1. Identify the property and the liable taxpayer;
2. Keep the records in a readily usable way, and update these records on a regular basis;
3. Value each property subject to tax, and maintain an up-to-date valuation roll;
4. Carry out an effective billing and collection process; and
5. Handle appeals and litigations.

2.7.1 The Concept of Equity and Fairness in Property Taxation

Woolery (1989) suggests that the terms "equity" and "fairness" are often used synonymously in tax literature. However, from the perspective of property taxation, a distinction should be made. Fairness should be related to the legislation upon which the tax is promulgated (Woolery, 1989). This means that the legislation should specify whether different types of property are to be taxed at different percentages of market value or whether different groups of taxpayers are to be given some form of preferential treatment, such as exemption.

Equity, or more specifically assessment equity is a measure of how well the property tax system is administered in terms of assessed values. Equity can be considered from two different viewpoints: firstly there is horizontal equity, which prescribes that two identical properties having the same value should have the same assessed value, and secondly, vertical equity which states that, for example, a property having value of twice that of another property should have twice the assessed value (De Cesare and Ruddock, 1998). Vertical equity can be either regressive, when high-valued properties are under-assessed relative to low-valued properties, or regressive, when the opposite holds true (IAAO, 1997). Both these contracts have an important bearing on the actual distribution of the tax liability.

Throughout the world there is no common or right general tax system or tax rate; it is a matter of preference. For example, in Kenya, a property tax system is in favour of residential properties over commercial and industrial properties (Olima, 2000). The exempted type of property varies from country to country. The commonly exempted properties, in most countries including Eritrea, include: churches, cemeteries, public hospital, governmental offices and institutions, charitable institutions, and educational institutions (Dowall *et al.,* 1991).

2.7.2 Property Valuation Systems

Property has value because it provides amenities and satisfactions of living, as in the case of residences; services in the production of goods, such as a manufacturing plant; and income in the form of rents or leases. Franzsen (1999) lists, the main appraisal approaches for a value-based property tax as follows:

1. Self-appraisal approach;
2. Traditional manual appraisal approach;
3. Mass appraisal approach; and
4. Banded appraisal approach.

2.7.2.1 Self-appraisal

In this approach owners value their properties. The real problem of self-appraisal is the equity of property tax can be destroyed, as people with similar valued properties may end up paying different levels of tax (Villela, 2001). This approach may lead to significant inequities, verification of values would be costly giving the natural tendency to under-estimate values and the tax base would be unstable, leading to a lack of buoyancy in revenue and possible high rate of non-compliance.

2.7.2.2 Traditional manual

The traditional manual approach of assessment relies heavily on expert knowledge and it is intensive on manpower resources as each property tends to be individually assessed (Olima, 2000).

2.7.2.3 Mass appraisal

This approach has the advantages of objectivity, economies of scale and the ability to update values frequently. Whilst its use is becoming more widespread it does suffer from a number of important drawbacks including high initial cost of introduction, lack of transparency in the derived models and the need for suitably qualified specialized staff (McCluskey *et al*, 1998).

2.7.2.4 Banded appraisal

The banded appraisal approach by definition is a robust approach to value assessment. Under this system each property is allocated to one of the value bands, although it is possible to vary the number of bands and to have fewer wider bands or narrower bands, as appropriate (Antwi, 1997). This means that properties within the same band pay the same property tax, and there is essentially no need to have detailed, discrete valuations of each property.

The banded approach is to a large extent flexible, the relation in respect to tax paid can be changed by altering the relative weights between the bands (Paugam, 1999). Further it is a quicker process, when timing is important, and is a cheaper process, when costing is important (Paugam, 1999).

2.7.3 Factors Influencing the Value of a Property

The value of a property depends in part upon conditions inherent in the property and in part upon factors, which are extraneous to it. The intrinsic factors include the topography of the land, the nature of the soil, and the design and condition of the buildings. Extrinsic factors include the environment in which a property is located, the proximity to other land resources, and the availability and proximity of transport and public services (Dale and McLaughlin, 1988).

Urban land value depends not only on location and accessibility, but it also responds to availability. Availability in turn depends on accessibility and the provision of public services and infrastructures (Adair *et al.*, 1987). Hurd (1903) attempted to explain the cause of different land values within an urban area and suggested that, "...since value depends on economic rent, and rent on location and location on convenience, and convenience on nearness, we may eliminate the intermediate steps and say that value depends on nearness."

Haig (1926) suggested that "Property value rent appears as the charge which the owner of a relatively accessible site can impose because of the saving in transport costs which the user of the site makes possible." His theory emphasized the correlation between houses rent and transport costs, the latter being the payment to overcome the 'friction of space'; the better the transport network, the less the friction (Haig, 1926). In attempting to quantify spatial variation in property rent Alonso's general theory of land value (Alonso, 1964) proposes that property values decline outward from the central business district (CBD) to offset declining revenue-earning ability and higher costs such as transport. Rent gradients emerge consisting of a series of bid-rents for each land use where the steepest gradient prevails.

This competitive bidding real estate values can be said to comprise two main components: land (or location) and improvements (buildings, and related features). Identical buildings in different locations can have widely differing rental and capital values. The difference is accounted for by the land/location element of total value: high value indicates high demand for that particular type of facility in that general locality; low value indicates that the market for that facility is poor. This principle has been expressed as the concept of bid rent (Alonso, 1964).

However, Gallimore *et al* (1996) appear more cautious in their view of measuring the influence of accessibility on residential property value. Accessibility to employment and shopping centres, leisure and educational facilities, exposure to neighbourhood and environmental factors exert themselves in a complex interaction when considered as influences on value.

2.7.4 GIS for Property Valuation

There have been various studies on the application of GIS to land and property appraisal as well as to real estate analysis. The advantage of the GIS in property appraisal is that a GIS technique enables a more quantitative approach based on the analysis of spatial data.

Kim (1993) researched spatial decision support for real estate investment analysis. Longley *et al.* (1994) used GIS for analyzing and comparing the tax value of Cardiff Inner City, Wales. In their study, GIS was used to display deviations between predicted house values and council tax assessments. Longley *et al.* (1994) suggest that a GIS provides a suitable means of devising property assessments based on comparisons with the asking prices of 'similar' properties in a given area.

Wyatt (1997) used GIS to create a property database and to automatically access location attributes such as accessibility to the marketplace and proximity to suppliers. In particular, Wyatt (1997) used network analysis to examine the influence of accessibility on property value.

Cheng-Ho *et al* (1996) used a GIS to generate distance variables (to work, schools, shopping malls, etc.) in a study of apartment rents.

In general GIS technology offers many tools to assist municipal offices, and property assessors in particular. Wyatt (1997) details the potential benefits of the GIS technology for property assessors: inventory of parcels on tax rolls, integrating multiple factors for valuation, utilizing spatial relationships in equalization analysis, updating and maintaining property parcel maps, and easier retrieval and display of property information.

2.8 Urban Planning

Urban planning involves many functions, scales, sectors, and stages. In general the functions of urban planning can be classified into general administration, development control, plan making, and strategic planning (Yeh, 1999).

The most commonly used planning tools are master plans, strategic plans and structural plans including different zoning measures. Experience has shown that general and master plans tend to be static and prescriptive based on the assumption that cities grow slowly, they also tend to ignore how household and commercial-sector demands for land change in response to price fluctuations (Yeh, 1999). For developing countries, a more appropriate and dynamic planning tool is structural planning. Structural planning provides a broad framework for local decision-making, thereby encouraging public participation and it is more indicative than a master plan, in that it requires not only projections of the future demands and needs of a community, such as housing, infrastructure, employment, transport, local markets, but also environmental aspects for example waste management (Masser *et al.*, 1991).

Planning policies are concerned with equity and better distribution of people and activities in the territory, which is why accessibility, regardless if it is measured in time, cost, distance, or population, is the most important variable that one must consider in the early stages of urban planning (Juliao, 1999). Database management, visualization, spatial analysis, and spatial modeling are the main uses of GIS in urban planning. Spatial analysis and modeling are used for site selection, identification of planning action areas, land suitability analysis, land use transport modeling, and impact assessment. Interpolation, map overlay, buffering, and connectivity measurement are the most frequently used GIS functions in spatial analysis and modeling. The use of these functions varies according to different tasks and stages of urban planning (Yeh, 1999). Thus the implementation of GIS provides the municipal offices with a significant opportunity to improve the effectiveness of its policy and efficiency of its programs.

2.8.1 Public Services

Municipal offices in Africa today face a rapidly growing demand for urban public services as a result of continuing rapid urban population growth. These services differ from country to country but they can be broadly categorized into water provision, solid waste disposal, physical infrastructure provision and maintenance (roads, drainage), street lighting, sewerage, health facilities, education, fire stations facilities. Bahl *et al.* (1992)

observes that local government services can be categorized into three types namely need services which are made available to all individuals irrespective of their financial resources for example education, health, fire station; amenity services benefits from their provision tend to be geographically concentrated for example street lighting, waste disposal and environmental health; and facility services these are provided to individual consumers and in principle be required to pay for them.

2.8.1.1 Public Service Allocation

The problem of optimally locating facilities and allocating the demand to the facilities has been of great interest to Municipal offices. Most of the infrastructure planning activities involves decision-making based on spatial location/allocation of facilities. This issue is of great interest in Third World where there is a large demand for infrastructure development, communication, educational facility, public distribution system, electricity, markets, and public health (Sanaei-Nejad, 2002). However, a number of factors should be considered when developing any allocation model. There are: the nature of the geographic area being served, the population density of the area in question, the land-use patterns of the locality, and the maximum travel speed responding units can expect to maintain in different parts of the city, if that is an emergency service to be located (John *et at.*, 1999).

2.8.1.1.1 Fire Station Planning

Emergency preparedness of a city is measured in terms of its ability to deploy emergency response units in a timely and effective manner of an event occurring. Response time is a primary consideration in deploying emergency response units i.e. defined as the travel time from the location of the response unit to the scene of an event. Fire service resource planning is dominated by two factors, time and distance; all fire services are always delivered to a geographical point and although the exact circumstance of an individual incident can not be predicted on most occasions the situation will get worse with the passage of time (John *et al.*, 1999). Emelinda (2000) recommends a maximum critical timeframe of eight minutes from time of call.

2.8.1.1.2 Health Facility Planning

Health care facility planning is one of the planning fields that use spatial data in its resources allocation process. GIS can be used into three areas of health care planning fields; these are spatial changes in health status, spatial epidemiology, and health care facilities accessibility or service area (Brown *et al.,* 1991)

One of the basic objectives of healthcare planning is to have an equal access to health care for all. This means that every resident should have equal chance to go to hospitals. Cadastral GIS can be used to map the distribution and catchments service area of hospitals and also to analyze accessibility of hospitals to each parcel.

A good example of using cadastral GIS for linking social profiles with health needs was undertaken by Hirschfield *et al.* (1995). Johns *et al.* (1995) used GIS to test the relationship between health outcomes and accessibility. Forbers *at al.* (1995) also used GIS to evaluate the potential locations for a new radiotherapy unit for cancer treatment in northwest England.

Evaluating the accessibility of existing health facilities is also another task carried by health facility planners Gatrell *et al.* (1999). The health planners determine the areas, which have poor accessibility for certain health facility. GIS has therefore been used as a catalyst to make decision-makers more aware of the geographical location and geographical intensity of the problems (Worrall *et al.*, 1997).

2.9 Summary

This chapter has broadly outlined the importance of urban land and its administration. Components of cadastre, historical development of cadastre, and importance of cadastre are mentioned. Designing techniques of GIS-based cadastral database and its importance for Municipal Offices activities with special application to property taxation and urban planning are briefly addressed and discussed in this chapter. Chapter three provides a preamble to the study area.

CHAPTER 3: THE STUDY AREA

3.1 Introduction

The study area is Asmara city, the capital of Eritrea. Eritrea is located in the eastern horn of Africa, bordering the Red Sea. Eritrea is a newly born country which came into existence in may 1991 after three decades of armed struggle won a victory against Ethiopian government forces. This chapter provides a background to Eritrea in general and Asmara city in particular. Further, the land information system, property taxation and urban planning of the city of Asmara are also discussed in this chapter.

3.2 Eritrea

3.2.1 Short History of Eritrea

The recorded history of Eritrea dates back to 400BC, however this study will attempt to highlight the modern colonial era. Eritrea had been colonized by different groups of colonialists for about a century, and like all African countries, it took its present shape at the end of the 19th century.

On 1 January 1890, the Italian king proclaimed the colony of Eritrea, with the port of Massawa as its capital. A year later, Italy moved the capital city to Asmara. By the early 1930's Eritrea was crisscrossed with new roads and communication networks. A narrow-gauge railway linked Massawa with Asmara and inland areas west of Agurdat (150 Kilometers west of Asmara). More than 300 small workshops and industries arose around the capital city and the two ports, and many large labour intensive farms and plantations were established in the countryside (MIE, 2002).

In April 1941 the British established a military administration in Eritrea. After the end of World War II, the British allowed new forms of organization that provided an institutional framework for political action, new clinics and schools were opened and Eritreans were hired into these new institutions (MIE, 2002).

On 2 December 1950, the UN (United Nations) voted to accept a proposal, from USA, that Eritrea be part of a federation under the authority of the Ethiopian crown, and this was effected on 15 September 1952. Ethiopia's abrogation of the federation and its harsh repression of nationalist sentiments created aggression. Then an armed struggle started against Ethiopian forces on 1 September 1961. After thirty years of bitter struggle, Eritrea achieved total *de facto* independence on May 24, 1991, in a stunning defeat of the occupying Ethiopian forces. On May 24, 1993, the *de jure* independence was announced after national referendum, soon afterward (MIE, 2002).

3.2.2 Location of Eritrea

Eritrea, as illustrated in Figure 3.1, is located in the eastern horn of Africa, and extends between 12°22'N and 18°02' N and 36°26'E and 43°13'E. The total area is about 125000 Km^2, which includes 350 islands in the Red Sea. Eritrea has three neighbouring countries namely Sudan to the north and west, Ethiopia to the south, Djibouti to the southeast and the Red Sea to the east, see Figure 3.1. Thus Eritrea is located in one of the most strategic places of the world and has a long coastline of 1200 kilometers.

3.2.3 Topography

Three physiographic features characterize the landmass of Eritrea: the highlands (central part of Eritrea), the lowlands (eastern coastal area and western lowland), and the escarpments and slopes.

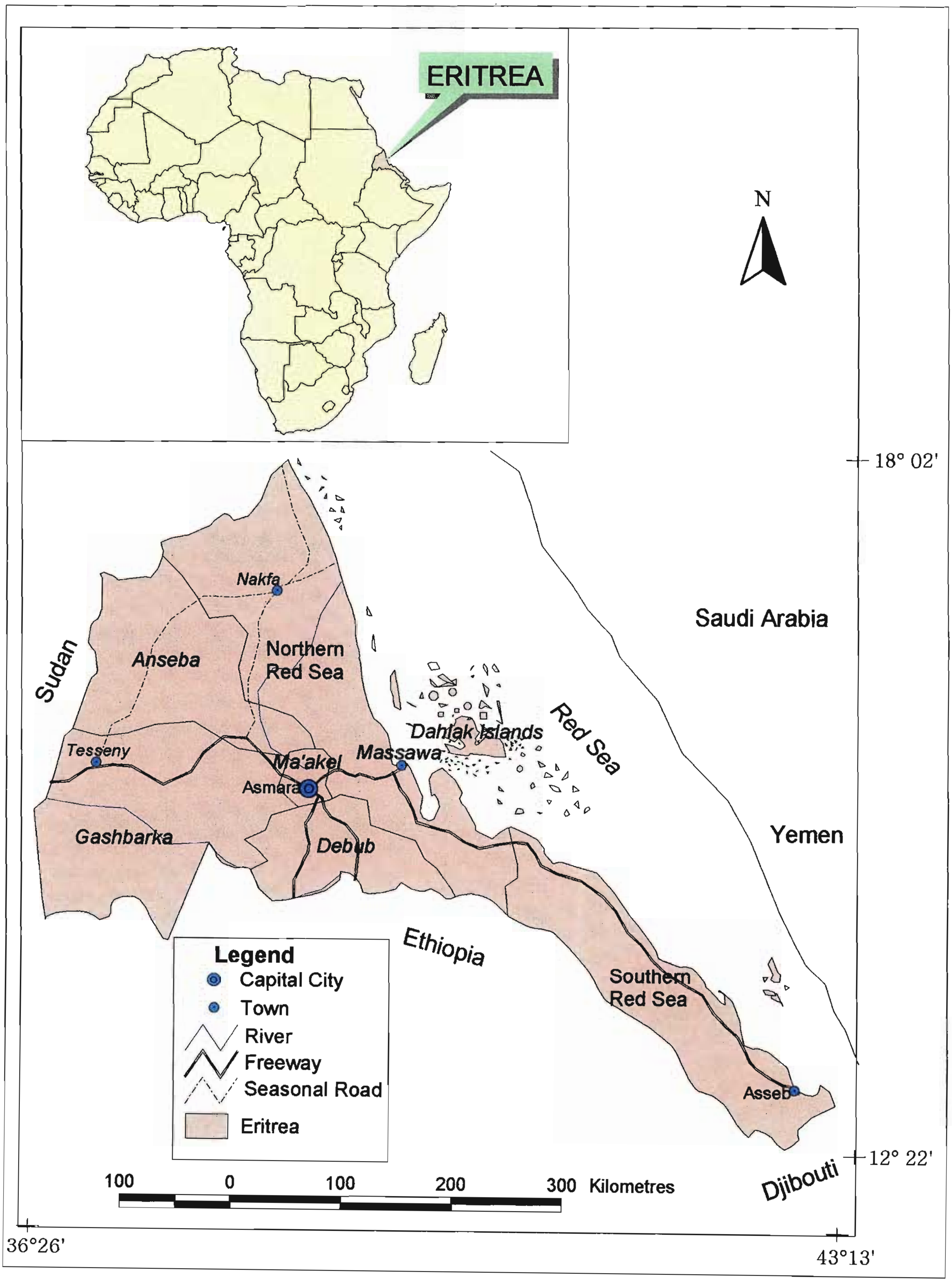


Figure 3.1 Location of Eritrea

3.2.4 Climate

The physiographic features determine the climate of Eritrea. The highest temperatures are in the coastal areas and occur from June to August and range from 25°C to as high as 45°C. The rainy season along the northern Red Sea coast extends from December to February. Rain is scarce along the southern Red Sea coast. In the central highlands, the highest temperatures are in May, reaching 30°C. However, temperature can fall as low as the freezing point at night during the winter months of December and January. The main rainy season in this area extends from June to early September. The western lowlands experience the hottest season in April to June with temperatures reaching 40°C. December is the coldest month, as temperature drops to 12°C. The rainy season in the western lowlands is similar to that of the highlands.

3.2.5 Population

The Eritrean population is estimated at about 3.6 million. Composed of nine ethnic groups, each with its own language while Tigrinya, Tigre, and Arabic are the most widely used languages. The population is almost equally divided into Christians and Moslems. The population growth of Eritrea is 3.8% and life expectancy at birth is 50 years (NEMP-E, 2001).

The geography of the country determines the activity of the society. Those who predominantly inhabit the highlands engage in sedentarized agriculture, those who live in the western lowlands practice pastoralism and agropastoralism, and the society of the coastal area is engaged in pastoralism. Approximately 80% of the Eritrean population live in rural areas, 20% of which comprises nomadic or semi-nomadic. The remaining 20% of the total population lives in towns (NEMP-E, 2001).

3.3 City of Asmara

3.3.1 Introduction

Although it would be easy to think of Asmara, the Eritrean capital, solely as an Italian-built colonial city, its origins date back some 700 years. A historical scripture, titled

"*Zanta Ketema Asmara*" literally meaning history of Asmara, tells that originally, it is said, there were four clans living in the current Asmara area on the central highlands. The clans decided to unite to defeat their common enemies. After the victory, a new name was given to the place, "*Arbaete Asmara*" which literally meaning the four are united. Eventually *Arbaete* was dropped and it has been called Asmara. Asmara was made a capital city in preference to Massawa by the Italian governor in 1891.

3.3.2 The Physical Set-up

3.3.2.1 Location

Asmara is by far the largest city in Eritrea; and is located in the central part of Eritrea, between 15°20'18" and 15°25'23" N, and 38°53'03" and 38°57'58" E. Figure 3.2 shows the location and extent of Asmara city. The total area of Asmara city is about 255 km^2. It has thirteen sub-administration unities.

3.3.2.2 Topography

Asmara is located in the central highland plateau (Figure3.3). Elevation values range between 2271 and 2352 metre absl. The landscape is characterized by gentle slopes, and generally slopes range between 0 and 20%. The slope gently decline as we move from the northern part of the city to the southern part of the city. The highest point in the city called "*Forto*" is in the western part of the city.

The high altitude and location relative to the Red Sea make the plateau, where Asmara is located, cooler, wetter and more suitable for rain-fed agriculture compared to the surrounding lowlands.

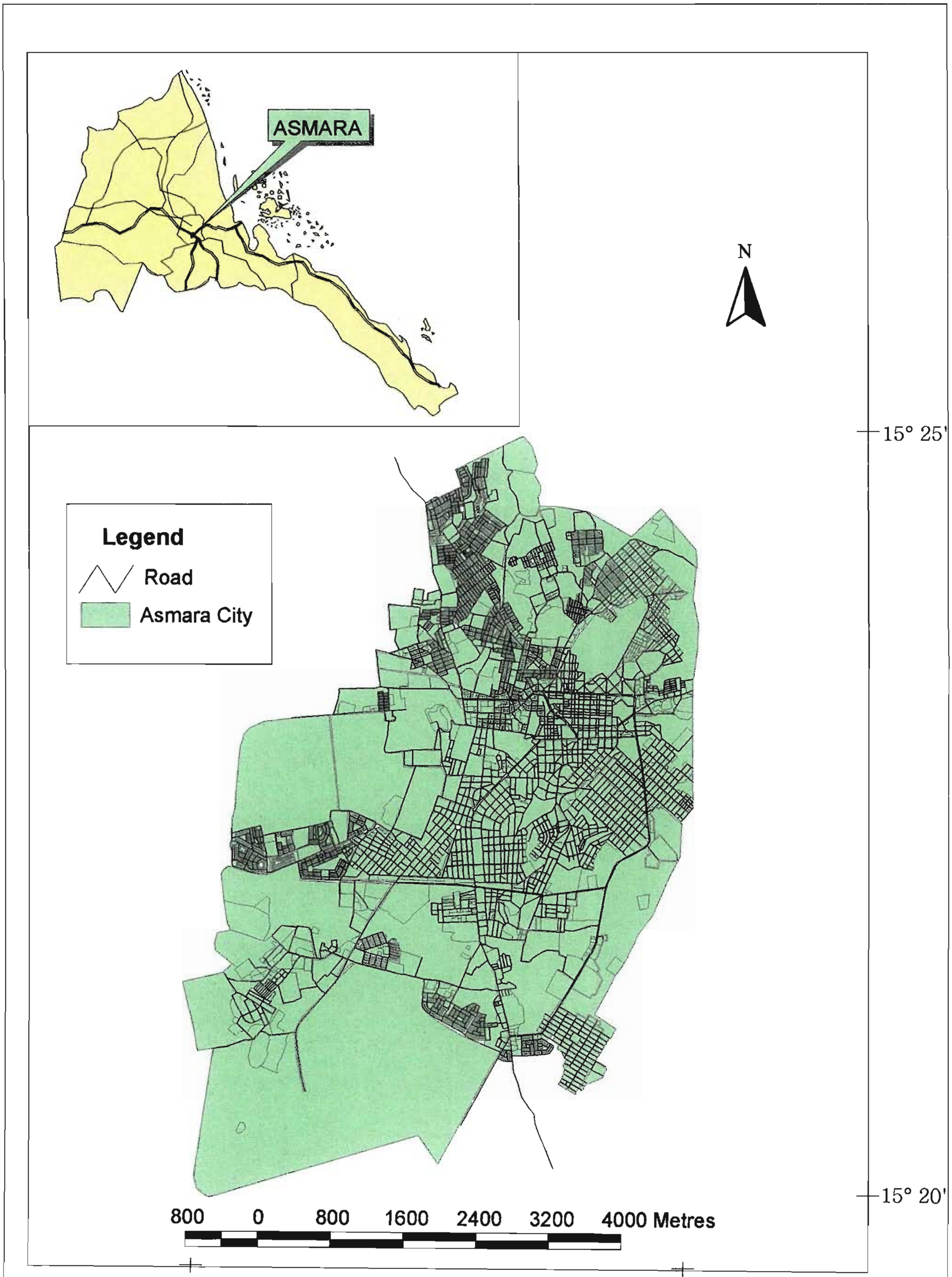


Figure 3.2 Location of Asmara City and its Extent

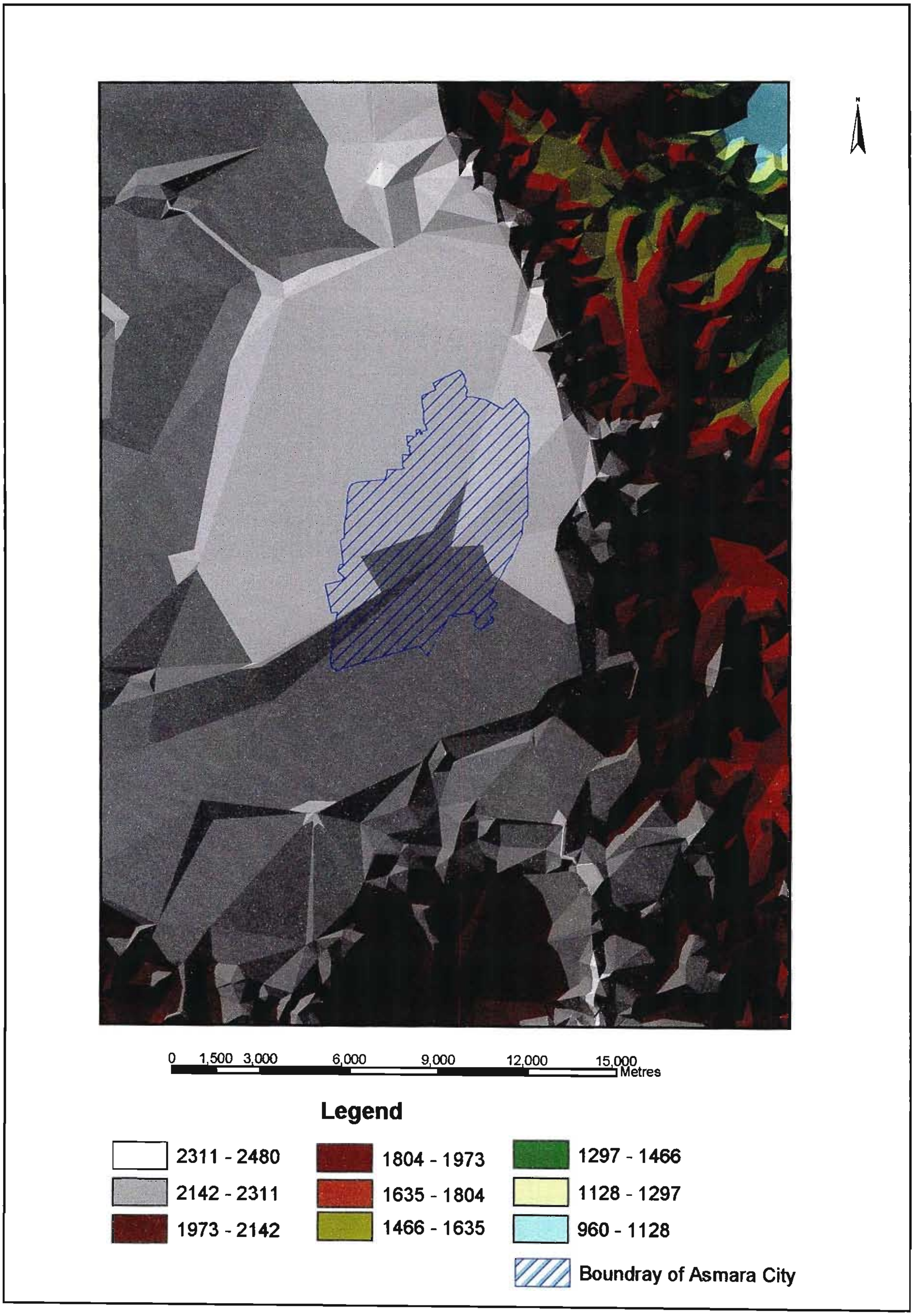


Figure 3.3 TIN of Asmara city and the Surroundings

3.3.2.3 Infrastructure

Basic infrastructure consists of safe water supply and sanitation, solid waste management, electricity and transport facilities. Almost all the basic infrastructure in Asmara city is date back to the Italian colonial era. It can be assumed that infrastructure in the city of Asmara is given a high priority for improvement by the government.

The thirty years of war and mismanagement during Ethiopian administration left Asmara in ruins. Water, sewerage, electricity and telephone systems, and upon independence in general all public service institutions in the city barely functioned.

3.3.2.3.1 Roads

The city is relatively served by roads, although the road network is not equally distributed with many of the asphalted roads being concentrated on the city centre. This has left the city fringes with few and narrow asphalted roads. As illustrated in Figure 3.4, according to the traffic office the roads in the city of Asmara can be categorized into four classes, namely: main roads that are broad asphalted roads where the speed limit is 80 km/hr; secondary roads that are unimproved asphalted roads with a speed limit of 60 km/hr; small roads that are very narrow and unimproved asphalted roads where the speed limit is 30 km/hr; and gravel roads where the speed is 15 km/hr. More than half of Asmara city is serviced by gravel roads.

3.3.2.3.2 Airport

Asmara International Airport is the main airport of the country. It is served by the national airlines, Eritrea Airways, as well as a number of international airlines and can handle all types of passenger planes currently in use.

3.3.2.3.3 Domestic water supply and sewerage services

Nearly 75% of the households in the city of Asmara are connected to a reticulated water supply. The water demand for Asmara city is estimated at about 200,000 m^3 a day. The newly developed areas of the city lack a sewerage system (NEMP-E, 2001).

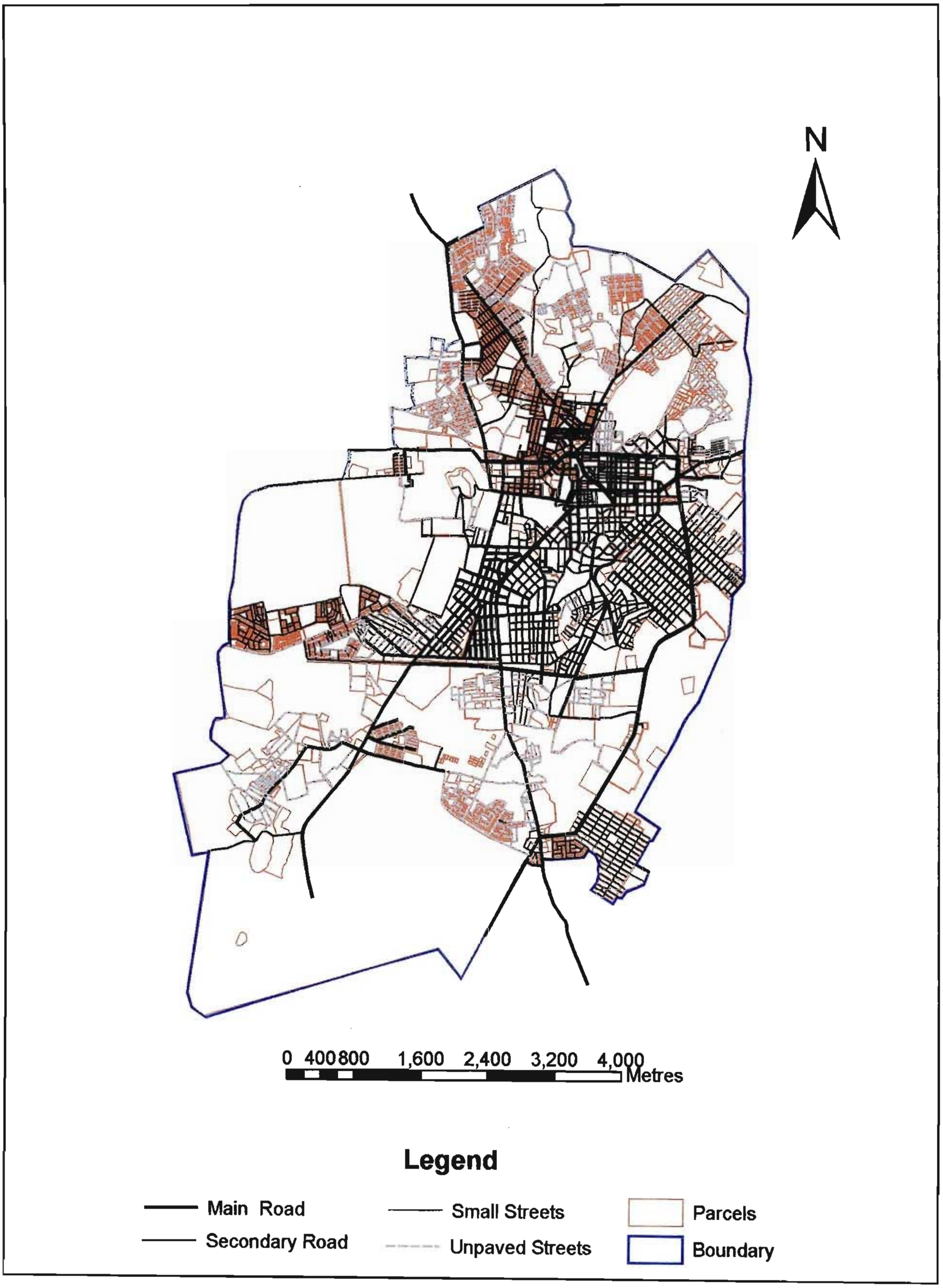


Figure 3.4: Road Classification in Asmara City

3.3.3 Socio-Economic Setting of Asmara City

3.3.3.1 Population

Asmara city comprises a population from all ethnic groups of Eritrea. The city has experienced dramatic growth in population since independence. The total population of Asmara city is about 400,000. About 43% of the population is under 14 years of age, 54% is between 14 and 64 years, and 3% is 65 years or more (NEMP-E, 2001).

3.3.3.2 Economic activities

The economic base of Asmara city has undergone a substantial expansion over the past few years, as the government started to privatize the industries, which were previously nationalized by the Ethiopian governors. The economy of the city is largely industrial and service sector-based. Small workshops, factories, retail trade and tourism are common.

3.3.3.3 Housing

There is an immense need to upgrade and build new houses in Eritrea. During the last ten years Asmara city witnessed a high demand for housing, commercial, and industrial buildings. The total number of parcels registered in the Municipal Office of Asmara city is 20,358. According to the NEMP-E (1995) study, 20% of the Eritrean population is estimated to be living in towns, half of which lives in Asmara city. The urban growth rate is between 5 and 7% per annum (NEMP-E, 1995).

3.3.3.4 Public Services

Public services such as health facilities, educational institutions, and safety and rescue services are very limited and poorly located. Almost all the services are located at the city centre. Table 3.1 shows the available number of basic public services in the city. Their distributions also illustrated graphically in Figure 3.5.

Table 3.1: Public Services in Asmara city

Public Services	Number
Hospitals and Clinics	12
Schools at all level	17
Fire station	1
Police station	4

Source NEMP-E (2001)

3.4 Land Tenure Systems in Eritrea

Soon after independence, the Eritrea government recognized the problems associated with divergent land tenure systems in Eritrea. It began to consider some type of national land reform and a new land tenure system was formulated in 1994. The new land tenure system initiated a nation-wide reform program vesting ownership of all land in the government while granting a usufructuary land for agricultural use and *Tessa* rights (land for indigenous residence) and providing land leases for domestic and foreign investors (Eritrea Land Proclamation No. 58/1994).

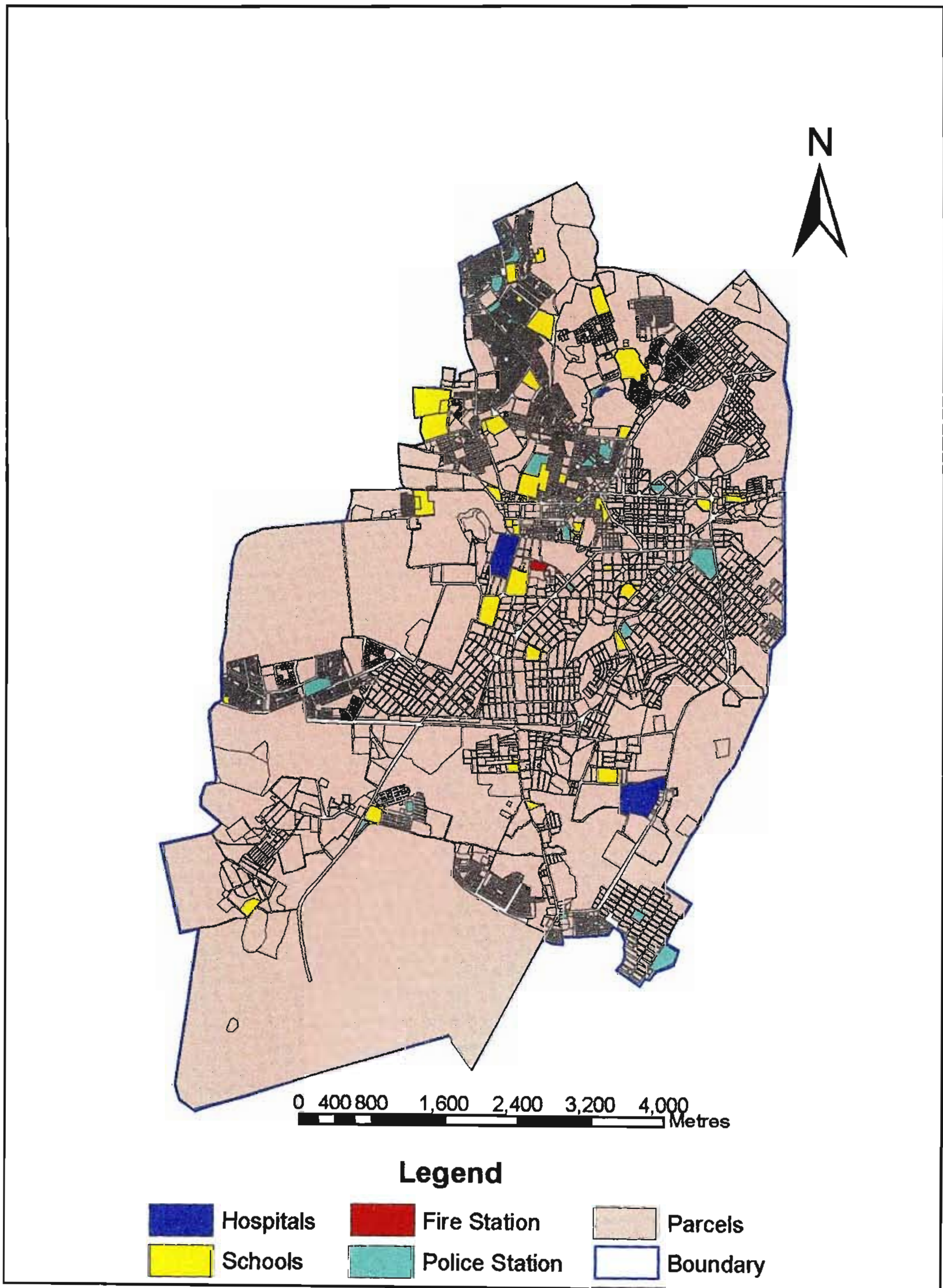


Figure 3.5: Distribution of Public Services in Asmara City

3.5 Land Information System in Eritrea

The long colonial oppression in Eritrea hindered well-developed mapping and land information systems. The idea of land information systems in Eritrea was developed by the Italians. During their colonial period, the Italians developed political, physical, and geological maps of Eritrea as well as town planning and tourist guide maps. A tourist map of Asmara city with a scale of 1:500,000 was also developed (Glianali, 1943). Although the Italian maps are now outdated, they are still used as the basis for current mapping projects.

More recently maps of Eritrea at scales of 1:500,000 and 1:1,000,000 have been drafted by the Department of Geography at the University of Bern. Most of the above maps, including maps produced by American and Russian agencies are currently used as base maps for GIS-based map production. The MLWE is currently developing standard geodetic reference benchmarks based on IKONOS imagery and GPS field surveying for mapping the country.

Therefore, the problem of official and standardized maps is a crucial issue in Eritrea. The Mapping Centre is vital for land information, management and general map users because having standard and officially accepted maps are essential to avoid confusion between the map users; provide a computable national and regional map; develop a common and standardized map in the country; and provide up-to-date information about all parts of the country at a time.

The production of accurate up-to-date maps and the design and development of land information systems are important in Eritrea. Poor land information can lead to under utilized or over utilized infrastructure systems. Eritrea can avoid such errors by using modern geo-spatial information technology to introduce sound planning and designing of its infrastructure and social services.

GIS can contribute to the identification and prioritization of utilities, enhance route planning, urban planning, population trends and analysis in Eritrea (Spatial Data Institute, 1996). LIS and GIS are also critical important tools for Eritrea to maximize its ability for inventory, assessment, evaluate property thereby maximize and introduce a fair, efficient, and effective property taxation system.

3.6 Introduction of GIS in Eritrea

GIS technology was introduced in Eritrea with the following objectives: to aid in solving the housing problem; to promote the infrastructure and social services of the urban and rural areas; to implement the land policy; and to improve the agricultural practice.

GIS was seen as an important tool to provide fast and accurate information. Without having accurate information about the land, it is not possible for decision-makers and planners to classify land according to an appropriate purpose. The idea of modern land information was realized soon after the independence. Eritrea Land Proclamation No.58/1994 makes the Municipal Office the responsible authority of land administration and maintains registers of the allotments of land. The Municipal Office has been developing guidelines for the various agencies and levels of government to follow land allocation, management and registration systems. As a pilot project, a GIS was applied with special reference to the proposed new expansion of Asmara into the agricultural hinterland. FAO funded the GIS program in the municipal office and Ministry of Agriculture in order to identify the land use system of Asmara city and it's surrounding to motivate a modern land use system in Eritrea to increase the productivity of the land.

Between 1996 and 1999 the use of GIS spread widely in different government agencies. Thus GIS was beginning to be used in the Asmara Municipality Office in 1996, in the Ministry of Agriculture in 1996 in the Ministry of MLWE in 1997, in the Statistics and Evaluation Office in 1997 and in Town Planning in 1997.

The introduction of GIS in Eritrea was in the form of development projects funded by foreign organizations for example UNDP, USAID (United States Agency for International Development), CIDA (Canada International Development Aid), UNFPA (United Nations Population Fund), and the University Bern, Switzerland. The existence and continuity of GIS in Eritrea depends on the existence of the foreign organizations aid.

3.7 Cadastral System and Land Registration in Eritrea

Historically, the Ministry of Justice administered the cadastral office, which means it was serving only the juridical uses of cadastre. Later, after independence, the cadastral office was transferred to the Municipal Office. The cadastral system of Asmara city originally designed specially to support the operation of the land market and the individual landowner; they were not designed as part of a wide land administration system. Thus the Eritrean cadastre contains only the textual part of the cadastral system. The cadastral documents are still held in paper format, and lack the cadastral map part of a cadastral system.

After independence, in 1994, the Asmara Municipal Office produced a cadastral map of Asmara from 1:50000 scale aerial photographs. These aerial photographs had many drawbacks. First the use of small scale, and secondly the technique used to mosaic and geo-rectify them was not reliable. As a result the measurements taken from the cadastral map would have enormous errors. Furthermore, the developed cadastral map is currently stored in AutoCAD polyline format and is not directly linked to the textual information of the cadastre.

More recently, Asmara Municipal Office started to register the paper-formatted ownership of houses into Access datasheet format. Some other departments of the municipal office for example Department of Property Taxation, Department of License and Department of Infrastructure are also using computers to store information related to the parcel.

3.8 Property Taxation System in Asmara City

Eritrea lacks modern legal and fiscal cadastres. Now there is a widespread recognition of the need for proper map-based legal and fiscal cadastres to serve the need of the property market participants and to improve control over the property tax base.

After independence, the focus of the government was to return the property, which was nationalized by Ethiopian governors, to their respective owners, and to assure and clear ownership of houses. Currently, powers to levy property tax in Asmara city are provided for the Municipal Office. Although property tax is considered the main source of revenue for the Municipal Office, the database system of the Asmara Municipal Office indicates that it has not been well utilized. Partly this is because of a lack of property valuation system.

The currently practised taxation system, which was introduced in 2000, is based on area assessment. Under such a system (Table 3.2) a charge is levied per square metre of the building area, and sometimes the total land area. Each building or property, which is less than or equal to 500 m^2 is supposed to pay 3.0 *Nakfa* (Eritrean currency) times the total area. If the property area is between 500 to 1000 m^2, it is charged 2.85 *Nakfa* times the total area of the property. Finally, the proposal lists that if the area is greater than 1000 m^2, the property levied 2.75 *Nakfa* multiplied by the total area.

Table 3.2: Existing Property Tax Rates, (based on total area)

Area of Property (m^2)	< 500 m^2	500-1000 m^2	> 1000 m^2
Tax rate (Nakfa/ m^2)	3.00	2.85	2.70

The assessment rate per area does not reflect location, and other influential factors, which have an impact on the value of the property. The existing property assessment system needs to be adjusted to reflect those factors.

Asmara Municipality Office sees property taxation as an attractive and promising option for financing public services operations and for providing the government with access to a broad and expanding tax base. Furthermore, the Municipality Office views property tax as a source for increased efficiency in financing service delivery. The Mayor of Asmara City, (2000) stated, "the users should pay for their improved standards. The public services, such as water supply, street lighting, sewerage, transportation road and health and safety services can be improved if taxes can fully cover both operating and capital costs of the Municipal Office." However, the performance and productivity of the property tax systems in Asmara City is still below the potential. An equitable and fair tax system on property values and location needs to be introduced in Asmara.

3.9 Urban Planning in Asmara City

The Italians introduced town planning to Eritrea at the beginning of the 20th century. The present Asmara is a result of Italian planning. But during Ethiopian colonial rule there was no town planning carried out in the city of Asmara. The zoning of land for residence, shops and other public services appeared to be undertaken without any basic urban planning system. Currently in the city of Asmara, urban services for example hospitals, schools, police stations, and fire stations are scarce and were not within proximity of the city. Large numbers of the population do not have easy access to the urban public services. Moreover, urban infrastructures for example asphalted roads, consistent public transport, garbage collection, sewerage, and streetlights are also confined to the city centre and some of developed parts of the city. Beside the poor quality of the infrastructure of the city, the locations of the existing public services are not reasonably sited to provide equal access to the inhabitants of the city.

Inefficient water supply, sewerage, and transport and difficult access to health, and rescue services are the main problems experienced by the population of Asmara. Positive economic functions, which cities fulfill, can be made more effective through appropriate investments in infrastructure, urban public services and shelter improvements. The lack of these facilities and services also affect social or equity problems.

After independence, Eritrea ought to examine the experience of other countries in terms of managed urban growth. The National Environmental Management Plan for Eritrea (NEMP-E, 1995) realized that effective policy must be established with respect to urbanization and the distribution and size of urban centre. Further NEMP-E suggested that the population of the capital city of Asmara should be regulated; distribution of water pipelines, electricity, sewerage and asphalted roads should be assured; and schools, health, rescue and safety services should be provided. This project helps to identify areas and parcels, which are least advantaged by the existing urban services and infrastructure.

It also attempt to help in siting new public services, and developing infrastructure.

Asmara Municipality Office makes countless land-related decisions daily, and deals with property development, infrastructure, and new development projects and also deals with activities such as public services allocation. All of these are referenced to geographical locations. The capacities of the Municipal Office to deal effectively and efficiently with those tasks are limited as there is no GIS-based cadastral database for Asmara city. Currently the central challenge of Asmara Municipal Office is planning and locating new public services in a sustainable, effective and efficient way, so that such services are equally accessed by all dwellers of the city.

3.10 Summary

This chapter has briefly explained the historical development of Eritrea and the city of Asmara. The present physical and socio-economic settings of the study area were discussed. The property taxation system and urban planning of Asmara city were also discussed. A number of materials and methods are used during data collection, designing database and analysis. A detailed description of the methods and materials are presented in chapter four.

CHAPTER 4: MATERIALS AND METHODS

4.1 Introduction

The study focuses on illustrating how to design and implement a GIS-based cadastral database to improve urban land administration in Asmara city. This chapter details and describes the different types of data sets utilized in this study. An overview of the data sources and methods of collection are given. A description of how the data sets have been developed into a cadastral data model is also provided. Finally, applications of the designed cadastral database for urban land administration, property taxation, and accessibility to hospitals and fire station are described.

4.2 Data Needed for the Study

In a conceptual sense, seven data components were identified; these were basic data features for building a cadastral database. Each of these may be conceived as containing a series of data entities, such as maps or tables related to map coordinates. These basic cadastral data components needed for this study were base maps, plan drawings, a parcel map, street network map, parcel tabular data, and roads tabular data.

Base Maps

Both the 1:50,000 topographic map of Eritrea and the IKONOS image of Asmara (see Appendix B) were used as base maps. These provided a framework and reference for integrating the parcel, street and administration maps and also overlay for a particular geographic application or locations.

Plan Drawings

These were the survey drawings generated for the designing process and created using AutoCAD software interactive graphic system. These CAD-drawings lacked topology and it was necessary to convert them into GIS-format ARC/INFO (ESRI, 1995).

Parcel Map

This map provided the basic drawings of land ownership boundaries for all public and private lands in Asmara city. This map was developed by converting the existing CAD drawings and data captured through on-screen digitizing from IKONOS image of Asmara city. This parcel map was linked to parcel attribute data.

Parcel Attribute Data

The attribute data included a variety of attribute datasets associated with the parcel map of Asmara city. The data included attributes such as parcel use, parcel type, ownership, type of ownership, parcel area, and parcel location. The information was linked with the parcel using a primary field.

Road Network

The road network of Asmara was produced by on-screen digitizing from the IKONOS image of Asmara city.

Road Tabular Data

The road tabular data included information about the network: road name, and speed limit of the road. This tabular data generally described road conditions.

Area Administration Boundary

The area administration boundary map defined the district administration areas and various sub-administrative boundaries.

The interrelationship between these cadastral data components are illustrated in Figure 4.1.

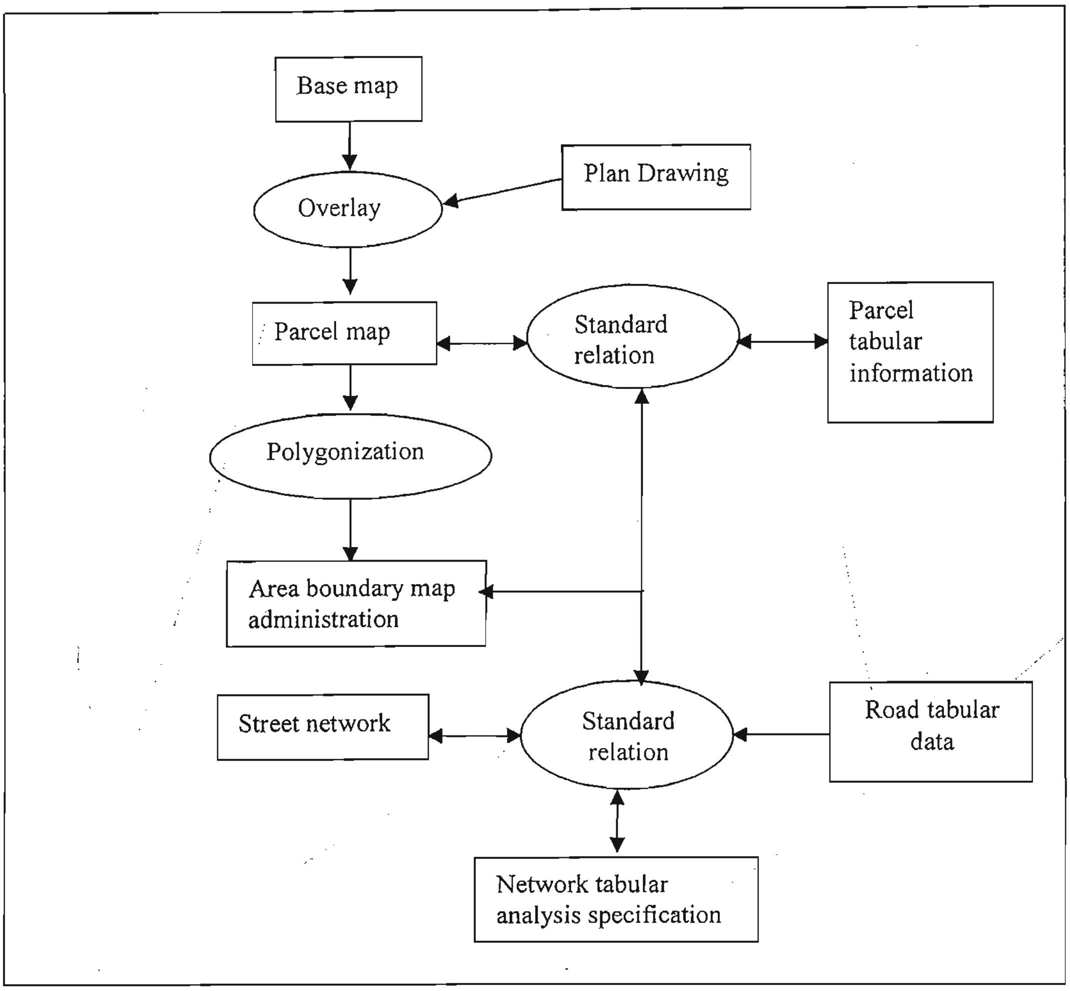


Figure 4.1: Interrelationships Between the Data needed for the Study

4.3 Selection of Software Packages

The following software packages were used in the study: ERDAS®, Version 8.4, PC ARC/INFO Version 3.5.1, ArcView 3.2, Pathfinder Office 2.1, Microsoft Access, and ArcGIS 8.1 (ESRI, 2002). ERDAS was used primarily for geo-rectification, image projection and visualization of IKONOS imagery. PC ARC/INFO was also used for conversion and building topology of the existing AutoCAD data of Asmara city. While ArcView, together with its Spatial and Network Analyst extensions were used for visualization, overlay, editing, geo-processing and analysis (ESRI, 1998). Pathfinder Office 2.1 was used for downloading and differentially correcting the GPS point readings. Microsoft Access was also used to store parcel attribute data and create relations between them. Finally ArcGIS 8.2 was used for creating database, location allocation modeling and visualization and printing out of maps.

4.4 Data Collection

A data collection activity was conducted over a period of two months in the city of Asmara; both primary and secondary data capturing techniques were used. The cadastral data required for this study were not collected and maintained by a single organization.

For the focus of the study relevant, reliable, comprehensive and analytical cadastral data were needed to enhance the quality of land administration. The spatial data required for the cadastral system were acquired using different procedures from different data sources mainly from a GPS, IKONOS image, and existing AutoCAD data. The non-spatial data required for the study were also collected from Asmara Municipal Office and from Housing and Land Commission.

4.4.1 Global Positioning System

One of the main tools of primary vector data collection is GPS (Goodchild *et al.*, 2001). Using Trimble Pro XRs GPS, selected points were captured. The selection process was done based on the IKONOS image. Features that were easily identifiable, for example cross roads and corners of buildings were selected; the selected points were widely dispersed across the image.

4.4.2 IKONOS Imagery

IKONOS imagery was used to up-date and capture the spatial cadastral data of Asmara city. It is found that high-resolution remote sensing imagery is of promising characteristics in terms of capturing urban features (Jensen *et al.*, 1999). IKONOS provides both multi-spectral and panchromatic data with a spatial resolution of four and one meter respectively. In order to benefit from the very high resolution, the panchromatic image was used to update and capture the parcels of Asmara city. The IKONOS image was captured on the 24th of October 2001. Its metadata is described in Appendix C.

4.4.3 CAD Data

CAD data that is available in Municipal Office is primarily collected for urban planning purposes, which was produced using AutoCAD software. In this study the CAD data was updated and converted into GIS format.

4.5 Data processing

Data processing in this study related to spatial data and non-spatial data processing.

4.5.1 Spatial Data Processing

Spatial data processing involved the conversion, differential correction, editing, geo-referencing, and, digitizing of geographic features. Figure 4.2 illustrates a flowchart of the steps used in spatial data processing.

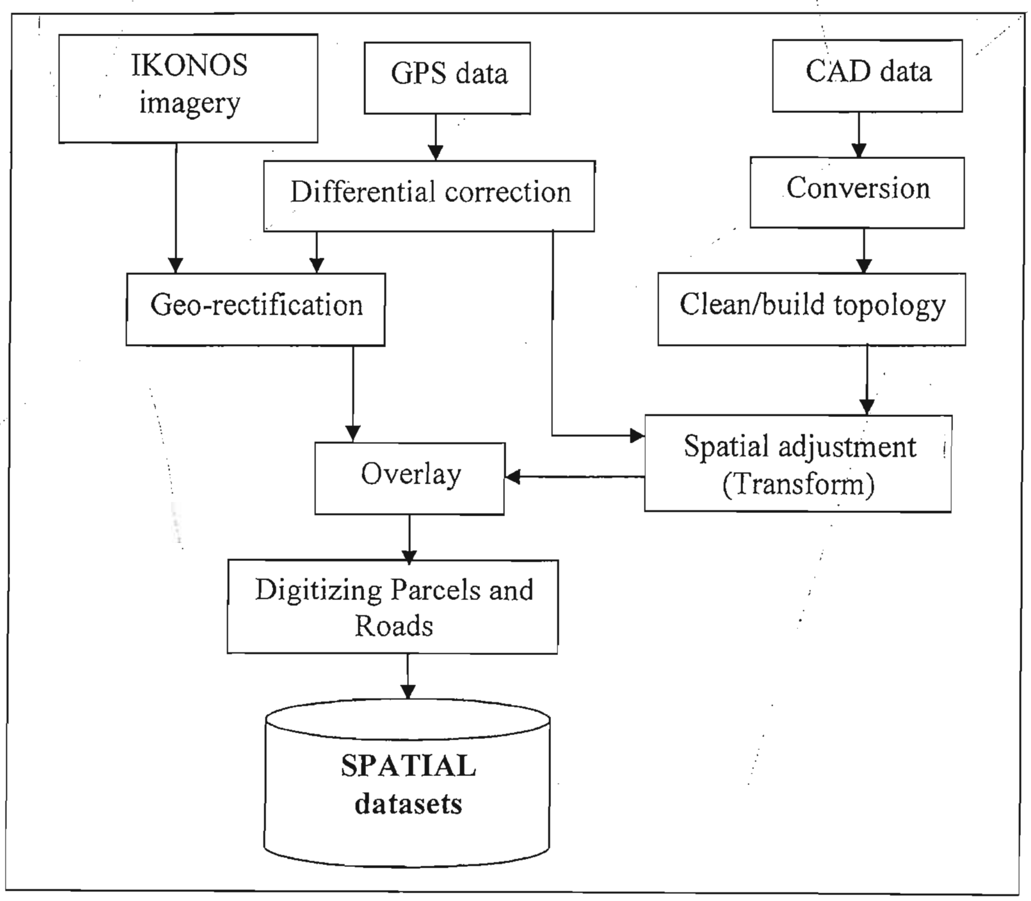


Figure 4.2: Flowchart of Spatial Data Processing

4.5.1.1 Differential Correction

After the GPS readings were downloaded, the data was corrected using the differential correction function of Pathfinder Office software. Finally, these readings were exported from Pathfinder Office software into shape-file format. These data were used for geo-referencing and georectification of both data sources that is the IKONOS and CAD drawings.

4.5.1.2 Geo-rectification

Geometric correction was needed to remove the image shape distortion and to project the image. Known location coordinates, captured by GPS in a field, were fed to the selected Ground Control Point (GCP) on the image, for geo-rectification. Following geo-referencing and projection, resampling was performed to move each digital value in the original image to the new position of the corrected image. ERDAS was used for this process. The northern hemisphere, zone 37 and WGS 84 datum were used as Universal Transverse Marcator (UTM) parameters. The procedure that was followed to geo-correct the IKONOS image of Asmara city is illustrated in Figure 4.3.

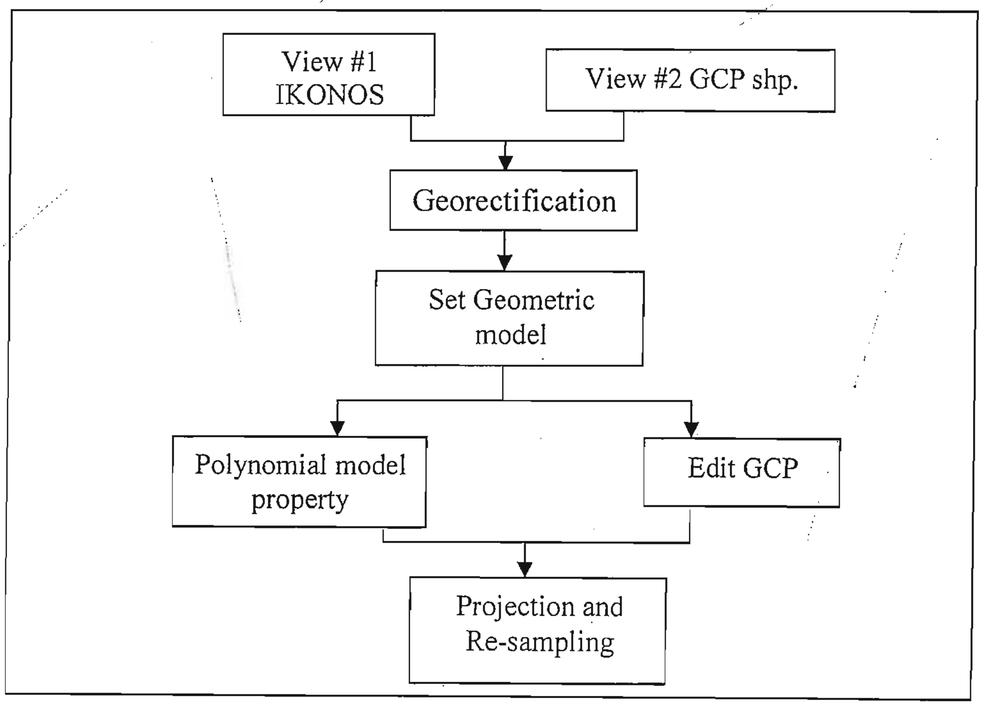


Figure 4.3: Flowchart of procedures followed in the geo-rectification of the IKONOS Image

4.5.1.3 Data Conversion

Data conversion is the process of transforming graphic and non-graphic analogue sources into a computer-readable format through data input, and/or transforming existing spatial digital data into a format that can be used by a GIS (Boots, 1999). In this study, the AutoCAD data (in dwg format) were exported into AutoCAD ASCII dxf drawing format so as to import them into PC ARC/INFO coverages. In PC ARC/INFO the DXF were imported using the "DXFARC" command.

4.5.1.4 Spatial Adjustment (Transformation)

When we use AutoCAD drawing files, there is no guarantee that the features will be in the same coordinates system as the data in other themes or layers. The AutoCAD drawing that is plan map of Asmara city was found in page units as inches. In this case, coordinate transformations were applied in PC ARC/INFO using the data from GPS point readings.

4.5.1.5 Spatial Data Building Topology

In this study topology was built using PC ARC/INFO, to create interrelationships or connectivity between the parcels. Build commands were applied to build the topology.

4.5.1.6 Digitizing

Digitizing refers to the creation of vector data from hardcopy materials or raster images that are traced using a digitizer keypad on a digital tablet or an on-screen displayed image (Hohl, 1998). On-screen digitizing was used to up-date and capture the cadastral map features (parcels and roads) from the one-meter resolution panchromatic IKONOS image of Asmara city.

4.5.1.7 Spatial Datasets

The end products of spatial data processing were: parcels of land in the form of polygons representing properties together with unique identifiers and roads of the city of Asmara and their unique identifiers.

4.5.2 Non-Spatial Data Processing

In this study, the non-spatial cadastral data entity had five attributes (*viz.* parcel owner, type of ownership or rights, parcel use, parcel location, and road network of Asmara city). These were obtained from the Municipal Office, and Housing and Land Commission. These non-spatial data lacked standards. Microsoft Access was used to normalize, and store the non-spatial data.

The conceptual relational database schema of the non-spatial cadastral entity is illustrated in Figure 4.4 and Appendix D. In Figure 4.4 attribute types are represented in a diagram as rectangular boxes enclosing the attribute type name. Field names are enclosed in ovals and are attached to their attribute type by straight lines.

A relational database schema was made up of attributes and their list of fields. From Figure 4.4 a relation between parcel owner and ownership type (rights) was "one to many" because one person can own two or more parcels of the same or different ownership type. A parcel can also be used for more than one use for example residential and commercial, the relation between these two attributes that is parcel owner and parcel use were "one to many". Ownership and parcel uses have a "one to many" relation, a lease parcel can be used for one or more uses.

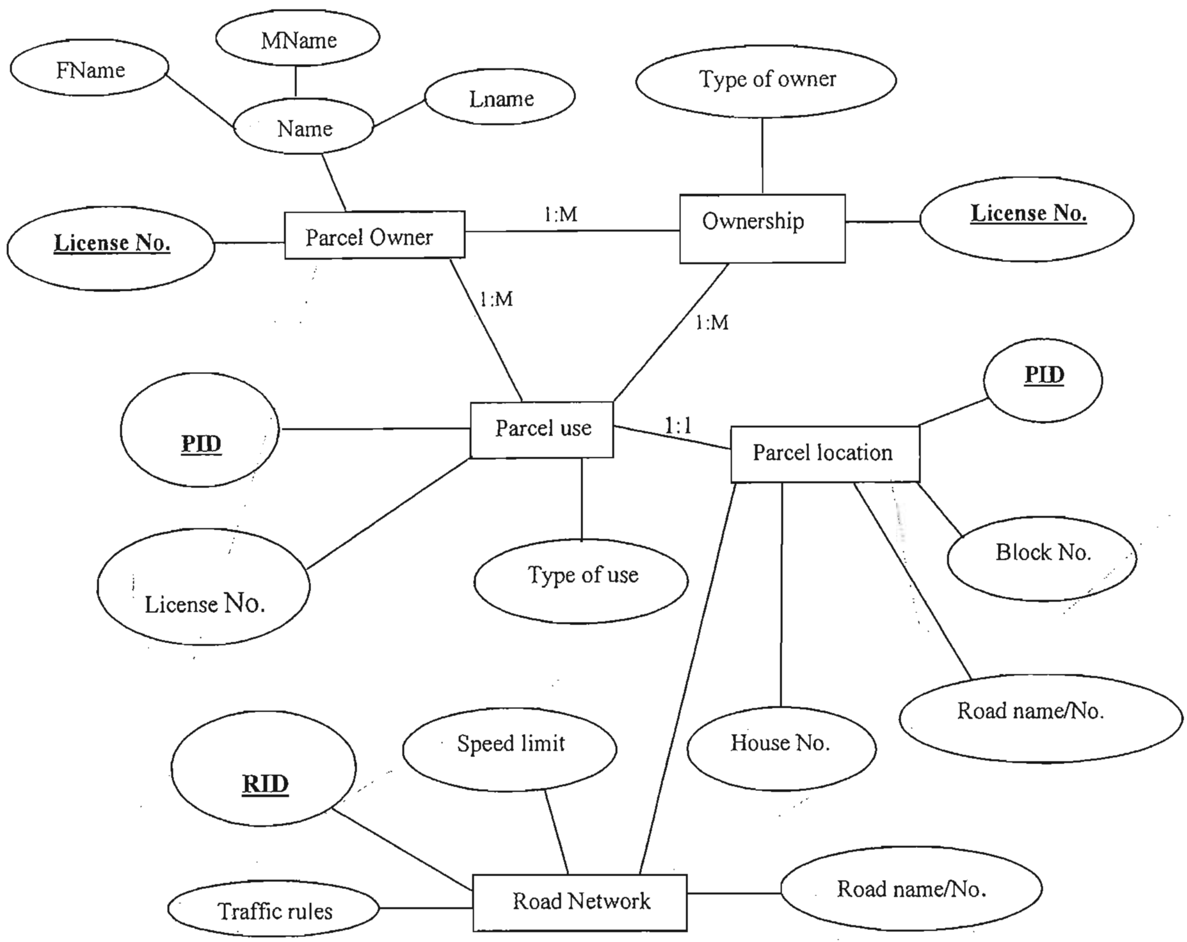


Figure 4.4: Relational Database Schema Diagram of the Non-spatial Cadastral data

PID and License No., in the relation were used as a key of relations for the relational database. PID's were created with reference to spatial data sets, it helped further to join the spatial and non-spatial data. The License ID were used to create a relation among the non-spatial data.

The roads network attribute, which comprise RID's (road identification), road name/number, traffic rule, and speed limit of each road were stored in Microsoft Access. RID were used to link roads to the spatial attribute table of the road network.

4.5.3 GIS-based Cadastral Database

The separately designed cadastral datasets were linked using GIS. The use of database is to link and to maximize the accessibility of data. Figure 4.5 illustrates a conceptual diagram for linking spatial and non-spatial datasets.

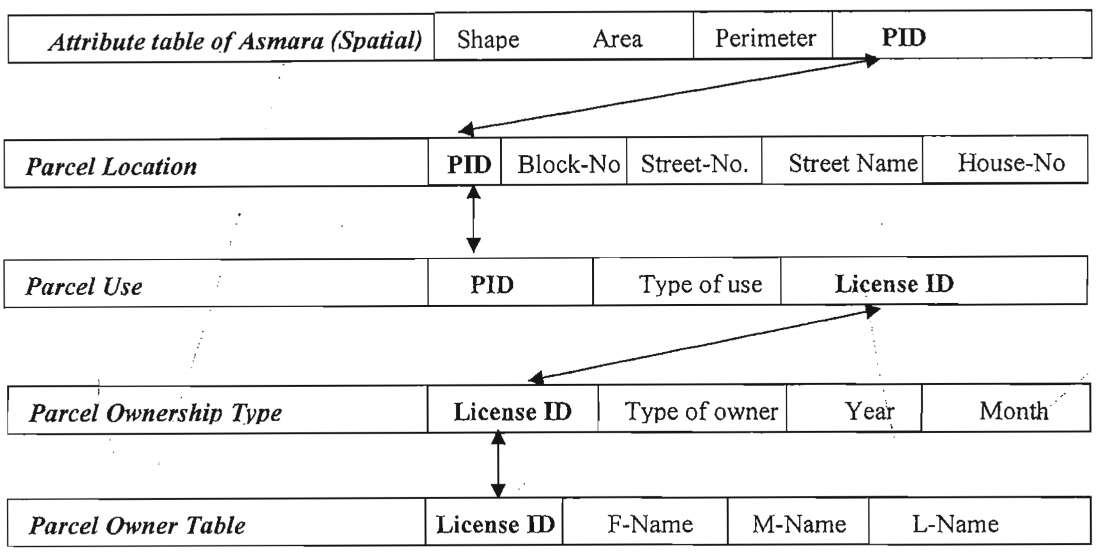


Figure 4.5: Conceptual Diagram of Spatial and Non-spatial Link.

The GIS-based cadastral data were stored in ArcCatalog of the ArcGIS package. Firstly, database was created and all the non-spatial data from mdb file of Microsoft Access exported to the created database in the form of dbf.

4.6 Modeling Network Data

A network model can be defined as a line graph, which is composed of links representing linear channels and nodes representing their connections (Lupien *et al.*, 1987). Network model is made up of links (arc segments) that have an associated attribute known as the impedance. The impedance represents the cost of traveling over the link or the measure of resistance to movement of goods through the link (Mitchell, 1995). For example most network roads set a maximum speed limit, which a given entity can travel across an arc. Other impedance factors are one-way streets, detours, and roadblocks. Cost is another means of impeding movement in a transportation model.

In this study the linear channels, nodes and connections were digitized from IKONOS image of Asmara city using the network edit tools. For the application of fire station and hospital catchment area assessment and new allocation, a network model based upon time and speed was used.

ArcView Network Analyst was used in conjunction with the ArcView 3.2 to model spatial networks. For the purposes of this study each street segment was assigned a speed limit based upon the traffic code of the city of Asmara. The GIS system automatically calculated length of each segment in meters, and then it was possible to calculate a cost field containing travel times taken to traverse each line segment.

In the attribute table of the road network a "ONEWAY" field was created that indicated whether a road was one way or not. All restricted turns at intersections were in the road tabular data.

4.7 Property Appraisal System

The recommended appraisal option for value-based property taxes for the city of Asmara was to develop a non-discrete value banded system. The application of a value-banded system has a number of important operational advantages to Asmara Municipal Office. It is a quicker and cheaper process, and demands less data. In this study, the main focus was to create these bands from the designed GIS-based cadastral database using some functionality of GIS and then further specify the relative level of tax rates, which could be used for equitably taxing properties.

4.7.1 Selecting Factors that Influence the Value of Property

Several procedures and factors are used to determine the value of a property. Residential property is a multidimensional commodity, characterized by durability and structural inflexibility as well as spatial fixity. The location factors of a land directly affect the property price. Each residential property has a unique bundle of attributes: its accessibility to work, to transport and to services, and the structural characteristics, neighborhood and environmental quality.

From personal interviews with officials of Municipal Office of Asmara the most influential factors were determined; these were proximity to the CBD, proximity to transport and proximity to public services. These were found to be the most influential factors to determine the value of a property in the city of Asmara.

4.7.2 Weighting Factors

In developing a banded property taxation system, where properties within the same band have the same relative value, Euclidean distances were calculated away from the selected factors (main road, CBD, and public services). The outputs were given as grid themes (raster) where each cell contained the distance from the nearest factor, cell values were standardized between 0-6, zero indicating the nearest to the feature and 1-6 indicating standard bands away from the feature. Standardized factor values were weighted and then combined using a weighted linear combination to arrive at a final property value map or index of proximity.

The three selected factors have different weight or influence on the value of a property. As such weighting of these factors was needed. Weighting of factors as described by Eastman *et al.* (1993) is to compare each factor with every other factor one by one in a pair-wise fashion, giving a qualitative description of how influential each one is relative to all the others. For example, in a set of "X" factors, (F_1, F_2..., Fx.) F_1 may be related as being 'much more important' than F_2 and 'slightly less influential than F_3 in achieving a given objective. These qualitative assessments are then converted to numerical values as in the Table 4.1.

Table 4.1: Weight Table

Associated Weight	Comparative Judgment
1	Equally Influential
3	Slightly More Influential
5	Strongly More Influential
7	Very Strongly More Influential
9	Absolutely More Influential

Source Eastman *et al.* (1993)

In interviewing property valuators it was obvious that accessibility to the main road (that is transport route) was the most influential factor on the value of a property. Proximity to main road in Asmara city has advantages for example garbage collection services, sewerage system provision, and access to public transport. Proximity to the CBD was the second most influential factor on the value of a property. Being near the CBD allows accessibility to urban amenities. The third factor was proximity to public services, such as, educational, health, security, and rescue services. Table 4.2 provides quantitative weights and qualitative descriptions of the factors. This weighting was arrived at using Eastman *et al* (1993) method of weightings.

Table 4.2: Quantifying Factors

Factors	Qualitative Weight	Quantitative Weight
Proximity to transport (F1)	Very strongly More Influential	7
Proximity to CBD (F2)	Strongly More Influential	5
Proximity to Public services (F3)	Slightly More Influential	3

Table 4.3: Relative Weights of the Selected Factors

	F1	F2	F3
F1	1	1.4	2.33
F2	0.71	1	1.67
F3	0.43	0.6	1

Table 4.4: Weights

Proximity to transport	**Proximity to the CBD**	**Proximity to public services**
0.47	0.33	0.2

The method used to arrive at the weightings of each factors was Saati's Eigen vector method (Saaty, 1990). From the Table 4.4 proximity to transport is weighted 0.47, proximity to CBD is 0.33, and proximity to public services is also weighted 0.2.

For a weighted linear combination of factors to be meaningful, the factors must all be standardized before multiplying by their respective weights. This means they should all be transformed or stretched to the same range of values indicating decrease value of the property with increasing cell value. Then the factors were multiplied by their respective weights, finally all the three factors were combined to produce index proximity.

Index proximity $\Sigma = F_1w_1 + F_2w_2 + F_3w_3$. (where F=factor value, w=factor weight)

4.7.3 Property Tax Rating

For this study, the base property tax rate was extracted from existing property tax that is based on the area of the building (Table 3.2). The rate was found to be 0.838 calculated using statistical methods. This relative tax rate was anticipated, as it was able to maintain vertical equity. The fourth band that was taken as a base band was a reference band from this band the relative tax level was determined. The relative tax levels are shown in Figure 4.6.

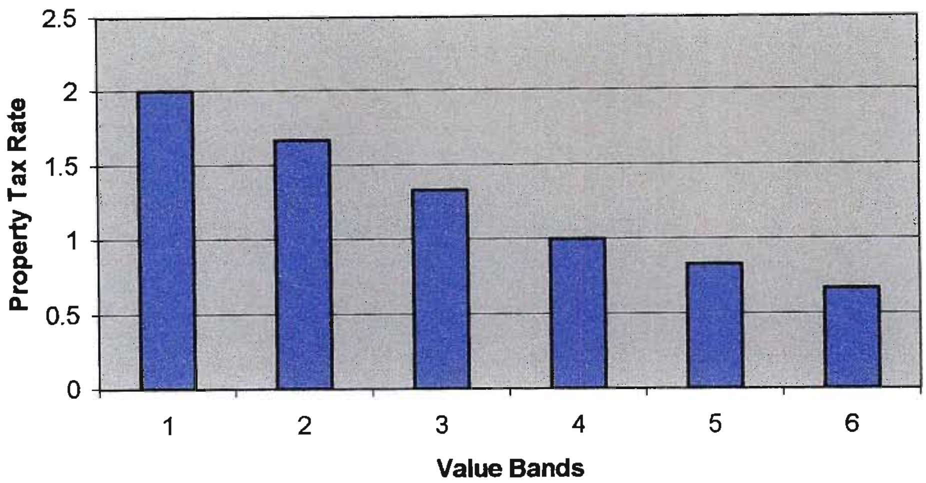


Figure 4.6: Bands Relative tax levels

Properties in the lowest tax band (band 6) are charged only two thirds of the tax levied by base band (band 4). Similarly, properties in band 1, which is the highest tax band, are charged twice of the tax charged by base band, (band 4). This method of property valuation system, which is based on banded system, is flexible and the number of bands can be increased or decreased if there is any new development in the area.

4.8 Service Area Assessment and Allocation

One area of GIS research in health care and fire station planning field is concerned with measuring accessibility of these service centers to each parcel. This section explains the methods used to identify service catchment areas of hospitals and fire station in Asmara city.

The location of three hospitals, one fire station, and the road network were extracted from the GIS-based cadastral database. GIS cost path analysis was used to determine service catchment areas of the hospitals and fire station via a road network. Cost path network analysis was run for the hospitals under the assumption that any parcel within 5km network distance from the hospital enjoys an acceptable level of health care provision (NEMP-E, 2001). The next step of the analysis was to define the size of demand within each hospital service catchment. This step identified how many people were served by the existing hospitals, and the number of beds that should be provided by each hospital. Hospital demand with hospital capacity is calculated using the following formula: Hospital bed demand is equal to population in the hospital catchments multiplied by the criterion of Ministry of Health that is 2 beds per 1000 person. Firstly, using select by theme functionality of GIS number of people that lives inside each hospital catchments were defined.

In the case of fire stations routes were developed to evaluate the service zones of each response time for various ranges of response times: 8, 16, 24, 32, and 40-minutes drive. A response time of 8-minutes drive is a recommendable response time (Emelinda, 2000).

4.8.1 Allocation

The service allocation module of a GIS deals with the static component of resource allocation. It is used to define the optimum location for siting services to ensure appropriate service is provided to the community. In the past, stations were sited using simple radius coverage schemes or assuming constant travel speed. In actuality, travel speed varies across a road network.

The issue of allocating fire station is the most basic issue that a fire department will have to address in its planning process. Various models and factors need to be taken into account by planners when allocating fire stations. Cities differ widely in their properties and in the demands they place on their emergency services. Since the research was focused on the geographical accessibility. Therefore, the focus within the analysis will be on the following factors: the nature of the geographic area being served, the land use pattern of the locality and the maximum travel speed responding units can expect to maintain. Eight minutes is adopted as the nominal response time for planning purposes.

There are three important factors that affect the location of a facility. These are the capacity of the facility, the amount of demand for such facility, and the transportation network that communicate such demand to the facility. In this study the demand for fire station and transport network were included. Based on the available vacant land and an 8-minutes drive time, the catchment or service area of the only fire station was mapped out. The results were used to suggest propose locations for new fire stations in Asmara city.

4.9 Summary

The steps taken to create the GIS-based cadastral database have been described. The techniques and methods used for data collection and processing: geo-rectification, data conversion, digitizing of parcels and roads are explained and illustrated. The methods and steps taken to create banded property taxation approach, and property rating have also been described and discussed. Finally, the techniques used to measure service catchment areas of hospitals and fire station in Asmara city are were described. Figure 4.6 summarizes the main methods utilized in this study. Chapter five provides the results and discussion of the research.

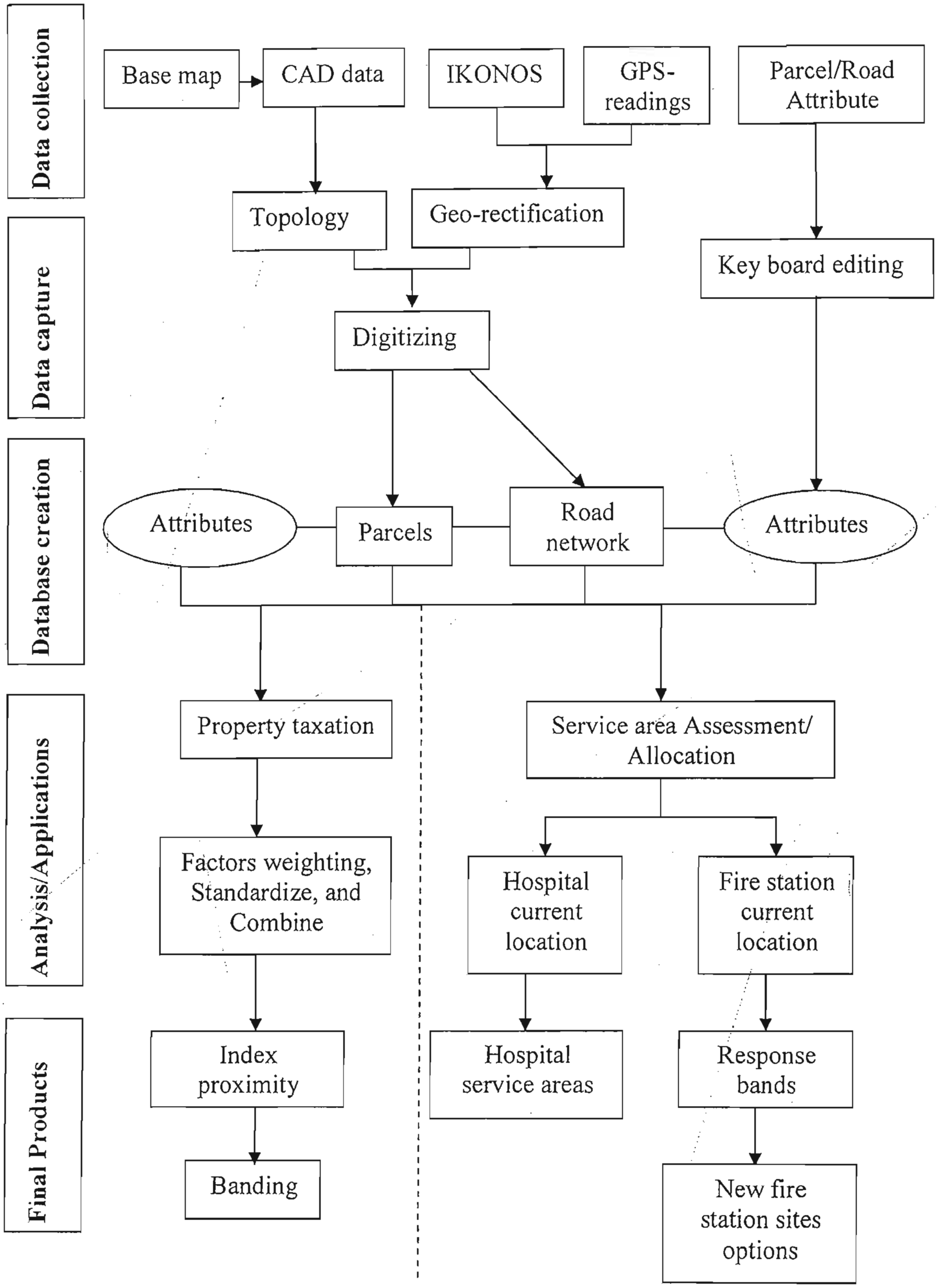


Figure 4.7: Summary of the main methods used in the study

Chapter 5: Results and Discussion

5.1 Introduction

The purpose of this chapter is to show the designed GIS-based cadastral database and also to describe and discuss the results obtained from querying the GIS-based cadastral database, which is useful for land administration. This chapter also describes and discusses the results obtained from implementing a banded property taxation approach in Asmara city using the GIS-based cadastre. Finally, this chapter describes the results obtained from the assessment of the service catchment areas of hospitals and fire station in the city of Asmara.

5.2 The GIS-based Cadastral Database

The final cadastral datasets are comprised of spatial and non-spatial cadastral data stored together. Part of the final GIS-based cadastral database is shown in Figures 5.1 and 5.2.

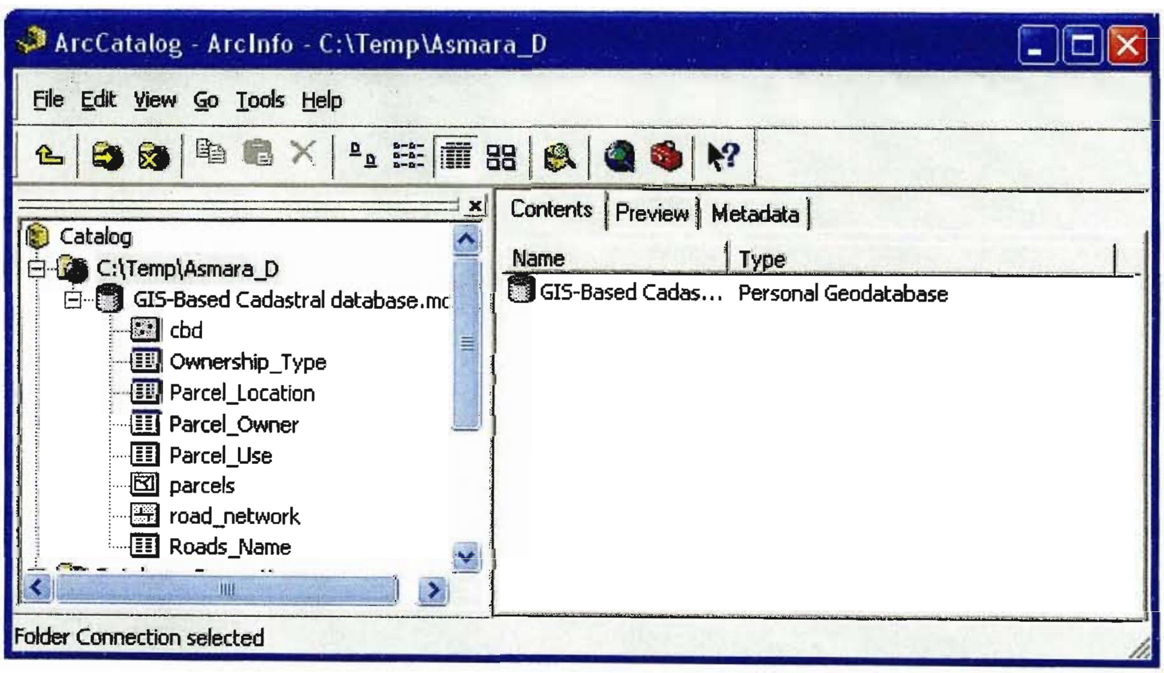


Figure 5.1: Designed database in ArcCatalog of ArcGIS

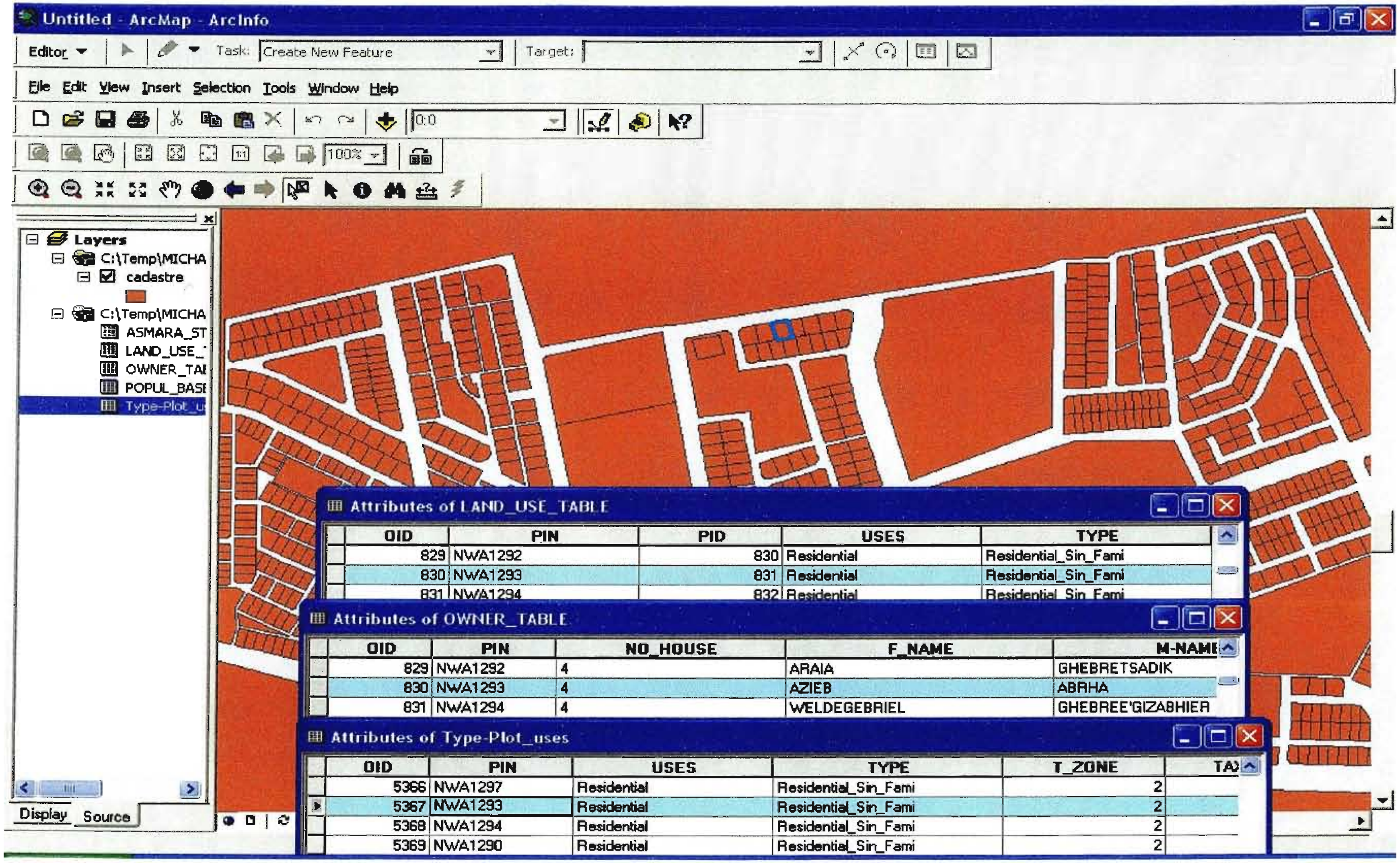


Figure 5.2 GIS-Based Cadastral Databases

5.3 Querying the GIS-based Cadastral Data

The query function of a GIS helps to extract information from the cadastral database, which is important for different urban land administration and planning. A number of thematic maps were generated from the GIS-based cadastral database by simply querying the database. The following eight maps of Asmara city were produced: Land Use (Figure 5.3), Residential Parcels (Figure 5.4), Alternative Land Uses (Figure 5.5), Vacant Areas (Figure 5.6), Administrative Zones (Figure 5.7), Parcel Areas (Figure 5.8), Parcels relating to Social and Religious Activities (Figure 5.9), and Commercial Parcels (Figure 5.10). These maps are simple examples of how such a database can be used in the day-to-day activities of land administrators. The database can easily be updated and queried as required.

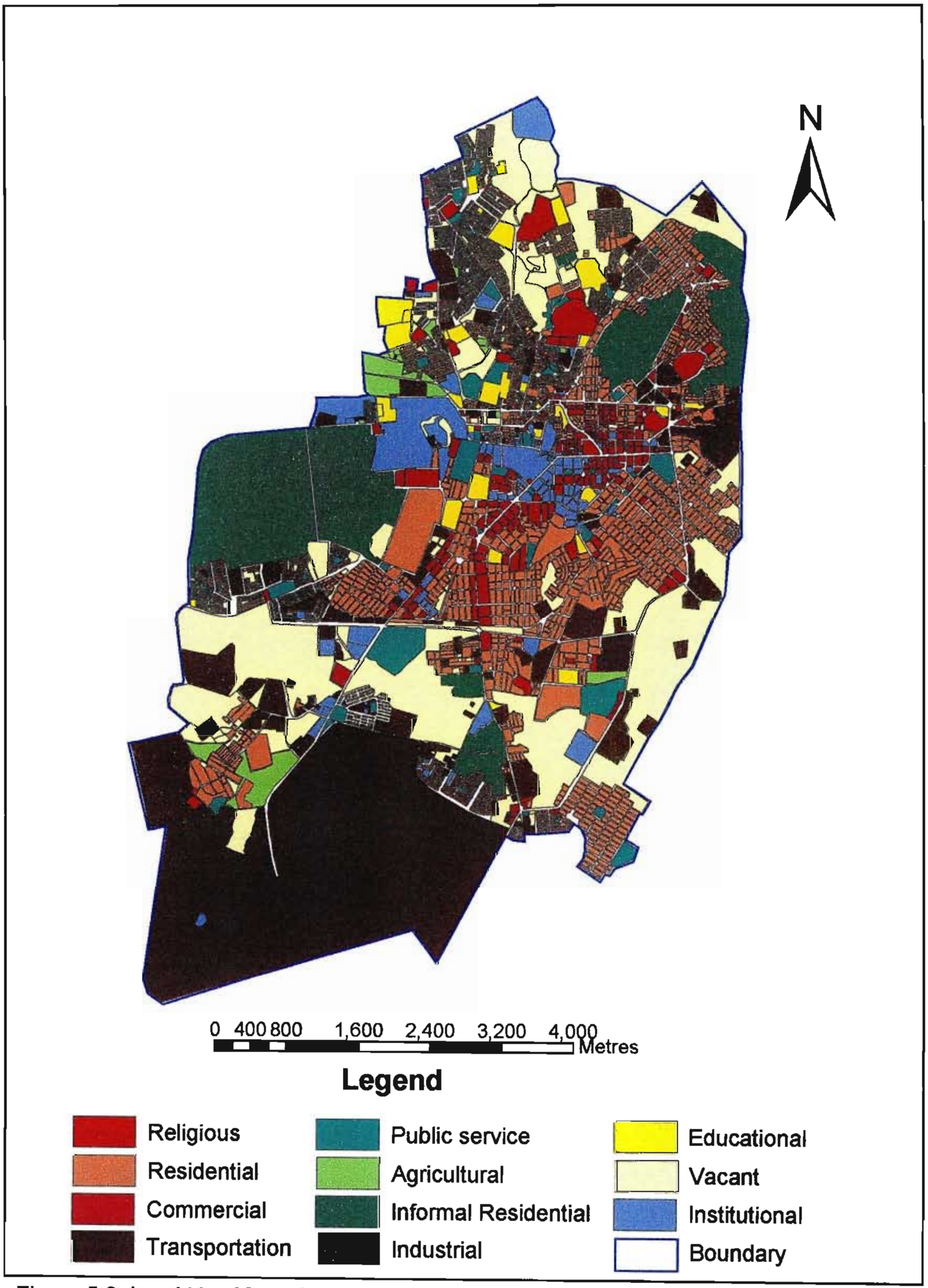


Figure 5.3: Land Use Map of Asmara City

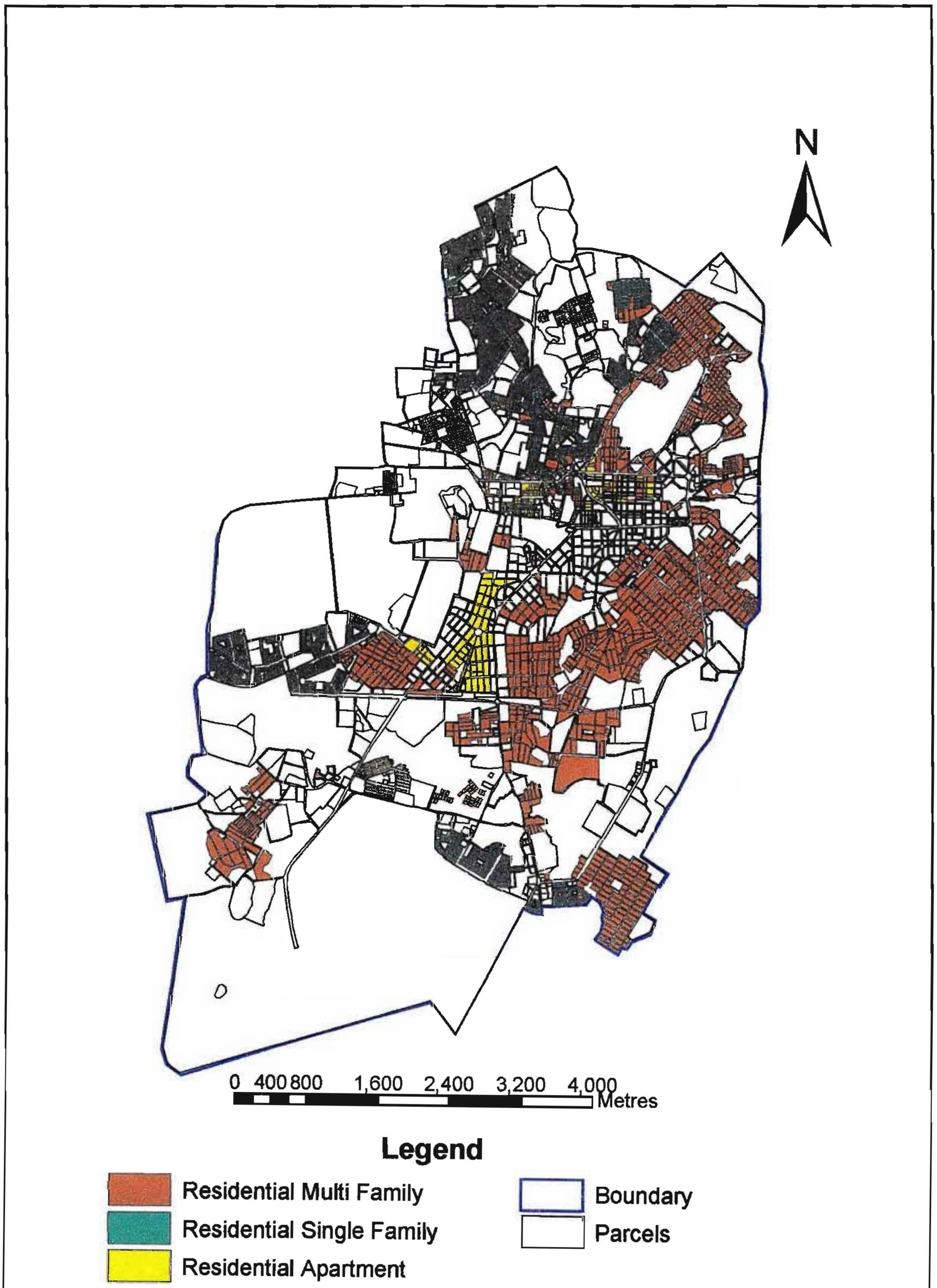


Figure 5.4: Residential Parcel Map of Asmara City

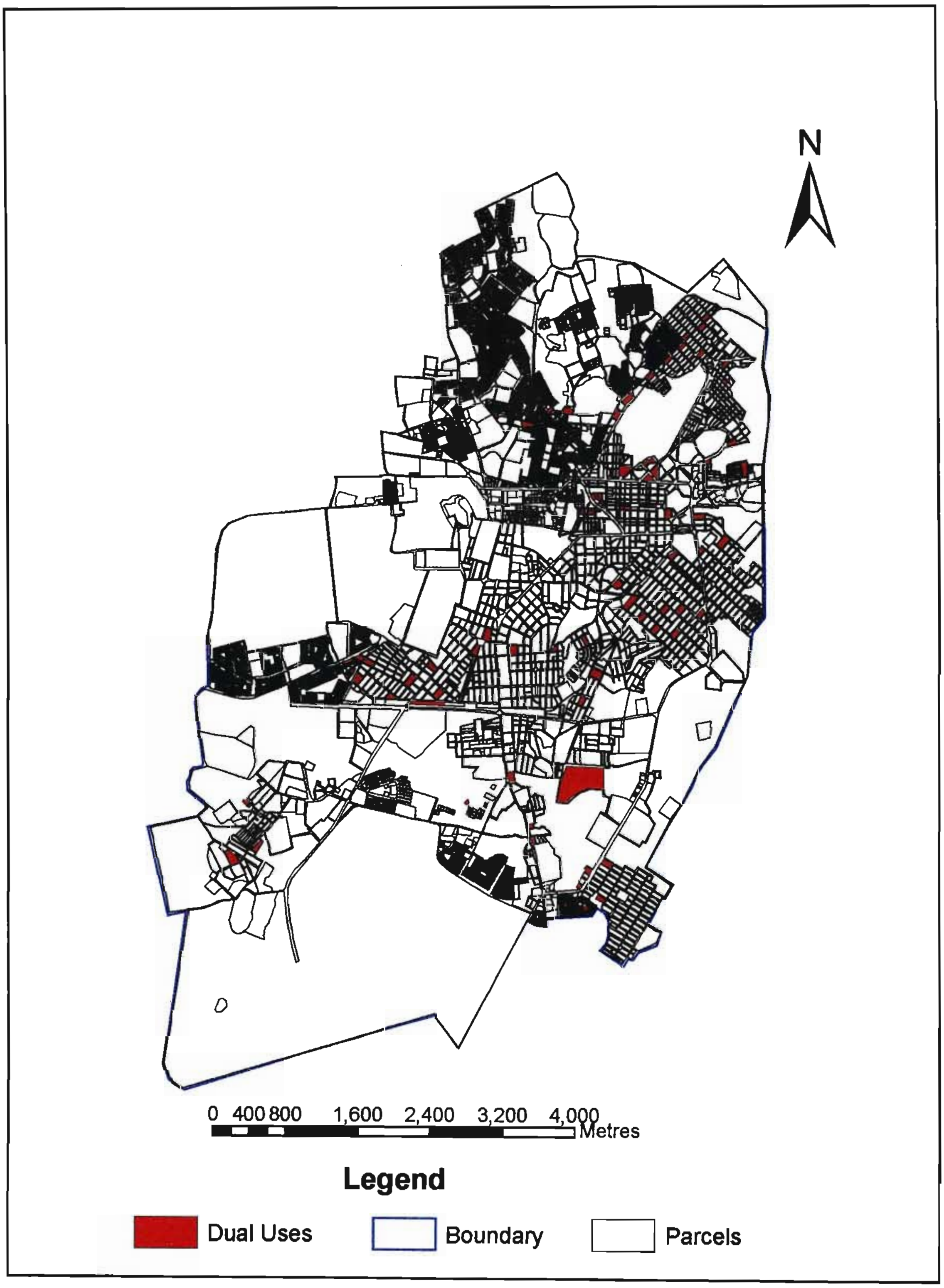


Figure 5.5: Alternative Land Use Map of Asmara City

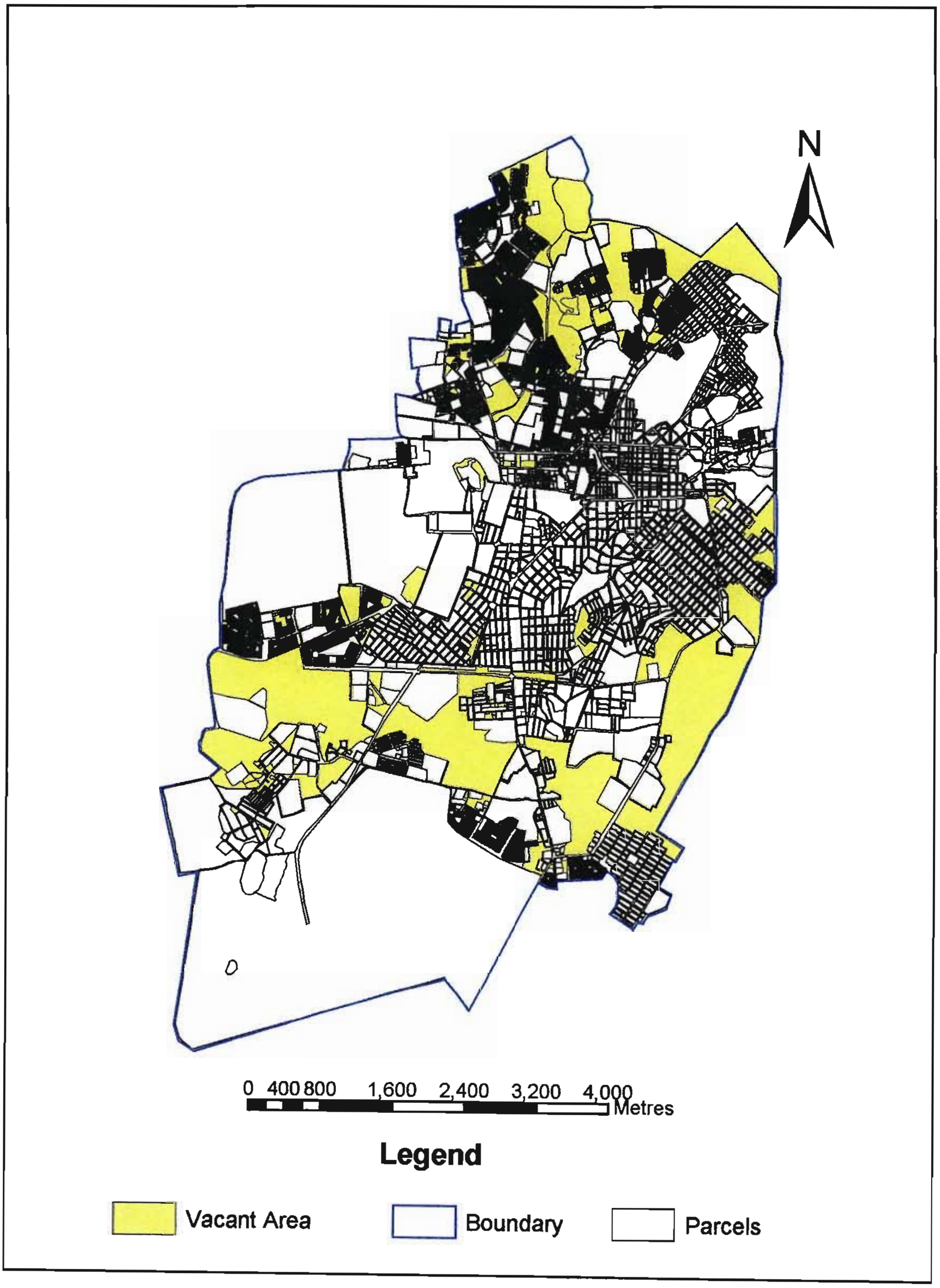


Figure 5.6: Vacant Area Map of Asmara City

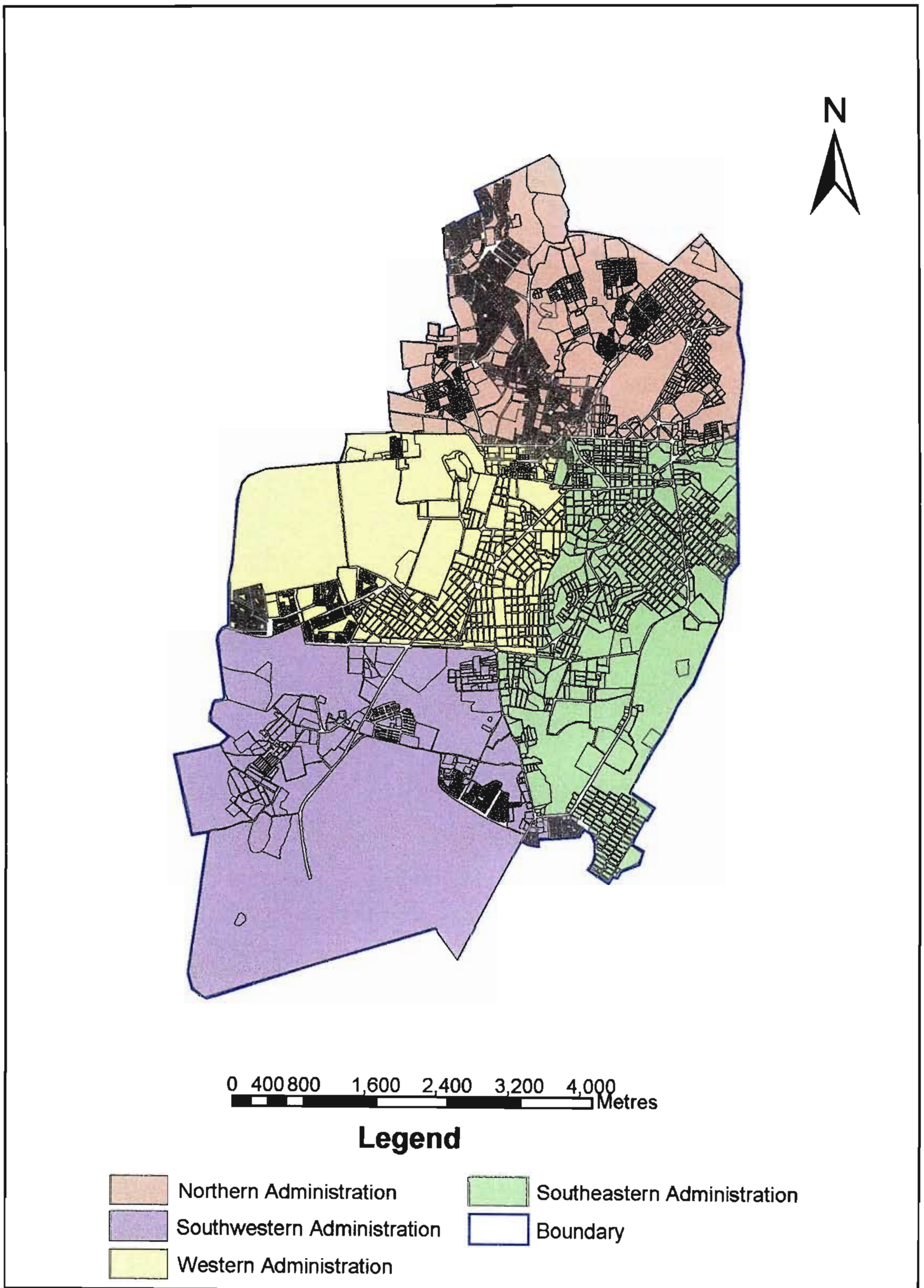


Figure 5.7: Administrative Zone Map of Asmara City

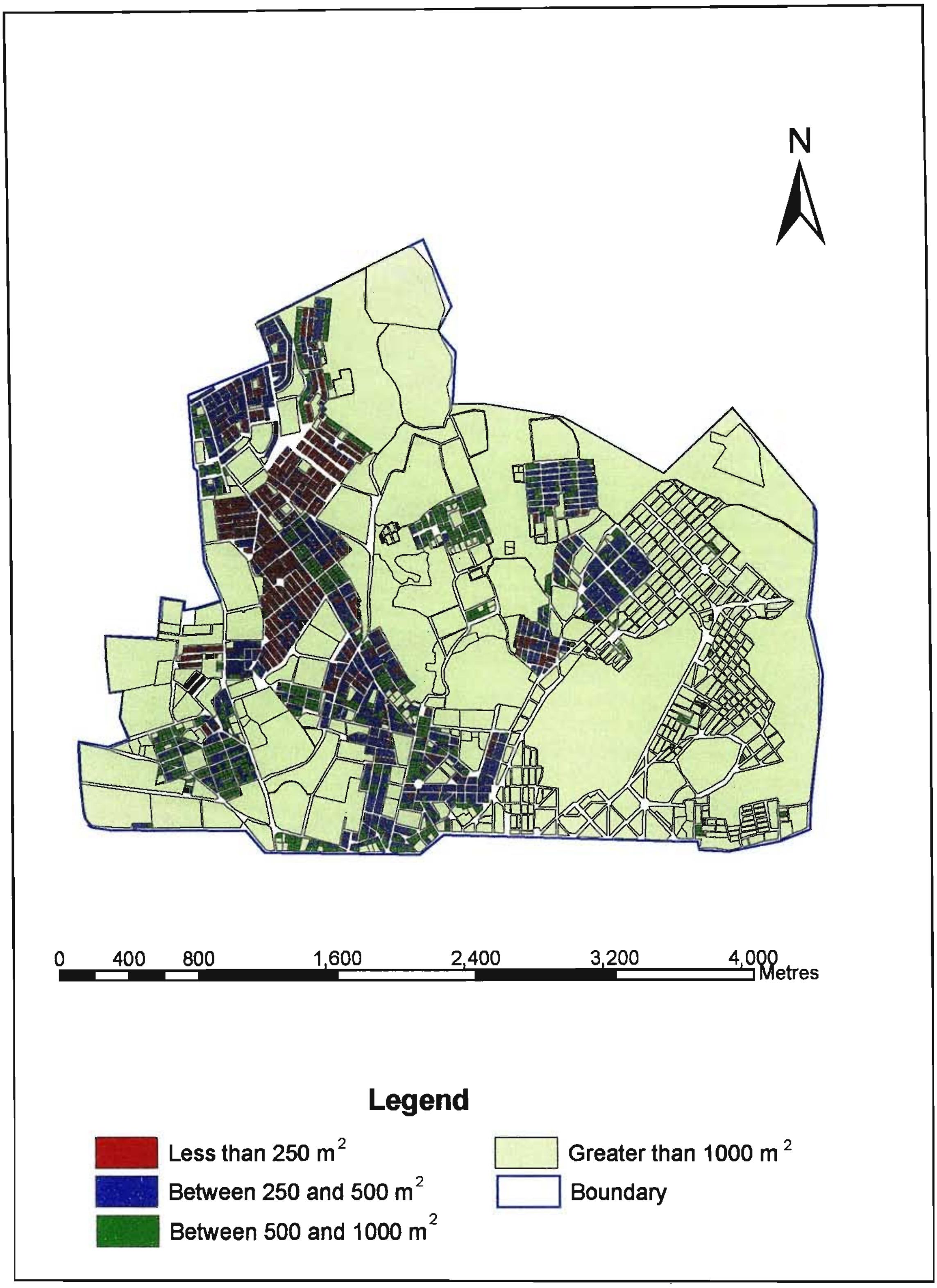


Figure 5.8: Parcels Area Map of Asmara City (North Administration)

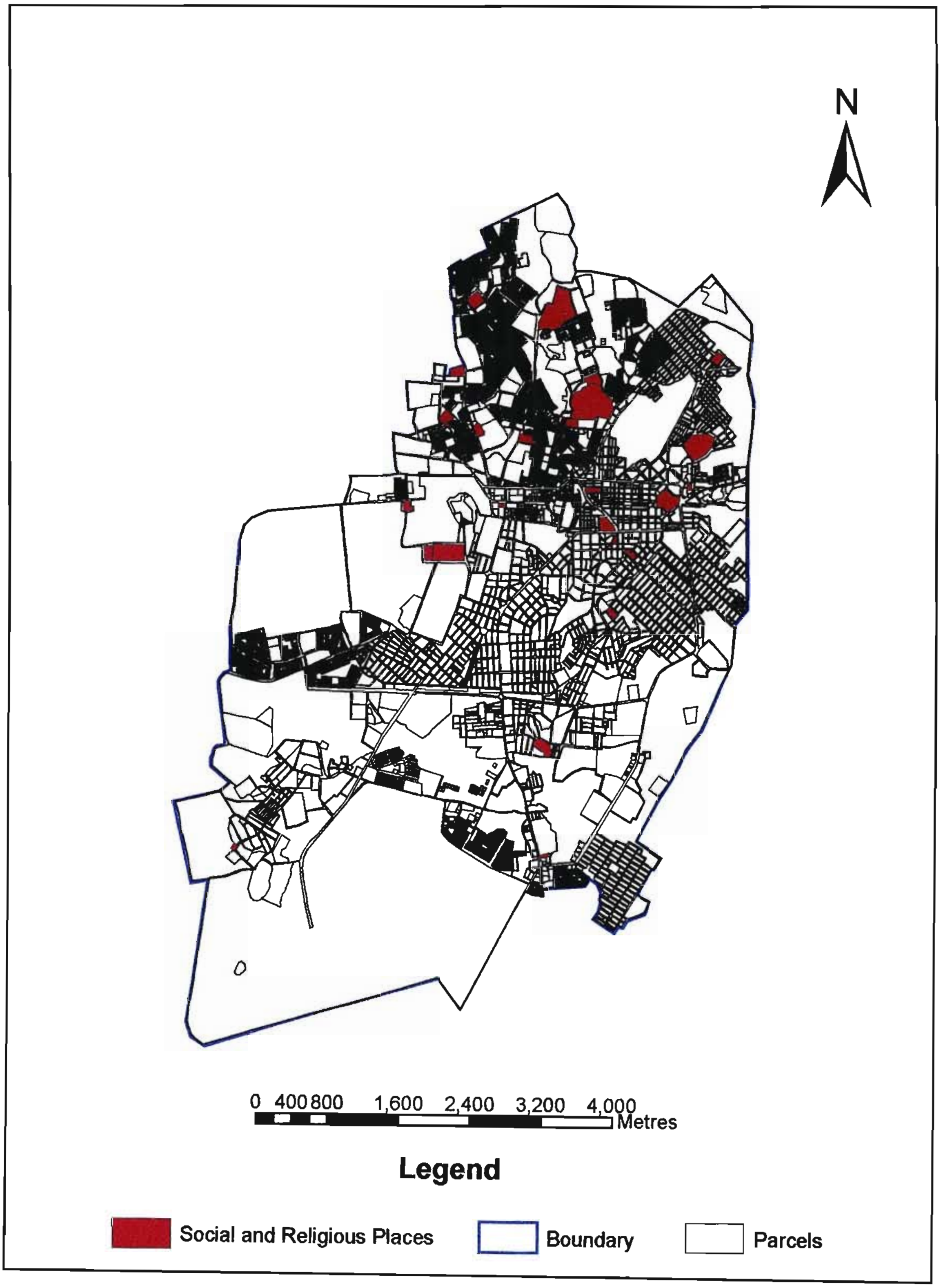


Figure 5.9: Social and Religious Map of Asmara City

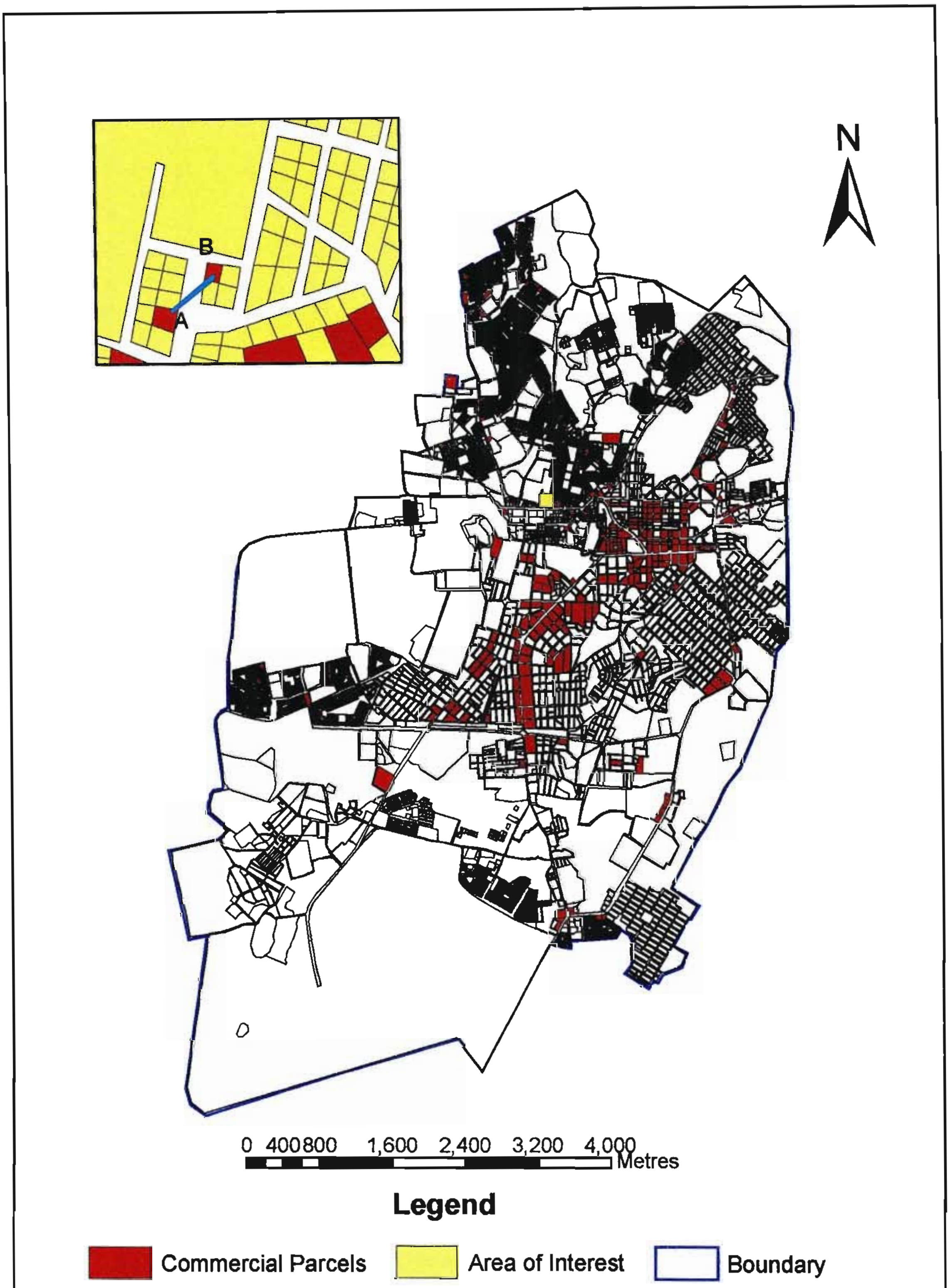


Figure 5.10 Commercial Map of Asmara city and Site of Two Restaurants (A and B)

5.3.1 Land Use of the City

A land use map was generated, Figure 5.3, to show the land use pattern of Asmara city, which is important for urban land administration. It is very detailed in that it describes eleven categories of urban land use and each individual property is described. These are Residential, Commercial, Industrial, Institutional, Agricultural, Public Services, Educational, Religious, Transportation, Informal Settlements and Vacant Area. Here each urban land use has been assigned a separate colour as displayed in the legend. This cadastral map was developed in this study from different data sources and is very important, as it is helpful for urban land planners and land administrators. This map is also extremely useful for planners and valuators to identify property tax liability. The total area occupied by each urban land use is given in km^2 in Table 5.1. Also included in Table 5.1 is the total area each land use occupies as a percentage of the entire city.

Table 5.1 Percentage Coverage of the different Urban Land Uses in Asmara city

Urban Land Use	**Area (km^2)**	**Area (%)**
Residential	81.6	32
Commercial	17.85	7
Industrial	22.95	9
Institutional	30.6	12
Agricultural	12.75	5
Public Services	10.2	4
Educational	12.75	5
Religious	7.65	3
Transportation	22.95	9
Vacant Area	20.4	8
Informal Settlements	15.3	6

Table 5.1 details that, a large area of Asmara city (32%) is used for residential purposes, which include: Single Family Residence, Multi Family Residence, and Apartments.

Governmental, Non-Governmental Organizations, Diplomat, and Private Offices thus Institutions collectively also occupies 12% of the total area of the city. Transportation that includes Roads, Railway station, Bus station, and Parking Area encompasses 9% of the city. Industrial, Vacant areas, Commercial, Informal Settlements, Educational, Agricultural covers 9%, 8%, 7%, 6%, 5%, and 5% of the total area of the city respectively. Public services, which comprise hospitals, fire station, police station, and recreational areas, occupy 4% of the total area of the city. Churches, Mosques, and Cemeteries account for 3 % of the total area of the city of Asmara.

5.3.2 Residential Parcels

Figure 5.4 shows residential parcels of Asmara city. The purpose of this map was to allow urban land administrators to have a general picture of the patterns of distribution and density of residential buildings on the ground for making planning decisions. Figure 5.11 below shows that of the total residential parcels, 65% are multi family residential parcels. 28% of the residential buildings are single-family residential parcels, and only 7% of the residential parcels are in the form of apartments.

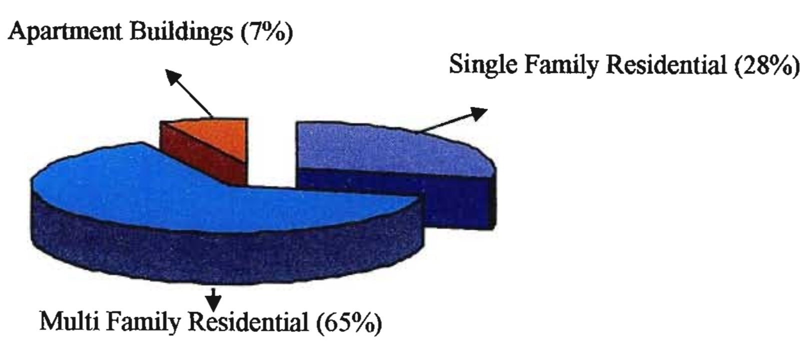


Figure 5.11 Residential Buildings based on Number

5.3.3 Alternative Land Use Map

An alternative land use map was also produced (Figure 5.5). This map indicates those buildings that have a secondary land use. This includes for example a residential building, which also has a shop on the property. This map is extremely useful for planners and valuators since residential properties that also operate businesses within their zones or bands are liable to pay higher rates. However, planners and administrators of Asmara city have no method of keeping up-to-date information readily available to control and manage such events. 24% of the residential parcels were identified as having a secondary land use such as grocery, stationary, etc.

5.3.4 Vacant Areas Map

The distribution of vacant land is shown in Figure 5.6. In the city of Asmara when the officials of the Municipal Office request information on vacant areas for development, the process of identifying such areas takes time and resources. Whereas in this database this request would take a couple of minutes to process and identify all available vacant areas. The vacant land map provides the planner with vital spatial information about where the vacant plots are located.

5.3.5 Administrative Zones Map

The administrative boundaries of the city are shown in Figure 5.7. Asmara city is divided into four Administration Zones. This map is of importance to administrators. This map can be used for many purposes for example census tracts.

5.3.6 Area of Parcels

A map showing the areas of individual parcels, (Figure 5.8), was created from the designed database as a means of comparison to the nominal parcel size obtained from the planning division of the Municipal Office. The result revealed that several properties in the city of Asmara are below the nominal parcel size. This could be due to the properties already being sub-divided when the policy that forbids parcel partition was introduced, or that the Municipal Office is unaware of the fact that these properties have been subdivided. This information helps the Municipal Office to maintain and control the size of parcels. In other words, administrators can use the database and prevent parcels of land from being subdivided into smaller sections and sold. If the Municipal Office does not manage this, the density in the city could increase to such an extent that the existing infrastructural services would be unable to cope.

5.3.7 Social and Religious Map

A map showing the social and religious facilities and charity institutions is shown in Figure 5.9. This map is important for Asmara Municipal Office property taxation department to exclude these plots from the assessment process as these parcels are exempted from property taxation.

5.3.8 Commercial Map

A map showing Commercial plots such as Groceries, Restaurants, Bars, and Cafeterias is shown in Figure 5.10. This map is important for the planning division of the Municipal Office. The planning division of Municipal Office has a policy in allocating new business shops whereby any two similar shops must be sited at least at a distance of 100 meters apart. However, as illustrated in the commercial plot map the distance between two restaurants; A and B, is less than 100 meters, we can see that this policy rule is not practically applied. Thus using this GIS-based cadastral data the planning division of the Municipal Office can allocate new business buildings and identify those existing shops nearer to each other.

5.4 Banded Property Taxation system

The standardized proximity to main roads, the CBD and public services are shown in Figure 5.12-5.14. The final property value indicator map i.e. index proximity is illustrated in Figure 5.15.

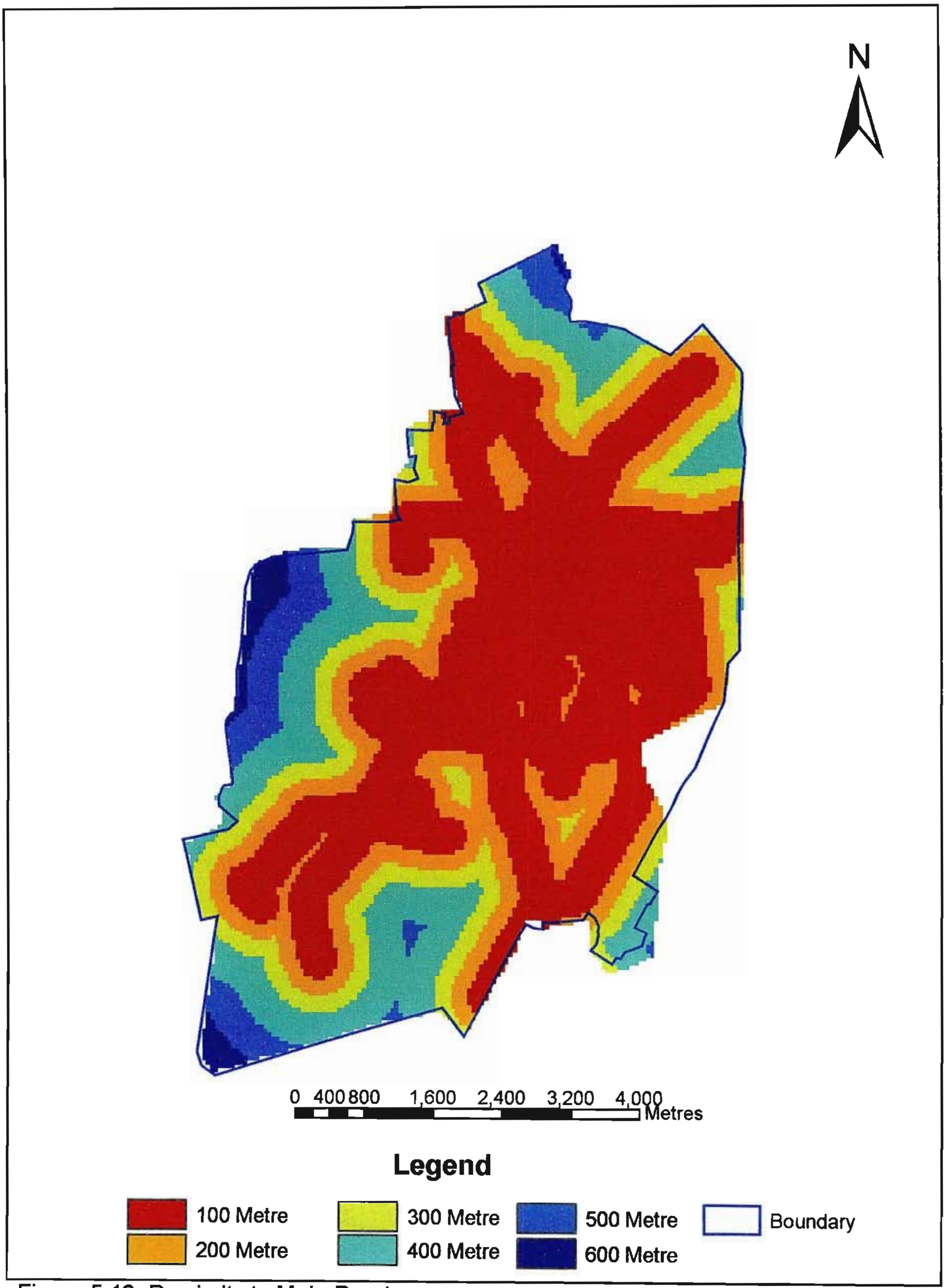


Figure 5.12: Proximity to Main Roads

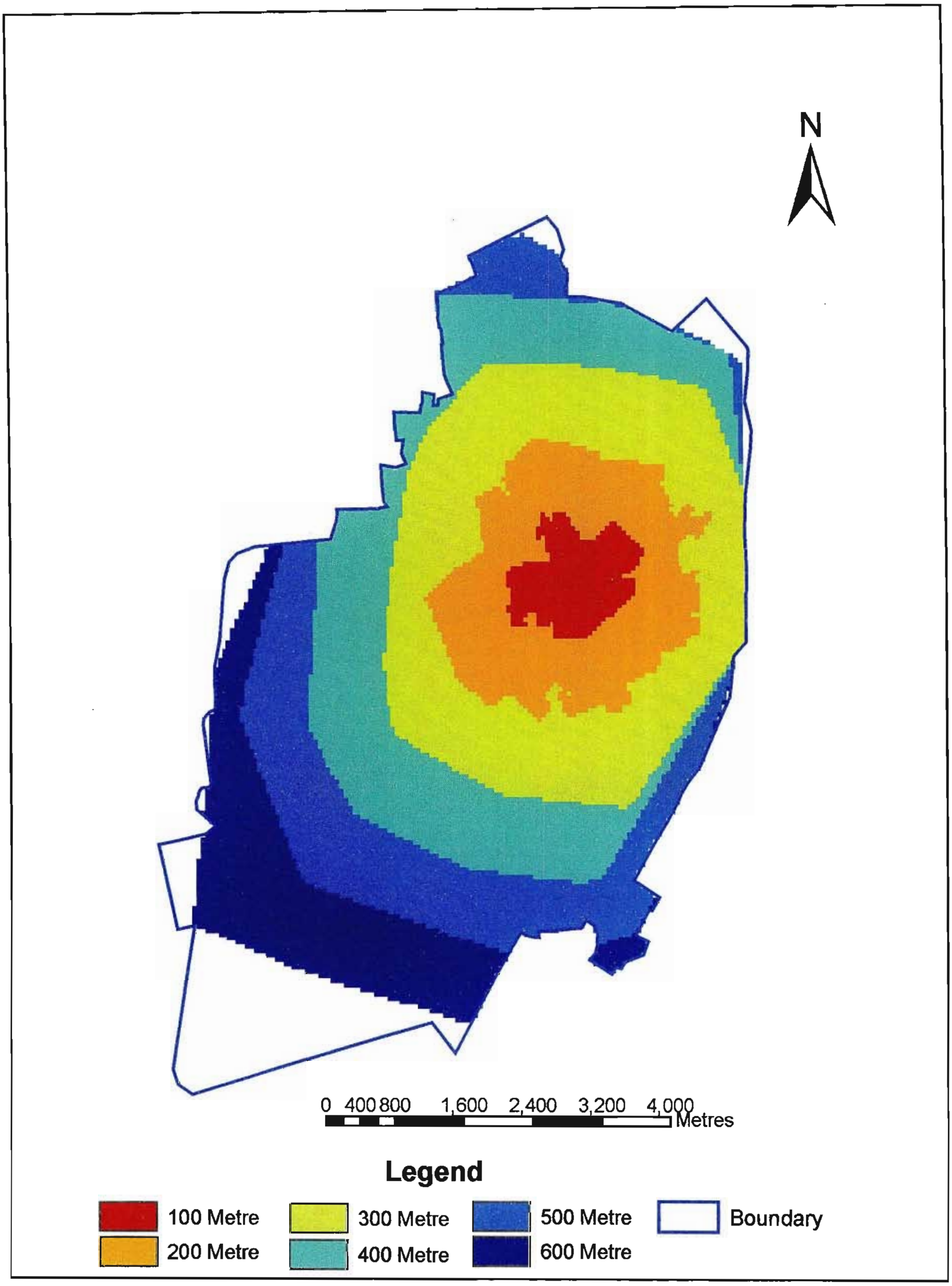


Figure 5.13: Proximity to the Central Business District

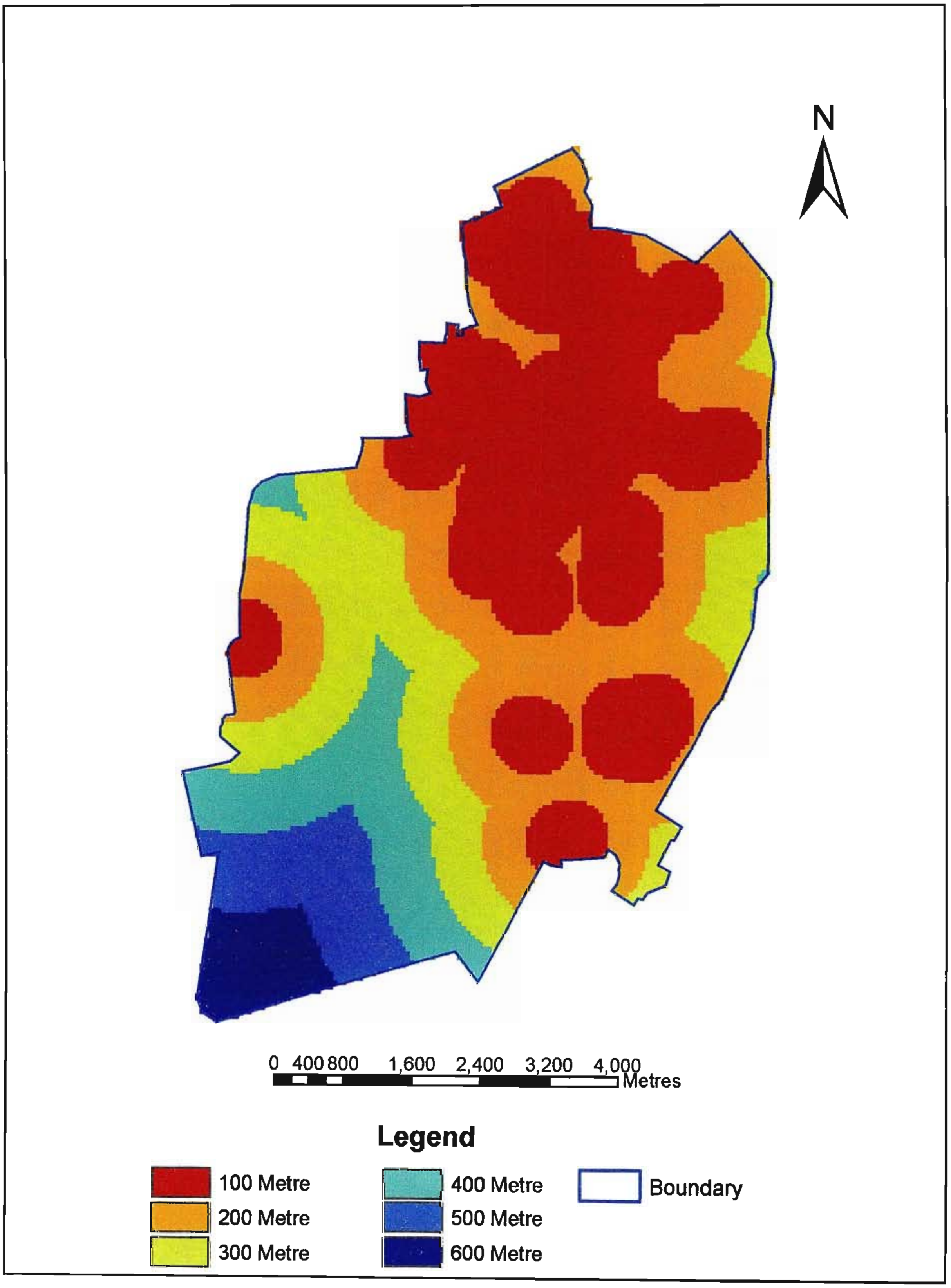


Figure 5.14: Proximity to the Public Services

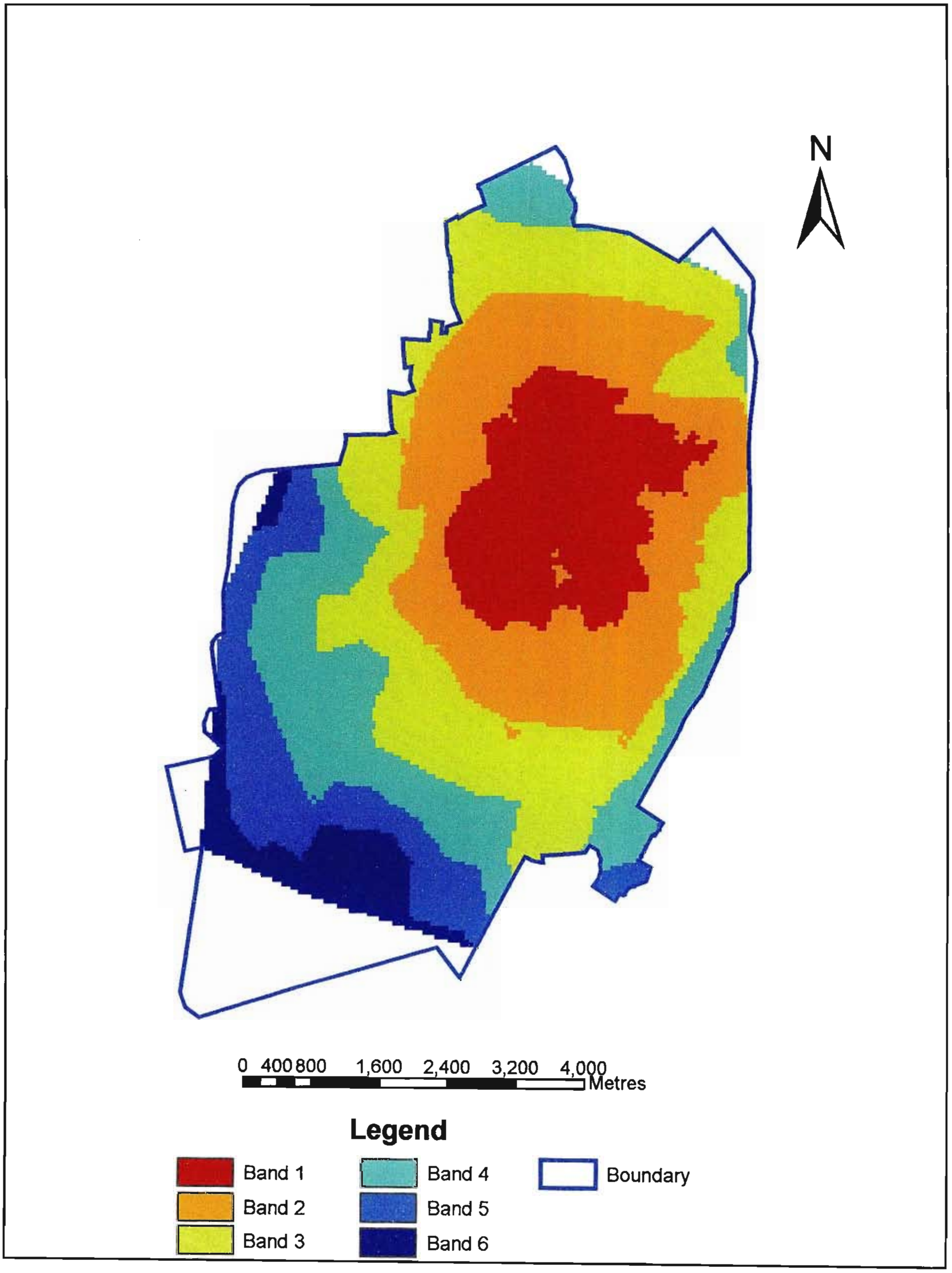


Figure 5.15: Combination of the three Factors

Each property is placed into one of the six value bands. There is no empirical justification for having six bands. The important issue here is one of flexibility and designing a value structure, which suits the local property market.

The banded value data was then overlaid upon the vector cadastral map, to assign the properties to one of the six bands. Figure 5.16 shows the overlaid map. From this map Tables 5.2 and 5.3, were extracted Table 5.2 shows the number of residential and commercial parcels found overlaid on each band. Table 5.3 also details the properties exempted from the tax levy.

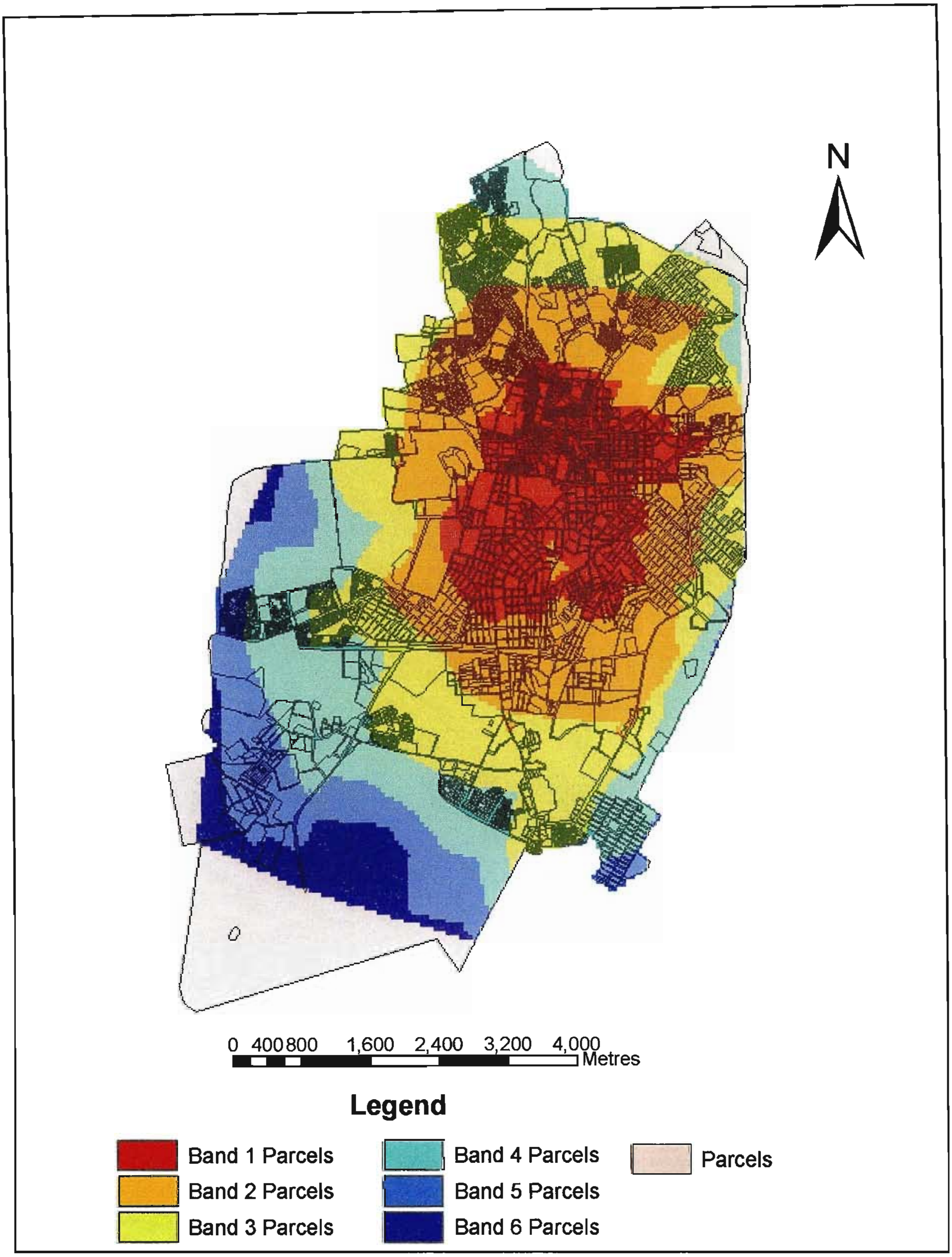


Figure 5.16 Overlay of Parcels with the Respective Taxation Bands

Table 5.2: Parcels liable to Property Tax

Bands	Residential Single Family	Residential Multi Family	Residential Apartment	Total	Commercial	Total
1	421	1266	1393	3080	975	4055
2	1743	1947	478	4168	988	5156
3	5118	2376	659	8153	624	8777
4	5228	2583	538	8349	459	8808
5	2107	1758	836	4701	278	4979
6	1436	2155	278	3869	114	3983
Total	16053	12085	4182	32320	3438	35758

Table 5.3: Parcels exempted from Tax

Type	Government office	Public service	Religious area	Charity organization	Vacant land	Total
Band 1	57	41	7	19	13	137
Band 2	29	31	16	16	14	106
Band 3	21	17	13	13	14	78
Band 4	31	17	13	11	17	89
Band 5	13	9	9	7	28	66
Band 6	11	-	1	-	25	37
Total	162	115	59	66	111	513

5.4.1 Tax Structure

In this study, the property was placed into one of the six value bands. The important issue of this banded appraisal system, as stated here is one of flexibility and designing a value structure that suits the city property market. In this study, band 4 was recommended and taken to be base band for Asmara city in consultation with tax officials. The property tax authority determines the level of tax liability for band 4 properties and then the tax liabilities for the other bands are calculated by reference to the relative tax rates.

In this tax system each property was not valued individually, they were merely placed into one of the six value bands or zones. The key objective is to determine the relative proportion of total tax to be paid by each property based on property value ratio, and on the bands determined. This method can maintain the horizontal and vertical equity of taxation system.

The amount of money to be levied depends on the bands to which a property has been allocated. Band 4 was taken as the base band, in this case Municipal Office determines the level of tax to be charged for band 4 parcels and the tax liability for the other bands is calculated by multiplying respective rates of each band.

5.5 Hospitals and Fire Stations Service Area Assessment and Allocation

5.5.1 Service Catchments of Hospitals

The result of the three hospitals service catchments within Asmara city is as shown in Figure 5.17.

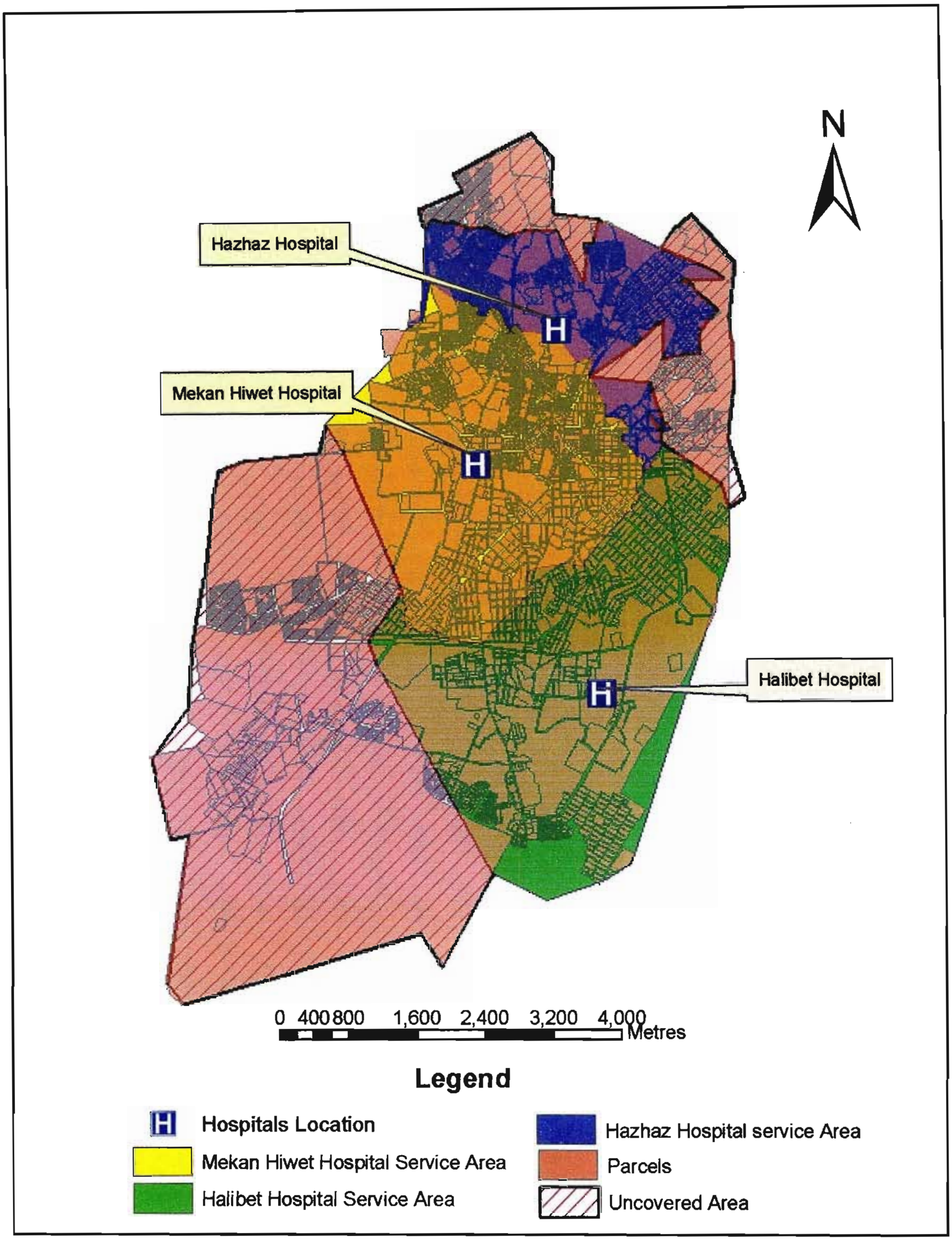


Figure 5.17 Public Hospital Service Catchment

This figure shows that the south-western part and some parts of the northeast of Asmara city are located outside the hospitals service catchment area. This means that the existing hospitals are not serving the entire city. The areas, identified outside of the hospitals service catchment areas are sparsely populated.

Table 5.4 below shows, number of beds needed for each hospitals based on the NEMP-E 2001 that is, 2 beds per 1000 person, criteria.

Table 5.4: Result of 5km Hospital Catchments Service Area

Hospital Name	**Hospital Capacity (beds)**	**Hospital bed capacity per 1000 person**	**Hospital demand (beds)**	**Population**
Mekan Hiwet Hospital	250	1.9	264	132100
Halibet Hospital	75	0.7	226	113150
Hazhaz Hospital	30	0.3	215	107750

Theoretically, all of the people living in the city of Asmara should have free access to any hospital, but practically this is judged by the capacity of each hospital. Accordingly, if the size of demand of any hospital's service catchment area is more than the hospital's capacity then the problem of service shortage will appear. Table 5.4 above, clearly illustrated that the size of demand within the service catchments area of the three hospital's is more than their capacity. To mention the figure it looks; Halibet Hospital capacity is 75 beds while its demand is 226 beds. Hazhaz Hospital capacity is 30 beds and its demand is 215 beds.

Accordingly, it can be said that there is a great need to increase existing hospital capacities in order to overcome the existing demand, as well as, the geographical accessibility of the exist Hospitals. Results show that there are problems relating to both geographical accessibility and functional capacity of the hospitals. This suggests that, Asmara city is not well serviced with hospitals.

5.5.2 Service Area of Fire Station

Using the network analysis model, service catchment were developed to evaluate the service area coverage of the existed one fire station for the following ranges of response time of 8, 16, 24, 32, and 40 minutes, Figure 5.18.

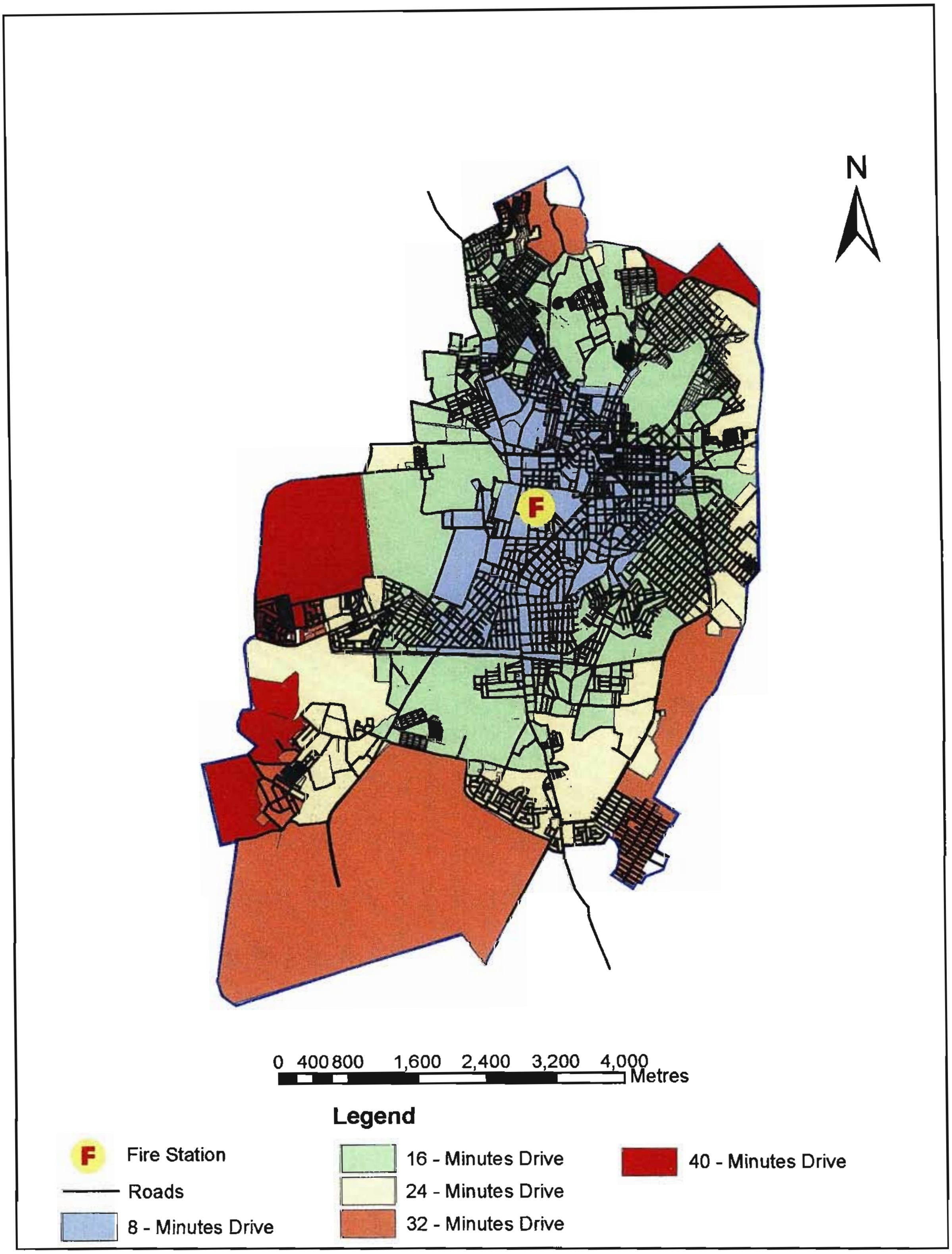


Figure 5.18 Fire Station Service Catchemnt within Specific Driving Time

The total service area coverage of each response time is calculated from Figure 5.18 and depicted graphically in Figure 5.19 below.

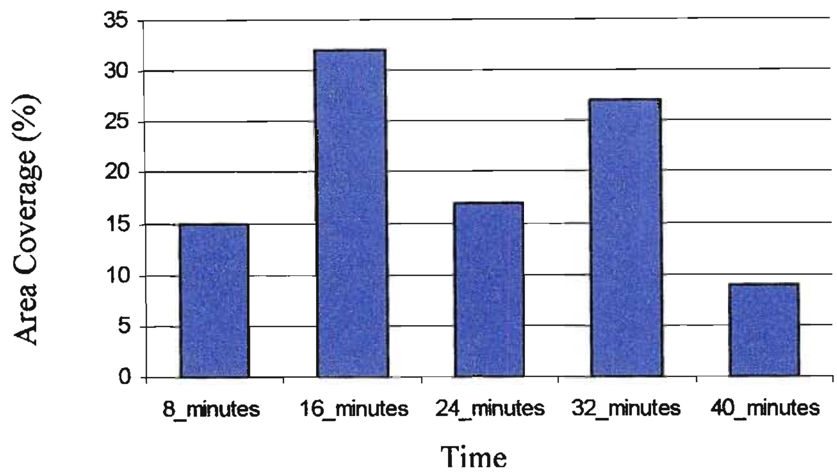


Figure 5.19: Percentage of Fire Station Service Area Coverage

Figure 5.19 indicates that only 15 % of the city of Asmara is within safe fire rescue service coverage, that is an ambulance or fire engine can reach a spot within 8-minutes time. 32% of the total area of Asmara city can be reached within 16-minute drive from the fire station. 17 %, 27 %, and 9 % of the city of Asmara can be reached within 24, 32, and 40-minutes drive respectively. Generally, the majority of the city is in the area, which is beyond the recommendable response time. Although the exact circumstance of an individual incident cannot be predicted, on most occasions the situation will get worse with the passage of time. This project develops two options which are expected to give full service to the entire city.

5.5.2.1 Allocation of Fire Stations

Using the station allocation model with the static component of resource allocation optimum siting of new fire stations were illustrated in Figure 5.20 and 5.21. These two options produced here drew up on response time through network analysis.

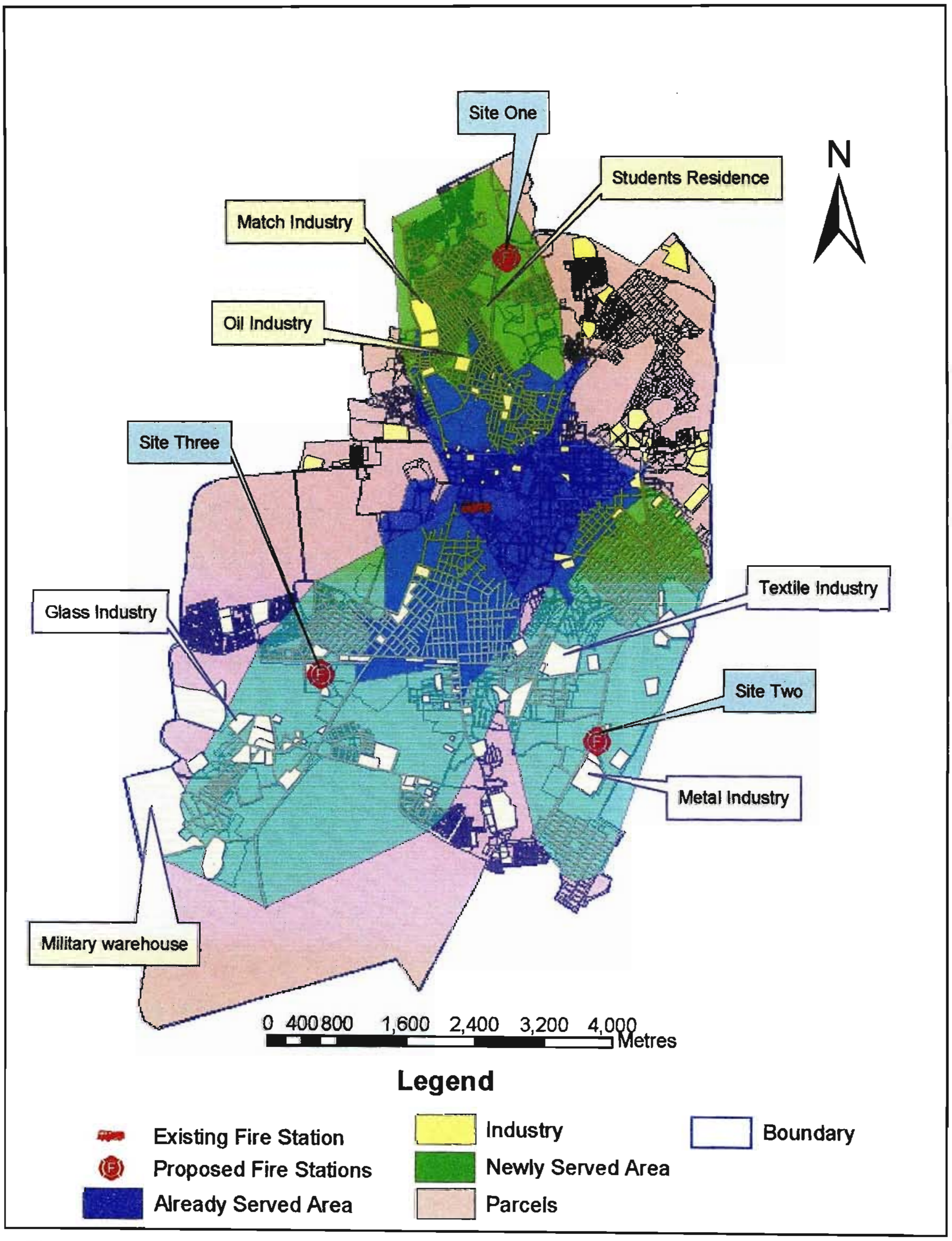


Figure 5.20: Option One

5.5.2.1.1 Option One

This option, Figure 5.20, consists of siting three fire stations at the most sensitive parts of the city, one of the stations, called site one, is located in the north of Asmara city. This station would be expected to cover the two large industries; Match Industry and Oil Industry, and also student's residential buildings and substantial private residential buildings. The second station, called site two, located in the southeast of Asmara city. This station would cover Metal Industry and Textile Industry and covers a considerable residential area, which are presently uncovered in the southeast of the city. The last station that is site three in this option would be located in the southwest of Asmara city. This station is expected to cover Military Warehouse, Glass Industry, Cement Industry, and expected to cover a considerable southwest residential buildings.

This option only assures the coverage of the north and southeast and southwest portion of the city. Although with this option the fire stations services area covers substantial sensitive areas, some portions of the city of Asmara are still left uncovered by the fire services; these parts are west and east of Asmara city. This part of the city is mainly residential. The civil aviation, which is located on the southwest part of Asmara city, has its own fire unit which serves only for the civil aviation.

Although there are uncovered areas surrounding southwest fringe of Asmara city, what makes this option so attractive is that only three new units would be required to increase the city's emergency service coverage, and all the susceptible industries are also under full emergency services coverage. Areas not covered are expected to have response times slightly more than 8-minutes by the nearest fire station.

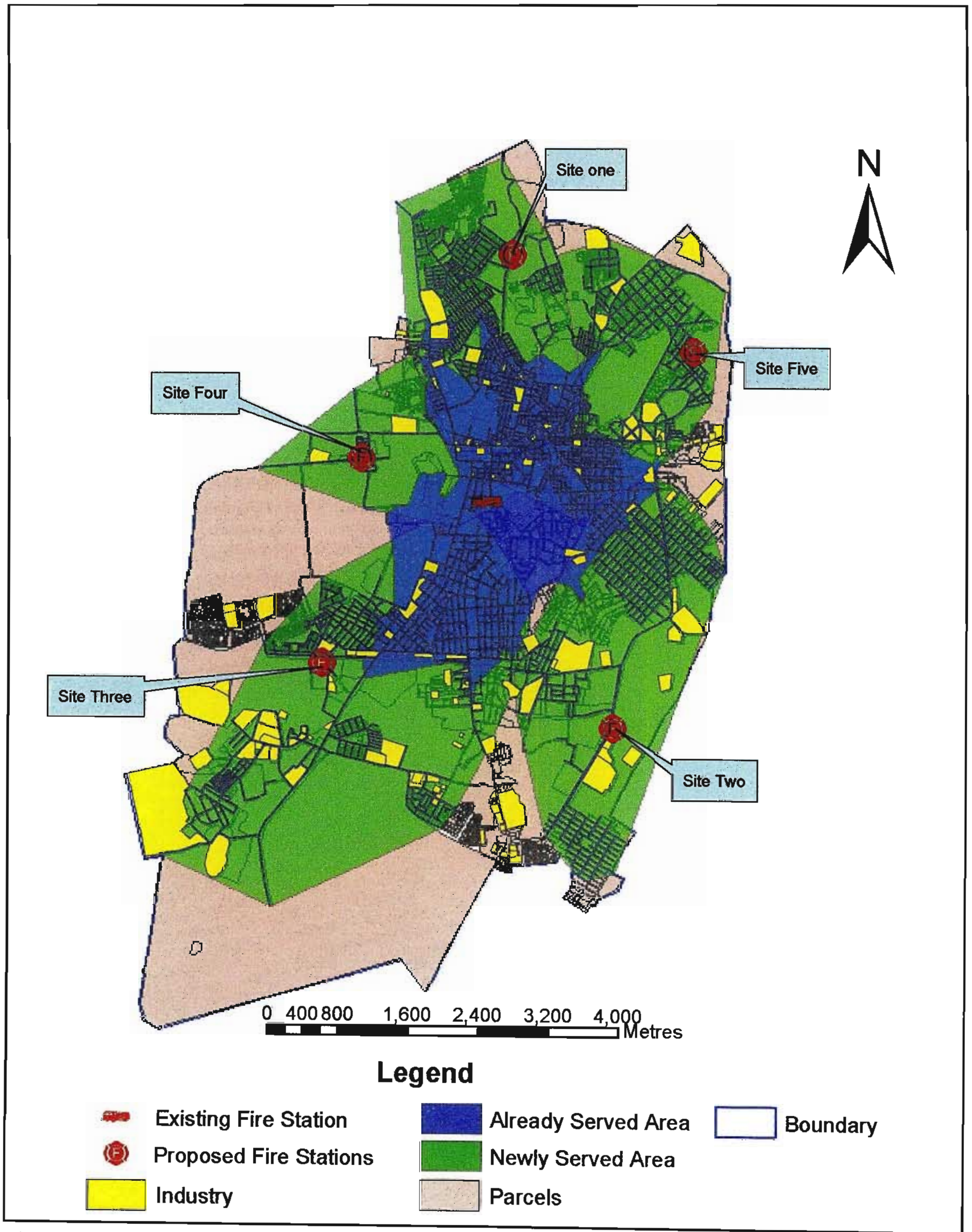


Figure 5.21: Option Two

5.5.2.1.2 Option Two

This option entails another alternative, which is very expensive and covers the entire city with fire stations service. That is keeping all sites, as they are located in option one. The only change is adding two more stations. These new stations are located on the north-eastern and north-western parts of the city of Asmara. These stations are expected to cover the residential areas of the city located on the east and west of Asmara city. Although it is expensive to site five new fire stations, this option would cover the whole city with satisfactory fire stations in terms of response time.

5.6 Summary

The results of the analytical GIS-based cadastral database produced in the study have been described. The implementation of the designed cadastral database for enhancing urban land administration, property taxation, and for assessments of hospitals and the only fire station services are also described and illustrated.

CHAPTER: 6 CONCLUSIONS AND RECOMMENDATION

The knowledge and applications of land information and GIS in Eritrea are very limited and there is shortage of sufficient, reliable, up-to-date and modern land information systems for decision-making. Further, GIS is implemented at a very low level, with little practical application. Therefore, it is believed that this study has indicated ways to improve knowledge and understanding of GIS as an analytical tool in the activities of the Asmara Municipal office.

It was recognized at the outset of this study that GIS-based cadastral data would provide efficient urban land information for urban land administration. The literature indicated that GIS-based cadastral data provide information to implement an effective equitable and fair property taxation system, and for assessment of service catchments for health facilities and fire stations.

As a consequence of lack of standard data, IKONOS imagery, GPS readings, and existing AutoCAD data were used for developing the spatial cadastral data. The IKONOS image had to be geo-rectified using GPS captured data; the existing AutoCAD data also had to be converted into GIS format, and geo-referenced using the GPS readings. Finally, the two data sources were overlaid for on-screen digitizing to arrive at the parcels and road network components of a cadastral system for Asmara city.

Information about the parcels that is non-spatial cadastral data (owner of parcel, type of ownership and rights, location of parcel, and uses of parcels) were linked to the spatial cadastral data using a primary key that is parcel ID (PID). ArcGIS was used to create, store and manage the database.

The study illustrated practical examples of how GIS-based cadastral data could support the different departments of the Municipal Office in Asmara city. The benefit of the designed GIS-based cadastral data to assist urban land administrators in their daily activities (planning process) was clearly illustrated. The implementation of the GIS-based cadastral data in the land administration process resulted in an improvement in the quality and quantity of planning-related data and is expected to help in any urban planning related decision-making.

The designed GIS-based cadastral database gives administrators the ability to handle factors, which were impossible to handle before, such as accessibility to CBD. In particular, the distance from any main street is computed as real distance using network analysis. Using GIS, many complicated analyses can be implemented and this can improve the accuracy of land appraisal as well as the automation of the land appraisal process.

One of the objectives of the study was to develop value based parcel banding for property taxation purposes. It is believed that banded property tax approach, if designed to reflect the structure of the property values in terms of number of bands, size of bands, and tax structure can overcome those technical and administrative, equity and fairness problems of property tax administration in Asmara city.

It was possible, by use of GIS-based cadastral data, to arrive at a value based six-band tax appraisal. Each parcel was assigned into one of these bands. Band 4 was taken as a base band for determining the tax rate to levy each other band. This system is believed to maintain the horizontal and vertical equity of taxation in the city of Asmara. It has been shown that the band tax system is a quicker and cheaper process for Asmara city.

The results of the service catchments of hospitals and the only one fire station indicate that a considerable area of the city of Asmara is not covered under the service area catchments. Using GIS, the designed cadastral database was interrogated for location allocation modeling to recommend appropriate locations for new fire stations. Two options have been developed and compared.

Considerable cooperation between the various ministries and departments interested in urban information needs to be strengthened so that some of constraints mentioned earlier can be removed. It is especially important to establish some kind of consistency with regard to cadastral data standards and accuracy requirements. Improved co-operation between the various government departments and the local authorities will improve the quality of data, and speed-up the accessibility of information for urban planners and land administrators.

The cadastral database developed from different sources, the core data collection and processing and manipulation were designed to provide critical planning information to enhance the work of land administrators with regard to the urban land use systems. The main purpose of the study was to increase knowledge in the following fields: the establishment of a viable and workable GIS-based cadastral database for the city of Asmara, the identification of the importance of cadastral GIS data, and the application of cadastral GIS in modelling and monitoring land use in the city of Asmara. This has been successfully achieved using modern technology such as IKONOS, GPS and ArcGIS in this study.

The Municipal Office of Asmara is identified as a primary beneficiary of this study it is recommended that the relevant authorities apply and use this database in their daily activities. Finally, it is recommended that similar studies be done in other cities of Eritrea and throughout the developing World.

References:

Abel, D.J., Kilby, P.J., and Davis, J.R., 1994: The System Integration Problem. *International Journal of Geographical Information Systems* Vol. 8, pp 1-9.

Adair, A. and McGreal, S. 1987: The Application of Multiple Regression Analysis in Property Valuation. *Journal of Valuation* Vol. 6 pp 57-67.

Alonso,W. 1964: *Location and Land Use, Toward a General Theory of Land Rent.* Harvard University Press

Anderson, S. 1981: *Land Information Systems (LIS), What is that? – An Introduction.* FIG 301.1, XVI Interntional Congress of Surveyors, Montreux.

Antenucci, J.C. 1991: *Geographic Information Systems: A Guide to the Technology*. Van Nostrand, New York.

Antwi, A. 1997: Property Valuation in the Absence of Market Data: Overcoming Empirical Hurdles in Transformation Economies, *Real Estate Valuation and Investment*, Vol. 1, No. 1, pp 31-38.

Armstrong M.P., and Densham P.J. 1990: Database Organization Strategies for Spatial Decision Support Systems. *International Journal of Geographical Information Systems*, 4, No. 1, pp. 3-20.

Aronoff S 1989: *Geographic Information Systems: A Management Perspective* WDL Publications, Ottawa, Canada.

Bahl, R. and Johannes F. 1992: *Urban Public Services Finance in Developing Countries.* Oxford University Press for the World Bank.

Bahl, R. 1998: *Land Taxes Versus Property Tax in Developing and Transition Countries,* Lincoln Institute of Land Policy, Massachusetts.

Baigent, E and Kain R.J.P 1992: *The Cadastral Map in the Service of the State: A History of Property Mapping,* Chicago University Press pp 423.

Balchin P N., Kieve, J L and Bull, G H. 1988: *Urban Land Economics and Public Policy,* Macmillan education Hampshire, UK.

Barnard B. D. 1953: *Cadastral Surveys and Records of Rights in Land.* FAO Land Tenure Study, Rome.

Boots B. 1999: Spatial Tessellation. In: Longley P.A., Goodchild M.F., Maguire D.J., and Rhind D.W. (eds.) 1999, *Geographic Information Systems: Principles, Techniques, Management and Applications,* New York John Wiley and Sons Inc. pp 503-526 Vol. 1.

Brown P., Hirschfield A., and Batey P., 1991: Application of Geo-demographic Methods in the Analysis of Health Condition Incidence Data, *Regional Science,* Vol. 70, pp 329-344.

Budic, Z.D. 1994: Effectiveness of Geographic Information System in Local Planning, *Journal of the American Planning Asociation,* Vol. 60. No. 2, pp 244-263.

Burrough, P. A., 1986: *Principles of Geographic Information Systems for Land Resources Assessment,* Clarendon press, Oxford.

Cheng-Ho, H. and Bible, D.1996: Applications of Geographic Information Systems for the Analysis of Apartment Rents *Journal of Real Estate Research,* Vol. 12 (1) pp 79-88.

Chou, Y.H. 1997: *Exploring Spatial Analysis in Geographic Information Systems.* Onward Press, Santa Fe.

Chrisman, R. R, 1997: *Exploring Geographic Information Systems,* New York: John Wiley and Sons Inc.

Codd E. 1970: *A Relational Model for Large Shared Data Banks Communications* of the ACM 13.

Dale P.F and McLaughlin J.D. 1988: *Land Administration Management an Introductory Reference to Cadastral Problem in 3rd World Countries*, Clarendon Press Oxford.

Dale P.F. and Mclaren R.A. 1999: GIS in Land Administration. In Longley P.A., Goodchild M.F., Maguire D.J., and Rhind D.W. (eds.) *Geographic Information Systems: Principles, Techniques, Management and Applications*, New York Wiley and Sons Inc. Vol. 2 pp 859-875.

Dangermond, J. and Freedman, C. 1986: *Findings Regarding a Conceptual Model of a Municipal Database and Implications for Software Design*. Geo-processing 3: pp 31-49.

Date C. J 1995: *Introduction to Database Systems*. (6th eds.) Reading Mass: Addison Wesley.

Davey K. J 1993: *Elements of Urban Management*, Urban Management Program Discussion Paper no. 11, The World Bank, Washington DC.

De Cesare, C. and Ruddock, L. 1998: A New Approach to the Analysis of Assessment Equity, *Appraisal Journal*, March/April, pp. 57-69. USA.

Densham, P.J., 1991: Spatial Decision Support Systems. In: Maguire D.J, Goodchild M.F., and Rhind D.W. (eds.) 1991 *Geographical Information Systems: Principles and Applications*. Longman, London Vol. 1, pp. 403-412.

Dillinger, W. 1986: *Property Taxation and the Fiscal Cadastre*. The World Bank Seminar on Land Information Systems. Annapolis. [Online] http://www1.worldbank.org/wbiep/decentralization/afrlib/afproptx.html

DoE, 1987: *Handling Geographic Information*. Department of Environment HMSO, London.

Doebele W. A, 1985: *Why Cadastral Systems are Important for Less Developed Countries*. The Urban Edge Longman Scientific and Technical, New York.

Dowall D. E and Giles C. 1991: *A Frame Work for Reforming Urban Land Policies in Developing Countries*. Urban Management Programme Discussion Paper no. 7, the World Bank[Online]http://www1.worldbank.org/wbiep/decentralization/listings.htm

Dunkerley, H.B.1983: *Urban Land Policy, Issues and opportunities*. World Bank Publications, Oxford University Press.

Eastman, J. R., Kyem, P. A. K., Toledano, T. and Jin, W. 1993: GIS and Decision making. United nations Institute for Training and Research. *Explorations in Geographic Information Systems Technology*, Volume 4. UNITAR European Office, Geneva.

Eden, R.J. 1988: *Modelling for Land Information System Development in Australia and in Particular Queensland*. Unpublished PhD Thesis University of Queensland.

Emelinda M.P 2000: *Geographic Information System Based Allocation of Emergency Response* Units along a Transportation Route. [Online] http://www.gis.esri.com/liabrary/userconf/proc95/to200/p161.html.

Enemark, S. 1997: *Cadastral Applications for Land Management*. Proceedings of European Conference on Geographic Information, Eurogi, Vienna, Austria, April, 1997.

Eritrea Land proclamation No. 58/1994, *In Creating a Legal Framework for land Registration in Eritrea:* Consolidated Final Report of the International Legal Consultant, Supra note 1, Annex F.

ESRI 1995: *Understanding GIS*: The ARC/INFO method, Environmental Systems Research Institute, Inc/. Redlands, CA USA.

ESRI 2002: *Arc User* Many Benefits Realized through Cadastral GIS, The Magazine for ESRI Software users, April-June 2002.

Féderation International Des Géomètres, FIG 1990: Congress papers, Commissions 7., Helsiniki. [Online] http://www.fgdc.gov/o1_nsdi_reports/cadastral.html

Féderation International Des Géomètres 1995: *Statement on the Cadastre*. International Federation of Surveyors Bureau, Canberra, Australia.

Forbers H., and Todd P. 1995: *Review of Cancer Services*, Northwest Regional Health Authority, Urban Research and Policy Evaluation Regional Research Laboratory, University of Liverpool.

Franzsen, R.C.D. 1999: Property Taxation in South Africa In: McCluskey, W.J. (eds.), *Property Tax: An International Comparative Review*. Ashgate Publishing Company, Aldershot, UK. pp 227-257.

Gallimore, P., Fletcher, M. and Carter, M. 1996: Modelling the Influence of Location on Value, *Journal of Property Valuation and Investment*, Vol. 14 (1) pp 6-19.

Gatrell, A. C. 1991: Concepts of Space and Geographic Data. In: Maguire D J, Goodchild, M. F, Rhind, D. W. (eds.) *Geographic Information Systems: Principles and Applications*. Longman, London, pp. 119-134, vol 1

Gatrell A. C. and Senior M. L. 1999: Health and Health Care Applications In: Longley P.A., Goodchild M.F., Maguire D.J., and Rhind D.W. (eds) *Geographic Information Systems: Principles, Techniques, Management and Applications*, New York John Wiley and Sons Inc. Vol.2

Gazdzicki, J. 1998: *Cadastral Infrastructure and Standards*, Cadastral Congress, Warsaw. International Monetary Funding yearbook, Washington D.C. [Online] http://www.worldbank.org/wbi/publicfinance/documents/propertytaxation

Glianali, R. 1943: *Dell Africa Italiana Anna*. Vol. 1, No.2, January 1943.

Goodchild M. F, Longley P. A, Maguire J., and Rhind D.W 2001: *Geographic Information Systems and Science* John Willey and Sons, New York

Haig, R. M. 1926: Towards an Understanding of the Metropolis, *Quarterly Economic Journal*, Vol. 40 pp 421-423.

Harriss, J. 1989: *Urban Poverty and Urban Poverty Alleviation, in cities.*

Healey, R.G 1991: Database Management Systems, In: Maguire D.J., Goodchild, M.F., and Rhind, D.W. (eds.) *Geographic Information Systems: Principles and Applications*. Longman, London, Vol. 1, pp 251-267.

Henssen, J.L.G 1990: Cadastral Indispensable for Development. *ITC journal the Netherlands*. 1990.

Henssen, J.L.G. 1995: *Basic Principles of the Main Cadastral Systems in the World.* Proceedings of Commission 7, Seminar on Modern Cadastres and Cadastral Innovation. Delft, The Netherlands.

Hirschfield A., Brown P., and Bundred P. 1995: The Spatial Analysis of Community Health Services on Wirral Using Geographic Information System, *Journal of the International Research Society*, Vol. 46, pp 147-159.

Hohl, P. 1998: *GIS Data Conversion: Strategy, Techniques, and Management.* Santa Fe. N.M. Onword Press.

Hurd, R.M. 1903: *Principles of City Land Values.* The record and Guide, New York.

Huxbold, W. E., 1991: *An Introduction to Urban Geographic Information Systems*, Oxford University Press.

IAAO 1997: *Standards on Property Tax Policy*, International Association of Assessing Officers, Chicago, USA.

Jensen, J. R. and Cowen,D. C. 1999: Remote sensing of Urban Suburban Infrastructure and Socio-Economic Attributes, *Photogrametric Engineering and Remote Sensing* Vol. 65 iss. 5 pp. 611-622.

John N. and Trevor N.A. 1999: *Fire Service Resource Planning and Allocation.* MIT Press Cambridge MA.

Johns A., and Bentham G. 1995: Emergency Medical Service Accessibility and Outcome from Road Traffic Accidents, *Public health* Vol. 34, no. 1, pp. 37-42.

Juliao R.P 1999: *Measuring Accessibility Using GIS.* [Online] www.geovisita.psu.edu/sites/geocomp99/Gc99/010/9c010.html

Kim, P. 1993: Spatial Decision Support for Real Estate Investment Analysis, *International Journal of Geographic Information System*, Vol. 7 (4) pp 379-392.

Kivell, P. 1993: *Land and the City, Patterns and Processes of Urban Change*. Routledge, London.

Konyimbih, T.M. 2001: Urban Ad Valorem Land Tax: Implementation Experiences in Some Kenyan Towns. *Journal of Property Tax Assessment and Administration*, Vol. 65 No. 5. pp15-24.

Larsson G. 1991: *Land Registration and Cadastral Systems Tools for Land Information and Management:* Longman Scientific and Technical john Wiley and Sons, inc. New York.

Lombard, K. and Church, R.L. 1993: The Gateway Shortest Path Problem: Generating Alternative Routes for a Corridor Routing Problems, *International Journal of Geographical Information Systems,* Vol. 1 pp 25-45.

Longely, P., Higgs, G., and Martin, D. 1994: The Predictive use of GIS to Model Property Valuations, *International Journal of Geographical Information Systems,* Vol. 8, No. 2, pp 217-235.

Lupien, A. E., Moreland, W.H. and Dangermond, J. 1987: Network Analysis in Geographic Information Systems. *Photogrammetric Engineering and Remote Sensing,* Vol.53, No. 10 pp. 1417-1421.

Maguire, D.J. 1991: An Overview and Definition of GIS, In: Maguire, D.J., Goodchild M.F., and Rhind, D.W. (eds.) *Geographic Information Systems: Principles and Applications.* Longman, London, pp 9-19.

Marwick, B. 1997: *Remodeling and Enhancing Victoria's Digital Cadastral Map Base.*

Masser I, and Campbell H 1991: Conditions for the Effective Utilization of Computers in Urban Planning in Developing Countries. *Computers, Environment and Urban Systems* Vol.15: pp. 55-67.

Masunu, Z. 2001: Property Tax Reforms in Tanzania - Case Study Dar es Salaam and Eight Major Urban Centers, *3rd African Real Estate Society Conference*, Arusha, Tanzania: 23-25 October.

McCluskey, W. J.; Almy, R. and Rohlickova, A. 1998: The Development of Property Taxation in the New Democracies of Central and Eastern Europe, *Property Management*, Vol. 16, no. 3, pp. 145-159.

McLaughlin, J D and Nichols S. E 1989: Resource Management: The Land Administration and Cadastral Systems Components. *Journal of Surveying and Mapping*, Vol 49, No2.

Medyckj, D. and Hearnshaw H.W.1993: *Human Factors in Geographic Information Systems*, Belhaven Press, London, 1993.

Meyer, W. 1994: *Changes in Land Use and Land Cover a Global Prospective*, Cambridge University Press.

MIE, 2002: *Eritrea a Country Hand Book,* Ministry of Information Press.

Mitchell, D.E. 1995: *School Consolidation, Bus Routing and GIS: The Pendleton Country. WV Case Study*. Unpublished Geographic Master's Thesis, Virginia Tech, September.

Mou, 1996: *Major Property Tax Issues in Africa, in Municipal Development Programme*: Property Tax in Eastern and Southern Africa: Challenges and Lessons Learned, Harare, Zimbabwe, pp 4-9.

NEMP-E, 1995: *National Environmental Management Plan for Eritrea*, Prepared by The Government of Eritrea For The People of Eritrea.

NEMP-E, 2001: *National Environmental Management Plan for Eritrea*, Prepared by The Government of Eritrea For The People of Eritrea.

Nsamba-Gayiiya, E. 2001: *Property Assessment and Taxation in Uganda*. Land policy, property tax and government: Partnership or Conflict, IRRV/IPTI Conference, Cambridge, UK.

Olima, W.H.A. 2000: The Dynamics of Property Taxation in Metropolitan Areas: The Nairobi Experience, *Journal of Property Assessment and Administration*, Vol. 5 (3), pp 73-85.

Oliver, V.G 1985: *Digital Cadastral Mapping Design and Development Considerations*, Unpublished MSc Theses. Department of Surveying Engineering, University of new Bruns Brunswick, Frederictor NB.

Paugam, A.1999: Reform Towards an Ad-Valorem Property Tax: Fiscal and Non-Fiscal Benefits in Transition Economies, *Journal of Property Tax Assessment and Administration*, Vol. 4, No.2, pp. 3-26.

Roger, J.P and Elizabeth B. 1992: *The Cadastral Map in the Service of the State: a History of Property Mapping*, Chicago: University of Chicago Press.

Saaty,T.L. 1990: *Decision Making for Leaders: The analytic hierarchy process for decisions in a complex world.* RWS publications, Pittsburgh.

Sanaei-Nejad S.H. 2002: *Using Location Allocation Models for Regional Planning in GIS* environment [Online] www.gisdevelopment.net/application/nrm/overview/nrm01.html

Simpson, S. R. 1976: *Land Law and Registration*, Cambridge University Press.

Spatial Data Institution 1996: *Mapping and Geographic Information Opportunity for Eritrea*, USA, August 1996.

Ting, L. and Williamson, I. P 1998: *Land Administration, Information Technology and Society*, presented at the 10th Annual Colloquium of the Spatial Information Research centre, University of Otago, New Zealand. Proceeding of the spatial information research centres 10th colloquium, pp329-340

Ting, L. and Williamson I. 1999: *Land Administration and Cadastral Trends*: The Impact of the changing humankind-land relationship and major global drivers. Proceedings of the UN-FIG Conference on Land Tenure and Cadastral Infrastructures for Sustainable Development. Melbourne, Australia.

Tukestra, J. 1998: *Urban Development and Geographic Information, Spatial and Temporal Patterns of Urban Development and Land Values Using Integrated Geo-data*, Villavicencio, Colombia Unpublished PhD Thesis ITC, Enschede.

UNDP 1992: Rio *Declaration on Environment and Development* (Agenda 21), Report of the United Nations Conference on Environment and Development.

United Nations 1996: *Land Administration Guidelines with Special Reference to Countries in Transition*, New York and Geneva.

UN-Habitat, 1996: The Habitat Agenda: goals and principles, commitments and global plan of action. Habitat 2, Istanbul, Turkey. UNCHS. [Online] http://www.unhabitat.org/unchs/english/hagenda/

Villela, L.A.2001: *Sub-national Taxation: The Property Tax and the Challenges for its Modernisation in Brazil.* Paper presented at Seminar on Property Taxation, Porto Alegre, Brazil.

Volkwyn, R. 1998: *GIS and Local Government: is it Giving a Return on the Investment? Computer Graphics*: CAD, CAD/CAM, CAE and GIS in Southern Africa, Vol 9, No. 3, June pp. 40.

Williamson, I. P. 1997: The Justification of Cadastral Systems in Developing Countries. *Geomatica*, Vol. 51, No.1 pp 21-36.

Woolery, A. 1989: Property Tax Principles and Practice. Cambridge: The land Reform Training Institute in Association with the Lincoln Institute of Land Policy. USA.

Worrall L. and Bond D. 1997:Geographic Information Systems, Spatial Analysis and Public Policy: the British experience. *International Statistical Review* Vol. 65 pp 365-380.

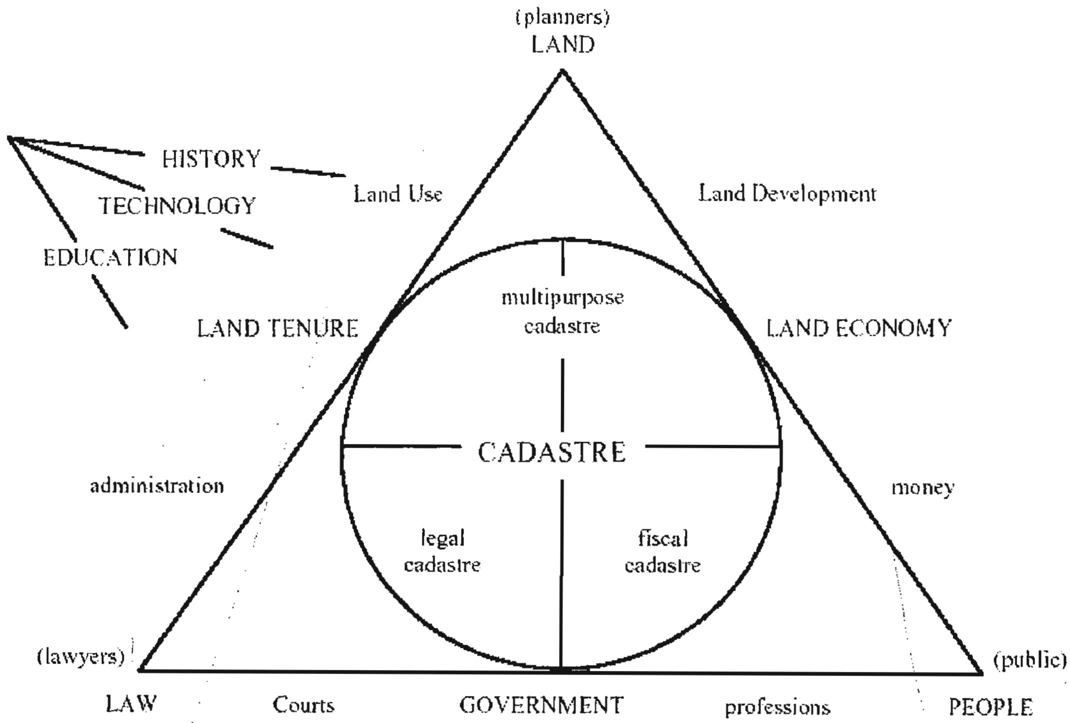
Wyatt, P. J 1997: The Development of a GIS-based Property Information System for Real Estate Valuation, *International Journal of Geographic Information Science*, Vol. 11 (5), pp 435-450.

Yeh, A G-O 1999: Urban Planning and Geographic Information System. In: Longley P.A., Goodchild M.F., Maguire D.J., and Rhind D.W. (eds.) 1999 *Geographic Information Systems: Principles, Techniques, Management and Applications*, . New York John Wiley and Sons Inc. Vol.2

Zeiler, M 1999: *Modelling Our World*: The ESRI guide to geodatabase design. Redlands, California: ESRI press.

Zhan, F.B. 1997: *A Set of Shortest Path Algorithms that Run Fastest on Road Networks*. Proceedings GIS/LIS 96. Falls Church, ACSMA/ASPRS: 755-764.

Appendix A: Models of Cadastre



Source FIG (1995) Cadastral components diagram

Appendix B: IKONOS Image of Asmara City

Appendix C: Metadata of IKONOS Imagery

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Company Information

Address

Space Imaging Middle East
Suite 408 Warba Centre
PO Box 35391
United Arab Emirates

Contact Information

On the Web: http://www.spaceimagingme.com
Customer Service Phone (World Wide): +971 4 266 1799
Customer Service Fax (World Wide): +971 4 268 9173
Customer Service Centre hours of operation:

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Product Order Metadata

Creation Date: 10/24/01
Product Work Order Number: 00055073
Product Order Number: 82409
Customer Project Name: IKA01SIME111
Product Order Area (Geographic Coordinates)
Number of Coordinates: 4
Coordinate: 1
Latitude: 15.40380000 degrees
Longitude: 38.84160000 degrees
Coordinate: 2
Latitude: 15.40390000 degrees
Longitude: 38.95340000 degrees
Coordinate: 3
Latitude: 15.25920000 degrees
Longitude: 38.95340000 degrees
Coordinate: 4
Latitude: 15.25920000 degrees
Longitude: 38.84170000 degrees
Product Order Area (Map Coordinates in Map Units)
Coordinate: 1
Map X (Easting): 494996.24 meters
Map Y (Northing): 1686995.53 meters
Coordinate: 2
Map X (Easting): 483002.22 meters
Map Y (Northing): 1687001.17 meters
Coordinate: 3
Map X (Easting): 483003.18 meters
Map Y (Northing): 1702995.10 meters
Coordinate: 4

Appendix D: Relationship Diagram for Cadastral Database showing all the Entity and their Relations