UNIVERSITY OF NAIROBI

USE OF GIS IN MAPPING OF CANCER PREVALENCE

A CASE STUDY OF UASIN GISHU COUNTY

By

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F19/2469/2009

A project report submitted to the Department of Geospatial and Space Technology in partial fulfillment of the requirements for the award of the degree of:

Bachelor of Science in Geospatial and Space Technology

APRIL 2014

Abstract

Events that occur anywhere are associated with location and time thus spatial and temporal components of these events can be combined to demonstrate aspects related to when and where these events occurred. Cancer is also an event associated with space and time therefore analysis can be done on cancer data to determine its spread, patterns and trends to come up with ways to halt its spread. GIS has been used in this project in management, analysis and displaying of the cancer data. GIS provides an efficient means of analyzing and visualizing cancer data thus depicting trends and patterns of the spread of cancer in space and time.

To determine the spatial and temporal prevalence of cancer, a GIS cancer database was developed using cancer data from the six constituencies of Uasin Gishu County. The data was recorded from the year 2004 to 2012 by the Eldoret Cancer Registry and contained specific data for gender and status (alive or deceased). Different maps and graphs were produced as a means to visualize and evaluate the extent at which cancer has spread in Uasin Gishu County.

Dedication

I dedicate this project to my grandmother Wanja and my dad Kirumba.

Acknowledgements

First, I'm grateful to the almighty God for seeing me through the project and everyday spiritual and mental support.

Secondly, I'm grateful to my supervisor Dr-Ing. F.N Karanja for her support and assistance throughout the project.

Thirdly, i appreciate Daisy Chepsumbai of Eldoret Cancer Registry for assisting me with cancer data that was used in this project.

I also appreciate the assistance of all the members of staff, Department of Geospatial and Space Technology and their everyday support throughout the five years I've been in campus.

Finally, I'm grateful to all my friends and classmates for their support, assistance and motivation.

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List of abbreviations

CT – Computer Tomography

DCR - Department of Civil Registration

DNA – Deoxyribonucleic acid

ECR – Eldoret Cancer Registry

GIS – Geographic Information System

HIV – Human Immunodeficiency Syndrome

HPV - Human Papilloma Virus

ILRI – International Livestock Research Institute

KEMRI – Kenya Medical Research Institute

LMICs - low and middle income countries

MRI - magnetic resonance imaging

NCI - National Cancer Institute

NCR - Nairobi Cancer Registry

TB - Tuberculosis

WRI - World Research Institute

CHAPTER ONE: INTRODUCTION

1.1 Background

Cancer is a broad group of diseases involving unregulated cell growth. In cancer, cells divide and grow uncontrollably, forming malignant tumors, which may invade nearby parts of the body (though, not all tumors are cancerous). The cancer may also spread to more distant parts of the body through the lymphatic system or bloodstream. There are over 200 different known cancers that affect humans but certain types are more life-threatening than others. (Holland, James F. (2009)

The causes of cancer are diverse, complex, and only partially understood. What is known is that there are many things that increase the risk of cancer which include; exposure to radiation, environmental pollutants, dietary factors, use of tobacco, certain infections, lack of physical exercise and obesity. Some of these factors can directly damage genes or combine with existing genetic faults within cells to cause cancerous mutations. However, a small percentage of cancer cases can be traced directly to inherited genetic defects. These defects predispose the hosts to cancerous infections even without having interacted with the other cancer causative agents.

Cancer cells are very similar to cells of the organism from which they originated and have similar DNA; though not identical. This is why they are not often detected by the immune system especially if weakened (Marek Roland, 2006). Cancer cells usually have an increased ability to divide rapidly and uncontrollably leading to the formation of large masses of tissue which may result to disruption of bodily functions due to destruction of organs or vital structures. Cancer begins in the genes - bits of biochemical instructions composed of deoxyribonucleic acid (DNA). Genes act as instructions to make molecules called proteins that serve as building blocks of cells, control chemical reactions and transport materials to and from cells. These proteins determine the function of each cell and ultimately the function of the entire body. A modification or mutation of the DNA results to formation of cancer cells. These mutations occur spontaneously or they may be caused by viruses, bacteria, fungi, parasites, nuclear and electromagnetic radiations, heat, chemicals in the air, water and food, mechanical cell injury, evolution and aging of DNA.

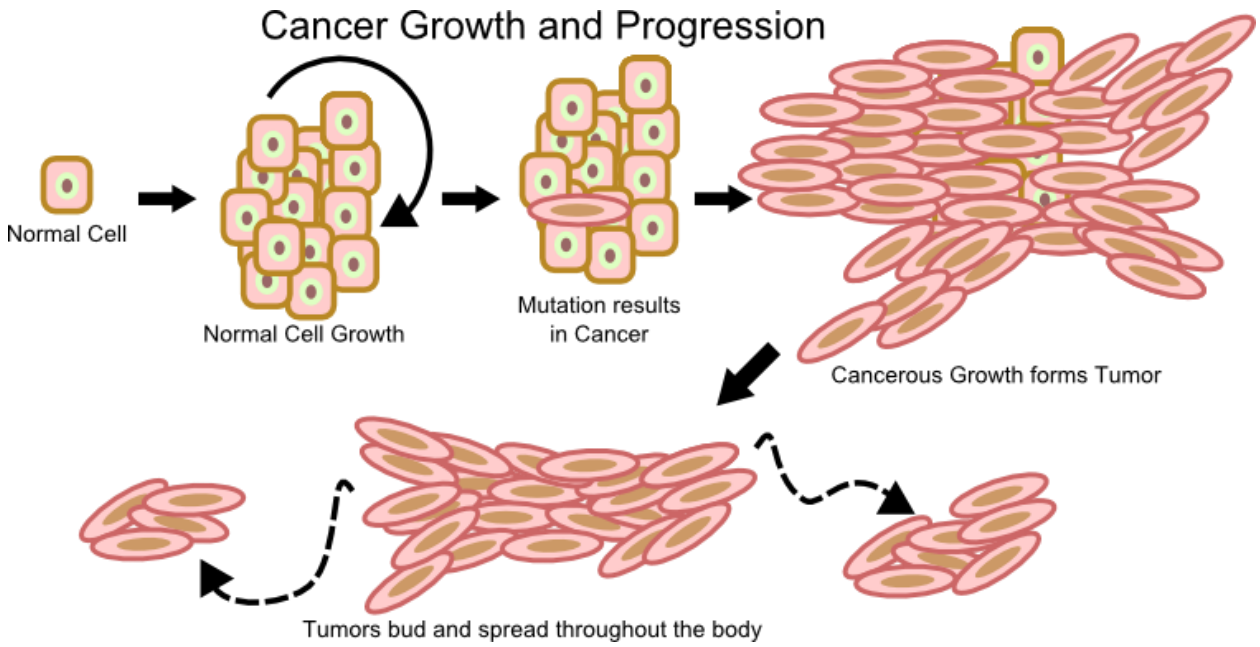

Fig 1.1 Growth and spread of cancer (University of North Carolina, 2012)

Cancer cells are formed continuously in the body (it is estimated that there are about 10,000 cancer cells at any given time in a healthy person). However those with the potential to form cancer are effectively destroyed by the immune system, but if the immune system is weak or the amount of cells produced is too much for the immune system to eliminate, this results to development of cancer. The cancerous growth forms tumor which later bud and spread throughout the body. Not all tumors are malignant, some do not extend into neighboring tissue, however the malignant tumors extend to neighboring tissue and break through a blood vessel and travel distant organs through the circulatory system or the lymphatic system.

Cancer develops across all ages, gender, geographic regions and races. However the trend is different for specific cancer types such as breast cancer which is more common in wealthy nations, whereas cervical cancer is common in poor countries. While cancer affects people of all ages, a few types of cancer are common in children but the risk of developing cancer generally increases with age. Though the causes of cancer are not known, researchers believe that many cancers can be prevented by not smoking, eating more vegetables, fruits and whole grains, eating less meat and refined carbohydrates,

maintaining a healthy weight, exercising, minimizing sunlight exposure and being vaccinated against infectious diseases. With a positive change of lifestyle and healthy environment, the growth of cancerous cells can be reversed in majority of cases (probably in 90% - 95%) and shrink and eventually disappear. (Marek Roland, 2006)

1.2 Problem Statement

Cancer has recently become one of the main killer diseases in Kenya. There are more cancer cases being reported today than 10 years ago and cancer is now the fourth highest killer disease in the country. In 2011, statistics from the Department of Civil Registration (DCR) showed that the disease claimed 11,907 lives amounting to 10.3 percent of the total deaths recorded in that year alone. Medical experts claim that the number of cancer patients could increase, noting that cancer-related complications claim up to 50 lives daily.

Cancer develops gradually over many years and if not detected early enough, it becomes difficult to treat. Most of the reported cancers are detected at late stages when the cancer has spread to other vital organs, a point at which little can be done for the patient. Moreover there is a shortage of health centers and personnel to handle the disease.

More effort has been put into improving detection mechanisms thus the increase in cases being recorded but little is done on cancer prevalence (Daily Nation, 2014). Cancer prevalence studies require detailed data from all over the country about the cancer types, age, gender, location and status of health facilities dedicated to cancer cases. Kenya is lagging behind in this situation as there are only two cancer registries in the country; Nairobi Cancer Registry (NCR) and Eldoret Cancer Registry (ECR). This has grossly hindered the cancer prevalence studies.

Prevention is better than cure thus the need to map the spread and correlate it with the possible causes so as to prevent new cases and device methods to deal with existing cases. The spatial distribution of cancer cases in Kenya varies erratically in relation to ethnicity, gender, age and environmental factors. The distribution also varies in time with most regions indicating an increase in number of detections recorded. However these

findings have resulted from very few and inadequate studies and this calls for better studies to give an indication of the cancer prevalence in all aspects; spatial and temporal. Geographical Information System offers the opportunity to do so by use of interactive maps which when combined with the cancer records, patterns and trends can be generated to show the prevalence of cancer.

In this project, Uasin Gishu County is the case study which will be used to show the prevalence of cancer with data (obtained from the Eldoret Cancer Registry) applied in GIS.

1.3 Objectives of the Study

Main objective: to show the spatial variation of cancer incidence and mortality using Uasin Gishu County as a case study. (Units of analysis are constituencies)

Specific objectives

1. Identify suitable data for cancer prevalence
2. Develop spatial cancer database
3. Apply the spatial cancer database to come up with useful information for counteracting the spread of cancer.

1.4 Overview of the Methodology

Digital maps of Uasin Gishu County and its six constituencies were obtained (shape files). Cancer data in tabular form were joined to the attribute tables for the maps to create a cancer database. The database together with the shape files are subjected to processing which results to thematic maps which finally depicted the cancer prevalence.

1.5 Scope and Limitations of the Study

The project is focused on the study of cancer prevalence using attribute data for cancer cases recorded. The case study for the project is Uasin Gishu County where the Eldoret Cancer Registry (ECR) is located. This area is suitable due to the increased cases of cancer recorded there. The data used in this project has been collected from the year 2004 to 2012 by the ECR

1.6 Report Organization

The report is organized into five chapters: chapter one is the introduction to the study, chapter two focusses on the literature review, chapter three discusses the methodology applied, chapter four presents the results, analysis and discussions and finally chapter five addresses the conclusions and recommendations.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

Any disease adversely affects the society directly or indirectly. The patient and immediate family are affected directly and the society at large is affected indirectly especially in economic matters. All disease result to loss of income for the government and the individual in attempts to eradicate the illness. Cancer specifically is very expensive to deal with starting from diagnosis up to treatment.

Moreover, poor health results to reduced work force which eventually affects the economy

2.2 Global Cancer Situation

Cancer is the leading cause of death worldwide. According to the World Health Organization, the disease accounted for 7.9 million deaths (about 13% of all deaths worldwide) in 2009. More than 70% of all cancer deaths occur in low- and middle-income countries. The overall burden of cancer in the world is projected to continue rising, particularly in developing countries. It is projected that an estimated 15.5 million people will be diagnosed, and 12 million will die of cancer in the year 2030. The annual mortality attributed to main types of cancer includes: lung cancer (1.3 million deaths), stomach cancer (803 000 deaths), colorectal cancer (639 000 deaths), liver cancer (610 000 deaths) breast cancer (519 000 deaths) cervical cancer (450,000) and oesophageal cancer (380,000). The most frequent types of cancer among men affect the lung, stomach, liver, colorectal, oesophagus and prostate. Among women the most common areas affected are breast, lung, stomach, colorectal and cervix.

The increased cases in developing countries result from adoption of western lifestyles which include; high-fat and low-fibre diets, increased consumption of tobacco and less physical activities. In many of these countries the silence that accompanies the disease is often the result of a complete lack of meaningful information for those affected by cancer—the disease may go undetected and untreated until it leads to death. Even then,

the cause of death may remain undiagnosed. In other places, the situation is worsened by medical practitioners who make wrong diagnosis which leads to treating of the wrong illness instead of cancer. This reveals that cancer is a hidden epidemic. (National Cancer Control Strategy, 2011)

Also in the developing world, most cancer cases are detected at advanced stages when very little can be done to successfully eliminate the disease and most times very expensive.

2.3 Kenyan Cancer Situation

In Kenya, cancer ranks third as a cause of death after infectious diseases and cardiovascular diseases. It causes 7% of total national mortality every year. Although population based data does not exist in the country, it is estimated that the annual incidence of cancer is about 28,000 cases and the annual mortality to be over 22,000. Over 60% of those affected are below the age of 70 years. In Kenya, the risk of getting cancer before the age of 75 years is 14% while the risk of dying of cancer is estimated at 12%. In many developing countries the rapid rise in cancers and other non-communicable diseases has resulted from increased exposure to risk factors which include tobacco use, harmful use of alcohol and exposure to environmental carcinogens. Other risk factors for some cancers include infectious diseases such as HIV/AIDS (Kaposi's sarcoma and lymphomas), Human Papilloma Virus (HPV), Hepatitis B & C (Liver cancer), bacterial infections such as Helicobacter Pylori (cancer of stomach) and parasitic infestations such as schistosomiasis (cancer of bladder)

The leading cancers in women are breast, oesophagus and cervical cancers. In men, oesophagus and prostate cancer and Kaposi sarcoma are the most common cancers. Based on 2002 data from the Nairobi Cancer Registry, of all the cancers registered breast cancer accounted for 23.3%, cervical cancer for 20% and prostate cancer for 9.4%. In 2006, around 2,354 women were diagnosed with cervical cancer and 65% of these died of the disease. (National Cancer Control Strategy, 2011)

2.4 Cancer Statistics (estimated)

- Globally, Cancer causes more deaths than HIV, TB and Malaria combined
- New cases of cancer will rise by half by 2030, reaching 21.6 million per year compared to 14 million in 2012 (the UN)
- Cancer deaths will likely rise from 8.2 million to 13 million per year as the world's population grows and ages and more people adopt risky lifestyle habits (report compiled by the International Agency for Research on Cancer (IARC)
- 70% of the global Cancer burden is in LMICs (low and middle income countries) like Kenya
- Cancer is the 3rd highest cause of morbidity in Kenya [7% of deaths per year], after infectious diseases and cardiovascular diseases
- Difficult to get accurate national data because most data is coming from Nairobi and other urbanized settings.
- Estimate 28,000 new cases of Cancer each year in Kenya with more than 20,000 deaths per year
- 60% of Kenyans affected by Cancer are younger than 70 years old
- Leading Cancers:
    - Women: Breast (34 per 100,000), Cervical (25 per 100,000)
    - Men: Prostate (17 per 100,000), Esophageal (9 per 100,000)
- 70-80% of cancer cases are diagnosed in late stages
- Number of radiation machines in the country: 4 (all in Nairobi)
- Number of treatment facilities: 4 (2 main, 2 limited)
- Number of oncologists in Kenya: under 10 (recommended figure is 300 oncologists per population of 100,000)

Childhood Cancer in Kenya (data from Feb 2013 presentation by Dr. Jessie Githanga, pediatric oncologist at Kenyatta National Hospital)

- Childhood cancer accounted for 15% of cancer admissions at KNH [1998-2008]
- 1 in 10 children survive cancer in Kenya [compared to 7 in 10 in the developed countries]
- Challenges in childhood cancer care: poor access to care for patients in remote/rural areas; limited specialist treatment centers; prohibitive cost of anti-cancer drugs; low levels of awareness in clinicians and public;
- Possible signs of childhood cancer: lumps/swellings; unexplained weakness or paleness; easy bruising/nose or gum bleeding; persistent unexplained fever/illness; constant pain; frequent headaches, often with vomiting; sudden eye or vision changes; sudden unexplained weight loss; limping/inability to walk properly (Kenya Network of Cancer Organizations, 2012)

2.5 Definition of cancer

Cancer is a term used for diseases in which abnormal cells divide without control and are able to invade other tissues. Cancer is not just one disease but many diseases. There are more than 100 different types of cancer. Most cancers are named for the organ or type of cell in which they start - for example, cancer that begins in the colon is called colon cancer. All cancers begin in cells, the body's unit of life. The body is made up of many types of cells. These cells grow and divide in a controlled way to produce more cells as they are needed to keep the body healthy. When cells become old or damaged, they die and are replaced with new cells. However, sometimes this orderly process goes wrong. The genetic material (DNA) of a cell can become damaged or changed, producing mutations that affect normal cell growth and division. When this happens, cells do not die when they should and new cells form when the body does not need them. The extra cells may form a mass of tissue called a tumor.

Not all tumors are cancerous; tumors can be benign or malignant. (National Cancer Institute, 2013)

- **Benign tumors** aren't cancerous. They can often be removed, and, in most cases, they do not come back. Cells in benign tumors do not spread to other parts of the body.
- **Malignant tumors** are cancerous. Cells in these tumors can invade nearby tissues and spread to other parts of the body. The spread of cancer from one part of the body to another is called metastasis.

Some cancers do not form tumors. For example, leukemia which is a cancer of the bone marrow and blood.

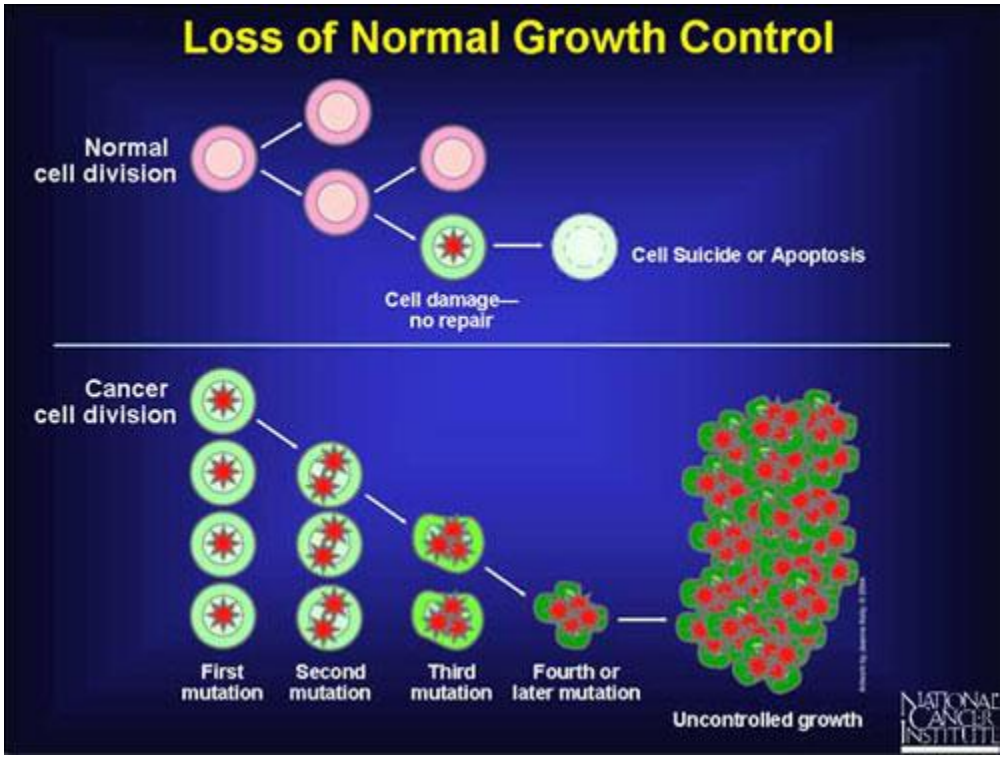

Fig 2.1 Growth of cancer cells (National Cancer Institute, 2013)

2.6 Types of Cancer

Cancer types can be grouped into broader categories. The main categories of cancer include:

- **Carcinoma** - cancer that begins in the skin or in tissues that line or cover internal organs. There are a number of subtypes of carcinoma, including adenocarcinoma, basal cell carcinoma, squamous cell carcinoma, and transitional cell carcinoma.
- **Sarcoma** - cancer that begins in bone, cartilage, fat, muscle, blood vessels, or other connective or supportive tissue.
- **Leukemia** - cancer that starts in blood-forming tissue such as the bone marrow and causes large numbers of abnormal blood cells to be produced and enter the blood.
- **Lymphoma and myeloma** - cancers that begin in the cells of the immune system.
- **Central nervous system cancers** - cancers that begin in the tissues of the brain and spinal cord.

2.7 Causes of cancer

Cancers are primarily an environmental disease with 90–95% of cases attributed to environmental factors and 5–10% due to genetics. Environmental, as used by cancer researchers, means any cause that is not inherited genetically, not merely pollution. Common environmental factors that contribute to cancer death include tobacco (25–30%), diet and obesity (30–35%), infections (15–20%), radiation (both ionizing and non-ionizing, up to 10%), stress, lack of physical activity, and environmental pollutants.

It is nearly impossible to prove what caused a cancer in any individual, because most cancers have multiple possible causes. For example, if a person who uses tobacco heavily develops lung cancer, then it was probably caused by the tobacco use, but since everyone has a small chance of developing lung cancer as a result of air pollution or radiation, then there is a small chance that the cancer developed because of air pollution or radiation. (Holland, James F. (2009)

Chemicals

Cancer pathogenesis is traceable back to DNA mutations that impact cell growth and metastasis. Substances that cause DNA mutations are known as mutagens, and mutagens that cause cancers are known as carcinogens. Particular substances have been linked to specific types of cancer. Tobacco smoking is associated with many forms of cancer, and causes 90% of lung cancer.

Diet and exercise

Diet, physical inactivity, and obesity are related to approximately 30–35% of cancer deaths. Physical inactivity is believed to contribute to cancer risk not only through its effect on body weight but also through negative effects on immune system and endocrine system. More than half of the effect from diet is due to over-nutrition rather than from eating too little healthy foods. Diets that are low in vegetables, fruits and whole grains, and high in processed or red meats are linked with a number of cancers. A high-salt diet is linked to gastric cancer, aflatoxin B1, a frequent food contaminate, with liver cancer, and Betel nut chewing with oral cancer.

Infections

Worldwide approximately 18% of cancer deaths are related to infectious diseases. This proportion varies in different regions of the world from a high of 25% in Africa to less than 10% in the developed world. Viruses are the usual infectious agents that cause cancer but bacteria and parasites may also have an effect. A virus that can cause cancer is called an *oncovirus.* These include human papillomavirus (cervical carcinoma), Kaposi's sarcoma herpesvirus (Kaposi's sarcoma and primary effusion lymphomas), hepatitis B and hepatitis C viruses (hepatocellular carcinoma). Bacterial infection may also increase the risk of cancer, as seen in Helicobacter pylori-induced gastric carcinoma. Parasitic infections strongly associated with cancer include *Schistosoma haematobium* (squamous cell carcinoma of the bladder) and the liver flukes.

Radiation

Up to 10% of invasive cancers are related to radiation exposure, including both ionizing radiation and non-ionizing ultraviolet radiation. Additionally, the vast majority of non-invasive cancers are non-melanoma skin cancers caused by non-ionizing ultraviolet radiation. Sources of ionizing radiation include medical imaging, and radon gas. Radiation can cause cancer in most parts of the body, in all animals, and at any age, although radiation-induced solid tumors usually take 10–15 years, and can take up to 40 years, to become clinically manifest, and radiation-induced leukemias typically require 2–10 years to appear. Unlike chemical or physical triggers for cancer, ionizing radiation hits molecules within cells randomly. If it happens to strike a chromosome, it can break the chromosome, result in an abnormal number of chromosomes, inactivate one or more genes in the part of the chromosome that it hit, delete parts of the DNA sequence, cause chromosome translocations, or cause other types of chromosome abnormalities. Major damage normally results in the cell dying, but smaller damage may leave a stable, partly functional cell that may be capable of proliferating and developing into cancer, especially if tumor suppressor genes were damaged by the radiation. Even if the radiation particle does not strike the DNA directly, it triggers responses from cells that indirectly increase the likelihood of mutations. Medical use of ionizing radiation is a growing source of radiation-induced cancers. Ionizing radiation may be used to treat other cancers, but this may, in some cases, induce a second form of cancer. Prolonged exposure to ultraviolet radiation from the sun can lead to melanoma and other skin malignancies. Clear evidence establishes ultraviolet radiation, especially the non-ionizing medium wave UVB, as the cause of most non-melanoma skin cancers, which are the most common forms of cancer in the world.

Non-ionizing radio frequency radiation from mobile phones, electric power transmission, and other similar sources have been described as a possible carcinogen by the World Health Organization's International Agency for Research on Cancer. However, studies have not found a consistent link between cell phone radiation and cancer risk.

Heredity

The vast majority of cancers are non-hereditary (sporadic cancers). Hereditary cancers are primarily caused by an inherited genetic defect. Less than 0.3% of the population are carriers of a genetic mutation which has a large effect on cancer risk and these cause less than 3–10% of all cancer. Some of these syndromes include: certain inherited mutations in the genes *BRCA1* and *BRCA2* with a more than 75% risk of breast cancer and ovarian cancer, and hereditary nonpolyposis colorectal cancer (HNPCC or Lynch syndrome) which is present in about 3% of people with colorectal cancer, among others.

Hormones

Some hormones play a role in the development of cancer by promoting cell proliferation. Insulin-like growth factors and their binding proteins play a key role in cancer cell proliferation, differentiation and apoptosis, suggesting possible involvement in carcinogenesis.

Hormones are important agents in sex-related cancers such as cancer of the breast, endometrium, prostate, ovary, and testis, and also of thyroid cancer and bone cancer. For example, the daughters of women who have breast cancer have significantly higher levels of estrogen and progesterone than the daughters of women without breast cancer. These higher hormone levels may explain why these women have higher risk of breast cancer, even in the absence of a breast-cancer gene. Similarly, men of African ancestry have significantly higher levels of testosterone than men of European ancestry, and have a correspondingly much higher level of prostate cancer. Men of Asian ancestry, with the lowest levels of testosterone-activating androstanediol glucuronide, have the lowest levels of prostate cancer.

Diagnosis and Detection

Early warning signs of cancer include changes in bowel or bladder habits, a sore that does not heal, unusual bleeding or discharge, thickening or a lump in the breast or any other part of the body, indigestion or difficulty swallowing, change in appearance of a wart or mole, or a nagging cough or hoarseness.

Detection is done by medical imaging techniques such as computed tomography (CT) and magnetic resonance imaging (MRI) scans which use computers to form a three dimensional image of the tumor and neighboring tissues. Also X-ray images of the breasts (mammograms) are used to detect and evaluate breast cancer. Ultrasound 17 scanning bounces high-frequency sound waves off a tumor and surrounding tissue to create an image of the tumor. The multimodality display technique combines the images from several imaging tools into one picture, providing a final three-dimensional image with much greater detail.

2.8 Cancer treatment

Traditional Treatment of Cancer

Cancer can be a very scary thing. The survival rates of some cancers is very low and treatments are not very effective, if one uses traditional medicine (one estimate puts it at 3%). On top of that, cancer is demonized as this scary thing which is growing in you and is going to kill you. Many people feel helpless and put blind trust in traditional medicine for treatment. Traditional medicine is very good in detecting and monitoring cancer but it is very poor and ineffective in the treatment of cancer. Detection is good and aided by imaging techniques such as NMR, CT-scan, ultrasound, PET, etc. and many other chemical, genetic, tissue, etc. tests. Below a few conventional medical treatments techniques are mentioned:

- **Radiation Therapy**

Attempts to locally destroy cancer cells with the various types of radiation such as X-ray, Gamma-ray, particle beams, isotopes, ultrasound, etc. Beams of radiation are focused mainly on the cancer growth and doses are calculated to minimize the collateral damage to surrounding tissues, which nevertheless occurs. This kind of treatment increases the entropy of the organism, suppresses the immune system, destroys healthy cells and potentially forms new mutated cells some of which could become cancerous (and possibly more dangerous than original cancer cells).

- **Chemotherapy**

This aims to destroy the cancer cells with various types of chemicals. The substances used are supposed to target mainly the cancer cells (sometimes via direct injection to cancer tissue) and doses are calculated to minimize the collateral damage to surrounding tissues, which nevertheless occurs. This kind of treatment increases the entropy of the organism, suppresses the immune system, forms a toxic cell environment, destroys healthy cells and potentially forms new mutated cells some of which could become cancerous (and more dangerous than original cancer cells).

- **Surgery**

This is another very invasive technique. Underlying logistics is to locally remove cancer cells with as few healthy cells as possible. This in turn should stop any further growth, since there are no cancer cells left in the body. This is a wrong assumption, since it is very difficult to find the exact boundaries of the cancer growth and remove all cells. Besides that, cancer cells can enter the blood stream and lymphatic fluid during an operation and spread to other parts of the body. This kind of treatment also increases the entropy of the organism, suppresses the immune system and destroys healthy cells and organs.

All mentioned above methods are very invasive, destroy healthy cells and suppress the immune system. This approach leads to an increase of entropy of the organism and lowers the chances of recovery from cancer. All these methods are designed to treat symptoms (cancerous growth), not the cause of cancer (non-functioning immune system and factors contributing to cancer cells formation). Since the cause of cancer is not addressed and treatment is not provided, cancer will, in the majority of cases, spread and recur (Holland, James F. (2009)

New Research in Cancer Treatment

- **Genetically engineered bacteria and viruses**

Some new promising research uses genetically engineered bacteria and viruses to infect and destroy cancer cells. This could be useful when cancer is already advanced and there are large masses of cancer cells. The potential drawback of these methods is the generation of large amounts of toxins from dying cancer cells, which in turn can suppress the immune system or even kill the patient. Also bacteria and viruses very often mutate which in turn can lead to infection and attack on healthy, non-cancerous cells.

- **Anti-cancer vaccines**

Anti-cancer vaccines or even custom-made anti-cancer vaccines for a particular patient and cancer type are also a very promising line of research. By providing fragments of cancer cells to the immune system, one can potentially get the immune system response to destroy live cancer cells.

- **Cancer markers**

Another promising line of research is related to chemical substances which could be used to mark cancer cells. This in turn will allow easier recognition of these cells by the immune system.

- **Cancer growth retarders / inhibitors**

This line of research is related to the use of chemical substances which could retard / inhibit the growth of cancer cells. An interesting research topics are the substances blocking activity of telomerase, the enzyme responsible for the management/elongation of telomeres. Telomerase is found in high concentrations in 80% of tumors and allows tumor cells to gain "immortality" by removing restrictions on the number of cell divisions. This enzyme may also be useful in extending the lifespan of healthy cells and in turn extend the lifespan of the organism (cancer cells and their growth may hold much valuable information about fountain of youth and immortality).

All the above mentioned methods show some promise. However these methods by themselves do not provide reliable cancer treatment

Prevention

Though the causes of cancer are not known, researchers believe that many cancers can be prevented by not smoking, eating more vegetables, fruits and whole grains, eating less meat and refined carbohydrates, maintaining a healthy weight, exercising, minimizing sunlight exposure and being vaccinated against infectious diseases. With a positive change of lifestyle and healthy environment, the growth of cancerous cells can be reversed in majority of cases (probably in 90% - 95%) and shrink and eventually disappear. (Marek Roland, 2006)

2.9 Role of GIS in Health Management

A geographic information system (GIS) integrates hardware, software, and data for capturing, managing, analyzing, and displaying all forms of geographically referenced information. Events that occur are associated with location and time thus spatial and temporal components can be combined to demonstrate aspects of when and where, from which analysis can be done to answer questions like how and why such events occur in space and time. GIS allows us to view, understand, question, interpret, and visualize data in many ways that reveal relationships, patterns, and trends in the form of maps, globes, reports, and charts. A GIS helps you answer questions and solve problems by looking at your data in a way that is quickly understood and easily shared. (ESRI, 2013)

With improvements in computer hardware and widespread availability of software for geographic information systems (GIS), mapping is no longer limited to academic cartographers or to national agencies with extensive computer resources.

GIS is comprised of three general areas: database development (building the GIS), spatial analysis and visualization of georeferenced data. Diseases such as Cancer cases occur in space and time, thus GIS can be applied in collection, management, analysis and displaying of the cancer data. Mapping of cancer helps in understanding the trend and patterns that cancer cases appear to take. This is useful in figuring out how to deal with the spread of cancer and of more importance is revealing the possible causes of cancer development thus avoiding future occurrences.

GIS has been extensively and intensively used by the National Cancer Institute (NCI) in the United States of America (U.S.A) in investigating the geographic patterns of cancer. Of particular interest are the significant advances in understanding the regional differences of cancer rates in the U.S.A. (Mason 1975; Mason 1976; Mason 1981; Pickle 1987; Pickle 1990; Devesa 1999) Although mortality rates had been published for decades in tabular form, it wasn't until Mason and colleagues mapped the rates at the county level that striking geographic patterns were evident. For example, high lung cancer mortality rates that were seen in coastal cities were later found to be due to asbestos exposure from shipyard work during World War II (Blot 1978). Also, high oral cancer rates among white women in southeastern states were found to be caused by their habit of dipping snuff (smokeless tobacco) (Winn 1981).

The role of NCI has changed to one of facilitator for localized geographic studies and developer of geographic methods widely applicable to cancer data, in addition to its traditional role of producing national statistics and conducting studies to determine the cancer causes and effective prevention, diagnosis and treatment.

Environmental exposure assessment

A GIS can be a useful tool for estimating exposure to environmental contaminants by providing information about potential exposures that cannot be obtained through traditional epidemiologic methods. NCI used GIS to estimate indirect exposure to agricultural pesticides and nitrate levels in private wells in two cancer epidemiology studies done in Nebraska and Northern Colorado respectively.

Spatial data analysis

NCI has used GIS for spatial data analysis for example in identifying significant clusters of high rates of several cancers at the zip code level in New York and has been used numerous times to evaluate cancer clusters brought to their attention by the public (Kulldorff 1997b, Kulldorff 1998). A more standard type of spatial analysis is exemplified by a study of the geographic patterns of late stage breast cancer in Los Angeles County. NCI modeled the proportion of all incident breast cancer cases in the county who were

diagnosed with late stage disease for the purpose of identifying population subgroups and geographic areas that could benefit from additional mammographic screening.

Communication of cancer statistics

In addition to designing tools that are useful to researchers, there is a need to communicate georeferenced data to policy makers, clinicians, patients, and the general public. GIS develops maps, globes, reports, and charts that are an efficient method of communicating the cancer statistics to medical experts, patients, policy makers and the general public thus sensitizing everyone in ways to deal with existing cancer cases and avoiding possible future occurrences. NCI has used Conditional choropleth maps to show the geographic distribution of counties within a state that have high versus low cancer mortality rates cross-classified with the direction of change in these rates.

CHAPTER THREE: METHODOLOGY

3.1 Overview

This chapter describes materials and methods used in the study. This basically involves the materials needed to develop spatial database, develop attribute data for Uasin Gishu County and methods used in the analysis of cancer prevalence. In addition, there is data identification, collection and preparation so as to be fit for use. Data preparation includes conversion and manipulation of tabular data while data extraction involves joining attribute tables so as to facilitate thematic mapping of attributes.

3.2 Area of Study

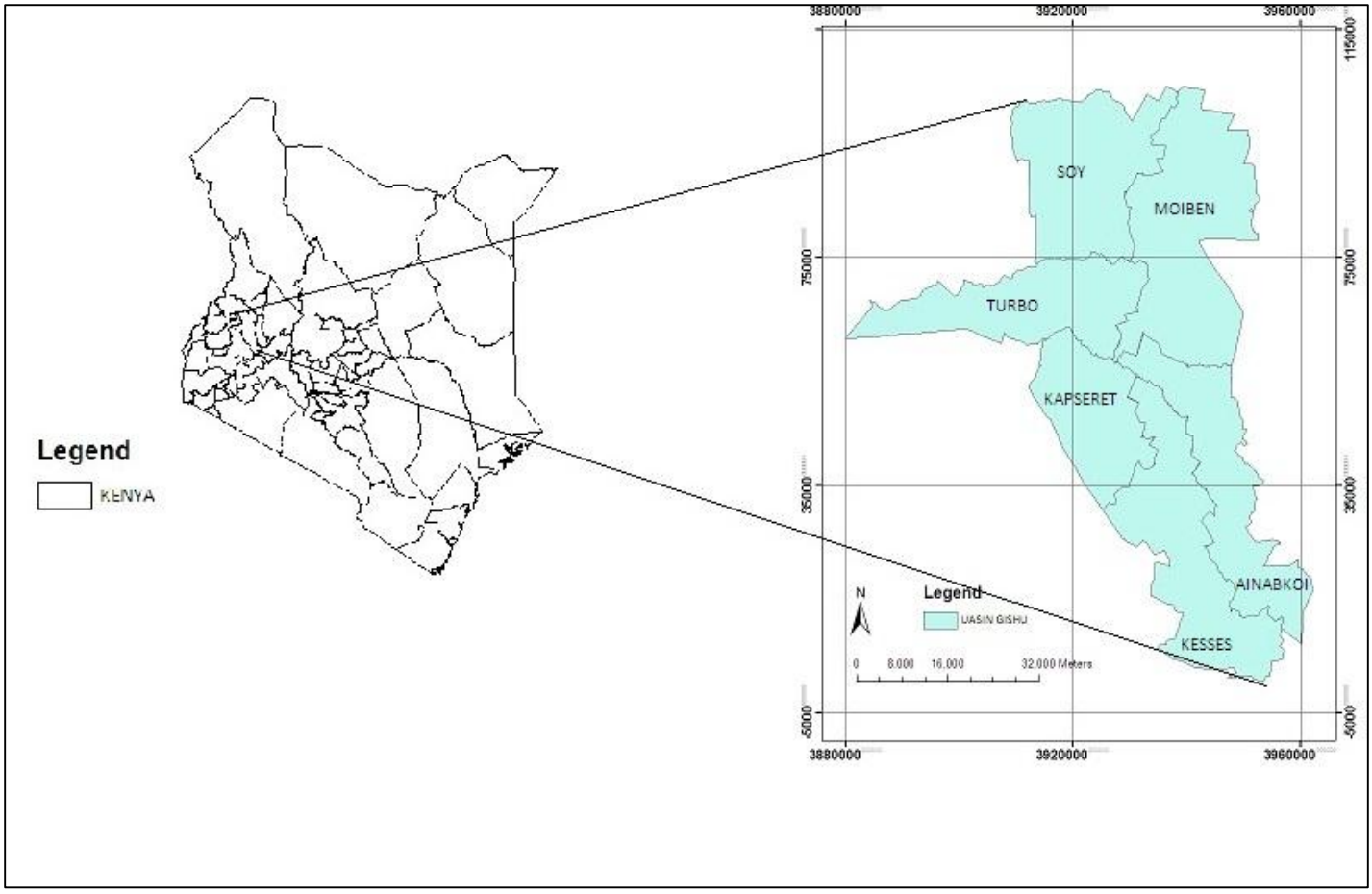

Fig 3.1 Area of Study – Uasin Gishu

The area of study is Usin Gishu County which lies 00° 30' 00" N and 35° 20' 00" E. In Uasin Gishu County elevation varies between 2100 metres above sea level to about 2700 metres above sea level.and its spatial extent is approximately 3345.2 square kilometres. Uasin Gishu is located in the Rift Valley province and its administrative headquarters are in Eldoret town which is approximately 330 kilometres from Nairobi City which is the capital city of Kenya. Uasin Gishu is bordered by Trans-Nzoia and Marakwet districts to the north, Elgeyo district to the east, Kericho and Nandi districts to the south and Kakamega district to the west.

3.3 Data sources and Tools

Cancer data used was obtained from the Eldoret Cancer Registry as excel files

Administrative boundaries data were obtained from World Resource Institute

Tools used:

Hardware

- Computer; 1GB ram, 120GB hard drive, 2.0 GHz dual core.
- flash disk 4GB

Software

- ArcMap 10
- Quantum GIS 2.0
- Microsoft office 2007

3.4 Mapping Spatial Distribution of Cancer

3.4.1 Data Collection

1. Administrative Boundaries

   The administrative boundaries map covering the area of study was obtained from ILRI and World Resource Institute (www.wri.com). It was in form of shape file showing Constituency boundaries in Uasin Gishu County.

2. Cancer Data

   Cancer data was obtained from the Eldoret Cancer Registry (KEMRI). The data consisted of location, gender and status of the cancer patients diagnosed from year 2004 to year 2012.

   More cancer data on causes of cancer and future projections of its spread was obtained from the World Health Organization website.

3. Population data

   Population data for the 6 constituencies was obtained from the Kenya Bureau of Statistics

3.4.2 Data Preparation

Sorting tabular data

All the tabular cancer data obtained from ECR and population data from KNBS was sorted in a suitable format in excel sheets for each constituency and also aggregates for the whole county.

3.4.3 Cancer Spatial Database Development

a. Clipping

The maps obtained from ILRI were in shape file format (shp). The units of analysis were constituencies therefore the area of study was clipped in Arc Map. All the constituency boundaries and the county boundaries were used as base.

b. Editing of Attribute Tables

Attribute tables were edited for relevant fields using Arc Map and exported to the database

c. Spatial cancer database

A spatial cancer database was created using Arc Map and the cancer prevalence tables created as spreadsheets were imported and linked to their respective unit of analysis in the area of study. A GIS database for cancer prevalence was therefore developed with relevant attributes joined and related.

3.4.4 Database validation

It was necessary to test the database on its functionality after it had been developed. Various analytical functions were performed on the database to verify its efficiency. This was done by querying the database and performing functions such as overlays and developing simple graphs and comparing them to the original data obtained from ECR.

3.5 Mapping of cancer prevalence

3.5.1 Spatial prevalence

To demonstrate the spatial distribution of cancer, six constituencies of Uasin Gishu County were considered (Turbo, Soy, Kapseret, Ainabkoi, Moiben and Kesses). The data obtained consisted of total cases for each constituency, gender and status (alive or deceased).

Bar graphs were developed to show the variation of total cancer cases in all six constituencies. Bar lengths reflected the number of total cancer cases in each constituency. In one situation, pie charts were used to portray the total number of cancer patients in every constituency.in this case, different sizes of pie charts(in diameter and thickness) gave a clear indication of which constituencies had more cancer cases than others and comparison was easy.

Pie charts were then developed to show the variation of the cancer cases between gender and status of cancer patients for every constituency.in this case, the pie charts contained total male and female cases to be compared in each constituency. The pie chart sizes were equal for all constituencies as they were to only portray the male to female ratio. The final analysis was done for cancer status (alive or deceased). This was also done using pie charts and total cancer cases for each constituency. Pie chart sizes were also equal because the intention was to portray the ratio of deceased patients to the alive patients.

Finally, a combination of line graphs was developed in Microsoft office to display the trend and numeric values of total cancer cases for every constituency.

3.5.2 Temporal prevalence

Cancer cases registered from the year 2004 to 2012 by the Eldoret Cancer Registry were used for each constituencies. The data obtained from ECR consisted of cancer cases registered from the year 2004 to 2012 therefore bar graphs were developed to show the temporal variation of cancer cases for every constituency from year 2004 to 2012. These bar graphs had different sizes according to the total number of cancer cases in each constituency. The bar lengths depicted the number of cancer cases for each year since 2004 to 2012. The graphs were a clear indication of the trend of cancer cases through the 8 year period. Combinations of line graphs were developed using Microsoft office to clearly show the trend and also display the numeric values of the cases for every year in each constituency.

Bar graphs were also developed to illustrate the temporal trend of death cases throughout the 2004 to 2012 epoch. This was an indicator of whether they were increasing or decreasing for each constituency.

All the pie charts and bar graphs were displayed in the base maps containing administrative boundaries. They were placed midway in the area bounded by the boundaries.

A large number of the cancer cases had no location. There was no way to show this on a map but there was a temporal aspect in the data as it was also collected from the year 2004 to 2012. However bar graphs generated in Microsoft office were used to show the trend of the unknown location cases.

CHAPTER FOUR: RESULTS AND DISCUSSIONS

4.1 RESULTS

4.1.1 Cancer Prevalence

a. Cancer prevalence by Spatial and Temporal distribution

Table 4.1 Cancer cases reported in every constituency from years 2004 to 2012 in Uasin Gishu County

YEAR	CONSTITUENCY	FEMALES ALIVE	FEMALES DECEASED	MALES ALIVE	MALES DECEASED	TOTAL
2004	U/G CENTRAL	4	7	3	6	**20**
2004	KESSES	2	5	3	5	**15**
2004	SOY	5	5	6	3	**19**
2004	MOIBEN	1	2	7	1	**11**
2004	AINABKOI	1	3	5	3	**12**
2004	KAPSERET	1	5	2	1	**9**
2004	UNKNOWN	80	35	65	51	**231**
2005	U/G CENTRAL	4	15	5	17	**41**
2005	KESSES	6	7	3	3	**19**
2005	SOY	7	6	2	14	**29**
2005	MOIBEN	3	4	4	5	**16**
2005	AINABKOI	5	4	2	2	**13**
2005	KAPSERET	3	5	2	4	**14**
2005	UNKNOWN	131	93	84	70	**378**
2006	U/G CENTRAL	14	16	13	17	**60**
2006	KESSES	1	9	2	7	**19**
2006	SOY	8	17	9	18	**52**

2006	AINABKOI	2	3	9	9	**23**
2006	MOIBEN	0	4	3	3	**10**
2006	KAPSERET	0	2	1	1	**4**
2006	UNKNOWN	62	111	43	114	**330**
2007	U/G CENTRAL	12	33	11	28	**84**
2007	KESSES	1	5	5	10	**21**
2007	SOY	2	9	3	11	**25**
2007	MOIBEN	1	5	3	5	**14**
2007	AINABKOI	0	3	0	5	**8**
2007	KAPSERET	0	2	1	1	**4**
2007	UNKNOWN	129	82	141	87	**439**
2008	U/G CENTRAL	4	25	5	23	**57**
2008	KESSES	4	6	1	7	**18**
2008	SOY	1	9	2	16	**28**
2008	MOIBEN	4	2	1	11	**18**
2008	AINABKOI	1	6	1	6	**14**
2008	KAPSERET	1	8	1	0	**10**
2008	UNKNOWN	157	110	180	111	**558**
2009	U/G CENTRAL	2	16	5	18	**41**
2009	KESSES	3	2	1	6	**12**
2009	SOY	3	6	4	8	**21**
2009	MOIBEN	2	7	2	10	**21**
2009	AINABKOI	1	1	0	3	**5**
2009	KAPSERET	3	2	0	3	**8**
2009	UNKNOWN	188	64	204	70	**526**

2010	U/G CENTRAL	11	11	5	12	**39**
2010	KESSES	2	6	2	4	**14**
2010	SOY	2	8	2	4	**16**
2010	MOIBEN	1	9	1	7	**18**
2010	AINABKOI	1	4	0	4	**9**
2010	KAPSERET	2	2	4	3	**11**
2010	TURBO		0	0	1	**1**
2010	UNKNOWN	292	32	216	40	**580**
2011	U/G CENTRAL	21	16	10	6	**53**
2011	KESSES	4	3	1	4	**12**
2011	SOY	10	10	8	13	**41**
2011	MOIBEN	8	9	5	19	**41**
2011	AINABKOI	5	2	1	5	**13**
2011	KAPSERET	2	7	3	2	**14**
2011	TURBO	1	4	0	2	**7**
2011	UNKNOWN	319	41	320	33	**713**
2012	U/G CENTRAL	18	6	8	11	**43**
2012	KESSES	6	1	5	6	**18**
2012	SOY	7	4	7	4	**22**
2012	MOIBEN	8	3	1	6	**18**
2012	AINABKOI	6	2	1	2	**11**
2012	KAPSERET	7	5	4	7	**23**
2012	TURBO	2	4	0	2	**8**
2012	UNKNOWN	61	26	38	30	**155**
		1655	**976**	**1486**	**1020**	**5137**

Table 4.1 shows the number of cancer cases reported in the six constituencies of Uasin Gishu County (i.e Turbo, Kesses, Soy, Moiben, Ainabkoi and Kapseret) from the year 2004 to 2012. The table also contains the number of female and male cases (alive and deceased) for each constituency during the same period.

4.1.2 Cancer Prevalence Analysis

Cancer trends and their spatial distribution

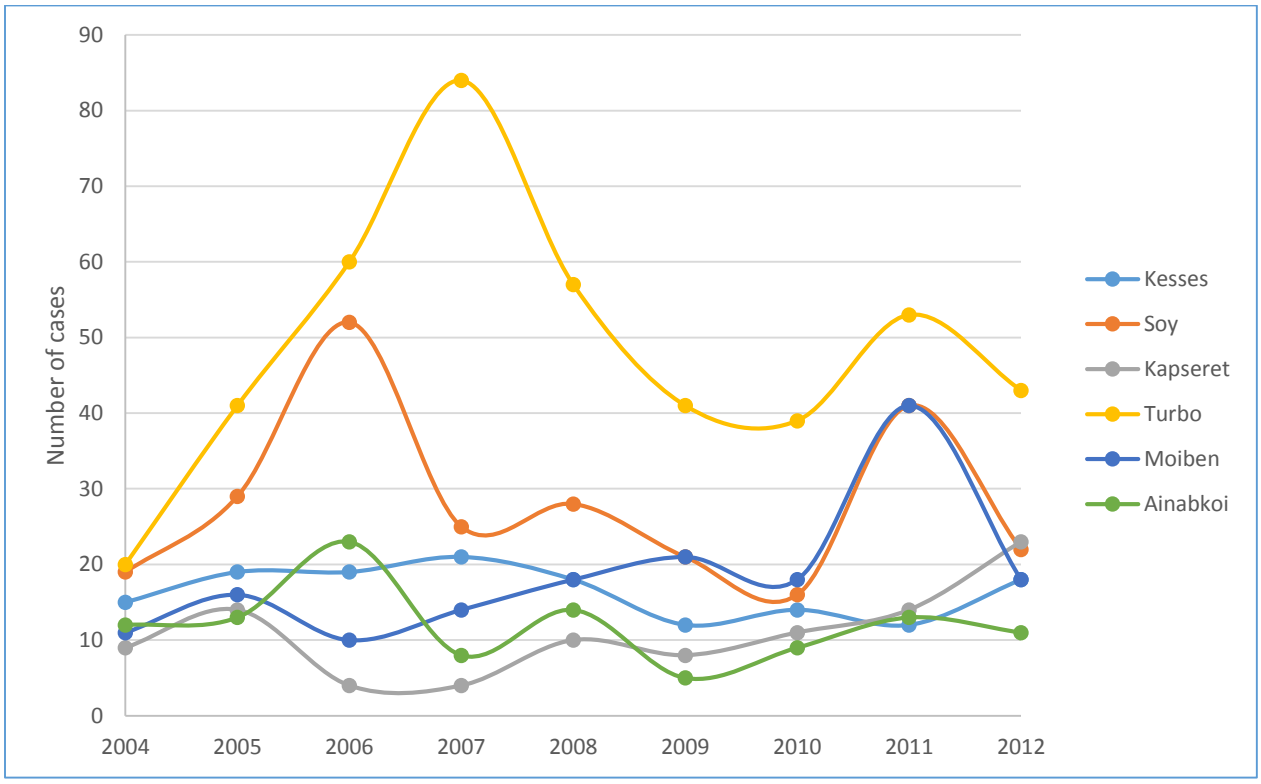

Fig 4.1 Cancer trends in Uasin Gishu County for years 2004 to 2012

Figure 4.1 shows the trend of total number of cancer cases for each constituency from year 2004 to 2012. It is observed that Turbo constituency had the most cases followed by Soy, Moiben, Kesses, Ainabkoi and finally Kapseret which had the least cases. This may be attributed to the large population in Turbo as compared to the other constituencies in that order.

Fig 4.2: spatial distribution of cancer cases – aggregated

It is observed from figure 4.2 that Turbo constituency had the most cancer cases and Kapseret had the least.

Fig 4.3: Spatial distribution of cancer cases for years 2004 to 2012

Figure 4.3 shows the spatial distribution of annual cancer cases for every constituency for years 2004 to 2012. As seen before in figure 4.1, the trend was inconsistently increasing and decreasing from one year to the next through the period.

b. Cancer Prevalence Among Gender

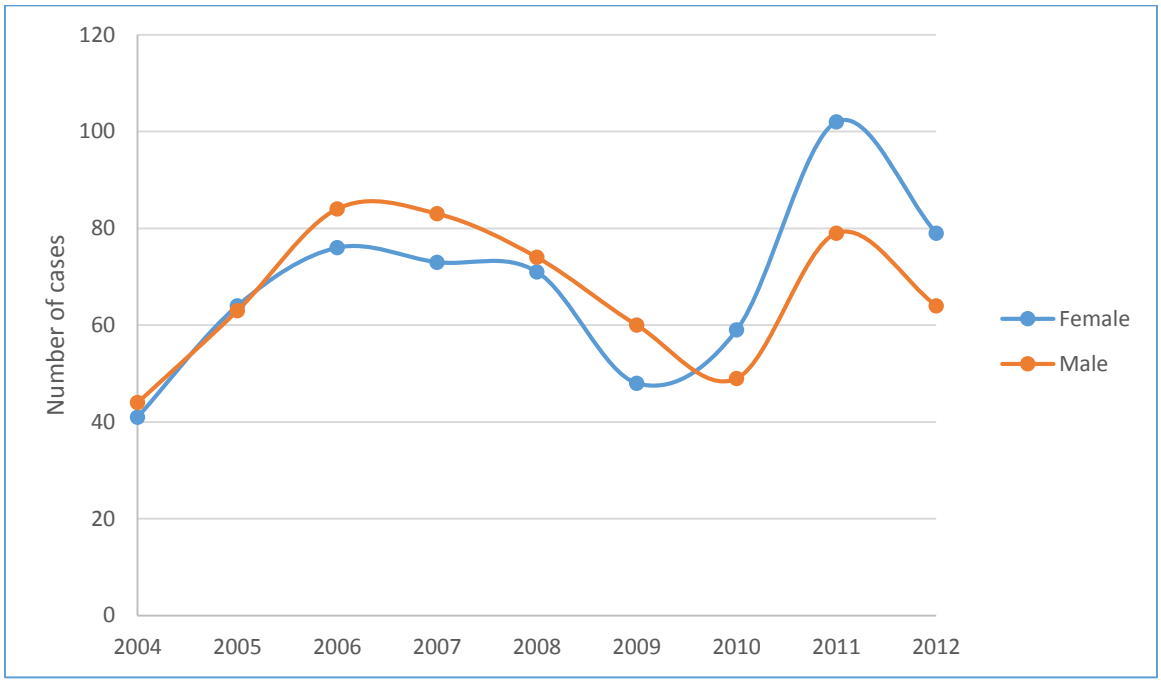

Fig 4.4 cancer prevalence among gender from year 2004 to 2012 in Uasin Gishu County

From figure 4.4, it was observed that there were more cancer cases corresponding to female gender compared to male gender. However the trend is inconsistent throughout the 2004 to 2012 period, as the cases increased and decreased from one year to the other. There were a total of 613 female cases as compared to 600 male cases.

c. Ratio of Male to Female cancer cases

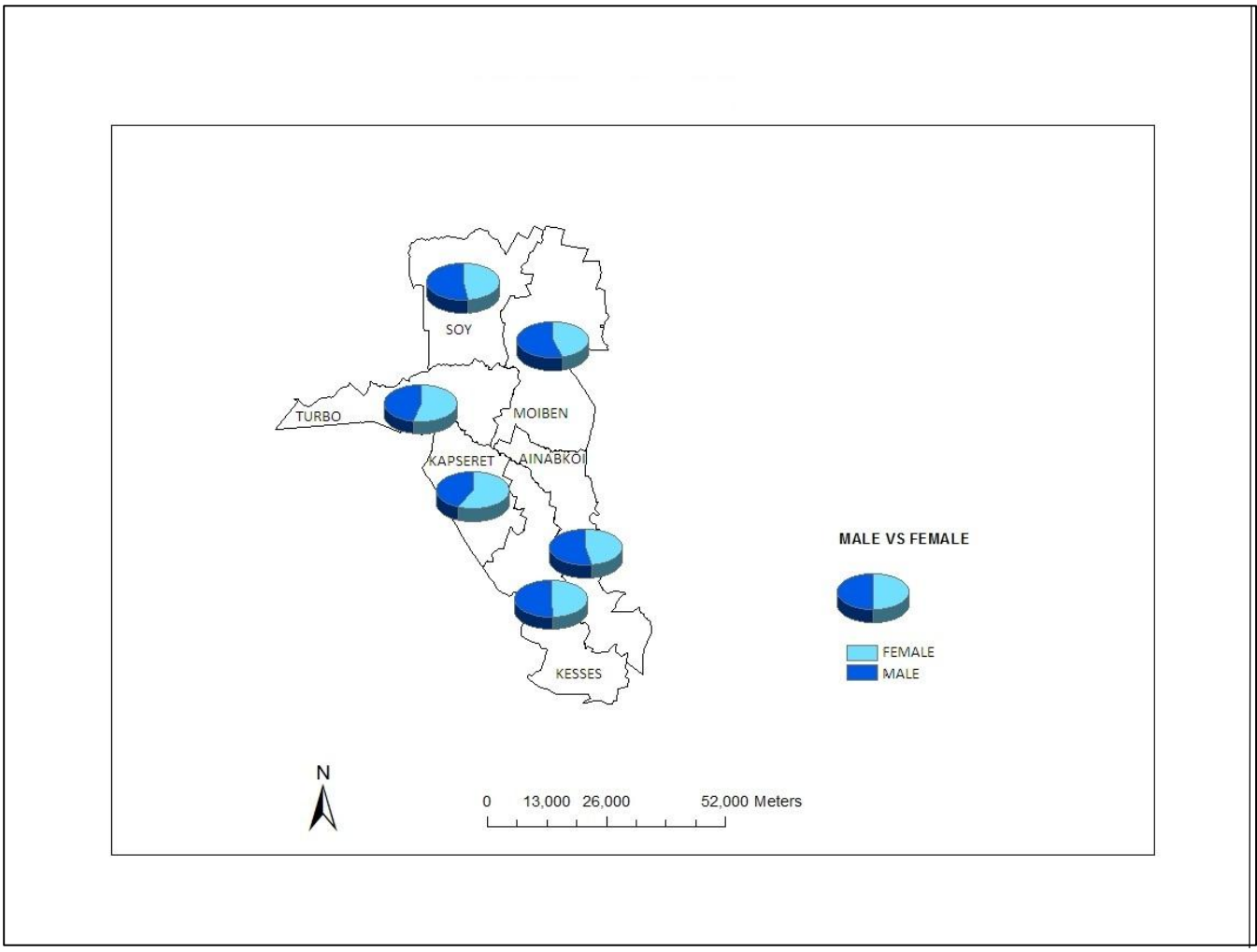

Fig 4.5 Ratio of male to female cancer cases in Uasin Gishu County

From figure 4.5 the ratio of male to female cases vary in every constituency. In Soy, Moiben and Ainabkoi, there were more males suffering from cancer than females, while in Turbo and Kapseret there were more female cases than male cases and finally in Kesses there were equal number of male and female cases.

d. Ratio of alive to deceased cancer patients

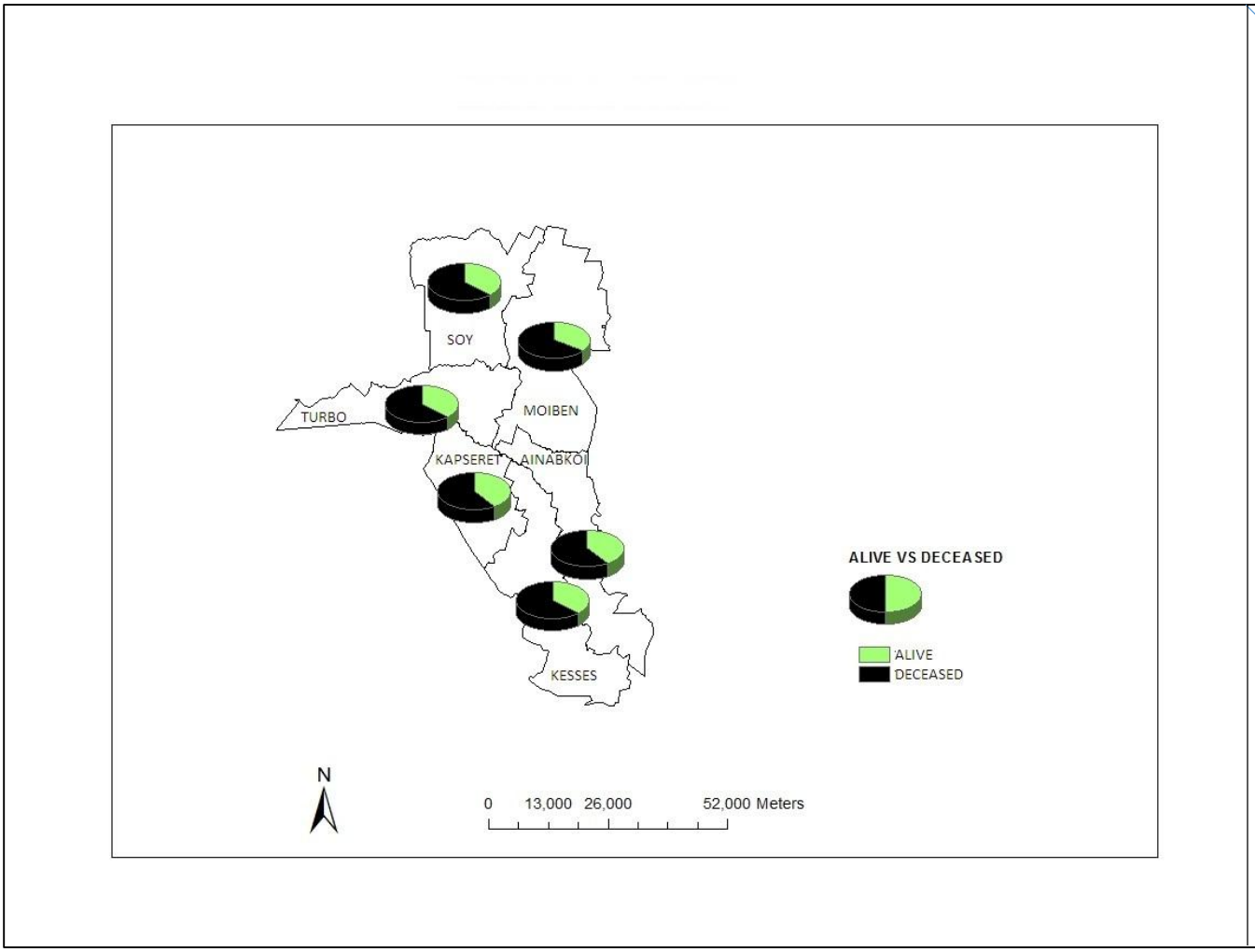

Fig 4.6 Ratio of alive to deceased cancer patients in Uasin Gishu County

Figure 4.6 shows the ratio of total cases of alive patients to deceased ones. It was observed that the number of deceased patients was more than the alive patients for all constituencies.

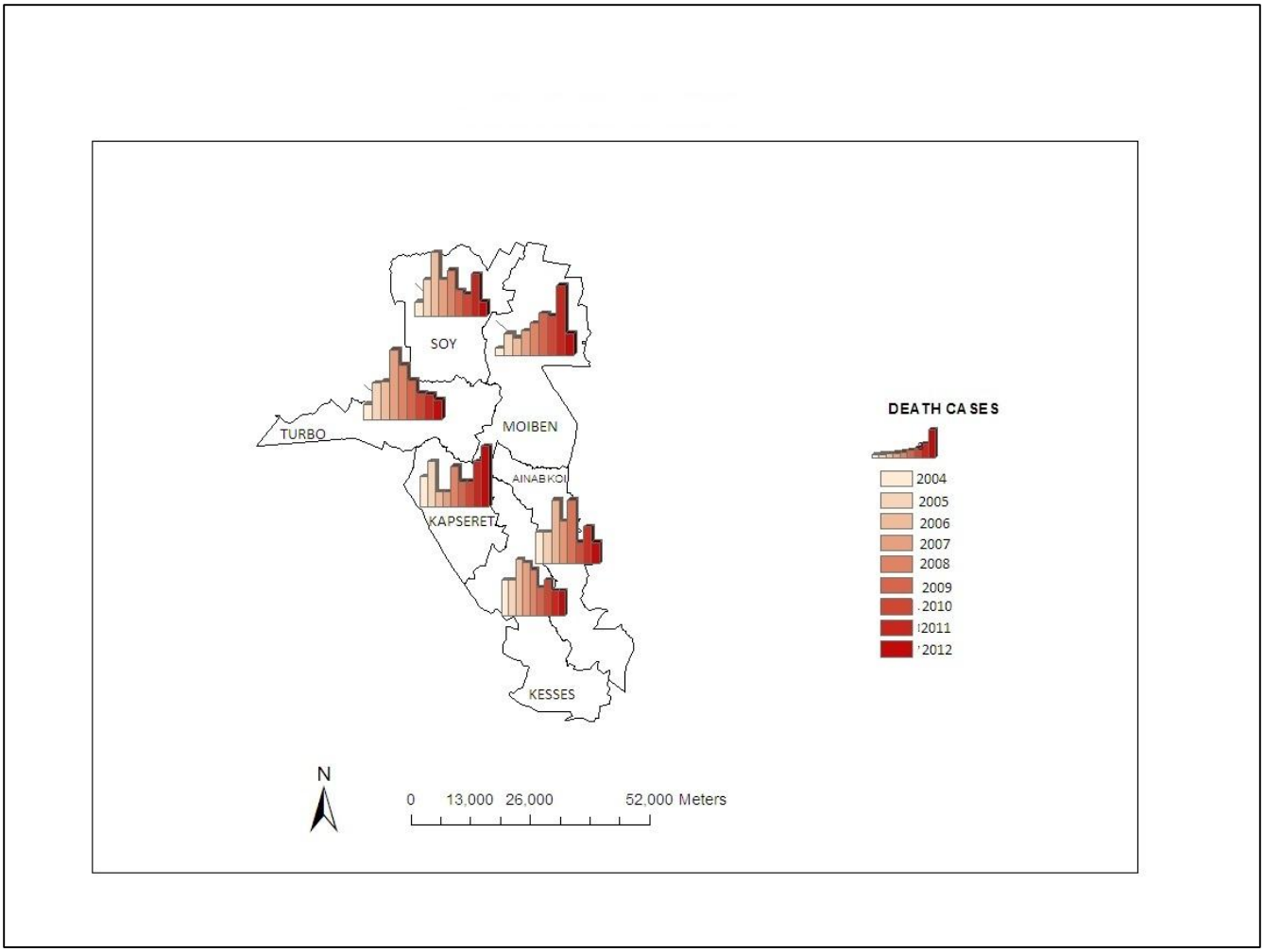

Fig 4.7 spatial distribution and trend of death cases for years 2004 to 2012

It was observed from figure 4.7 that the death trend was erratic and there was no steady pattern as the number increased and decreased from one year to the next

e. Number of recorded cases whose location was unknown

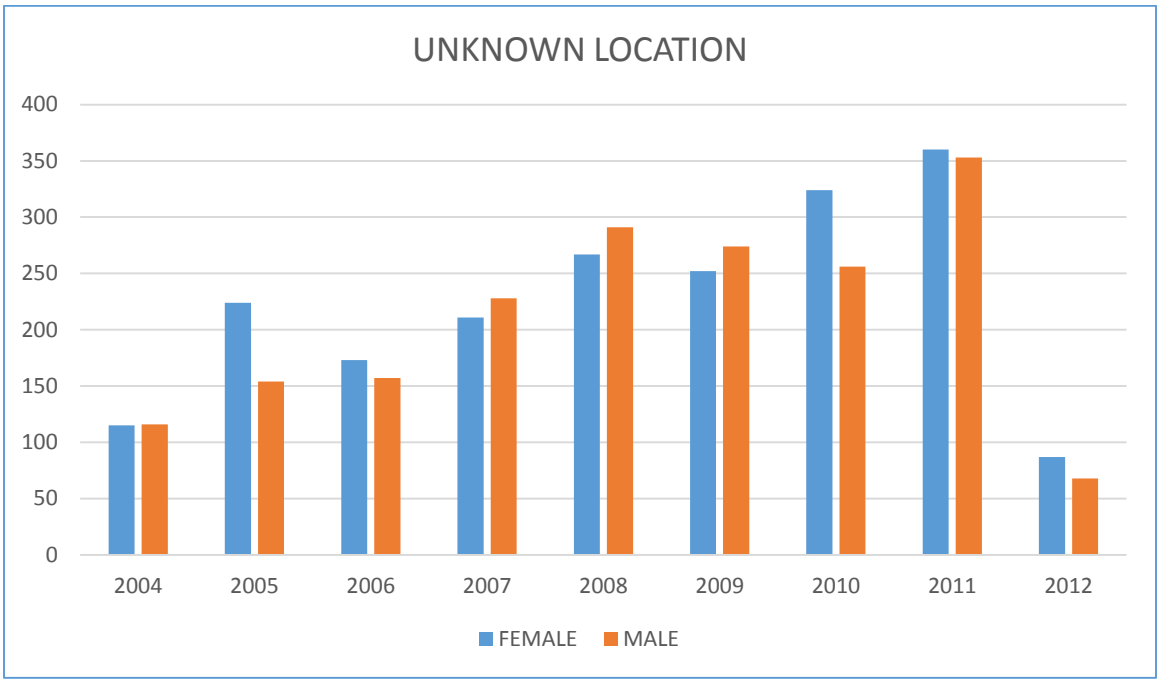

Fig 4.8 number of cancer cases whose location was not known

It was observed that 3910 cases out of the total 5137 cases recorded were of unknown location. That was more than two thirds of the total cancer cases recorded in the Eldoret Cancer Registry were of unknown location. The number increases from the year 2004 to 2011 and reduces drastically in 2012.

4.2 Discussions

Mapping is an important tool that portrays the trends and patterns followed by an event or certain occurrences. In this case, cancer was mapped thus showing its occurrence in time and space (spatial and temporal distribution). In the process, the probable causes of cancer can be determined. Mapping thus facilitates decision making in terms of figuring out how to deal with the cancer cases already detected and coming up with strategies to avoid future infections.

The results above indicate an increase in cancer cases reported every year. The totals vary between the constituencies with Turbo constituency having the most cases and Kapseret constituency with the least cases reported. This can be attributed to the large population in Turbo constituency as compared to the rest of the constituencies.

It was also observed that some constituencies (Soy, Moiben and Ainabkoi) had more male cases than others (Turbo and Kapseret) while Kesses had equal numbers of male and female cases reported. However, the overall number of female cases reported were more than the male cases.

The number of deaths reported every year was higher than the number of surviving cancer patients for all the constituencies. The death trend was however erratic and there was no steady pattern as the number increased and decreased from one year to the next.

Of particular interest, is the trend and number of reported cancer cases whose location was not known. The number increases from the year 2004 to 2011 after which there's a sharp decrease in that number. There were a total of 3910 cases of unknown location out of a total of 5137 cases recorded. This can be discusses from two perspectives, the first being that record keeping in the Eldoret Cancer Registry was very poor, and the second being that patients did not give their locations due to personal reasons. Both situations result to a serious deficit and hindrance to mapping as the locations are the basis of mapping. This made the project difficult to develop at the mapping stage. This further results to difficulties in determining the extent to which cancer has spread and as a result it's difficult to mobilize resources to cater for the detected cases and more resources to sensitize the public so as to avoid future infections. The drastic reduction in the unknown

location cases may be attributed to the increased sensitization of the seriousness of the cancer situation in Kenya in the past few years.

CHAPTER FIVE: CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The main objective of this study which was to show the spatial variation of cancer incidence and mortality using Uasin Gishu County as a case study was achieved. Constituencies were the units of analysis. Maps showing the spatial and temporal distribution of cancer cases among gender were produced. More analysis was done using map and graph combinations to show trends and patterns of cancer prevalence and the overall cancer situation in Uasin Gishu County. Specific objectives were also achieved as a spatial cancer database was created and applied in coming up with information to facilitate counteracting the spread of cancer.

5.2 Recommendations

More data was required pertaining to specific cancer types, health facilities and personnel but it was not available. Even worse, as stated in the results and discussions, large numbers of the reported cases were of unknown location thus hindering complete mapping of the cancer prevalence. Cancer being an epidemic and the increasing number of cases being reported annually, it should be treated more seriously. Among the most effective methods of dealing with an epidemic, is determining the extent of prevalence both in time and space so as to figure out how to deal with the reported cases and even better, prevent future cases (prevention is better than cure). This can be achieved by mapping the spatial and temporal prevalence of cancer and therefore the following are recommended:

1. Cancer Registry – cancer registries are the main source of cancer data which is essential for mapping. The government should develop cancer registries in all counties and employ the relevant workforce to facilitate cancer data collection.

2. Cancer mapping – since the project was successful, similar projects should be carried out for the whole country in order to determine the extent which cancer has spread in the country thus coming up with strategies to hinder its spread.

3. Cancer prevention – as stated ‘’prevention is better than cure’’ therefore the public should be sensitized on the cancer situation especially in matters concerning diagnosis, treatment and of great importance, ways by which cancer can be avoided.

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APPENDIX

TABLE A1. Cancer cases recorded by Eldoret Cancer Registry for years 2004 to 2012

YEAR	CONSTITUENCY	FEMALES ALIVE	FEMALES DECEASED	MALES ALIVE	MALES DECEASED	TOTAL
2004	U/G CENTRAL	4	7	3	6	**20**
2004	KESSES	2	5	3	5	**15**
2004	SOY	5	5	6	3	**19**
2004	MOIBEN	1	2	7	1	**11**
2004	AINABKOI	1	3	5	3	**12**
2004	KAPSERET	1	5	2	1	**9**
2004	UNKNOWN	80	35	65	51	**231**
2005	U/G CENTRAL	4	15	5	17	**41**
2005	KESSES	6	7	3	3	**19**
2005	SOY	7	6	2	14	**29**
2005	MOIBEN	3	4	4	5	**16**
2005	AINABKOI	5	4	2	2	**13**
2005	KAPSERET	3	5	2	4	**14**
2005	UNKNOWN	131	93	84	70	**378**
2006	U/G CENTRAL	14	16	13	17	**60**
2006	KESSES	1	9	2	7	**19**
2006	SOY	8	17	9	18	**52**
2006	AINABKOI	2	3	9	9	**23**
2006	MOIBEN	0	4	3	3	**10**
2006	KAPSERET	0	2	1	1	**4**
2006	UNKNOWN	62	111	43	114	**330**
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2008	UNKNOWN	157	110	180	111	**558**
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2010	AINABKOI	1	4	0	4	**9**
2010	KAPSERET	2	2	4	3	**11**

2010	TURBO		0	0	1	**1**
2010	UNKNOWN	292	32	216	40	**580**
2011	U/G CENTRAL	21	16	10	6	**53**
2011	KESSES	4	3	1	4	**12**
2011	SOY	10	10	8	13	**41**
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2011	TURBO	1	4	0	2	**7**
2011	UNKNOWN	319	41	320	33	**713**
2012	U/G CENTRAL	18	6	8	11	**43**
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2012	AINABKOI	6	2	1	2	**11**
2012	KAPSERET	7	5	4	7	**23**
2012	TURBO	2	4	0	2	**8**
2012	UNKNOWN	61	26	38	30	**155**
		1655	**976**	**1486**	**1020**	**5137**