THE USE OF GEOGRAPHIC INFORMATION SYSTEM FOR MAPPING HIV/AIDS SUSCEPTIBLE AREAS IN ADDIS ABABA, ETHIOPIA

A THESIS SUBMITTED TO THE SCHOOL OF GRADUATE STUDIES ADDIS ABABA UNIVERSITY IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN REMOTE SENSING AND GIS

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THE USE OF GEOGRAPHIC INFORMATION SYSTEM TECHNOLOGY FOR HIV/AIDS PREVENTION PLANNING, EVALUATION AND SURVEILLANCE IN ADDIS ABABA, ETHIOPIA

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ABSTRACT

This study focuses on GIS based mapping of high HIV/AIDS vulnerable areas of Addis Ababa city which helps planning and wise allocation of resources to prevent the spread of the epidemic. In this study GIS techniques were found to be useful to offer helpful information on the spatial distribution of HIV/AIDS risk factors. Using GIS, different criterion (factor) maps have been prepared; these maps are the Female Population Density criterion map, the Young Population Density criterion map, the Economically Inactive (Low Income) Population Density criterion map, the Commercial Sex-workers Density criterion map, and the Establishments (i.e. those establishments that incorporate the commercial sex-workers as part of their business) Density criterion map. A map that shows the existing HIV positive population density was also prepared and used to assign weights to the criteria maps. Different GIS data processing techniques have been deployed to extract specific information for the required analyses. Spatial multicriteria decision analysis approach was used for selecting evaluation criteria and deriving commensurate (standardized) criteria maps. Criteria weights were derived on the basis of the Pairwise comparison method. The GIS analyses indicated that sex-workers concentration is high in the central northwestern part of the city. Similar results were found for the female population distribution, the young population distribution, and the distribution of establishments that incorporate commercial sex-workers as part of their business. The result of the GIS analysis showed that 4% of the total area of the city is found in the 'Highest Susceptible' zone. This zone includes in particular Woreda 7, Woreda 6, Woreda 5, and Woreda 4 areas of the city. The result also showed that 11%, 34% and 51% of the areas of the Addis Ababa city are found in the 'Higher', 'High' and 'Low' susceptible zones respectively. The spatial distributions of the existing VCT centers and the developed HIV/AIDS susceptibility map show some degree of correlation. When it is intended to open a new VCT center, it is recommended that first priority should be given to those areas which have sparsely distributed VCT centers; doing so increases the accessibility to VCT centers which are the first and most important step to combat the disease.

1. INTRODUCTION

1.1. Background

A Geographic Information System (GIS) is a computer system for capturing, storing, querying, analyzing, and displaying geographic data. Like any other information technology, GIS can be divided into the following four components

- **Computer System**. The computer system includes the computer and the operating system to run GIS.
- **GIS Software**. The GIS software includes the program and the user interface for driving the hardware. Common user interfaces in GIS are menus, graphical icons, and commands.
- **Brainware**. Equally important as the computer hardware and software, the brainware refers to the purpose and objectives, and provides the reason and justification, for using GIS.
- **Infrastructure**. The infrastructure refers to the necessary physical, organizational, administrative, and cultural environments for GIS operations. The infrastructure includes requisite skills, data standards, data clearinghouses, and general organizational patters.

In this study the mapping of HIV/AIDS susceptible areas in Addis Ababa, Ethiopia in particular has been done through utilization of GIS, which is a powerful technique for the capturing, storing, querying, analyzing, and displaying of spatial data.

1.2. Overview of HIV/AIDS in Addis Ababa

Extremely high rates of HIV infection are known to exist in Addis Ababa. The Ministry of Health reported that the sero-prevalence rate for pregnant women attending antenatal clinics at sentinel surveillance sites in Addis Ababa was at 15.1%. Often community respondents chose to discuss vulnerability in relation to risks of infection by HIV (or to other serious diseased if respondents were unaware of or reluctant to talk about HIV). The groups most vulnerable to infection were identified as commercial sex workers and young people, particularly unemployed educated young adults. The group most vulnerable to HIV/AIDS is female youth. A preliminary assessment conducted by Zelalem on 105 poor women (including housewives, maids, students, unemployed youth and commercial sex workers) found that 69 were found to be carriers of the virus. Some respondents felt that women in low economic classes are victims as they are exposed to many sex partners to fulfill their need for food, clothing, and other necessities.

Commercial Sex Workers (and their Clients)

Many respondents agreed that the most vulnerable group is the prostitutes or commercial sex workers. In addition, young men and others who have sex with these women are at risk. As with street children, commercial sex workers may live in scattered locations throughout the city but work in more affluent commercial areas. Kebele 31 is reported as one of the areas were commercial sex workers are especially active. The fact that women do not have adequate employment opportunities was given as the motivation for turning to commercial sex workers.

The large number of commercial sex workers in some areas and their exposure to HIV infection has many reported consequences. It was felt that the lure of income, as well as the dress and accessories worn by prostitutes, was adversely influencing the psychology of young girls in the area. Others expressed sadness that women and girls need to resort to such a risky and morally questionable profession. One woman was fearful that her family would find out how she made a living.

Women/Young Girls

HIV/AIDS disproportionately affects women, especially young women, in Addis Ababa. This is due to a number of factors unique to women that increase their risk of acquiring HIV relative to men:

- Low cultural, social, and economical status leading to difficulties in negotiating sexual activity with men,
- Early marriage to or sexual debut with older sexual partners who had most probably met many women before,
- Commonness of unwanted pregnancies and unsafe abortions

Young People

The young people are particularly vulnerable and are the key to the future course of the HIV epidemic. They are the essential focus for prevention messages in every sexual health program. Since most new infections are in young people, even modest changes in behavior will have significant impacts on the epidemic.

Others

Other groups were also described as being highly vulnerable to HIV infection. For instance, IDPs (Internally Displaced People) stated that their marginalization from public services made them less likely to receive information and treatment. Another group described to be at great risk are men, and less often women, who lead wild lives, including use of alcohol and drugs as will as promiscuous behavior. Sexual encounters in these cases may not be commercial but rather just young people acting upon their urges unfettered by social restrictions or fear of infection. One health professional indicated that truck drivers and ex-soldiers are also at high risk for infection.

1.3. Statement of the problem

In Sub-Saharan region HIV/AIDS is the most challenging problem in terms of social, economical, political, and cultural aspects. The city of Addis Ababa is also carried the burden of this problem. Even nowadays it is a common thing to lose someone so close due to this disease. In order to alleviate this major problem different strategic plans have been proposed and carried out by different governmental and non-governmental bodies; Of course, most of the strategies are good but if it was for GIS techniques manipulated to develop these strategies; then it would have been better. In order to ease this acute spread of the disease, an integrated and well-planned method of prevention planning, evaluation, and surveillance of the HIV/AIDS spread is necessary.

1.4. Objectives

1.4.1. General Objectives

- To apply GIS techniques to HIV/AIDS prevention planning, evaluation, and surveillance in the Addis Ababa city.

- To recommend the best strategy to resource allocation for prevention of the spread of HIV/AIDS, and to give care and support to those parts of the society who have fallen victim to the disease.

1.4.2. Specific objectives.

- To assess the spatial distribution of high HIV/AIDS susceptible areas of the Addis Ababa city.

- To maximize the number and quality of VCT centers in the city and to identify top priority areas of the city and establish such health facility centers.

- To identify those areas of the city that show high HIV/AIDS prevalence and to investigate the factor/s associated with this high incidence and to establish a strategic plan to combat the problem.

- To monitor the entire progress of the prevention and care/support activities.

2. INTRODUCTION TO GEOGRAPHIC INFORMATION SYSTEM (GIS)

2.1 Definition of GIS

There have been a number of attempts to define a GIS (Marble et al. 1984; Cowen 1987; Goodchild 1987; Grimshaw 1994). On careful inspection, most of the GIS definitions focused on two aspects of the system: technology and/or problem solving. The technological approaches define GIS as "a set of tools for the input, storage and retrieval, manipulation and analysis, and output of spatial data" (Marble et al. 1984). This approach ignores the problem-solving aspects of GIS. However, it can be argued that the GIS functionality can play a crucial role in a comprehensive decision-making process. Foote and Lynch (1996) make three important observations with respect to the functionality of GIS systems.

First, GIS can be considered as a special-purpose digital database in which a common spatial coordinate system is the primary means of storing and accessing data and information. GIS systems have the ability to perform numerous tasks utilizing both the spatial and attribute data stored within them. These functions distinguish GIS from other management information systems.

Second, GIS is an integrated technology. It allows for integrating a variety of geographical technologies, such as remote sensing (RS), global positioning facilities management (AM/FM). These geographical technologies can in turn be integrated with analytical and decision-making techniques.

Third, it is argued that an ultimate aim of GIS is to provide support for making decisions. GIS can be thought of "as a decision support system involving the integration of spatially referenced data in a problem solving environment" (Cowen 1988). GIS is for making decisions. The way in which data are entered, stored, and analyzed within a GIS must mirror the way that information will be used for a specific analysis or decision -making task (Foote and Lunch 1996).

GIS should be viewed as a process rather than as merely software or hardware. The system contains a set of procedures that facilitate the data input, data storage, data manipulation and analysis, and data output for both spatial and attribute data to support decision-making activities (Grimshaw 1994).

2.2 GIS Functions

Given the definition so a GIS system, its functionality can be subdivided into four main components or subsystems: data input, data storage and management, data manipulation and analysis, and data output (Fig. 2.1). Each component can be described in terms of the functions that the respective subsystem performs.

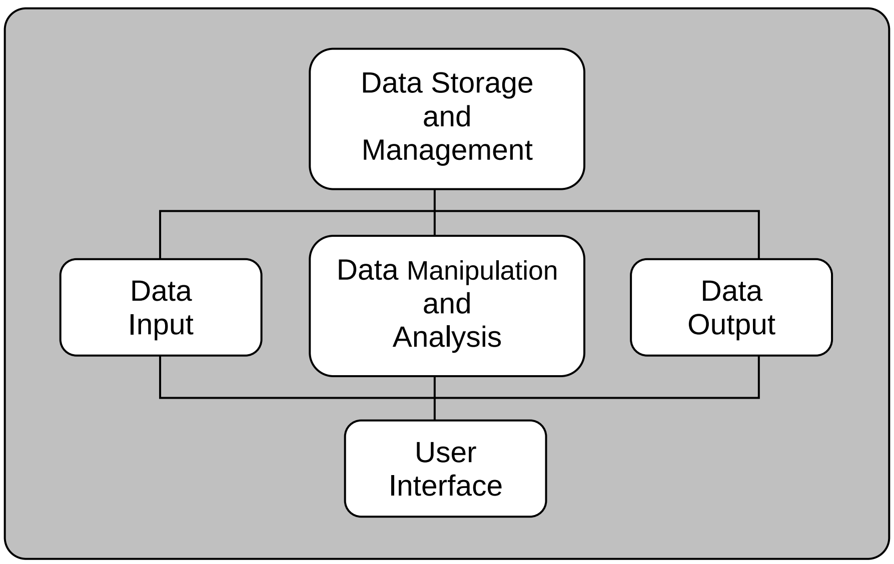


Figure 2.1 The four components of GIS subsystem

2.2.1 Data Input and Output

2.2.1.1 Data Input

Data input refers to the process of identifying and gathering the data required for a specific application. The process involves acquisition, reformatting, georeferencing, compiling, and documenting the data. The data input component converts data from their raw or existing form into one that can be used by a GIS. The data required for a particular project are usually available in different forms that include analog maps, tables, charts, and existing digital data sets, maps, aerial photos, satellite images, surveys, and other sources in digital formats. An advantage gained from a GIS is the efficiency of integrating a wide range of data and information sources into a compatible format. GIS can be sued not only for producing maps automatically, but it is unique in its capacity for integration and spatial analysis of multisource data sets, such as data on population, topography, hydrology, climate, vegetation, transportation network, and public infrastructure (Martin 1991; Cassettari 1993; DeMers 1997). GIS systems typically provide alternative methods of data input, including keyboard entry for nonspatial attributes and occasionally locational data, manual locating devices (e.g. digitizers and computer mouse), automated devices (e.g., scanning), or by the importation of existing data files (conversion directly from other digital sources).

Digitizing

The digitizing process involves encoding analog data (hard-copy maps or graphics) into digital data. This method uses a digitizing table and mouse with a cursor to trace and record points, lines, and polygons needed for a particular data set. Digitizing is an efficient method to use when just a few maps with minimal geographical data need to be captured. GIS database is directly related to the quality of the digitizing process (Aronoff 1989; Environmental Systems Research Institute 1995).

Scanning

A scanner converts an analog source document into digital raster form by using either a flat-bed scanner or a drum scanner (Pazner et al. 1993). It is used in GIS to input map and photo information. The quality of this information is related to the quality of the scanner and the quality of the base map being scanned. Unlike in the digitizing process, the user has limited control as to what type of data will be picked up during the scanning process. The scanning method is generally chosen when large amounts of data need to be captured. For example, a map with thousands of polygons or with large irregularly shaped features is a good map to scan.

Remote sensing

Remote sensing is one of the main sources of data for a GIS. It can be defined as a process of gathering data about the surface of the Earth and the environment from a distance, usually by aircraft or space sensors (Iensen 1996). Landsat and SPOT (Satellite Pour l'Obseration de la Terre) satellite systems are the major providers of remotely sensed data for land management, environmental monitoring and management, and urban planning.

The huge amount of information available from orbiting satellites must be processed (reduced or simplified) before it can be incorporated into GIS. This process involves three major steps: (Jensen 1996).

- Image preprocessing,
- Image Enhancement, and
- Classification

A remote-sensing image is in raster format. It consists of cells (rasters) each containing a value recorded by the sensor. Since the raw remote-sensing images contain radiometric and geometric errors, they have to be preprocessed to remove the radiometric "noise" and errors. A wide range of techniques is available for he radiometric and geometric correction of remotely sensed data (Novak 1992; Jensen 1996).

Remotely sensed data need to be enhanced to improve the appearance of an image for visual analysis or subsequent machine analysis. The enhancement process involves a variety of point and local image enhancement operations. The former operations modify the brightness value of each pixel in an image independently, while the latter operations modify the value of each pixel in the context of the brightness values surrounding it (Jensen 1996).

Remote-sensing data must also be classified before being imported to a GIS. Classification is usually an automated procedure whereby each pixel or group of pixels in each wavelength is examined by statistical techniques. This can be done because different ground surface phenomena (such as built-up areas, cropland, forest, or water) manifest different spectral response patterns, that is, different combinations of digital numbers based on their spectral reflectance and emittance properties. Therefore, automated classification is also referred to as spectral pattern recognition.

Global positioning systems

The other type of geographical information technology that is of importance for data input is the global positioning system (GPS) (DeMers 1997). GPS operates through a constellation of satellites orbiting above the Earth, which are used to determine precise coordinate locations. Although the system was originally developed by the U.S. Department of Defense as a navigational aid, it has evolved far beyond its military origins over the past decade or so. The GPS technology is now available for geodetic control surveying, "on-site" digitizing, and the location of entities. The basic idea behind GPS technology is simple. Each satellite broadcasts a constant stream of timing information from highly accurate atomic clocks. The satellites transmit signals that can be decoded by specially designed receivers to determine positions of varying accuracy. The GPS receiver measures a signal's time and range data and converts them to navigation and position data. In essence, the receiver "reads" the timing information from GPS satellites and compares the signals with their own clock to calculate the distance to each satellite. The receiver calculates the location by triangulation. Consequently, at least three satellites must be available at any one time to provide and accurate location fix. A fourth satellite in view makes possible the determination of altitude. By simultaneously recording the position of multiple satellites by multiple sensors, computations can yield very accurate (within 1cm) locational information for each sensor (Dodson and Haines-Young 1993). Examples of GIS/GPS data integration for spatial decision making include vehicle tracking and navigation, precision farming as well as locating specific locations of buildings, squares etc.

The Internet

Until recently, the Internet just provided communications and supporting resources for GIS professionals. However, this is changing and the Internet is quickly becoming and important data source for GIS-based research and projects. Individuals, universities, and organizations such as the U.S. Geological Survey, U.S. Bureau of the Census, and NASA have made public-domain spatial data and GIS algorithms/programs available to the community. There are a number of Web sites that provede list of geographical data sources. A useful survey of the Internet resources for GIS and spatial decision-making is offered by the Geographer's Craft home page at http://www.utexas.edu/depts./grg/gcraft/notes/sources/sources.html

Data sharing and interchange

One way to avoid the data input bottleneck is to use data already generated by a third party. Data sharing is becoming commonplace in the GIS world and is fostering a new era of data standardization and the generation of metadata (data on data) to describe the lineage and estimated accuracy of GIS layers.

Data interchange is the process of converting existing digital data into the data structure and file format used internally by a GIS. The data interchange standards provide a means for efficient and effective integration of input data. There are a number of national and international data interchange standards and formats (Guptill 1991; Moellering 1991; Cassettari 1993). The Digital Exchange Format (DXF) (format for AutoCAD files and some scanning products is probably the most widely used means to exchange geographical data between CAD systems, desktop mapping systems, and advanced GIS systems. It is most efficient as a means of encoding graphic elements but have limited capabilities in terms of handling topology, attributes, and more complex data structures. The exchange of any DXF file must be accomplished by additional information about the coordinate references, layering conversion, and symbology rules.

2.2.1.2 Data Output

The data output component of GIS provides a way to see the data or information in the form of maps, tables, diagrams, and so on. The output subsystem displays to users the results of GIS data processing and analysis. The results may be generated in the hard-copy, soft-copy, or electronic format (Aronoff 1989; Pazner et al. 1993; DeMers 1997). Maps are the most standard output format but frequently are accompanied by tabular display. A variety of output devices are used, including display monitors, pen plotters, electrostatic plotters, laser printers, line printers, and dot matrix printers and plotters. Results, particularly in the map forms, are often modified or enhanced interactively through cartographic map composition functions to add elements such as legends, titled, north arrows, scale bars, color modification, and symbology adjustments. Output functions are determined by the user's needs, so user involvement is important in specifying the output requirements. Some GIS systems support many different plotters, printers, three-dimensional display devices, as well as multimedia output (Cassettari 1993). For example, IDRISI for Windows v.2.0 (A GIS software) has a media viewer. It offers animated displays of time-series images and video clips and audio enhancements wit the playing of sound files (Eastman 1997).

In general, types of output can be classified into four categories:

1. Text output: tables, lists, numbers or text in response to queries; the results might be a list or table of selected objects with attributes; queries might result in numerical results (e.g., total, distances, areas, counts).
2. Graphic output: maps, screen displays, diagrams, graphs, perspective plots, and so on; interactive graphics devices allow users to point to objects and identify them in their correct spatial context.
3. Digital data: stored on disk or tape, or transmitted across a network.
4. Other, not yet commonly used, such as computer-generated sound and video clips.

2.2.2 Data Storage and Management

The data storage and management component of a GIS includes those functions needed to store and retrieve data from the database. The methods used to implement these functions affect how efficiently the system performs operations with the data (Aronoff 1989; Antennucci et al. 1991). Most GIS systems are database oriented. The database can be defined as a collection of non-redundant data in a computer organized so that it can be expanded, updated, retrieved, and shared by various uses. It is important, however, to view a GIS database as more than a simple medium for storing data and information. The GIS database can be thought of as a representation or model of real-world geographical systems. To this end it is useful to make a distinction between geographical entities and objects. A geographical entity is a term used with respect to an element of a real-world system; that is, entities are contained in geographical space. An object is a GIS representation of a geographical entity. For example, geographical entities such as towns, highways, and states are represented in GIS databases in the form of point, line, and area (polygon) objects. The objects are described by locational or spatial data, which records the location of a given object (point, line, or polygon), and attribute or nonspatial data, which describes characteristics of he object.

A GIS-based decision analysis requires representation of real-world geographical systems in a digital format. The problem is that the real-world geographical systems are too complex for even the most advanced information systems, and they must therefore be simplified. This simplification of reality is referred to as a data model. A GIS database is a collection of spatially referenced data that acts as a model of reality. The contents of a GIS database represent a particular view of the reality.

Managing Spatial Data

Spatial data represented at the physical level are arranged in one of two methods for a GIS: raster and vector.

Data in raster format are stored in a two-dimensional matrix of uniform grid cells (pixels), normally square or at least rectangular, on a regular grid. Each cell is supposedly homogeneous, in that the map is incapable of providing information at any resolution finer than the individual cell. Areas are made up of contiguous pixels with the same value. Lines are made by connecting cells into a one-pixel-thick line. Points are single cells, which mean that all the area represented by that cell becomes unavailable for other spatial entities. All spatial objects have location information inherent to where they lie in the grid. The map shows exactly one value (land use, elevation, political division) for each cell. The size of the grid can vary, and therefore the spatial resolution of the data is determined by the grid size. The higher the level of resolution, the greater the detail that can be distinguished on an image. Raster data resolution may vary from sub meter to many kilometers. The spatial resolution of images acquired by satellite sensor systems is usually expressed in meters. For example, some Landsat images have30-m resolution. This means that to objects, 30m long or wide, sitting side by side, can be separated (resolved) on the image.

Data in vector format are entities represented by strings of coordinates. A point is one coordinate; that is, points on a map are stored in the computer with their "exact" (to the precision of the original map and the storage capacity of the computer) coordinates. Points can be connected to form lines (straight or described by some other parametric function) or chains. Thus a line is represented as a number of coordinates along its length. Chains can be connected back to the starting point to enclose polygons or areas. A polygon is represented as a set of coordinates at its corners. For example, a point that represents a village or town may have a database entry for its name, size, services, and so on. A line that represents a road may have a database entry for the various socioeconomic, environmental, and population characteristics. Each of these spatial objects may have an identifier that is a key to an attached database containing the attributes (tabular data) of the entity.

In the vector representation, the various geographical objects have a definite spatial relation called topology. The topology defines spatial relationships between objects (points, line, and polygon). It allows a GIS to perform spatial analysis functions on geographical data. The most important spatial relations include: connectivity (lines are connected at nodes), adjacency (polygons are adjacent if they share a common boundary line), and containment (one polygon can contain another as an "island"). Topology can be stored as part of the map representation (in the database tables) or built from the coordinates of each entity. It is interesting to note that in the raster data structure, the only topology is cell adjacency, and this is implicit in the representation (i.e., defined by the grid addresses), not explicit as in vector topology.

Raster versus vector data model

Each of these two data models has its advantages and disadvantages (Burrough 1986; Martin 1991; DeMers 1997). An important advantage of the raster model is that it is possible to represent continuously varying data. Many physical variables, such as rainfall or temperature, vary continuously. Raster is the native format for satellite imagery, and it is suitable for scanned images. These features are of particular importance for incorporating remote sensing data into GIS. Modeling and interpolation are simpler in the raster format, because the grid of data is dense and complete. On the other hand, vector format has advantages over raster in the following areas: precision that is limited only by the quality of the original data, efficiency in data storage [since only points about which there is information or which form parts of boundaries are stored (information for the areas between such points are inferred from the topology)], topology (explicit topology makes some kinds of spatial analysis easy), and high-quality output.

Managing Attribute Data

As mentioned earlier, geographical objects are described by two types of data: locational data, which relate the objects to their location in geographical space, and attribute data, which describe other properties of the objects apart from their locations. GIS typically employ database management system (DBMS) strategies for handling these two types of data. Most standard databases are classified according to a model of how the data are viewed by the user. A great number of data models have been proposed, such as flat data structure, hierarchical, network, relational, and object-oriented models (Aronoff 1989;

Huxhold 1991 DeMers 1997). The relational model is the most popular database used to organize data in GIS. The flat data model is a convenient way to store and process data for multicriteria decision making (Kirkwood 1997). GIS data models can also be classified according to the data management architecture. Maguire (1995) provides a convenient classification of GIS data models. He distinguishes three categories: file processing, hybrid, and extended or integrated DBMS.

The process of conceptualizing the reality and its representation in GIS databases can be described at several levels of abstraction (Burrough 1992a):

1. <u>Conceptual models of the world</u>. Two views of the world can be distinguished: The real world can be seen as being populated by fully defined and fully definable entities, or the reality can be viewed as being a smooth, continuous spatial variation.
2. <u>Data models of the world</u>. The world consists of sets of discrete objects, their associated attributes, and relationships between objects; if entities are fully definable (e.g., parcels of land, roads), there is a little problem with representing the reality in terms of a discrete object model (e.g., areas, lines); this model can be referred to as the exact data model (or discrete object model); however, if the entities are incomplete, inexact, and incompletely definable (e.g., soil types, vegetation types, elevations, geological units), the data model of the world should represent the world as being made up of complex continua (or field model).
3. Database models. These models can be thought of as the encapsulation of the data models so that geographical data can be stored and manipulated and analyzed; for the exact data models, the database contains a set of objects, attributes, relationships between objects, and a set of rules defining how they behave; this type of database model is implemented by means of discrete objects such as points, lines, areas, and volumes of regular or irregular forms; on the other hand, complex continua can be represented in terms of discretized surfaces, continuous smooth mathematical functions, and continuous nondifferentiable mathematical function (e.g., stochastic surfaces); there is a wide range of methods for implementing this type of database mode, including irregular or irregular tessellation, TIN (triangular irregular network), regionalized variables, and square and equilateral grids.

4. Graphic models. Both the discrete object and the field models can be implemented by means of the raster and vector data structures; these structures can be considered as two different approaches for representing the real world in terms of the object or field models.

2.2.3 GIS Analytical Operations

The distinguishing feature of GIS systems is their capability of performing an integrated analysis of spatial and attribute data. Generally, the GIS analytical operations are categorized in to two broad groups:

1. The fundamental functions; include:
   - Measurement,
   - (Re) classification,
   - Scalar operations
   - Overlay operations and,
   - Connectivity operations,
   - Neighborhood operations,
   - etc.
2. Advanced Functions; Include:
   - Statistical modeling (focuses on the spatial association between values observed at different locations and the systematic variation of phenomena by location; i.e., spatial dependency and spatial heterogeneity). (Anselin and Getis 1992)
   - Mathematical modeling (Focuses on optimization and simulation)

   a) Optimization: is a normative approach to identify the best solution for a given decision problem (Wilson et al. 1981; Thomas and Huggett 1980). It is a modeling method that seeks to find the best (maximum or minimum) solution to a well-defined management problem.

   b) Simulation: In a broad sense, simulation is a methodology for performing experiments using a model of the real-world system (Rubinstein 1981; Mather 1991)

3. METHODOLOGY

3.1. The Study Area

Addis Ababa is the capital city of the Federal Democratic Republic of Ethiopia. The city is located at the geographic center of Ethiopia. Addis Ababa is also the political, economic, and the cultural, center of the country.

Demographic Characteristics

Based on figures from the Central Statistical Agency of Ethiopia (CSA) published in 2005, Addis Ababa has an estimated total population of 3.2 million. Over 51% of the population is female.

Almost all ethnic groups are represented in Addis Ababa due to its position as capital of the country. The major ethnic groups represented are the Amharas (48.3%), Oromo (19.2%), Gurage (17.5%), and Tigrean (7.6%), while others constitute 7.4% of the population. (CSA 1993).

82% of the population are Orthodox Christians, 12.7% Muslims, 3.9% Protestants, 0.8% Catholics, and 0.6% followers of other religions (Hindus, Jews, Bahais, Jehovah's Witnesses, Agnostics, etc.) (CSA 1993).

The CSA estimated that presently there are no rural parts to the city, so 100% of the inhabitants are considered urban dwellers; Addis Ababa contains 24% of all urban dwellers in Ethiopia. With an estimated area of 530.14 square kilometers, this chartered city has an estimated density of 5,607.96 people per square kilometer. (CSA 2005).

General Health Service in Addis Ababa:

There are 24 hospitals in Addis Ababa (five of which are owned by the Addis Ababa Health Bureau). 24 health centers and 46 health posts. In addition, there are 487 clinics categorized into lower, medium, higher and special types; these include privately owned clinics and those owned by non-governmental organizations (NGOs) (AACAHB2002).

Organizations engaged on HIV/AIDS prevention and Control Activities:

In Addis Ababa there are different organizations engaged on HIV/AIDS prevention and control activities. There are about 79 different organizations (CBOs, NGOs, and PLWHA Asso.) engaged in IEC/BCC activities throughout the city. There are also about 24 organizations (NGOs, and CBOs) working on Condom Promotion and Distribution activities. All the governmental health institutions and seven NGOs are providing health services related to the prevention and control of sexually transmitted infections. Care and support services are also given by about 92 organizations (NGOs, CBOs, PLWHA Asso.). There are about 51 VCT centers of which the majority are private owned.

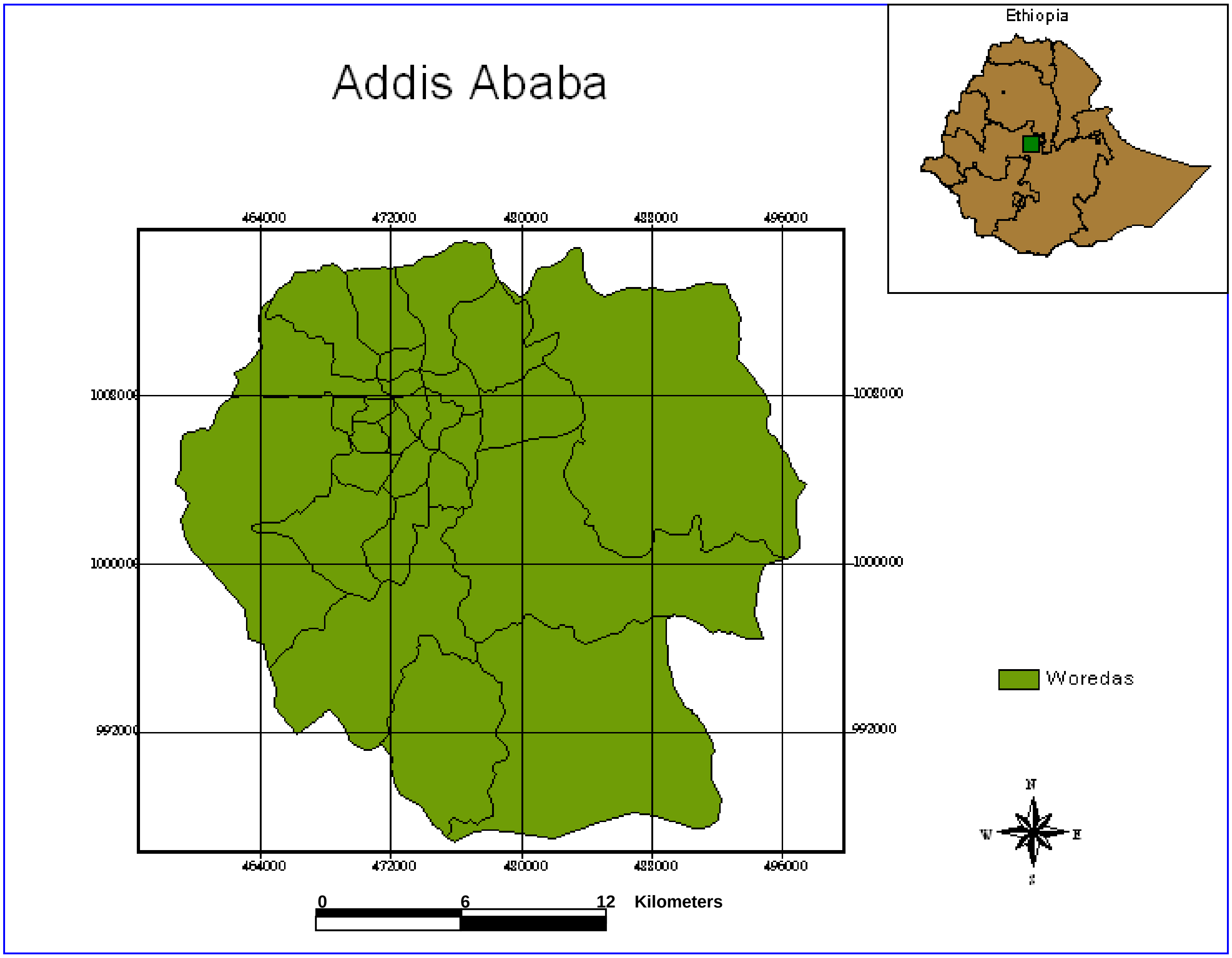


Figure 3.1 The Study area

3.2. Materials and Data

For the HIV/AIDS susceptible map production the criteria which are described below are selected. The selected criteria are not universal criteria. The general consensus is that any independent variable must be i) operational (has a certain degree of affinity with the dependent variable), ii) complete (is fairly represented all over the study area), iii) non-uniform (varies spatially), iv) measurable (can be expressed by any of the different types of measuring scales), and v) non-redundant (its effect should not account for double consequences in the final result).

- Projected population data of the year 2006 and the 1994 Census for each Woreda of the Addis Ababa city (Source: Central Statistics Authority 2005). From which the following demographic characteristics were derived:

  -<u>The density of the female population in each woreda</u>; considering that women are likely to be infected with HIV at younger ages and at higher rates than men. The high prevalence rates are expected among women due to several factors; including lack of knowledge or lack of skills in negotiating condom use and early sexual intercourse with older men who are more likely than young men to be infected with HIV. So the spatial distribution of the women population could be used as one factor to create HIV susceptibility map.

  -<u>The density of the young population (age between 15 and 25</u>); taking the fact that the young is highly vulnerable to the disease. And the spatial distribution of this age group might also lead to the future HIV vulnerable areas and helps to assist in directing resource and in targeting programs for HIV prevention and care.

  -<u>The density of the economically inactive (low income population</u>); population in each woreda; in which case it is easy to identify areas where there should be HIV/AIDS related health services should be provided at low price or even free of charge.

- <u>The density of commercial sex workers in each woreda</u>; due to the fact that sex workers are most vulnerable groups of the society.

- <u>The density of establishments that incorporate the commercial sex workers</u> as part of their means of business generating strategy; knowing where these places are concentrated in the city, it will be of great importance to contact the individuals and give lessons concentrating on the preventive measures and precautions.

- <u>The number of HIV Positive population in each woreda</u>, which is helpful in deducting the possible factors associated with the high prevalence in their order of importance. (Source: Addis Ababa Health Bureau).

- <u>The location and other attributes of each VCT center</u> in the city, form which their spatial distribution, type of service, price, level of confidentiality etc were taken (Source: Field data collection).

- <u>A digital map of the Addis Ababa city</u>. From which the administrative boundary of each woreda and some other attributes were taken. (Source: Ethio-GIS, data collection available in the AA University, Science faculty in the RS-GIS Lab.)

- <u>Software</u>

The followings are software used in the study:

-ArcView GIS 3.2a for GIS surface data acquisition, analysis, and presentation.

3.3. Methodology of the Data Processing

In order to achieve the above listed objectives of the study, GIS and Multicriteria Decision Analyses techniques have been employed. All the locations of the VCT centers, economically inactive population distribution, the young population distribution, the female population distribution and related data have been collected, checked and interpreted.

The GIS methods, which play vital roles in handling, visualizing, analyzing and presenting spatial attribute, vector and raster data has been used to integrate all the relevant data that has been collected so far, to conduct more realistic HIV/AIDS prevention, control and surveillance assessment of the city. Criteria for GIS analysis have been defined on the basis of AIDS information resources available.

By the application of GIS software, which allows stacking of georeferenced data for comparison and integration as well as data query, all the factor maps that have positive or negative relation to the spread of HIV/AIDS have been prepared and systematically integrated to derive HIV/AIDS susceptibility map, so that the main objective of this work is to be satisfied.

The general method applied in the processing of the collected data from various sources is shown in the flow diagram below:

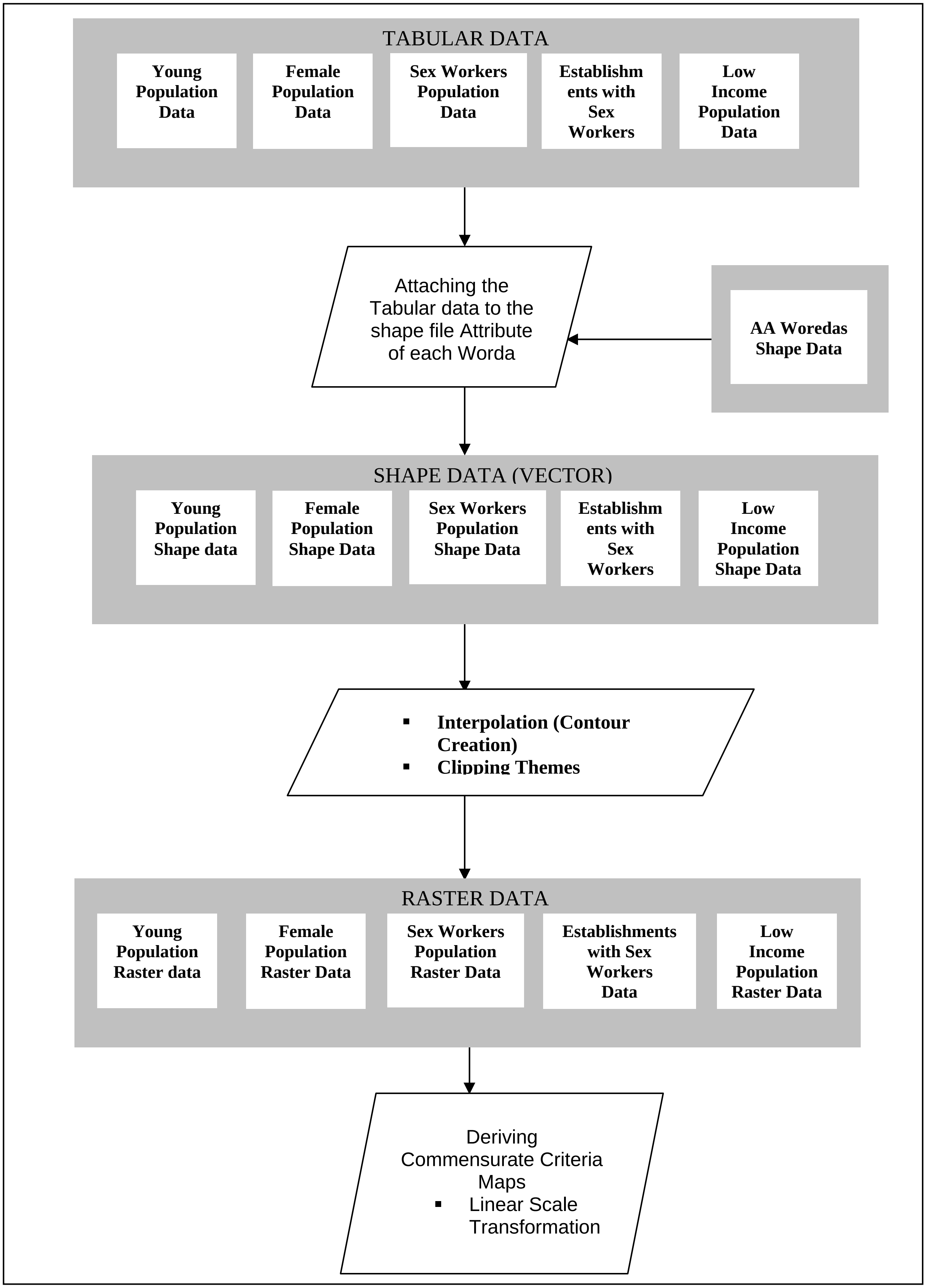


Fig 3.2a The Methodology Flowchart

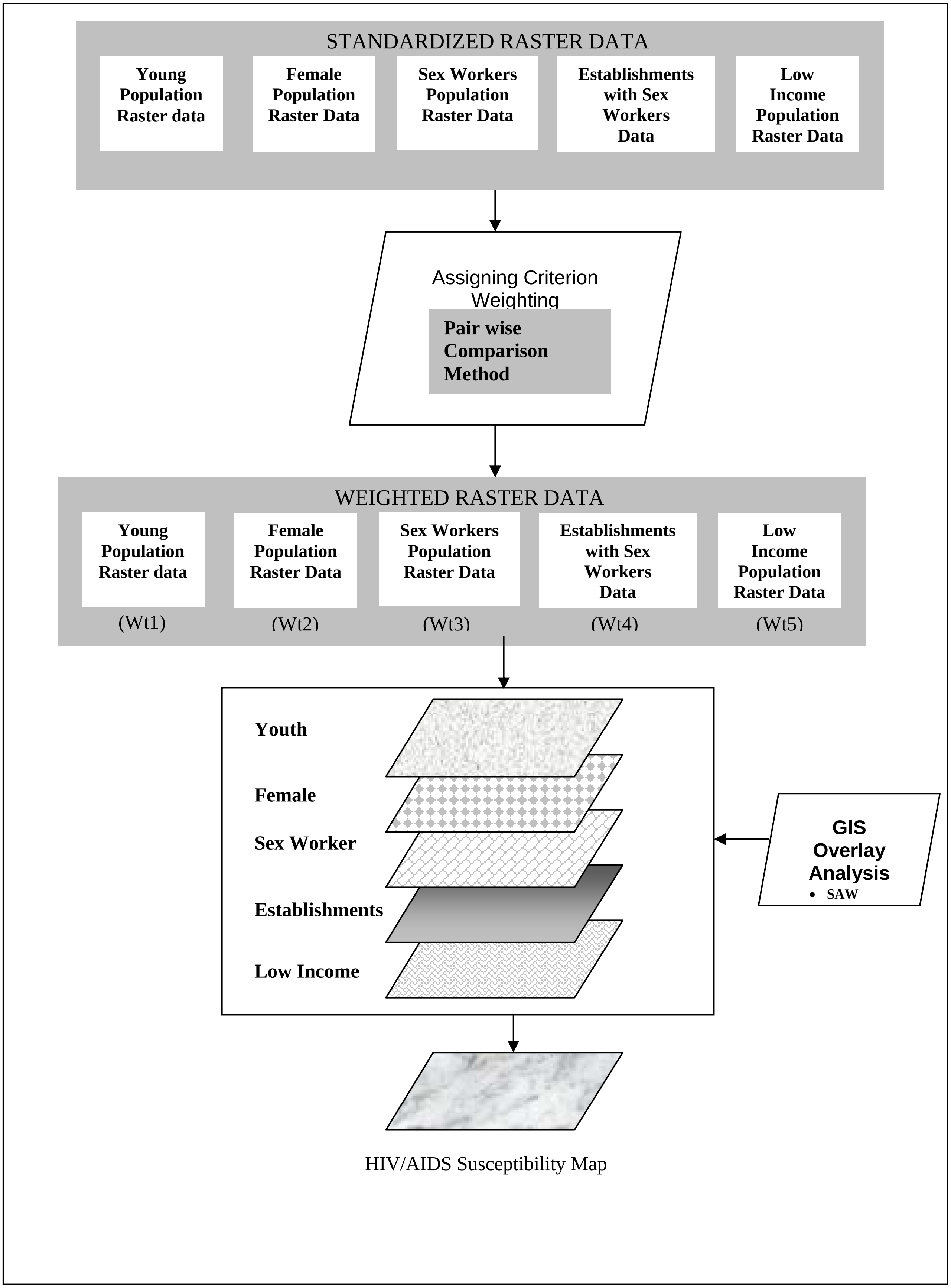


Fig 3.2b The Methodology Flowchart

3.3.1. Quantitative Data Collection

Secondary quantitative data were collected from the government institutions such as the Central Statistical Agency (CSA), the Addis Ababa City Administration Health Bureau and from private health centers as well as previous research materials.

3.3.1.1 Type of Data collected for the Young population Target Group

According to UNESCO, the young were categorized those between the ages of 15 and 25. And the estimates of the young population in each woreda of the Addis Ababa city is given in the following table (Adapted from CSA 1994 Census)

Woreda	Young Population (Age 15-25)
Woreda 1	10214
Woreda 2	9287
Woreda 3	10134
Woreda 4	28723
Woreda 5	33053
Woreda 6	28261
Woreda 7	32000
Woreda 8	34103
Woreda 9	20562
Woreda 10	31197
Woreda 11	34829
Woreda 12	23179
Woreda 13	25163
Woreda 14	22461
Woreda 15	25764
Woreda 16	28957
Woreda 17	50537
Woreda 18	24046
Woreda 19	46424
Woreda 20	31846
Woreda 21	32045
Woreda 22	14248
Woreda 23	40925
Woreda 24	46704
Woreda 25	31383

Woreda 26	17043
Woreda 27	19734
Woreda 28	26501

Table 3.1 Total Young Populations in each Worda *Source*: CSA 1994)

3.3.1.2 Type of Data collected for the Female population Target Group:

Secondary data were collected from the Central Statistics Authority (CSA)

Woreda	**Female Population**
Woreda 1	39739
Woreda 2	30591
Woreda 3	60859
Woreda 4	54776
Woreda 5	61176
Woreda 6	51691
Woreda 7	50969
Woreda 8	64415
Woreda 9	40967
Woreda 10	60145
Woreda 11	63081
Woreda 12	45308
Woreda 13	48995
Woreda 14	43639
Woreda 15	51083
Woreda 16	57710
Woreda 17	95270
Woreda 18	47089
Woreda 19	87347
Woreda 20	60916
Woreda 21	59708
Woreda 22	27714
Woreda 23	79297
Woreda 24	86970
Woreda 25	56914
Woreda 26	27790
Woreda 27	34502
Woreda 28	43617

Table 3.2 Total Female Populations in each Worda *Source*: CSA 1994 Census)

3.3.1.3 Type of Data collected for the Female Sex Workers Target Group:

The Female sex workers target group is broadly categorized in to three categories:

- Bar/Hotel-based sex workers: women who were paid by bar/hotel owners as 'barmaids' but who also used the bar/hotel to pick up sex clients, and those who were not paid by the bar/hotel owners but visited to the bar/hotel to pick up ex clients.
- Home-based sex workers: women who worked from their homes where they were involved in commercial sex work with/without selling local alcoholic beverages.
- Street-based sex workers: women who went onto the streets in the evenings to pick up sex clients.

Woreda	Count of Female Sex Workers
Woreda 1	324
Woreda 2	539
Woreda 3	211
Woreda 4	272
Woreda 5	900
Woreda 6	237
Woreda 7	655
Woreda 8	46
Woreda 9	143
Woreda 10	87
Woreda 11	70
Woreda 12	19
Woreda 13	156
Woreda 14	427
Woreda 15	338
Woreda 16	487
Woreda 17	345
Woreda 18	589
Woreda 19	464
Woreda 20	320
Woreda 21	478
Woreda 22	116
Woreda 23	171
Woreda 24	178
Woreda 25	242

Woreda 26	36
Woreda 27	228
Woreda 28	56

Table 3.3 Count of Female Sex Workers in each Worda (*Source*: Family Health International 2002)

3.3.1.4 Type of Data collected for Economically Inactive population Target Group:

The economically inactive target groups were considered as those parts of the society with minimum annual gross income. The population in this group is, the unemployed, the little children who are not old enough to go for work. The idea attached to this fact that the more economically inactive population concentration in a give Woreda, then the more poor people in that area; then it follows that more vulnerable to HIV/AIDS infection,

Woreda	**Economically Inactive Population**
Woreda 1	12346
Woreda 2	11226
Woreda 3	12249
Woreda 4	34719
Woreda 5	39953
Woreda 6	34161
Woreda 7	26481
Woreda 8	41223
Woreda 9	24854
Woreda 10	37709
Woreda 11	42100
Woreda 12	28018
Woreda 13	30416
Woreda 14	17149
Woreda 15	31143
Woreda 16	35002
Woreda 17	61087
Woreda 18	29065
Woreda 19	56116
Woreda 20	38495
Woreda 21	38734
Woreda 22	17223
Woreda 23	49469
Woreda 24	56454
Woreda 25	37935

Woreda 26	20601
Woreda 27	23853
Woreda 28	32034

Table 3.4 Total Economically Inactive populations in each Worda (*Source*: CSA 1994 Census)

3.3.1.5 Type of Data collected for The Establishments that Incorporate Female Sex Workers:

These establishments are places where female sex workers are hired as ‘barmaids’ or they are given the permission to stay in the establishments with out serving as ‘barmaid’ and not given any wages. These are places where commercial sex workers meet their sex clients. Such places could be Hotels, Bars, Nightclubs, Local Alcoholic drink houses (Tej-Bets, Areke-Bets, Tella-Bets) as well as Chat-Bets.

Woreda	*Establishment Count
Woreda 1	376
Woreda 2	365
Woreda 3	499
Woreda 4	462
Woreda 5	1344
Woreda 6	490
Woreda 7	851
Woreda 8	474
Woreda 9	306
Woreda 10	550
Woreda 11	565
Woreda 12	225
Woreda 13	354
Woreda 14	560
Woreda 15	546
Woreda 16	637
Woreda 17	616
Woreda 18	574
Woreda 19	940
Woreda 20	723

* Those establishments like Hotels, Bars, Tej-Bets, Arekie-Bets that incorporate these sex workers to run their business.

Woreda 21	832
Woreda 22	223
Woreda 23	581
Woreda 24	777
Woreda 25	628
Woreda 26	246
Woreda 27	372
Woreda 28	320

Table 3.5 Count of Establishments in each Worda (*Source*: Family Health International 2002)

3.3.1.6 Type of Data collected for The VCT Centers

The data of VCT (Voluntary Counseling and Testing) centers are also collected to see their spatial distribution, service quality, service charge, type of counseling and the degree of confidentiality.

Id	Vct_center	Wereda	Lat	Lon
1	Addis Ababa Higher Poly Clinic	Wereda 21	1004059.65	474723.04
2	Addis Ketema Higher Clinic	Wereda 07	1008197.39	471518.73
3	Africa Higher Clinic	Wereda 07	1007716.74	471757.84
4	Amedie Higher Clinic	Wereda 05	1007024.86	473438.12
5	Arada Health Center	Wereda 02	1006678.92	474821.88
6	Arsho VCT Center	Wereda 03	1006135.30	474080.58
7	Bethezatha Higher Clinic	Wereda 18	1003911.39	476452.74
8	Bethezata VCT Center	Wereda 23	1001539.23	471313.06
9	Blue Nile Higher Clinic	Wereda 16	1006876.60	480801.71
10	Dejazmach Balcha Hospital	Wereda 04	1005789.36	473141.60
11	D'Afrique Higher Clinic	Wereda 22	1004553.85	472597.98
12	Dr. Kinde Electronic Clinic	Wereda 21	1004405.59	474624.20
13	Ethiopia Higher Clinic	Wereda 09	1009001.66	474327.68
14	Federal Police Hospital	Wereda 04	1005877.56	472462.92
15	Gandhi Memorial Hospital	Wereda 04	1005443.41	473289.86
16	Hayat General Hospital	Wereda 17	999957.78	481839.53
17	Kasenchis Health center	Wereda 15	1005295.15	477045.79
18	Kaliti Health Center	Wereda 17	1000155.46	478528.39
19	Kirkos Health Center	Wereda 18	1003268.93	476551.58
20	Lideta Health Center	Wereda 21	1004751.53	475167.82
21	Mary Joy	Wereda 25	1008853.40	470423.49
22	Medical Missionaries of Mary-MMM (CSSC)	Wereda 13	1008013.26	476996.37
23	Menaheria Higher Clinic	Wereda 07	1007865.00	472548.56
24	Organization of Social Services for AIDS (OSSA)	Wereda 15	1005789.36	476699.85
25	Saint Gebriel Hospital	Wereda 17	1003219.51	479615.63
26	Saris Clinic	Wereda 20	1000847.35	473932.32
27	Senay Higher Clinic	Wereda 20	1001440.39	474228.84
28	Tekle Haimenot Higher Clinic	Wereda 02	1007321.38	474970.14
29	Tikur Anbessa Hospital	Wereda 03	1005987.04	474426.52
30	Tirat Higher Clinic	Wereda 18	1003219.51	475859.70
31	Yekka Health Center	Wereda 12	1010978.46	478330.71
32	Woreda 17 Health Center	Wereda 17	998228.08	482827.94
33	Zewditu Memorial Hospital	Wereda 14	1006728.34	476502.16
34	Entoto Pro pride Clinic	Wereda 11	1011818.61	475217.24
35	Woreda 7 Health Center	Wereda 07	1007914.42	473042.76
36	Gulele Health Center	Wereda 09	1008705.14	473734.64
37	Global Clinic	Wereda 19	997931.56	473685.22
38	Betel General Hospital	Wereda 24	1005739.93	467228.33
39	Selam Health Center	Wereda 28	1004625.69	483618.66
40	Woreda 24 Health Center	Wereda 24	1003664.29	467112.35

Table 3.6 Location of VCT centers (*Source*: Field Data Collection)

3.3.1.6 Type of Data collected for The Sero-Prevalence from all the VCT Centers in Addis Ababa:

In order to create a susceptibility map of HIV/AIDS vulnerable areas of the Addis Ababa city, first it is important to map the spatial distribution of the existing HIV/AIDS epidemic and then relate each possible factor to the existing occurrence and try to build up a correlation between each spreading factor and give ranks to the factors. Based on this fact the unlinked data of HIV blood test results (i.e., the result of the blood test is truncated from the identity of the VCT client) were collected from the four data encoding centers of the Addis Ababa Health Bureau. The data collected was the HIV blood results from all the VCT centers in the year 2005.

HIV blood test result collected from the Lideta Health Center (Data-encoding center For seven Woredas) for the year 2005

The Lideta Health center serves as the data-encoding center for the data collected from all the VCT centers in seven Woredas (i.e. Woredas 22, 26, 27, 19, 04, 18, and 01)

Woreda	HIV Status	Sex		Total
		Male	Female	
Woreda 22	Negative	550	878	1428
	Positive	48	213	261
	Total	598	1091	1689
Woreda 26	Negative	555	728	1283
	Positive	76	134	210
	Total	631	862	1493
Woreda 27	Negative	417	608	1025
	Positive	53	131	184
	Total	470	739	1209
Woreda 19	Negative	703	1186	1889
	Positive	100	281	381
	Total	803	1467	2270

Woreda 04	Negative	392	864	1256
	Positive	63	170	233
	Total	455	1034	1489
Woreda 18	Negative	498	741	1239
	Positive	46	171	217
	Total	544	912	1456
Woreda 01	Negative	879	1186	2065
	Positive	141	278	419
	Total	1020	1464	2484

Table 3.7a Voluntary Blood test result (*Source*: Field Data Collection)

HIV blood test result collected from the Woreda 24 Health Center (Data-encoding center For six Woredas) for the year 2005

The Woreda 24Health Center serves as the data-encoding center for the data collected from all the VCT centers in six Woredas (i.e. Woredas 16, 24, 17, 23, 28, and 21)

Woreda	HIV Status	Sex		Total
		Male	Female	
Woreda 16	Negative	399	616	1015
	Positive	53	147	200
	Total	452	763	1215
Woreda 24	Negative	597	826	1423
	Positive	75	195	270
	Total	672	1022	1694
Woreda 17	Negative	680	902	1582
	Positive	114	242	356
	Total	796	1148	1944
Woreda 23	Negative	350	548	898
	Positive	47	132	179
	Total	397	681	1078

Woreda 28	Negative	350	548	898
	Positive	47	132	179
	Total	397	681	1078
Woreda 21	Negative	348	630	978
	Positive	66	195	261
	Total	416	830	1246

Table 3.7b Voluntary Blood test result (*Source*: Field Data Collection)

<u>HIV blood test result collected from the Kolfe Health Center (Data encoding center For seven Woredas) for the year 2005</u>

The Kolfe Health center serves as the data-encoding center for the data collected from all the VCT centers in seven Woredas (i.e. Woredas 03, 06, 09, 11, 12, 13, and 25)

Woreda	HIV Status	Sex		Total
		Male	Female	
Woreda 03	Negative	488	752	1240
	Positive	85	204	289
	Total	573	958	1531
Woreda 06	Negative	688	837	1525
	Positive	76	203	279
	Total	764	1041	1805
Woreda 09	Negative	444	828	1272
	Positive	67	212	279
	Total	511	1042	1553
Woreda 11	Negative	367	637	1004
	Positive	99	335	434
	Total	466	972	1438
Woreda 12	Negative	413	691	1104
	Positive	52	167	219
	Total	465	858	1323

Woreda 13	Negative	771	856	1627
	Positive	113	212	325
	Total	884	1068	1952
Woreda 25	Negative	871	1042	1913
	Positive	68	145	213
	Total	939	1187	2126

Table 3.7c Voluntary Blood test result (*Source*: Field Data Collection)

Summarized HIV Blood Test Data collected from Voluntary Counseling and Testing (VCT) Services In Addis Ababa by Age and Sex group: (Adapted from Addis Ababa Health Bureau)

Region: Addis Ababa

Period: Jul 2005 to Sep 2005

	Pretest Counseled			Tested			Positive Case			Post Test Counseled			HIV Positive Referred		Total
Age	**M**	**F**	**Total**	**M**	**F**	**Total**	**M**	**F**	**Total**	**M**	**F**	**Total**	**M**	**F**	
<15			0			0			0			0			**0**
15-19	1658	5047	6705	1674	5252	6926	34	196	230	1589	5047	6636	16	51	**67**
20-24	5715	10109	15824	5841	10597	16438	172	1098	1270	5527	10239	15766	62	313	**375**
25-29	6242	6761	13003	6545	7014	13559	515	1431	1946	6238	6755	12993	183	491	**674**
30-34	3771	2603	6374	3925	2678	6603	628	792	1420	3743	2590	6333	239	307	**546**
35-39	2218	1471	3689	2290	1499	3789	545	527	1072	2182	1447	3629	246	224	**470**
40-44	1184	640	1824	1212	648	1860	338	221	559	1154	623	1777	145	110	**255**
45-49	728	379	1107	736	384	1120	220	133	353	722	386	1108	106	65	**171**
50+	883	384	1267	894	388	1282	209	114	323	858	374	1232	105	71	**176**
Unrecorded	26	20	46	25	24	49	4	5	9	24	18	42	1	2	**3**
Total	**22425**	**27414**	**49839**	**23142**	**28484**	**51626**	**2665**	**4517**	**7182**	**22037**	**27479**	**49516**	**1103**	**1634**	**2737**

4. GIS-BASED DATA PROCESSING AND ANALYSIS TECHNIQUES:

The collected data were processed using a GIS platform. (i.e. ArcviewGIS 3.2a) and HIV risk susceptibility map of Addis Ababa was created. To do so the following steps were generally followed:

First, the tabular data collections were attached to the respective spatial features (i.e. the numeric figures were integrated with the attributes of the respective Woreda shape files).

Second, the geographic centers of each Woreda were taken and the specific numeric values were assigned to each point. (i.e. the young population density, the female population density, the commercial sex workers density, the establishments density, the economically inactive population density and HIV positive population density of each woreda were represented as point features geographically).

Third, the point features were interpolated in to surface data to show the five factor data (layers) of the area and they are kept into separate factor maps that are assumed to govern the spread of the HIV/AIDS epidemic in the city of Addis Ababa.

Fourth, the five factor maps were standardized (i.e. common scale were given to the different values, so that they can be analyzed in the GIS map overlay facility and give a new output map as the result of the overlying of the factor maps).

4.1. Integrating the Tabular data collected to the Attributes of the Woredas Shape File

This process generally involves the attachment of the tabular data to their respective geographical locations, so that we will be able to see the spatial distribution and relation of these values.

4.1.1. Processing the 'Young Population' GIS Layer:

The initial input to create the 'Young Population Density' factor map (layer) was the tabular data format, from which I got the total number of young population in each Woreda. The 'Young Population' data was integrated to the corresponding attribute data of the Woredas shape file. In order to make the data analysis more meaningful, the total young population data is derived into a density data. To do so, I created a new field, as 'Young Population Density' and calculated the density values for each Woreda using the following formula:

$$\text{Young Population Density} = \frac{\text{Tot. Young Pop. in each Woreda}}{\text{Area of each Woreda}}$$

Woreda	Population (Age 15-25)	Area of the Woredas (Sq.Km)	Young Pop. Density Per Sq.Km
Woreda 1	10214	1.60	6383.75
Woreda 2	9287	1.89	4913.76
Woreda 3	10134	2.18	4648.62
Woreda 4	287.23	1.98	14506.57
Woreda 5	33053	1.34	24666.42
Woreda 6	28261	1.75	16149.14
Woreda 7	32000	2.12	15094.34
Woreda 8	34103	12.73	2678.95
Woreda 9	20562	2.27	9058.15
Woreda 10	31197	9.14	3413.24
Woreda 11	34829	13.74	2534.86
Woreda 12	23179	13.72	1689.43
Woreda 13	25163	3.45	7293.62
Woreda 14	22460	2.70	8318.52
Woreda 15	25764	3.59	7176.60
Woreda 16	28957	12.00	2413.08
Woreda 17	50537	73.74	685.34
Woreda 18	24046	3.99	6026.57
Woreda 19	46424	43.61	1064.53
Woreda 20	31846	6.99	4555.94
Woreda 21	32045	3.44	9315.41
Woreda 22	14248	4.04	3526.73
Woreda 23	40925	15.80	2590.19

Woreda 24	46704	56.77	822.69
Woreda 25	31383	11.53	2299.12
Woreda 26	17043	80.32	212.19
Woreda 27	19734	32.85	600.73
Woreda 28	26501	106.33	249.23

Table 4.1 Young Population densities per square kilometer of each woreda

Now, the tabular data format is attached to a spatial data, so that it is possible to display it geographically on a map.

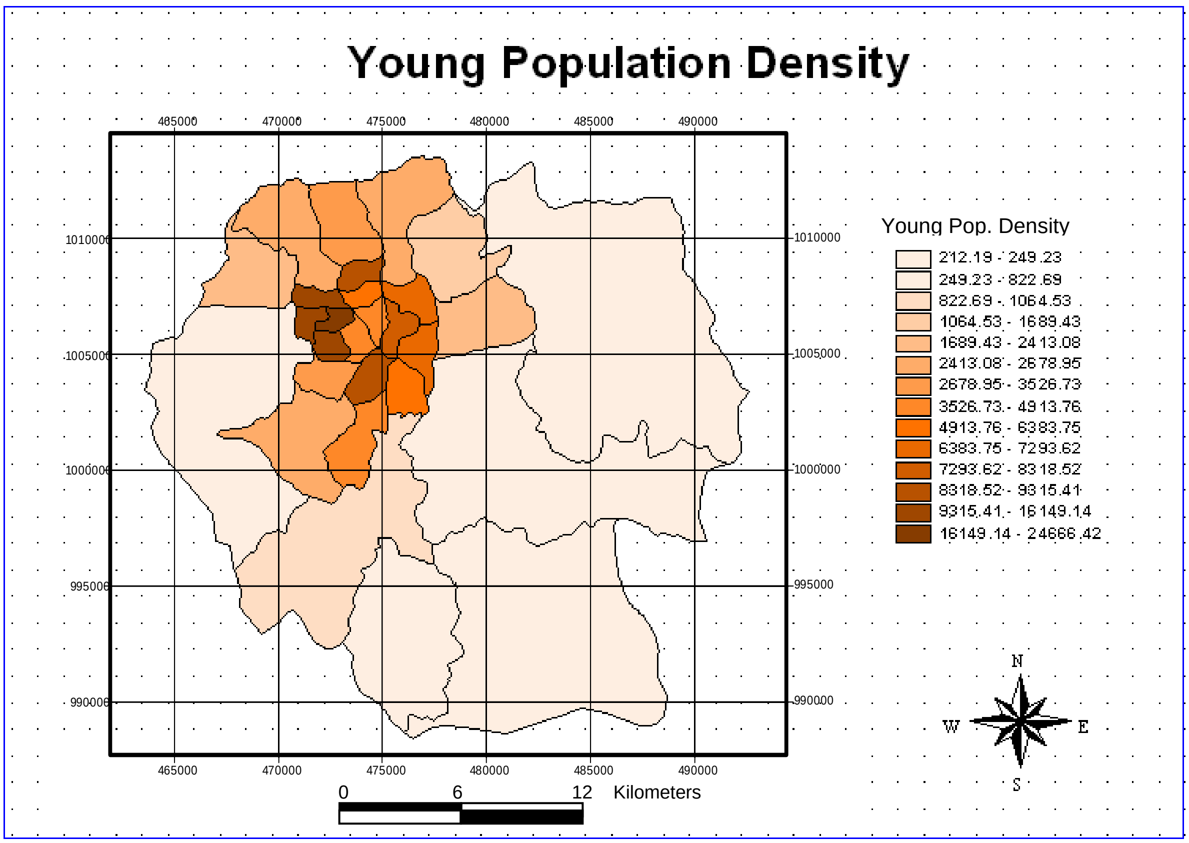


Figure 4.1 Young Population Density map of Addis Ababa

4.1.2. Processing the ‘Female Population’ GIS Layer:

The initial input to create the ‘Female Population Density’ factor map (layer) was the tabular data format; from which I got the total number of female population in each Woreda. The ‘Female Population’ data was integrated to the corresponding attribute data of the Woredas shape file. In order to make the data analysis more meaningful, the total female population data is derived into density of ‘Female Population’ per square kilometer. This was done by creating a new field, as ‘Female Population Density’ and calculated the density values for each Woreda using the following formula:

$$\text{Female Population Density} = \frac{\text{Tot. Female Pop. in each Woreda}}{\text{Area of each Woreda}}$$

Woreda	Female Population	Area of the Woredas (Sq.Km)	Female Pop. Density Per Sq.Km
Woreda 1	39739	1.60	24836.88
Woreda 2	30591	1.89	16185.71
Woreda 3	60859	2.18	27916.97
Woreda 4	54776	1.98	27664.65
Woreda 5	61176	1.34	45653.73
Woreda 6	51691	1.75	29537.71
Woreda 7	50869	2.12	24574.40
Woreda 8	64415	12.73	5060.09
Woreda 9	40967	2.27	18047.14
Woreda 10	60145	9.14	6580.42
Woreda 11	63081	13.74	4591.05
Woreda 12	45308	13.72	3302.33
Woreda 13	48995	3.45	14201.45
Woreda 14	43639	2.70	16162.59
Woreda 15	51083	3.59	14229.25
Woreda 16	57710	12.00	4809.17
Woreda 17	95270	73.74	1291.97
Woreda 18	47089	3.99	11801.75
Woreda 19	87347	43.61	2002.91
Woreda 20	60916	6.99	8714.74
Woreda 21	59708	3.44	17356.98
Woreda 22	22714	4.04	6859.90

Woreda 23	79297	15.80	5018.80
Woreda 24	86970	56.77	1531.97
Woreda 25	56814	11.53	4906.22
Woreda 26	27790	80.32	345.99
Woreda 27	34502	32.85	1050.29
Woreda 28	43617	106.33	410.20

Table 4.2 Female Population densities per square kilometer of each woreda

The following map shows the spatial distribution of the 'Female Population' density

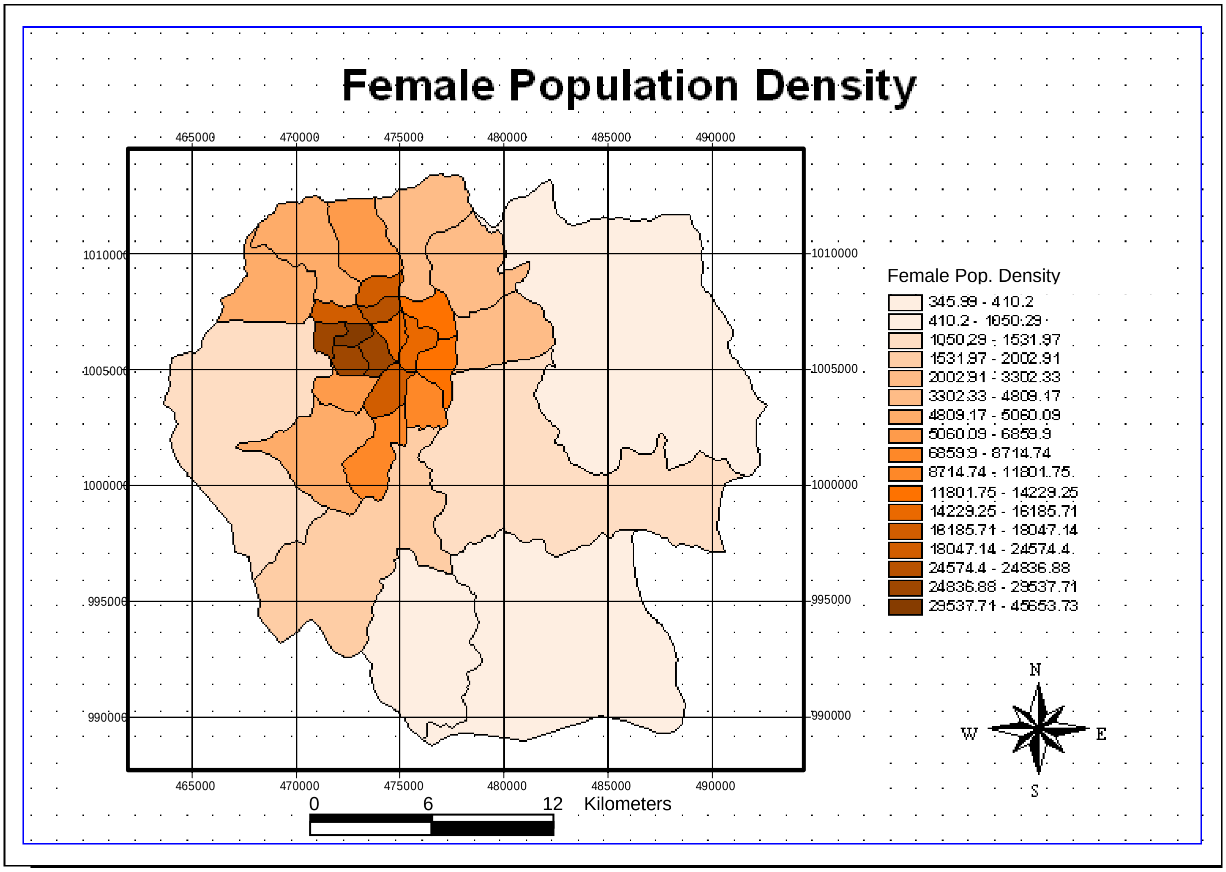


Figure 4.2 Female Population Density map of Addis Ababa

4.1.3. Processing the 'Female Sex Workers Population' GIS Layer:

To create the 'Female Sex Workers Population Density' factor map (layer) I took the tabular data format, from which I got the total number of female sex workers in each Woreda. The 'Female Sex Workers Population' data was integrated to the corresponding attribute data of the Woredas shape file. In order to make the data analysis more meaningful, the total female sex workers population data was derived into density of 'Female Sex Workers Population' per square kilometer. This was done by creating a new field, as 'Female Sex Workers Population Density' and calculated the density values for each Woreda using the following formula:

$$\text{Sex Workers Population Density} = \frac{\text{Tot. Sex Workers Pop. in each Woreda}}{\text{Area of each Woreda}}$$

The following map shows the spatial distribution of the 'Female Sex Workers Population' density

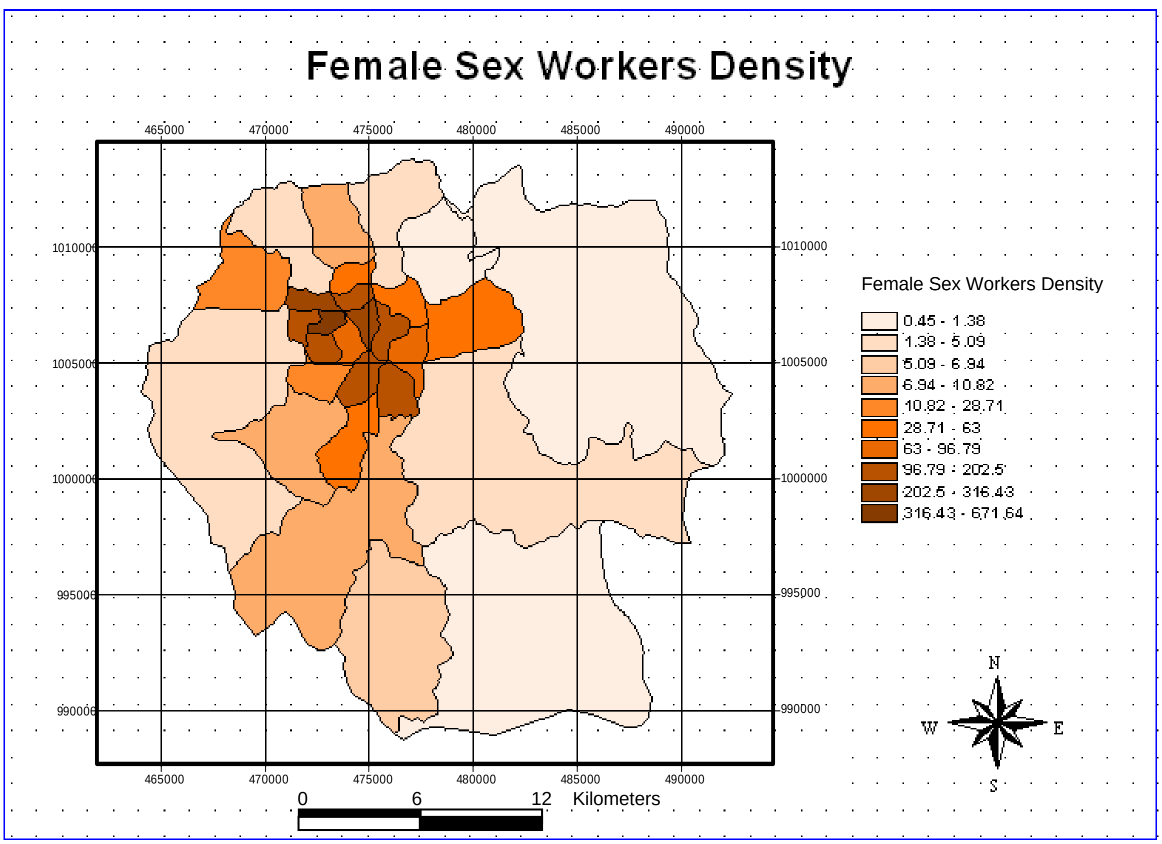


Figure 4.3 Female Sex Workers Population Density map of Addis Ababa

4.1.4. Processing the factor map (GIS Layer) that shows the 'Establishments Incorporating Female Sex Workers':

To make the 'Establishments Incorporating Female Sex Workers' Population Density factor map (layer) I took the tabular data that shows the total count of the female sex workers in each Woreda. The 'Female Sex Workers Population' data was integrated to the corresponding attribute data of the Woredas shape file. In order to make the data analysis more meaningful, the 'Establishments Incorporating Female Sex Workers' population data was derived into density of 'Establishments Incorporating Female Sex Workers' Population per each square kilometer. This was done by creating a new field, as 'Establishments Density' and calculated the density values for each Woreda using the following formula:

$$\text{Establishments Density} = \frac{\text{Tot. Establishments. in each Woreda}}{\text{Area of each Woreda}}$$

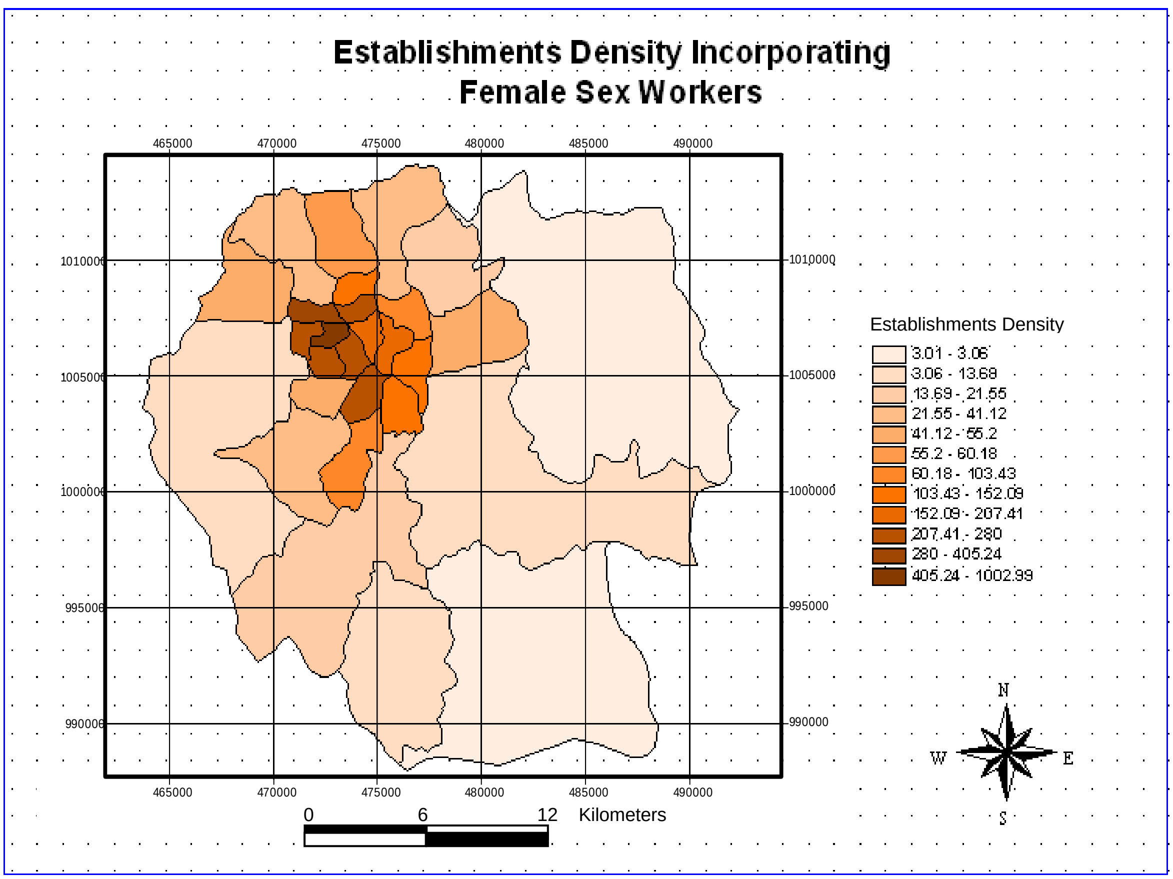


Figure 4.4 Establishments (Incorporating Sex Worker Density map of Addis Ababa

4.1.5. Processing the 'Economically Inactive Population' GIS Layer:

To make the 'Economically Inactive Population' Density factor map (layer), I took the tabular data that shows the total Economically Inactive population in each Woreda of the Addis Ababa city. The 'Economically Inactive Population' data was integrated to the corresponding attribute data of the Woredas shape file. In order to make the data analysis more meaningful, the 'Economically Inactive Population' density per each square kilometer was calculated. This was done by creating a new field, as 'Economically Inactive Population Density' and calculated the density values for each Woreda using the following formula:

$$\text{Economically Inactive Population Density} = \frac{\text{Tot. Economically Inactive Population in each Woreda}}{\text{Area of each Woreda}}$$

Woreda	Economically Inactive Population	Area of the Woredas (Sq.Km)	Econ. Inactive Pop. Density Per Sq.Km
Woreda 1	12346	1.60	7716.25
Woreda 2	11226	1.89	5939.68
Woreda 3	12249	2.18	5618.81
Woreda 4	34719	1.98	17534
Woreda 5	39953	1.34	29815.67
Woreda 6	34161	1.75	19520.57
Woreda 7	26481	2.12	12670.33
Woreda 8	41223	12.73	3238.26
Woreda 9	24854	2.27	10948.90
Woreda 10	37709	9.14	4125.71
Woreda 11	42100	13.74	3064.05
Woreda 12	28018	13.72	2042.13
Woreda 13	30416	3.45	8816.23
Woreda 14	27149	2.70	10055.19
Woreda 15	31143	3.59	8674.93
Woreda 16	35002	12.00	2918.83
Woreda 17	61087	73.74	828.41
Woreda 18	29065	3.99	7284.46
Woreda 19	56116	43.61	1286.77

Woreda 20	38495	6.99	5507.15
Woreda 21	38734	3.44	11259.88
Woreda 22	17223	4.04	4263.12
Woreda 23	49469	15.80	3130.95
Woreda 24	56454	56.77	994.43
Woreda 25	37935	11.53	3278.74
Woreda 26	20601	80.32	256.49
Woreda 27	23853	32.85	726.12
Woreda 28	32034	106.33	301.27

Table 4.3 Economically Inactive Population densities per square kilometer of each woreda

The tabular data format is attached to a spatial data, so that it is possible to display it geographically on a map.

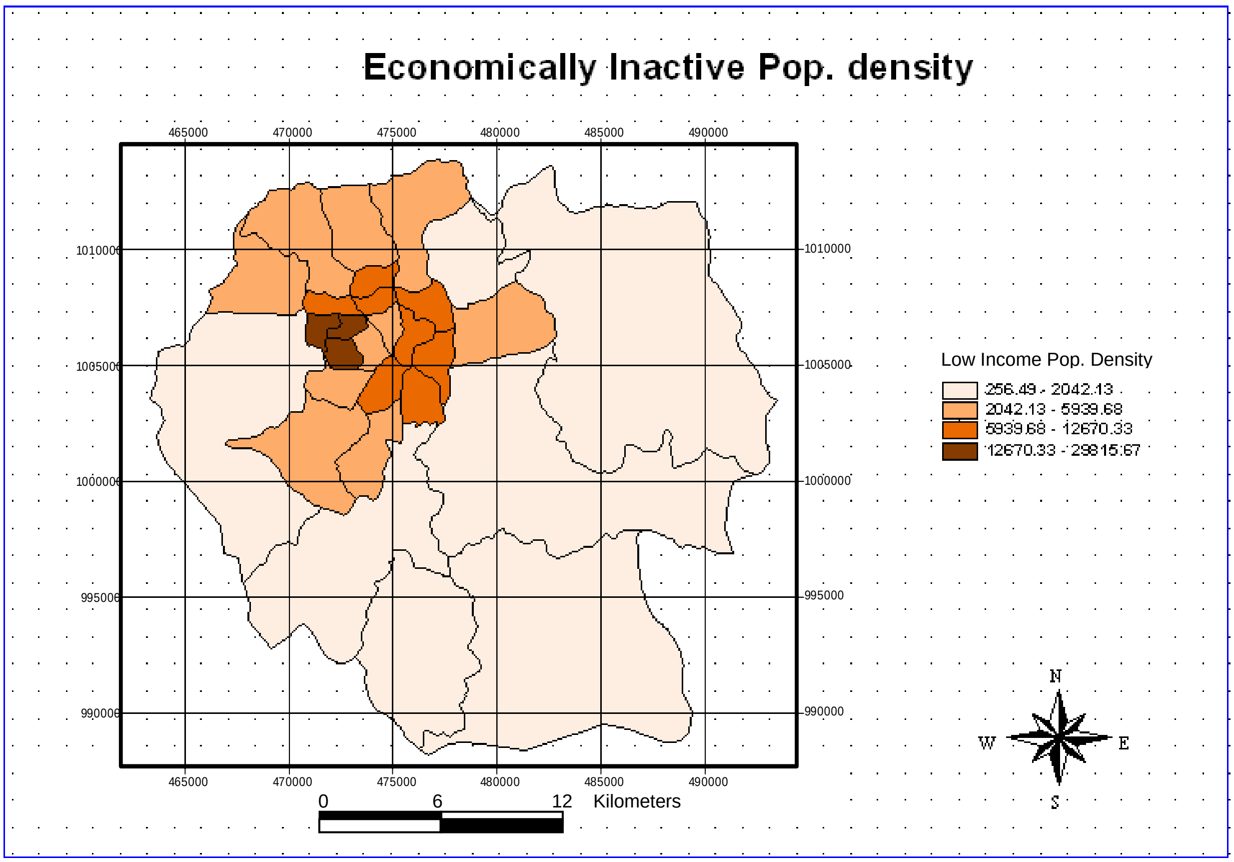


Figure 4.5 Economically Inactive Population Density map of Addis Ababa

4.1.6. Mapping the Existing HIV Positive Population Distribution

In order to create the HIV/AIDS susceptibility map of the Addis Ababa city, the existing spatial distribution of the HIV/AIDS epidemic must be mapped, and then compared to the suggested spreading factors. The degree of correlation between each factor map and the existing HIV/AIDS spatial distribution map is calculated, so that it will be helpful when giving weights to each of the criterion map.

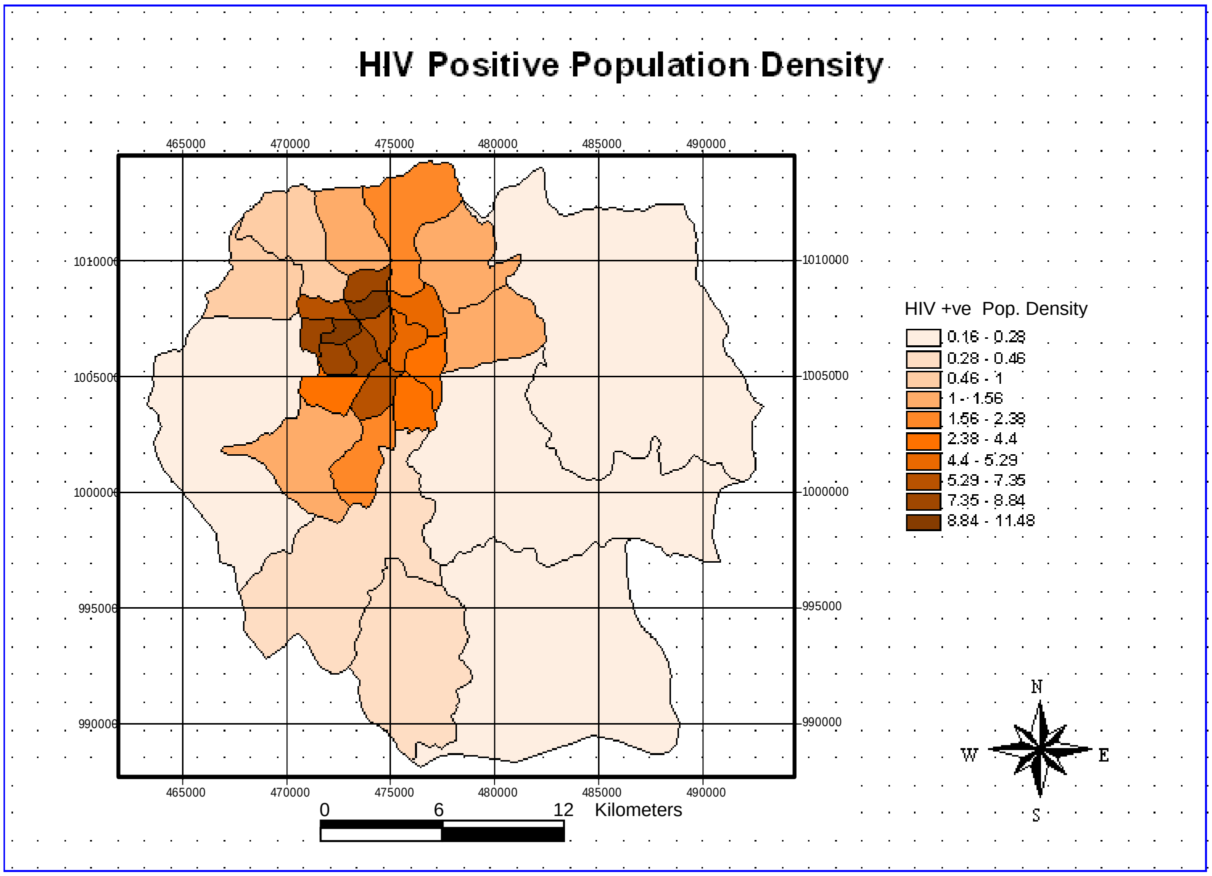


Figure 4.6 HIV Positive Population Density map of Addis Ababa

4.1.7. Mapping the VCT Centers Distribution

In order to see the spatial distribution of the Health Centers that work in the areas of HIV/AIDS prevention and control activities, it is important to have a separate map that shows the spatial distribution of such facilities (for example the spatial distribution of VCT center).

The procedure followed to create the VCT centers map is that; first the geographic co-ordinates of the locations of each VCT center was collected using the GPS (Global Positioning System) device and then they are displayed in the map as point features using the ‘Add Event Theme’ facility of the ArcView GIS3.2a software.

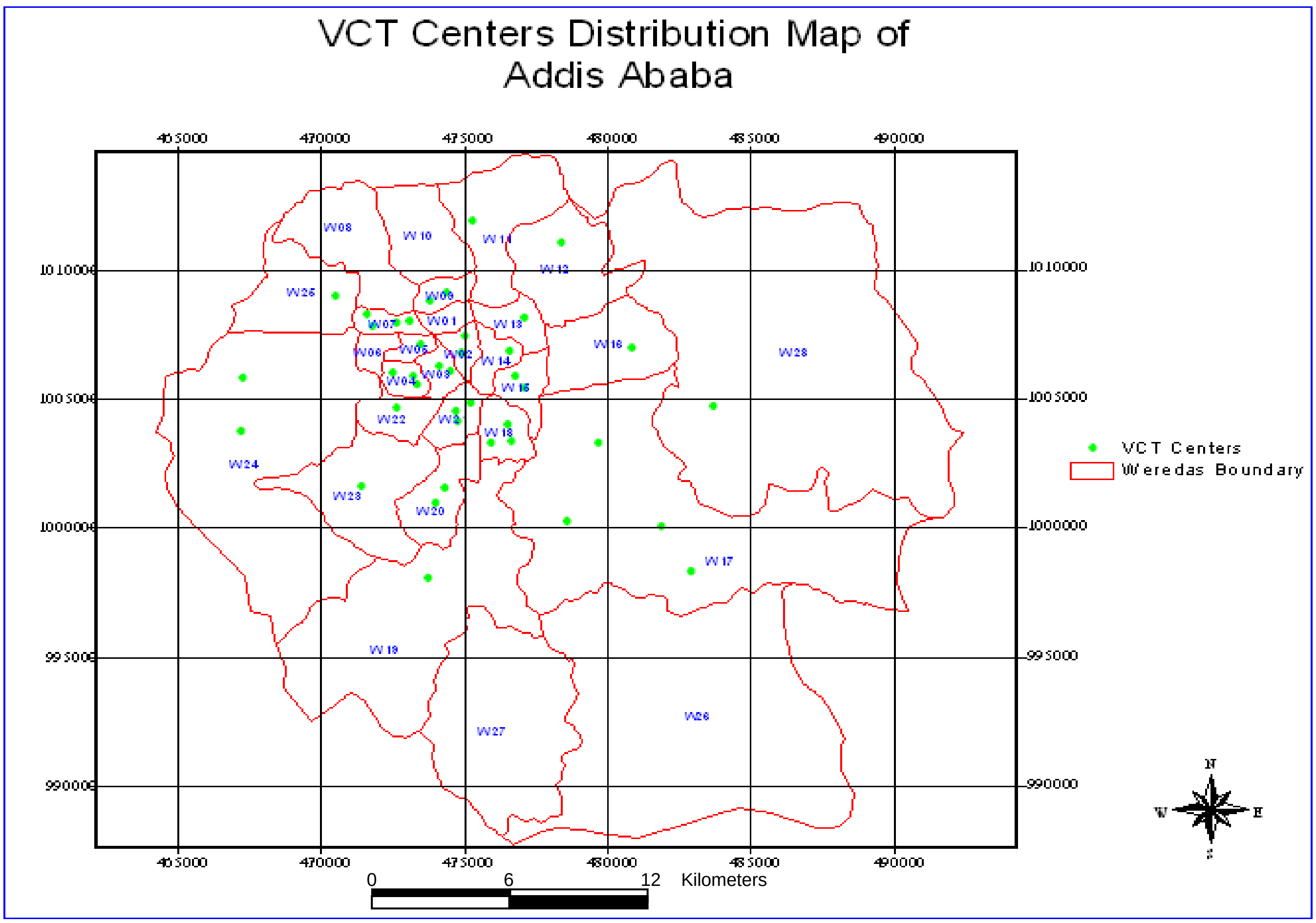


Figure 4.7 VCT Centers distribution map of Addis Ababa

4.2. Deriving Commensurate Criterion Maps:

If all the factor maps have variety of scales on which attributes can be measured, multicriteria decision analysis requires that the values contained in the various criterion map layers be transformed to comparable units. To be more specific, if we want to combine the various criterion maps layers, the scales must be commensurate. A number of approaches can be sued to make criterion map layers comparable. To this end, criterion maps can be classified on the basis of the types of information available for constructing the maps. Criterion maps can be categorized as deterministic, probabilistic, or fuzzy. Deterministic maps assign a single value to each object (point, line, polygon, or pixel) in a map layer. It follows that for deterministic criteria there will be a deterministic relationship between an alternative (represented by an object or combination of objects) and its consequences. Linear scale transformation is the most frequently used deterministic method for transforming input data into commensurate criterion maps.

Since the type of information for constructing the maps in this thesis are shape files with specific quantitative values, then it is most appropriate to use the 'Linear Transformation' method to derive a commensurate map layers for each of the criterion map, that are considered the HIV/AIDS epidemic spreading factors .

4.2.1. Linear Scale Transformation:

The linear scale transformation method converts the raw data into standardized criterion scorers. The formulae for standardizing the row data is to divide each raw score by the maximum value for a given criterion; that is,

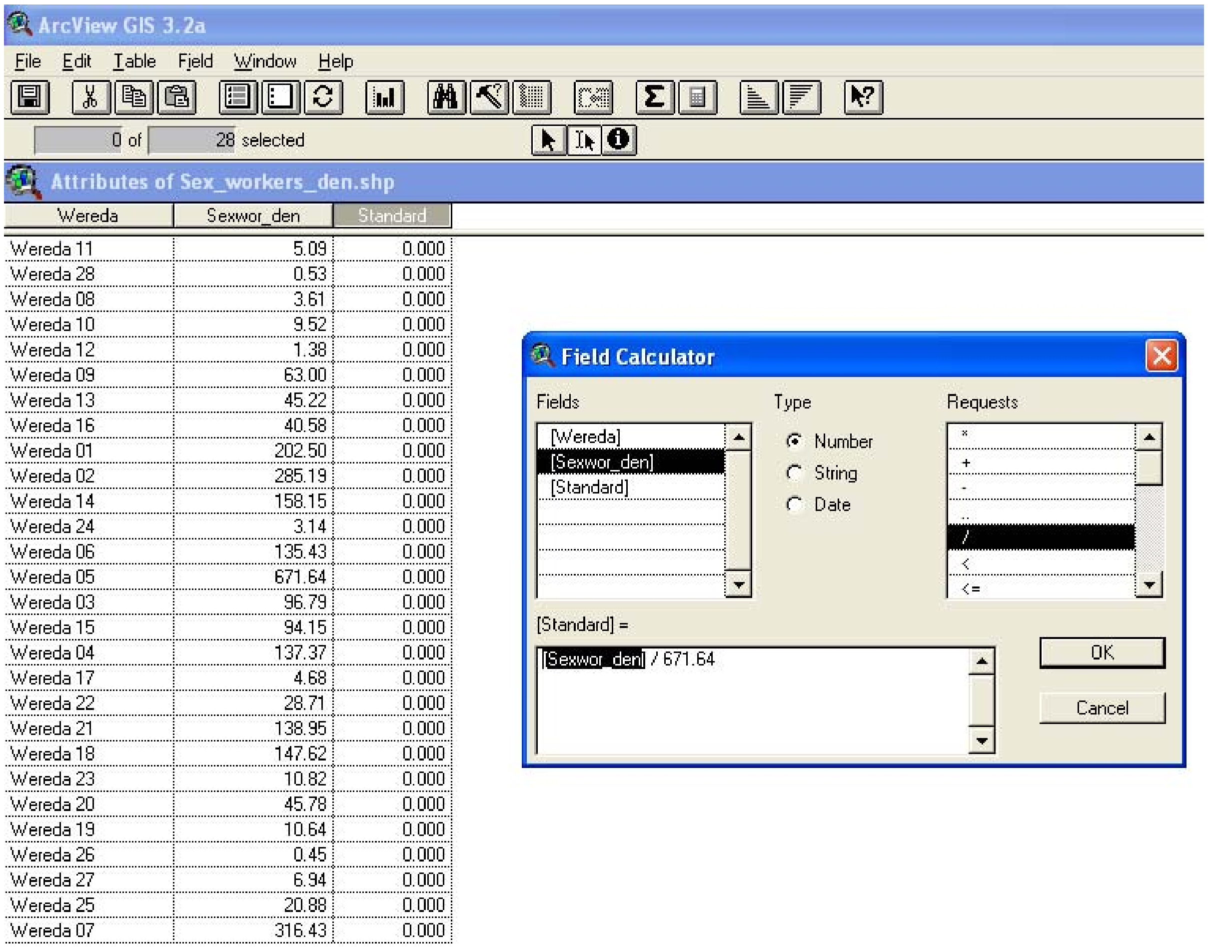
$$\boxed{x'_{ij} = \frac{x_{ij}}{x_j^{max}}}$$

where x'_{ij} is the standardized score for the *i*th object (alternative) and the *j*th attribute, x_{ij} is the raw score, and x_j^{max} is the maximum score for the jth attribute. The value of standardized scores can range from 0 to 1. The higher the value of the score, the more attractive is the criterion value.

The advantage of this method is that it is a proportional (linear) transformation of the raw data. This means that the relative order of magnitude of the standardized scores remains equal. For example, if the raw data are 3, 15, and 26, suing the above formula we obtain the standardized scores 0.115, 0.577, and 1.0, respectively. By standardizing the data, we do not change the relative order of magnitudes; that is 3/15=0.115/0.577, 3/26=0.115/1.0, and 15/26=0.577/1.0.

4.2.2. Standardized Values of the raw data of the Criterion Maps:

As stated above the idea of creating commensurate criterion maps is to derive standardized scores to the raw data so that we can apply multicriteria spatial analysis. Below is the standardized score of the ‘sex workers population’ criterion map derived from the ‘sex workers population density’ values in the ArcView GIS 3.2a ‘Calculate’ facility.



Wereda	Sexwor_den	Standard
Wereda 11	5.09	0.008
Wereda 28	0.53	0.001
Wereda 08	3.61	0.005
Wereda 10	9.52	0.014
Wereda 12	1.38	0.002
Wereda 09	63.00	0.094
Wereda 13	45.22	0.067
Wereda 16	40.58	0.060
Wereda 01	202.50	0.302
Wereda 02	285.19	0.425
Wereda 14	158.15	0.235
Wereda 24	3.14	0.005
Wereda 06	135.43	0.202
Wereda 05	671.64	1.000
Wereda 03	96.79	0.144
Wereda 15	94.15	0.140
Wereda 04	137.37	0.205
Wereda 17	4.68	0.007
Wereda 22	28.71	0.043
Wereda 21	138.95	0.207
Wereda 18	147.62	0.220
Wereda 23	10.82	0.016
Wereda 20	45.78	0.068
Wereda 19	10.64	0.016
Wereda 26	0.45	0.001
Wereda 27	6.94	0.010
Wereda 25	20.88	0.031
Wereda 07	316.43	0.471

Figure 4.8 Deriving Standardized values for the row data

4.3. Preparing the Criteria Maps by the method of Interpolation:

The Criteria maps that have been shown in the above sections have sharp boundaries that change the population density abruptly between two adjacent Woredas, which in real case do not. To represent the actual event on a more realistic way, I found it better to produce the criteria maps with smoother boundaries, so that the value in a given geographical location will also affect some extent of the surrounding proximity.

The idea of creating the criterion maps with a smoother boundary is that, first the value for a given polygon is assigned to the geographic center of the same polygon, and then all the other polygons are also represented by the midpoints of the respective polygons. What we get now is the point representation of the polygon theme by point theme.

Second, using the idea of interpolation of point data into surface data, it is possible to create a criterion map, which has a smoother boundary and a better representation of the actual event.

4.3.1. The IDW Method of Interpolating Point Data in to Surface Data

To interpolate the point data that represents the geographic centers of each woredas and the number values associated with them, I used the IDW method of interpolating a point data into surface data. The IDW method of interpolation Gives values to each cell in the output grid theme by weighting the value of each point by the distance that point is from the cell being analyzed and then averaging the values.

The following were the parameters used during interpolation of the point data in to surface data by the IDW method:

- <u>Nearest Neighbors</u>: Uses the N nearest points to the cell being analyzed. (N=12)

- Power: The exponent of distance used in the calculation. Controls the significance of surrounding points on the value given to the cell being analyzed. A higher power results in less influence from distant points. (Power = 2)

- Barriers: Used to limit certain points from being used in the calculation of a new value for a cell, even if the point is one of the nearest neighbors or within a certain distance. For example you wouldn't want to use an elevation point on one side of a ridge to create an elevation value on the other side of the ridge. Barriers can be (No Barriers).

4.3.2. The Standardized and Rasterized Criteria Maps

In this section, I presented the rasterized criterion maps that have equal cell size, equal number of cell rows and cell columns, so that they are ready to be used as an input for the GIS overlay analysis.

The following are the rasteriztion parameters used during the shape-to-vector conversion:

- Output Grid Extent: The same as the corresponding shape files
- Output Grid Cell Size: 5 map units (meters)
- Number of Rows: 500
- Number of Columns: 550

Note: Increasing the output grid cell size, the number of rows, and the number of columns values eventually increases the quality of the output grid map, but doing so will require a high processing capacity machine.

The 'Young Population Density' standardized Criterion Map

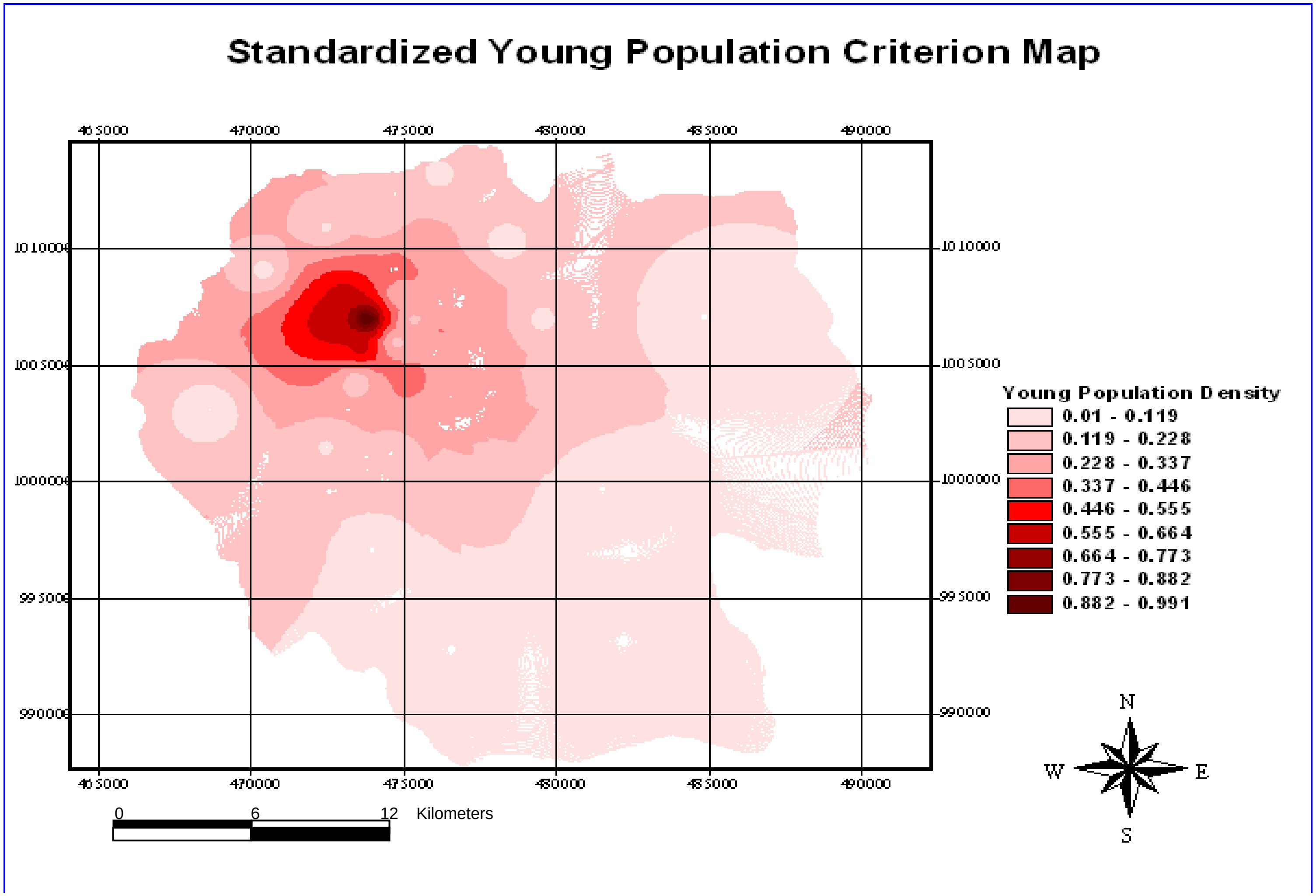


Figure 4.9 Standardized Young Population density map

The 'Female Sex Workers Density' standardized Criterion Map

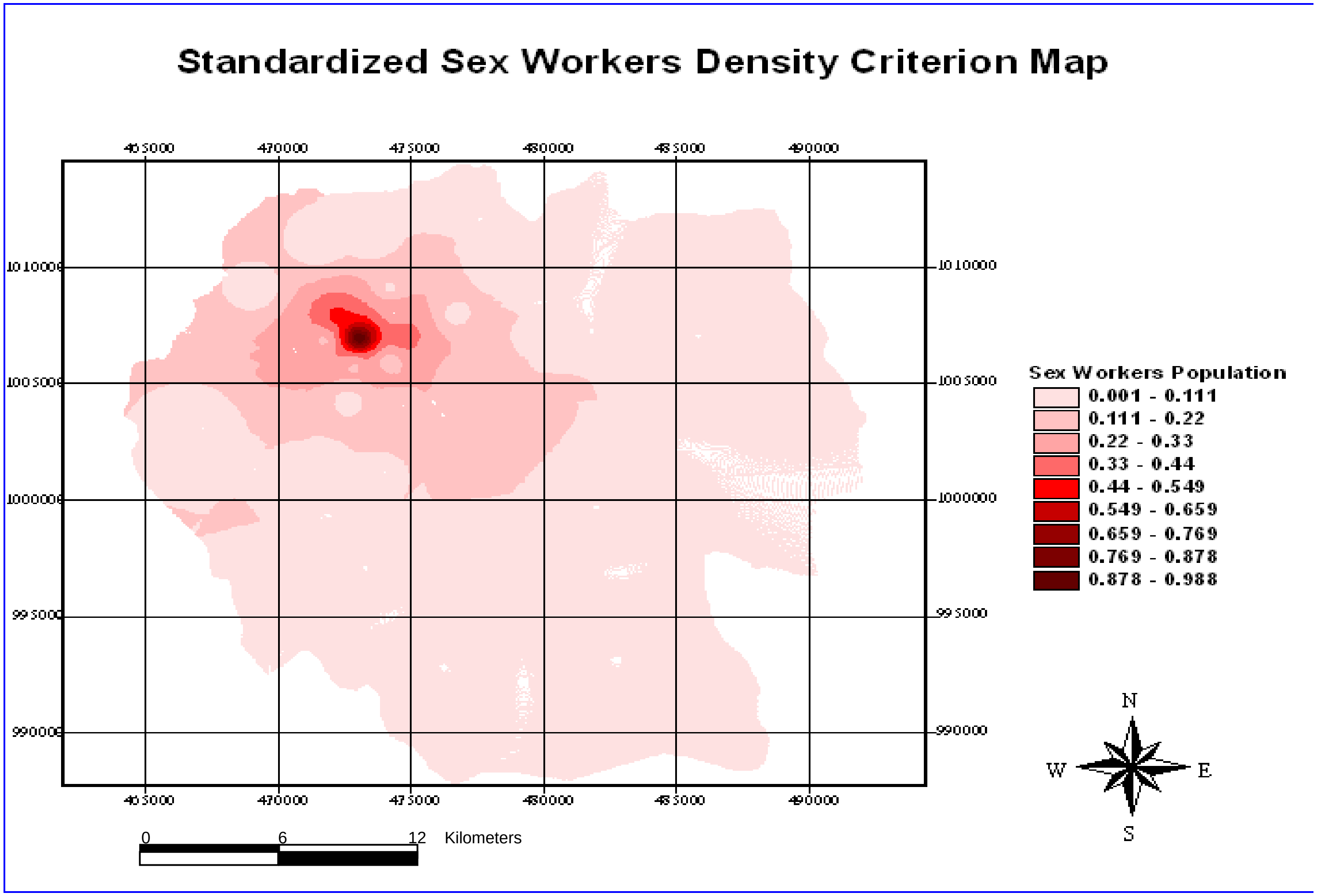


Figure 4.10 Standardized Female Sex Workers Population density map

The 'Female Population Density' standardized Criterion Map

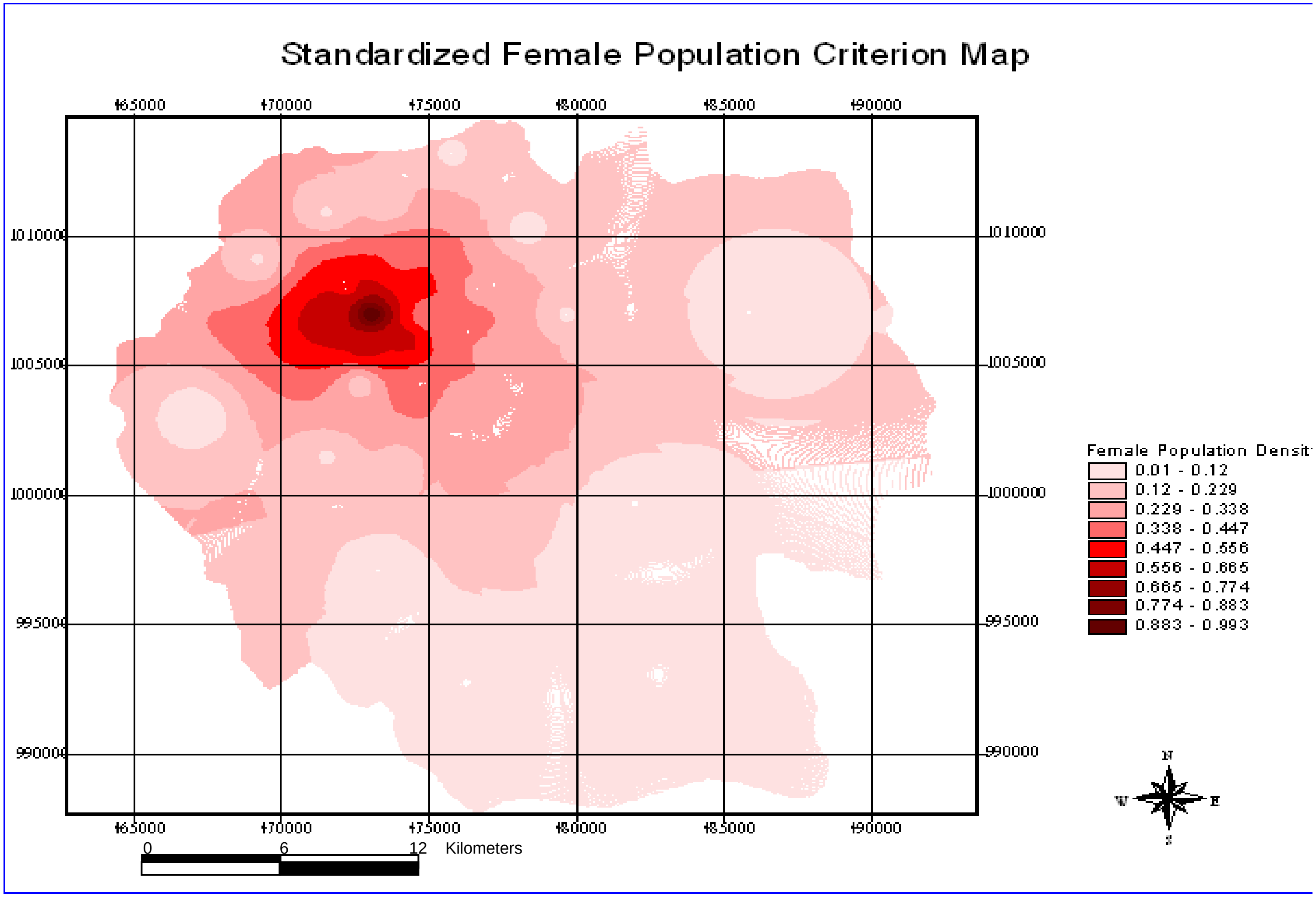


Figure 4.11 Standardized Female Population density map

<u>The ‘Economically Inactive (Low Income) Population Density’ standardized Criterion Map</u>

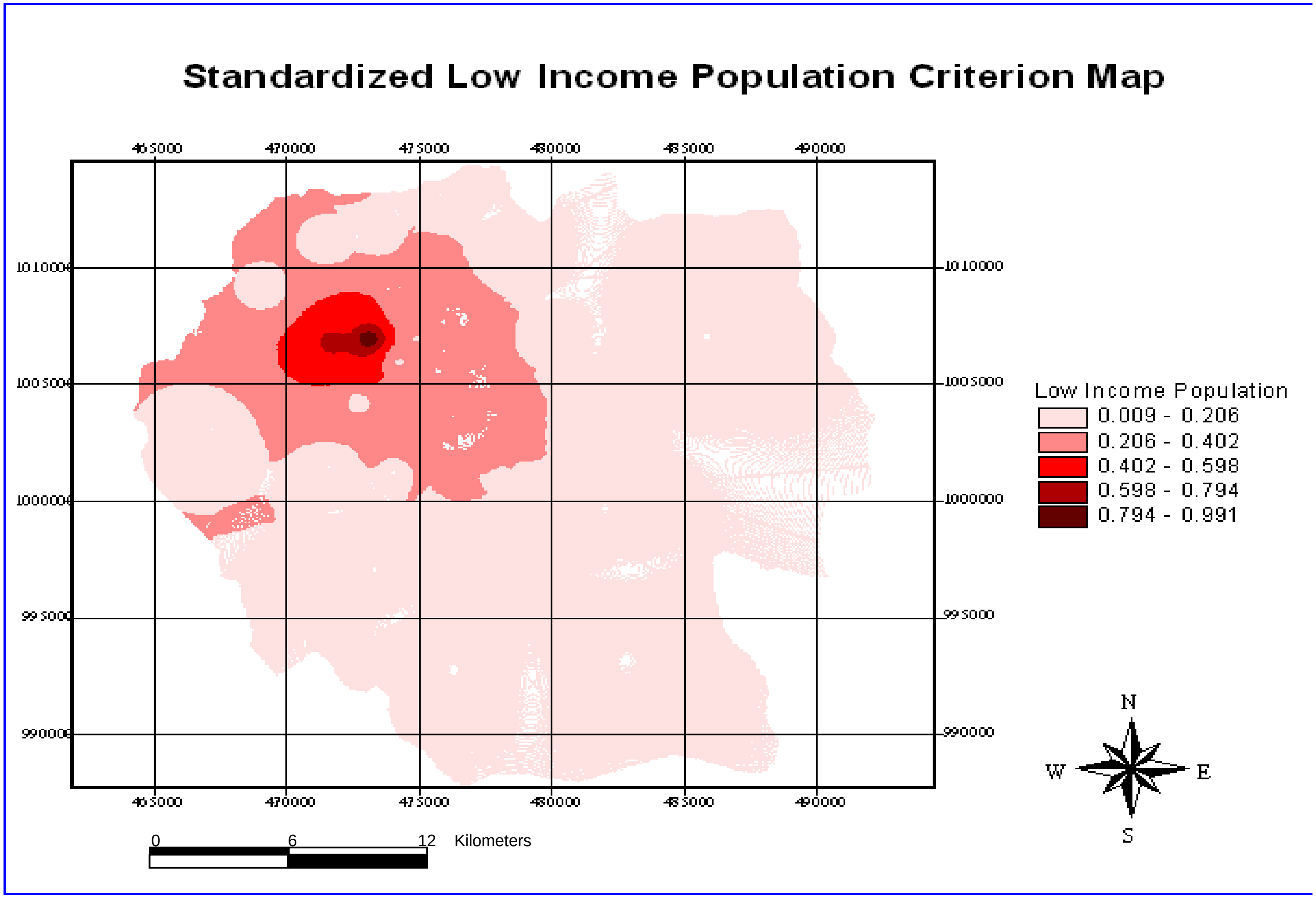


Figure 4.12 Standardized Economically Inactive Population density map

The 'Establishments Incorporating Sex Workers Density' standardized Criterion Map

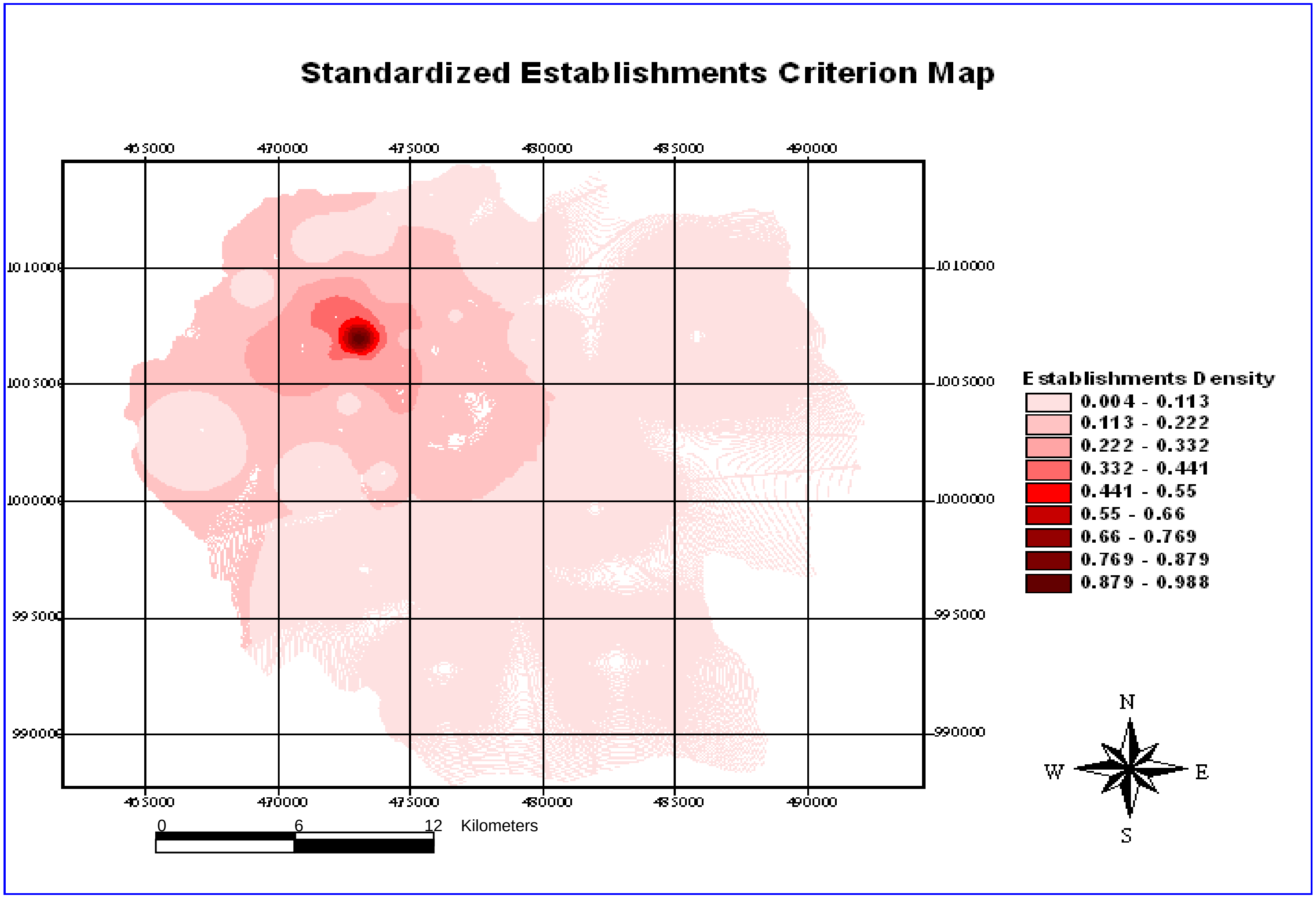


Figure 4.13 Standardized Establishments Incorporating Sex Workers density map

4.4. Criterion Weighing

The purpose of criterion (objective or attribute) weighting is to express the importance of each criterion relative to other criteria. A number of criterion weighting procedures are available; each of which differ in terms of their accuracy, degree of easiness to use, and understanding on the part of the decision makers, and in the theoretical foundation.

4.4.1. Estimating Weights

Multicriteria Decision Making (MCDM) problems typically involve criteria of varying importance to decision makers. Consequently, information about the relative importance of the criteria is required. This is usually achieved by assigning a weight to each criterion. The derivation of weights is a central step in eliciting the decision maker’s preferences. A weight can be defined as a value assigned to an evaluation criterion that indicates its importance relative to other criteria under consideration. The larger the weight, the more important is the criterion in the overall utility.

Assigning weights of importance to evaluation criteria accounts for (1) changes in the range of variation for each evaluation criterion, and (2) the different degrees of importance being attached to these ranges of variation (Kirkwood 1997). The weight value is dependent on the range of the criterion values, that is, the difference between the minimum and maximum value for a given criterion. A criterion weight can be made arbitrarily large of small by increasing or decreasing the range. The general rule is that we are concerned with the perceived advantage of changing from the maximum level to the minimum level of each criterion outcome, relative to the advantages of changing from the worst to the best levels for the other criterion under consideration (Pitz and McKillip 1884; Elton and Gear 1997). The weights are usually normalized to sum to 1. In the case of *n* criteria, a set of weights is defined as follows:

$W = (w_1, w_2, w_3, \ldots, w_j, \ldots, w_n)$, and $\Sigma w_j = 1$.

4.4.2. Pairwise Comparison Method

The pairwise comparison method was developed by Saaty (1980) in the context of the *analytic hierarchy process* (AHP). This method involves pairwise comparisons to create a ratio matrix. It takes as an input the pairwise comparisons and produces the relative weights as output. Specifically, the weights are determined by normalizing the eigenvector associated with the maximum eigenvalue of the (reciprocal) ratio matrix.

When considering the HIV/AIDS susceptibility-mapping problem, it involves evaluating the relative importance of the five criteria: the ‘Young Population’, the ‘Female Population’, the ‘Sex Workers Population’, the ‘Establishments Incorporating Sex Workers’ and the ‘Economically Inactive Population’. The following table shows scale for pairwise comparison:

The procedure consists of three major steps: generation of the pairwise comparison matrix, the criterion weights computation, and the consistency ratio estimation.

1. *Development of the pairwise comparison matrix*. The method employs an underlying scale with values from 1 t 9 to rate the relative preferences for two criteria (see Table A). We compare two factors at a time and give a quantitative value for the qualitative judgments.

The assignment of quantitative values (scale) to each of the criterion is done with the help of quantitative comparison of the criterion (factor) maps with that of the existing HIV/AIDS special distribution map. So assigning the scale to the criterion maps in this case is a semi-qualitative as well as a semi-quantitative approach.

The following table shows the Scale for Pairwise Comparison as adopted from Saaty (1980).

Intensity of importance	***Definition***
1	Equal importance
2	Equal to moderate importance
3	Moderate importance
4	Moderate to strong importance
5	Strong importance
6	Strong to very strong importance
7	Very strong importance
8	Very to extremely strong importance
9	Extreme importance

Table 4.5 The Scale for pairwise comparison *(Source*; Adapted form Saaty (1980))

2. *Computation of the criterion weights*. This step involves the following operations: (a) sum the values in each column of the pairwise comparison matrix; (b) divide each element in the matrix by its column total (the resulting matrix is referred to as the normalized pairwise comparison matrix); and (c) compute the average of the elements in each row of the normalized matrix, that is, divide the sum of normalized scores for each row by 3 (the number of criteria). These averages provide an estimate of the relative weights of the criteria being compared. Using this method, the weights are interpreted as the average of al possible ways of comparing the criteria. The following table shows the scale values assigned using the pairwise comparison of the Evaluation criteria:

Criteria	***YP***	***FP***	***SW***	***ES***	***EI***	
YP	1	4	0.333	0.333	8	
FP	0.250	1	0.250	0.500	4	
SW	3	4	1	2	9	
ES	3	2.000	0.500	1	5	
EI	0.125	0.250	0.111	0.200	1	
Sum of original scores	***7.375***	***11.25***	***2.194***	***4.033***	***27***	

Table 4.6 A matrix that shows the initial row scores

Where *YP*: Young Population
FP: Female Population
SW: Sex Workers Population
ES: Establishments incorporating Sex Workers
EI: Economically Inactive Population

(c) compute the average of the elements in each row of the normalized matrix, that is, divide the sum of normalized scores for each row by 5 (the number of criteria). These averages provide an estimate of the relative weights of the criteria being compared. Using this method, the weights are interpreted as the averages of all possible ways of comparing the criteria. The following table shows the averages of the scale values.

Normalized score=score/Σscores

Weight=Σ(normalized scores)/no. of criteria

Criteria	*YP*	*FP*	*SW*	*ES*	*EI*	*Weight*
YP	0.136	0.356	0.152	0.083	0.296	0.204
FP	0.034	0.089	0.114	0.124	0.148	0.102
SW	0.407	0.356	0.456	0.496	0.333	0.409
ES	0.407	0.178	0.228	0.248	0.185	0.249
EI	0.017	0.022	0.051	0.050	0.037	0.035
Sum of Normalized scores	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**

Table 4.7 A matrix that shows the normalized scores and the weight

3. *Estimation of the consistency ratio.* In this step we determine if our comparisons are consistent. It involves the following operations: (a) determine the weighted sum vector by multiplying the weight of the first criterion (YP) times the first column of the original pairwise comparison matrix, then multiply the second weight (FP) times the second column of the original matrix, after that multiply the weight of the third criterion (SW) times the third column of the original

matrix, then multiply the weight of the fourth criterion (ES) times the fourth column of the original matrix, after that multiply the weight of the fifth criterion (EI) times the fifth column of the original matrix, finally, sum these values over the rows; and (b) determine the consistency vector by dividing the weighted sum vector by the criterion weights determined previously:

Formula expression for the Weighted Sum Vector is given below:

Weighted sum vector=Σ(weight of the i^{th} criterion)*(original score of the i^{th} column)

The resulting weighted sum vectors are:

YP	***FP***	***SW***	***ES***	***EI***
1.113	0.521	2.245	1.447	0.182

Formula expression for the Consistency Ratio is shown below

$$\textbf{Consistency vector} = \frac{\Sigma(\text{weight of the } i^{th} \text{ criterion*original score of the } i^{th} \text{ column})}{\text{weight of the } i^{th} \text{ criterion}}$$

The resulting Consistency vectors are:

YP	***FP***	***SW***	***ES***	***EI***
5.446543	5.118851	5.484187	5.808716	5.146337

Now that we have calculated the consistency vector, we need to compute values for two more terms, lambda (λ) and the consistency index (CI). The valued for *lambda* is simply the average value if the consistency vector:

$$\lambda = \frac{5.446543+5.118851+5.484187+5.808716+5.146337}{5} = 5.4009269$$

The calculation of RI is based on the observation that (λ) is always greater than or equal to the number of criteria under consideration (n) for positive, reciprocal matrixes, and $\lambda = n$ if the pairwise comparison matrix is a consistent matrix. Accordingly, $\lambda - n$ can be considered as a measure of the degree of inconsistency. This measure can be normalized as follows:

$$CI = \frac{\lambda - n}{n-1} = \frac{5.4009269-5}{5-1} = 0.10023$$

The CI term, referred to as the *consistency index*, provides a measure of departure from consistency. Further, we can calculate the *consistency ratio* (CR), which is defined as follows:

$$CR = \frac{CI}{RI} = \frac{0.1002}{1.12} = 0.08949$$

where RI is the random index, the consistency index of a randomly generated pairwise comparison matrix. It can be shown that RI depends on the number of elements being compared. The consistency ratio (CR) is designed in such a way that if CR < 0.10, the ratio indicates a reasonable level of consistency in the pairwise comparisons; if, however, CR ≥ 0.10, the values of the ratio are indicative of inconsistent judgments. In such cases one should reconsider and revise the original values in the pairwise comparison matrix. Since 0.08949 is less than 0.10, the ratio indicates a reasonable level of consistency in the pairwise comparisons.

Therefore, we can take the calculated criterion weights: 0.204, 0.102, 0.409, and 0.249, 0.035 for the YP, FP, SW, ES and EI criteria respectively.

The pairwise comparison method can be criticized for its mindfulness of responses to the underlying questions (Goodwin and Wright 1998). The questions simply ask for the relative importance of evaluation criteria without reference to the scales on which the criteria are measured. This fuzziness may mean that the questions are interpreted in different, and possibly erroneous, ways by decision makers. One advantage of the paired-comparison method is that only two criteria have to be considered at a time.

The following table shows the Random Inconsistency Indies (RI) for=1, 2, …,15

n	**RI**	***n***	**RI**	***n***	**RI**
1	0.00	6	1.24	11	1.51
2	0.00	7	1.32	12	1.48
3	0.58	8	1.41	13	1.56
4	0.90	9	1.45	14	1.57
5	1.12	10	1.49	15	1.59

Source: Adapted from Saaty (1980)

Table 4.8 Random Inconsistency Indices (RI) (*Source*: Adapted from Saaty (1980)

4.4.3. Reasons to use the Pairwise Comparison Method

Although there are several criteria weighting methods for multicriteria decision analysis, which method to use would depend on te trade-offs one is willing to make between ease of use, accuracy, the degree of understanding on the part of the decision maker, and the theoretical foundation underlying a given method; the availability of computer software; and the way the method can be incorporated into GIS-based multicriteria decision analysis. For example, if the ease-of-use feature and time and cost involved in generating a set of weights are the major concerns, one of the ranking or rating methods should be applied. On the other hand, if the accuracy and theoretical foundations are the main concern, pairwise comparison anis more appropriate. Empirical applications suggest that the pairwise comparison method is one of the most effective techniques for spatial decision-making including GIS-based approaches (Eastman et al. 1993; Malczewski et al. 1997a).

4.5. Overlay Analysis

To get the desired output map (i.e. the ‘HIV/AIDS Susceptibility Map’), the GIS map-overlay facility is applied. There are a number of overlay rules that can be sued for producing an output map from the different factor maps (layers). Additive decision rules are the best known and most widely used overlay methods in GIS-based decision making system (Goodwin and Wright (1998).

4.5.1. Simple Additive Weighting (SAW) Method:

Simple additive weighting (SAW) method is the most often used technique for tackling spatial multiattribute decision-making. The technique is also referred to as *weighted linear combination* (WLC) or *scoring method*. It is based on the concept of a weighted average. The decision maker directly assigns weights of “relative importance” to each attribute. A total score is then obtained for each alternative by multiplying the importance weight assigned for each attribute by the scaled value given to the alternative on that attribute, and summing the products over all attributes. When the overall scores are calculated for all the alternatives, the alternative with the highest overall score is chosen.

The GIS-based SAW method involves the following steps:

1. Define the set of evaluation criteria (map layers) and the set of feasible alternatives.
2. Standardize each criterion map layer.
3. Define the criterion weights; that is, a weight of “relative importance” is directly assigned to each criterion map.
4. Construct the weighted standardized map layers; that is, multiply standardized map layers by the corresponding weights.
5. Generate the overall score for each alternative using the add overlay operation on the weighted standardized map layers.
6. Rank the alternatives according to the overall performance score; the alternative with the highest score (rank) is the best alternative.

The SAW method can be operationalized using any GIS system having overlay capabilities. The overlay techniques allow the evaluation criterion map layers (input maps) to be aggregated to determine the composite map layer (output maps). The method can be implemented in both raster and vector GIS environments (Eastman 1993; Environmental Systems Research Institute 1995).

The following diagram shows the procedures followed to apply the SAW method:

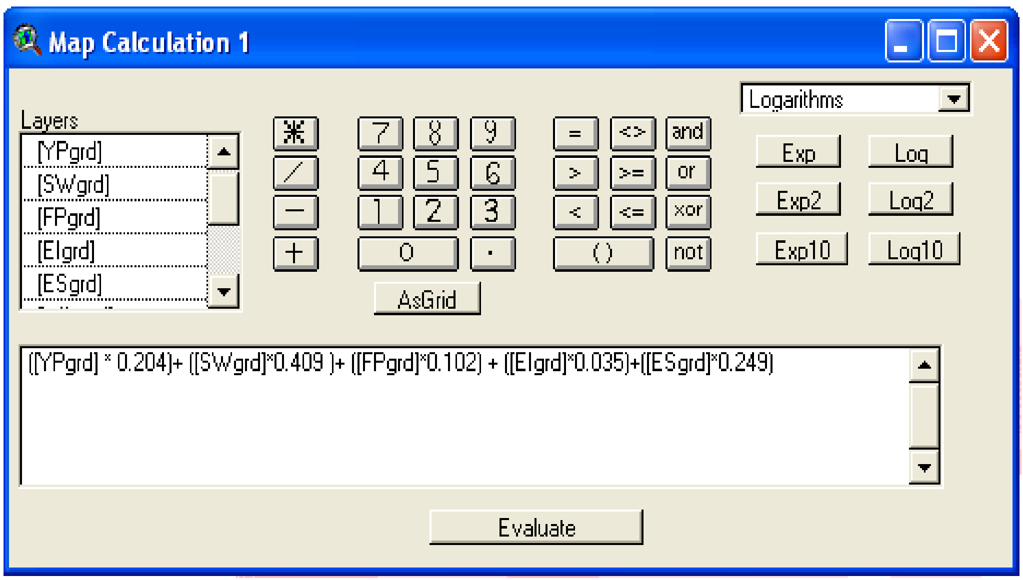


Figure 4.14 Applying the Simple Additive Weighting (SAW) method using ArcView GIS3.2a Software

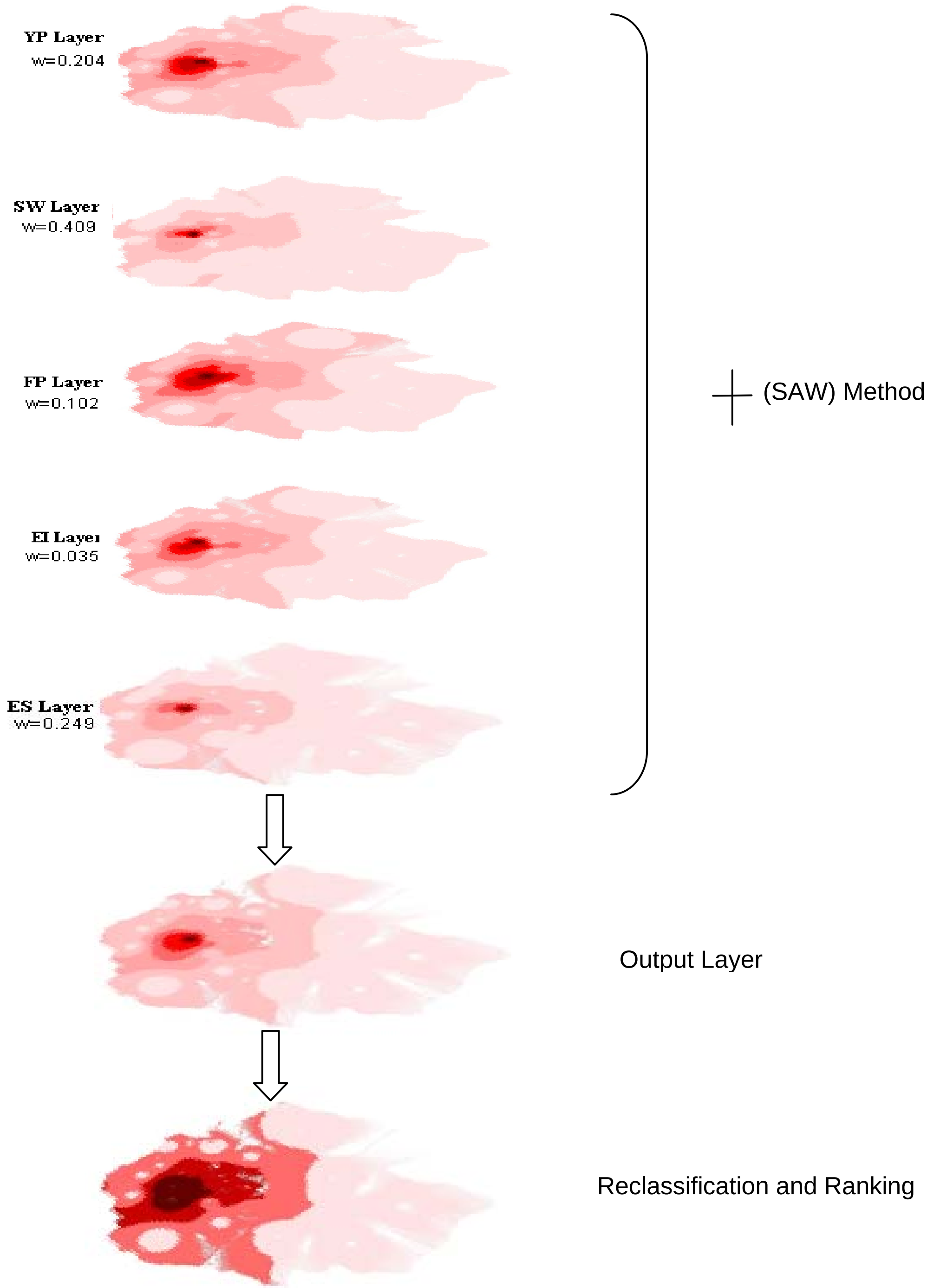
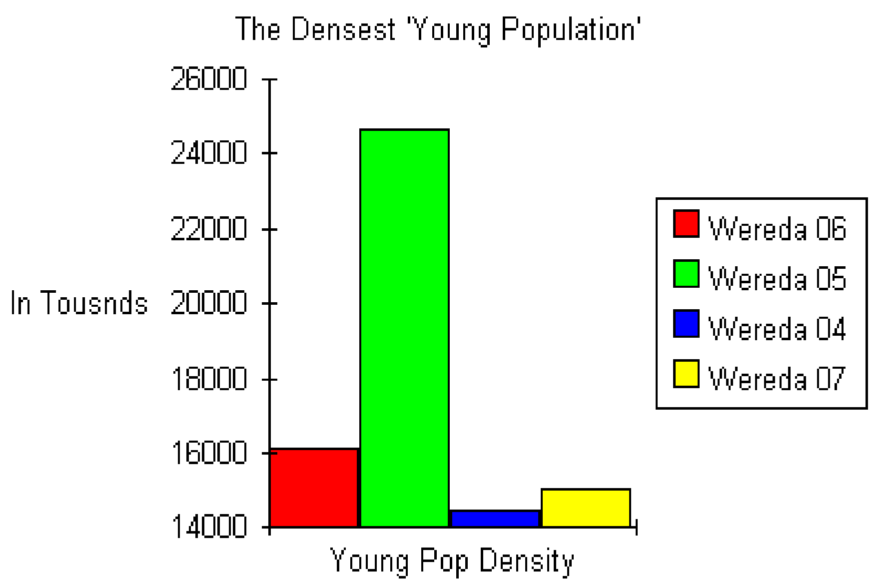


Figure 4.15 Diagrammatic representation of the Simple Additive Weighting (SAW) method

5. RESULTS

5.1. Young Population (YP):

The following Woredas are found to inhabit the densest 'Young Population' in the city:



Wereda	Young Pop Density
Wereda 05	24666.42
Wereda 06	16149.14
Wereda 07	15094.34
Wereda 04	14506.57

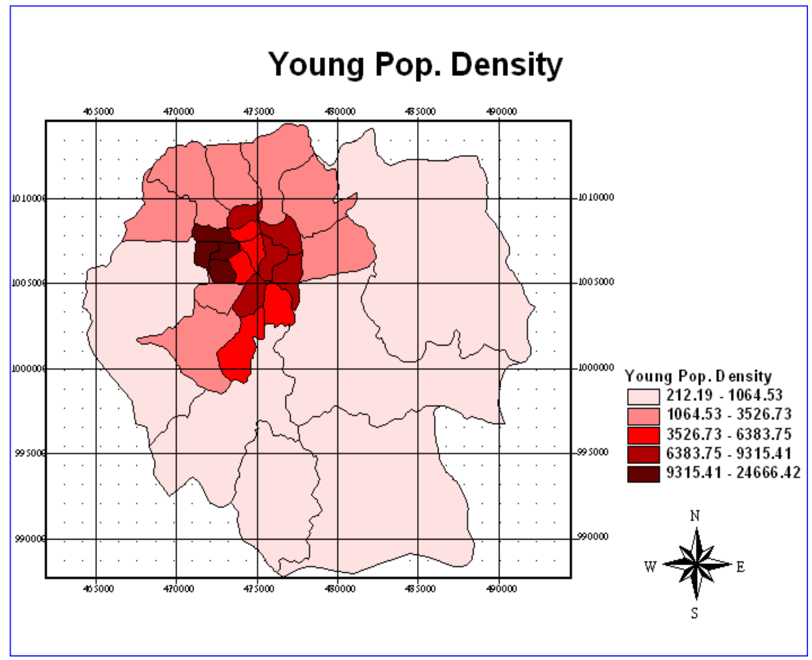
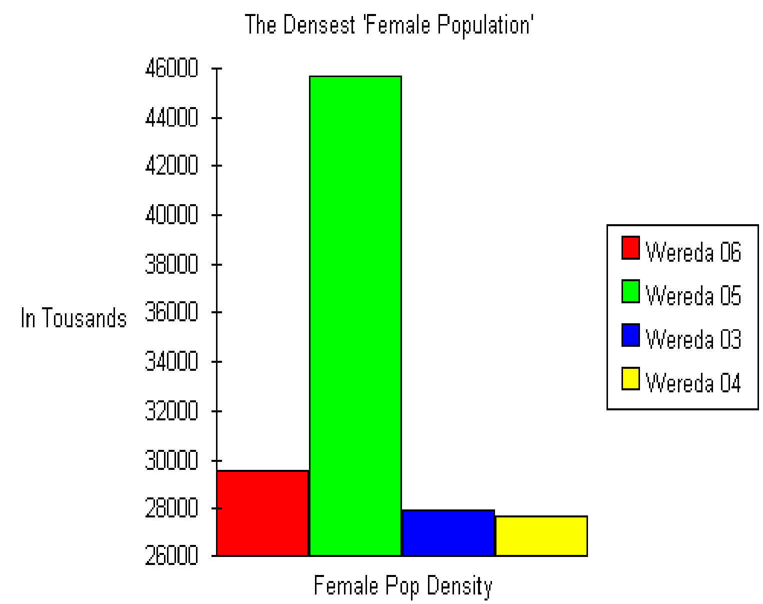


Figure 5.1 Results for high density of young population distribution in Addis Ababa

5.2. Female Population (FP):

The following Woredas are found to inhabit the densest 'Female Population' in the city:



Wereda	Female Pop Density
Wereda 05	45653.73
Wereda 06	29537.71
Wereda 03	27916.97
Wereda 04	27664.65

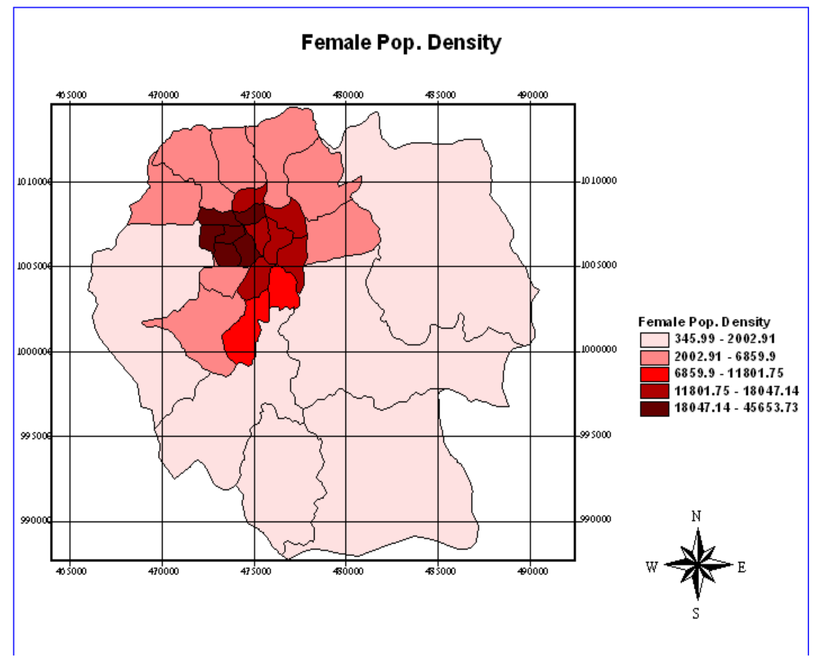
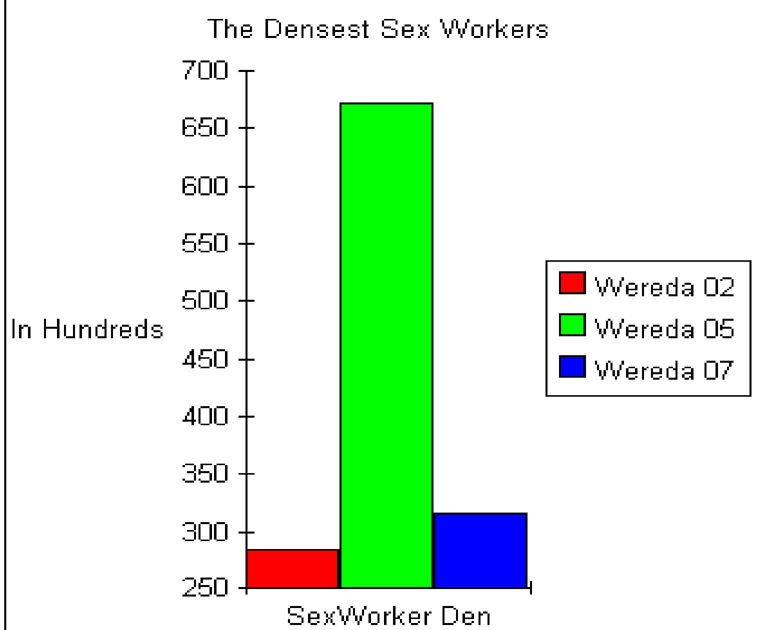


Figure 5.2 Results for high density of female population distribution in Addis Ababa

5.3. Female Sex Workers (SW):

The following Woredas are found to inhabit the densest 'Female Sex Workers Population' in the city:



Wereda	SexWorker Den
Wereda 05	671.64
Wereda 07	316.43
Wereda 02	285.19

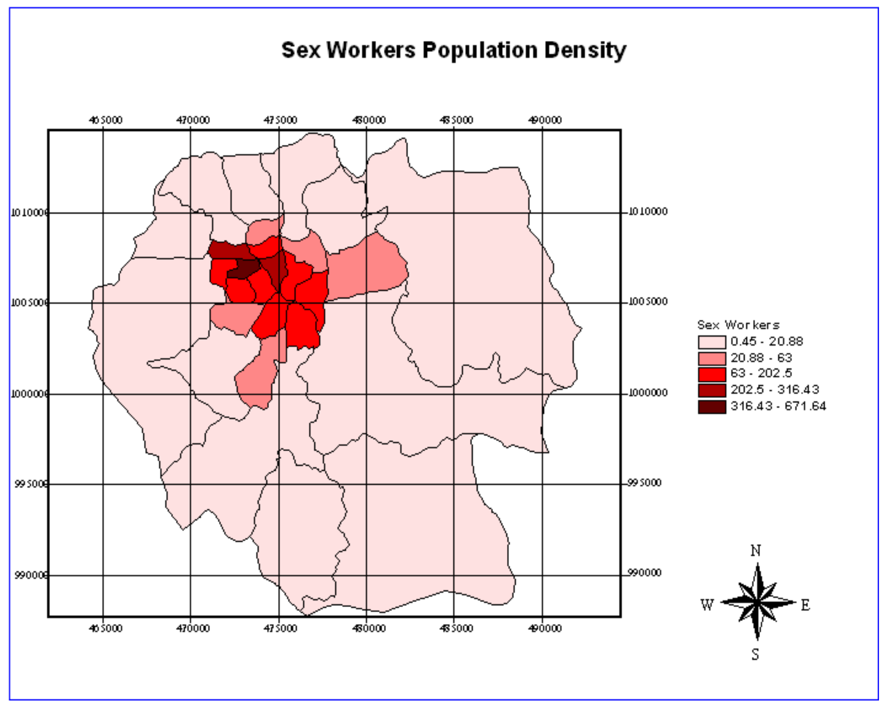
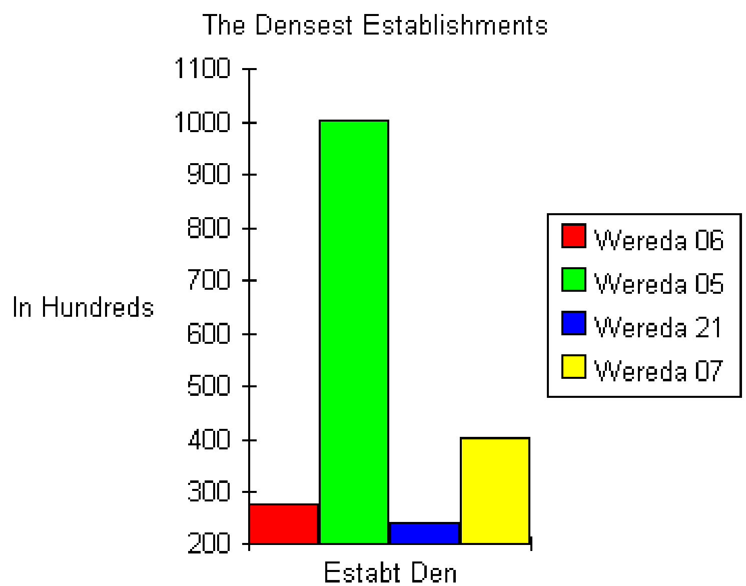


Figure 5.3 Results for high density of female sex workers population distribution in Addis Ababa

5.4. Establishments Density (ES):

The following Woredas are found to inhabit the densest ‘Sex-worker Hiring Establishments or Sex-workers quarters to meet their clients’ in the city:



Wereda	Estabt Den
Wereda 05	1002.99
Wereda 07	405.24
Wereda 06	280.00
Wereda 21	241.86

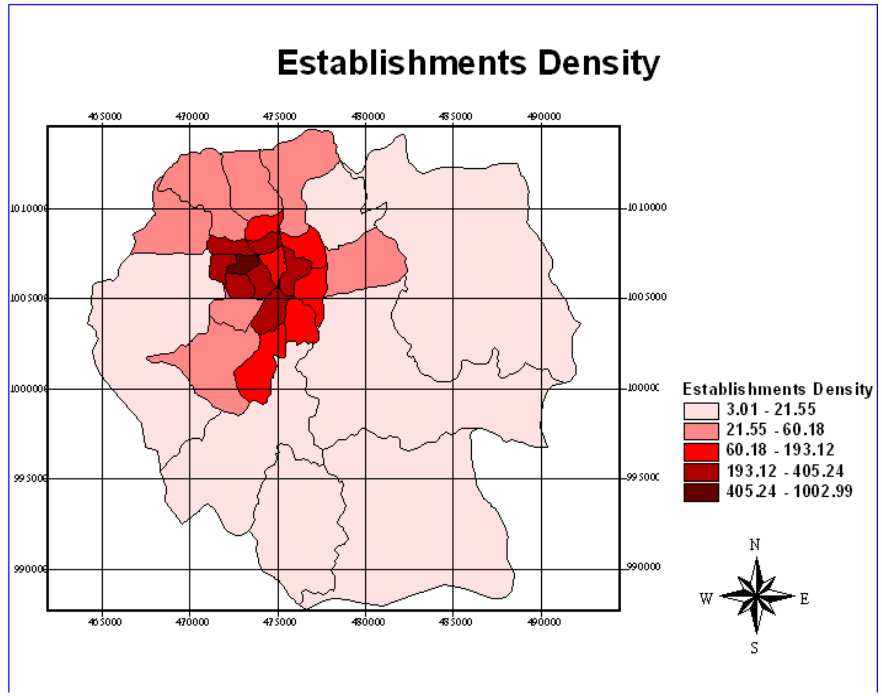
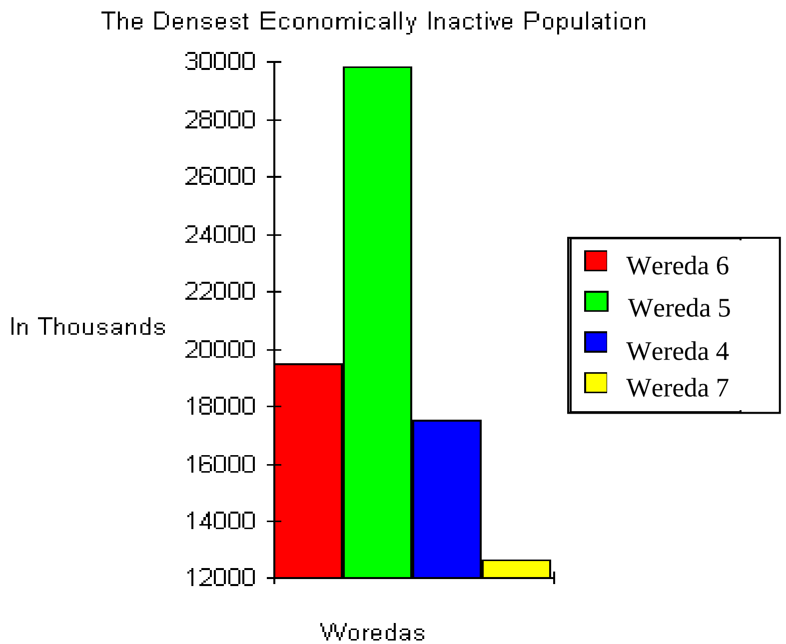
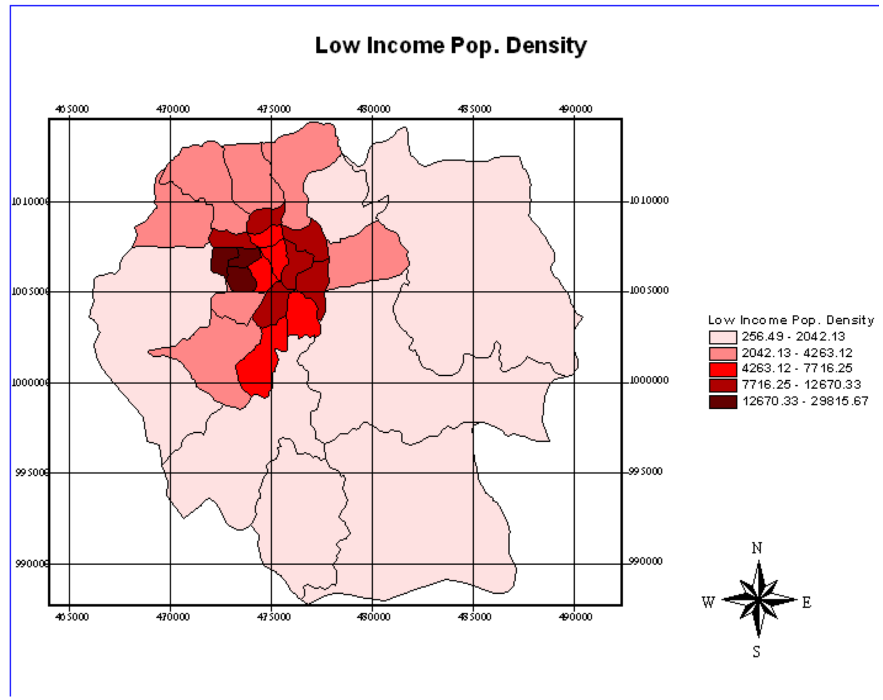


Figure 5.4 Results for high density of establishments incorporating female sex workers distribution in Addis Ababa

5.5. Economically Inactive Population (ES):

The following Woredas are found to inhabit the densest 'Economically Inactive Population' in the city:





Wereda	Eco_Inac Pop
Wereda 05	29815.67
Wereda 06	19520.57
Wereda 04	17534.85
Wereda 07	12670.33

Figure 5.5 Results for high density of economically inactive population distribution in Addis Ababa

5.6. Abundance of the VCT Centers in Each Woreda:

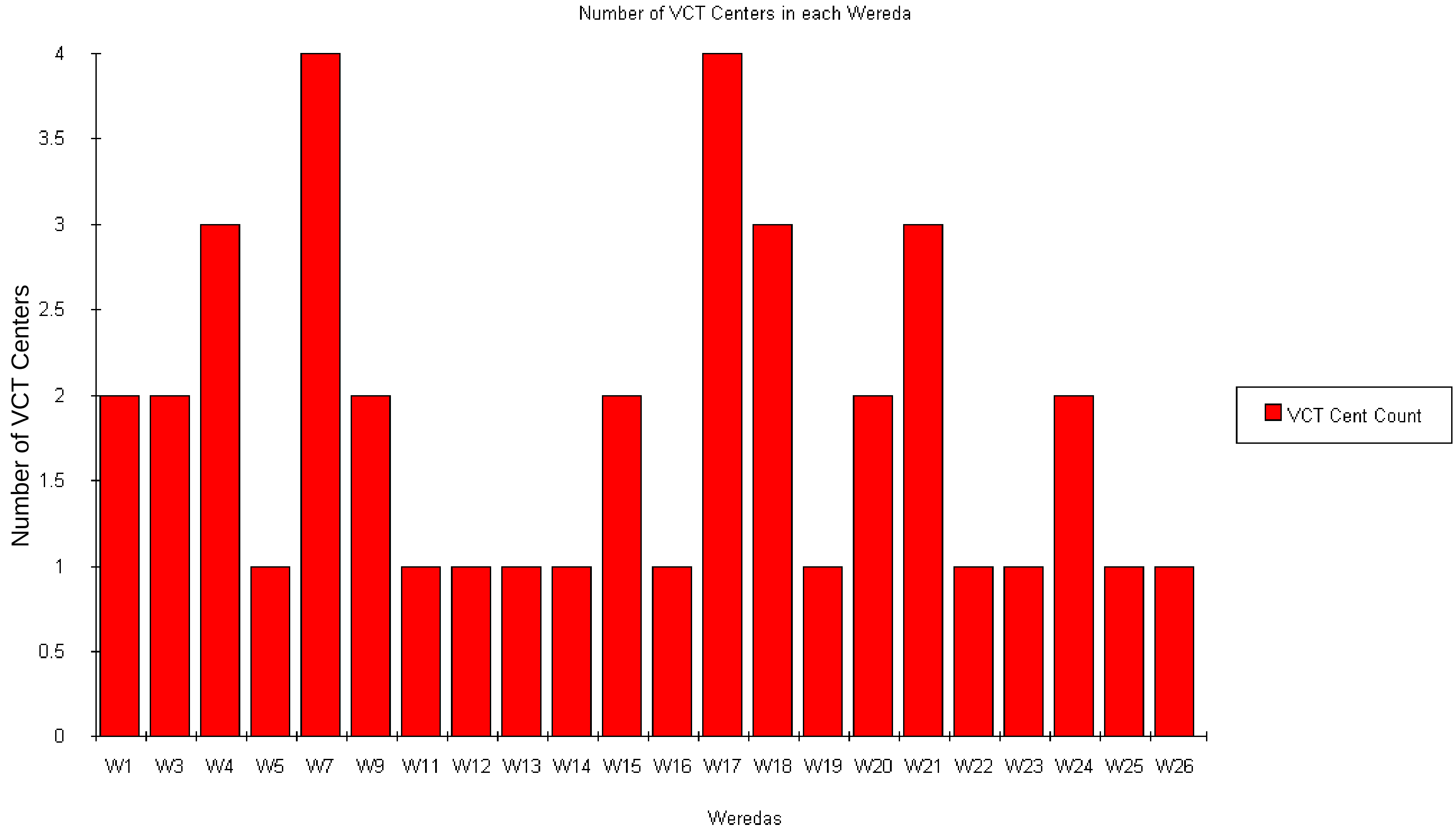


Figure 5.6 Results for number of VCT centers in Addis Ababa

5.7. HIV/AIDS Susceptibility Map of Addis Ababa:

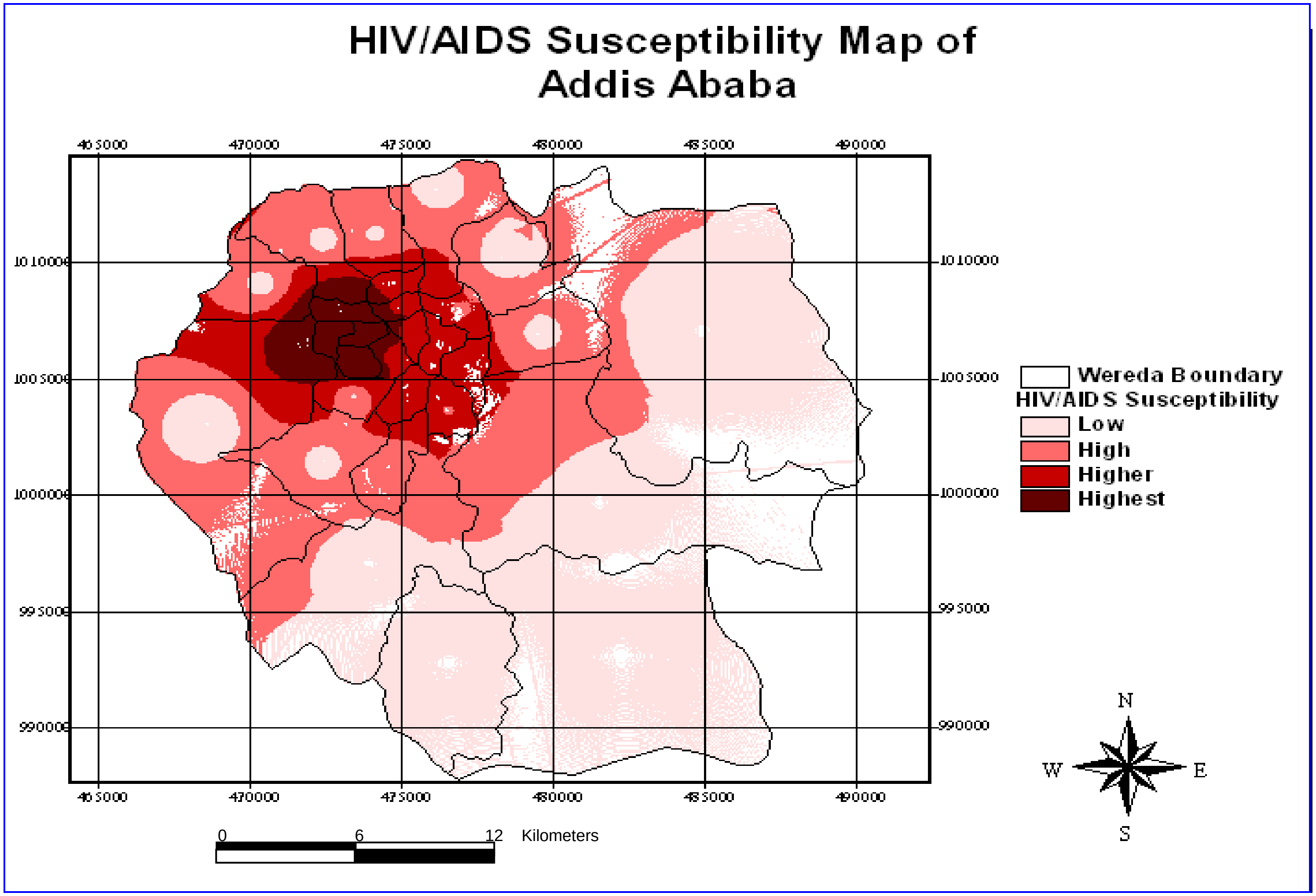


Figure 5.7 HIV/AIDS Susceptibility map of Addis Ababa

5.8. HIV/AIDS Susceptibility Zones and VCT Centers distribution Map of Addis Ababa:

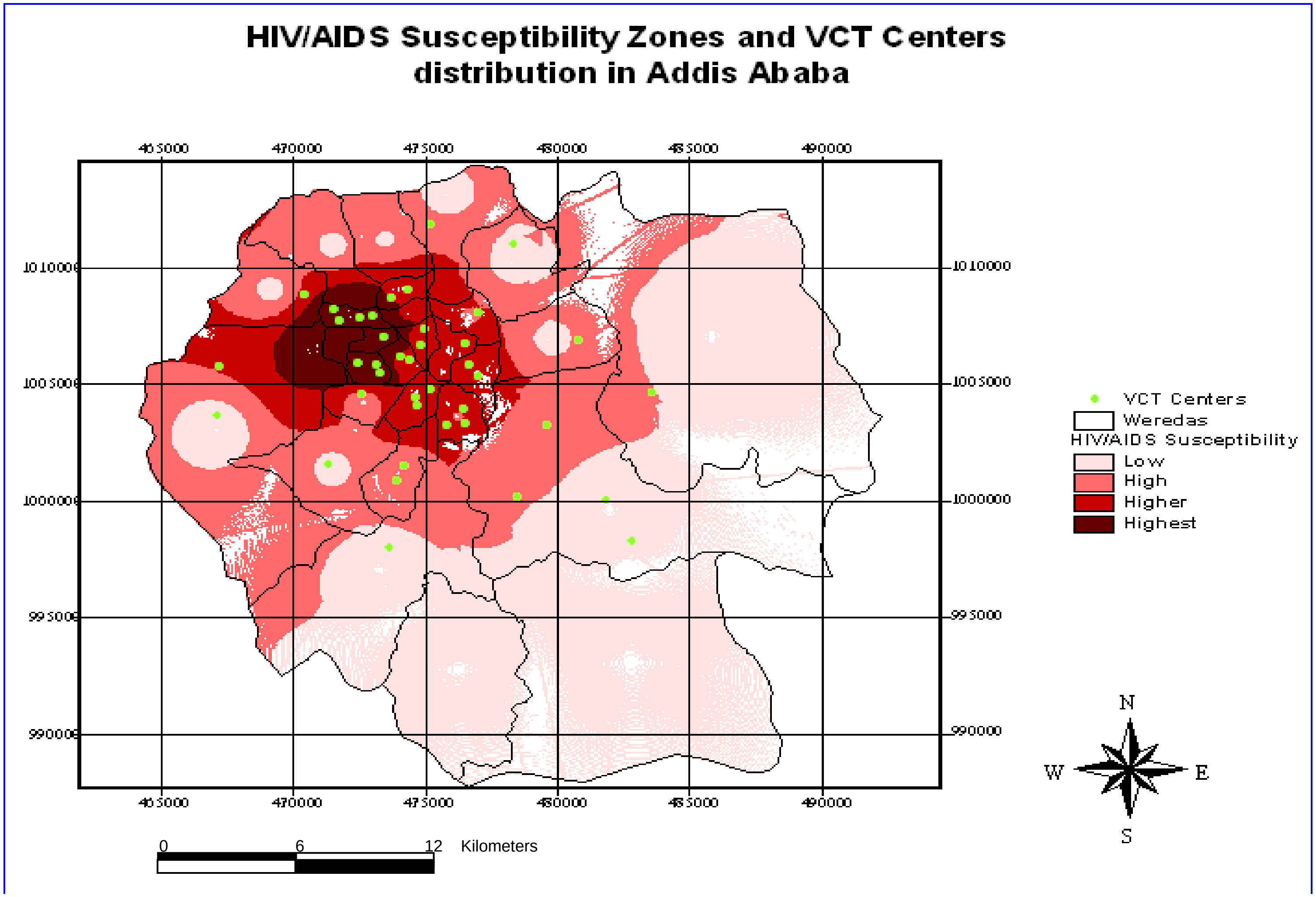


Figure 5.8 HIV/AIDS Susceptibility and VCT Centers distribution in Addis Ababa

6. DISCUSSIONS

Results are discussed by comparing the spatial distributions of those HIV/AIDS spreading factors, such as results on the distribution of ‘Young Population’, the ‘Female Population’, the ‘Sex Workers’, the ‘Establishments’, and the ‘Economically Inactive Populations’. The results from the HIV/AIDS susceptibility map and the abundance and distributions of the VCT centers, which play a significant role in the prevention and control of the epidemic, are also discussed.

6.1. Results from the criterion maps

In this section, the special distributions of the factors that are considered the facilitators to the spread of HIV/AIDS epidemic are discussed.

6.1.1. The ‘Young Population’ Spatial Distribution

Considerably dense ‘Young Populations’ are found in the following four Woredas, appearing in order of density, (i.e. Woreda 5,Woreda 6, Woreda 7, and Woreda 4). Woreda 5 is found to be the densest ‘Young’ populated area of all.

Concerning the geographical locations, these Woredas are found adjacent to each other. So different Anti-HIV activities that target the ‘Youth’ could be planned and implemented in these areas.

6.1.2. The ‘Female Population’ Spatial Distribution

Significantly crowded ‘Female Populations’ are found in the four Woredas, (i.e. Woreda 5, Woreda 6, Woreda 3, and Woreda 4). Particularly Woreda 5 is the densest populated area by the ‘Female People’.

In these Woredas, HIV/AIDS prevention and control programs that target the female could be effective. In a similar case as that of the ‘Young Population’ distribution, these Woredas are geographically adjacent to each other. Hence it is wise and cost-effective to establish health care centers that provide services related to HIV/AIDS prevention and control activities at the geographic center of these four Woredas so that it helps the wise resource allocation to the implementation of HIV/AIDS Prevention, Care & Support strategies.

6.1.3. The ‘Sex Workers Population’ Spatial Distribution

Woreda 5, Woreda 7, and Woreda 2 respectively are found to inhabit relatively dense commercial sex workers. Another research by CARE/WFP (Urban Livelihoods Assessment, in 2002 showed that the high concentration of these commercial sex workers is attributed to the high concentration of commercial areas in these Woredas. Woreda 5 has the highest concentration of these ‘sex workers’.

So it would be much effective, if a project on HIV/AIDS prevention and control activities, which is focused on these ‘Sex Workers’ is to be designed and implemented specifically on these Woredas.

6.1.4. The ‘Establishments’ Spatial Distribution

Concerning the ‘Establishments’, the result showed that Woreda 5 has the densest ‘Establishment’ concentrations, which are serving as quarters to the female sex workers to meet their sex clients. Other Woredas like Woreda 7, Woreda 6 and Woreda 21 are also host high concentration of these establishments, which are to be mentioned next to Woreda 5.

An integrated HIV/AIDS prevention and control activities, which incorporate establishment owners should be designed and implemented especially in these Woredas.

6.1.5. The ‘Low Income Population’ Spatial Distribution

Compared to all other Woredas, Woreda 5 has found to host the densest ‘Economically Inactive’ population in the city. Next to Woreda 5, the other Woredas like Woreda 6, Woreda 4 and Woreda 7 respectively host the high density of ‘Economically Inactive’ population in the city.

It would be practical to establish institutions that provide HIV related health care services for a minimum charge or for free.

6.2. Results from the HIV/AIDS Susceptibility Map

The HIV/AIDS susceptibility map of Addis Ababa, which is developed by integrating the GIS techniques and Multicriteria Decision Support System, has four major HIV/AIDS susceptibility zones. These susceptibility zones are ranked in relative terms as: the ‘Highest’, the ‘Higher’ the ‘High’, and the ‘Low’ susceptible zones to HIV/AIDS risk.

Out of the 28 Woredas in the city, four Woredas are completely found in the ‘Highest Susceptible’ zone and seven Woredas are partially found in the ‘Highest Susceptible’ zone. The area covered by the ‘Highest Susceptible’ zone is about 4% of the total area of the city. This zone includes in particular Woreda 7, Woreda 6, Woreda 5, and Woreda 4. The area percentage that is found in the ‘Higher Susceptible’ zone is about 11% of the total area of the city. 34% and 51% of the total area of the capital is found in the ‘High’ and ‘Low Susceptible’ zones respectively. We can learn from the Susceptibility map that the majority of Addis Ababa is found in the ‘Low’ susceptible zone. Generally, the central northwest part of the city is found under the ‘Highest’ and ‘Higher’ HIV/AIDS susceptible zones, whereas the eastern and southern parts of the town are found in the ‘Low Susceptible’ zone.

6.3. VCT Centers Distribution

When we look at the spatial distribution of the existing VCT centers in the city, comparatively the highest numbers of the VCT centers are found in Woreda 7 and Woreda 17 areas of the city. But Woreda 17 is out of the ‘Highest’ susceptible zone. These Woredas have four VCT centers each. The next high numbers of VCT centers are found in the Woreda 4, Woreda 18, and Woreda 24 areas. There are 8 VCT centers in the ‘Highest Susceptibility’ zone, which has the smallest area coverage. 17 CVT centers are found in the ‘Higher Susceptibility’ zone, which has a bit larger area coverage than the ‘Highest Susceptible’ zone. The rest of the VCT centers (i.e. 12 out of the 37 VCT centers) are found in the ‘High’ and ‘Low’ susceptibility zones. Generally high concentrations of VCT centers are found in the ‘Highest’ and ‘Higher Susceptible’ zones. This shows that the current geographical distribution of the VCT centers is fair.

6.4. Limitation to the study

- The ‘Economically Inactive populations’ factor map was basically derived form the secondary data collected form the CSA, which is reported by the 1994 census, and it was not updated since then, so there were doubts if the data represent the actual situation at preset.
- The addresses of some of the clients at the VCT Centers are probably wrong. This is due to the fact that some clients have doubts that their identity is going to be exposed. This probably caused a biased figure on the number of clients from each Woreda, which ultimately affected accuracy of the map that shows the spatial distributions of the existing HIV positive population density.
- Since the mobile nature of the street based sex workers, it was difficult to map them geographically specific to some place, despite the fact that these street based sex workers are categorized under the highly vulnerable group of the society.

7. Conclusions and recommendations

7.1. Conclusions

- About 4% of the total area of the city is found in the ‘Highest Susceptible’ zone. This zone includes in particular Woreda 7, Woreda 6, Woreda 5, and Woreda 4 areas of the city. About 11%, 34% and 51% of the areas of the Addis Ababa city are found in the ‘Higher’, ‘High’ and ‘Low’ susceptible zones respectively.

- Woreda 5 is the most sensitive area where all the five HIV/AIDS spreading factors are comparatively at high concentrations.

- The spatial distributions of the existing VCT centers are more in the ‘Highest’ and ‘Higher’ HIV/AIDS susceptibility zones. This showed that the locations of the existing VCT centers are good.

- The GIS technique applied in this study was of great help to understand the degree of correlation of the highest ‘HIV/AIDS’ susceptible zones and the spatial distribution of the existing VCT centers. The GIS technique was also played an important role to identify ideal places to establish new VCT centers.

7.2. Recommendations

7.2.1. Policy and advocacy level

- Sustained political commitment and involvement of leaders is needed at all Woredas of the city, especially at Woredas that are found in the ‘Highest’ susceptible zone, to support the vulnerable group.
- Governmental, non-governmental and other bilateral organizations need to promote the establishment and running of recreational facilities and libraries, land focus on the provision of employment opportunities for the youth.

- The media has to continue its efforts: to address the vulnerable group; and the general population to build comprehensive knowledge on HIV/AIDS.
- Decision makers at higher government levels should pay special attention to some of the Woredas that are found in the 'Highest' vulnerable areas to HIV/AIDS.
- Parents, religious organizations, governmental and non-governmental organizations need to be mobilized to influence public opinion on HIV/AIDS and related high-risk behaviors.
- Comprehensive HIV/AIDS prevention and control interventions and job creation should be targeted at youth (15-25 years old), particularly the females.

7.2.2. Program level

- This research considered only some factors such as females, the youth, the sex workers, the establishments that incorporate sex workers and the economically inactive population of the society. But it would have been better if we consider much more factors that could be the ultimate causes of high HIV risk behavior including 'Drug Use', 'Educational Level', 'Schools Distribution' etc to derive the 'HIV/AIDS Susceptibility' map, But this takes more time and resource, and in the future it is important to do a better research using GIS as a data processing and analysis tool by the different organizations that work in the areas of HIV/AIDS prevention and control.
- Increased awareness and expansion of VCT services are required to promote and sustain behavioral change. The VCT services should be more accessible and affordable to the community.
- HIV/AIDS intervention programs should extend to the different vulnerable groups and special strategies should be designed to each group.
- Increased involvement of female sex workers is needed to address their needs in intervention activities; this may be accomplished through expansion of female sex workers forums and provision of vocational training.
- Emphasis should be given to discouraging drug and alcohol use amongst the youth. Some of the intervention activities could be conducted in schools by integration with

the activities of school clubs. If appropriate measures are not taken at this stage, drug and alcohol use may lead to serious problems.

- Promotion of abstinence and decreasing the magnitude of premarital sex amongst the youth should be given priority. In addition, promotion of other preventive methods should be targeted and individualized. Promotion of condoms should continue for all sexually active individuals.
- Negotiation skills should always be a priority in training. In particular females should be encouraged to demand condom use and should be protected against violence.
- Establishment of programs promoting the use of condoms, particularly programs targeting female se workers, should be a high priority. Governmental and non-governmental institutions operating in the target Woreda could organize these programs; moreover, health workers, volunteers and peer groups could facilitate implementation of the programs.
- Programs designed to control HIV/AIDS transmission should aim to bring about behavioral change and focus on the promotion of safer sex.
- Control programs for sexually transmitted infections (STIs) that are provided by health institutions need to be strengthened to include youth friendly services, early diagnosis and treatment.
- An enabling environment or environmental intervention (e.g. control of illegal video showing housed and nightclubs) is required.

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