AN ANALYSIS OF CUTANEOUS LEISHMANIASIS (CL) IN AL-DAWADMI GOVERNORATE, SAUDI ARABIA USING GEOGRAPHICAL INFORMATION SYSTEM (GIS)

Hamad Mansour A. Aldossari

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School of Environmental Sciences

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Abstract:

Leishmaniasis has been described by the World Health Organisation as a 'neglected disease' and not well understood, which reflects the variations in transmission cycle, reservoirs, vectors, clinical manifestations, and its associations with many human factors. One country where Cutaneous Leishmaniasis (CL) is a major health issue is Saudi Arabia. This thesis investigates factors influencing the prevalence of CL in Al-Dawadmi Governorate, Saudi Arabia in the period between January 2006 and April 2011 from a multidisciplinary perspective.

Meteorological data were used to investigate the influence of climatic variables on the seasonality of CL in the study area. The research also involved surveys of land use / cover around six communities in the protectorate and a case-control study of 125 CL cases and 125 controls to assess the role of socio-economic factors. Additionally, an assessment was made of CL cases that were not officially reported to the health authority.

Four main factors were found to influence the prevalence of CL cases in the governorate. There was a very strong, temporally-lagged, relationship between monthly temperature and rainfall and reporting of CL cases. Within individual communities, the case-control results indicated there was a strong association between the presence of certain land cover types or land uses within 300 metre and the probability of contracting CL. A number of socio-economic and demographic factors were also found to be correlated with a higher risk of contracting CL. In addition, socio-economic factors and contrasts in accessibility to health services influenced the reporting of CL cases to the authorities.

Overall, the results suggest that a multi-faceted approach to reducing the prevalence of CL is required. Public authorities need to be aware of the meteorological trigger conditions, undertake reservoir eradication activities in certain circumstances, improve access to key diagnostic health services and, most cost-effectively, undertake initiatives to improve public awareness of the key risk factors, relevant mitigation measures and the advantages of seeking prompt treatment.

Dedication:

This thesis is dedicated to my loving parents, wife and two kids, who have endured 5 years of work toward this degree. Only through their encouragement, faith and support, I have been able to be successful and be where I am today.

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Chapter One: Introduction:

1.1. Introduction:

Maintaining good health and preventing diseases are crucial aspects for the people's quality of life. Nowadays, health concerns pose some serious economic and social challenges as diseases account for millions of deaths worldwide annually. In general, diseases are classified into communicable (or infectious) and non-communicable diseases wherein each type has its own different causes and is transmitted differently (WHO, 2013a; Webber, 2009). One of the main differences between these two types is that communicable diseases can be transmitted from one person to another, whereas in the case of non-communicable diseases, they are not usually passed to another person (WHO, 2013a; UN, 2011; Griffiths, 1998; Judith and Aral, 1996). Another major difference is vehicles of transmission where the vectors play an important role in the transmission of the communicable diseases whilst genetic, local environment, dietary habits and lifestyle play a major role in the causation of the non-communicable disease (WHO, 2014a; Sharma and Majumdar, 2009; Willett et al., 2006; Sergey et al., 2011).

Both communicable and non-communicable diseases have been found to play a very important role in people's lives. According to the World Health Organization (WHO) approximately 57 million people died in the year 2012, almost 46 million (80%) of these deaths were caused by diseases (WHO, 2013a). Non-communicable diseases are by far the leading reason with 36 million deaths representing about 63% of the total deaths worldwide. The most common types of non-communicable diseases are cardiovascular diseases, Cancer, Chronic respiratory diseases and Diabetes (Ibid). Communicable diseases also play an important role in people's lives by causing the death of approximately 9.8 million people in 2012, representing nearly 17% of the estimated global burden of all deaths (Ibid). The most common fatal communicable diseases are Diarrhoeas, Tuberculosis, Malaria, AIDS, Leishmaniasis and lower respiratory infections (WHO, 2012). So, it is apparent that both types of diseases are important and play a very significant role in the global burden of all deaths. However, communicable diseases are much more amenable to many types of human interventions than non-communicable diseases are (UN, [No date]a; Brown, 2011). Also, it is really hard or even impossible to do something from environmental perspectives about deaths of some non-communicable diseases like Cancer, Diabetes or Heart diseases but is more possible to put interventions into practices to reduce the risk of some communicable diseases such as Malaria, TB and Leishmaniasis (UN, [No date]a; Brown, 2011). Therefore, the focus of this study will be on communicable diseases only.

Human communicable diseases are often classified in three main ways as shown in Figure 1.1. They are classified on the basis of the pathogens into bacteria, viruses, fungi, parasites and protozoa (Crum-Cianflone, 2008; Bower et al., 1994; Tibayrenca and Ayalab, 2012). Another classification is based on the source of infection as either anthroponoses when the source is another infected human or zoonoses when the source is an infected animal (Hubálek, 2003; Ahmad et al., 2010). Communicable diseases are also classified based on the mode of transmission as direct or indirect. Direct transmission occurs more or less immediately after direct contact with the human, animal or environmental reservoir. On the other hand, the indirect transmission from human to human or animal to human depends on transmission vectors such as mosquitoes and sandflies or vehicles such as food, water and surgical instruments (Keeling and Rohani, 2007; Miller and Zawistowski, 2013; Last, 1988; CDC, 2014a.)

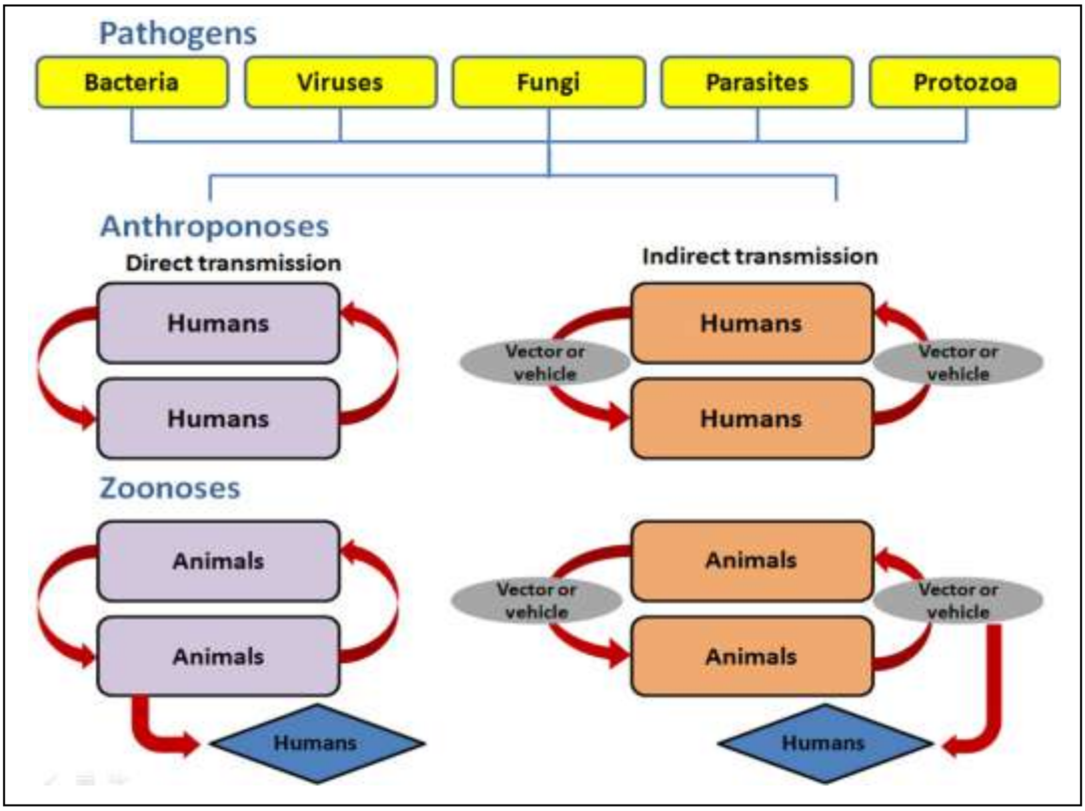


Figure 1.1: Communicable disease pathogen, source and transmission classifications (adapted from Wilson, 2001; PHE, 2013)

Communicable diseases are transmitted by a variety of different mechanisms (SAHealth, 2014; Faraj, 2011; ABPI, [No date]; Pankhurst and Coulter, 2009; ACPHD, [No date]) which are:

1. Physical contact with an infected person or animal by touch (Staphylococcus), sexual contact (AIDS), fecal-oral or urine-oral (Entamoeba Histolytica) and droplets (Tuberculosis).
2. Contact with contaminated objects (Norwalk virus), food (Salmonella), blood (AIDS) or water (Cholera).
3. Bites by infected insects or animal (Malaria, Rabies).
4. Through the air by droplets (Influenza).

1.2. The Global Importance of Communicable Diseases:

Throughout history, many people have been killed by various types of communicable diseases. For example, one of the earliest historically documented rigorous communicable disease outbreaks was the Justinianic Plague in Egypt in 541 AD that spread all over the Mediterranean Basin countries reaching Europe and lasted for about 225 years killing almost 60% of the European population by the middle of the 8th Century (Biraben and Goff, 1975; Drancourt and Raoult, 2002). Another example is in the period between 1347 and 1352 AD when the Black Death accounted for one-third of the European population and almost two-thirds of the population in China within only 5 years (Byrne , 2012; Carpenter and Bishop, 2009; Deloria and Salisbury, 2004). Also, in the 19th Century, 70% to 90% of the urban population in Europe and North America were infected with Tuberculosis (TB) and about 80% of those infected people died of it (Barnes, 1995; Harvard University, [No date]).

However, since the beginning of the 20th Century, the global burden of disease has been shifting noticeably from communicable diseases to non-communicable diseases (which is known as the epidemiological transition) as well as remarkable changes in mortality and morbidity rates due to the massive economic developments worldwide (which is known as demographic transition). This shifting trend in health indicates that major communicable diseases that killed millions of people throughout history will become less important reasons for deaths worldwide over the coming 20 years due to health care improvements (WHO, 2008a). The Director of the WHO Department of Health Statistics and Informatics Dr. Boerma stated in 2008 that, ‘*’we are definitely seeing a trend* *towards fewer people dying of infectious diseases across the world''* (Ibid). So based on that, it can be said that non-communicable diseases are becoming higher in health burden importance than communicable diseases and this can already be seen in many parts of the world including the USA as exemplified in Figure 1.2.

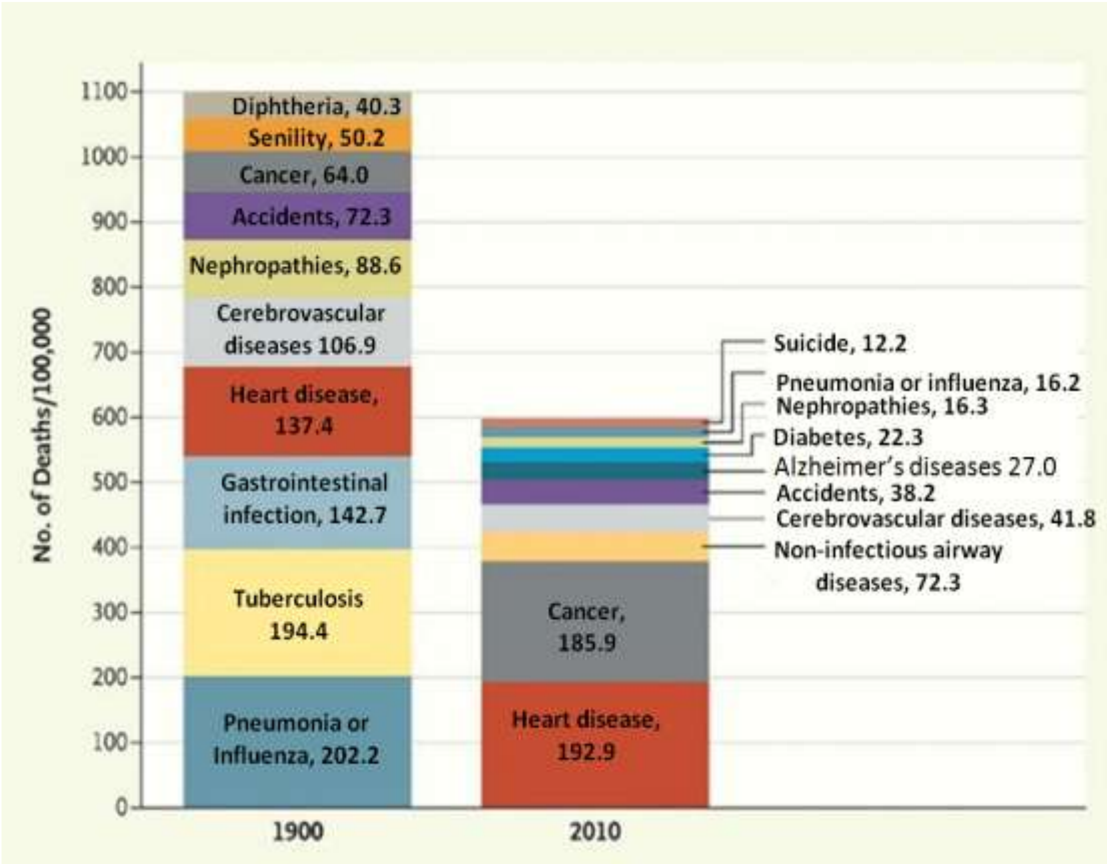


Figure 1.2: Causes of deaths in the USA in 1900 and 2010 (Schimpff, 2012)

Figure 1.2 compares the main causes of deaths in the USA in the years 1900 and 2010 demonstrating the obvious shift from communicable to non-communicable diseases. For example, the main killer in 1900 was Pneumonia or Influenza causing 202.2 out of 100,000 deaths, while in 2010 the number dropped dramatically to only 16.2 out of 100,000 deaths. In contrast, Cancer was the reason for 64 out of 100,000 deaths in 1900 and increased significantly to be the cause of 185.9 out of 100,000 deaths. The increase in non-communicable disease is more likely to be a result from changes in human dietary habits and lifestyle as well as the surrounding environment (WHO, [No date]a; Sharma and Majumdar, 2009; Belal and Al-Hinai, 2009). On the other hand, childhood immunization programs and antibiotic inventions have resulted in totally eradicating some vital diseases such as Smallpox (Koplow, 2002), or reducing the number of cases and the danger of other diseases such as Diphtheria, Tuberculosis , Measles and Whooping cough (Relman et al., 2009; Schlipköter et al., 2010). Some examples of the reduced communicable diseases are shown in Figure 1.3 (Langmuir, 1962; CDC, 2003; CDC, 2012a; PHAC, 2006; Mathews and MacDorman, 2013; Korpi, 2011; Basu, [No date]; Armstrong, 1999; PHE, 2014; Wolcott and Hanes, 2013; WHO, 2014b).

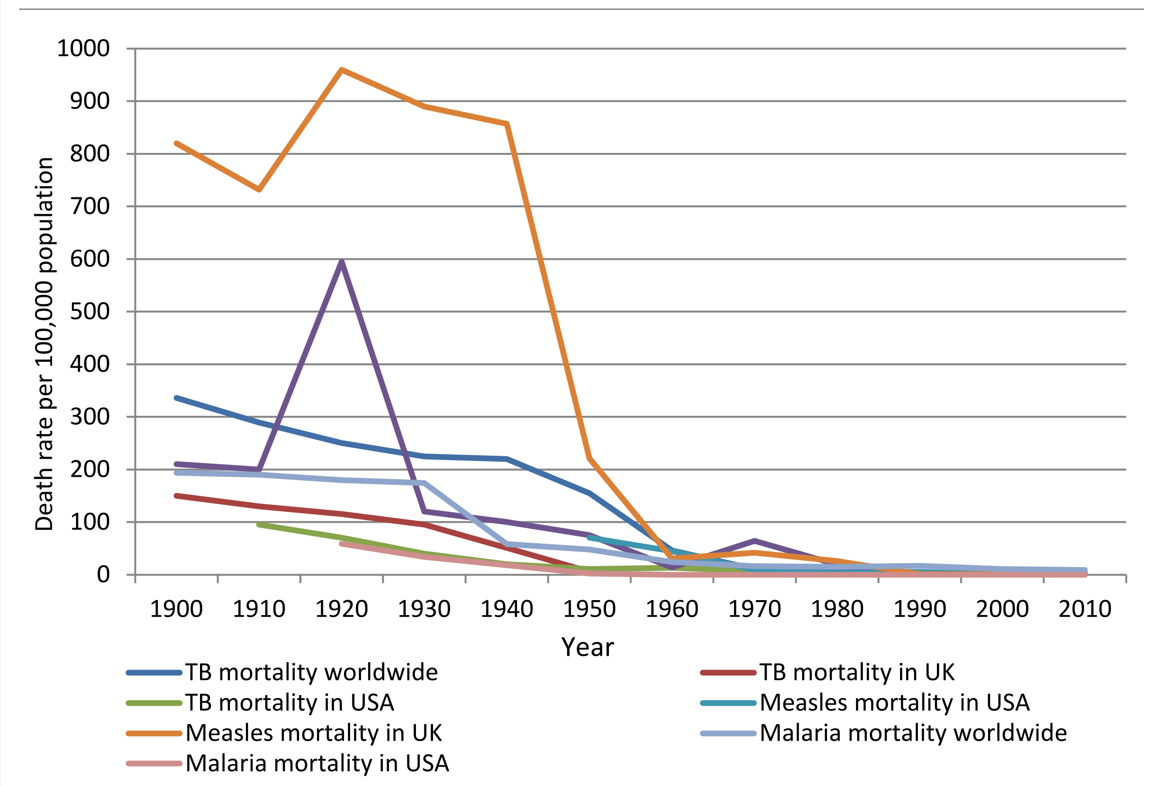


Figure 1.3: Some examples of reduced communicable disease mortality in the period between 1900 and 2010.

Beside such medical improvement, however, some communicable diseases and especially vector-borne diseases remain a major health concern today as no vaccines against these diseases have been invented yet. Vector-borne diseases like Malaria, Leishmaniasis and Dengue still represent an important part of the global health burden. According to the WHO (2004), CIESIN [No date], CDC (2014b) and Lemon et al., 2008 between 3 and 5 million people die annually from such diseases and nearly 3.5 billion people are infected or in high danger of being infected with at least one type of these vector-borne diseases. Among vector-borne diseases, Malaria has been identified as the widest distributed disease affecting 106 countries and putting almost 3 billion people in danger of acquiring the disease. The exact number of Malaria deaths is unknown but it is estimated to be between 1.5 and 3 million people annually (CDC, 2014c; WHO, 1997; Nayyar et al., 2012). Leishmaniasis is suspected to be the second largest vector-borne disease killer globally after Malaria (Stauch et al., 2014; Momeni and Aminjavaheri, 1994; Kolaczinski et al., 2004). Leishmaniasis currently occurs in 88 countries with annual cases between 200,000 and 400,000 and it leads to the deaths of about 20,000 to 40,000 persons annually (Stauch et al., 2014; Alvar et al., 2012; WHO, 2014c; Silva et al., 2014).

Vector-borne diseases are very sensitive to climate conditions (WHO, [No date]b; Mondzozo et al., 2011). Most vectors that can transmit diseases such as mosquitoes and sandflies are very sensitive to climate conditions namely temperature, relative humidity and precipitation (Killick-Kendrick, 1999; WHO, 2014d; Boussaa et al., 2005). Although climate is only one of many factors influencing diseases, health specialist and public health policy makers are very concerned and worried about the possible impact of climate changes upon diseases including vector-borne diseases (Thomson et al., 2011). Climate change has been an issue since the middle of the 20th Century when the temperature of the earth's atmosphere started rising due to the dramatic increase in the amount of greenhouse gas emissions (Shuman, 2011; Khasnis and Nettleman, 2005; Meteorological Office, 2014).

As a result of climate change, the Intergovernmental Panel on Climate Change (IPCC) has estimated in its Fifth Assessment Report in 2013 that the average global temperature will rise between 3.5°C and 4.0°C by the end of the 21st Century if the amounts of greenhouses emissions remain at the same current level (IPCC, 2013). This temperature rise is going to increase the likelihood of the prevalence of many vector-borne diseases globally. The anticipated temporal and spatial changes in temperature, relative humidity and precipitation are expected to affect the biology and the ecology of disease vectors as well as the intermediate hosts and consequently the risk of vector-borne disease transmission (Patz, et al., 2000; Ready, 2008; Githeko et al., 2000). Even though disease vectors can regulate their internal temperature by adapting their behaviours, they cannot alter their development stages in the same manner and are so significantly dependent for their survival on climate (Lindsay and Birley, 1996; Githeko et al., 2000). In addition, climate change is more likely to affect some socio-economic aspects of people's lives such as changes in their activities, occupations which might bring them in contact with disease vectors as well as forcing some people to migrate to probable endemic areas for vector-borne diseases (IPCC, 2001; IOM, 2008; Spencer, 2006). As climate, vector ecology and socio-economic factors vary from one country to another as well as within them, there is a real need for more studies of regional rather than global scope to understand the possible influence of climate change upon some vector-borne diseases (Hiwat and Bretas, 2011; Kovats et al., 2005; Parry et al., 2004).

Among vector-borne diseases, Leishmaniasis is a very important disease in many parts of the world. Leishmania parasites are the etiological agents caused by a group of protozoan diseases that are transmitted to mammals including humans by the bite of an infected phlebotomine female sandfly (Roscoe, 2009; Ryan et al., 2006; Lima et al., 2002). It is estimated that 1.5 to 2 million new leishmaniasis cases and 70,000 deaths occur globally every year; 350 million people are thought to be at risk of infection and developing the disease (García et al., 2009; Croft et al., 2006).

Leishmaniasis is characterised by a spectrum of clinical manifestations from minor, self-healing skin ulcers to severe disfigurement and, in rare instances, death (Claborn et al., 2008). The clinical spectrum observed in patients reflects the complexity of the disease epizoology. Many Leishmania species can cause the disease and many different species of sandflies and mammals have been identified as Leishmaniasis disease vectors and reservoirs respectively.

The importance of the disease is more likely to increase in the future under the influence of climate change and it may spread into new areas that are currently free of the disease. Leishmaniasis has been identified by the WHO as well as other researchers as one of the communicable diseases that has been neglected and is as not well understood as other similar vector-borne diseases like Malaria in terms of its epidemiology and vector ecology (WHO, 2013b; CDC, 2013a; Dujardin et al., 2008; Guerin et al., 2002; Desjeux, 2004; Hotez, 2013; Balasegaram et al., 2008). So, as a result of a belief in the importance of Leishmaniasis as well as the fact that not much is known about the disease, it was selected to be the focus of this study. The Kingdom of Saudi Arabia (KSA) (the origin country of the author) has been described by the WHO as one of highest endemic countries for Cutaneous Leishmaniasis (CL) (WHO, 2013c). The Ministry of Health in KSA and policy makers have been paying more attention to Leishmaniasis in recent years aiming to eradicate or at least reduce its danger in the health burden. Therefore, KSA was selected to be the study region, with the broad aim of contributing to health authority and policy maker requirements by looking at the disease from a multidisciplinary perspective encompassing vectors, intermediate hosts, local environment and socio-economic factors. The main aim of the study was therefore to better understand the risk factors associated with the prevalence of CL in one region of KSA (Al-Dawadmi Governorate) and to provide insights that could inform public health strategies.

1.3. Disciplinary Positioning:

Having identified the subject area of the thesis it is also important to clarify the disciplinary perspective from which it is being undertaken. This disciplinary perspective is one of health geography. The idea that the local environment has an impact upon human's health has been around for centuries since the time of Hippocrates, the Ancient Greek scholar in the period between the 4th and the 3rd centuries BC. In Hippocrates medical theory: *'On Airs, Waters, and Places'* local environments were found to affect human health (Ferrari, 1990, p 16). After Hippocrates, subsequent civilisations extended and developed their knowledge and understanding about the associations between the local environment and health. For instance, Roman aristocrats realised that there was a strong association between the increase in temperature during summer and the occurrence of Malaria. Therefore, they used to spend their summers in cooler areas up hills to avoid mosquitoes and so Malaria (Patz et al., [no data]; NRC, 2001; WHO, 2014).

Such an environmental association has been identified on many occasions by investigations of geographical variations, and nowhere more obviously than in the case of Dr. John Snow who did a classic piece of medical geography research during a 1854 Cholera outbreak in the Soho district of London. During that outbreak approximately 600 people died in less than 10 days. Dr. Snow knew that to contain the disease there was a primary need to identify the source of infections. He created a map showing the homes of people dying from Cholera as well as the location of water pumps. By using such approach, Snow was able to show that use of one water pump – the public pump in Broad Street – was the main cause for most deaths (McLeod, 2000; Philo, 1995).

The term ‘Medical Geography’ was first used at the International Geographical Union (IGU) Congress in Washington, USA in 1952 (Pacholi, 1993). The use of the term and the development of the subject area has expanded substantially since then. Medical geography is a branch of applied geography, that studies the spatial and temporal pattern of phenomena related to health as well as health care, and investigates the association with the local environment or any other factors (Stimson, 1981, cited in Annimer, 1992; Meade et al 1988; Phillips, 1981). A definition of medical geography was given by Ricketts, et al. (1994 pp. 321-322) as:

‘’Both an ancient perspective and relatively new specialty, using the graphical techniques and tools of geography to analyse health care issues. It encompasses health issues related to the spatial variation of resources as well as disease ecology’’.

As with the discipline of geography itself, studies in medical geography often draw upon insights from a number of other disciplines including medicine, sociology, epidemiology, economics, anthropology, and politics (Coombes, 1993; Ricketts, 1994). As a result, research in medical geography may require the simultaneous consideration of a range of variables for one or more spatial units, geographical area being the item of common interest. In this sense, the geographical area can be considered as a common link between all the other disciplines (Twigg, 1992).

Jones and Moon (1987) and Mayer (1981) suggested that medical geography in general splits into two main streams. The focuses on the geographical explanation of disease existence and distribution (i.e. why does this diseases exist in this area and not in that area). The second stream examines the geography of healthcare services in terms of their provision, availability, utilization and spatial accessibility. Smith (1986) stated that ‘’*the distinction between the study of health status and the provision of health care remains clear enough for them to be considered separately*’’ (Smith in Johnston et al., 1986 p 293). However, it is now arguable that it is no longer so common to separate these two streams due to the changes in the methodological frameworks used within geographical studies (Coombes, 1993, Philo, 1995).

Up until the early 1980s most medical geography studies used quantitative approaches (Curson, 1984). Since then there has been a growing emphasis on matters of health care services which rely mainly on qualitative methods. Notable studies were carried out by Donovan (1986) and Cornwell (1984) using an ethnographical approach which was described as a major breakthrough in terms of advancing medical geography as a discipline (Coombes, 1993). Such ethnographic studies answered the pleas from Jones and Moon (1987) and Eyles and Woods (1983) for a more comprehensive investigation of health within the wider totality of society.

Associated with this change in perspective has been a tendency for the term health geography to become more widely used than medical geography. This shift is complementary to changes in direction within public health, in that the new public health also has its focus on the totality of health and society including the economic, political, social and physical environments (Coombes, 1993). Many geographical studies nowadays look at spatial aspects of health from such a broad multidisciplinary perspective, including the use of both quantitative and qualitative methods, and this is the kind of approach that is going to be adopted in this thesis.

1.4. Thesis Structure:

This section provides an outline of the thesis contents. Chapter 1 has provided an overall background on infectious diseases and their importance to health. Climate and climate change have been described and the reasons for focusing on vector borne diseases, more precisely CL, have been discussed. Chapter 2 reviews the important literature related to the main aims of this thesis. This includes general background on Leishmaniasis, climatic influences upon the disease, socio-economic and demographic variables associated with the disease, prevention, control and reporting issues ending up by stating the main research questions.

Chapter 3 introduces the country of the study, Saudi Arabia, including information on topography, climate, vegetation, economic development, agriculture, demography and health status. This chapter ends by justifying the selection of Al-Dawadmi Governorate as the main focus of the study and provides some general background about the governorate. Chapter 4 presents the fieldwork methodology including the selection of communities within Al-Dawadmi Governorate, data sources and field data collection.

In this thesis, there are four main empirical chapters; 5, 6, 7, and 8 which will examine the prevalence of CL in Al-Dawadmi Governorate from different perspectives. Chapter 5 investigates the influence of climate variables upon the prevalence of CL in the study area. Chapter 6 examines the association between the prevalence of CL in the selected communities and the surrounding land uses and covers, highlighting the most risky areas and the critical distances from them. Chapter 7 uses a case-control approach to analyse human characteristics that may affect CL transmission and then draws upon land use findings from Chapter 6 in a multi-variate modelling framework that aims to provide a better understanding of the disease epidemiology in Al-Dawadmi Governorate. Chapter 8 considers the issue of under-reporting of CL exposure in the study area and highlights the main barriers that have prevented people reporting their exposures to the health authority.

Chapter 9 summarizes the main findings from the four analytical chapters (5 to 8), and discusses conclusions in relation to the overall aims of the study. This chapter then discuss the public health implications, limitations of the research and suggestions regarding future work.

Chapter Two: Literature Review:

2.1. Chapter Overview:

Chapter 1 explained the importance of Leishmaniasis as a public health issue in many parts of the world, including Saudi Arabia. The purpose of this chapter is to discuss in more detail what is known about the transmission, epidemiology, protection, treatment and recording of Leishmaniasis in order to identify the key factors requiring further research. Therefore, this chapter is organised in the following way. It starts with some general background, moving on to the epidemiology of Leishmaniasis, followed by environmental and socio-economic factors influencing the risk of contracting Leishmaniasis. After that, methods of preventing and treating Leishmaniasis will be reviewed as well as factors influencing the reporting of the disease. Insights from these reviews then lead to restatement of the research problem and identification of the key questions.

2.2. General Background:

In this section a general background on Leishmaniasis history, transmission, lifecycle, typology and geographical distribution will be presented.

2.2.1. History of Leishmaniasis:

Leishmaniasis has a very long history and descriptions of conspicuous lesions consistent with the disease have been recorded on tablets in the library of King Ashurbanipal from the 7th Century B.C, some of which might have been derived from previous text from 1500 to 2500 B.C (Cox, 2002). In the 10th Century, Muslim physicians such as Avicenna described precisely the lesions and symptoms of what was called “Balkh sore” in north Afghanistan, and there are later records for various names for Leishmaniasis from different civilisations such as “Delhi boil" in India and "Baghdad boil" in Iraq (Khan and Muneeb, 2005; Budd, 1857). Incan text and the accounts of Spanish conquistadors in the 15th and the 16th Centuries mentioned the presence of skin lesions on agriculture workers returning from the Andes (Stanford University, [No date]a). One of the earliest most detailed clinical descriptions of CL was given by Alexander Russell after examining a Turkish patient in 1756 (Russell, 1756). Old World Visceral Leishmaniasis, which is also called “kālā āzār” or “Black fever” was first distinguished from similar diseases like Malaria in 1824 in Jessore, India (Elliott, 1863).

Until now, who first discovered the organism of Leishmaniasis remains unclear. Surgeon Major Cunningham of the British Indian Army noted it in 1885 but he was not able to relate it to the disease (Cox, 2002). A Russian military surgeon named Peter Borovsky who served in Tashkent, Uzbekistan, undertook research on the aetiology of oriental sores and published his findings in 1898. His findings have been described as the earliest, most accurate, description of the causative agent, vector and protozoa. Yet, Borovsky’s findings were published in a low circulation journal as well as in the Russian language leading them to not being widely known (Hoare, 1938). In 1901, William Leishman who was a Scottish army doctor, recognized the specific organism in smears taken from a dead patent’s spleen who suffered from Dum Dum fever. In the same year (1901) Captain Charles Donovan took smears from another patient in Madras, India, and found the same findings as Leishman did. These findings were known later as Leishman-Donovan (Kean et al., 1978). At that stage, the vector of CL was unknown and the researchers could not identify it until 1921 when the Sergeant brothers Eduard and Etienne completed an experimental proof of CL transmission to human by sandflies belonging to the genus *Phlebotomus* (Parrott et al., 1921). Over recent decades the complex patterns of the Leishmaniasis parasite, vectors, reservoirs and habitats have been studied by many researchers such as Lainson and Shaw, 1987; Farrell, 2002; Myler and Fasel, 2008.

2.2.2. *Leishmania* Transmission and Lifecycle:

The *Leishmania* parasite alternates between insect and vertebrate hosts, with interspecies transmission occurring through the female sandfly bite (Mittra and Andrews, 2013; Dossin et al., 2008). It is either zoonotic or anthroponotic depending on the species of *Leishmania* parasites involved. The lifecycle of *Leishmania* includes insect (sandflies) and vertebrate phases as shown in Figure 2.1. The cycle starts when the infected female sandfly sucks a blood meal from an animal or a person and injects the promastigote stage into the body (stage 1), which invades local or recruited host cells, mainly macrophages (stage 2). Promastigotes transform into amastigotes inside macrophages (stage 3). Amastigotes multiply in infected cells and affect different tissues, depending on which *Leishmania* species are involved (stage 4). An uninfected sandfly takes its blood meal from an infected host with amastigotes which are ingested and consequentially the sandfly becomes infected as well (stages 5 and 6). In the sandfly's midgut, the parasites separate into Promastigotes (stage 7). These promastigotes migrate to the proboscis (stage 8) and so the cycle starts again.

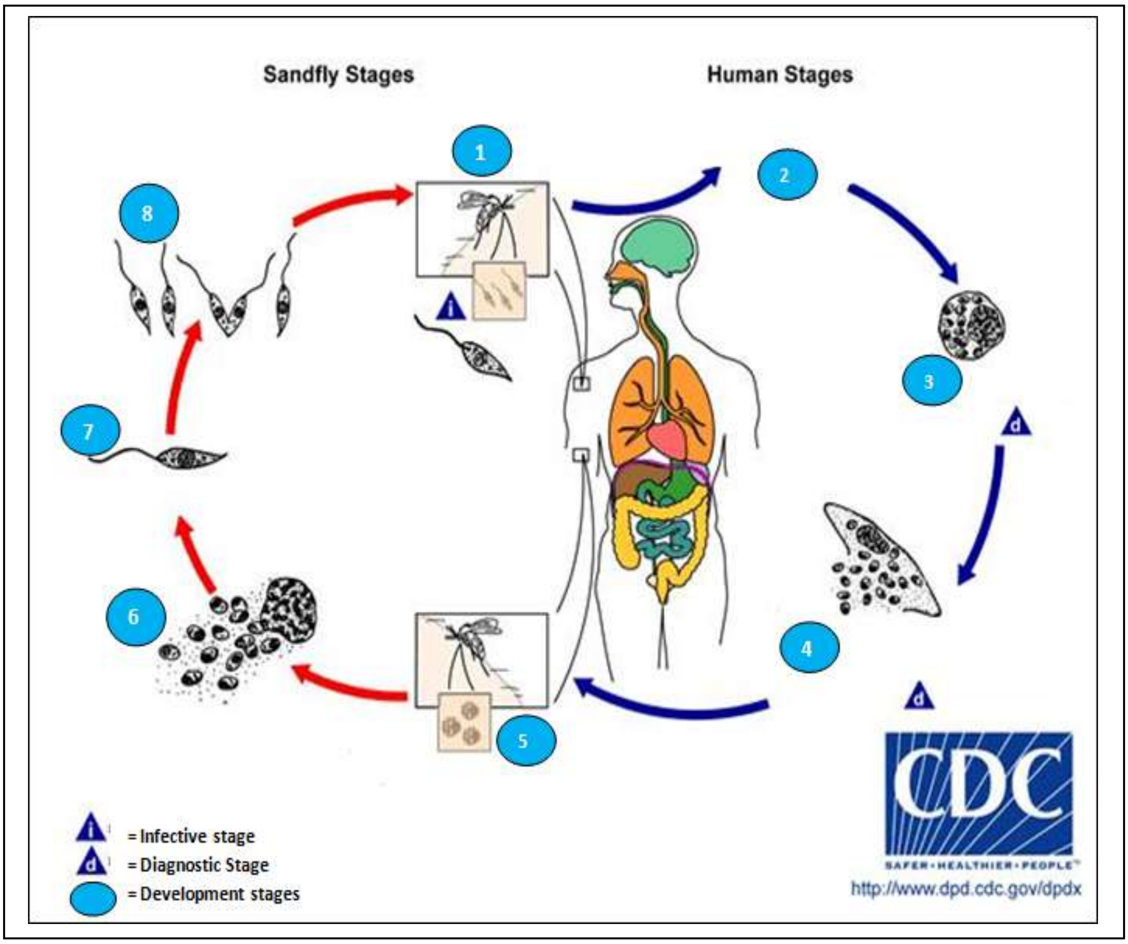


Figure 2.1: Leishmania lifecycle (adapted from CDC, 2013b)

2.2.3. Principal Types of Leishmaniasis:

Generally speaking, there are at least twenty species of *Leishmania* parasites infecting humans with unique characteristics and symptoms for each species (De Long and Burkhart, 2013; WHO, 2014c). There are main four forms of Leishmaniasis caused by the *Leishmania* parasites which are: Visceral (VL), Cutaneous (CL), Diffuse Cutaneous (DCL) and Mucocutaneous Leishmaniasis (MCL). All these types occur in both the Old and New Worlds and are caused by different species of parasite as summarised in Table 2.1 (Philadelphia et al., 2006; CDC, 2014d; Mahboudi et al., 2002; González et al., 2008).

Table 2.1: Leishmaniasis types and responsible parasite species

Leishmaniasis	Old World Parasite	New World Parasite
Visceral (VL)	*L. donovani* *L. infantum* *L. tropica*	*L. chagasi* *L. amazonensis*
Cutaneous (CL)	*L. tropica* *L. major* *L. aethiopica*	*L. brazilinsis braziliensis* *L. braziliansis panamensis* *L. braziliansis guyanebsis* *L. mexicana* *L. maxicana amazonensis* *L. mexicana venezuelensis* *L. mexicana garnhami* *L. peruoiana* *L. Mexicana pifanio.*
Diffuse Cutaneous (DCL)	*L. aethiopica*	*L. venezuelensis* *L. amazonensis* *L. mexicana*
Mucocutaneous (MCL)	*L. donovani.* *L. infantum* *L. major.*	*L. braziliensis* *L. guyanensis*

VL has been classified as the most severe type of Leishmaniasis and often causes death if not treated quickly and successfully (Chappuis et al., 2007). It has an extremely devastating effect on many inner parts of the body and the major symptoms are enlargement in the spleen and liver, dramatic weight loss, change in the skin colour, anaemia and pancytopenia (see Figure 2.2 A) (Desjeux, 2004; Magill, 2000). This type is found in the dry regions of the Mediterranean and South America, east Africa, China, the Indian subcontinent, and some parts of the Middle East (Fernando et al., 2001). CL is the most common form of Leishmaniasis causing lesions on the exposed parts of the body. It is a self-healing disease and the infection often clears within a few months leaving permanent scarring (see Figure 2.2 B). CL is mostly common in dry regions in India, Afghanistan, Mediterranean coasts, central Asia (former Soviet Union), Middle East and South America (Nimri et al, 2002; WHO, 2014e). In MCL, the parasite infection can lead to part or total destruction of the mucous membranes of the nose, mouth and throat cavities which can be severely disfiguring. This type of Leishmaniasis has been considered as chronic, not self-healing and difficult to treat as well as leading to the sufferer being rejected by his / her community (see Figure 2.2 C) (WHO, 2014f; Desjeux, 2004). The last known type of Leishmaniasis is DCL which is also an infection on the skin, but ulcers are widely spread over the whole body and it not as obviously ulcerating as CL (see Figure 2.2 D). This type has also been considered as chronic, not self-healing and difficult to treat (Ibid). Both MCL and DCL are common in the central and south parts of South America (Magill, 2000).

Figure 2.2: Leishmaniasis symptoms and ulcer types.
A) VL symptoms (Fairlamb, 2012), **B)** CL ulcer (Armed Forces Pest Management Board, 2014), **C)** MCL ulcer (Stanford University, [No date] b), **D)** DCL ulcers (Calvopina, 2006)

2.2.4. Geographical Distributions:

Leishmaniasis is a global disease, currently known to be affecting 88 countries: 72 are developing and 16 developed countries (Figure 2.3). According to the WHO (2013c) and El-Beshbishy and others (2013) 90% of CL cases occur in Afghanistan, Algeria, Brazil, Iran, Peru and Saudi Arabia, while 90% of VL cases occur in Bangladesh, India, Nepal, Sudan and Brazil (Figure 2.4). Although sandflies are principally found in the warm parts of the world, their distribution extends northwards to just above the latitude 50°N in south west Canada, and their southern distribution reaches about latitude 40°S (Killick-Kindrick, 1999). Additionally, their altitudinal distribution is from below sea level by the Dead Sea in Jordan up to 3300 metres above sea level in Afghanistan (Ibid).

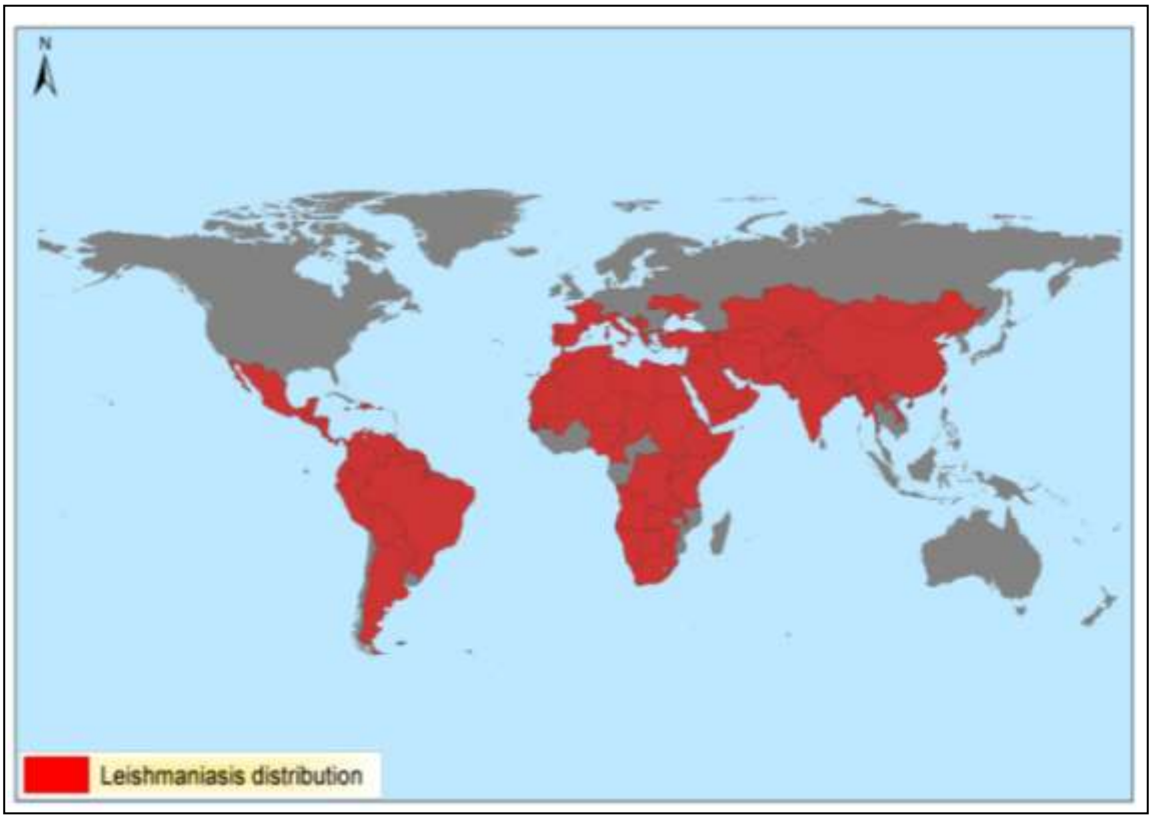


Figure 2.3: Leishmaniasis geographical distribution (adapted from WHO, 2010a)

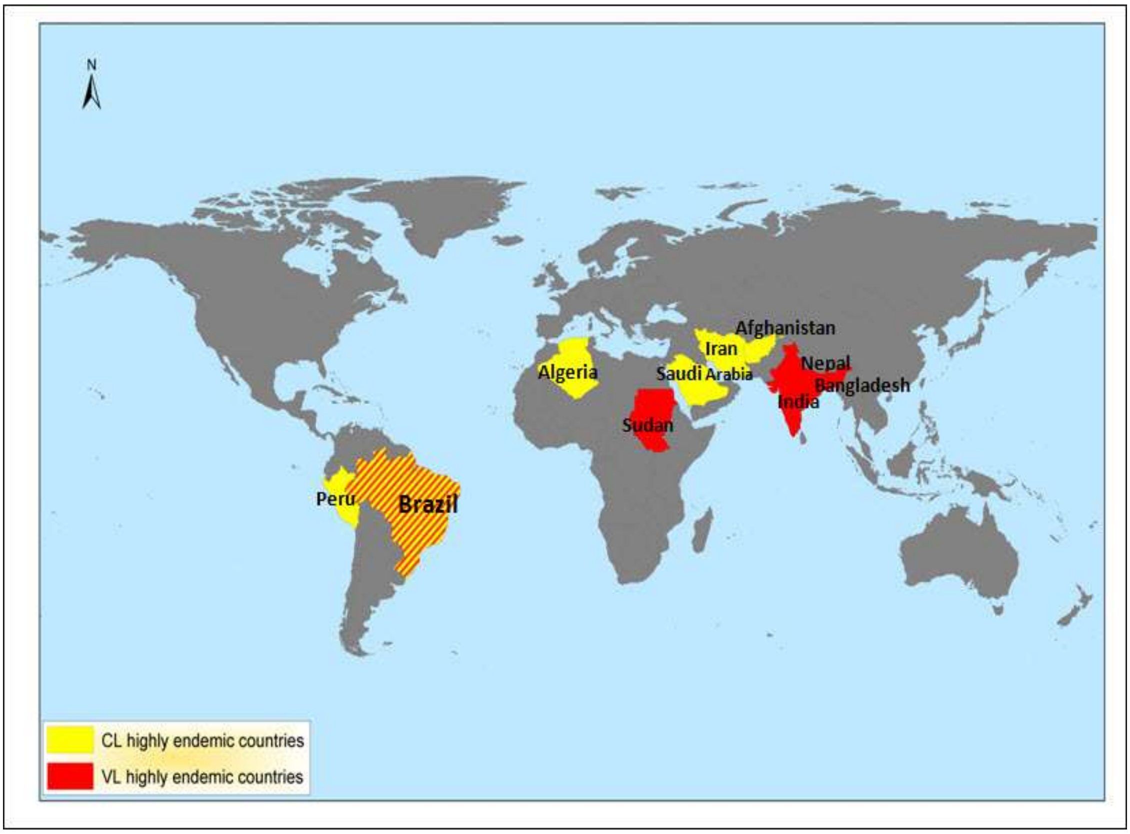


Figure 2.4: CL and VL highly endemic countries (adapted from WHO, 2010a)
** Note: Brazil is an endemic country for both CL and VL

So, from the above review, it is apparent that Leishmaniasis in its four forms (VL, CL, MCL, and DCL) is a widely distributed disease and affects enormous numbers of countries mostly in tropical and sub-tropical regions. However, the majority of cases are more geographically concentrated as 90% of VL cases (the most severe form of Leishmaniasis) occur in five countries. Similarly, 90% of CL cases (the most common type of Leishmaniasis) occur in six countries, one of which is Saudi Arabia, the focus of this study.

2.3. The Epidemiology of Leishmaniasis:

In this section, the preferred resting and breeding habitats of the Leishmaniasis vector (sandflies) and the parasite reservoirs as reported in the research literature will be reviewed.

2.3.1. Leishmaniasis Vector:

All types of Leishmaniasis are transmitted by blood sucker female sandflies belonging to the order Dipra: Psychodidae: *Phlebotominae*. More than 700 sandfly species have been described and classified in six genera (Lane, 1993; Adler and Theodor, 1957), three of these genera have been found in the New World (*Warileya, Lutzomyia* and *Brumptomyia*) and three (*Phlebotomus*, *Chinius* and *Sergentomyia*) in the Old World (Killick-Kendrick, 1990, Killick-Kendrick 1999). Of these six genera, only *Lutzomyiah* and *Phlebotomus* are responsible for *Leishmania* transmission. Nevertheless, in exceptional cases, *leishmania* can be transmitted without these genera, for instance on rare occasions by accidental laboratory infection or blood transfusion (Roscoe, 2009). According to Killick-Kendrick (1990) and Young and Arias (1991), 88 species of *Lutzomyiah* and 39 of *Phlebotomus* have been confirmed as *Leishmania* vector transmitters. Sandfly distributions vary between the New and Old World. In the New World the distribution of sandflies is generally associated with rainforests, whilst in the Old World it is open arid and semi-arid areas (Gossage, 2004). So, sandflies are able to find suitable habitats in arid, semi-arid areas (such as wall cracks and rodent burrows) as well as in rainforests (e.g. in tree trunk holes or leaf litter).

Sandflies are very small in size as an adult is between 1.3 and 3.5 mm in length with brown to black colour. They are characterised by their dense hairy wings which are held in an erect V shape over the body (see Figure 2.5) (Lane, 2003). Male and female sandflies can be distinguished by the prominent pair of claspers at the end of the male abdomen (Gossage, 2004) whereas for the female the mouthparts are modified to cut the skin of vertebrates (Ibid; Lewis, 1975). Sandflies breed in dark and wet areas with a source of organic matter such as rodent burrows and leaf litter. The female sandfly is the only transmitter for the *Leishmania* parasite as they feed on blood meals from vertebrates as a protein source for egg development as well as on plant juices, sap and honeydew. The male sandfly feeds on plant juices, sap and honeydew but not blood meals (Schlein et al., 2001; Young and Fairchild, 1974; Schlein and Muller, 1995).

Figure 2.5: A tiny adult sandfly on a person's thumb (LSTM, [No date])

Sandflies hop rather than fly and the hopping travel distance from breeding and resting areas varies depending on sandfly species, gender and local environments. Sandflies can be classified in terms of their travelling distance into two classes: New World and Old World species. In many studies, the Old World species have been found travelling for longer distances than the New World species which is probably related to the local habitats. Additionally, female sandflies have been found travelling for longer distances than males which is perhaps due to their larger search areas for blood meals (Connelly, 2005). Table 2.2 lists some of the travel distances found for sandfly species in different parts of the world.

Table 2.2: Reported sandfly travelling distances from resting and breeding sites:

Distance sandflies can travel from their breeding and resting habitat	Sandfly species (if specified)	Study country/region	Author/s
Less than 50 m	Not specified	Maharashtra, India	The Public Health Department, Government of Maharashtra, [No date]
70 m and not farther than 128 m	Lutzomyia species	Southeaster Brazil	Casanova et al., 2005
20,000 flies were marked and released, 90% were recaptured within 57m. The maximum distance was 200 m and only 4 sandflies were recaptured there.	Phlebotomines Species	Panamanian rain forest, South America	Byron et al., 1974
Up to 100 m	Not specified	Central Europe	Department of Defence USA, 2001
Between 100-200 m	Lutzomyia species	South America	Braverman, 1994
Less than 200 m	Lutzomyia species	Neotropical forests, north of Brazil	Chaniotis et al., 1974; Morrison et al., 1993
Less than 200 m in a single night	L. shannoni	Colombia	Alexander, 1987
Up to 200 m	Not specified	New world	Chaniotis et al., 1974; Alexander, 1987; Morrison et al., 1993; Casanova et al., 1995
Up to 200 m	Lutzomyia species	Colombia and South American rain forest	Chaniotis et al., 1974; Alexnder and Young 1992
Used a sandfly recapturing method for 2,208 sandflies. 1082 sandflies were recaptured within 50 m, 1060 within 50-100 m and 66 further than 500 m	Lutzomyia species	El Callejon, Colombia	Morrison et al., 1993
A total of 4337 sandflies were released Almost all of them were recaptured within 110 m. One was recaptured approximately 250 m away and another nearly 520 m from the release point.	P.nyssomyia intermedia & P.nyssomyia neivai	Sao Paulo, Brazil	Galati et al., 2009
Between 500 and 700 m	L. longipalpis	Colombia and Brazil	Dye et al., 1991
Less than 1000 m	Phlebotomus species	Sudan	Quate, 1964
Up to 1000 m	P. sergentomyia	Kenya	Mutinga et al., 1992
More than 1000 m	Phlebotomus species	Israel	Faiman et al., 2011
Up to 1500 m	Phlebotomus species	Arid and semi-arid areas	Alexander, 1992
Up to 1500 m	Arid and semi-arid regions' sandflies	Old world	Killick-Kendrick et al., 1984; Doha et al., 1991; Casanova et al., 2005
Up to 1500 m	Phlebotomines Species	Saudi Arabia	Lewis and Büttiker,1980; Büttiker and Lewis, 1983
Up to 1500 m	P. papatasi	Tunisia	Ben saleh et al., 2000
Can reach more than 1500 m	P. papatasi	Not specified	Braverman, 1994
1000 m for male sandfly 2000 m for female sandfly	Phlebotomus species	Not specified	Connelly, 2005
Up to 2300 m	Phlebotomus species	Arid and semi-arid regions	Killick-Kendrick, 1977 ; Wallace et al., 1979
Up to 2300 m	P.ariasi	France	Killick-Kendrick et al., 1984

Most commonly, female sandflies have been found breeding in areas like rodents' burrows, wall cracks, animal shelters and in household waste disposal areas. Such environments provide the organic matter, heat and humidity which are required for sandfly egg development stages (WHO, 2006). The development of sandflies can be classified into four main stages: egg, larvae, pupae and adult. Female sandflies lay between 80 and 100 eggs of average size of 0.3-0.4 mm (Shevchenko, 1929; Shevchenko, 1930; Ferro et al., 1998) on various moist surfaces which hatch on average in one to two weeks unless the temperature is low (Volf and Volfova, 2011). After hatching, larvae feed on the surrounding organic matters for a period of about two weeks. Subsequently, the sandflies move into a pupae phase and start transforming into a caterpillar with growth in wings and eyes. After approximately five to ten days, the adult sandfly emerges and is all ready to bite (Perfil'ev, 1968). Adult female sandflies generally bite between dusk and dawn when they are most active, but can also do so during daytime if disturbed in their resting areas (CDC, 2013c). CL infection typically develops weeks or even months after the bite occurs. With VL it can take months or even years for the infection to develop (Ibid).

2.3.2. Sandfly Breeding and Resting Habitats:

Many chemical factors have been found to control where gravid female insects choose as resting and egg laying sites (Bentley and Day, 1989). In the case of sandflies, however, little is known about the factors that attract and stimulate female sandflies to lay their eggs (Wasserberg and Rowton, 2011). The main factor appears to be the availability of organic matter (Yatich, 1987). In the literature, a number of studies have identified particular habitats which sandflies use for rest or breeding. Schlein et al. (1990) ran a laboratory experiment on *P.papatasi* females and found that they were significantly attracted to livestock faeces. Another study by El Naiem and Ward (1990) reported that rabbit burrows and faeces were preferable habitat for *L.longiplpis*. Dhiman et al. (1983) found sandfly larvae in decaying organic materials around livestock shelters in India. The larvae were within 5 cm of the ground in locations which had fairly high relative humidity. Other studies have also found strong associations between *Phlebotmous* and *Lutzomyia* sandflies and livestock shelters and troughs in different parts of the world (e.g. Alexander, 2000; Ximenes et al., 1999; Dye et al., 1991; Quinnell and Dye, 1994; Kelly and Dye, 1997).

Low humidity, high temperatures and aquatic conditions lead to larvae death making such environments are unfavourable for sandflies. Therefore, female sandflies tend to rest and breed in areas with high relative humidity such as river banks or close to water tanks (Yatich, 1987). Mukhopadhyay et al. (1990) did a study in Bihar, India and found that river banks were preferable habitat for sandflies to rest and breed as well as finding large numbers of larvae in such sites. Chaniotis and Tselentis (1996) studied 79 water wells in Greece and found that 37 of them harboured sandflies. Likewise, Sangiorgi et al. (2012) studied possible habitats for *Phlebotomine* sandflies in Bahia State, Brazil. Their results indicated that the highest density of sandflies was collected from sites close to water tanks.

Other studies have noted rodent burrows and rock cracks as preferable habitats for sandflies. Petrisheva and Izyamkaya (1941) found massive numbers of sandfly eggs after sifting through approximately 1050 kg of soil taken from rodent burrows and crevices in rocks in Sebastopol, Ukraine. Mutinga and Kamau (1986) also sifted soil from different sites from Marigat region, Kenya aiming to locate *Phlebotmous martini* sandflies' breeding sites. Their results indicated that sandfly eggs and larvae were only found in samples from rodent burrows and termite hills.

Other environments that have been found attracting sandflies to rest and breed are construction and house waste sites (WHO, 2014c; Mackay Regional Council and Reef Catchments, 2013). Such sites provide organic material for adult sandflies and their larvae, as well as rodents which represent a main blood source. A study in Spain by Najera (1964) concluded that house waste is preferable breeding habitat for sandflies after finding many larvae in collected house waste in Madrid. Additionally, Tayeh et al. (1997) linked the poor waste disposal system and the existence of construction waste heaps to the occurrence of rodents, adult and larvae sandflies in Aleppo, Syria.

Abandoned or mud houses have been also identified in many studies as preferred habitats for sandflies and rodents. Such areas provide shelters for rodents and walls full of cool cracks and organic material for sandflies to rest and breed. A report by Rozendaal and WHO (1997) found a strong association between cracked walls and mud houses with the prevalence and density of sandflies in Africa. Likewise, a research in Thailand by Kanjanopas et al. (2013) and in India by Kaul (1991) found there was a very strong association between the number of Leishmaniasis cases and the existence of abandoned houses in nearby areas.

In addition, strong relationships have been found between Leishmaniasis and vegetation including all Leishmaniasis cycle elements; male sandflies, female sandflies and reservoirs. While female sandflies depend mostly on blood meals for their survival, males depend mainly on soft stemmed edible plants as a source of dietary sugar which means that they are tied in their existence to vegetation cover (Wasserberg et al., 2003; Ben Salah et al., 2000; Thompson et al., 2002). The consequence of this need is that female sandfly occurrence is also influenced by that of males in terms of mating and breeding. Another aspect of this relationship is that rodents dig their burrows mostly next to vegetation for food, shading and protection. This also affects the distribution of female sandflies because they live in a strong ecological association with their reservoirs (Ashford, 1996; Saliba and Oumwish, 1999; Wasserberg et al., 2003). Many other studies from different parts of the world have confirmed the strong association between vegetation distributions, the occurrence and density of sandflies and thus Leishmaniasis (Zijlstra and El-Hassan., 2001; Killick-Kenderick & Killick-Kenderick, 1987; Schlein and Jackobson, 1999; Alexander et al., 2001; Sanchez-Tejeda et al., 2001; Quintana et al., 2010; Duque et al., 2004).

2.3.3. *Leishmania* Parasite Reservoirs:

Broadly speaking, there are two main types of Leishmaniasis: (1) zoonotic Leishmaniasis where the reservoirs are either wild or domestic animals and (2) anthroponotic Leishmaniasis in which reservoirs are human (WHO, 1990). Considering zoonotic Leishmaniasis, the animal reservoirs differ according to the type of *Leishmania* species and geographic location. Dogs, foxes, other canines and rodents are the most common reservoirs (Acha, 1989; Despommier et al., 1994; Wallace and Killick-Kendrick, 1987; Markell, 1999; WHO, 1991). However, other animals in areas where sandflies are prevalent may also be involved in the epidemiology of Leishmaniasis and these are referred to as secondary or incidental reservoirs (Garner and Saville, [No date]). So far, neither birds nor amphibians have been reported in any study as having the *Leishmania* parasite (Montoya-Leram, 1996). With anthroponotic Leishmaniasis, humans are directly involved in the disease transmission as reservoirs in two forms: VL caused by *L.donovani* and CL caused by *L. tropica* (CDC, 2014e; Siriwardana et al., 2007).

Additionally, humans have played a reservoir role in some Leishmaniasis outbreaks caused by *L.braziliansis* and *L.panamensis* (WHO, 2010b).

From the above literature review above it can be concluded that sandflies exist in many parts of the world and live in various types of environments varying from arid and semi-arid regions in the Old World (e.g. Saudi Arabia) to rainforest sites such as in most parts of South America. Even though there are still gaps in knowledge about sandfly resting and breeding habitats, many key habitat associations have been identified and can be used to highlight risk areas as well as providing a solid platform for future research (Wasserberg and Rowton, 2011). Other points that need to be considered in highlighting risk areas are sandfly travel distances and the different *Leishmania* parasite reservoirs. Better understanding of these aspects would help reduce the prevalence of the disease.

2.4. Climate Factors Influencing Leishmaniasis:

It is widely recognised that there is a very strong association between climate conditions and many vector-borne diseases as discussed earlier in Chapter 1. Magill et al. (2000) found that changes in temperature play a vital part in vector-borne diseases and vector distributions, feeding and biting behaviour. Leishmaniasis is known to be a very climate-sensitive disease (Killick-Kendrick, 1999; WHO, 2014c). In the literature, there are only a few studies that have investigated the direct impacts of climate upon Leishmaniasis. Nevertheless, strong evidence has been found of associations between temperature, rainfall, relative humidity and Leishmaniasis prevalence (Chaves and Pascual, 2006; Boussaa et al., 2005; Cardenas et al., 2006; Salomón et al., 2012).

A study by Cross and Hyams (1996) in southwest Asia highlighted climate conditions as one of the most important factors in the prevalence of CL. They also stated that temperature and relative humidity were significant influences on the sandfly life cycle and development, as the larvae are very sensitive to high temperature and low humidity and die if the temperature is high and humidity is less than 33% (Silverman et al., 1981). Cross and Hyams (1996) did a laboratory temperature simulation test on adult sandflies and found that all of them died within two hours at temperatures above 40°C. They also stated that temperatures below 10°C are unfavourable for sandfly survival, but do not necessarily lead to the death of the larvae as they are able to become dormant until the suitable conditions return. Another study in South Africa by the Bounoua et al. (2013)

found that sandflies are most prevalent in areas where the temperature ranges between 16 and 27.5°C combined with a relative humidity of roughly 70% or more.

Singh (1999) studied the influence of temperature upon the occurrence of eight sandfly species in Rajasthan, India. These species were only found at temperatures ranging between 17 and 36°C, with the maximum occurrence of sandflies (39.5%) recorded at 32°C combined with relative humidity of 58%, and the lowest (1.2%) in January with an average temperature of 20.8°C and relative humidity of 46.3%. Between the eight species there were some variations in the optimum temperature. For instance, in the case of *P.papatasi* (the most dominant species) the optimum temperature was between 28 and 34°C. For *P.sergenti* it was between 31 and 33°C, for *S.punjabensis* it was between 27 and 34.4°C and for *S.christophersi* it was between 29 and 33.3°C. Two species were found to exist only in specific temperatures, namely *S.clydie* at 33°C and *S.eadithae* at 29.3°C.

Yaghoobi et al. (1999) investigated the association between sandfly occurrence and climate in Iran between May 1995 and May 1996. Their study reported that sandfly (*P.papatasi*) prevalence was highest between late April and October with two peaks in June and September. They also noted that there was a significant drop in the number of sandflies from the end of October through to March when the weather was colder and the rainy season starts. They suggested that cold weather delays sandfly development stages and rain destroys breeding sites (Hunter, 2003). A study in Colombia by Molina et al. (2007) assessed the associations between climate phenomenon and the prevalence of sandflies using regression modelling. Their results showed that there were strong positive associations between the prevalence of sandflies and rainfall (P = 0.001), maximum temperature (P = 0.003) and relative humidity (P = 0.002). Similar findings have been reported by many other studies; for instance, one in India found that sandflies existed only in areas with a temperature between 17 and 36°C and colder areas had no reported cases of Leishmaniasis (Boussaa et al., 2005).

Temperature and relative humidity have also been found to influence sandfly development stages. A laboratory study by Kasap and Alten (2005) in Turkey aimed to assess such influences. They used sandfly eggs from laboratory-reared colonies of *P.patasi* and exposed the eggs to six constant temperature regimes of 15, 18, 20, 25, 28 and 32°C for 14 hours a day with a relative humidity range between 65 and 75%. At 32°C the sandflies emerged within about 28 days, at 18°C it took approximately 245 days for the egg development to adult sandflies and no adult sandfly emergence was observed at 15°C. A similar study by Safyanova (1946) found the development stages for *P.papatasi* at temperatures between 25 and 28°C took 49 days, with a longer time of 84 days required at temperatures between 23 and 24°C. These findings are supported by other studies who have also found that as temperature decreases the length of time for sandfly development increases (Dryden, 1988; Dryden, 1993).

In addition, temperature controls seasonal and daily variations in sandfly activity. Boussaa et al. (2005) studied sandfly populations in Marrakech, Morocco, during the period between October 2002 and September 2003. Sandflies were active throughout the year but with two main periods in October to November and April to July. The temperature fluctuated between 23 and 36°C in the former and between 11 and 19°C in the latter. It was also concluded that there was higher sensitivity to temperature for male than female sandflies. A study in Asir region, Saudi Arabia by Faraj (2011) found that sandflies were only active between June and September and were significantly associated with temperature ($P < 0.001$).

With respect to daily activity cycles, sandflies tend to become active immediately after sunset when the weather becomes cooler in hot semi-arid areas, increase towards midnight and then start decreasing until totally stopping after sunrise when the temperature starts rising again (Cross and Hyams, 1996; Sawalha et al., 2003; Mohscn, 1983; Hanafi et al., 2007; EI-Badry et al., 2008). A study by Whelan (2003) found that most sandfly activities and biting started one hour either side of sunset and stopped one hour after sunrise. Guernaoui et al. (2006) tracked sandfly activities in Chichaoua Governorate, Morocco, during the day. Their results showed that sandflies became active directly after sunset and reach a peak between 19:00 - 21:00 hours, no active sandflies were observed after sunrise (5:00 to 7:00 hours) when the temperature started increasing and relative humidity decreasing. A similar study of *P.papatasi* in Tunisia also found no recorded activity after 5:00 am (Chahed, 2010-2011).

Finally, climate conditions can influence Leishmaniasis transmission rates. A study by Narvaez et al. (2003) investigated the possible correlation between climate conditions and Leishmaniasis transmission rates in Mexico during the period between February 1993 and March 1995. They found there was a high transmission rate between November and March when the temperature was lower and relative humidity higher, creating an ideal ecological environment for disease transmission. Research by Cardenas et al. (2006) studied the impact of El Nino upon the transmission of Leishmaniasis in Colombia in the period between 1985 and 2002. This study indicated that during the El Nino (dry season) in 1987, 1992, 1994, 1997 and 2002 the number of Leishmaniasis cases increased, while during the La Nina (wet season) in 1988–1989, 1995–1996, 1998 and 2001 they decreased dramatically. The difference was attributed to drought conditions reducing human immunity and increasing the probability of Leishmaniasis transmission. These findings were supported by Franke et al. (2002) who found there was a noticeable increase in sandfly densities and Leishmaniasis transmission rates during El Nino seasons in Brazil.

From the above, it is clear that climate conditions can influence many aspects of Leishmaniasis. Temperature, relative humidity and rainfall have been found to influence sandfly prevalence, development stages, seasonal and daily activity as well as disease transmission rates. The published literature suggests that any increase in temperature between 10 and 40°C combined with relative humidity above 33% is likely to result in a greater prevalence of sandflies, speed up their development stages and so Leishmaniasis risk (Cross and Hyams, 1996; Silverman et al., 1981; Dryden, 1988; Dryden, 1993). However, the influence of these climate phenomenon upon Leishmaniasis varies quite widely based on other factors such as geographical location and sandfly species. What is more, sandflies have been described as a very adaptable species to new climate conditions making it even more difficult to understand their ecology and optimum environment on large geographical scales (Shope, 1999; Harhay et al., 2011; Boussaa, 2005; Pita-Pereira, 2008). Therefore, further research is still needed and probably needs to focus on smaller geographical areas so that the specifically relevant conditions affecting sandflies can be better understood.

2.5. Socio-economic and Demographic Factors Influencing Risk of Leishmaniasis Infection:

Socio-economic and demographic factors have been found to influence many aspects of daily life that are associated with the risk of contracting Leishmaniasis. These include housing conditions, number of occupants in the household, neighbourhood cleanliness, use of protection against insects, level of education, occupation, and affording the cost of accessing and utilizing health care services. Higher socio-economic status is often associated with reduced Leishmaniasis risk whilst low economic conditions increase the risk for Leishmaniasis in various ways (Kolaczinski et al., 2008; Hasker et al,. 2012). Housing condition depends mostly on socio-economic status as lower economic classes are more likely to live in inadequately lit and poorly ventilated houses constructed with poor materials such as mud or sticks with many cracks in walls providing perfect habitat for sandflies to rest and breed. Several studies have found strong associations between the prevalence of Leishmaniasis and such poor housing conditions (Boussery et al., 2001; Barnett et al., 2005; Kolaczinski et al., 2008; Schenkel et al,. 2006). Additionally, low socio-economic conditions often increases the number of occupants in the household in order to reduce living expenditures. Crowding in households generally leads to sleeping outdoors and reducing the use of bed net and other protection methods and as a result increasing the risk in coming in contact with disease vectors including sandflies. Several studies have found that the risk of Leishmaniasis infection increases with the number of occupants in the household (Kolaczinski et al., 2008; Sabra, 2013; Reithinger et al., 2010).

Leishmaniasis has been also found to be more prevalent in rural than urban areas since risk factors such as livestock, vegetation and dumping areas are more common in the former. Lower socio-economic classes have also been found living in rural areas more than urban because of the lower living costs as well as the type of jobs they are often involved in such as farming, grazing and manual jobs (Hashighushi and Laundries, 1991; Abranches et al., 1983; Farrell et al., 2002; Aliro et al., 2010). In addition, the level of neighbourhood cleanliness has also been found associated with the socio-economic condition as lower classes often live on the outskirts of cities or in rural areas with generally poor waste management and open or on surface sewerage systems which increase sandfly and rodent populations in the area and thus Leishmaniasis risk (Sutherst, 2004; Cortes et al., 2007; Wondimeneh et al., 2014; Marco et al., 2006).

Additionally, poorer people have been found to be protecting their households less efficiently than higher socio-economic classes. They often use no protection at all as they cannot afford it or use cheap methods which are not effective against sandflies. The use of appropriate protection methods helps to reduce the probability of disease development. Two studies in Afghanistan and the Peruvian Andes noted that after applying insecticide sandfly populations dropped almost 55% in the former and 70% in the latter (Reyburn et al., 2000; Davies et al., 2000). Also the use of good bednets resulted in reducing contraction of VL in Nepal by approximately 70% (Bern et al., 2000) and of CL in Syria by roughly 50% (Tayeh et al., 1997b). Developing Leishmaniasis has also been found to be strongly associated with some types of occupations that are more common in low socio-economic classes (Ahmadi et al., 2013; Harandi et al., 2011). Numerous studies have stated that outdoor jobs such as working in forests, grazing land or farming are strongly associated with Leishmaniasis infection risk. A study in Brazil of 141 CL cases evaluated the association between the type of occupation and exposure to the disease and found that the majority of cases (49.1%) were farmers (Júnior et al., 2009). Another study in Brazil found that almost 70% of Leishmaniasis cases were either farmer or woodland labourers (Heimgartner and Heimagartner, 1976). Likewise, a study in Colombia of 126 Leishmaniasis cases found that there was a strong association between Leishmaniasis exposure and occupations that interacted with vegetation or forests as 47% of the cases were farmers, 35% were soldiers located in forest camps and only 18% were working in different occupations (Martinez et al., 1997).

Other factors have been found to be associated with the type of occupation, such as gender and age. Many outdoor jobs are more suitable and common for men than women of working age between 18 and 50 years due to the nature of the jobs such farming and manual labourers. This association has been reflected in the gender and age groups associated with disease development. In Martinez et al.'s (1997) study 86% of the reported Leishmaniasis cases (126) were men aged between 18 and 57 years old. Other studies in Iran (included 137 CL cases) and in Brazil (included 141 CL cases) found almost 70% of the former and 68.1% of the latter were men aged between 20 and 40 years old (Ahmadi et al., 2013; Júnior et al., 2009). Also, according to a report from the Ministry of Health in Saudi Arabia in 2011, there were 1951 reported CL cases of which 79% were men and 62.5% aged between 15 and 44 (MOH, 2012).

Furthermore, people in lower socio-economic groups are often more likely to have lower levels of education, which in turn can lead to higher disease burdens and cognitive or physical impairment (Adler et al., 1993; Droomers and Westert, 2004; Mackenbach et al., 1996). The higher level of education for people the more likely they are aware of Leishmaniasis risk factors (vector, reservoirs, habitat and seasonality) and consequently avoid them.

From the above studies it can be argued that socio-economic and demographic factors have a very strong influence upon the risk of contracting Leishmaniasis. It can be stated that populations of lower socio-economic status have a higher risk of developing the disease. Also, men in general and in particular of working age between 18 and 50 tend to be more vulnerable to developing Leishmaniasis in comparison to female and males in other age groups. However, it is also well known that socio-economic factors vary widely between countries as well as within them (Jürgen and Hoffmeyer, 2008; Vijayakumar et al., 2007). As a consequence, some care is needed in extrapolating results from one study to another. It is also clear that it is important to investigate combinations of factors in particular regional settings in order to better understand how they can interact with each other to influence disease risk.

2.6. Leishmaniasis Prevention and Control:

Preventing humans from coming in contact with sandfly habitats is almost impossible. This is basically because of the large variation in sandfly habitats and also because the high adaptability of sandflies to other new habitats. What makes avoiding sandflies even harder is recent findings suggesting that humans and sandflies are now moving closer in proximity to each other (Vieira et al., 2012; Naucke et al., 2008). Sandflies have been reported in many studies as existing in human settlements, urban areas and within houses (Beier et al., 1986; Ferro et al., 1995; Feliciangeli and Rabinovich, 1998). In addition, settlements and urban sprawl resulting from rapid population growth may invade some sandfly natural habitats making coming in contact with sandflies more likely in endemic areas. So, with the difficulties in controlling human activities and with the absence of a prophylactic vaccine against any form of Leishmaniasis, vector control remains the most effective way to control the disease (Faber et al., 2013). These control measures are directed at several levels which are: vector (sandflies), reservoirs (dogs or rodents), human and environment (Ibid; Farrar et al., 2008).

2.6.1. Sandfly Control:

There are several approaches to control sandflies including chemical control, management of surrounding environments and personal management. For effective sandfly control more than one approach should be involved in the strategy. Additionally, these controls need to be well adapted to the characteristics of sandfly species which varying widely in terms of travel distances, biting and resting behaviours, preferable reservoirs and habitats (Farrar et al., 2008). Some of the most effective sandfly control measures are discussed next.

2.6.1.1. Spraying Insecticides:

Applying residual insecticides in and around settlement areas in endemic zones is crucial to eradicate or reduce sandfly populations. Spraying houses is the most commonly used intervention for controlling sandflies that are endophilic (rest indoors after feeding) (Stanford University, [No date]c; Farrar et al., 2008). The spraying should be undertaken in human houses, livestock shelters and known sandfly resting areas up to six feet in height from the ground which is the maximum height sandflies can reach (Ibid). In Kabul, Afghanistan and the Peruvian Andes spraying houses with pyrethroid lambdacyhalothrin resulted in reducing sandfly populations by approximately 55% and 70% respectively (Ibid; Reyburn et al 2000; Davies et al., 2000). As insecticide is short-lived, its sustainability is very important to ensure eradicating sandflies successfully. However, sandflies are very adaptable and can also become resistant to spraying insecticide in some cases so new products may need to be regularly developed (Hassan et al., 2012; Roscoe, 2009; Stanford University, [No date]c).

2.6.1.2. Insecticide-treated Materials:

As sandflies are mostly active and bite between dusk and dawn, sleeping people are vulnerable to infection and using bed nets provides substantial protection from sandflies as well as other vector-borne diseases. For instance, a case-control study in Nepal identified that people using untreated bed nets while sleeping were 70% less likely to develop VL in comparison to people without the use of bed nets (Bern et al., 2000). Another example is the introduction of insecticide-impregnated bed nets for almost 10,000 people in Aleppo, Syria by the WHO which resulted in the contraction of CL dropping by almost 50% (Tayeh et al., 1997b). However, special bed nets are required for protection from sandflies as typical bed nets have openings of 1.3-1.5 mm which are believed ineffective with sandflies as they might enter through the openings because of their small size. The ideal bed net should have no openings larger than 0.9 mm to achieve the required effectiveness (Reyburn et al., 2000; Tayeh et al., 1997b).

2.6.1.3. Destruction of Breeding Sites:

To date, only a few breeding sites of sandflies have been identified: *P.papatasi* and *P.duboscqi* in rodent burrows are the best examples (Farrar et al., 2008). In Central Asia, the destruction of rodent burrows resulted in eliminating both the vector and reservoir and thus Leishmaniasis (Ibid; Saf'janova, 1971). A study in Bihar, India by Farrar et al. (2008) found that after changing house building materials from traditional mud or straw to plastered brick the number of Leishmaniasis vectors and reservoirs and thus disease cases dropped noticeably

2.6.2. Reservoir Control:

Given the large variety of animals that can carry the *Leishmania* parasite, the total control of Leishmaniasis reservoirs is believed impracticable. Nevertheless, where there is a strong link between the disease occurrence and specified animal species then controlling the reservoirs can be achieved. In Russia and China, when they realized controlling sandflies was not possible they turned to destroying rodent burrows and preventing re-colonization which resulted in reducing the number of Leishmaniasis cases dramatically (Stanford University, [No date]c). Also, in the North Jordan Valley and Sidi Bouzid town in Tunisia (endemic zones for CL) rodents' burrows were destroyed by deep ploughing and removing natural vegetation around communities. This approach resulted in a dramatic decrease in the CL reservoir and vector population and so the number of CL cases dropped very significantly by almost 90% in Tunisia and by an unstated percentage in Jordon (Anders, 2008, Ben Salah et al., 2007).

In the case of VL, where dogs rather than rodents are more commonly involved in the transmission, different measures have been used. A study by Ashford et al. (1998) found killing or removing dogs infected with Leishmaniasis far from people diminished the number of VL cases. In 1997, Killick-Kendrick and others tested deltamethrin impregnated collars on dogs and stated that this method reduced the number of dogs bitten by sandflies by 96%. The same method was applied in endemic VL villages in Iran where all dogs were fitted with deltamethrin impregnated collars and the results were positive with a significant drop in the number of infected dogs as well as VL children cases (Gavgani et al., 2002).

2.6.3. Personal Prophylaxis:

One of the most effective ways of limiting the risk of Leishmaniasis is through personal health education and awareness (Sharma and Singh, 2008; Hassan et al., 2012). If people know about Leishmaniasis vectors and reservoirs it will help them reduce their risk of exposure to sandflies. Additionally, knowing the biting behaviour of sandflies will increase the usage of fine-mesh nets around the bed while sleeping and avoid sleeping on the floor or outdoors in the sandfly peak biting times. In addition, better awareness can lead to people keeping their surrounding environment clean to avoid attracting sandflies and rodents by disposing of household wastes in a secure places far from rodents and sandflies as well as maintaining their homes free from rodents burrows (Sharma and Singh, 2008; Hassan et al., 2012).

From this literature review it is apparent that controlling the Leishmaniasis vector at any level is a fundamental factor in reducing disease risk. However, controlling the disease can be influenced by many socio-economic variables such as housing conditions, household income, level of education and awareness of the disease. There is consequently a need to investigate how disease awareness and use of control measures interact with socio-economic factors to influence disease risk.

2.7. Leishmaniasis Diagnosis, Treatment and Recording:

There is an extensive literature on ways of diagnosing and treating Leishmaniasis as well as the factors influencing the willingness of infected people to seek health care treatment. These aspects will be discussed in the following section.

2.7.1. Leishmaniasis diagnoses:

An early diagnosis of Leishmaniasis is crucial as the disease is a serious infection for both communities and individuals. To date, no single approach has been accepted as the gold standard means of diagnosing Leishmaniasis. However, there are two general ways of diagnosing the disease which are clinical signs and laboratory tests. Both VL and CL have their early infection signs. For the former, many signs can be used as infection indicators such as irregular fever (for more than two weeks), weight loss, spleen inflation, abdominal pain, loss of appetite, cough, joint pain, skin darkness, bleeding (especially nosebleeds) and emaciation. For the latter, red papules appear at the sites of the sandfly bites between two weeks and two months after the exposure. Then the lesions become irritated and extremely itchy and start enlarging and ulcerating. After that the lesions get hard and crusted (Murray et al., 2012). However, even though both VL and CL have their early symptoms, the clinical signs might led to misdiagnosis as VL symptoms might be confused with other similar conditions such as Malaria, Schistosomiasis, Leukaemia, Tropical Splenomegaly and Milliary Tuberculosis. In the same way, CL can be misdiagnosed as the early symptoms are not hugely different from other similar skin conditions like tropical ulcers, Leprosy and infected insect bites (Claborn, 2014; Lainson et al., 1987; Singh, 2003). Hence, there are some reservations about clinical diagnoses and a laboratory test is believed to be the best option in the case of any suspicion of Leishmaniasis infection to get a definite answer. These laboratory methods include parasitological, immunological and molecular tests (Grogl et al., 1993; Singh, 2006).

2.7.2. Treatment:

Leishmaniasis is a complex disease and the response to treatments varies between the different clinical forms, between and within *Leishmania* species, geographical locations and the condition and the host immune system (Anders, 2003). So, as a result of this complexity, the treatment and management of each infected case should be individualized. The parenteral administration of pentavalent antimonials has been the main treatment for Leishmaniasis since the middle of the last century (TIH, 2000). There are different types of pentavalent antimonials used such as Sodium Stibogluconate, Meglumine antimonite, Amphotericin B, Pentaamidine, Miltefosine and Paromomycin (Croft and Coombs, 2003; Magill et al., 2012; Mukhopadhyay et al., 1996; Chance, 1995). However, all these drugs have their limitations and are not evenly effective against all form of Leishmaniasis (TIH, 2000). Also, some patients may experience side effects from certain drugs and therefore require alternative medicines.

Since VL is a vital disease, treatment is invariably required and without it death is almost certain. In the case of CL, which is not fatal, drug treatment is not always necessary, so that permanent immunity can be obtained which is good for people in endemic areas. However, for patients with disfiguring lesions or either DCL or MCL, treatment is commonly applied (Davies et al., 2003; Herwaldt ,1999; Norton et al., 1992; Anders, 2003). The treatments for both VL and MCL require patients to be hospitalised for several weeks with specialised equipment and experienced medical personnel (Yatich, 1995). Since CL is self-healing treatment may not be sought, especially by people who have some barriers preventing them from reporting and seeking medical care. The possible health care accessibility barriers will be discussed next.

2.7.3. Accessibility to Health Care Services and Leishmaniasis Treatment:

A crucial aspect of treating Leishmaniasis is accessing health care centres and obtaining medical services. Accessibility to health care centres is influenced by various socio-economic and demographic factors which also effect Leishmaniasis development. Quick response and successful treatment has been identified as a cut-off point between death and survival for people infected with VL and also to reduce the risk of the development of CL into MCL (Chappuis et al., 2007; Davies et al., 2003; Herwaldt, 1999; IAMAT [No date]). People of high socio-economic status are more likely to be able to access and utilize health care services than those of low socio-economic status who cannot afford the high cost (Vellakkal et al., 2013). Additionally, people in rural areas have been found to experience more difficulties in accessing and utilizing health care services in comparison to urban populations as they are more likely incur higher costs and travel for longer distances (Bettencourt et al., 2007; Mitchell et al., 2006; Wilkinson and Cameron, 2004).

2.7.4. Factors Influencing Health Care Accessibility:

2.7.4.1. Individual Barriers:

Patients’ recognition of their need for health care services and their decisions to seek medical care treatment can be considered as the first step of any process of health care accessibility (Gulliford et al., 2002). The possibility of using a health service depends on the balance between patients’ perceptions of their health needs and their beliefs, attitudes and earlier experiences with health services (Mechanic, 1978). In addition, the patient’s expectation as a service user might not be consistent with that of health care suppliers. This is obvious in the non-uptake of preventive treatments, delays in patients visiting health care centres with serious health conditions requiring treatment or unsuitable demands on primary health care centre (PHCC) and emergency services (Gulliford et al., 2002).

2.7.4.2. Travel Cost Barriers:

Broadly speaking, people would prefer to travel for as short distance as possible to obtain health care services. Several studies have found that residents who live far from health care facilities utilise them less than closer residents (Joseph and Phillips, 1984; Posnett, 1999; Jones at al., 1999). Poor physical access to health care facilities is known to reduce the utilization of services, and perhaps leads to poorer health outcomes (Lovett et al., 2002; Jones and Bentham, 1995; Jutting, 2004; Tienda and Mitchell, 2006). Few studies have examined the impact of spatial accessibility to health care facilities on actual health care delivery. Nattinger et al. (2001) and Athas et al. (2000) found that increasing travel distance was significantly associated with decreased utilization of breast cancer treatment. Fortney et al. (1995) argued that travel distance influences the possibility of utilization of alcoholic and mental health treatment. Similarly, Goodman et al. (1997) stated that greater distance to hospitals was strongly associated with lower probability of admission for discretionary conditions.

2.7.4.3. Financial Barriers:

Financial barriers may influence people utilising health care facilities. Even where health treatment is essentially free for all citizens, patients may incur costs caused by time lost from work or in travelling to and from health care facilities. This cost can influence different socio-economic groups in various ways. For some patients, access might not be compromised, while for others costs might be a significant deterrence (Lundberg et al., 1998). The impact depends on the amount of the cost and patient's ability and willingness to pay. It would be better to say, people are different and equal cost does not necessarily mean equal access (Gulliford et al., 2002). Financial barriers can also affect health care suppliers in terms of facilities, availability of specialised personnel and their ability to provide the needed level of care. In general terms, lower socio-economic status people have a lower probability and willingness of accessing and utilizing health services.

2.7.4.4. Socio-cultural Barriers:

The required cost to complete a journey to and from health care centres is also associated with the type of transport used, which is related strongly to the socio-cultural and economic characteristics of patients and their surrounding environments. Transport type has its impact on accessibility in different ways (Tomlinson, 1998). Private vehicle availability is an important issue in health care accessibility. A survey by North Cornwall Primary Care Trust on users of six hospitals in Cornwall and Plymouth stated that 80% of respondents found it difficult to access healthcare other than by private car (Hamer, 2004). Another study in Riyadh, Saudi Arabia, found that almost 86% of the study samples from three PHCCs had used their own cars to visit their doctors (Mansour and Al-Osimy, 1993; El Shabrawi, 1992). A private vehicle can be defined as a vehicle owned by the household and its availability does not always mean easy access to a health care centre. To exemplify that, seriously ill people, children, elderly and disabled people cannot access to health facilities without help from others (Al-Shahrani, 2004).

In the absence of a private car, alternative methods can include public transportation systems, which tend to be better in urban than rural areas in most countries. Walking is an alternative option for those who do not have access to a private vehicle or public transport. However, the walkable distance will itself be influenced by factors such as age, gender, the patient's physical condition and climate.

2.7.4.5. Organisational Barriers:

Organisational barriers are associated with the policies of the health system in the country, as well as the health system itself. It has been found that the most effective organizational factor affecting access to health care centres in the UK was their opening hours (Higgs and Gould, 2001). Working hours are affected by many factors such as the climate and other considerations which mean they are different from one country to another. In the case of most countries, opening hours are between 8.00 and 17.00 hours from Monday to Friday for all PHCCs and the main specialist departments in hospitals. Some studies have shown that people generally prefer visiting their doctors in the evening (Bunnett, 1979). This is often because earlier in the day is not convenient for employed people. Another organisational barrier is the cost of the treatment as many countries do not provide health care services free of charge, particularly for people of different nationalities. Waiting lists and time required for treatment are other potential organisational barriers (Gulliford at el., 2002). Moreover, the availability of particular equipment or specialist personnel can influence accessibility too. For example, in some health care centre not all necessary personnel or equipment are available forcing local residents to pay higher cost travelling to other health care centres to meet their needs. This is more common in rural areas where the demand for some types of care is not high and therefore local health authorities do not provide it everywhere.

Overall, people who face any of the above barriers are less likely to report and treat a disease if exposed. Under-reporting of CL cases can be considered as a major problem in endemic countries for two reasons. Firstly, diagnosing and reporting CL exposure in its early stage can help minimizing any lasting skin damage. People with obvious symptoms might be rejected from their communities especially if ulcers are on visible parts of the body like the face, neck or hands. Early reporting and treatment can solve this matter and avoid any future psychological or cosmetic treatments arising from the exposure. Secondly, under-reporting of cases might mislead health authorities and policy makers in understanding the importance of the disease in the country or the region and how to deal with it. Assessing the extent and character of under-reported cases is therefore an important research need.

2.8. Problem Statement and Research Questions:

From the above literature review, several points stand out and are worth re-emphasising here. It is apparent that Leishmaniasis is a global problem affecting 88 countries worldwide, but with a geographical concentration as 90% of VL occurs in five countries and similarly 90% of CL occurs in six countries, one of which is Saudi Arabia, the focus of this study. It is also clear that there are multiple factors influencing the prevalence of the disease. These include climatic characteristics, the nature of local environments and the distributions of the disease reservoirs and vectors. In addition, socio-economic and demographic variables are an important influence on how potential exposure is translated into the risk of actually contacting the disease and subsequently seeking treatment for it.

So, in order to understand the actual pattern of the disease risk in terms of reported cases, there are several influential factors operating at different temporal and spatial scales. There is a temporal influence because climate variables (temperature, relative humidity and rainfall) are fairly fundamental controls on the prevalence and the distribution of the disease. When the climate becomes appropriate, the next influence is the habitats for the CL vector and reservoir. This represents a spatial control. When these habitats are active and suitable, then the next consideration is the activities and behaviours of the local population. Do they practice certain activities or behave in ways that are more likely to bring them into contact with CL vectors? If people do live in an environment where they are more likely to come into contact with the vector, do they use any sort of protective measures which could influence the likelihood of being bitten? Finally, if somebody starts to develop the symptoms of the disease then there is the influence of health care accessibility in terms of whether or not they get the condition diagnosed and reported. So, it is apparent that there a hierarchical order of influences as summarised above and represented in Figure 2.6.

First stage

Suitable climate condition

The ideal climate condition for sandflies has been identified as:

- Temperature ranging between 10 and 40°C.
- Relative humidity above 33%.
- Enough rain to increase the relative humidity and vegetation cover but without inundating areas.

The optimum temperature, relative humidity and rainfall vary depending on the geographical location and the sandfly species

↓

Second stage

The availability and distribution of active habitats for Leishmaniasis vectors and reservoirs such as:

- Livestock shelters or grazing sites.
- Rodent burrows or termite hills.
- Abandoned or mud houses.
- Construction or house waste disposal sites.
- Farms or vegetated areas.

↓

Third stage

Socio-economic and demographic variables that influence the activities and behaviour of local people:

- Housing conditions and neighbourhood level of cleanliness.
- Household occupants, household income and level of education.
- Age, gender and occupation of household members.
- Household members' sleeping behaviour (indoor or outdoor).
- The use of effective sandfly protective methods.

↓

Final stage

Influences on diagnosis, reporting and treating of CL symptoms:

- Individual factors: are people willing to be treated?
- Travel cost factors: how far the clinic is and can people travel?
- Financial factors: how much will the travel cost and is it affordable?
- Socio-cultural factors: Car availability and can patient gets to health care centre?
- Organisational factors: dermatologist availability and opening hours.

Figure 2.6: Order of factors influencing Leishmaniasis development and treatment.

The literature review in this chapter indicates that various studies have looked at the influence of climate factors upon the incidence of Leishmaniasis (e.g. Chaves and Pascual, 2006; Boussaa et al., 2005; Cardenas et al., 2006; Salomón et al., 2012). Others have investigated the influence of local environments (e.g. Schlein et al.,1990; Dhiman et al, 1983; Mukhopadhyay et al.,1990; Mutinga and Kamau, 1986; WHO, 1997; Wasserberg et al., 2003; Salah et al., 2000) or socio-economic and demographic variables (e.g. Kolaczinski et al., 2008; Boussery et al., 2001; Sabra, 2013; Reithinger et al., 2010; Abranches et al., 1983). However, it also seems clear that to have a better understanding of the epidemiology and societal implications of the disease, all these three aspects need to be considered together. However, the literature review did not find identify any studies that have investigated the combined influence of climate, local environment and socio-economic factors upon the prevalence, distribution and reporting of Leishmaniasis in any part of the world.

This study therefore sets out to rectify this knowledge gap in the context of arid and semi-arid regions. Since Saudi Arabia has been described by the WHO as one of the highest endemic countries for CL, it was selected to be focus of this study and the following four main questions have been identified as the focus for the investigation:

Question 1: How does CL vary according to climate conditions in the selected study area?

Question 2: Does the prevalence of CL in a particular community vary according to the local environment and proximity to different types of land use / land cover?

Question 3: Do CL cases vary according to socio-economic and demographic characteristics of local populations?

Question 4: Is there evidence of under-reporting of CL cases in the study area? If so, do the characteristics of the officially reported cases differ from those that were not reported?

Chapter 3 discusses the selection of a study area for more detailed investigation and the overall study design is presented in Chapter 4. Results relating to the above four questions are presented in Chapters 5 to 8 and the overall conclusions from the study are discussed in Chapter 9.

Chapter Three: Study Area:

3.1.1. Introduction to Saudi Arabia:

Saudi Arabia is located in the southwest region of the Asian continent known as the Middle East at the crossroad between the Old World continents: Asia, Africa and Europe (SGS, 2012). It extends from the Red Sea on the west to the Arabian Gulf on the east. To the north, it is bounded by Jordan, Iraq and Kuwait; on the east by the Arabic Gulf, Bahrain, Qatar and United Arab Emirates; and to the south by Yemen and the Sultanate of Oman as shown in Figure 3.1 (Ibid). The area of Saudi Arabia is approximately 2 million km^2, encompassing about 75% of the total area of the Arabian Peninsula. Saudi Arabia is situated within the arid zone between latitudes 16' and 32' north, and between longitudes 36' and 60' east, and the Tropic of Cancer splits the Kingdom into two halves (Ibid).

Figure 3.1: Geographical location of Saudi Arabia

3.1.2. Topography of Saudi Arabia:

Saudi Arabia can be divided into five main areas based on their topographical nature. These regions are: the Tihamh Plain, the Hejaz and Asir Mountains, Najd Plateau, the Crescent of Arabian Desert and the lowland as shown in Figure 3.2 (SGS, 2012).

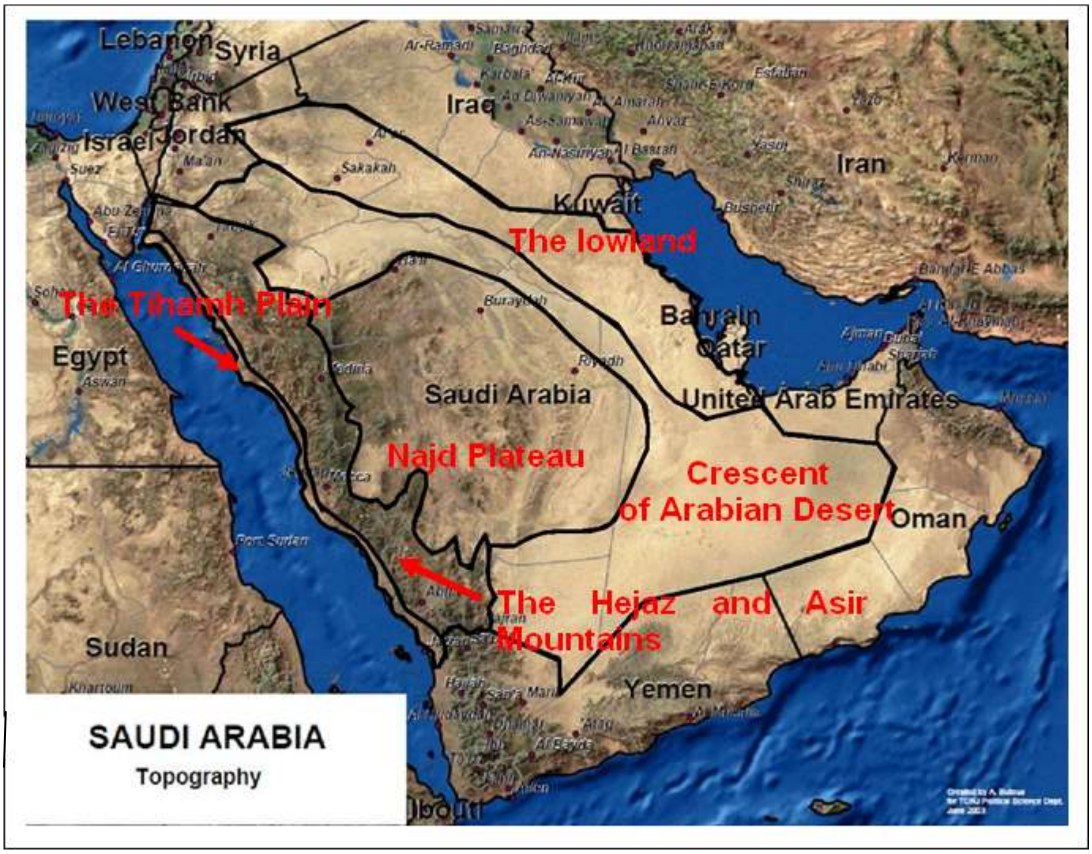


Figure 3.2: Topography of Saudi Arabia

3.1.2.1. The Tihamh Plain:

The Tihamh Plain boarders the Red Sea in the west of the country. The plain is narrow in the north west and becomes wider to the south west. It rises gradually from the sea to the Hejaz and Asir Mountains. It is an open plain, generally divided into salt pans, wadis and their tributaries and shoreline (Zarins and Zahrani, 1985).

3.1.2.2. The Hejaz and Asir Mountains:

The western coastal escarpment can be considered as two ranges of mountains; the Hejaz and the Asir Mountains. The Hejaz Mountains hardly ever exceed 2100 m above sea level, and the elevation gradually decreases towards the south to approximately 600 m in the area of Makkah. South of Makkah, the Asir Mountains exceed 2400 m in numerous places with some peaks above 3000 m with the highest in Al-Sodah, Abha with an elevation of roughly 3,150 m (SGS, 2012). On the western side of the highlands, the Hejaz and Asir Mountain fall sharply in a series of dramatic escarpments ending up by merging with the Tihamh Plain, whilst the eastern slope of the mountains melds into the interior parts of the country (Thesiger, 1947).

3.1.2.3. Najd Plateau:

Najd Plateau lies east of the Hejaz and Asir Mountains. It is mostly rocky plateau interspersed with small deserts and scattered mountain clumps. The plateau slopes eastwards with an elevation of approximately 1350 m on the west and reaching about 770 m on the east end of the plateau. Many wadis exist in the plateau which slopes eastwards toward the Arabian Gulf. Najd Plateau has many oases, pastures and large agricultural areas such as Al-Qaseem, Riyadh, Al-Afalaj, Wadi Al-Dawaser and Al-Kharj which make the region relatively highly populated (SGS, 2012).

3.1.2.4. The Crescent of Arabian Desert:

At least one-third of the total area of the country is covered by three major sandy deserts. The Ruba’a Al-Khali or The Empty Quarter in the south is the largest desert region in the country occupying about 500,000 km^2 (Mandaville, 1986). The elevation varies from 780 m in the southwest to roughly sea level on the northeast. The Ruba’a Al-Khali has different types of sand bodies which include moving dunes, crescents dunes, longitudinal dunes and massive mountainous sand dunes which can be as high as 250 m. On the north of Al-Ruba’a Al-Khali, the An’Nfood desert covers an area of about 60,000 km^2 with an average elevation of 1000 m. Both the Ruba’a Al-Khali and An’Nfood deserts are connected by an arch shape sand body called Ad’Dahna desert with an average width of 60 km. Due to the harsh nature of these regions, populations are sparsely distributed with some ecological researchers and oil discovery teams (SGS, 2012).

3.1.2.5. The Lowland:

The eastern part of the country is flat lowlands and coastal plains. It is generally featureless with gravel and sand cover. In the south part of the region is Al-Jfrah desert which reaches the Arabian Gulf and integrates with the Ruba’a Al-Khali desert and on the north is Al-Dibdebah gravelled plain. The coastal areas are merging sandy plains, salt flats and marshes. Consequently, the land surface is uninhabitable in places where the water rises almost to the surface and the sea is shallow with shoals and reefs (Ibid).

3.1.3. Climate:

The country can be divided into three main climate zones which are coastal zones and lowlands, mountainous areas and interior areas (Ibid) as shown in Figure 3.3.

3.1.3.1. Coastal Zones and Lowlands:

Along the coastal line of the Arabian Gulf and the Red Sea, the desert temperature is moderate by the nearness to these water bodies. Temperature rarely rises more than 40°C in summer and rarely drops below 15°C in winter. Relative humidity in these areas is typically between 30% in winter to about 91% in summer. It does not frequently pass these percentages of humidity but it reaches 100% sometimes for extended periods especially on the eastern coast. Precipitation in general is low in these areas with an average rainfall of 55 mm annually and mostly occurs in winter and spring (Jörg and Steinkohl, 2004).

3.1.3.2. Interior Areas:

In the interior part of the country which contains Najd Plateau and the great deserts, the average temperature in summer is about 45°C but also it is common to reach more than 56°C. In winter, the temperature is mostly between 8°C and 14°C and seldom drops below 0°C. The average temperature in both spring and autumn is about 29°C (PME, 2014a). Precipitation in the interior areas is generally low with an average of 100 mm annually, the rain is unpredictable and the rain for the whole year might consist of several torrential outbursts causing some flash floods and then disappear (Ibid; LCCS, 1992). As these regions are remote from water bodies, they have low relative humidity fluctuating between 3% and 55% and rarely pass higher than these percentages.

3.1.3.3. The Mountainous Areas - Asir and Hejaz Mountains:

In the Asir Mountain Region on the southwest of the country, the average temperature is about 19°C because of the high altitude and it reaches 34°C in summer and about 0°C in winter. The region is subject to the Indian Ocean Monsoon which occurs between October and March with a rainfall of approximately 300 mm per year, mostly in summer between June and October. Relative humidity in the area is varying from 15% in winter to 81% in summer days. The north part of the western mountains which is called Hejaz Mountains is slightly warmer and drier than the Asir Mountains. The temperature is about 21°C on average, reaching 40°C in summer and drops in winter to approximately 0°C in the high areas. Most of the region's rain falls in summer between June and October with an average of 192 mm annually, with relative humidity varying between 18% in winter and 89% in summer (PME, 2014a).

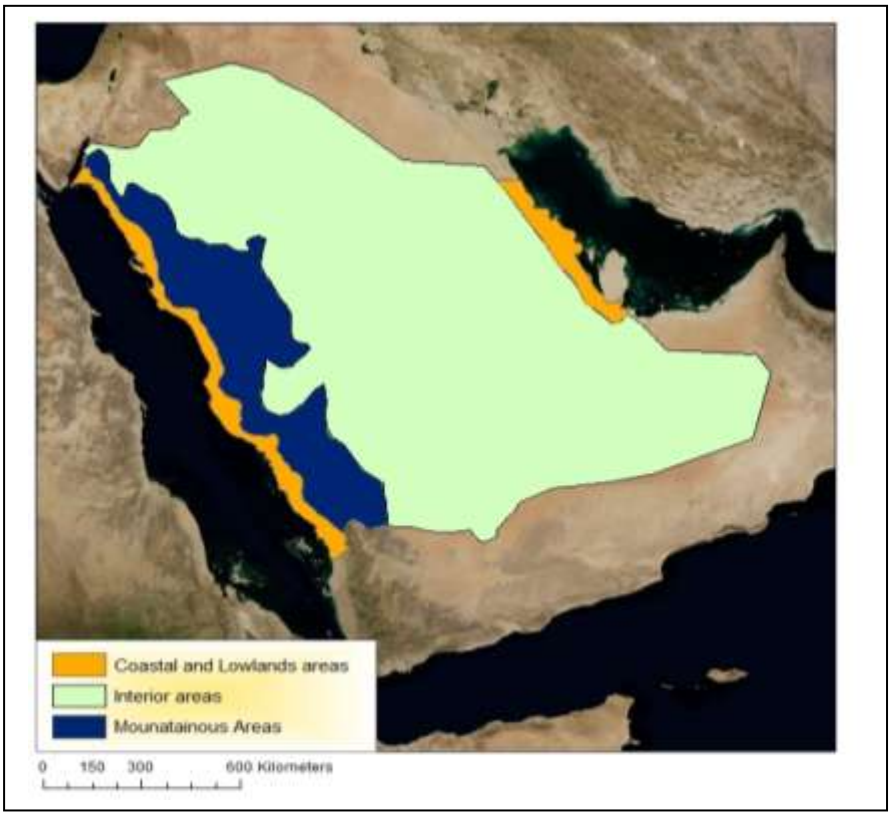


Figure 3.3: Climate zones in Saudi Arabia

3.1.4. Vegetation:

Vegetation and climate have intimate relationships. These relationships have been widely studied by many geographers and ecologists. Belsky (1989) and FAO [No date] have stated that the vegetation in arid and semi-arid regions depends largely on rainfall and other factors affecting the distribution and the availability of water. In Saudi Arabia, the variation in climate variables is clearly responsible for the variation in the spatial and temporal distribution of vegetation. Therefore, the diversity of vegetation cover increases with the increase of rainfall, while other factors of soil texture and depth as well as the topography become more important in determining vegetation composition and density (Belsky, 1989). As mentioned earlier, the southwest part of the country namely the Asir mountainous area has the highest amount of precipitation with an average of 300 mm per year. Therefore, it is the richest flora and fauna in the country.

3.1.5. Historical Background of Saudi Arabia:

The Kingdom of Saudi Arabia was founded by King Abdul Aziz Bin Saud. In January 1902, he captured Riyadh City, the Al-Saud dynasty's family capital, from the rival Al-Rsheed family. The conquests were continued by taking Al-Ahsa Region from the Ottoman Empire in 1913 and by the year 1922 he completed his conquest of all Najed area. By the year 1925 he conquered the Hejaz Region and named himself as the King of Najed and Al-Hejaz. Many neighbouring areas afterwards have joined to his country either peacefully or by battles. In 1932, the Kingdom of Saudi Arabia was proclaimed with Abdul Aziz Bin Saud as King (KAIR, [No date]).

Before the country’s unification, the population could be classified into two groups; Settled and Bedouin. Settled people were either in cities such as Makkah and Madinah depending mostly for their income on visitors to the holy places, or in areas with natural resources such as farming or fishing areas meeting the level of food sufficiency. On the other side, the majority of population were Bedouins with a general pastoral lifestyle who used to migrate seasonally with their animals following the grazing lands. After the unification and more precisely in the middle of the 1970s, the population distribution experienced a new trend by shifting from the pastoral or rural lifestyle to urban areas where the governmental services can be delivered such as education, health and security.

3.1.6. The Impact of Oil Discovery and Exploration:

Before the discovery of oil, the main source of the country’s income was the pilgrims to Makkah which amounted to about 100,000 pilgrims annually in the late 1920s (Mokyr, 2003). However, the oil discovery has changed the entire economics and lifestyle in the country. The first step in the oil discovery was in April 1930 when King Abdul Aziz agreed with the Standard Oil Company of California to drill for oil in the eastern part of the country after the discovery of some oil wells in Bahrain eastwards of the Kingdom of Saudi Arabia. By the year 1932, the first oil well had been constructed (Well One) but was disappointing with very low amounts of oil. After numerous tries and accurately in March 1938 in Al-Dammam, Well Seven, the massive oil reserve was found and in 1939, the Kingdom started its limited oil exportation which picked up significantly after the Second World War (KAIR, [No date]).

Even though the country depended mostly on income from oil between the 1940s and the beginning of the 1970s, the international oil price did not contribute much for the development which fluctuated between less than $1 in 1940 and $3.35 in 1973 per barrel (Herrington, 1987). In 1974 and due to the sharp increase in the oil revenues after the Arab – Israeli war, Saudi Arabia has become one of the fastest growing economies in the world. Saudi Arabia enjoyed a huge surplus in its overall trade with other countries with a rapid increase in imports as well as huge governmental spend on the country's development and defence. Since then, the petroleum sector accounts for about 47% of the budget revenue and 57% of the GDP and 89% of the total export earnings (MEP, 2012a).

3.1.7. Recent Economic Development:

The real need was for comprehensive strategies to exploit the massive oil revenue in the country's development. Through a five-year development plan, the Saudi Government has sought to allocate its petroleum revenue to transform its relatively undeveloped and young, petroleum-based economy into a modern industrial state while keeping the country Islamic values and customs. In spite of the fact that the economic planners have not met all their aims yet, the Saudi economy has developed significantly. Most of Saudis' standard of living has increased and their lifestyle has changed. Table 3.1 shows the development of Saudi Arabia's infrastructure and its industrial's five-year plan programmes (MEP, [No date]a; SCO, [No date]).

Table 3.1: Saudi Arabia's five-year development plans

Plan	Period	Goals
1st Five Year Plan	1970-1975	Raise the standard of living, promote general welfare, and provide for national security and economic and social stability while retaining religious values
2nd Five Year Plan	1975-1980	Reducing economic dependence on oil and developing human resources
3ed Five Year Plan	1980-1985	Diversification of the economy into productive sectors (agriculture, industry, and mining)
4th Five Year Plan	1985-1990	Education and training programs
5th Five Year Plan	1990-1995	Completion of the infrastructure and industrial and agricultural development projects
6th Five Year Plan	1995-2000	Lowering the cost of government services without cutting them and sought to expand educational training programs
7th Five Year Plan	2000-2005	Economic diversification and a greater role of the private sector in the Saudi economy
8th Five Year Plan	2005-2010	Economic diversification in addition to education and inclusion of women in society
9th Five Year Plan	2010-2015	Eliminate poverty and increase development in infrastructure, medical services, educational capacity, and residential housing

MEP, 2012

With these development plans, the Gross Domestic Product (GDP) of Saudi Arabia has increased sharply by over 14,000% during the past 40 years, from $ 4.18 billion in 1968 to $ 567.8 billion in 2011 as shown in Figure 3.4 (MEP, [No date]b).

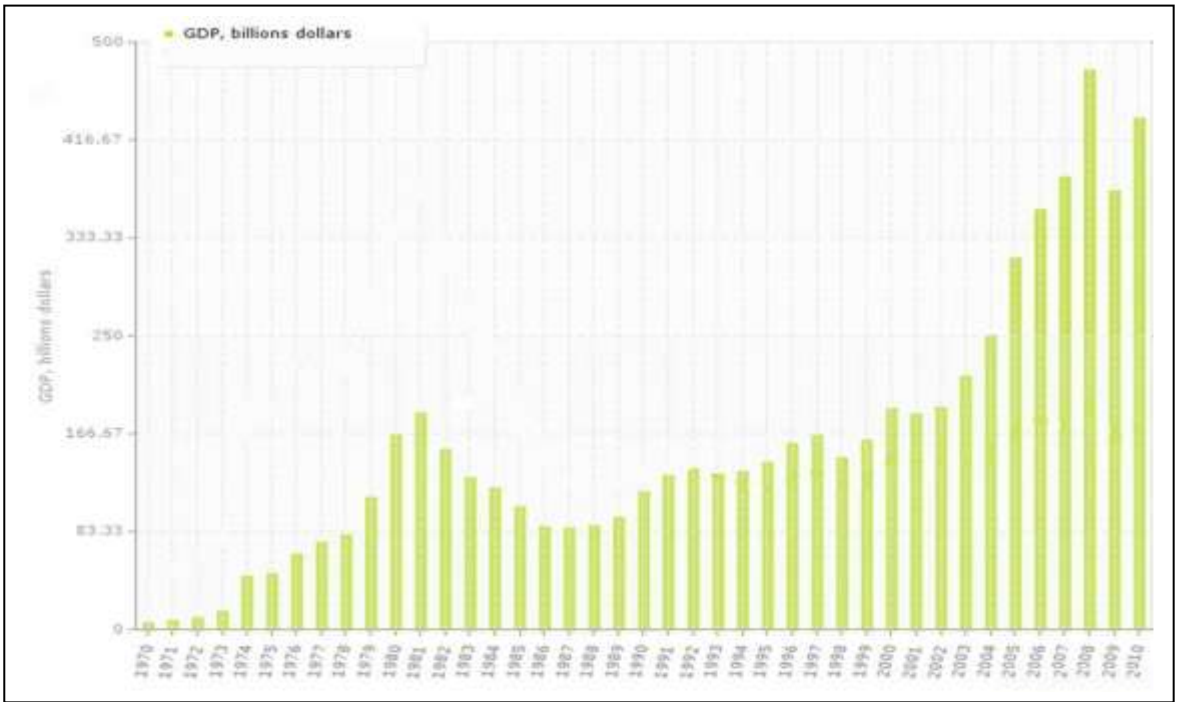


Figure 3.4: Saudi Arabia's GDP between 1970 and 2010

3.1.8. Regions of Saudi Arabia:

For administrative purposes, Saudi Arabia is divided into 13 regions as shown in Table 3.2 and Figure 3.5. Each of these regions has a regional governor appointed by the king and linked to the Ministry of the Interior. Moreover, another division is made within each region to smaller governorates or imarah.

Table 3.2: Regions of the Kingdom of Saudi Arabia

ID	Region Name	Location of Regional Headquarters
1	Riyadh	Riyadh City
2	Makkah	Holy City of Makkah
3	Madinah	Holy City of Madinah
4	Eastern Province	Dammam City
5	Al-Jowf	Sikaka City
6	Al-Baaha	Al-Baha City
7	Aseer	Abha City
8	Al-Qaseem	Buraidah City
9	Hael	Hael City
10	Tabouk	Tabouk City
11	Northern Borders	Arar City
12	Jazan	Jazan City
13	Najran	Najran City

MCI, 2012

Figure 3.5: Regions of the Kingdom of Saudi Arabia

3.1.9. Agriculture in Saudi Arabia:

Saudi Arabia has achieved massive agricultural development since the mid 1970s overcoming the difficulties of low subterranean water, limited rain, limited local labour and scattered cultivatable areas. Saudi Arabia became a self sufficient country in many products such as wheat and other crops (Vincent, 2008). The Ministry of Agriculture has supported farmers by distributing more than 2 million hectares of reclaimed uncultivated land free of charge. Moreover, it covers nearly 50% of the cost of agricultural equipment and fertilizers as well as supplying seeds and saplings at nominal prices. To finance this development, Saudi Arabia has established the Agricultural Bank which extends long term interest free loans to individual farmers and companies (MOFA, 2012). With all this governmental support, the size of cultivated areas has increased dramatically.

In Saudi Arabia, approximately 49 million hectares are cultivated land (22.7% of total area). Based on the Ministry of Agriculture statistics, more than half of the Saudi's cultivated areas (66%) are in the central parts of the country, namely in Riyadh, Al-Qaseem and Hael regions. The southern part of the country, Asir, Jazan and Najran combined, rank second with 19% of the cultivated lands, while Tabouk and Al-Jouf in the northern part rank third with 7%. Together the eastern and the western parts of the country account for the remaining 8% of the total cultivated lands (see Figure 3.6).

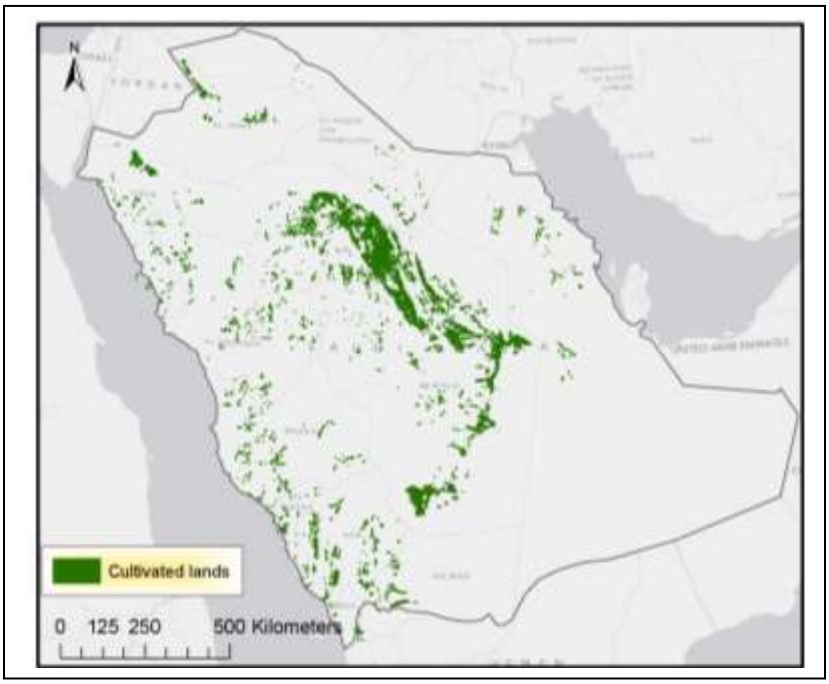


Figure 3.6: Cultivated lands in Saudi Arabia’s regions in 2009

There are many factors playing an important part in crop distributions and production such as geographical location, microclimate, arable land availability and water resources. As can be seen from Figure 3.7, Al-Jouf and the Northern Borders region which have a Mediterranean Sea climate are the main producers of fruits in the country. Date crops are produced mostly in Madinah Region whilst the soil texture in Najran region is suitable for citrus farming (MOA, 2009).

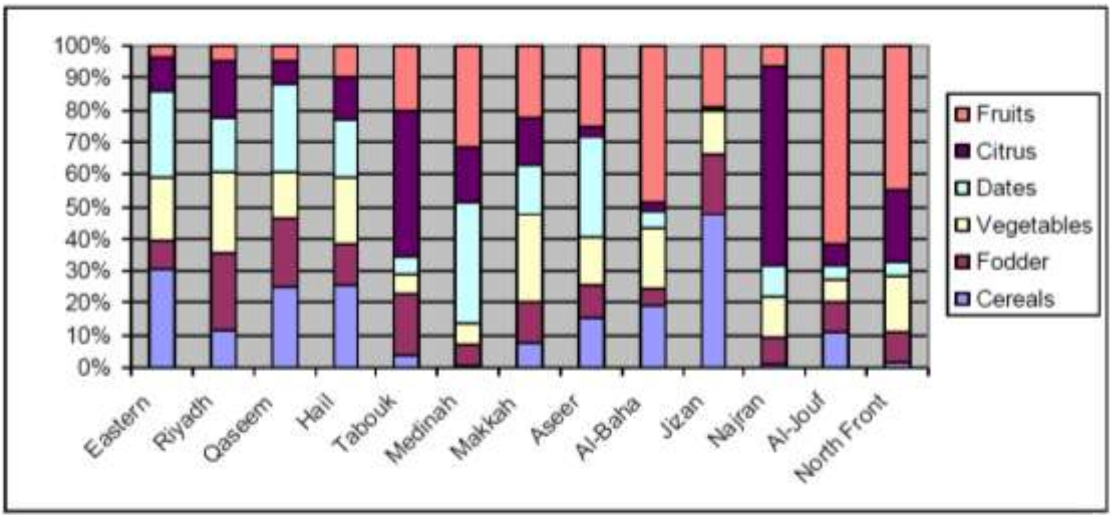


Figure 3.7: The main crop production in Saudi Arabian regions in 2012

3.1.10. Society:

3.1.10.1. Population:

The population of Saudi Arabia had risen by approximately 385% in the period 1975-2010, from about 7 million to about 27.1 million (CDSI, 2012a). This enormous increase in the population is due to two main reasons which are natural growth and in-migration. Natural growth has occurred after the massive changes in the Saudi lifestyle and after the transformation from the Bedouin to a settled lifestyle. Additionally, the rate of deaths has decreased as a result of medical care availability, increase in education and awareness, and a higher level of safety and justice. In terms of in-migration, it has been increasing in response to the demand for manpower to meet development plans.

3.1.10.2. Saudi Census:

Population censuses have been conducted in the country five times since unification, specifically in the years 1962, 1974, 1992, 2004 and 2010. The 1962 population census was considered as incomplete due to the large number of missing people who could not be included in the census. However, unofficial numbers were announced from the Department of Statistics stating that the population was 3.3 million (Ashwan, 1990). The second population census was conducted in 1974, it was initially considered by the Saudi government to be the first complete census. Some serious problems, nevertheless, in the collected data were obvious, first and foremost regarding the reported age - gender composition of the national population, making this census complete but with a low level of accuracy and reliability. Some numbers were released unofficially by the Ministry of Planning and the Ministry of Finance and National Economy in 1977 stating that the total population was 9,600,000 among them 89% were Saudis (6,218,361) and only 11% were non-Saudis (771,639) (CDSI, 2012a).

The population census undertaken in 1992 can be considered as the first complete and reliable census in Saudi Arabia. The total population was 16,948,338 including 12,310,053 Saudis (72.6% of the pop) and 4,638,335 non-Saudis (27.4% of the pop). Between 1992 and 2004, the total population increased by approximately 34% to 22,678,262. The number of Saudis was 16,527,340 (72.9% of the pop) and 6,150,922 were non-Saudis (27.1% of the pop). The most recent population census which was released in 2010 has stated that the total population was 27,136,977 among them 18,707,576 (69% of the pop) Saudis and 8,429,401 non-Saudis (31% of the pop) (Ibid).

The annual growth of the population in Saudi Arabia has been changing over time following international population growth trends. Population growth rate was 6.4% in 1980 decreasing by nearly half to 3.5% in 1990 then reaching 2.4% in 2000 ending up with 2.2% at the latest census data in 2010 (CDSI, 2012a; UN, [No date]b, The World Bank, [No date]a). These decreases can be related to many economic and social factors such as the increase in life expectancy, the later marriage age as well as the aims of birth control in the Saudi society (USDS, 2012).

Regarding the population density in Saudi Arabia, it is overall 13.5 people per km^2. However, as most of the terrain is unsuitable for cultivation, the coastal parts and the interior oases and cultivated lands have the majority of the population. Some cities have reported densities of 1000 people per km^2. The Makkah region, which has the Holy Land of Makkah and the major city of Jeddah, is the highest populated region in the country with 25.5% of the total population. Similarly, Riyadh region has another 25% followed by the Eastern Province with 15.1% of the total population. On the other hand, other regions have low population densities. Northern Borders is the lowest with only 1.2% of the total population followed by 1.5%, 1.6% and 1.9% for Al-Baaha, Al-Jowf, Najran, respectively (Figure 3.8 A). Non-Saudis distribution varies also from one region to another due to jobs availability. According to the 2010 population census, 83.1% of the total non-Saudis are in four regions which are: 33.2%, 29.4%, 14.4% and 6.1% in Makkah, Riyadh, Eastern Province and Madinah Region, respectively. Figure 3.8 B & C show the total distribution of Saudis and non-Saudis over the 13 regions (CDSI, 2011).

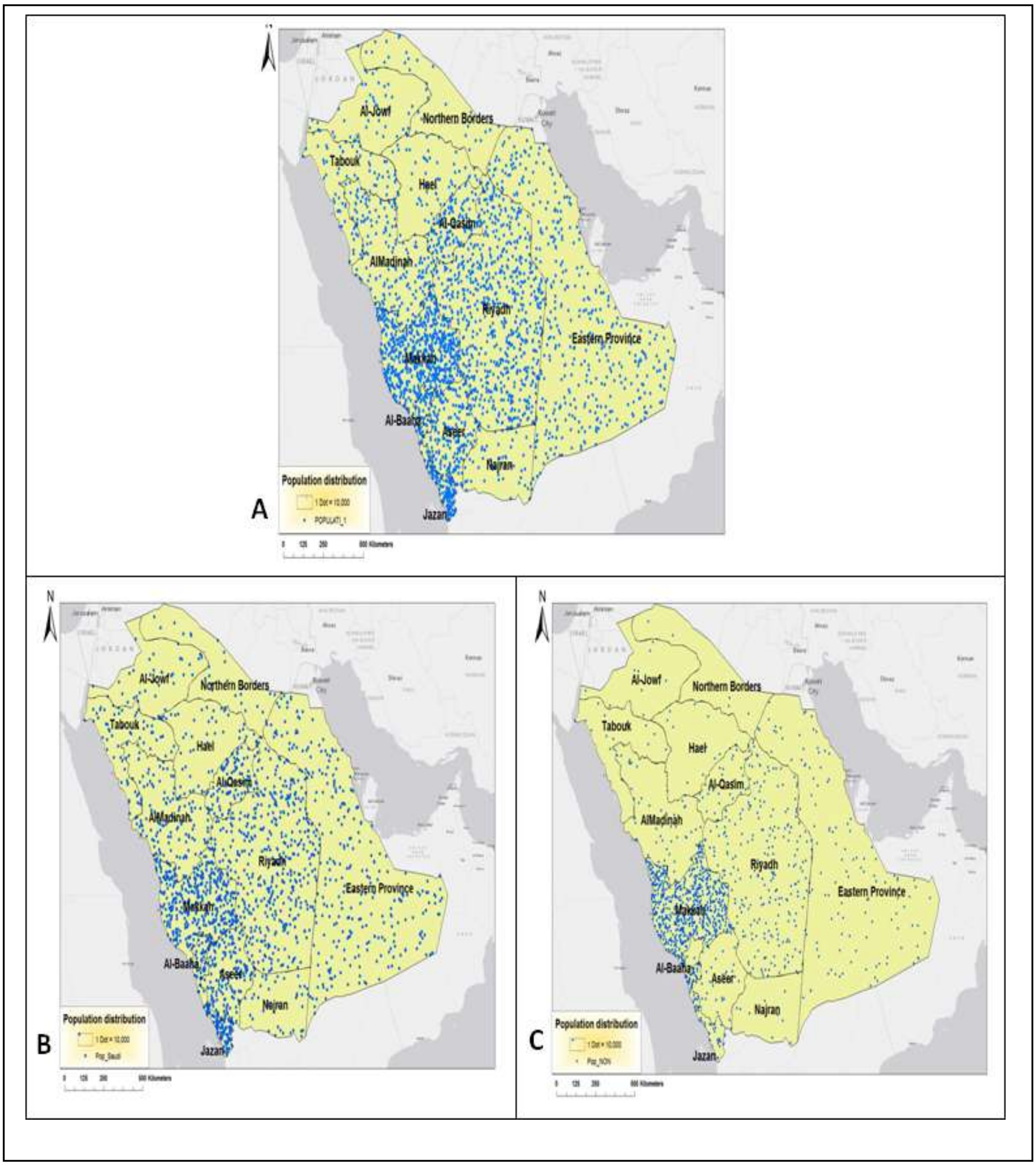


Figure 3.8: Population distribution in 2010, A) Total population, B) Saudis' distribution and C) non-Saudis' distribution.
*Note each blue dot (•) = 10,000 pop

3.1.10.3. Demography:

The demographical structure of Saudi Arabia has been changing over time as a result of some economic and social factors. Economically, the development in the field of health and medical services availability as well as the rise in public awareness because of the increase in education level and the governmental illiteracy eradication programmes have contributed to these changes. Moreover, some social aspects have also similar impacts on the demographical changes such as late marriage age, birth control plans for the purpose of well brought up children as well as the rise of females' involvement in the work place.

Generally speaking, Saudi Arabia has an overwhelmingly young population. Based on the 2010 census data, 38.1% of Saudis were under the age of 15 years, 60.1% were in the age between 15–64 years old, and only 1.8% were 65 years and older and the age structure has not changed a lot over time in the country (CDSI, 2012a). Yet, other demographical numbers have changed noticeably in the past 40 years such as birth, death, fertility and mortality rates. Birth rate has been decreasing noticeably from 48.5 per 1000 pop in 1974 to 33.40 per 1000 pop in 1995 and reaching 29.40 in 2010 which is clearly influenced by the economic and social factors. The same factors have also affected the fertility rate from 7.2 per women in 1974 to 5.0 and 4.2 children per women in 1995 and 2010, respectively (Ibid). Additionally, the development in health services and public awareness have reduced the mortality rate from 93 deaths per 100.0000 live births in 1974 to 25.6 and 17 per 100.000 live birth in 1995 and 2010, respectively (CDSI 1974, 1992, 2005 and 2010, LCCS, 2006). Life expectancy in Saudi is generally high and can be compared to developed countries with 77.78 years for females and slightly lower for males with 73.66 years (CDSI, 2012a; LCCS, 2006).

3.1.11. Education in Saudi Arabia:

The educational system in Saudi Arabia has many goals for its development. These goals are focused on the improvement of the level of education ensuring that the general education will meet the economic and social requirements. It is also aimed at providing education facilities and eradicating illiteracy among the Saudis. Education levels are divided into four main stages namely primary level, high school level, university level and post graduate level. The primary level is for the educational needs of children from ages 6 to 12. The high school level has two levels which are intermediate level for children ages 12 to 15 and secondary level for children ages 15 to 18. The university level on the other hand is currently confined mainly in the cities and large towns only. Lastly, the post graduate level includes master's and PhD degrees (MOHE, 2006).

People in all regions of the country mostly have an equal opportunity of accessing each level of education. However, the highest percentage of illiterate people is in the Jazan Region, whilst the lowest is in the Riyadh Region as shown in Figure 3.9 (MEP, 2006). Obviously, basic education always provides awareness and therefore some level of self-protection from epidemic diseases and vector-borne diseases. Therefore, education variables can play an important role when unusual diseases occur.

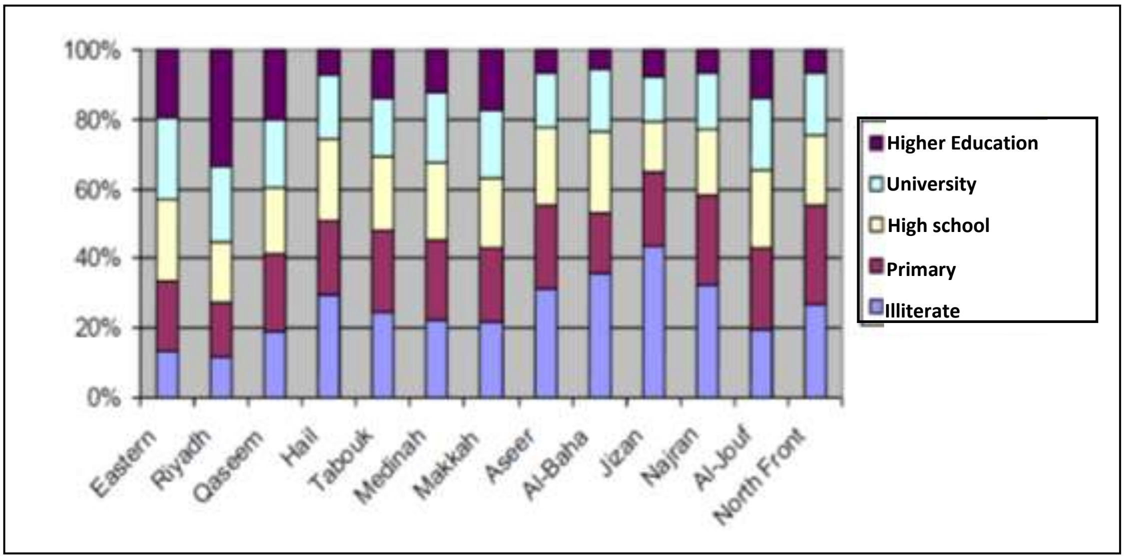


Figure 3.9: Education levels in Saudi Arabian regions in 2009

3.1.12. Health Care in Saudi Arabia:

The health care system in Saudi Arabia is based on the belief that the government should supply the health care services freely for its citizens (Albejaidi, 2010). Initial efforts to build a public health care system in the country started in 1926 with the issuance of a decree by King Abdul Aziz establishing the "Health Department" under the supervision of the Ministry of Interior. The principle of this department was to set up hospitals and clinics in several cities in the western parts of the country (Makkah, Madinah, Jeddah and Al-Ta'if), which basically aimed to provide health services for thousands of pilgrims who visit the Holy Land every year in Makkah (Shobokshi, 1999).

Even though the oil was first discovered in 1938, the growth in the health sector was slow due to the low national income. The year 1950 can be considered as the real start for health services in Saudi Arabia with the increase of the country's oil income and also with the creation of the Ministry of Health (Ibid). The real challenge to the Ministry of Health at that time was to take national responsibility to develop the health services with high quality and reliability all over the country. It began by building 11 general hospitals and 25 primary health care centres across the country (Al-Shaowaier, 2002). Since the end of the 1960s, oil income has been playing an important role in the country's development in many aspects. One of the most important aspects is the governmental expenditure in the health care sector especially in Ministry of Health which is increasing noticeably (Table 3.3). As a result of this expenditure, the number of general hospitals rose from 74 in 1969 to 249 in 2011, as well as the number of PHCCs rose from 292 to 2094 in the same period as shown in Table 3.4.

Table 3.3: Governmental expenditures on the Ministry of Health

Year	National income in American million dollars	MOH budget in American million dollars	MOH budget (% of Governmental Budget)	National income per capita in US dollars
1960	984	29	2.94	$ 287
1970	6385	177	2.77	$ 10,752
1980	100,000	5660	2.31	$ 952
1990	144,000	8600	5.97	$ 9,113
2000	185,000	12,000	6.49	$ 8,937
2011	296,000	18,320	6.2	$ 10,962

The annual statistic books from CDSI, 1985, 1995, 2000, 2003, 2009, 2011 and 2012

Table 3.4: Health care sector growth in Saudi Arabia

Year	Number of general hospitals	Change %	Number of Primary health care centres	Change %
1950	11	----	25	----
1970	74	572%	292	1068%
1985	105	42 %	1306	347%
1996	175	66.5 %	1725	32%
2011	249	42.3 %	2094	17.9%

The annual statistic books from CDSI, 1985, 1995, 2000, 2003, 2009 and 2012

3.1.13. Diseases in Saudi Arabia:

The general plans of the Ministry of Health in Saudi Arabia are to focus on health care through implementation of an overall immunization program against fatal diseases such as Hepatitis, Measles and Whooping cough. Additionally, to focus on chronic diseases such as Diabetes, Cancer, Hypertension, Cardio Vascular and Hereditary diseases, which have been increasing over the last 40 years as a result of population growth and the tremendous changes in their lifestyle, such as the changes in the food types and eating behaviour as well as the lack of physical activities and the increase of obesity. Furthermore, the Ministry of Health is constantly improving its prevention and control programs aiming to eradicate infectious diseases. These activities in the last decades have resulted in eliminations of several diseases such as Poliomyelitis, Smallpox and Diphtheria (see Table 3.5). Some diseases, nevertheless, are still endemic in the country, namely Malaria, Schistosomiasis and Leishmaniasis and they are widely distributed all over the country. Even though these infectious diseases are endemic in many places, the number of cases has been noticeably decreasing all over the time as a result of the control and surveillance of the epidemiological control units spread over the country (MOH, 2009). These reductions in infectious disease can be seen in Figure 3.10 which shows the average cases per 100,000 populations.

Table 3.5: Changes in prevalence of selected diseases in Saudi Arabia

Disease	1974	1980	1990	2000	2010
Diabetes ▲	2.5%	5%	7.2%	9.2%	13.4%
Breast cancer ▲	N/A	0.3%	0.6%	1%	1.4%
Leukaemia ▲	0.4%	0.5%	0.6%	0.8%	1%
Hypertension ▲	N/A	8%	13%	24%	26.1%
Cardio-vascular ▲	0.7%	1.5%	2%	3.6%	4.5%
Poliomyelitis ▼	N/A	163 cases	23 cases	2 cases	No cases
Tuberculosis ▼	N/A	3135 cases	1342 cases	591 cases	81 cases

(% infected percentages of the total population, N/A no data available)
MOH annual statistic books for 2002, 2006 and 2012.

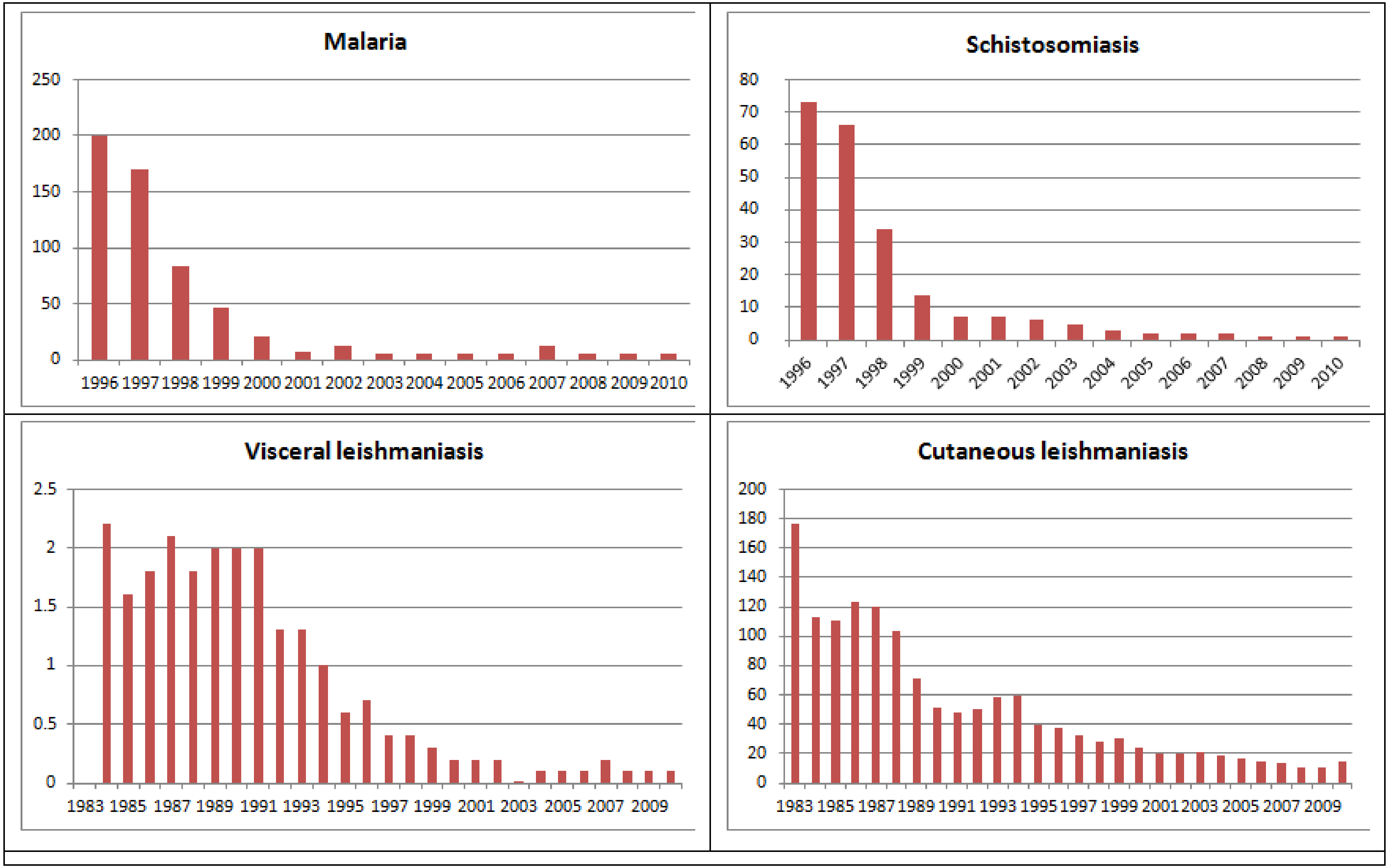


Figure 3.10: Infectious diseases per 100,000 population in Saudi Arabia (MOH annual statistic books for 2000, 2008, 2009, 2010 and 2012)

Based on the reports from the Ministry of Health and other governmental organizations, there is a large variation in the distribution of these four infectious diseases across the country. Figure 3.11 shows the average rate of these diseases per million population per region in the period between 2000 and 2010 in Saudi Arabia.

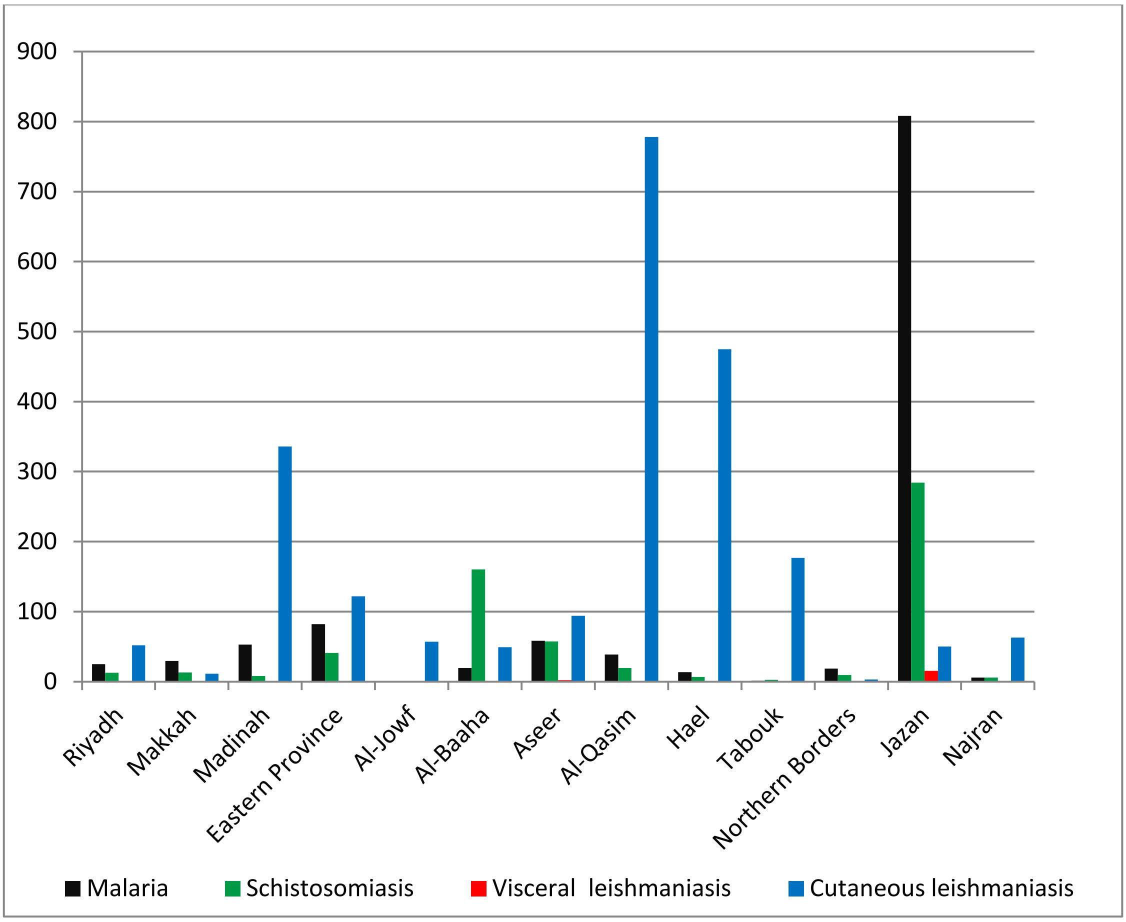


Figure 3.11: Malaria, Schistosomiasis, Visceral Leishmaniasis and Cutaneous Leishmaniasis rates per million population in Saudi Arabia between 2000 and 2010. (MOH annual statistic books for 2002, 2006, 2008, 2010 and 2012)

From the graph above, it can be seen clearly that regions in the Tihamh Plain and the lowland (Aseer, Jazan, Makkah, Medinah and Eastern province) are at high risk of Malaria, Visceral Leishmaniasis, and Schistosomiasis transmission. On the other side, inner regions are at high risk of Cutaneous Leishmaniasis transmission, particularly Al-Qaseem, Hael and Eastern regions. This can be related to the number of farms and livestock which are much larger than other regions as well as the large agricultural lands by the edge of the Arabian Desert.

3.2. Study Area:

3.2.1. Study Area Selection:

As this study focuses on CL more than the other infectious diseases, CL incidence per million population in regions across the country in the period between 2002 and 2010 is listed in more detail in Table 3.6. According to Bonita et al. (2006) and Fletcher and Fletcher (2005) the disease incidence rate can be defined as a measure of the number of new cases that develop in a particular population in a given period of time, whereas the disease prevalence rate refers to the number of cases of a disease that are present in a particular population at a given time. In the period between 2002 and 2010 there was not that much change in the population in each region. Therefore, the incidence rate per million population was calculated by averaging the number of reported incidents for the same years divided by the total population in 2010.

Table 3.6: CL incidence rate in each region between 2002 and 2010

Region	2002	2003	2004	2005	2006	2007	2008	2009	2010	Pop in 2010	Rate per million pop
Riyadh	236	501	359	439	306	305	325	235	401	6777146	52
Makkah	105	116	115	60	64	52	57	35	21	6120045	11.4
Medinah	553	762	767	526	643	619	287	625	1000	1777933	336
Al-Qaseem	880	1273	1102	1082	981	852	758	654	1464	1215858	778
*Al-Ahsa	1246	991	865	948	846	817	379	444	457	1587294	515
Eastern Province	36	25	21	44	54	16	18	16	11	2518486	10
Aseer	277	231	181	123	149	153	140	181	271	1913392	94
Tabouk	118	100	203	187	149	165	90	106	159	791535	177
Hael	399	374	379	329	249	189	165	186	234	597144	475
Northern Borders	0	2	1	0	0	0	0	0	1	320524	3
Jazan	74	48	67	75	73	86	92	28	81	1365110	50
Najran	19	22	26	58	70	30	12	15	15	505652	63
Al-Bahah	47	45	1	0	45	0	0	23	0	411888	49
Al-Jouf	3	0	78	44	4	44	30	0	0	440009	57

*Al-Ahsa is a governorate in the Eastern Provence but was listed separately from the region by the Ministry of Health due to its large size and the high number of CL cases.
(MOH annual statistic books for 2003, 2006, 2009, 2010 and 2011).

The table above shows clearly the variation in CL incidence across the country. In some regions, CL is endemic and others are almost free of cases. The highest endemic region is Al-Qaseem with an incident rate of 778 cases per million population followed by Al-Ahsa, Hael and Medinah with rates of 515, 475 and 336 per million population, respectively. The Northern border is the lowest with the rate of 3 cases per million population followed by the Eastern Province and Makkah with 10 and 11.3 cases per million population, respectively.

Al-Qaseem Region – the highest endemic region to CL - was selected at first to be the focus area of this study. As the researcher is not familiar with the region as well as the providers and the availability of the required data for this study, there was a real need for an exploratory field trip. In May 2011, this exploratory trip took a place in Saudi Arabia, namely in both Riyadh City and Al-Qaseem Region. The 4-week planned trip was extended to 11 weeks as a result of the unsurprisingly long governmental procedures and bureaucracy. In Riyadh City, some ministries and other governmental institutions were visited to address the data's sources for official correspondence. The second part of the visit was to AL-Qaseem Region in order to have a general idea about the area and to visit foremost the Ministry of Health's office as well as other ministries in the region. During the visit to Al-Qaseem Region, many obstacles appeared. Firstly, CL data was kept widely scattered in nine general hospitals in the region beside the main data centre 400 km away with many difficulties in accessing these data. Secondly, the cooperation level and facilities availability in Al-Qaseem Region were much lower than expected as the region has neither an insect laboratory nor anatomist and taxonomist who can be involved in this study. Thirdly, a higher cost for data collection in terms of time and expenditure as the researcher is not familiar with the region.

These obstacles resulted in a decision to change the study area to another region which is also endemic to CL. To avoid any similar impediments and difficulties, Al-Riyadh Region was selected to be the study area. Several reasons motivated this choice. Firstly, the level of cooperation and facilities availability is much higher in Al-Riyadh Region than any other regions. Secondly, all ministries and almost all governmental and non-governmental institutions are located in Riyadh, which helped speed up correspondence and data collection. Thirdly, most research centres and national libraries are also located in Al-Riyadh Region. Fourthly, more contact persons are known in Riyadh Region which helped massively in speeding correspondence and data collections. And finally, the region is familiar to the researcher which reduced the cost in both expenditure and time significantly.

Even though Riyadh Region as whole has a quite low number of CL cases (52 per million population), some governorates in the region have endemic levels of the disease. Riyadh Region is divided into nineteen governorates, and the exposure to CL varies between these governorates as shown in Table 3.7. The incidence rates per million population were calculated using the same technique previously used in Table 3.6.

Table 3.7: CL incidence rates in the Riyadh Region's governorates between 2005 and 2010

Governorates	2005	2006	2007	2008	2009	2010	Pop in 2010	Rate per million pop
Riyadh & Aldiriyah and Rumah	4	23	20	15	16	8	5356238	3
Al-Kharj	68	44	55	18	27	24	376325	104
Al-Dawadmi	215	165	158	218	129	177	217305	815
Al-Majmaah	7	5	3	18	11	4	133285	60
Al-Quwayiyah	75	30	18	4	1	8	126161	182
Wadi Addwaser	0	0	0	0	0	0	106152	0
Al-Aflaj	0	0	0	0	0	0	68201	0
Az-Zulfi	1	0	0	0	3	1	69294	14
Shaqra	8	4	4	12	10	8	40541	179
Al-Hawtat Wa Al-Hariq	53	13	17	12	10	8	58050	325
Afif	3	0	5	0	18	9	77978	77
As-Sulayyil	0	0	0	0	0	0	36383	0
Duruma	1	0	7	26	9	4	24429	319
Al-Muzahimiyah	1	0	1	0	0	0	39865	25
Thadiq	0	0	0	0	0	0	17165	0
Huraymila	3	6	4	0	0	4	15324	196
Al-Ghat	0	0	0	0	0	11	14405	139

MOH annual statistic books for 2006, 2009, 2010 and 2011.

From the table above, it is obvious that some governorates are free of the disease such as Wadi Addawasir, Al-Aflaj, As-Sulayyil and Thadiq while others are endemic like for instance Al-Dawadmi with an average of 815 per million population followed by Hawtat Bani Tamim Wa Al-hariq and Duruma with 325 and 319 per million population, respectively. Al-Dawadmi governorate is considered as one of the highest endemic areas for CL in the country based on the Ministry of Health annual records (MOH 2002, 2006, 2008 and 2010). Considering this fact as well as Al-Dawadmi's location in Riyadh Region made it an appropriate location to be the focus of this study.

Even though, Al-Dawadmi Governorate is located in Al-Riyadh Region which has a relatively low CL rate (52 per million population), it is adjoining to Al-Qaseem Region which has the highest CL incident rate between the regions (778 per million population) as shown in Figure 3.12. This geographical adjacency between both areas (Al-Dawadmi Governorate and Al-Qaseem Region) and the similarity in the high CL endemicity rates might be an obvious indicator that they have similar physical and human characteristics and the study results could be a reflection for the CL problem in both areas and provide a basis for generalising the results.

3.2.2.1. Al-Dawadmi Governorate:

Al-Dawadmi Governorate is located in the Riyadh Region in the central part of the country. Al-Dawadmi lies between the latitude 23'.30'' and 25'.30'' north and between longitudes 43'.30'' and 45'.30'' east. It is nearly 300 km west of Riyadh City, the capital of the country, with an area of 43,121 km^2 (see Figure 3.12). The land's height is approximately 1340 metres above sea level in the south west of the governorate and slopes towards the north east reaching 621 m in the north east end of the governorate. Al-Dawadmi Governorate has 4 major cities which are Al-Dawadmi City, Nifi, Sajer and Albjadiah, with 36 towns and more than 444 villages or group of houses as shown in Figure 3.13.

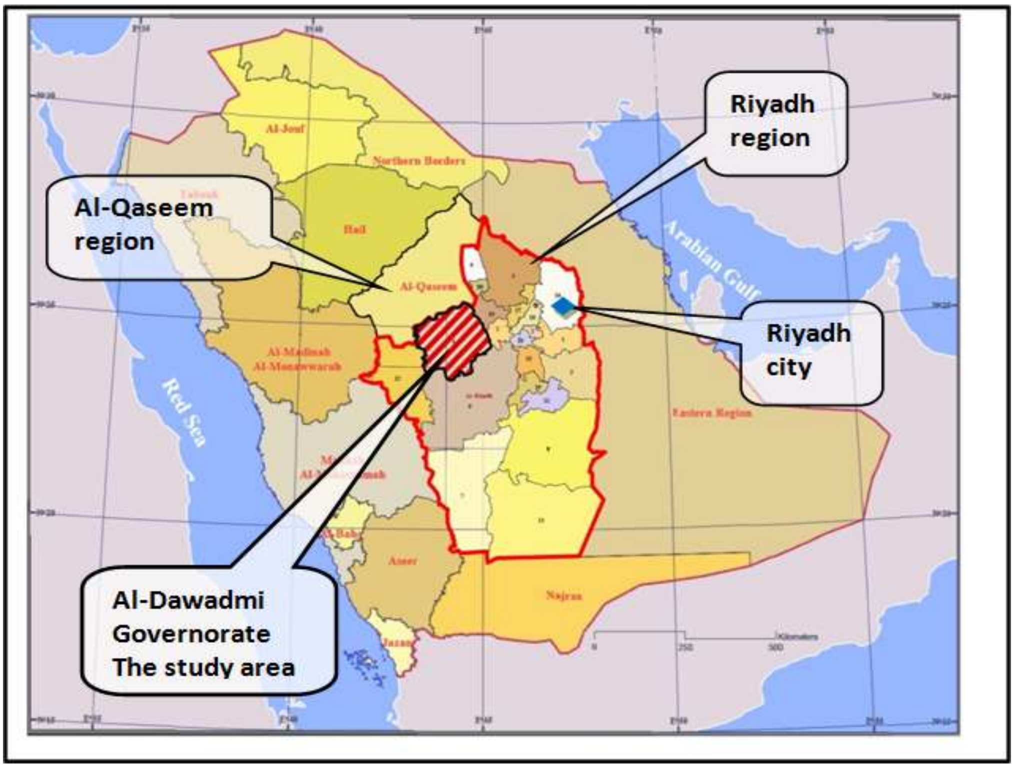


Figure 3.12: Al-Dawadmi Governorate general location

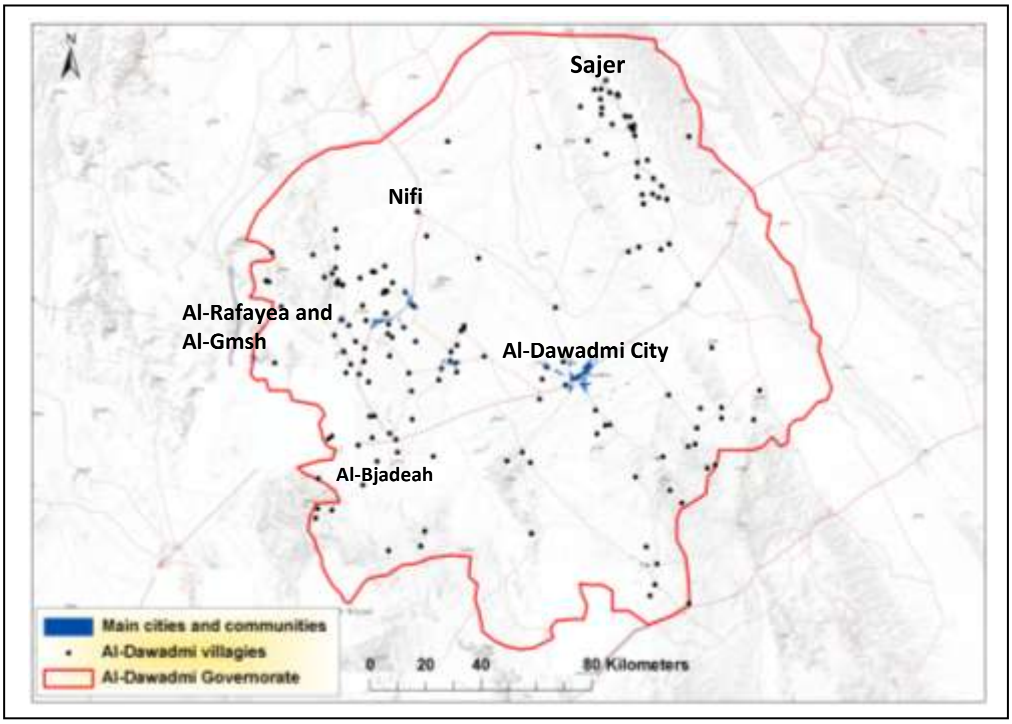


Figure 3.13: Al-Dawadmi Governorate's main communities

3.2.2.2. Climate of Al-Dawadmi Governorate:

Al-Dawadmi Governorate has a desert climate with large temperature variation between summer and winter. In summer, temperature ranges between 32°C and 40°C during the day and between 19°C and 25°C at night. However on some hot days the temperature might reach 48°C. Humidity in summer is very low fluctuating between 5% and 13%. In winter, temperature ranges between 15°C and 21°C during the day and between 5°C and 10°C at night. In some days with clear sky and low wind, the temperature can reach 0°C (Zahran, 2010; Alriyadh.gov, 2008). Most of the rain falls in winter and varies from year to year with an annual average of 110 mm. Autumn and spring have moderate temperature ranging between 22°C to 30°C during the day and between 15°C and 22°C at night. Some rains might fall in these seasons and also with high possibility of sandstorms mostly during the day (Zahran, 2010). These climatic conditions are ideal for both the CL vector and reservoir as mentioned in Chapter 2, so it is not surprising that the disease is endemic in the governorate.

3.2.2.3. Wadis:

In general, Saudi Arabia does not have any permanent rivers, but it does have many wadis which are either permanently or irregularly dry riverbeds. These wadis were formed during more humid climate episodes. Wadis in desert regions carry water only after torrential rainstorms which happen once in a few years (West and Hampshire, 2013). Soil in these wadis mostly consists of alluvia laid down by flood deposition which occupy large areas and are deep with originally good structure in medium to fine textures (Ghazanfar and Fisher, 1998). In addition, these wadis are also rich in flora seeds carried by floods and laid down by the depositions making such areas rich in natural vegetation (Ibid; Glennie, 1987).

In Al-Dawadmi Governorate, there are 19 major wadis sharing mostly the same geological, topographical and hydrological features. Most of these wadis have an overall northeast slope joining all to Al-Remah Wadi in Al-Qaseem Region north of Al-Dawadmi Governorate which is the largest dry wadi in the country ending up in the Al-Thowerat sand dunes by the Arabian Gulf. These wadis have hundreds of tributaries where water bodies start accumulating in these natural streams (Mandaville, 1990) as shown in Figure 3.14. These hundreds of tributaries and wadis in Al-Dawadmi Governorate result in large areas of permanent and temporarily natural vegetation cover and also make the areas suitable for farming and grazing. Such land cover is an ideal habitat for both CL vector and reservoir.

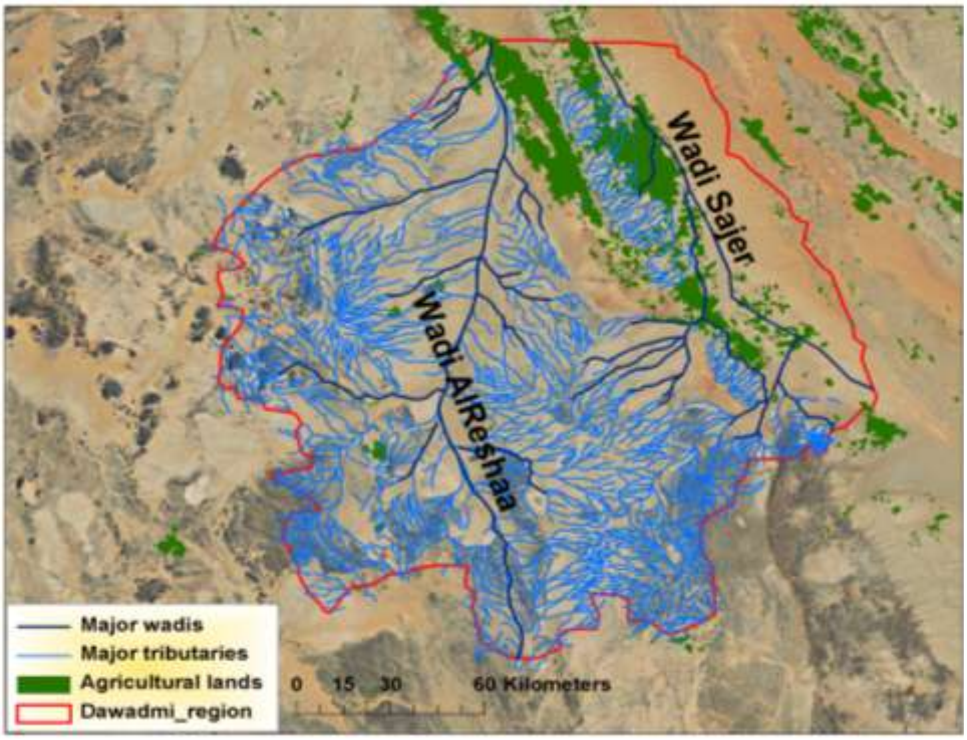


Figure 3.14: Al-Dawadmi Governorate's main wadis and tributaries

3.2.2.4. Flora:

Within the governorate, natural vegetation differs in terms of types, densities and distributions. Generally speaking, there are two types of natural vegetation cover which are permanent or seasonal growth vegetation after rainy seasons as shown in Table 3.8 (Ghazanfar and Fisher; 1998, Novikova, 1970; Miller and Cope, 1996).

Table 3.8: Natural vegetation cover in Al-Dawadmi Governorate

ID	Permanent vegetations	Seasonal vegetations
1	*Haloxylon Salicornicum*	*Neurada procumbens L.*
2	*Paniccum turgidum*	*Stipa tartilis*
3	*Rhanerium eppaposum*	*Launoea*
4	*Zizyphus spina-christi Willd*	*Aristida plumosa*
5	*Tamarix amplexicaulis*	*Megathyrsus maximus*
6	*Calligonum comosum*	*Rhazya stricta*
7	*Acacia ehrenbergiana Hayne*	*Cenchrus clliaris*
9	*Calotropis procera*	*Orobanche sp*
10	*Tamarix spp*	*Trifolium*
11	*Acacia origena*	

These listed vegetations are the most common types in the governorate with wide variation in their distribution and densities. Several studies have stated that *Haloxylon Salicornicum, Rhanerium eppaposum* and *Paniccum turgidum* (Figure 3.15) are the most dominant types of vegetation in the area (Novikova, 1970; Chaudhary, 1999). These vegetations grow mostly in wadis and tributaries, which are very widespread in the governorate making it as one of the densest natural vegetated areas which also provide good habitat for sandfly vectors and reservoirs.

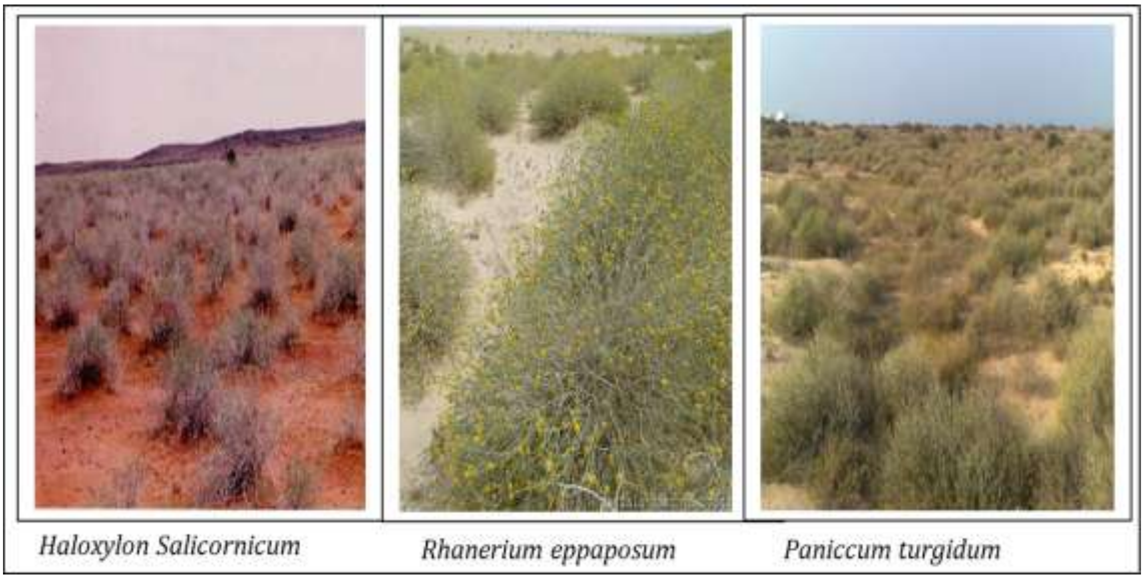


Figure 3.15: The three most common natural vegetation types in Al-Dawadmi governorate

3.2.2.5. Fauna:

The inner region of the country where Al-Dawadmi Governorate is located is home to a multitude of wild life including insects, spiders, scorpions, birds, prey, lizards, snakes and many mammal species including dogs, foxes and rodents (SWA, 2012). From these fauna species, rodents have been identified as the main CL parasite's reservoir in the area (Doha and Samy, 2010; El-Sibae et al., 1994, Strauss et al., 2008; Uthman et al., 2005, Calvet et al., 2000; Saliba et al., 1994; Jaber et al., 2013). No previous studies of rodent species in the governorate have been found. However, studies in nearby regions (Al-Qaseem and Al-Madinah regions and Al-Riyadh City) were used to address the possible existing rodent species there. These studies stated that there are eight main rodent species dominant in the area which are *Gerbil, Acomys dimidiatus, Rattus Frugivorus, Rattus Alexandrines, Mus musculus, Psammomys obesus, Meriones crassu and Meriones libycus* (El-Sibae et al, 1994 Alahmed and Al-Dawood 2001, Strauss et al. 2008, El-

Badry et al. 2008, Ibrahim et al. 1994, Peters et al. 1990). Two of these rodents, *Psammomys obesus and Meriones libycus,* are considered to be the reservoir host for CL parasite.

3.2.2.6. Population of Al-Dawadmi Governorate:

According to the Population and Housing Census in 2010 (CDSI, 2012), Al-Dawadmi Governorate had a total population of 217,305 distributed in 43,121 housing units and a population density of 5 persons per km^2. This population is scattered across the governorate in cities, towns, small villages and small groups of houses or even in individual houses as shown in Figure 3.13 previously. The number of Saudis is 173,425 making up 79.8% of the total population, whilst non-Saudis are 43,880 with 20.2% of the total population. For gender classification, both Saudi males and females are more or less in an equal percentage with 49.1% males with (85,142 population) and 50.9% females with (88,283 population). For the case of non-Saudi the number of males is much higher than females, 77.3% of them are males (33,924 population) and 22.7% are females (9,956 population). This large variation in non-Saudis gender can be justified by the nature of the region as most of non-Saudis come as manual labourers, shepherds or farmers which are male jobs.

3.2.2.7. Settlements:

Settlement patterns in Al-Dawadmi Governorate are influenced by physical features of the land, and by socio-economic and cultural perspectives. The typical pattern of housing materials and settlements vary from one area to another. In general, settlements can be found as cities, towns, clustered villages, scattered traditional group of houses and sometimes scattered individual houses. In Al-Dawadmi, there are five main types of housing and each type has its own characteristics as summarised in Table 3.9 and Figure 3.16.A to 3.16.E

Table 3.9: Housing types in Al-Dawadmi Governorate

ID	Housing Type	Building material	Water	Sewage	Electricity	Insect and rodent protection	location	waste disposal and cleanliness of the neighbourhood
1	Modern houses (Figure 3.17.A)	Bricks and good plaster	Good water networks	Good network or deep septic tank	Well supplied	Good protection, with no gaps or cracks on the building	New wards or far from old communities centres	Collected by local authorities
2	Traditional houses (Figure 3.17.B)	Bricks & stones and some plaster.	Reasonable or good water network	Shallow or on surface septic tank and mostly with moist surface.	Moderately well supplied	Moderate protection, with some gaps, cracks and holes on walls, windows and doors	Old parts of the community	Collected by local authorities
3	Mud houses (Figure 3.17.C)	Mud, wood and strew or hay.	Shallow or on surface network or vehicle	On surface septic tank and mostly with moist surface.	Poorly supplied with on wall installations	Poor protection with many gaps, cracks and holes on walls, windows and doors, and building materials are attractive for insect and rodent for resting and breeding.	Old parts of the community	Collected by local authorities in communities or collect and burn in remote areas
4	Farm house (Figure 3.17.D)	Bricks and stones or mud wood and strew or hay.	Well or vehicle	On surface septic tank and mostly with moist surface or outdoor defecating areas	Not or poorly supplied	Low protection with many gaps, cracks and holes.	Farms	Close from the house then burn
5	Tent (Figure 3.17.E)	Cloth	Well or vehicle	Outdoor defecating areas	No electricity	No protection	Farms, country side or desert	Close from the house then burn

Figure 3.16.A) Modern house

Figure 3.16.B) Traditional house

Figure 3.16.C) Mud house

Figure 3.16.D) Farm house

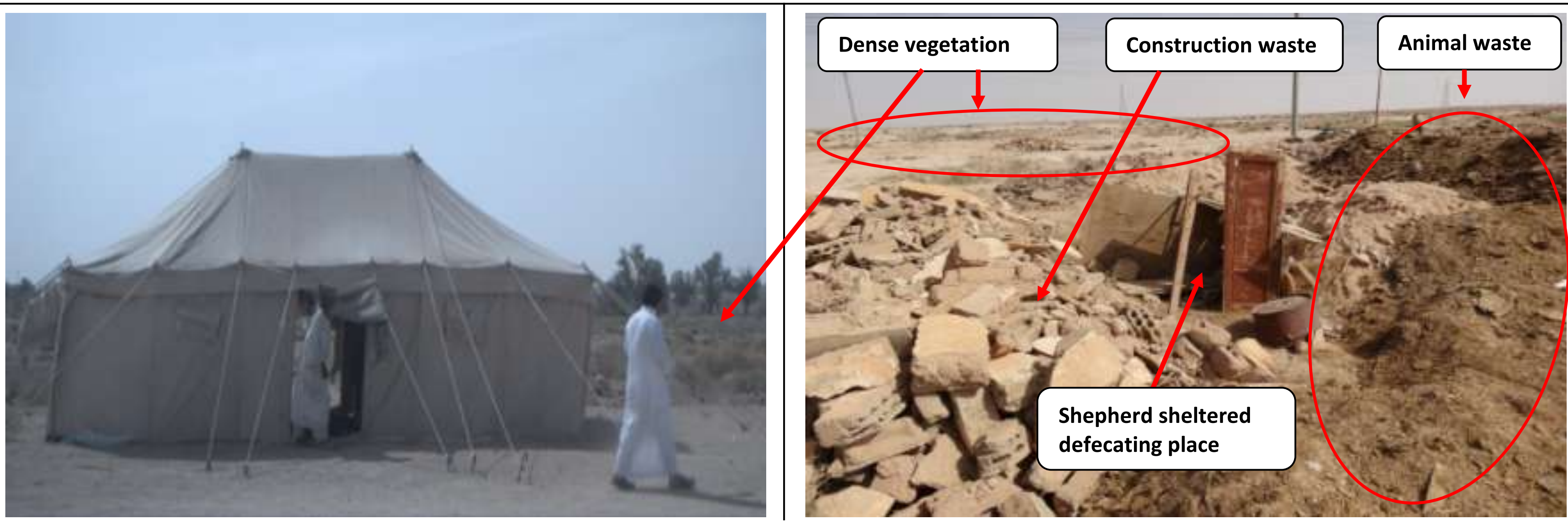


Figure 3.16.E) Shepherd tent

3.2.2.8. Agriculture:

Al-Dawadmi Governorate is an agricultural region which can be divided into eastern and western parts. The eastern part has large farming areas which produce grain, clover, and vegetables especially in Wadi Sajer. The western part of the governorate has smaller farms and widely scattered fields especially in wadis and tributaries, with date palms and vegetables mostly in the south of Al-Dawadmi City and in the Rfaya'a Algmsh area as shown in the figure (Figure 3.14). This number of farms and fields can be stated as a generous food and housing provider for CL vectors and reservoirs.

3.2.2.9. Livestock and Poultry:

Due to the grazing and farming nature of the region, livestock is a major resource and sheep, goats, camels and cows are the most common types of livestock there (Figure 3.17). Based on the researcher's knowledge and the collected information from the field, sheep and goats are commonly kept in farms and also in sheepfolds in houses, whilst cows are mostly kept in dairy farms and hardly ever in houses. Camels are often in open grazing lands or in fences in the desert. Poultry are also common in the governorate (Figure 3.16) and kept in houses or in poultry farms. In the governorate, there are 11 main livestock markets in the four large cities and in some towns, beside many smaller markets or selling in farms in the small towns or villages (Al-Dawadmi Governorate, 2010). Animal and poultry shelters were classified in the literature (see Chapter 2) as very suitable places for CL vector and reservoir as they contain normally some organic waste, crops as well as a warm and humid environment.

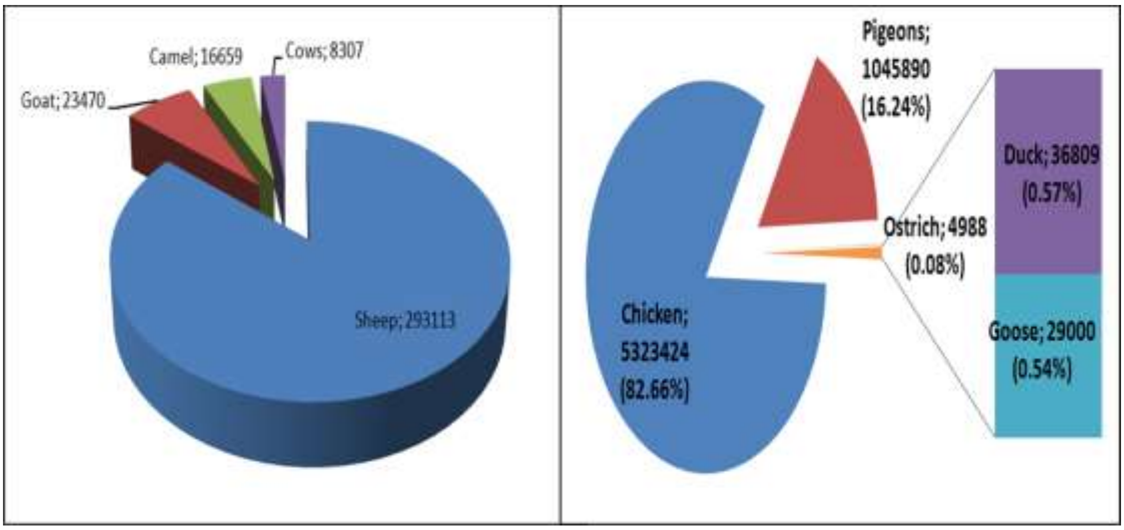


Figure 3.17: Livestock and Poultry population in Al-Dawadmi Governorate in 2012.

In short, the most important point to emphasize here is that Al-Dawadmi Governorate has environmental characteristics that are good for both the CL vector and reservoir to survive. The region has a combination of suitable climate conditions, dense natural vegetation cover, CL host species with scattered farming and grazing lands with the population living scattered amongst them in very mixed housing styles. In such environmental conditions, people are most likely to interact with CL vectors and reservoirs making the governorate unsurprisingly one of the highest endemic areas for CL.

Chapter Four: Study Design:

4.1. Introduction.

At an early stage and after selecting CL to be the focus of this study and upon conducting a wide literature review which was then followed by some meetings with experts in the field of epidemiology and CL in general and more precisely in Saudi Arabia, four main questions were highlighted to be investigated. These questions are related to different aspects and have not been covered in the literature widely in general or in the case of Saudi Arabia (Figure 4.1 shows the overall study design activities). These four questions were mentioned broadly in Chapter 2 and for convenience, are re-stated here:

Q1: How does CL vary according to climate conditions in Al-Dawadmi Governorate?

Q2: Does the prevalence of CL in a particular community vary according to the local environment and proximity to different types of land use / land cover?

Q3: Do CL cases vary according to socio-economic and demographic variables?

Q4: Is there evidence of under-reporting of CL cases in the study area? If so, do the characteristics of the officially reported cases differ from those that were not reported?

These 4 questions were categorised into two sets in the basis of what data are needed to be collected and how they are going to be answered. The first category includes question number one, which is going to examine the seasonality of the disease and the impact of climatic phenomenon upon its incidence rate in Al-Dawadmi Governorate. The answer for this question is going to be based on the level of the whole governorate and not on a community's level. The second category includes the remaining questions; number two, three and four. And the only way to answer these questions is by undertaking some sort of field survey including digitizing land uses and covers as well as a questionnaire survey.

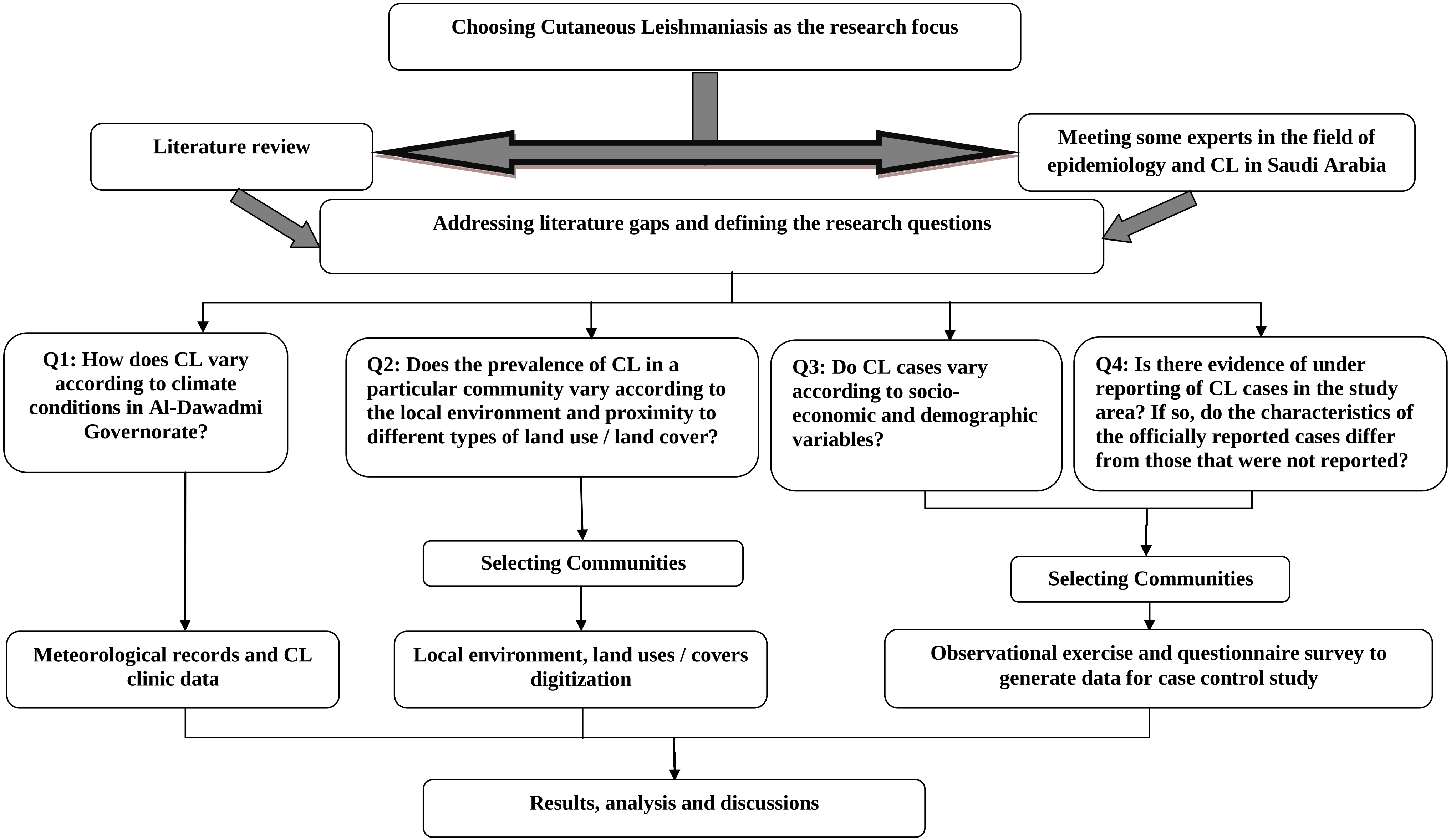


Figure 4.1: Study design framework.

In order to answer question number two, three and four, a set of communities in Al-Dawadmi Governorate needed to be selected for further investigation. Two key factors have been considered for this selection which are: CL incidence rate (high and low) and communities' proximity to general hospitals or dermatologist clinic (close and remote). Generally speaking, communities in an ideal world will be in four different sets of characteristics in terms of CL incidence rate and proximity to health facilities as shown in Figure 4.2.

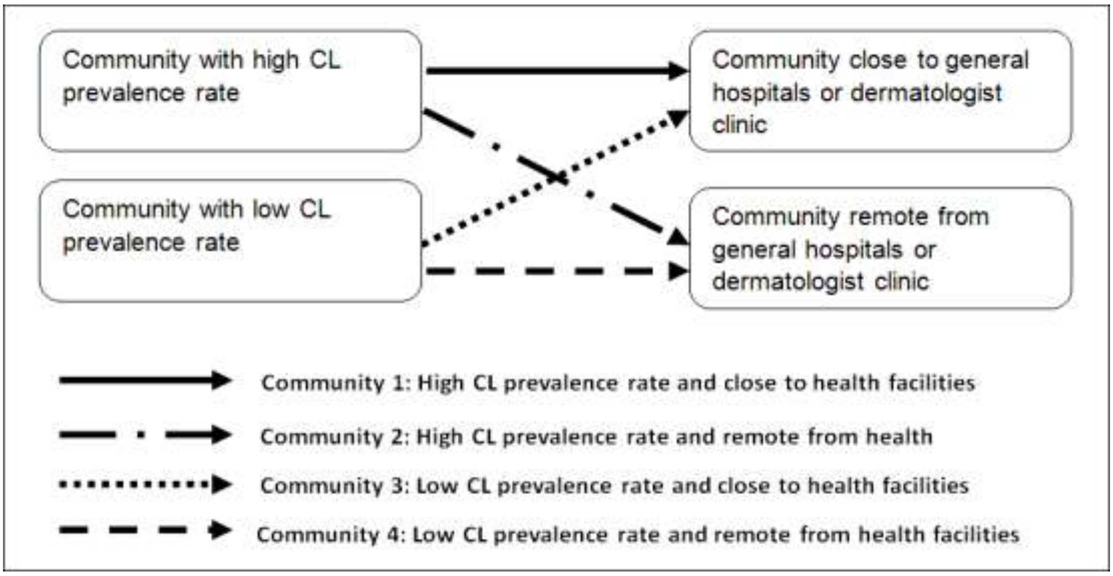


Figure 4.2: Communities' CL prevalence rate and proximity to health facilities.

However, in the case of Al-Dawadmi Governorate's communities, only three different set of communities' characteristics could be found which were: 'high CL incidence rate and close to clinics', 'communities with low CL incidence rate and both close to and remote from clinics'. Based on the provided official CL statistics from the Ministry of Health in Saudi Arabia, the kind of combination between 'communities with high CL incidence rate and remote from clinic' could not be found which is a self-fulfilling prophecy as full reporting of CL cases is believed to be problematic from the clinics in the remote communities. To examine the influence of accessibility and other socio-economic and demographic variables upon the CL incidence and reporting rates, a sample of different remote of clinics communities were selected with the intention of investigating the CL incidence rate and determining whether these are actually as low as the official statistics suggest or not.

4.2. Selecting Communities:

As stated earlier, a set of communities needed to be selected on the basis of CL incidence rate and proximity to general hospitals or dermatologist clinics. In the governorate, many communities fell under the selection scope, but with some suggestions from the Field Epidemiology Training Program (FETP) in Al-Dawadmi Governorate, many of them were eliminated due to their high survey cost in terms of time and expenditure or due to difficulties in accessing the areas or interviewing locals there. From many suggested communities, six were selected which were believed to be the most appropriate to be used to answer the questions of the research. These communities were a mixture of: a part of a city (the south sector of Al-Dawadmi City), towns (Al-Gmsh and Arwa towns) and a small group of villages (Al-Fegarah and Afgrah area which has 12 small villages and group of houses). The selected communities are shown with some additional details in Table 4.1 and their geographical distribution is shown in Figure 4.3.

Table 4.1: Selected communities for this study and their classifications

ID	Community		Pop in 2010	Average annual CL cases	CL rate per 1000 population	Proximity to clinic	CL prevalence rate
1	**South of Al-Dawadmi City**		5954	89	15	Close	High
2	Al-Rafayea and Al-Gmsh		7426	110	14	Close	High
3	Mesedah		2932	14	4.77	Close	Low
4	Al-Desmah		1224	3	2.4	Close	Low
5	Arwa		2751	3	1.1	Remote	Low
6	Al- Fegaiah and Afgrah area	Alwidi, Al-Rfa'a, Alrfeah Albedea'ah and alhaid villages	7255	7	0.95	Remote	Low
	Al- Fegaiah and Afgrah area	Afgrah and Al-Meleneyah villages	906	2	2.2	Remote	Low
	Al- Fegaiah and Afgrah area	Al-Nbwan village	1174	3	2.5	Remote	Low
	Al- Fegaiah and Afgrah area	Al-Shamyah, Alkhobah villages	665	2	3	Remote	Low
	Al- Fegaiah and Afgrah area	Al-Fegarah and deseah village	1445	3	2.1	Remote	Low

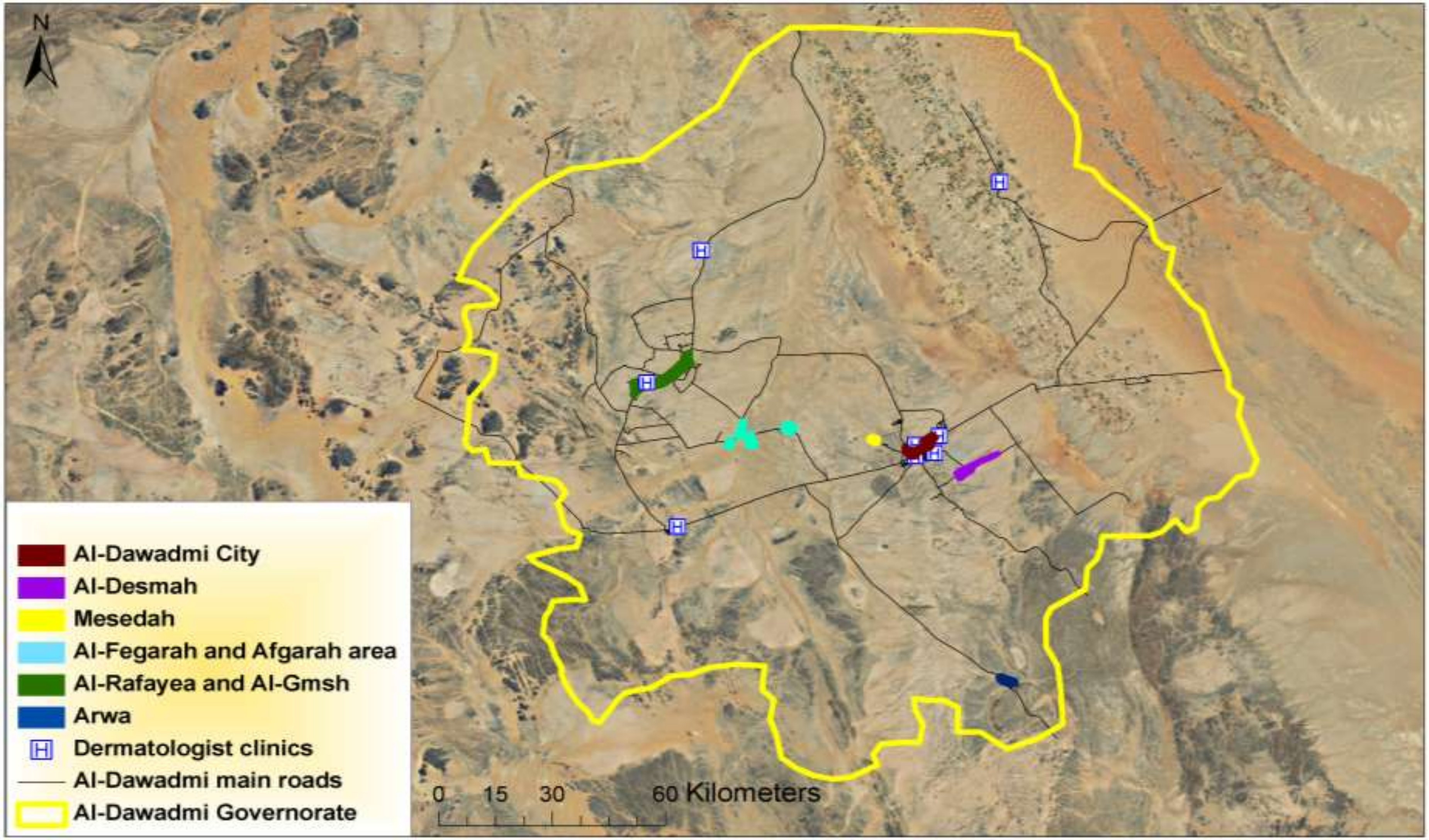


Figure 4.3: The selected communities in Al-Dawadmi governorate.

As this study sought to identify risk factors associated with CL, several observational epidemiological methods could have been used such as cohort, case control and cross-sectional studies (Song and Chung, 2010; Mann, 2003; Gail and Benichou, 2000). Bearing in mind the low budget for the survey as well as the short time for the field trip, a case control study method was selected as the most appropriate approach to be used, as it is comparatively quick, inexpensive and easy to carry out. This method compares people who have already had exposure to the disease (cases) with people who have not been exposed to the diseases (controls), and then looks back retrospectively to compare how widely the exposure to a risk factor is present in each group to assess the association between the risk factor and the disease (Schlesselman, 1982)

Cases were individuals that reported their suspected CL exposure to one of the dermatologist clinics in Al-Dawadmi Governorate, were then diagnosed as CL and received at least initial medical treatment. Controls were individuals who had been selected at random from the same community, age group, nationality and gender as the cases. One control was matched to each case considering the previously mentioned four variables. This matching can be justified as in epidemiology of human diseases these variables almost always affect the manifestations of a disease and in order to reduce the confounding effects these factors were matched between each case and its control (Wachoider et al., 1992; Kolaczinski et al., 2008).

Since poorer housing conditions have been reported as a main risk factor for CL in many parts of the world, this factor was used in calculating the sample size (WHO, 2015; Alvar, et al., 2006). Data from previous studies indicated that the odds ratio (OR) for CL exposure in poor housing condition is around 3.6 (Singh et al, 2014; Yared et al, 2014). Using this figure and assuming equal number of CL cases and controls, the sample size was calculated for 80% power and a 2-sided significance level of 5% and a continuity correlation, the minimum sample size was suggested to be 120 cases and 120 controls. The sample size was calculated using the Australasian National Statistical Service sample size calculator website available at: (http://www.nss.gov.au). In this study a confidence level of 95% was used as it is commonly adopted in epidemiological studies (Rothman et al., 2008; McNeil et al., 1996).

Ethical approval was obtained from the School of International Development Ethics Committee of the University of East Anglia, UK (see Appendix A). Interviewed individuals were briefly informed of the purposes and methodology of the study. If more information was requested then deeper explanations were given. Also, participants were told it was not obligatory to take part in the interview and even if they had started answering the questions they could withdraw from it at any time. Given cultural values in the study area initial consents were obtained from the head of the household. Children and females were interviewed either directly with the attendance of the head of the household or the head of the household was requested to ask the questions and write down the answers.

4.3. Data Collection:

As Al-Dawadmi Governorate is close to Al-Riyadh city - the researcher's most lived in city - several previous visits had been made to Al-Dawadmi Governorate in the years 2001, 2003, 2009, 2011 and 2012. These visits provided some knowledge about the region and a general understanding of the local culture and behaviour which guided and benefited in the preparations of the fieldwork, questionnaire design and survey.

4.3.1. Fieldwork Preparations:

The main aim of the field trip was to collect the necessary data to answer the main research questions. From the literature review, a list of data was highlighted to be gathered from different sources during the planned fieldwork visit. Different preparations were undertaken before conducting the field trip which included sending letters to various ministries and organizations regarding visiting permissions, data access requests and collection. These contacted institutions are listed in Table 4.2.

Table 4.2: Contacted institutions and purposes

ID	Institution	Purpose
1	Saudi Cultural Bureau in London and Al-Imam Mohammed Bin Saud Islamic University in Riyadh, Saudi Arabia	Permission to start the fieldwork.
2	Ministry of Health	• Health and human infection data. • Reported CL cases in the study area. • Information of general hospitals and primary health care centres.
3	The Ministry of Municipal and Rural Affairs	General topographic maps.
4	Saudi Geological Survey	General topographic maps.
5	Ministry of Agriculture	• Precipitation records. • Vegetation cover data.
6	High Commission for the Development of Arryiadh	Digital maps of Riyadh region.
7	Presidency of Metrology and Environment	Meteorological data.
8	King Abdul Aziz city for Science and Technology	Satellite images.
9	Ministry of Defence and Aviation	Digital base map of Al-Dawadmi Governorate.
10	Central Department of Statistics and Information (CDSI)	Demographical data.
11	International Development Ethic committee at the University of East Anglia	Ethical approval

4.3.2. Fieldwork Visits:

A fieldwork visit was undertaken between April and August 2012. Tasks of this field trip can be divided into two parts: part one which included collecting various soft copy and hard copy of maps, statistics, epidemiological documents and literature. The second part was fieldwork survey where several environmental locations were visited in the selected governorate for the study. In these visits, CL possible habitats were studied, local people were interviewed, information about CL cases were gathered and the researcher took part in some of the fieldwork duties like sandfly eradication programme under the Ministry of Health office in Al-Dawadmi Governorate.

The FETP in the governorate beside some individual help from local residents and some known people assisted the researcher in visiting some individual research investigation locations. They also helped locating some houses descriptive addresses, greatly helped in digitizing vegetation, land use / land cover and also helped in accessing some closed farms or fenced areas. Additionally, and most importantly they introduced the researcher and his work team to some of the local residents, especially in the case of small villages or group of houses where the local inhabitants are not used to see unknown people surveying in their areas.

Global Position System (GPS) devices were used to record the coordinates of the visited physical places as well as the exact locations of the housing units of the interviewed people. For addressing locations and digitizing the land use / land cover, Garmin Oregon 650T which has a built in camera with 5 MB resolution and with 3 metre accuracy alongside Garmin 60CSx with about 5 metre accuracy were used (see Figure 4.4).

Figure 4.4: The GPS devices used for data collection

4.3.3.1. Data Collected on Field Trips:

Large amounts of data were collected during the conducted field trip. The following part will explain the collected data with sources and the data collection processes for each of the research questions.

Question one, basically is going to examine the seasonality of CL in Al-Dawadmi Governorate. From the literature review as discussed in chapter 2, a strong association between the occurrence of CL and climate conditions has been found (Killick-Kendrick, 1999; WHO, 2014c). Temperature, rainfall and relative humidity were stated as the strongest climate phenomenon associated with the incidence of the disease (Cross and Hyams, 1996; Singh, 1999; Dryden, 1993). For this study meteorological data were collected for Al-Dawadmi Governorate as well as nearby regions which could be used for meteorological data interpolations. These data include: daily temperature (maximum, mean and minimum), daily relative humidity (maximum, mean and minimum) and the average monthly rainfall for the selected study period from Jan 2006 to April 2011. These data were provided from two different data sources which were the Presidency of Meteorology and Environment in Al-Dawadmi city (PME) and the Ministry of Agriculture in Al-Dawadmi Governorate (a distribution map for the meteorological stations is shown in Appendix B). The former provided all the meteorological data for Al-Dawadmi Governorate and adjoined meteorological stations in several spreadsheets on a daily basis format for temperature and relative humidity and in an averaged monthly format for precipitation. Both temperature and relative humidity data required personal effort in transforming them from a daily to average monthly basis format. Even though, degrading the meteorological data from daily to monthly format inevitably results in some loss of information, this step was unavoidable to match the Ministry of Health' CL case reporting format which was on a monthly basis where within the month the day that the incident occurred was not identified.

The Ministry of Agriculture provided only the precipitation data from their three meteorological stations in the governorate, which are located in Al-Dawadmi City, Sajer and Nifi. The provided precipitation data were in hard copy format with many missing or illegible numbers forcing the researcher with some members of the staff to re-open the archived data and trace the missing values. These collected meteorological data will be used to examine the seasonality of the disease in the study area.

The subject of question two examines the influences of vegetation and other land use / land cover upon CL prevalence. In literature, strong relationships have been found between vegetation cover and land use / cover with the prevalence of CL (Wasserberg et al., 2003; Ben Salah et al., 2000; Mutinga et al., 1986; Alexander, 2000; Ximenes et al., 1999). Some of these studies have examined the degree to which proximity to some vegetation types or some land use / land cover are related to the prevalence of CL, which will be further examined here. However, as the land use / land cover and vegetation cover data does not exist anywhere in digital format, personal efforts were required to digitize these phenomena.

Since the region has a wide variety of vegetation types, general vegetation classification were addressed in the light of their preference to CL's vectors and reservoirs, densities and distribution. Generally speaking, rodents and sandflies in arid and semi arid region generally prefer the types of vegetation with short stems and long trailing vines that provide food and good natural cover for their burrows (Dr. Al-Dahhan, Dr. Alzahrani and Dr. Emarah, Ministry of Health, personal communication, 2012). Eight common vegetation species in the region have short stems and long trailing, but with wide variation in preferences, densities and distribution of the rodents dependent on the vegetation species. Rodents in the arid and semi arid regions generally prefer *Haloxylon salicornicum* which is dominant in Al-Dawadmi Governorate, beside two other types, which are *Citrullus colocynthis* and *Lycium shawii*. These two plants are less dominant in the governorate (Naeem et al., 2000; Yan et al., 2004; Feulner, 2002; Woldewahid, 2003). Therefore, these two types were digitized separately. With the belief that rodents might be adapted to other vegetation species in the region either with short stems and long trailing or with long trunks, two more vegetation categories were added to the digitizing classes as listed (see Table 4.3):

Class A: Preferable natural vegetation for rodents and dominant in the region.

Class B: Preferable natural vegetation for rodents and not dominant in the region.

Class C: Other natural vegetation species with short stems and long dense trailing vines.

Class D: Other natural species with long trunks.

Table 4.3: Expected vegetation types in Al-Dawadmi Governorate

Vegetation Class	Vegetation type	Digitized location code	Vegetation density			
			High	Medium	low	Does not exist
A	*Haloxylon salicornicum*					
B	*Citrullus colocynthis* *Lycium shawii*					
C	*Rhanerium eppaposum* *Tamarix spp* *Tamarix amplexicaulis* *Calligonum comosum* *Paniccum turgidm*					
D	*Acacia origena* *Calotropis procera* *Acacia ehrenbergiana Hayne* *Zizyphus spina-christi Willd*					

It should be acknowledged that uncertainty is an issue in defining vegetation densities as no straightforward definition or distinction could be found for each category. Nonetheless, a simple personal classification was applied to define vegetation densities in this study to three classes: high, medium and low as illustrated in Figure 4.5 A, B & C.

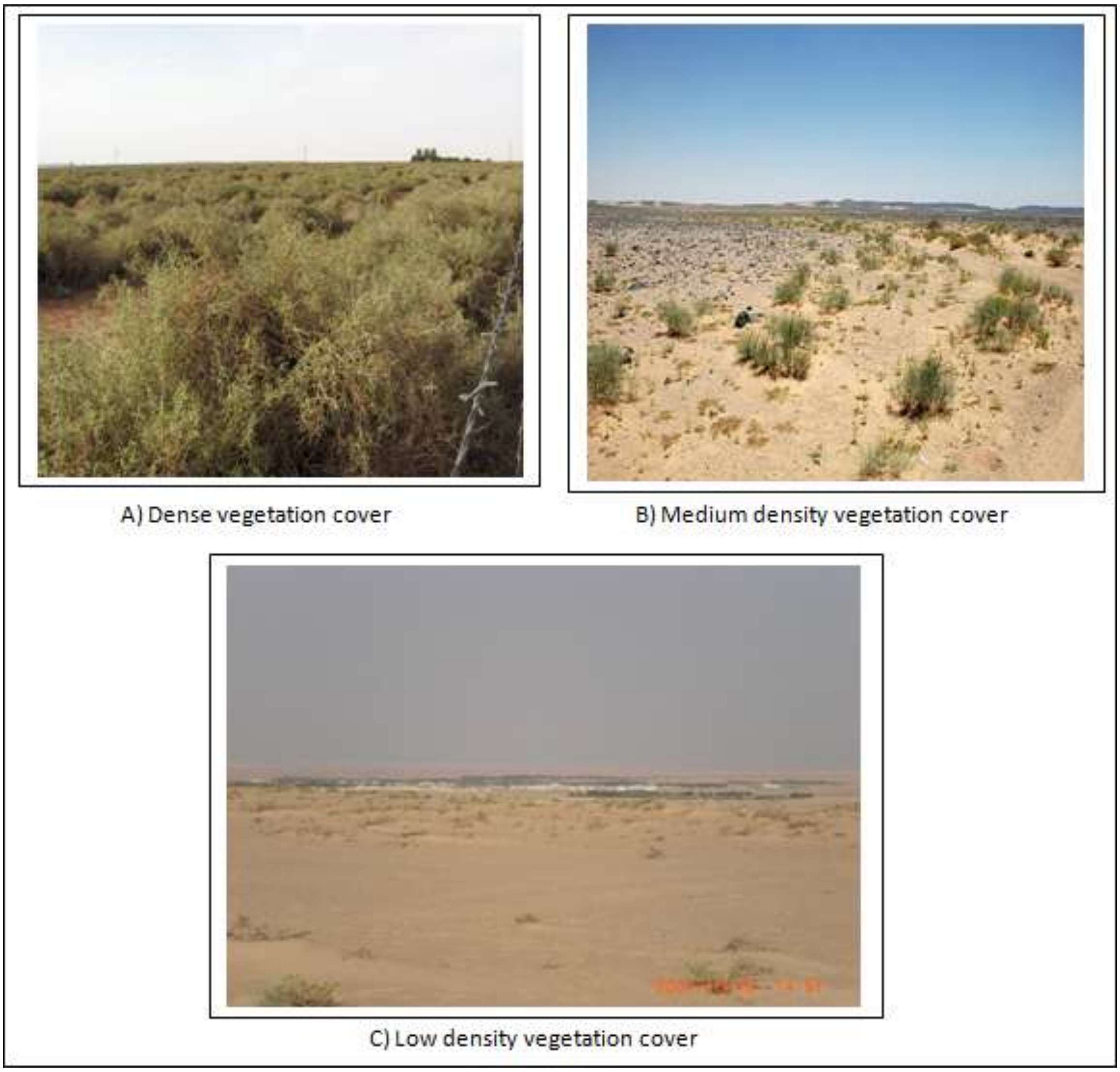


Figure 4.5: Illustration of vegetation densities.

Regarding the other land use / cover that were found in literature as preferable habitats for both sandflies and rodents, they were also defined, located and digitized in buffer zones of 1500 metres from each located cases and control. This distance was stated to be the maximum travelling distance of the sandflies from their resting and breeding sites as discussed previously in Chapter 2. These land use / cover includes:

- Livestock shelters
- Poultry houses.
- House wastes dumping areas.
- Construction material waste.
- Abandoned houses.
- Mud houses.
- Camping areas (Estarahat).
- Vegetable fields
- Fodder farms.
- Palm farms.
- Water wells
- Silos or crop storage rooms.

Question number three investigates the variation in CL incidence according to some demographic and socio-economic factors. Environment studies and studies on vector born diseases have found that in most cases, there are strong relationships between occurrence of the diseases and some socio-economic and demographic variables as discussed broadly in Chapter 2. To answer question number three, some demographical and socio-economic pieces of information were required to be gathered from the local population. A questionnaire survey was the only way to collect such data, so one was designed and used to get these data.

The designed questionnaire was written in English and then translated into Arabic for the convenience of both Arabic and English speakers. After designing the questionnaire, there was a real need to pilot it in both languages in order to examine if participants would be able to understand and answer the questions and also to resolve ambiguities of some of the questions. The questionnaire was piloted, especially upon considering that in some cases, the listed questions will be asked to people in rural areas who might not be familiar with the nature of epidemiological and social research. However, during piloting of the study stage by the end of May, which is not a high season of exposure to CL in the governorate, it was not easy to find CL cases in hospitals or primary health care centres in the area of study. Therefore, some random local residents were selected to pilot the questionnaire with, including Saudis and non Saudis of different age groups and professions. Initially, a total of 36 questionnaires were distributed in different three levels of questionnaire piloting which resulted in later, some changes like rephrasing, merging and removal of some questions were carried out.

The last question that is aimed to be answered by this study is to find if there are any under-reported CL cases in the governorate or not? And if yes, then what are the main obstacles behind the exposures not being reported. This question will be answered by trying to locate the under-reported cases and if found then carrying out a comparison exercise between officially reported cases and under-reported cases covering many factors like socio-economic, demographic and proximities to health care facilities.

4.3.3.2. CL Patient's Data:

In general, statistics and information about diseases in Saudi Arabia are being collected and published by the General Directorate of Information and Statistics at the Ministry of

Health only in their annual statistic books or in other reports. Nevertheless, data of infectious diseases are restricted and only some pieces of information are published briefly including some extremely generalised numbers per regions in the publications of the Ministry of Health.

This study depends mostly on the unpublished CL reporting forms. These reporting forms were collected from the General Directorate of Health Affairs in Riyadh Region and from the office of Ministry of Health in Al-Dawadmi Governorate. The later institution is responsible for collecting the CL reporting forms from the eight general hospitals and dermatologist clinics of the governorate and sending them to the main unit in Riyadh City on a monthly base. Basically, each reporting form represents a case where someone was diagnosed at one of the scattered clinics in the governorate as exposed to CL and got at least the first CL treatment.

A total of 864 CL reporting forms were collected reflecting all CL reported cases in the governorate in the period between January 2006 and April 2011. These forms have the following fields (a sample is shown in appendix C) that are supposed to be completed accurately before the first treatment, which are:

- National ID number
- Health record number
- Diagnosis date
- Diagnosis centre
- Case age
- Residency status
- Case gender
- Case nationality
- Case occupation
- Housing type
- Residency address
- Contact details
- Expected location to come in contact with sandfly
- Places you have been to in the past three months before the exposure
- Ulcer/s condition
- Number of ulcers
- Is there anybody in your household now who has similar symptoms
- Types of drug/medicine used.

In general, the collected reporting forms were filled in poorly and illegibly apart from some fields such as the personal and the contact numbers but not housing addresses due to the absence of post coding system in the country. Even though, the collected data are very valuable, there was a real need for these to be fully completed. A geographical clarification was also required to utilise the data in a GIS database.

4.3.3.3. Questionnaire Survey Design:

CL reporting forms do not include any environmental data that might be related to the exposure to CL. Consequently, beside the digitizing task, the objective of the designed questionnaire was to gather these data and locate the cases accurately which were not located properly in the reporting forms. The designed questionnaire focused mostly on characteristics, behaviour, housing type, awareness and the surrounding environment of CL cases and controls, objective of which is to give better understanding of the human and natural factors associated with the exposure to CL.

The designed questionnaire had a total of 39 questions covering five different parts. The first part included questions to measure general CL awareness such as the awareness of the vector, reservoir, seasonality of the disease and the protective measures used in the household against the insects and sandflies. The second part included questions related to the accessibility and the utilization of general hospital and primary health care centres which was used to examine the impact of accessibility on utilizing and reporting and under-reporting CL cases. The third part consisted of housing information and behaviour and activities of household members; especially before the onset of CL. The fourth part included questions to determine whether the exposure to CL was due to any unusual activities or due to any recent visit to sandfly-prone places or not. The last part had some questions related to under-reported cases and reasons for the exposure not getting reported (the designed questionnaire is attached in Appendix D)

Using a case control method to answer some of the research questions requires interviewing two different groups of people, namely CL cases and controls. These interviews were carried out in households, as some data were required to be observed and exact housing locations were required to be addressed using GPS devices. The heads of the households were asked to answer the main general questions in the first three parts of the questionnaire. In case of the heads of the households were not the CL cases or were not the selected controls, then questions in parts 4 and 5 were asked directly to the cases or the controls as long as they were able to participate. Otherwise, the heads of the households were asked to help getting the answers especially from children and females, as interviewing them individually and directly were unacceptable according local ethical and cultural values.

4.4. Implementing the Survey:

At an early stage, many of the collected CL reporting forms of individuals were eliminated from the list of people to be interviewed in this study for several reasons. For instance, CL cases in communities far from our selected six communities were eliminated as they are out of the areas of interest and carrying out research there would have cost a lot (distribution maps for the interviewed CL cases are shown in Appendix E, F and G). Additionally, cases apart from the ones reported in the past two and a half years between (Jan 2009 and April 2011) were removed as older cases were more likely to contain fewer details as people tend to remember details of only recent past. Also, CL cases over the age of 70 were removed from our interest due to expected difficulties in getting the questionnaire answered well and to avoid any possible embarrassment of asking households about interviewing their family members who might have already passed away. Moreover, some other cases were eliminated for the CL affected people who were not willing to be interviewed or whose contact information could not be found.

Regarding the selected controls, they were selected in two different ways; through patient's records of primary health care centres and through help from interviewed CL cases. Records of primary health care centres were used to find many controls through their patients' records, especially in Al-Dawadmi City, Al-Rafayea, Al-Gmsh and Arwa where the researcher was given access to the data. However, this way was time consuming and most of the records were rather old and had not been updated recently. The other way which was used later and found to be faster and more appropriate was by asking interviewed CL cases about people falling into certain selected matching characteristics which were; in the same community or neighbourhood, in a similar age group, gender and nationality. The questionnaire survey has resulted in collecting a total of 314 answered questionnaires, 157 of them were CL cases and 157 were controls. However, some questionnaires were incomplete or missing crucial data or considered as providing misleading information. Therefore they were removed. Additionally, some unmatched cases and controls in the specified matching categories (community or neighbourhood, age and nationality) were removed, ending up with 250 well answered questionnaires in equal number of 125 cases and 125 controls which will be used to answer questions two and three of this research questions. Table 4.4 shows the steps taken in selecting our interviewed people.

Table 4.4: Steps taken in selecting the people interviewed in the study

Description	Number of CL cases	Left cases
Total CL cases in the governorate in the study period between Jan 2006 and April 2011	864	
Total cases in the selected communities	383	
Cases in the selected communities between Jan 2009 and April 2011	198	
Cases eliminated older than 70 years old	9	189
Could not be contacted or refused to be interviewed	29	160
Withdrawn people during the interview	3	157
Collected answered questionnaires for cases	157	
Misdiagnosed	6	151
Incomplete or misleading	19	132
Mismatch cases and controls	7	125
Total answered questionnaire	125 cases	

Besides interviewing cases and controls, a third group of people was required to be interviewed. This group is the under-reported CL cases. The task was to know if there were any under-reported cases, and if yes then what were the factors behind not reporting their exposures. Finding under-reported cases was a very hard task as no data regarding them existed in any record. To overcome this problem, two different ways were followed to find such cases, which were: using existing CL reporting cases forms and by asking for help from the interviewed cases and controls. To get result in the former way, in the reporting forms a listed question asks “is there anybody in your household having the same disease or similar symptoms now?” with ‘’YES’’ and ‘’NO’’ answers. In the case of getting a ‘’YES’’ answer and not finding other reported case from the same address within the period of three months which is the average time for CL ulcer development, then it is most likely to have an under-reported case in the same address. However, this way was very likely to be a wrong indicator for under-reported cases for many reasons, such as: due to the absence of a unique posting system the case might be reported with a different descriptive address, or they might be treated in a different clinic in or out of the governorate especially with the absence of catchment area regulation for clinics and patients could be treated in any clinic. Additionally, they might have similar symptoms but those not necessarily being related to CL as discussed previously in Chapter 2.

In addition to the provided 864 CL reporting forms, 109 possible non-reported cases were identified for further investigation. However, lots of them were eliminated straight away as they were either located far, beyond the reach of contacts or refused to participate. After sorting out in this manner, 17 under-reported cases were found and interviewed. The second way used was by asking interviewed people or locals about any known under-reported CL cases. This way resulted in finding another 24 under-reported CL cases, most of them were non-Saudis and manual labourers especially farmers and shepherds. A total of 41 under-reported cases were interviewed and their details will be used to investigate the factors behind not reporting their exposure to the disease (a distribution map of unreported CL cases is added in Appendix H).

By this means all the necessary data to answer the main questions of the research were collected. Figure 4.5 shows the data collection framework which will provide better understanding of the steps followed.

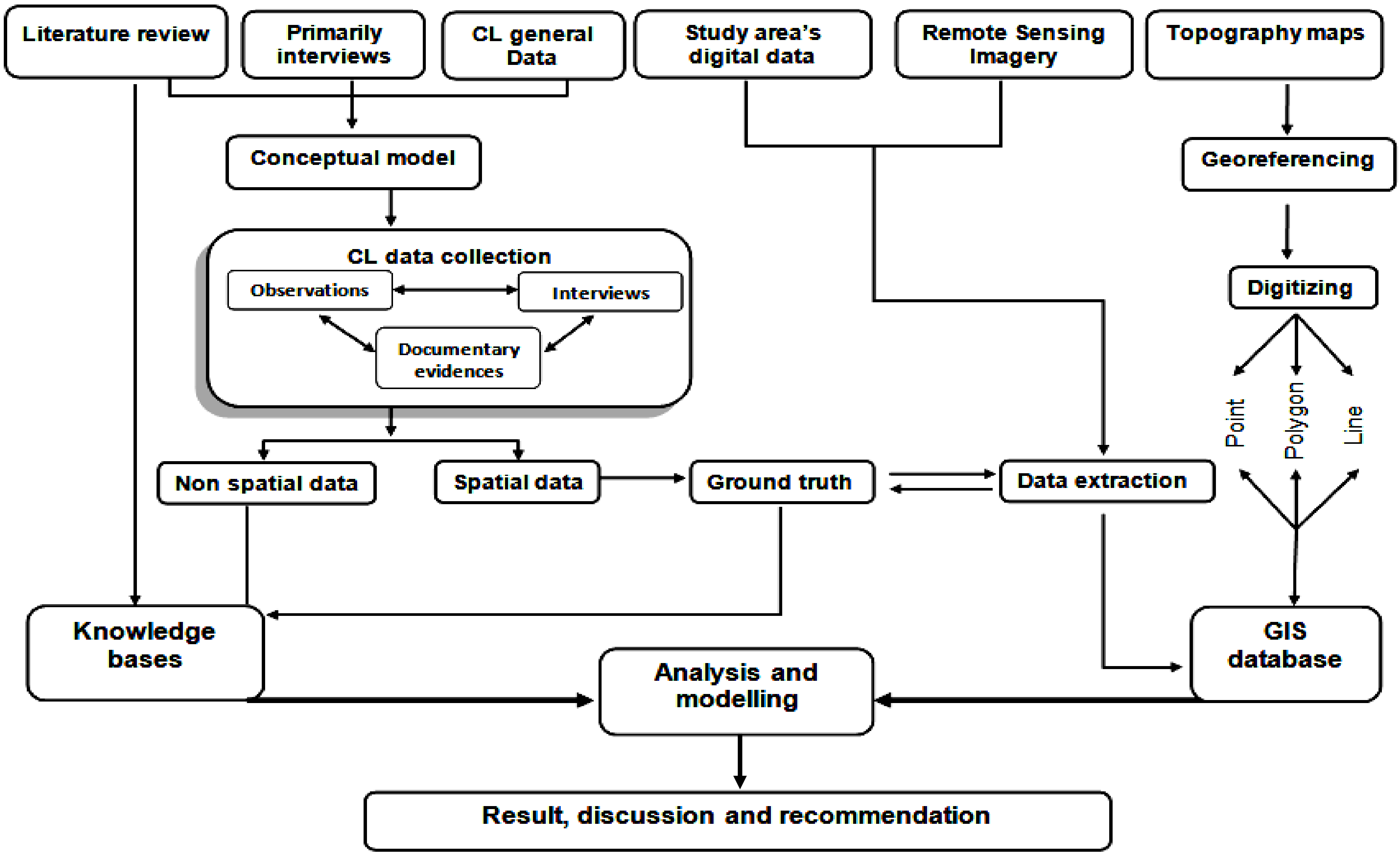


Figure 4.5: Summary of the data collection framework

4.5. Reflections on the Field Work and Limitations:

Starting with the positive side of the data collection field work, it must be acknowledged that, without the help and support from some ministries, friends and individual known and unknown people this field work and the amount of collected data would not have been done. Even with very long procedures and the usual bureaucracy, the General Directory of Health Affairs in Riyadh Region provided permissions to access the CL reporting forms which are believed to be the core of this study. In Al-Dawadmi Governorate the FETP provided all facilities and support and some of their staff have helped in some tasks in official and unofficial ways. In terms of the interviewed people, they were mostly very co-operative and the majority of them completed the interview without causing any difficulties.

Moving toward the difficulties and limitations, most of the faced difficulties and limitation were expected. They were in each stage, from requesting data and permissions from ministries and institutions, while moving to the land survey, even at the last stage of interviewing people. All these stage by stage difficulties are listed here:

Difficulties and limitations related to requested permissions or already existing data collection:

- Long procedures and bureaucracy from some ministries or government institutions.
- There were refusals to get some permission due to data restrictions in some health sectors such as having access to PHCC records in Nifi, Al-Bjadeah and Sajer areas.
- Some ministries provided documents which could not be taken out of their building or be copied either. So, long time was spent reading massive piles of documents and then writing down some important information or numbers.

Difficulties and limitations related to vegetation and land use digitizing:

- As the starting date was during the beginning of the summer, the possible time to be in the field was limited due to the extremely hot temperature which reached 57 ℃ under the sun in the afternoon, making the long time required for digitizing very risky due to possibilities of heatstroke and dehydration.

- A long time was required to get permissions to access the high number of inaccessible areas like fenced lands or farms and to discover the nature of the land use inside.
- Due to the nature of some areas, it was difficult to access or cross using normal cars or on foot. The problem was solved by borrowing a 4X4 car for some days.
- In some areas, local residents were not comfortable with strangers surveying there. And they were interrupting the work team many times. It used to consume a long time showing the official documents to the locals and to get their trust.

Difficulties and limitations related to interviewing people:

- As no post code system exists in the country, long time was spent searching for the given addresses. And on many occasions the cases and controls came to guide the interview team from obvious known land marks such as a fuel station, a grocery or a mosque.
- Local hospitality made the expected time to finish the interview longer. The expected 30 to 45 minutes was extended to 4 hours in some cases where they spent a long time on serving tea and coffee and on most occasions, ended up with a feast before answering the questionnaire.
- Some interviews were eliminated as they did not have CL but had similar symptoms to it and got reported as CL cases. They either discovered themselves that it was not a CL case or it became evident from their answers.
- It was very difficult to interview adult females either directly or indirectly in many cases, especially in the case of the Saudis in the remote communities. On the other hand, the task was easier with the Saudis in Al-Dawadmi City as well as with the non-Saudis.
- Some cases were withdrawn from the interview for some particular reasons such as reaching a sensitive part of their privacy (information of the female members, income, occupation etc).
- Difficulties in communicating with non-Saudis especially in the cases of non-Arabic or non-English speakers and explaining to them about the objective of the research work.
- Unpunctuality from the interviewee.

Chapter Five: CL Seasonality in Al-Dawadmi Governorate:

5.1. Introduction and Seasonal Trends:

Four variables will be used in this chapter to examine the seasonality of the temporal distribution of CL cases in Al-Dawadmi Governorate. These variables are temperature (maximum, minimum and mean), precipitation, relative humidity and the number of reported CL cases. All these variables are in the form of monthly summaries for the period between January 2006 and April 2011. These variables are represented in Figure 5.1 (mean temperature was used only in the graph rather than the maximum and minimum temperature as they follow the same trend and to avoid any duplication and confusion).

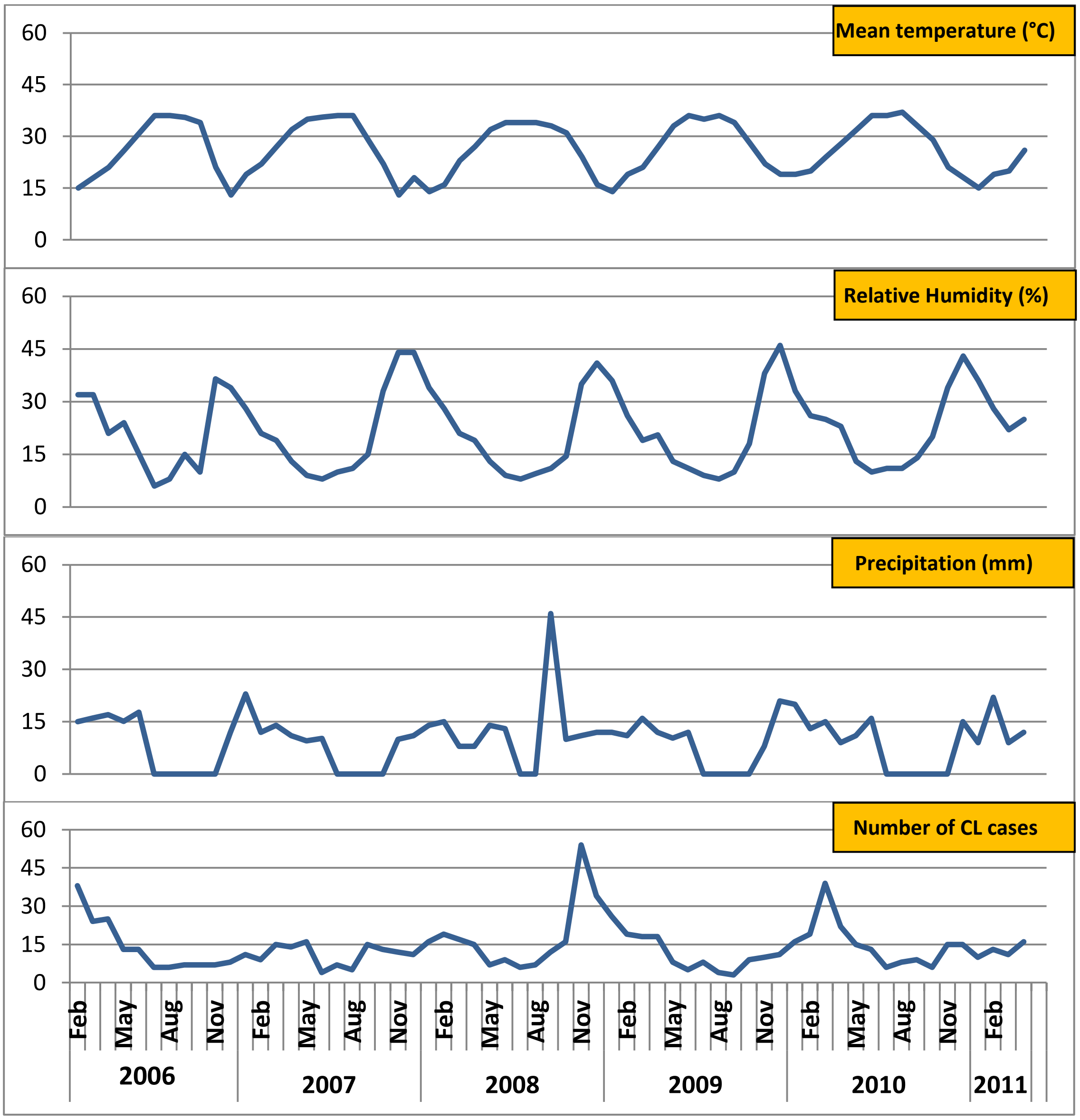


Figure 5.1: Temporal distribution of mean temperature, relative humidity, precipitation and reported CL cases between January 2006 and April 2011.

From the figure above, it can be seen clearly that the pattern of mean temperature variation in the first chart is extremely consistent from one year to another. It peaks between June and August with temperature between 34°C and 37°C and drops to the lowest temperature between November and January reaching an average temperature between 12°C and 15°C. In the case of maximum and minimum temperatures, they are both following the same trend reaching the maximum temperature between 40°C and 42°C in summer and a minimum temperature between 6°C and 9°C in winter. In the case of relative humidity, it can also be seen in the second chart that it has a similar consistent outline from year to year. It peaks in November and December time with humidity level of about 45% and dropping in summer time between June and August to just about 10%.

The third chart in the graph shows the rainfall which has an underlying fluctuation pattern where it has no rainfall at all in a block of 3 to 4 months between May and August and has some rain between September and April with some differences in the amount of the rain from one year to another. Over the study period, there is a stand out rainfall spike namely in September 2008 which will be considered in the study in terms of whether it has any impact on the number of reported cases in the governorate in general and the outbreak of CL in the same year or not. In short, it can be said that both temperature and relative humidity are behaving fairly consistently over the years at the same time as rainfall is a little more erratic.

The final chart in Figure 5.1 shows the number of reported CL cases over the study period. It can be stated that the chart actually does not have that enormous seasonal pattern, neither like temperature and relative humidity with strong consistency, nor like rainfall with less consistency. However, it can be seen that in general there are lower number of reported CL cases in the middle of the year (between May and August) and higher numbers in the colder times between October and February. Over the study period, there are two obvious outbreaks namely in October 2008 and February 2010 which will be considered to find out if climate conditions were associated with these outbreaks or not.

In the final chart, it is apparent that the first 5 months of the record were acting differently from the rest where they have much higher number of reported cases than the same months in the other years. They have a total reported number of 113 cases, wherein there were 53, 67, 68, 74 and 49 cases in the years 2007, 2008, 2009, 2010 and 2011, respectively. This happened because the first few months of many medical records often have higher number than the exact numbers, which then mislead and drive the study results. This misleading recording often happens by adding older records from previous months to the first recorded months making the final records often much higher than the actual figures. Therefore, to avoid any possibilities of being misled, these 5 months were eliminated from all the analysis in this study.

5.2. Descriptive Study:

In this part, the collected data will be summarised in a descriptive study as shown in Table 5.1:

Table 5.1: Seasonality descriptive statistics

	Minimum	Mean	Maximum	Std. Deviation
CL cases	3	13.50	54	9.25
Maximum temperature	18.00	32.15	43.00	7.70
Minimum temperature	8.00	20.67	31.00	7.86
Mean temperature	13.00	26.31	37.00	7.65
Relative humidity	6.00	21.48	46.00	11.24
Precipitation	0.00	9.55	46.70	8.41

This study uses monthly meteorological and reported CL cases data to investigate the relationship between changes in climatic variables and the incidence of CL. Table 5.1 reports the descriptive statistics and suggests that the monthly mean number of CL cases 13.5. The monthly mean of the maximum, minimum and mean temperature of the study area is 32.1°C, 20.7°C and 26.3°C, respectively. The mean humidity of the area is 21.5% while the average precipitation is 9.5 mm per month.

After this summary, the correlation between these variables was examined as well as the skewness measure to know the extent to which a distribution differs from normal distribution. Both correlation and skewness examinations were applied in 3 different categories in order to find the best model fit to be used further in this study’s analyses which are:

1. All the data are in their original condition as collected.
2. The dependent variable (number of CL reported cases) was transformed into natural logarithm (Ln) and all the independent variables are still in their original condition (log normal model).

3. Both dependents and independent variables were transformed into Ln.

Additionally, each category of these categories has 4 different classes based on the number of selected months to be involved in the study, which are:

A. All the study period months (a total of 64 months).
B. The first 5 months of the study (January to May 2006) were eliminated (a total of 59 months).
C. Two outbreaks (October 2008 and February 2010) were eliminated (a total of 62 months).
D. Both the two outbreak months and the first 5 months were eliminated (a total of 57 months).

All these results are shown in Table 5.2 and Table 5.3:

Table 5.2: Climate phenomenon correlation matrix:

categorises	1 (original data)				2 (log normal model)				3 (all are transformed into Ln)			
CLASS	A	B	C	D	A	B	C	D	A	B	C	D
CL cases	1	1	1	1	1	1	1	1	1	1	1	1
Tmax	-.476-**	-.432-**	-.541-**	-.512-**	-.548-**	-.517-**	-.559-**	-.526-**	-.520-**	-.487-**	-.535-**	-.501-**
	.000	.001	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
Tmin	-.481-**	-.434-**	-.559-**	-.530-**	-.562-**	-.529-**	-.577-**	-.543-**	-.527-**	-.492-**	-.553-**	-.519-**
	.000	.001	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
Tmean	-.448-**	-.395-**	-.551-**	-.518-**	-.536-**	-.500-**	-.565-**	-.531-**	-.502-**	-.464-**	-.540-**	-.505-**
	.000	.002	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
Precipitation	.481**	.470**	.564**	.540**	.557**	.535**	.587**	.617**	.515**	.493**	.537**	.515**
	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
Relative humidity	.429**	.414**	.445**	.447**	.560**	.546**	.551**	.537**	.492**	.483**	.481**	.472**
	.000	.001	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000

** Correlation is significant at the 0.01 level (2-tailed).

Table 5.3: Climate phenomenon skewness measure

Categorises	1 (original data)				2 (log normal model)				3 (all are transformed into Ln)			
Class	A	B	C	D	A	B	C	D	A	B	C	D
CL CASES	2.099	2.457	1.361	1.130	.096	.155	-.161	-.237	.096	.155	-.161	-.237
Tmax	-.202	-.268	-.243	-.335	-.202	-.268	-.243	-.335	-.477	-.565	-.511	-.607
Tmin	-.136	-.222	-.184	-.278	-.136	-.222	-.184	-.278	-.515	-.608	-.542	-.461
Tmean	-.191	-.264	.-218	-.297	-.191	-.264	.-218	-.297	.-519	-.595	-.525	-.605
Precipitation	244	361	374	403	244	361	374	403	-.621	-.488	-.570	-.431
Relative humidity	.436	.395	.394	.461	.436	.395	.394	.461	-.392	-.411	.-339	.551

From the correlation matrix in Table 5.2, it can be seen clearly that even though there are some changes and improvements in the correlations between variables, these are not especially large. The most important benefit of eliminating some months is much stronger for the original data. However, among all these correlations matrices, the log normal model (category 2) gives the highest level of correlation between variables which can be said is giving the best model fit.

In the skewness measure, there are some considerable changes between the variables when they are in their original format as collected and after transforming them into natural logarithm (Ln). Table 5.3 also shows that the log normal model (category 2) is giving the lowest positive or negative skewed data distribution which is also can also be considered as the best model fit too.

In the light of both Tables 5.2 and 5.3, the log normal model is giving the best model fit, meaning it will be selected to be used in this study. However, in this model there are four different classes and one should be selected to use for the analysis. From the four classes (A, B, C and D), a careful assessment was undertaken to make the decision and select the most appropriate class to be used. Even though ‘’Class A’’ has all months that fall into our study period, it will not be selected as the first five months were suggested to be removed to avoid any misleading information as explained earlier. ‘’Class C’’ is also suggested not to be used for the same issue of being affected by the first five months as well as removing the two outbreak months from the analysis which is believed they occurred due to some climatic conditions in prior months. Consequently, the influence of these prior months will remain even after removing the two outbreaks and might also influence the regression models of this study. In spite the fact that ‘’Class D’’ does not include the first five months as well as the two outbreaks, it is not also suggested to be used due to the same problem that might happened after removing the two outbreaks. So, even though ‘’Class B’’ in category 2 has the lowest correlation between variables among other classes in the same category, it was selected to be used in the study as it matches the concept of selecting our months by eliminating the first five months only and to overcome the issue of the outbreaks and the effect of them will be controlled.

5.2. Multicollinearity:

From the correlation matrices in Table 5.2, it appears that the three temperature variables seem to have moderately negative relationships with CL cases, while humidity and precipitation have moderately positive relationships with the number of reported CL cases. As can be seen also the temperature records (Tmax, Tmin and Tmean) are very similar in their level of correlation with CL cases, which is unsurprising as they follow the same fluctuation trends in their moves. Additionally, precipitation and relative humidity have a similar level of correlation to temperatures but with a positive value. These correlations similarity often causes the problem of multicollinearity in the data. Therefore, these variables were tested to know the levels of multicollinearity which are shown in Table 5.4.

Table 5.4: Climate phenomenon multicollinearity test

Variables	VIF value in model		
	1	2	3
Maximum temperature	6.349		
Minimum temperature		6.271	
Mean temperature			6.303
Precipitation	4.319	4.381	4.327
Relative humidity	6.124	5.579	5.579

From the collinearity test table above, the Variance Inflation Factor (VIF) is often used to judge the level of multicollinearity (O'Brien, 2007). VIF measures the severity of multicollinearity in an OLS regression analysis and creates an index that measures how much the increase in an estimated regression coefficient resulted from the multicollinearity (Longnecker and Ott, 2004). The acceptable level of VIF has been an arguable issue in literature. However, many studies have published that the acceptable level of VIF is not greater that 5.00 (Hair et al., 1995; Kennedy, 1992; Neter et al., 1989; Tabachnick and Fidell, 2012; Larson-hall, 2010). From the table above, it can be seen that both temperature and relative humidity have VIF higher than 5.00 in all three models. Therefore, solving the multicollinearity problem was necessary for all variables.

Even though many studies have tried to solve the matter of multicollinearity, the complete elimination of it is not possible (Chatterjee and Hadi, 2013; Draper and Smith

2003). The degree of multicollinearity can be reduced by adopting different methods such as Principal Component Analysis (PCA), applying running means to reduce the variation in one or more of the multicollinear variables, increasing the number of study samples or converting one of the multicollinear variables into a categorical (nominal) variable rather than a scale variable. Additionally, it can also be solved by removing one of the variables with the highest VIF or combining variables until multicollinearity is no longer an issue (Crown, 1998; Bhar, [No date]).

Some of the mentioned methods were implemented to reduce the multicollinearity in this study. PCA was applied, but it did not get a good balance between the five factors, where the first factor (mean temperature) has an Eigenvalue of 4.07 out of 5 and almost every variable has 0.9 correlations with it. Therefore, PCA was not very useful to use in this study as it cannot separate the influence of temperature versus rainfall and relative humidity. A running average mean was applied in this study which is commonly used to reduce irregularities (random fluctuations) in time series data. There was a choice of applying the running mean on any of the variables as they all have high VIF values. However, based on previous studies which stated that temperature and rainfall are very significant key factors in arid and semi arid areas in terms of fluctuation and influencing the CL incidence rates (Faraj, 2011; Toumi et al., 2012), and also based on primary regression results the running average mean was applied only on relative humidity which is believed to have less significant influence in arid and semi arid areas where it is generally low most of the year. Two months running mean (current and prior month) was applied on relative humidity and the result was used as a new variable. Multicollinearity test was re-applied and there was a significant reduction in the VIF values in all variables as shown in Table 5.5.

Table 5.5: Multicollinearity test after averaging relative humidity

Variables	VIF value in model		
	1	2	3
Temperature maximum	1.682		
Temperature minimum		1.967	
Temperature mean			1.972
Precipitation	1.473	1.445	1.397
Relative humidity	2.098	2.145	2.122

5.3. Stationarity:

Before using these variables in any regression model, stationarity needs to be examined. A stationary time series is one whose statistical properties for instance mean, variance, median, autocorrelation, etc., are all constant over time. An Augmented Dickey-Fuller (ADF) test was used to test the stationarity and all the variables were found to be stationary (at 5% level) as shown in Table 5.6:

Table 5.6: Stationarity test

Variables	*P* value
Ln CL	0.0007
Maximum temperature	0.0382
Minimum temperature	0.0401
Mean temperature	0.0417
Relative humidity	0.0452
Precipitation	0.0041

5.4. Ordinary Least Squares (OLS) Regression:

This study is going to use three different models to examine the seasonality of CL in Al-Dawadmi Governorate. Each model will include one of the temperature variables (maximum temperature (Tmax in Model 1) minimum temperature (Tmin in Model 2) mean temperature (Tmean in Model 3), relative humidity (RH) and precipitation (Preci). Log of CL cases (Ln CL) was used as the dependent variable in all three models and climate variables were used as the independent variables. RH and Preci were used in all the three models whilst one of the three temperature variables was used in each of the three models as shown in Table 5.7.

Table 5.7: Ordinary Least Squares regression (OLS)

Variables	Regression Models		
	1	2	3
Tmax	-0.021 (0.031)		
Preci	0.022** (0.007)	0.021** (0.009)	0.023** (0.007)
RH	0.005 (0.017)	0.002 (0.014)	0.010 (0.014)
Tmin		-0.026 (0.019)	
Tmean			-0.013 (-0.023)
Constant	2.714*** (0.989)	2.682*** (0.798)	2.271*** (0.844)
Observations	59	59	59
R-squared	0.336	0.345	0.330

Standard errors in parentheses
*** p<0.01, ** p<0.05

From the OLS regression above, it can be seen that all temperature coefficients were negative and none of them was statistically significant in any model. The coefficient of precipitation is positive and statistically significant at the 5% level in all 3 models, whereas relative humidity has a positive coefficient but is not significant in any of the 3 models. After having the OLS regression and having the general understanding of the regression, new two indices were added to the variables. As the two outbreaks are most likely to be influenced by climate variables as well as they are going to have a very strong influence on the overall regressions, there was a real need to control for these factors. These two outbreaks were controlled by adding a dummy variable index (0, 1) with value 1 for the outbreak months and 0 for the rest of the months. This dummy variable will be added to the regressions under the name ‘’Outbreaks’’. The second variable was added to our models in order to control the long-term trend which is basically by adding a time line index from 1 to 59 in the model. Long term trend control was applied here as changes in CL incidence might be a result from non-climatic factors such as changes in sandflies eradication governmental activities or changes in reporting practices. This dummy variable will be added to the models under the name ‘’Long-term control’’. All these regression models including the two dummy variables are shown in Table 5.8.

Table 5.8: OLS with all dummy variables

Variables	Regression Models		
	1	2	3
Tmax	-0.028 (0.020)		
Preci	0.020** (0.008)	0.019** (0.008)	0.020** (0.008)
RH	.0.002 (0.013)	0.005 (0.014)	0.002 (0.014)
Tmin		-0.032 (0.022)	
Tmean			-0.037** (0.021)
Outbreaks	1.314 *** (0.335)	1.320 *** (0.333)	1.366*** (0.333)
Long-term control	0.003 (0.003)	0.002 (0.004)	0.003 (0.003)
Constant	3.003 *** (0.916)	3.833*** (0.712)	2.325*** (0.771)
Observations	59	59	59
R-squared	0.497	0.507	0.498

Standard errors in parentheses
*** p<0.01, ** p<0.05

From Table 5.8, it can be seen that the coefficient of temperatures is still negative but have become statistically significant at 5% level in model 3 only. The coefficient of precipitation is positive and significant at 5% level in all models, relative humidity is also still positive and not significant at any level in all models. Regarding to the new added dummy variables, the outbreaks are statically significant at 1% level whereas long-term control was not significant in any of the models.

5.5. Lag Order Selection:

The Akaike Information Criterion (AIC) test was used to find the optimal lag of the three regression models which was found to be 4 months in all three models as whole model with all variables. Considering the biological fact which is there has to be a lag between the laying of sandflies eggs through the other development stages (egg, larvae, pupa and adult) and coming in contact with cases and then eventually getting the case reported to health authorities which often take between 2 and 4 months time as discussed in Chapter 2, DF-GLS test was used. DF-GLS works by moving backwards in time in order to find the highest number of prior months that is statistically significant to the incidence of a disease. Using this method the following optimal lag orders for each individual variable were obtained. Two months lag order were found to be the optimal lag order for the 3 temperature variables and one month prior lag was found to be the optimal for both relative humidity and precipitation as shown in Table 5.9.

Table 5.9: Lag-Order selection

Variables	Tmax		Tmin		Tmean		Precipitation		Relative humidity	
Lag	***P***	**Coef**	***P***	**Coef**	***P***	**Coef**	***P***	**Coef**	***P***	**Coef**
Currant month	<.001	-0.040	<.001	-0.041	<.001	-0.039	<.001	0.035	<.001	0.025
Prior 1 month	<.001	-0.031	<.001	-0.041	<.001	-0.039	**.001**	**0.023**	**<.001**	**0.024**
Prior 2 month	**.002**	**-0.041**	**.002**	**-0.031**	**.004**	**-0.029**	.158	0.013	.084	0.022
Prior 3 month	.075	-0.018	.081	-0.018	.102	-0.017	.990	0.000	.081	0.016
Prior 4 month	.001	-0.844	.064	-0.044	.072	-0.004	.375	-0.008	.803	0.007
Prior 5 month	.021	-0.024	.028	-0.038	.008	-0.027	.004	-0.026	.290	0.038
Prior 6 month	<.001	-0.460	<.001	-0.048	<.001	-0.048	.001	-0.031	<.001	0.026

The suggested optimal lag order is matching what has been found so far in literature about time lag in arid and semi arid regions. It has been found to be between two and four months lag for temperatures and between one and three months for relative humidity and precipitation (Faraj, 2011; Toumi et al., 2012). So, it can be justified that temperature is enabling good climatic condition for sandflies laying eggs and to get them developed to adult sandflies and precipitation and relative humidity are the triggers for coming in contact with people.

5.6. Autocorrelation:

In this study analysis, it is not possible to presume that CL reported cases in any month are not related to the cases in the prior months and would not have any impact on the cases in the following few months. This type of relationship is known as autocorrelation. Autocorrelation is usually a problem with time series data (Dubin, 1998; Analysights 2011). The Durbin-Watson test for autocorrelation was inconclusive at the 5% level of significance (d-statistic of 1.49, 1.46 and 1.50 for regressions with maximum, minimum and mean temperature, respectively). Nonetheless, using the alternative Durbin-Watson test, H0 of no autocorrelation could not be conclusively rejected. There are different methods to control the possible autocorrelation in the data, for instance, Auto-Regressive Integrated Moving Average (ARIMA), Newey-West standard errors and Exponentially Weighted Moving Average (EWMA). In this work, these models were explored and the results were very similar but the ARIMA model was a slightly better fit, so it was used in this study.

5.7. Auto-Regressive Integrated Moving Average (ARIMA):

ARIMA model can be considered as a type of regression model where the dependent variable has been stationarized and the independent variables are all lags of the dependent variable and / or lags of the errors (Shil et al., 2013). ARIMA can also be considered as a regression model which includes a correction for autocorrelated errors (Ibid). ARIMA regression models are shown in Table 5.10

Table 5.10: ARIMA Regressions

Variables	Regression models		
	1	2	3
T max (L2)	0.028** (0.0128)		
Preci (L1)	0.109 (0.057)	0.109 (0.059)	0.126** (0.054)
RH (L1)	0.127 (0.143)	0.092 (0.137)	0.150 (0.140)
T min (L2)		0.025** (0.012)	
T mean (L2)			0.0328*** (0.012)
Outbreak	1.083*** (0.113)	1.058*** (0.124)	1.051*** (0.101)
Long-term trend	0.002 (0.038)	0.002 (0.034)	0.001 (0.004)
Constant	-1.499 (0.850)	-0.970 (0.636)	-1.540** (0.733)

Standard errors in parentheses
*** p<0.01, ** p<0.05

The results of ARIMA regression which is considered to be the final models are showing that the coefficients for all temperatures are positive. Both maximum and minimum temperatures are statistically significant at the 5% level while the mean temperature is significant at the 1% level. Precipitation is also has positive coefficient in all models and significant at 5% level in model 3. Relative humidity and Long-term control still not significant at all in any of our models while outbreak is statistically significant at the 1% level in all the three models.

From the previous regression models before the ARIMA one, some of the expected associated climatic factors with the incidence of CL cases were not as significant as expected such as temperature and precipitation. However, having refined the models in this way, it can be seen apparently that these relationships match what have been found in other studies (Faraj, 2011; Toumi et al., 2012; Karakis et al., 2013; Viana et al., 2011). From the multiple regressions in ARIMA model, it can be summarised that the incidence of CL cases has been found to be strongly associated with both temperature and precipitation in Al-Dawadmi Governorate. Temperature in the lagged 2 months were found to be statistically significant with a *P* values of 0.05 in both models 1 and 2 (maximum and minimum temperature) and with *P* value of <0.001 in model 3 (mean temperature). Precipitation has also been found to be significant at 5% level at model 3. Relative humidity was not found as significant in all three models. The outbreak dummy variable was statistically significant in all models whereas long-term trend was not at all in any of the three models.

The conclusion of these regressions suggests that temperature was identified as the most important factor associated with the incidence of CL cases in Al-Dawadmi Governorate. If the temperature in the previous 2 months (long term for sandflies to lay eggs and get developed) was suitable for sandflies, then there were more cases. Additionally, precipitation played an important role with more cases if the rainfall was suitable in the previous month or two (short term) where sandflies, rodents are more active and most likely people go out and come in contact with sandflies. Relative humidity has not been found as a significant factor associated with the incidence of CL in the multiple regressions above and beyond temperature and precipitation variables, while it is statistically significant by itself as shown in the correlation matrices (Table 5.2). Outbreaks have always been statistically significant at 1% level in all the study's models. On the other hand long-term trend was not significant all over the study but was added in all regressions for controlling purposes.

With these results, more focus can be paid to the two outbreaks to see whether temperature and precipitation have acted differently and participated in these two outbreaks with the same months lag as it has been found above or not. Figure 5.2 highlights the key variables (Tmax, Tmin, Tmean and Precipitation) as well as the outbreak two periods.

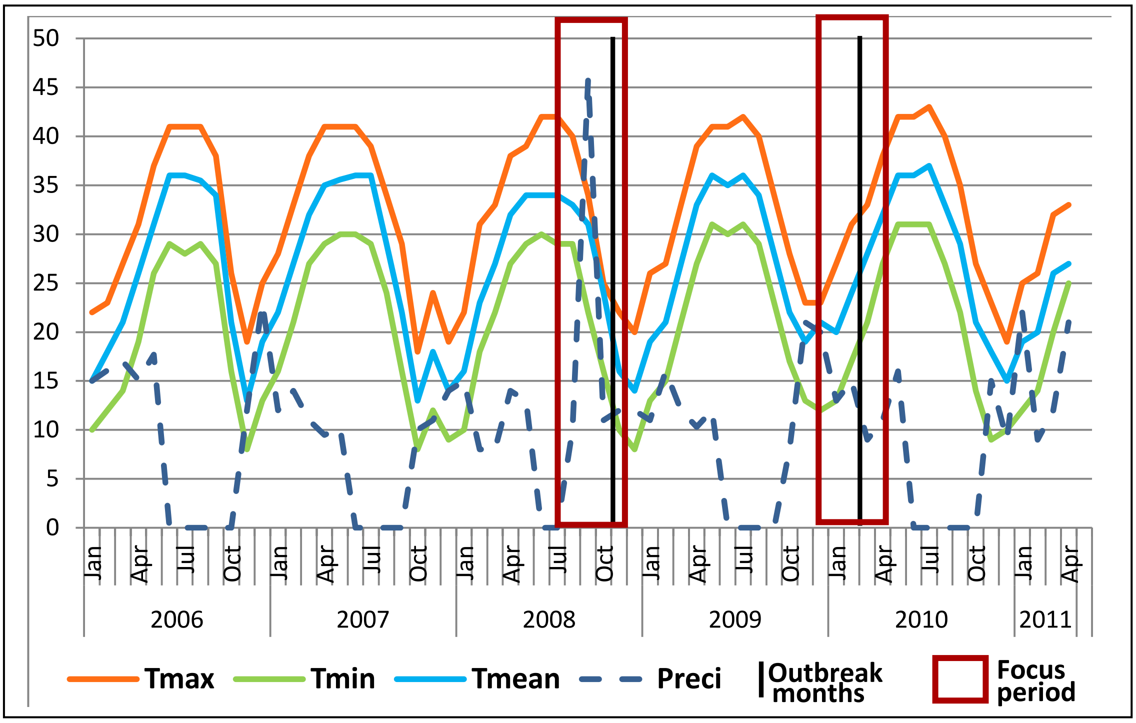


Figure 5.2: CL outbreaks with temperature (max, min and mean) and precipitation variables

From the figure above, it is obvious that both outbreaks have strong associations with both mean temperature and precipitation. In the case of the outbreak in October 2008, it can be seen that that period has a slightly cooler summer as the mean temperature is slightly cooler than the other mean temperatures in the same months in the other years. It is in the range of 32°C and 34°C in the previous 2 to 4 months which is considered to be in the range of the ideal temperature for sandflies to lay their eggs and to get developed. Additionally, one month before the outbreak, there was a noticeably high amount of rainfall with about 46 mm in the area which is believed to have a strong participation in the outbreak allowing sandflies and rodents to become more active as a result of the increase in the vegetation cover and also the increase in the likelihood people go out for camping or visiting green areas where it is highly probable they will come into contact with sandflies.

In the case of the February 2010 outbreak, mean temperature was also acting differently from the same period from the other years. It can be seen that there was a warmer winter where temperature were just below 20°C in the prior 2 months whereas it was on average between 13°C and 16°C in the same time in the other years. Regarding precipitation in the second outbreak, the amount of the recorded rainfall in the previous month was not as high as it was in the other outbreak. However, it is still in a rather high level in contrast to the overall precipitation trend as it is only one of four months in the study period with rainfall over 20 mm. Additionally, it is also possible that the amount of rainfall in the previous month of the outbreak in the area was much higher than the recorded value due to one of the following situations: The first assumption is that, as the rainfall has that kind of localization pattern where it can have a thunderstorm with heavy rainfall in a small part of the land and no rain at all in an adjoining area. So, in this case it might have quite low amounts of rain in the area where the meteorological station is, where it gave us lower amounts of rainfall, and much higher level of rainfall in nearby populated areas where the high number of cases came from. The first assumption has not been possible to check due to the only four recording stations and no other sources were available.

The second assumption is that it is possible there were rather high amounts of rainfall that occurred in late December 2009 and January 2010, of a total of 41 mm or even more in both successive months. But due to the monthly layout recording system, they were recorded separately. Due to the absence of daily or weekly data records of rainfall in the governorate, this assumption could not be investigated or proved. However, a new graph of the rainfall in two accumulative months (current and previous one) was created beside the reported CL cases in order to see the level of association between the amounts of rainfall in the previous two months and the CL outbreaks as shown in Figure 5.3.

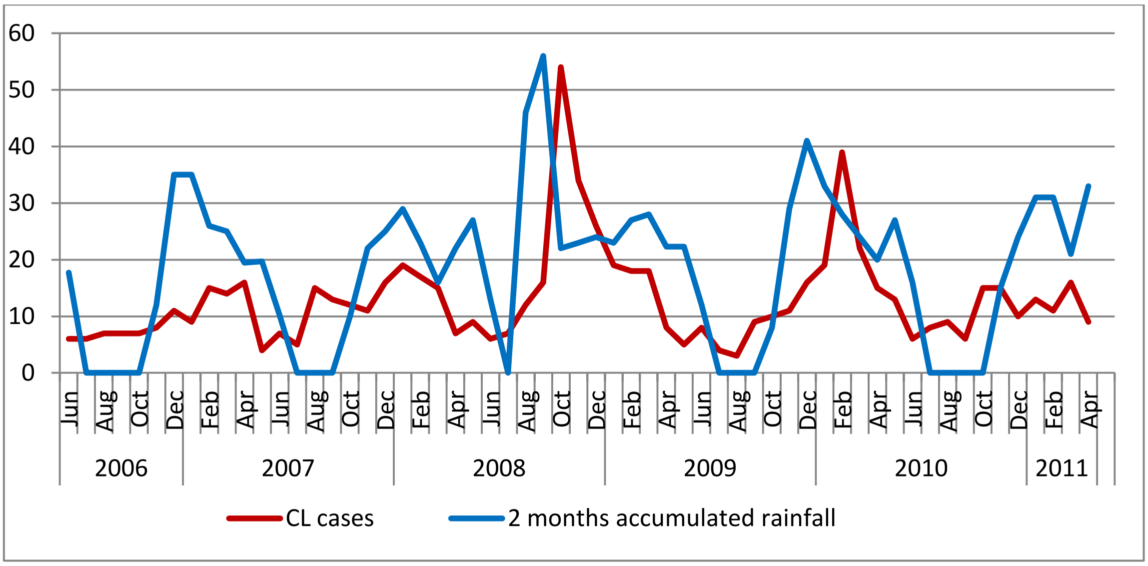


Figure 5.3: Amount of accumulative rainfall in current and previous month and the number of reported CL cases in Al-Dawadmi Governorate between January 2006 and April 2011.

The graph above highlights that there is a distinct tendency of the CL outbreaks just after a rainy period with a certain amounts of rainfall. It shows that both outbreaks have occurred one or two months after rainy periods with amounts of 40 mm or more (56 mm in 2008 and 41 mm in 2010 outbreak) and came a couple of months after months with ideal temperatures for sandflies to lay eggs and to get them developed. So, besides knowing that temperature is a very important factor as it controls sandfly development and activities as well as the activities for both rodents and humans, rainfall is also a very important key factor in the incidence of CL based on the pervious analysis as temperature is enabling the processes and rainfall is the trigger. This can be seen obviously in the case of November and December 2006 (Figure 5.3) where the rainfall was slightly higher but the number of the CL cases acted differently from the outbreaks and this was probably due to three colder months before from September to November as temperature ranged between 10°C and 15°C which is not suitable for sandflies.

5.8. Conclusion:

In general terms, the findings of the seasonality analysis match what has been found so far in other studies (i.e. Faraj, 2011; Toumi et al., 2012, Karakis et al., 2013; Viana et al., 2011). However, no previous studies were found mentioning the required amounts of rainfall for severe CL outbreaks which was found to be 40 mm or more. These findings can be used as an early warning signal for the local authorities in the study area or in similar areas with the same environmental conditions. If the temperature in a block of months is in the range between 23°C and 34°C which is ideal for sandflies to lay eggs and these to develop, and the previous one or two months were rainy with amounts of rainfall of 40 mm or more then, there is a very high possibility of a severe CL outbreak based on the available data and analysis.

Chapter Six: The Impacts of Land Use and Land Cover upon the Prevalence of CL in Al-Dawadmi Governorate:

6.1. Introduction and Background:

In Chapter 2, it was noted that there are strong associations between some land use / land cover with the prevalence of CL. In this Chapter, these associations will be investigated in order to answer one of the main research questions, which is:

> **"Does the prevalence of CL in a particular community vary according to the local environment and proximity to different types of land use / cover?"**

In order to answer the above question, various patterns of land use / land cover were assumed to be associated with the prevalence of CL in Al-Dawadmi Governorate. Such associations were highlighted as justified and comprehensive explanations were produced in chapters 2 and 4. It might be worth briefly mentioning these land use / land cover once again in this chapter.

First of all, six vegetation classes were categorised based on their types and densities. These are as follows:

- Very dense natural vegetation cover
- Dense natural vegetation cover
- Vegetable and crop farms
- Fodder farms
- Palm farms
- Mixed vegetation farms

Beside these vegetation classes, other probable land use patterns associated with CL were also addressed. Some of which are:

- Construction waste disposal sites
- Abandoned or mud houses
- Livestock shelters
- Built up areas

In order to understand the association between the incidence of the disease and the highlighted land use / cover patterns, some comparisons are needed between two population groups that are varying in their exposure status and in their proximities from the highlighted land use / cover patterns. These two groups are 125 CL cases (people who have been exposed to CL) and 125 CL controls (people who have not been exposed to CL, the control group represent those at risk of becoming cases). CL cases and controls were selected, spatially located and interviewed. The steps and procedures of the interview were explained broadly in Chapter 4 and will be mentioned here briefly. These two groups were selected carefully to make sure that each case and its matching control were located in the same neighborhood in order to ensure that they share more or less the same features and land use / land cover patterns with some variations only in their proximities to these land use and land cover patterns.

So, after highlighting these ten patterns of land use / land cover, there was a real need to locate and digitize those patterns which are inside 1500 metre radius of buffer zones around each of the cases and controls in the study area. This is the distance that sandflies can travel from their resting and breeding habitats in arid and semi arid areas. This reference was also found in literature and was mentioned earlier in the Literature review Chapter (see Table 2.2). This digitizing task was accomplished after the field trip to Al-Dawadmi Governorate had been conducted as discussed extensively in Chapter 4.

In the current stage, cases and controls were spatially located and the land use / land cover patterns that might be associated with the exposure to CL were highlighted, spatially located and digitized. Finally, for each case and each control, the distance from the entrance of each housing unit to the edge of the nearest land use or land cover patterns out of any of the ten mentioned types were measured in metres. These measured distances will be used in all the analysis in this chapter. The distribution of the reported CL cases and their matching controls from the above land use / land cover patterns were summarised and represented in some graphs, aiming to understand the overall association, as shown in Figures 6.1 and 6.2 which demonstrate the number of CL cases in red bars and the number of controls in blue bars on the vertical axes and their distances from each land use or land cover pattern on the horizontal axes.

From these land use / land cover patterns, built up areas were located and digitized in order to identify their overall distribution and also to see whether CL cases and controls were located in built up areas such as cities, towns, villages, small groups of houses or even in isolated individual housing units. The last type was not included. From Figure

6.1, it can be seen that there is no huge difference between the distribution of cases and controls from such land use as the great majority of the cases (77%) and controls (82.5%) were in effect within 100 metres of built-up areas and only a few interviewed people of both groups were located further than 300 metres from such land use.

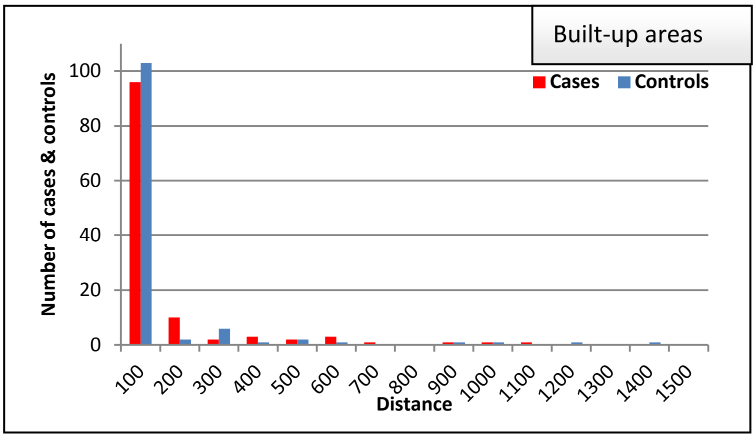


Figure 6.1: The distribution of CL cases and controls from built up areas

For the other nine land use / land cover patterns, the distribution of distances for cases and controls are summarised in Figure 6.2.

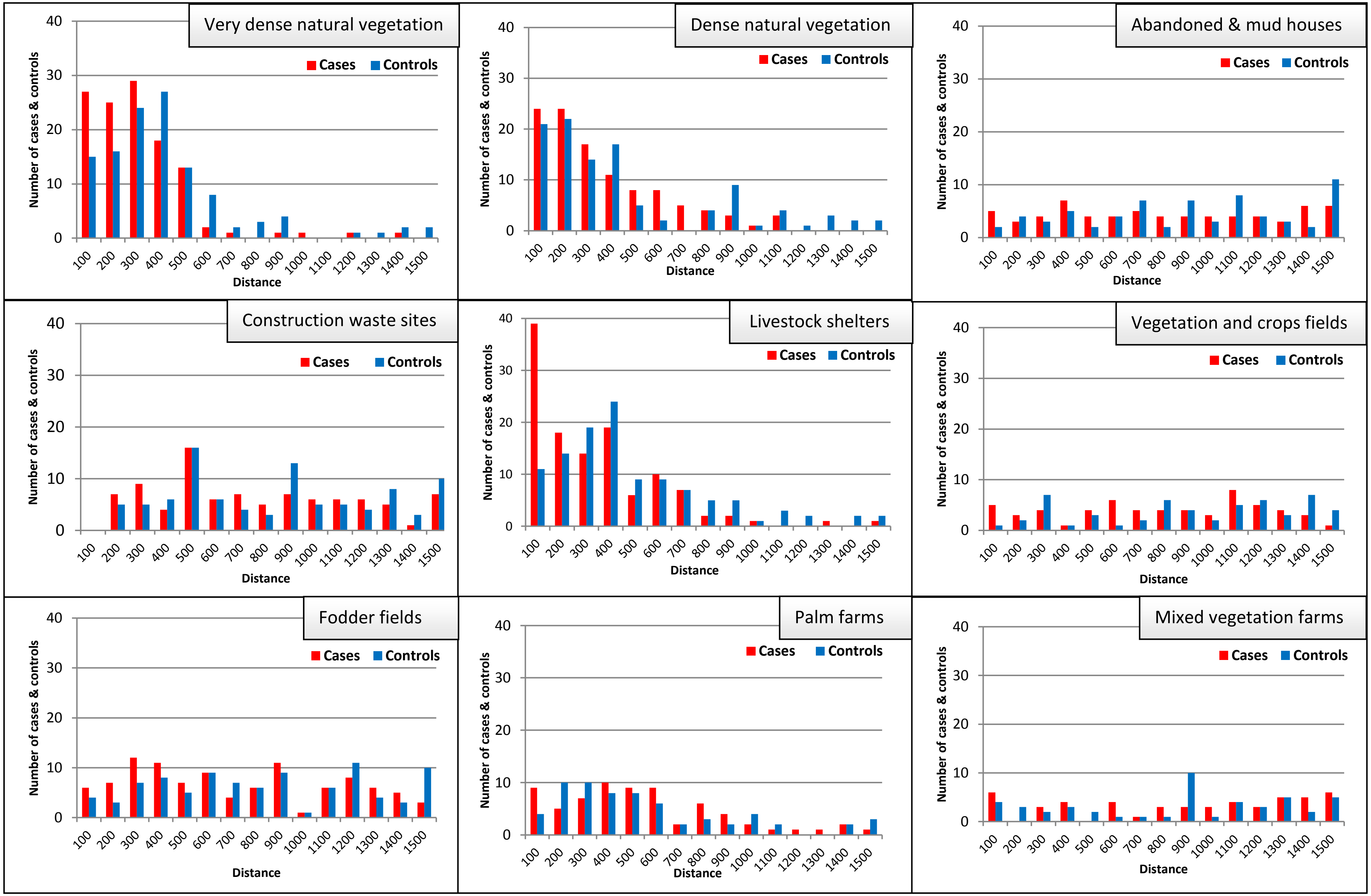


Figure 6.2: Distributions of CL cases and controls from different land use / cover types

Figure 6.2 shows that there is a very strong variation in the distribution of CL cases and controls from certain land use / land cover types. The top left graph shows that the majority of the CL cases were within 300 metre of very dense natural vegetation cover. In addition, more CL cases (65%) were located within this distance in comparison to controls (44%). For both groups, a general declining trend is visible from 400 to 600 metres and very few cases or controls are found further than this distance. Similarly, but with a slightly wider distribution over the 1500 metre range, 52% of CL cases and 45.5% of the controls were found within 300 metres of dense natural vegetation cover, with a decline out towards 900 metres and few records beyond this distance. For livestock shelters there is a very high concentration of cases within 100 metres (about 31% of cases which was much higher than for any other category apart from built up areas). The number of CL controls within the same 100 metre band was much lower at only 9%. Again, there were few cases or controls beyond 900 metres of livestock shelters.

No strong differences in the distributions of cases and controls from the other land use types. For ‘’construction waste sites’’, ‘’fodder fields’’ and ‘’palm farms’’, both cases and controls were scattered across a 1500 metres range with a slight concentration in the distances between 500 and 900 metres for the first, between 200 and 500 for the second and between 100 and 600 for the third. The distributions of CL cases and controls from ‘’abandoned and mud houses’’, ‘’vegetation and crops fields’’ and ‘’mixed vegetation farms’’ are relatively evenly scattered over the 1500 metres range.

These relative distributions are suggestive of a higher CL risk associated with closer proximity to very dense natural vegetation, dense natural vegetation and livestock shelters. There is no evidence of raised risk associated with proximity to categories such as ‘’fodder fields’’ or ‘’ palm farms’’. However, some caution is needed when interpreting these results because there is no control for other personal or household factors that might increase risk. Therefore, further analysis is needed which statistically compares groups of cases and controls that share more or less the same personal and household characteristics and differ only in their proximities from the specified land use / land cover types.

From the researcher’s knowledge and observations during the field trip, it was noted that some land use / land cover patterns varied in their distributions and densities between urban and rural areas. For instance, vegetable, crops and fodder farms were found to exist more in rural than in urban areas. In contrast, there were more construction wastes disposal sites and built up areas in urban than rural areas. Other obvious variations were observed from the differences in distributions, lifestyle and occupations between Saudis and non-Saudis. Non-Saudis were found to be in notably different or depressed conditions than the Saudis in terms of standards of living areas, land use / land cover patterns surrounding the housing, housing types and neighborhood hygiene. For example, non-Saudis were found to be concentrated in the South west part of Al-Dawadmi City in traditional or mud houses because of the lower cost of living there. There are also enormous differences in the types of occupation between Saudis and non-Saudis, with the former being mostly involved in indoor jobs such as working in offices, and the latter being mostly involved in outdoor jobs and activities where they get close to various land use / land cover patterns. Such outdoor occupations include working as farmers or shepherds in farms, grazing lands and livestock areas.

In the light of the aforementioned differences between the urban and rural areas and between Saudis and non-Saudis, the interviewed 250 people were subdivided into five population classes with a view to achieving more robust results, with possible variations based on living areas and nationality. These five population classes are:

- All interviewed people (125 cases / 125 controls)
- All interviewed Saudis (79 cases / 79 controls)
- All interviewed non-Saudis (46 cases / 46 controls)
- All interviewed people in urban areas (72 cases / 72 controls)
- All interviewed people in rural areas (53 cases / 53 controls)

For both cases and controls, initial tests on the collected data showed that the data were not normally distributed. Therefore, non-parametric tests were preferred. It was necessary to establish the nature of associations between CL occurrences and the land use / land cover patterns. Several non-parametric tests could have been applied to answer this question statistically. These non-parametric are critically reviewed in the following paragraphs.

To examine whether proximities to land use / land cover patterns varied between the two groups (cases and controls) without any reference to individual pairs, the Kolmogorov-Smirnov test (KS) can be used. This test is sensitive to both location and shape of the distributions of the two samples (Simard and L'Ecuyer, 2011). However, it also has some limitations. When testing normality, for instance, the power of the test is quite low, generating statistics based on whole samples instead of the respective matching pairs (Weber et al., 2006; Simard and L'Ecuyer, 2011). To achieve a more powerful analysis one option is the Sign Rank test (SR). This is a relatively simple non-parametric test which evaluates the hypothesis about the population distribution medians and their variation from zero based on matched pairs of observations. It is a test that allocates a sign to each pair based on whether the first observation is higher or lower than the second without any consideration of the magnitude of difference (Whitley and Ball, 2002). Consequently the omitted magnitude information is a source of inefficiency and reduces the statistical power of the test (Ibid).

The weaknesses of the KS and SR tests are overcome by the Wilcoxon Signed Ranks (WSR) test which is the non-parametric equivalent of the dependent two-sample t-test for parametric analysis. It is commonly used to investigate changes over time, or where the subjects in a study are exposed to more than one condition and the assumption for normality is violated (Derryberry et al., 2010). The test overcomes the weaknesses of the KS and the SR tests by comparing the differences in the distribution of matching pairs and also considering the magnitude of these differences.

6.2. Wilcoxon Signed-Ranks test:

For the above reasons the WSR test was used to compare the distances from the entrance of each housing unit for each case and its matching control to the nearest edge of each one of the highlighted ten land use or land cover types that were thought to be associated with the prevalence of CL vector or reservoir within 1500 meters buffer zones. The results of the applied WSR tests are summarised in Table 6.1.

Table 6.1: Wilcoxon signed-rank test results

Interviewed class / Land use/cover	Z and Sig	Very dense natural vegetation	Dense natural vegetation	Construction waste disposal site	Abandoned or mud houses	Livestock shelters	Vegetable and crop farms	Fodder farms	Palm farms	Mixed vegetation farms	Built up areas
All interviewed people (N= 250)	Z	-4.265	-2.422	-.342	-.697	-6.089	-1.783	-.909	-1.450	-.832	-.628
	Sig	<.001	.017	.721	.490	<.001	.077	.365	.147	.410	.540
All interviewed Saudis (N=158)	Z	-2.769	-1.915	-1.711	-.749	-2.242	-.493	-1.131	-.509	-1.117	-.337
	Sig	.005	.057	.088	.459	.024	.699	.254	.637	.276	.753
All interviewed non-Saudis (N=92)	Z	-3.103	-1.999	-.423	-.748	-2.563	-2.143	-.323	-.107	-1.270	-1.192
	Sig	<.001	.044	.686	.469	<.001	.031	.767	.922	.234	.241
All people in urban areas (N=144)	Z	-3.774	-1.573	-2.225	-2.338	-2.644	-1.002	-.536	-1.822	-.569	-.837
	Sig	<.001	.119	.028	.021	.009	.327	.596	.070	.576	.402
All people in rural areas (N=106)	Z	-4.837	-2.347	-1.158	-.670	-4.904	-2.894	-2.006	-.799	-.196	-.337
	Sig	<.001	.018	.258	.512	<.001	.005	.044	.432	.850	.746

Significant values

From Table 6.1, it can be observed that in all five population classes there were significant differences in the distances of cases and controls from very dense natural vegetation cover and livestock shelters. In all five analyses, cases were found in closer proximities to such land cover and land use types than controls. Similarly, in three out of five population classes the cases were found significantly closer to dense natural vegetation cover than controls. These three population classes were all interviewed people; interviewed non-Saudis and interviewed people in rural areas. The latter two classes also had significantly different distributions of cases and controls from vegetable and crop farms.

The distributions of cases and controls from construction waste disposal sites, abandoned and mud houses and fodder farms were each significantly different only in a single population group which was all interviewed people in urban areas for the first and second land use categories and for all people in rural areas for the third. Apart from the difference mentioned above, no other variations between cases and controls were found to be statistically significant.

Some other observations can be made about the results in Table 6.1. Firstly, from the Z statistics it is clear that very dense natural vegetation cover and livestock shelters had the strongest overall associations with CL incidence rate. In addition, it appears from the Z values that the influence of very dense vegetation cover is stronger upon Saudis in comparison with non-Saudis, as well as upon people in rural areas in comparison with people in urban areas. Likewise, the influence of livestock shelters is slightly stronger upon non-Saudis in comparison to Saudis. Yet, the association with the same land use was much stronger upon people in rural areas in comparison with those in urban areas. These findings reflect differences in where different land cover types occur and population classes live (e.g. Saudi versus non-Saudi). The reasons why certain land use and land cover types are associated with CL cases are discussed in more detail in the following section.

6.3. Discussion on Distributions of Cases and Controls:

Very dense natural vegetation cover is considered to be an ideal habitat for rodents, both as a food source and a natural cover for their burrows. It is also an ideal habitat for sandflies as it provides meals for the male sandflies and also a resting and breeding site for the females (Ben Salah et al., 2000; Martinez et al., 1997; Schlein and Jackobson, 1999; Killick-Kenderick & Killick-Kenderick, 1987). Such land cover is widely distributed in and around the communities being studied. Its close proximity to the communities was observed during a field trip that was carried out and supporting data was also accumulated from official reports of the Ministry of Health in the Governorate (MOH, 2012). This wide distribution can be assumed to be the reason for its significance in all the population classes. During the field trip, some of the very dense vegetation sites were visited and investigated closely, and an enormous number of active rodent burrows were found in a small area (about 17 burrows within roughly 3 m^2); see Figure 6.3. These rodent infested areas are producing a strong indicator of the high population of sandflies prevalent in the nearby community too, which obviously exposes the community to the risk of CL.

Figure 6.3: A picture taken south of Al-Dawadmi City showing the number of active rodent burrows in a medium dense natural vegetation area.

Livestock shelters were also found to be statistically significant in the distribution of cases and controls among all population classes. This land use provides an ideal habitat for the CL vector and reservoir for food as well as shelters (Dhiman et al., 1983; Quinnell and Dye, 1994; Dye et al., 1991; Killick-Kendrick et al., 1984; Alexander, 2000). Generally speaking, livestock shelters are often supplied with vegetables, crops and fodder for livestock, and they are humid and rich in organic waste materials. This means that they easily and consistently provide food for rodents and being full of cracks, they often serve as a hiding place for sandflies to rest and breed (see Figure 6.4). Al-Dawadmi Governorate is an agricultural region. Here, the general lifestyle of most people is nomadic tribal (Bedouins). They have got a high dependency on livestock, animal shelters and are widely distributed with higher concentration in rural than urban areas. The shelters are also much closer to non-Saudis than Saudis as the former are mostly farmers or shepherds living where most farms and animal shelters are. This can be seen clearly when comparing the significant distribution values among the population classes as these values are stronger in rural than urban areas. The wide existence of such land uses in the study region is likely to be the reason for being significant in all five population classes.

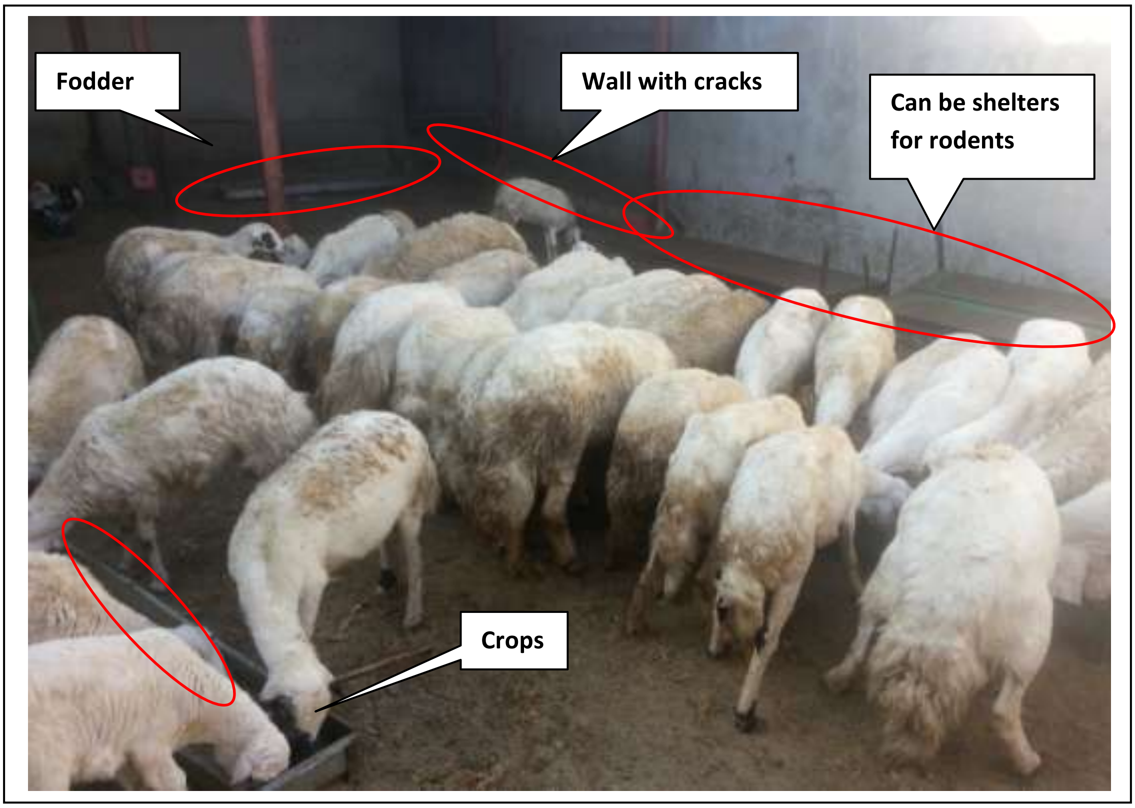


Figure 6.4: A picture of a livestock shelter, highlighting the reasons for sandflies and rodents to get attracted to such places.

Additionally, from Tables 6.3 and 6.4, dense natural vegetation cover is considered to be moderately significant in the association level with CL. This land cover shares the same characteristics and provides the same features for sandflies and rodents as the very dense natural vegetation cover, but in moderate level. Dense vegetation distribution is less common compared to the very dense vegetation, and this land cover is more common in rural areas and south of Al-Dawadmi City. This can be seen from Table 6.3 where the distribution between cases and controls were significant only among three population classes out of five. The difference in distribution between cases and controls was found to be significant among all interviewed people in general, all interviewed non-Saudis and also all interviewed people in rural areas.

Due to the rapid population growth in Al-Dawadmi City, there has been an enormous growth in the number of new housing units and projects which are causing a great deal of construction waste. This waste is commonly disposed of by individuals who often do it in some locations just on the outskirts of the urban area. This happens even when general waste is collected by the local municipality and taken far from the urban areas to either incinerators or dumping sites. The heaps of construction waste provide natural shelters for rodents and other animals, where they live and rapidly multiplies along with sandflies that also inhabit there and infest the whole area (Tayeh et al., 1997b). See Figure 6.5. Such land use is common at many sites just out of the urban area in Al-Dawadmi City and mostly south west of the city. These kinds of construction disposal sites are, however, not common in other communities. For this reason, the significant difference in distribution between cases and controls from such land use was found only in one population class which is all people in urban areas.

Figure 6.5: A picture of a construction waste dumping site, taken on the southern outskirts of Al-Dawadmi City.

The distribution of cases and controls from abandoned and / or mud houses were found to be statistically significant in one population class which is in the case of all interviewed people in urban areas where cases were found to be in closer proximity than controls to such land use. Abandoned or mud houses with mud construction materials and walls full of cracks beside ground septic tank are considered as very ideal habitats for rodents and sandflies. As such place provides suitable shelter with not much disruption for rodents and for the sandflies to rest and breed in the cracks (Rozendaal, 1997; Kanjanopas et al., 2013; Kaul, 1991) see Figures 6.6 and 6.7. Currently, there are not many abandoned houses in most communities apart from some within the Mesedah Community where there are quite a large number of these houses. Mud houses are also less common in the area being studied especially in large cities with the exception of the south west part of Al-Dawadmi City next to the livestock market, with non-Saudi occupants.

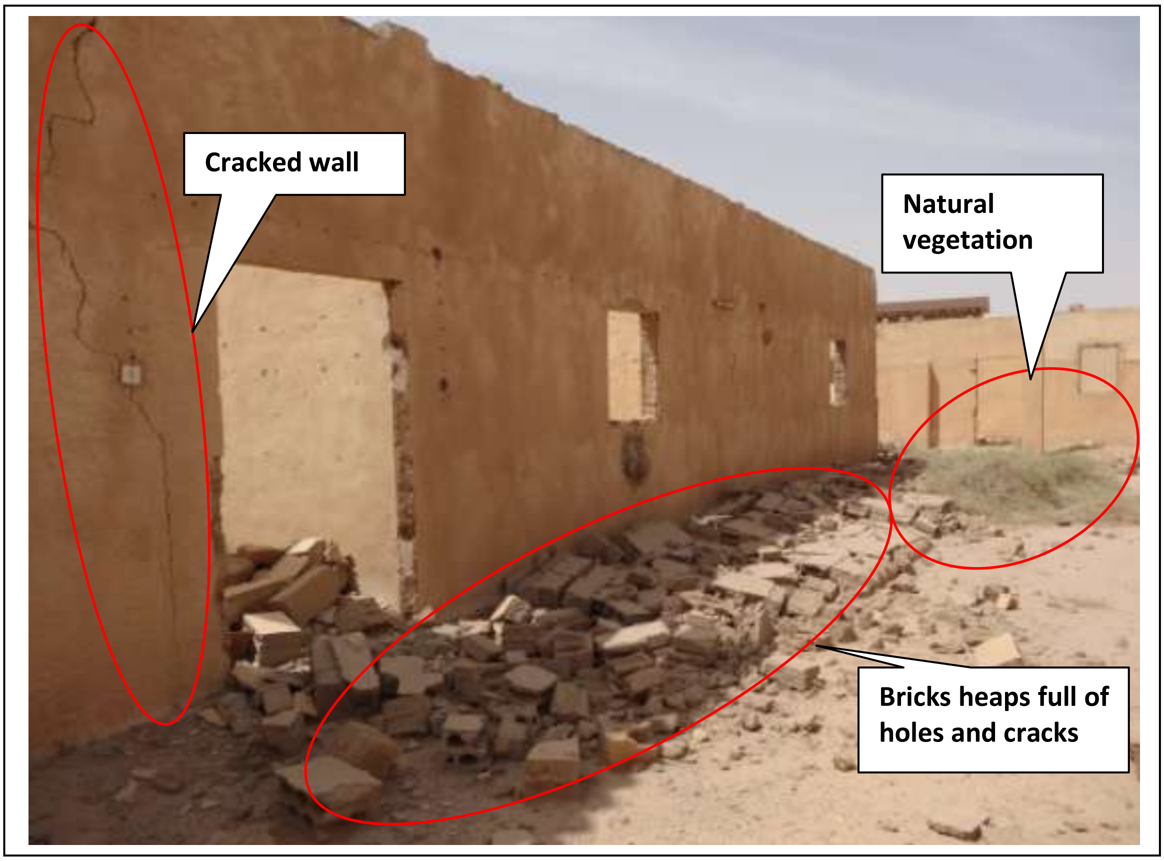


Figure 6.6: A picture of an abandoned house in Mesedah Community

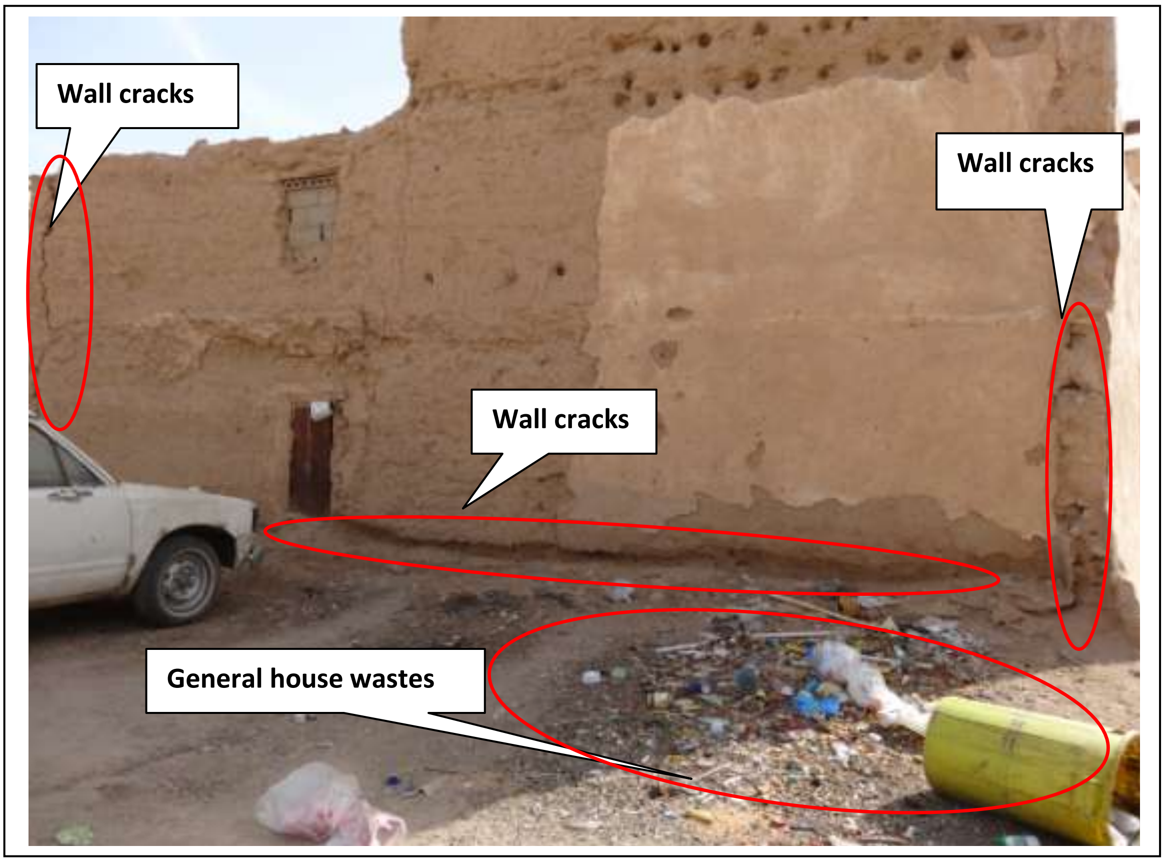


Figure 6.7: A picture taken south of Al-Dawadmi City of a mud house full of wall cracks and surrounded with general housing waste

On the subject of vegetable and crop farms, the distribution between cases and controls in two population classes were found to be statistically significant. These classes are: all interviewed non-Saudis and all interviewed people in rural areas. It is not surprising that differences occurred only in these two classes as non-Saudis commonly work as farmers or shepherds and live more commonly in rural areas with a higher possibility of coming into contact with sandflies. In general, most farms with either low quality plaster or un-plastered housing units with many cracks in the walls are suitable habitats for sandflies to rest and breed. Housing units in farms also have shallow or on-surface septic tanks or even outdoor defecation areas and sometimes adjacent water ponds and waste disposal sites as exemplified in Figure 6.8. Additionally, rays of light from farm houses at night amidst the dark surrounding areas attract rodents and sandflies from nearby areas. Farms also have livestock shelters that provide food and housing for rodents and sandflies. Furthermore, the common household wastes often attract other animals like dogs, cats, foxes which might be a secondary blood source for sandflies (Garner and Saville, [No date]). So, it can be concluded that farms are very suitable place for sandflies and rodents with so many possible habitats that were mentioned above.

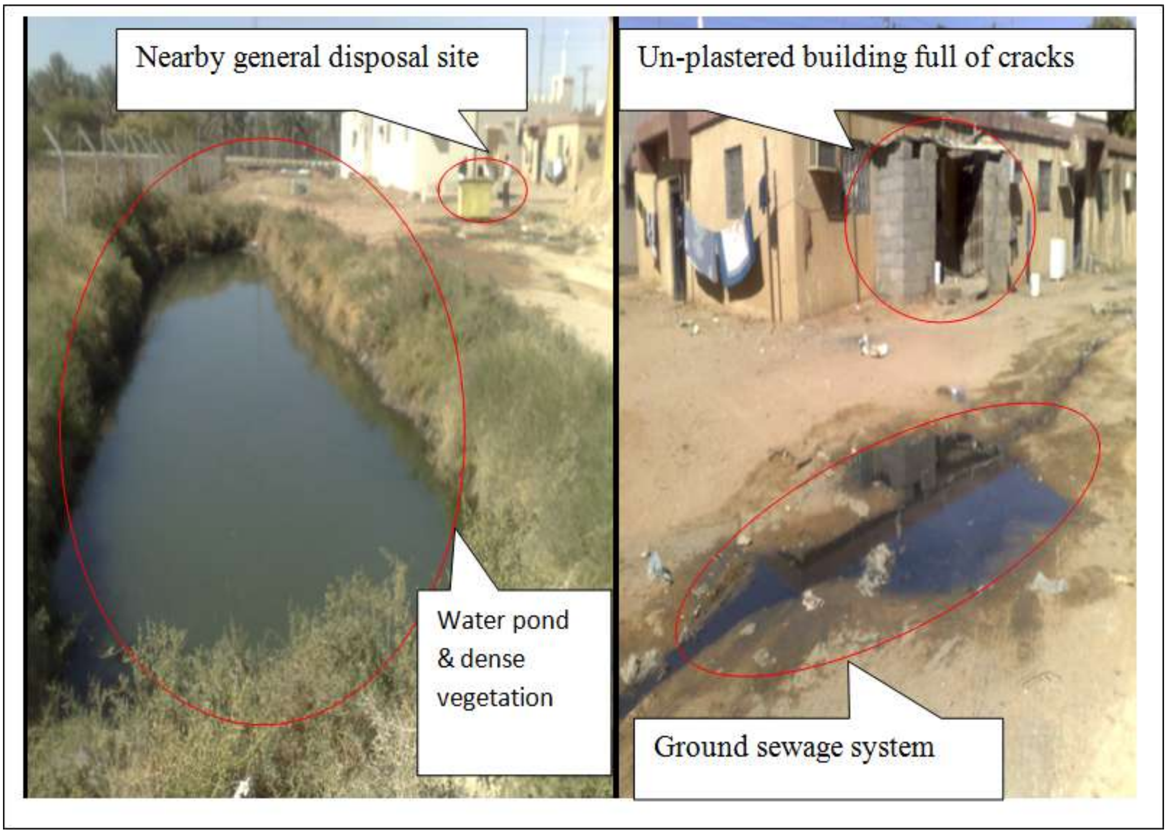


Figure 6.8: Pictures of a farm house and the surrounding area taken at a farm in Al-Dawadmi Governorate.

From Table 6.4, the distributions between cases and controls were not found to be statistically significant in any of the population groups from palm, mixed vegetation farms and built up areas. This is probably due to the low population at large farms such as mixed vegetation and palm farms. In regards to the built up areas, as can be seen from Figure 6.1 most interviewed people were relatively within 100 metres from such land use with very low variation which might resulted in not being significantly associated with CL in this study.

In the light of the WSR test, the distribution between cases and controls from certain land use / land cover patterns was found to be statistically different. The results of this test show that some land use / land cover patterns play a very important role in the CL transmission in Al-Dawadmi Governorate by providing the ideal habitat for both the CL vector and the reservoir. However, this test does not tell whether there is a certain distance effect for each land use / land cover. In other words, 'Do the land use / land cover patterns have the same influence in the same distances or do they vary with each one of them having its own critical distance with high influence risk factore?' To answer this question, the odd ratios were used.

6.4. Odds Ratio (OR):

The odd ratios (OR) were used to find out the critical distance between locations of cases and controls and their proximity to the specified land use / land cover patterns and intended to find the difference. This research aimed to determine whether distance to certain land use / land cover patterns had any link to the CL incidence rates in Al-Dawadmi Governorate, and if "YES", then what are the critical distances? The OR works by calculating the differences between the number of cases and controls within specific distance intervals (in 100s metre from 100 to 1500 metre). The critical distances in this study were identified by starting from 100 metre onwards up to the point of finding the highest OR combined with a strongly significant *P* value and before any obvious drop in both values in the following distance interval.

In the first place, 15 sequential distance intervals, each of 100 metres, were applied. The general observations suggested that most critical distances were more obvious within the first 500 metres of the land uses / land covers. Therefore, these intervals were simplified and reduced to 7 rather than 15 ending up with the values 100, 200, 300, 400, 500, 1000 and 1500 metre as exemplified in Table 6.5. However, it was found that not all population classes have critical distances from all land use / land cover patters. Therefore, there was no real need to report all OR tables here and they will, therefore, be listed in the Appendix section (see Appendix I 1, 2, 3 and 4). The outstanding critical distances (in metre) from land use / land cover patterns were summarised in Table 6.6.

Table 6.2: The number of interviewed people within the selected distance intervals (125 cases / 125 controls)

Land use	Distances intervals	100m	200m	300m	400m	500m	1000m	1500m
Very dense vegetation cover	Cases	27	52	81	99	112	117	119
	Controls	15	31	55	82	95	112	118
	Odd ratio	2.0204	2.16	2.343	1.9967	2.7206	1.6975	1.1766
	P value	0.0449	0.0052	0.0011	0.017	0.0055	0.2586	0.776
Dense vegetation cover	Cases	24	48	65	76	84	105	108
	Controls	21	43	57	74	79	95	107
	Odd ratio	1.1768	1.1888	1.2924	1.0689	1.193	1.6579	1.018
	P value	0.6216	0.5112	0.3118	0.7963	0.5069	0.1159	0.9248
Abandoned or mud houses	Cases	0	7	16	20	36	67	92
	Controls	0	5	10	16	32	63	93
	Odd ratio	1	1.4237	1.6881	1.2976	1.1756	1.1368	0.9593
	P value	1	0.5558	0.2176	0.472	0.5699	0.6127	0.8854
Construction waste disposal sites	Cases	5	8	12	19	23	44	67
	Controls	2	6	9	14	16	39	67
	Odd ratio	2.5625	1.3561	1.3687	1.4212	1.5362	1.1978	1
	P value	0.2663	0.5834	0.4953	0.3518	0.2246	0.5021	1
Livestock shelters	Cases	39	57	71	90	96	118	120
	Controls	11	25	44	68	77	104	113
	Odd ratio	4.6998	3.3529	2.4205	2.1555	2.1373	1.7830	2.5487
	P value	< 0.0001	< 0.0001	0.0007	0.0042	0.0072	0.2492	0.0879
Vegetable and crop farms	Cases	5	8	12	13	17	38	59
	Controls	1	3	10	11	14	29	54
	Odd ratio	5.1667	2.7806	1.2212	1.2029	1.6696	1.4459	1.1754
	P value	0.1365	0.1379	0.6556	0.668	0.3836	0.1998	0.5253
Fodder fields	Cases	6	13	25	36	43	74	102
	Controls	4	7	14	22	27	59	93
	Odd ratio	1.5252	1.9566	1.9821	1.8938	1.9033	1.6231	2.6998
	P value	0.5214	0.1681	0.0582	0.0374	0.0252	0.0579	0.0056
Palm farms	Cases	9	14	21	31	40	63	69
	Controls	4	14	24	32	40	57	64
	Odd ratio	2.347	1	0.8498	0.9584	1	1.2122	1.1744
	P value	0.1653	1	0.6216	0.8842	1	0.4477	0.5264
Mixed vegetation	Cases	6	6	9	13	13	27	50
	Controls	4	7	9	12	14	28	47
	Odd ratio	1.5252	0.8499	1	1.0930	0.9203	0.9544	1.1064
	P value	0.5214	0.776	1	0.8331	0.8386	0.8787	0.697
Built up areas	Cases	96	106	108	111	113	119	120
	Controls	103	105	111	112	114	117	119
	Odd ratio	0.7071	1.0627	108	0.9203	0.9086	1.3561	1.2101
	P value	0.2732	0.8616	0.5654	0.8386	0.8268	0.5834	0.7581

Table 6.3: Distance thresholds for different land use / land cover types patterns.

Interviewed class / Land use/cover	Very dense vegetation	Dense vegetation	Construction waste	Abandoned or mud houses	Animal shelters	Vegetable and crop farms	Fodder farms	Palm farms	Mixed vegetation farms	Built up areas
All interviewed people	300m				100m		500m			
All interviewed Saudis	300m				200m					
All interviewed non-Saudis	300m				100m		500m			
All people in urban areas	300m	200m			100m					
All people in rural areas	300m	100m			100m	500m				

From the summarised OR table above, many land use / land cover patterns share more or less the same distance thresholds where their influences are more obvious and people that fall within these distances are more likely to develop CL if the climate condition was ideal. It was observed that both very dense natural vegetation cover and livestock shelters have clear threshold distances that occur in all population classes, meanwhile some distances only occur in some population classes within other land use / land cover patterns.

It is apparent that the critical distance from very dense vegetation cover was found to be 300 metres for all population classes, which means people within this distance from such land cover are at high risk of constructing CL in comparison with people living further away. However, even though the critical distance was found to be similar between all population classes, the influence of such land cover was found far stronger in the case of non-Saudis in contrast with Saudis. It was found that non-Saudis who have such land cover within 300 m were almost 8 times at higher risk of developing CL (*P* value of <0.001) in comparison to non-Saudis. On the other hand, Saudis who have such land cover within the specified distance were approximately 2 times higher in risk (*P* value of 0.02) of having CL than those Saudis who have not. These strong variations are believed to be caused by other factors accompanied by the presence of such land cover. For instance, non-Saudis within 300 metres of such land use are more likely to be living in rural areas or in the outskirts of urban areas where the level of cleanliness and housing condition is generally low and there is a higher possibility of being engaged in some occupation that interacts with such land cover. On the other hand, non-Saudis who are away from such land cover are living in urban areas with better housing conditions and neighbourhood hygiene and not widely coming in contact with such land cover. It is also the same in the case of the difference between Saudis who have and who do not have very dense vegetation in the addressed distance but in lower variation level as most Saudis have got more or less the same housing conditions with fairly good neighbourhood hygiene. As a result, most characteristics found in the study of them was more or less same with some variation only in the vegetation density and presence.

Regarding the critical distance from livestock, it was found to be 100 metres for all population classes apart from all interviewed Saudis where the distance was slightly longer with 200 metres. Although the difference in the critical distance was very small between the population classes, the influence of such land use is enormously higher in the cases of non-Saudis in comparison to Saudis. This statement is based on the observations from both the ORs and the *P* values. It was found that non-Saudis who have livestock within 100 metres from their housing units were 45 times higher at risk of developing CL than non-Saudis who have not (see Appendix I, 2). This strong OR was enhanced with a *P* value of 0.003. This enormous variation in the values is believed due to the other associated factors such as housing condition and occupation. Non-Saudis who have livestock within 100 metres from home are often farmers or shepherds living in poor quality housing in farms or grazing lands. Poor level of hygiene in such settlements provides ideal habitats for nearby sandflies and rodents. Non-Saudis who live further than this distance are more likely to be engaged in other occupations like indoor, domestic or civil service jobs with rare interaction with animals and surrounding sandflies' habitats. Regarding Saudis who have livestock shelters within 200 metres from their housing units, they were about 3 times at higher risk (*P* value of 0.007) of developing CL in contrast with Saudis who have not.

Moreover, the influence of the presence of livestock shelters within the 100 meters from housing units was found more obvious in rural areas in comparison to urban. People in rural areas who have such land use are almost 13 times higher at risk with a *P* value of <0.001 of contracting CL than people in rural areas that do not have (see Appendix I, 4). The risk of developing CL due to having livestock within 100 metres was much lower in urban areas as the OR was 4.23 and the *P* value was 0.004. These variations are caused by the difference in the distributions and densities of other factors and habitats as exemplified earlier.

The significant distance from dense vegetation cover was found to be 100 metres in rural areas and 200 metres in urban areas and no other significant distances were found for other population classes. The reason behind this is believed due to the moderate presence of such land cover in contrast to the very dense vegetation. From both fodder, vegetable and crop farms the critical distance was found to be 500 metres where people within the distance are at high risk of developing CL than people living further away. This critical distance can be considered as moderately far if compared with the previous distances, but as such farms are often large in size, having a small and scattered population, the distance was found to be moderately high. From the other five patterns of land use / land cover no critical distance was found. However, as they were found to be preferable habitats for sandflies, therefore, the association between the distance and the incidence of CL is following Tobler's first law of geography: '*'Everything is related to everything else, but near things are more related than distant things''* (Tobler, 1970). Meaning that the closer people are located from Leishmaniasis' risk factors the more likely they will develop the disease.

In summary, the thresholds from the selected land use and land cover patterns were very obvious for two land use and cover classes which are very dense natural vegetation cover and animal shelters; and less obvious for fodder farms and dense vegetation cover. Even though there were some differences in the thresholds derived, the values were generated as they were more or less the same in most cases for each land use / cover pattern. It can be said that 300 metres from very dense natural vegetation cover is the critical distance where people within this distance are at a high risk of developing CL. In the case of animal shelters, less distance was found that is less than 100 metre and this might be due to the fact that a shorter journey is needed for the rodents and sandflies to get to the food, resting and breeding sites. Although dense vegetation cover was found to be statistically significant with CL in the studied area, no critical distances were found in the majority of the population groups apart from 200 metres from all people in urban areas and 100 metres in rural areas. This might be due to the distribution of such land use, where it is less common than the previous two with lower population densities around them. The distance from fodder, vegetable and crop farms were found to be 500 metres and the reason for this moderate and higher threshold value was discussed earlier.

6.7. Conclusion:

The results from the conducted non-parametric tests showed that there are some land use / land cover patterns that stand out distinctly as the strongest features or land types associated with the prevalence of CL in Al-Dawadmi Governorate. People in closer proximities from these land use / land cover patterns were found to be at higher risk of contracting CL in contrast with people in farther proximities. However, the influence of these land use / land cover patterns on the prevalence of CL in the studied area has been found to be varying based on nationality (Saudis vs. non-Saudis) and living area type (urban vs. rural). These two variation features are believed to be influencing many aspects of life such as housing condition, occupation, level of awareness, neighbourhood hygiene.

Some land use / land cover patterns were found having clearer impact on CL than others either as they are more preferred by CL vector and reservoirs than others or due to their distribution. From the conducted non-parametric tests, very dense natural vegetation cover was found to be the strongest land cover associated with CL in Al-Dawadmi Governorate. The proximity of cases and controls from such land cover was found to be the fundamental key factor of developing CL where people in close proximity to land cover were at higher risk of developing CL than people living farther away. The critical distance from such land use was found to be up to 300 metres, which means that people who live within this distance are more likely to develop CL than others. Livestock shelters were also found to be strongly associated with CL in the studied area. Such land use provides the ideal habitat for both CL vector and reservoir as discussed earlier. Animal shelters are widely distributed in the area because of the lifestyle of people and their dependency on animals. Therefore, the risks of such land use were found affecting all involved population classes. However, the influence of such land use was found to be much stronger on non-Saudis than Saudis as the formers are more likely to get in contact with livestock and sandflies. Also the influence was found to be more obvious in rural than urban areas due to the distribution of livestock in areas like farms or grazing lands. The critical distance was found to be 100 metres from livestock where people within this distance are in high probability of contracting the disease.

Dense vegetation cover was also found to be playing an important part in the prevalence of CL in the studied area. This 'land cover pattern' shares the same characteristics and provides the same features for sandflies and rodents such as the very dense vegetation cover but at moderate levels. This type of land cover is less common in its distribution as can be seen by the number of the affected population classes which are non-Saudis and people in rural areas. People within 200 metres from such land cover are at high risk of developing CL in the study areas if other environmental conditions are also suitable for harbouring the disease. Moreover, vegetable, crop and fodder farms were found to be strongly associated with CL in Al-Dawadmi Governorate. Such land use/ land cover types have various preferable habitats for both sandflies and reservoirs as discussed earlier. The distribution of these farms and the fact that more farmers are non-Saudis were behind the affected population classes from such land use, which are non-Saudis and people in rural areas. The critical distance from farms was found to be about 500 metres. People within this distance from such land use are more likely to interact with sandflies and therefore, develop CL.

Construction waste disposal sites and abandoned or mud houses were also found to be strongly associated with the prevalence of CL. People in urban areas were the only affected population class from such land use type and this is basically because of their distribution as they are more common in urban areas namely south west of Al-Dawadmi City. Even though no critical distances were found from these land use types by the OR analysis, they are following the epidemiological rules, the closer people are to such land use type the more they are at risk of developing the disease.

To conclude this chapter, it appears that there are very strong associations between the incidences of CL cases and the surrounding land use / land cover patterns in Al-Dawadmi Governorate. These associations vary from one land use / land cover type to another where very dense natural vegetation and livestock shelters were found to be the most susceptible area in our study. In addition, the distance from these land use / land cover patterns makes a difference in terms of defining the risk zone, which was found to be 300 metres for dense vegetation and 100 metre for animal shelters. Other land use patterns were also found to be associated with the distance factor but they were not as obvious as these two. The findings in this part of the study will be used for further analysis by combining them with other socio-economic factors with the aim of getting a broader understanding of the prevalence of CL in Al-Dawadmi Governorate.

Chapter Seven: Socio-economic and Demographic Factors Associated with the Prevalence of CL in Al-Dawadmi Governorate:

7.1. Introduction:

As previously discussed in Chapter 2, one of the main difficulties in understanding and undertaking control measures against CL is the diversity of factors that are involved in its transmission such as the vector and reservoir species, environmental conditions as well as the differences in human awareness and behaviour. All these considerations are believed to play a very significant role in disease transmission (Sharma and Singh, 2008). This chapter utilizes data from a questionnaire survey conducted in Al-Dawadmi Governorate to investigate the most important socio-economic and demographic factors associated with the prevalence of CL, and to find the answer to one of the main questions of the research, which is:

> **"Do CL cases vary according to socio-economic and demographic characteristics of the local population in Al-Dawadmi Governorate?"**

In order to answer this question, a case-control study approach which is comparatively quick, inexpensive and easy to do was employed. This method compares cases (people who have been exposed to CL) and controls (people who have not been exposed to CL, control group represent those at risk of becoming cases) and then looks back retrospectively to assess how widely the exposure to a risk factor is present in each group to identify the association between the risk factors and the disease (Breslow and Day 1980; Silvia, 1999). The data used to implement this approach were collected through face-to-face interviews employing a standardized questionnaire which was piloted and tested as explained previously in Chapter 4. The questionnaire sought to obtain data on the following aspects:

- Public awareness of CL
- Conditions of housing and surrounding areas
- Demographic and socio-economic variables
- Activities of household members
- The experience of cases regarding their exposure to CL

Cases were selected randomly from several communities in the central part of the governorate where CL is commonly reported. Controls were also selected at random, but with the aim of matching cases on some key characteristics namely age, gender, nationality and neighbourhood. The reasons for matching and the procedures followed to achieve it were discussed broadly in Chapter 4.

During the survey work, 125 cases and 125 controls were interviewed and their socio-economic and demographic data were entered into a database for further analysis using the SPSS software. Additionally, the interviewed people were subdivided into the following five classes in the population based on their nationality and area of residence as explained in Chapter 6.

- All interviewed people (125 cases / 125 controls)
- All interviewed Saudis (79 cases / 79 controls)
- All interviewed non-Saudis (46 cases / 46 controls)
- All interviewed people in urban areas (72 cases / 72 controls)
- All interviewed people in rural areas (53 cases / 53 controls)

7.2. Characteristics of the Survey Respondents:

Before applying more sophisticated analysis, the frequencies of different characteristics among the survey respondents were examined. As a first step, the matched cases and controls were checked for their similarity in the nationality, neighbourhood, gender and age group variables. It must be acknowledged that during the field work, it was not possible to exactly match all cases and controls in terms of age groups. However, even if they did not match 100%, they were selected as carefully as possible and with no more than 2 to 5 years difference between them which was thought not to influence their activities hugely, especially for the two age groups, 6 to 18 years old and 18 to 50 years old where most age differences occurred. Figures 7.1.A to 7.1.D show the frequencies of four key matching variables for the cases and controls.

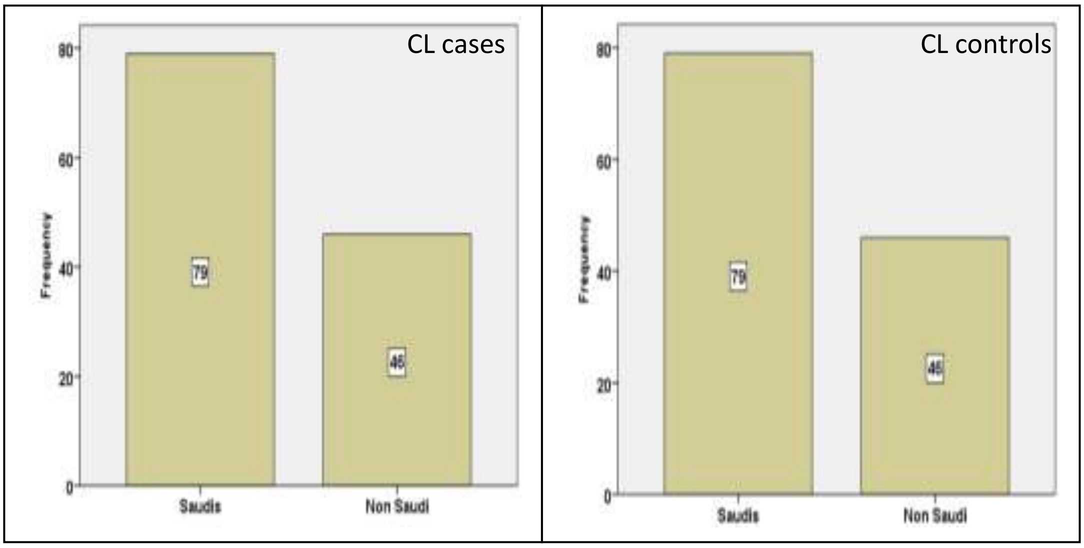
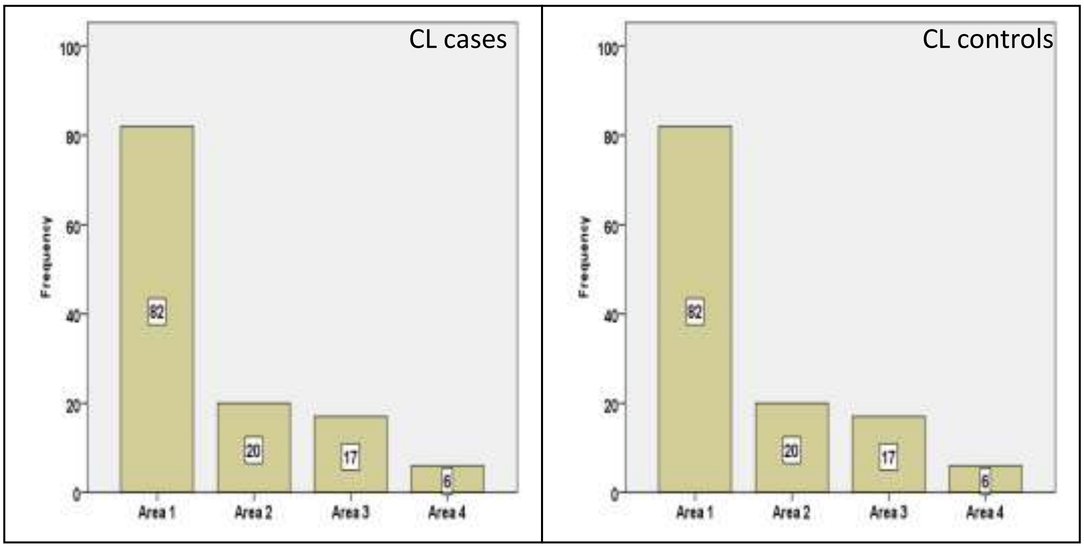


Figure 7.1.A: Distribution of CL cases and controls based on nationality



Area 1 includes: Al-Dawadmi City and Al-Huzaymiah area. Area 2 includes: Al-Grain, Al-Refaya'a and Al-Gmsh. Area 3 includes: Al-Dsmah, Arwa, Masil and Mesedah. Area 4 includes: Afgarah, Alfegarah, Al-Haid and Al-Widi

Figure 7.1.B: Distribution of CL cases and controls based on living area

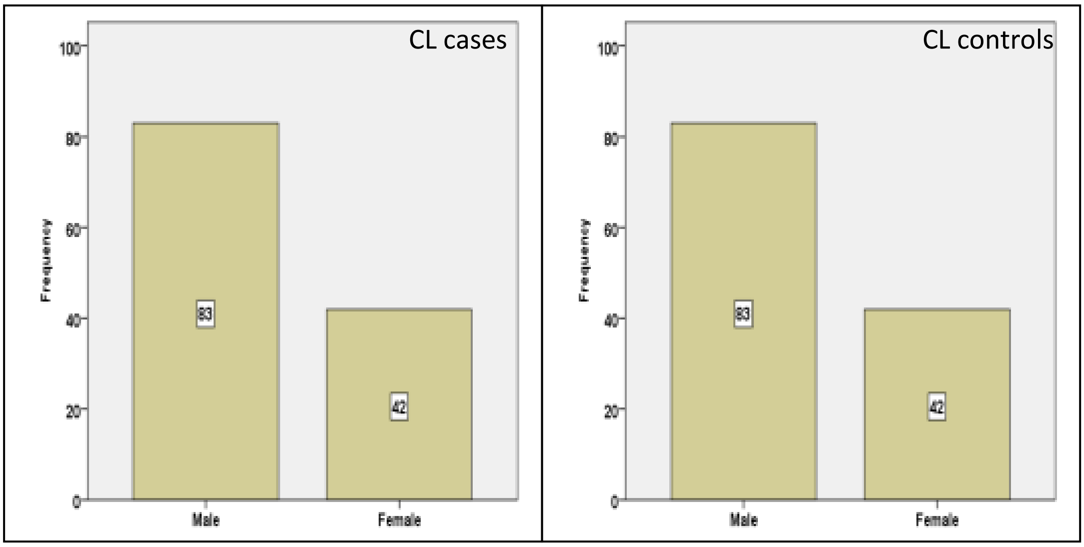


Figure 7.1.C: Distribution of CL cases and controls based on gender

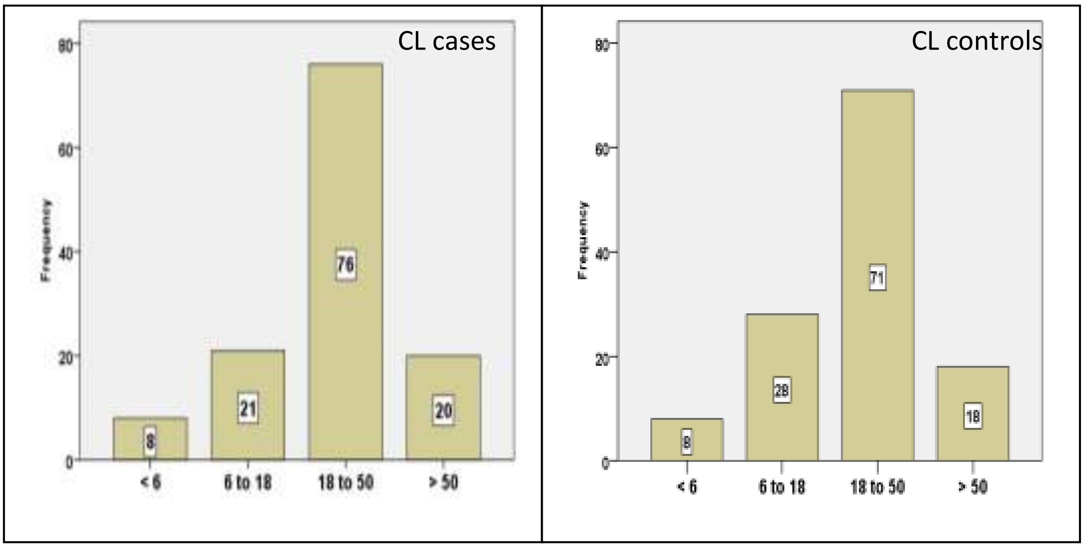


Figure 7.1.D: Distribution of CL cases and controls based on age group

As anticipated, these graphs show a good equivalence between cases and controls regarding the numbers of survey respondents in different categories. The matching of cases and controls considering these four variables also influenced the frequency distributions for other related socio-economic and demographic variables such as housing type, household income and the presence of domestic animals as shown in Figures 7.2.A to 7.2.C.

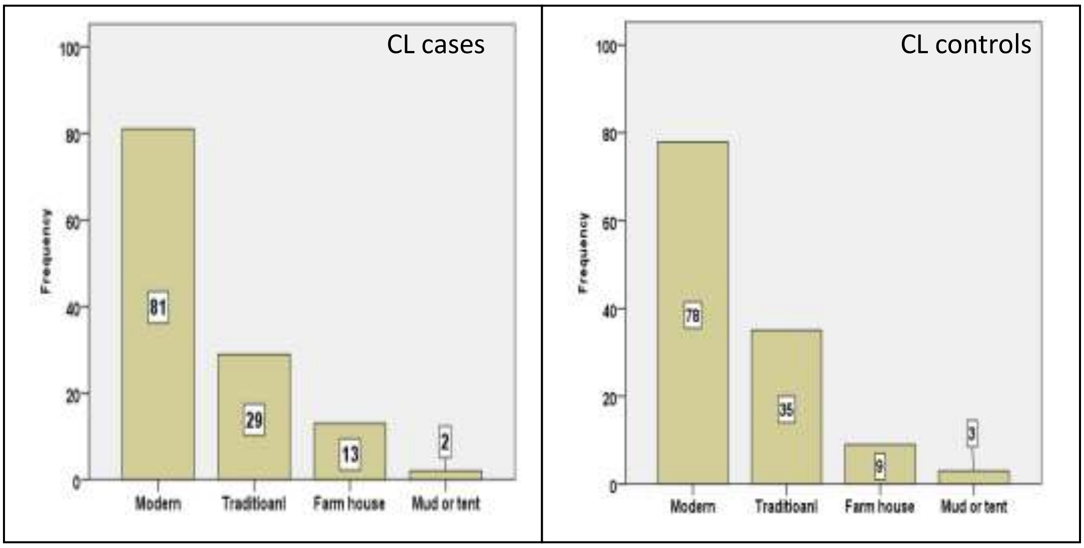


Figure 7.2.A: Distributions of CL cases and controls based on housing types

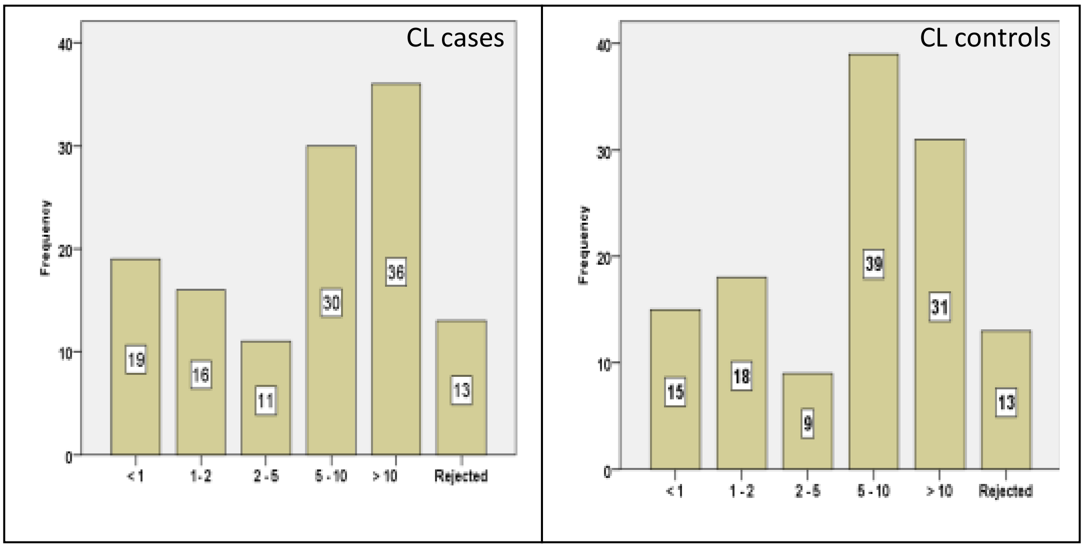


Figure 7.2.B: Distribution of CL cases and controls based on family income (in thousand Saudi riyals)

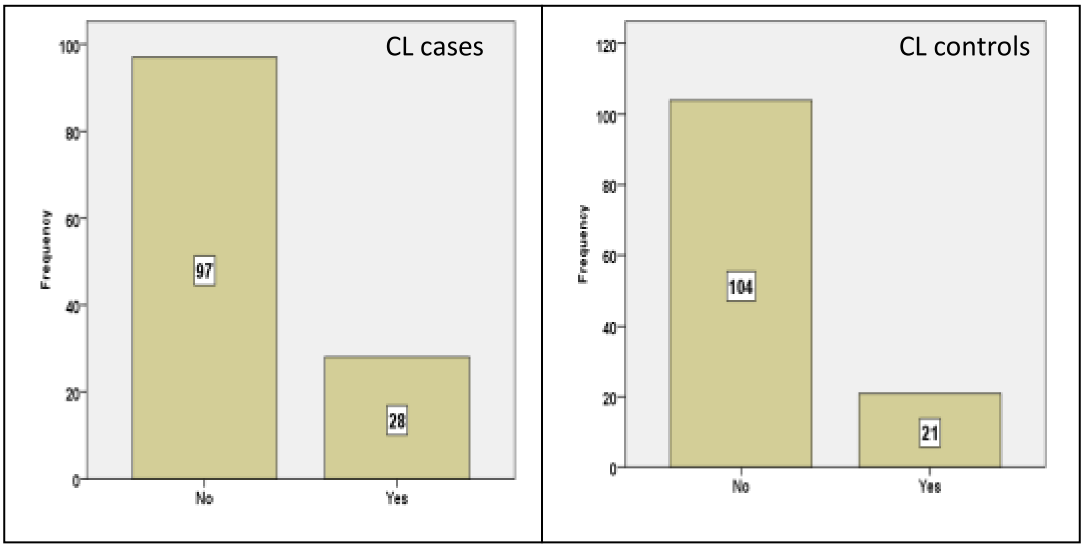


Figure 7.2.C: Distribution of CL cases and controls based on the existence of domestic animals

Cross-tabulations were generated to investigate the influence of other variables on the incidence of CL. In these tables, the extent of any differences between cases and controls were investigated using Chi-square (χ^2) if the answers were categorical and Mann-Whitney U tests (MWU) if the answers were ordinal or continuous. The sub-sections below present the results of these assessments in three parts, firstly considering awareness of CL, then housing conditions, and finally other socio-economic and demographic factors.

7.2.1. Variations in Awareness of CL between Cases and Controls:

The first part of the questionnaire was designed to gather and compare answers by CL cases and controls regarding their CL awareness level in some aspects. This part includes 6 questions which are: 1) What is the CL vector? 2) What is the CL reservoir? 3) What is the size of an adult sandfly? 4) What are the preferable habitats for CL vector and reservoir? 5) What is the seasonality of CL? And finally 6) Do you protect your household from insects? For questions 1, 2, 3 and 6, there were options for only a correct or a wrong answer. For question 4, 16 multiple choice answer options were given with 8 correct preferable habitats and 8 wrong. Subsequently, the result based on the answers for this question were divided into 3 awareness levels which are low awareness (≤ 2 correct answer), intermediate awareness (3 to 5 correct answers) and fairly aware with (≥ 6 correct answers). Regarding the seasonality mentioned in question 5, the answers varied between 0 and 2 correct answers out of 2. The answers for questions 1, 2, 3 and 6 were compared using a Chi-square test as they were nominal, meanwhile MWU tests were used in the case of questions 4 and 5 as these were ordinal questions. All the results were summarized in Table 7.1.

Table 7.1: General awareness level of public about CL in Al-Dawadmi Governorate

Questions \ population class		All people 125 cases/controls		All Saudis 79 cases/controls		All non-Saudis 46 cases/controls		All people in urban areas 72 cases/controls		All people in rural areas 53 cases/controls	
		Cases	Controls	Cases	Controls	Cases	Controls	Cases	Controls	Cases	Controls
What is the CL vector?	Correct	22	33	16	25	6	7	16	22	6	11
	Wrong	103	92	63	54	40	39	56	50	47	42
	χ^2	.093		.102		.562		.257		.186	
What is the CL reservoir?	Correct	20	35	14	27	5	8	14	23	7	12
	Wrong	105	90	65	52	41	38	58	49	46	41
	χ^2	.022		.018		.481		.086		.121	
What is the size of an adult sandfly?	Correct	12	19	9	19	3	0	11	15	1	4
	Wrong	113	106	70	60	43	46	61	57	52	49
	χ^2	.179		.037		.078		.386		.169	
What are the preferable habitat for CL vector and reservoir?	≤ 2/8	45	37	23	21	22	16	27	21	18	16
	3 to 5/8	69	71	50	48	19	23	38	41	31	30
	≥ 6/8	11	17	6	10	5	7	7	10	4	7
	MWU	.205		.533		.248		.406		.290	
What is the seasonality of CL?	0/2	63	40	35	16	28	24	36	20	27	20
	1/2	37	38	23	25	14	13	17	24	20	14
	2/2	25	47	21	38	4	9	19	28	6	19
	MWU	.001		.001		250		.017		.025	
Do you protect your household from insects?	No	62	39	34	20	28	19	30	20	32	19
	Yes	63	86	45	59	18	27	42	52	21	34
	χ^2	.012		.004		.157		.022		.030	

From Table 7.1, two major aspects can be highlighted and discussed, which are: firstly, whether the locals have the knowledge about CL vector and reservoir or not (how big the adult sandfly is and what are the vectors and reservoirs). And secondly, whether people are aware about the seasonality of the disease or not and consequently in what manner they react to avoid getting in contact with sandflies. The first part shows that the general awareness level of vectors and reservoirs of CL and knowledge of their preferable habitats was very poor. It can be seen that 82.5% of all cases and 73.5% of controls did not have the slightest idea about the vectors of CL. Similarly, 84% and 91% of the cases and 72% and 85% of the controls did not know anything about the reservoirs of CL or about the size of an adult sandfly. Moreover, 36% of the cases and 30% of the controls were found to have a very low awareness level of preferable habitats of vectors and reservoirs of CL. And it can be said that 55% of cases and 57% of controls were moderately aware and only about 9% of cases and 13% of controls were fairly aware of such habitats. For these four questions, no huge differences between cases and controls were found based on either their nationality or living areas as in general, all of them mentioned in the data table were found to be poorly aware. Consequently, not many significant variations were found in the collected answers between cases and controls. On the subject of the awareness level among the interviewed people about CL and protection methods from insects, no huge differences were found either, as just like in case of the previous aspects, it was also low in general.

However, in spite of the low general awareness level, the answers were found varying significantly between cases and controls where controls were generally found to be more aware than cases in all five classes in the population. As a result, significant values were found in the MWU and χ^2 tests. For example, 44% of the Saudi cases were unaware of the seasonality of CL while for the Saudi controls the ratio was only 20%., Likewise, 50% of the cases in urban areas were unaware of the seasonality. And for the controls, the percentage value was almost half of that of the cases (27%). Furthermore, both Saudi cases and controls were found to be more aware in comparison to non-Saudi cases and controls. For example, while 44% of the Saudi cases and 20% of the controls were unaware of the seasonality, the numbers were 61% and 52%, respectively for non-Saudi cases and controls. No strong influence of living areas on the level of awareness was found between urban and rural areas. In general, 50% of cases in urban and rural areas and 27% of controls in the former and 37% in the latter were unaware of the seasonality of the diseases.

Protection from insects in the household was found to be significantly different between cases and controls in most of the classes in the population, where controls were found using protection methods more than cases. For instance, 50% of the total cases were found using some protection methods while the number was higher for controls, with 69%. Similarly, 46% of Saudi cases were taking some protective measures against insects in the household while three quarters of the controls (75%) were doing so. Nationality and living areas were also found influencing the overall percentage of people taking protective measures against insects. This scenario was observed while comparing data of Saudis and non-Saudis and those of urban and rural areas. For the former, Saudis were found protecting their households more than non-Saudis. Among the Saudis, 57% of the cases and 75% of the controls were found taking protective measures in households against insects. While among the non Saudis, 39% of the cases and 58% of the controls were doing so. For the latter, people in urban areas were found using more protection than in rural areas. In urban areas, 60% of non-Saudi cases were found protecting their households against insects and it was only 39% in rural areas.

Referring to the preparation of Table 7.1, people were interviewed so that their level of awareness of CL vectors, reservoirs and preferable habitats of those two factors could be realized. In general, their awareness level was found to be very poor. However, some fundamental points can be stated from these interviews. Controls were found to be more aware than cases in all aspects which might be the reason for not developing the disease. The awareness level about the seasonality of the disease was found not hugely differing from the previous aspects as it was generally low and also, controls were found to be more aware than cases in all five classes in the population. Likewise, the number of people protecting their household from insects was found generally low and in the same pattern where percentage value of controls that were found protecting their houses was more than that of the cases in general. Awareness level among the interviewed people about CL vectors, reservoirs and preferable habitats of those two factors did not differ much between cases and controls. This is because their awareness level was low hence low frequencies. On the other hand, strong variations were found between the answers given by cases and controls regarding the awareness level about the seasonality of the disease and taking protective measures against insects in the household. As a result, many significant values regarding this strong variation could be found in the table (7.1). Further assessments will be used later in this chapter to have better understanding of the association between the level of awareness combined with other factors and the incidence of CL. It should be mentioned that in some Chi-square comparisons, the *P* values may not be reliable especially where cell expected frequencies are less than 5. This, for instance, occurs with non-Saudi and people in rural areas' awareness about sandfly size as only 3 and 5 answers respectively were correct.

7.2.2. Variations in Housing Characteristics between CL Cases and Controls:

This section aims to assess the associations between the housing characteristics and the exposure to CL. Eleven questions were asked in this part to both cases and controls, which are:- 1) What is the type of your housing unit? 2) How many members are there in your household? 3) How long have you been living in the current address? Questions 4 and 6 were about if they have livestock or domestic animals and questions 5 and 7 were about where they keep their livestock and domestic animals, if applicable. Question 8 was if they have green areas within the household boundaries and questions 9, 10 and 11 were about the providers for water and sewage services in their household as well as their methods of household waste disposal. The answers for this part were straightforward and nominal. Therefore, the Chi-square test was used to compare the frequencies between answers by cases and controls as shown in Table 7.2.

Table 7.2: Housing characteristics of cases and controls of CL in Al-Dawadmi Governorate

Questions (population class)		All people 125 case/controls		All Saudis 79 case/controls		All non-Saudis 46 case/controls		All people in urban areas 72 case/controls		All people in rural areas 53 case/controls	
		Cases	Controls	Cases	Controls	Cases	Controls	Cases	Controls	Cases	Controls
What is your Housing type?	Modern	81	78	63	61	18	17	64	56	17	22
	Traditional	29	35	16	18	13	17	8	16	21	19
	Farm	13	9	0	0	13	9	0	0	13	9
	Mud /Tent	2	3	0	0	2	3	0	0	2	3
	$\chi 2$	.672		.699		.684		.074		.644	
How many members are there in your household?	Alone	15	10	1	0	14	10	5	4	10	6
	2-4	38	33	21	8	17	25	23	18	15	15
	5-7	41	50	30	45	11	5	25	30	16	20
	≥ 8	31	32	27	26	4	6	19	20	12	12
	$\chi 2$	.380		.031		.338		.763		.360	
How long have you been living in your current house? (in years)	< 1	9	6	5	3	4	3	7	5	2	1
	1 to 10	51	47	32	18	19	29	34	22	17	25
	> 10	65	72	42	58	23	14	31	45	34	27
	$\chi 2$	.571		.031		.110		.064		.264	
Do you have livestock?	No	79	108	51	70	28	38	54	67	25	41
	Yes	46	17	28	9	18	8	18	5	28	12
	$\chi 2$	<.001		<.001		.021		.003		.001	
How far do you keep your livestock from your household?	N/A	79	108	51	70	28	38	54	67	25	41
	In or close	39	8	22	4	17	4	15	2	24	6
	far	7	9	6	5	1	4	3	3	4	6
	$\chi 2$	<.001		<.001		.003		.003		.001	
Do you have Domestic animals?	No	97	104	62	68	35	36	60	64	37	40
	Yes	28	21	17	11	11	10	12	8	16	13
	$\chi 2$	.265		.211		.804		.335		.513	
How far do you keep your domestic animals from your household?	N/A	96	104	61	68	35	36	59	64	37	40
	In or close	26	15	16	8	10	7	12	6	14	9
	Far	3	6	2	3	1	3	1	2	2	4
	χ^2	.118		.197		.462		.281		.392	
Do you have green areas inside your house boundaries?	Yes	54	27	41	11	13	16	38	15	16	12
	No	71	98	38	68	33	30	34	57	37	41
	χ^2	.003		<.001		.198		.018		.161	
What kind of water supply do you have?	Network	99	109	72	78	27	31	71	72	28	37
	Vehicle	10	4	7	1	5	4	1	0	10	4
	Well	16	12	0	0	14	11	0	0	15	12
	χ^2	.125		.062		.688		.917		.125	
What kind of Sewage do you have?	Septic	121	124	79	79	42	45	72	72	49	52
	Outdoor	4	1	0	0	4	1	0	0	4	1
	χ^2	.175		1.000		.168		1.000		.169	
How do you dispose of your home wastes?	Local Authority	99	104	73	75	26	29	71	70	28	34
	Close	20	6	1	1	19	5	1	2	19	6
	far	6	15	5	3	1	12	0	0	6	13
	χ^2	.003		.768		<.001		.222		.007	

From Table 7.2, some questions have emerged clearly with significant differences between answers by cases and controls. The most obvious differences were found between answers to the question of possessing livestock by cases and controls. It was found that almost 37% of the total cases have livestock while it was only 13.5% for the controls. In addition, the location for keeping the livestock was also found to be significantly different between cases and controls. It was found that 85% of cases who have livestock were keeping them in or close from their housing units while only 15% were keeping them far away. In contrast, 47% of the controls who were found having livestock were keeping them in or close to their housing units and 53% were keeping them far away. The presence of livestock and distance between housing unit and livestock shelter were also found differing based on nationality and living areas. It was found that 35.5% of the Saudi cases have livestock while it was only 11.5% for controls. Among the Saudis, 78.5% and 44.5% were found keeping their livestock in or close to their home for cases and controls, respectively. For non-Saudis, the numbers were more or less similar to those of Saudis with 39% of cases and 17.5% of controls having livestock. However, most non-Saudi cases that have livestock (94.5%) were keeping them in or close to their home while it was 50% for controls. In case of the differences between urban and rural areas, it was obvious that more cases in rural areas were found having livestock than in urban areas with 25% for the former and 53% for the latter and the same scenario for controls too, with 7% in urban areas and 22.5% in rural areas. In urban areas, 83.5% were keeping their livestock in or close to their houses and 86% in rural areas, in contrast to this, 40% of controls in urban and 27.5% in rural areas were keeping them in or close to their home. However, even though the *P* values of the place of keeping the livestock were statistically significant in all population classes, the small frequencies for certain categories reduce the reliability of the tests.

From the comparison mentioned above, it is apparent that there is a very strong association between the existence of livestock, distance between housing unit and livestock shelter and the incidence of CL. These findings can be supported by the other findings from the previous chapter where the proximity to livestock shelters was found to be strongly associated with the exposure to CL (see section 6.6). Even though domestic animals were quite similar to livestock as they might provide blood meals and /or resting and breeding sites for sandflies in their cages, no obvious associations were found.

Another aspect of the housing condition is answers by cases and controls about the presence of green areas within the boundaries of households were found to be significantly different. Vegetations within the household boundaries are often small gardens made for the purpose of decoration or in some cases for vegetable production. The difference in the presence of such land use between cases and controls was found significant in three out of five classes in the population, which were all interviewed people, interviewed Saudis and all people in urban areas. In the case of the non-Saudis and people in rural areas, the small percentage value for such land use and the small variations in the answers have emerged to be insignificant. From the answers, it was found that 43% of the cases and 21.5% of the controls out of all the interviewed people were having green areas within the boundaries of their household. The presence of vegetation within the household boundaries was found strongly varying based on nationality and living areas. The table shows that 52% of the Saudis were having such land use while it was present in the case of 35% of the non-Saudis. Such land use was also found to be more common in urban areas in comparison to rural as 53% of cases for the former were having such land use while the number was 30% for the latter. This variation in the presence of vegetation within the household boundaries based on nationality and living areas can be justified. The economic status of Saudis allowed them to have the modern lifestyle and house types with such land uses within their household boundaries for the purpose of decoration. While it was not in the case of non-Saudis with small houses associated with comparatively lower economic status. Additionally, the small or medium houses in urban areas force people to have such land use patterns within their household boundaries whereas in the case of houses in the rural areas are generally larger with many options of having green spaces in larger sizes stretching out of the boundaries of the house.

Another aspect was the answers of cases and controls were found to be significantly different regarding their methods of household waste disposal. Even though the way of disposing the house waste was anticipated to be a part of the matched variables such as neighbourhoods should receive same type of government services and have more or less the same level of hygiene, some variations were found between answers by cases and controls. In most cases, the number of answers in areas where the household waste is collected by the local authorities was almost the same with small variations. However, most of the obvious variations were found either if people dispose of their household waste close to or far away from their housing units. This condition occurs mostly in rural areas where the local authority services do not cover farm areas or countrysides. This assumption can be seen clearly where the largest variations were found in the case of non-Saudis in general as well as in rural areas. There were 41.5% of non-Saudi cases found disposing of their household wastes close to their houses and only 2% were disposing it of far away from home while only 11% of the non-Saudi controls were disposing of waste close to house and 26% far away. For all people in rural areas, 36.5% of cases and 11% of controls were found disposing of their household waste close to the house while 11.5% of the cases and 24.5% of controls were disposing those of far away from home. The Chi-square values for both classes in the population were significant due to such variations and therefore, it was also significant in the case of all interviewed people. However, it should be acknowledged that the reliability of some tests for factors such as water supply and waste disposal is reduced because of small numbers in some categories which, in turn, generates expected cell frequencies below the desired threshold of 5.

In short, as the household wastes provide good habitats for both vector and reservoir, the distance of disposing them of, if not collected by the local authority, influences the incidence of CL which was also found previously in Chapter 6. Regarding the number of the household members and their duration of living in the current address, no significant differences were found between answers by cases and controls. Regarding the answers to the questions about the water and sewage services providers, no significant variations between case and controls with different housing types were found.

7.2.3. Variations in Socio-economic and Demographic Characteristics between CL Cases and Controls:

This part was designed to cover some socio-economic and demographic aspects as well as activities of cases and controls that are assumed to be associated with the exposure to CL. This part includes five questions. Questions 1 and 2 were about the level of education and occupations of cases and controls. Question 3 was to address the regular activities from dusk until dawn for the household members. Question 4 was to find the use of transportation methods in the household and question 5 was to find the family's monthly income in Saudi riyals (SR 1.00 = USD 0.267). All the answers in this part were straightforward and nominal apart from questions 2 where some occupations were merged together as they are more or less the same in terms of the nature of the job and also very few people were doing some jobs and using those numbers which are not frequent might result in weakening the Chi-square test. In question 2, babies, housewives and maids were combined under (home staying class) as they spend most of their time at home. Additionally, non-Saudi workers such as blacksmiths, builders, drivers, mechanics and carpenters were combined under outdoor jobs as they were more likely to work outdoor most of the time. Frequencies of all the answers were compared using Chi-square as they were nominal apart from the monthly income of the family which was ordinal and MWU was used. All the answers are represented in Table 7.3. However, many of the frequencies were relatively low which consequentially will affect the reliability of the Chi-square test.

Table 7.3: Socio-economic and demographic variables between CL cases and controls in Al-Dawadmi Governorate.

Questions	population class	All people 125 cases/controls		All Saudis 79 cases/controls		All non-Saudis 46 cases/controls		All people in urban areas 72 cases/controls		All people in rural areas 53 cases/controls	
		Cases	Controls	Cases	Controls	Cases	Controls	Cases	Controls	Cases	Controls
What is the education level of the case/ control?	Illiterate	10	6	4	3	6	3	1	3	9	3
	Write and read	10	6	4	3	6	3	4	1	6	5
	Elementary	7	6	2	1	5	5	2	3	5	3
	Secondary	9	19	4	9	5	10	4	9	5	10
	High school	22	30	15	16	7	14	15	13	7	17
	Diploma	23	14	13	7	10	7	13	8	10	6
	University or higher education	44	44	37	40	7	4	33	35	11	9
	χ^2	.166		.378		.280		.432		.104	
What is the occupation of the case/ control?	Civilian	42	46	38	40	4	6	31	32	11	14
	Student	33	37	30	34	3	3	23	26	10	11
	Farmer	15	14	0	0	15	14	0	0	15	14
	Home stay*	14	9	11	5	3	4	7	4	7	5
	Outdoor jobs*	12	14	0	0	12	14	8	10	4	4
	Shepherd	9	5	0	0	9	5	3	0	6	5
	χ^2	.726		.279		.866		.375		.973	
Which activities do your household members do between dusk and dawn?	Group 1*	64	77	53	58	11	19	40	54	24	23
	Group 2*	40	31	14	14	26	17	21	11	19	20
	Group 3*	6	8	1	0	5	8	2	2	4	6
	Group 4*	15	9	11	7	4	2	9	5	6	4
	χ^2	.248		.549		.146		.096		.838	
What do you use for transportation?	Car	106	95	79	79	27	16	66	61	40	34
	Moto/bike	7	12	0	0	7	12	4	6	3	6
	On foot	12	18	0	0	12	18	2	5	10	13
	χ^2	.210		1.000		.070		.390		.391	
How much is your family's monthly income (Saudi Riyal)?	<1000	19	15	0	0	19	15	4	4	15	11
	1000-2000	16	18	0	0	16	18	7	7	9	11
	2000-5000	11	9	2	3	9	6	10	5	1	4
	5000-10000	30	39	29	33	1	6	17	24	13	15
	>10000	36	31	35	30	1	1	26	22	10	9
	Refused	13	13	13	13	0	0	8	10	5	3
	MWU	.980		.512		.322		.809		.992	

Group 1*: No special activities and most of the time is spent indoor. Group 2*: Sitting or sleeping outdoors. Group 3*: Dealing with animals. Group 4*: Visit green areas

It can be seen from Table 7.3 that there were not any significant differences between the answers by cases and controls which is believed due to the applied matching. However, even thought without significant values, some differences occurred clearly in the case of the types of occupation they were involved in. The types of occupation were found varying quite clearly based on the nationality and living areas as each one has its own occupational characteristics and lifestyle. Regarding the occupation of different nationalities, approximately 83.5% of the Saudi cases and 93.3% of the controls were either students or civilians and in contrast, 52% of the non-Saudi cases and 41% controls were either farmers or shepherds. Concerning the living areas, students and civil services were the dominant occupations in urban areas with 75% of the cases and 80.5% of the controls doing those. Farmers and shepherds were the major occupations in rural areas with 40% of the cases and 36% of the controls doing those. The associations between students and civilians with CL in the case of Saudis in general and in urban areas were not very clear. And the large reported number with CL is probably as those two were the most common occupations among the others classes in the population. In the case of farmers and shepherds, the associations with CL were slightly clearer as working location of these jobs were more likely to coincide with the preferable habitats of sandflies and rodents. Such working locations include farms, grazing lands, areas with poor hygiene and livestock yards and other areas which were discussed earlier in Chapters 2 and 6. However, with the absence of comprehensive census data including occupations and the percentages that they were making in the area being studied, it was hard to do any further assessment and judgment. It should be mentioned that during the questionnaire survey, the selection of controls was slightly biased especially in the case of house staying jobs and job of shepherds. During the field trip, it was not easy to meet housewives to match the cases due to cultural reasons and there were difficulties in meeting shepherds as they were either in far away areas like grass lands or not contactable. As a result, the field work had to be carried out by meeting people of the same age groups but with different occupations which consequently influenced the frequencies of the answers and the Chi-square values for some classes in the population.

Another important aspect of the demographic factors that was required to be covered was the level of education of both cases and controls. Level of education is believed to be a very important aspect of any health issue which influences directly or indirectly people's activities, behaviour, income and the level of awareness of the associated risk factors with diseases (MHRA, 2003; Dodani et al., 2005). From the collected answers, it was found that nearly 35% of the cases and controls were highly educated with either university or higher education level and only 8% of the cases and 5% of the controls were illiterate. The distribution pattern based on level of education was more obvious among different nationalities as Saudis were more likely to be highly educated than non-Saudis in general. This judgment was stated based on the fact that most of the non-Saudis in Al-Dawadmi Governorate were mainly unskilled labours, farmers or shepherds. This can be observed from Table 7.3 as approximately 47% of Saudi cases and 51% of the controls were highly educated and only 5% of the cases and 4% of the controls were illiterates. For non-Saudis, 15% of cases and 8.5% of controls were highly educated and similarly 13% of cases and 7% of the controls were illiterate.

Additionally, the education level distributions patterns were found varying based on the living areas between urban and rural with higher education level in the former and lower in the latter in general. In urban areas, 46% of the cases and 48.5% of controls were highly educated while only 1.5% of cases and 4% of controls were illiterate. On the other hand, 20.5% of cases and 17% of controls were highly educated and 17% of cases and 6% of controls were illiterate in rural areas. From the mentioned numbers above, it is apparent that the association between the incidence of CL and the level of education does not follow the expected theoretical trend as CL cases were found to be more associated with higher educated personnel than lower educated ones. However, this unexpected association was believed to be due to higher educated people are outnumbered than people with other levels of education. However, due to the absence of comprehensive census data, no further analysis or judgments can be stated.

Another factor to be analysed from Table 7.3 is the monthly income. Generally speaking, income is strongly related to the types of occupations which are also strongly associated with the nationality. This striking differences can be observed from the table as approximately 80% of the Saudi cases and controls had higher monthly income (between 5,000 and > 10,000 SR) while 76% of the non-Saudis cases had lower income (< 1,000 to 2,000 SR). In general, low income is strongly correlated with lower socio-economic status, which consequently produces inadequacies in every aspect of life standards and increases the possibility of coming in contact with risk factors of the diseases (Ross and Deverell, 2010). However, from Table 7.3, no significant differences between cases and controls in general were found which was probably due to the matching task that resulted in reducing the overall variations. Another aspect related to the monthly income was the use of transportation method in the household. In general, most of the interviewed people, 85% of cases and 76% of controls were found using cars while the rest were either using motorbike / bike or were on foot. It was obvious that nationality and living areas were affecting this aspect from multiple perspectives such as economic (cheap running cost) and cultural (it is rare for a Saudi family not to have a car). From the table, 100% of the Saudi families (cases and controls) were using cars while it was 59% of the non-Saudi cases and 35% controls were using cars. More people were found using cars in urban areas (91% of cases and 85% of controls) while it was slightly less in rural areas where most of the non-Saudis were located. However, among different classes in the population, no strong variations were found between the answers by cases and controls which were anticipated due to the conducted matching.

Activities of people from dusk to dawn were believed to be a major factor in the exposure to CL. In the literature, this time period was found to be the major activity period of the sandflies (see section 2.3). From the interviewed people, it was found that 51% of cases and 61.5% of controls were spending most of their time at home, while 32% of cases and 25% of controls were found sitting or sleeping outdoors. 5% and 12% of the total cases were found dealing with livestock and visiting green areas and for the controls it was 6.5% and 7%, respectively. Nationality and the living areas were found influencing the activities. For example, 67% of Saudi cases and 73% of controls were found spending their time indoors while 17.5% of the cases and controls were sitting and sleeping outdoors. In contrast, in the case of non-Saudis, only 24% of the cases and 41% of the controls were found sitting indoors while 56.5% of cases 37% of the controls were sitting and sleeping outdoors. Furthermore, the living areas were also found to be influencing the activities of the people, but this time the influence was not as definitive as it was for different nationalities. For instance, approximately 56% of cases and 75% of controls in urban areas were found spending their time indoors, while it was 45% of the cases and 43% of the controls in the rural areas. Within Table 7.3 some of the Chi-square values were unreliable because of low frequencies in the answers from the selected CL cases and controls.

7.3. Implications of the Analysis:

From the first section about the CL awareness level, it was indeed found that most of the interviewed people were unaware of the disease and all of its asked aspects (vector, reservoirs, habitats, seasonality and protection). Yet controls, Saudis and people in urban areas were found to be slightly more aware of the disease in comparison to cases, non-Saudis and people in rural areas, respectively. In this section, 2 out of 6 questions have stood out strikingly where the collected answers between cases and controls were significantly different in favour of controls. Controls were found to be more aware of the seasonality of CL than cases. As a result, perhaps the controls were more careful in getting in contact with the risk factors of CL during active seasons. Likewise, in case of using effective protective measures like insecticide or bed nets against insects, controls were found to be taking much more protective measures than cases. Therefore, taking adequate protective measures might be a fundamental CL transmission factor.

In the housing characteristics part, four variables were found strongly associated with the incidence of CL where the answers between cases and controls were significantly different. These variables were the presence of livestock and the distance between housing units and livestock shelters, the presence of green areas within the household boundaries and the way of disposing of household waste. All these variables were found to differ based on nationality and living areas and mostly in favour of controls. More livestock were found present in the case of non-Saudi's population class in comparison to Saudis and also in rural areas in contrast to urban. Most of the CL cases who were found keeping livestock in or close to their housing units consequently put themselves in high risk of developing CL. Additionally, a strong association was found between the availability of green areas within the household boundaries and the incidence of CL where the answers between cases and controls were significantly different. In the matter of cases having more green areas than controls, the most obvious differences between the answers were found in three out of five classes in the population, which were:- all people, all Saudis and people in urban areas.

The ways of disposing of household wastes were also found to differ significantly between the answers given by cases and controls in some classes in the population and believed to play an important role in the disease transmission by providing suitable habitats for CL vector and reservoirs. In most cases, household wastes were collected by the local authority (municipality). However, in areas where the municipality services do not reach, the way of disposing wastes becomes significant. Most of the cases in remote areas were found disposing of their wastes close to their homes while controls were disposing it of far away. All these findings in this section were supporting as well as being supported by the same findings from Chapter 6 where the association between proximity to livestock, green areas and household wastes and the incidence of CL were investigated.

Regarding the topic of the socio-economic and demographic variables, occupation type was the only prominent variable that seems to be influencing the incidence of CL noticeably. Most of the Saudis were either civilian or students while most of non-Saudis were either farmers or shepherds. For the former, no obvious relationships were found between students, civilians and incidence of CL. the reason for large number of Saudis taking up those two jobs is probably because those jobs are outnumbering other types of jobs in the region. On the other hand, farmers and shepherds were more likely to be involved with activities at livestock shelters, farms, countryside and grazing lands with a higher probability of coming in contact with sandflies.

From the above discussions, 6 variables out of 22 were found standing out strikingly and appeared to be the strongest associated variables with the incidence of CL in Al-Dawadmi Governorate. These variables were:- knowing the seasonality of CL, taking protective measures against insects in the household, the presence of livestock and the distance between housing units and livestock shelters, the availability of green areas within the household boundaries and the way of disposing of household wastes. These six variables were planned to be used for further analysis and modelling. However, as these variables were measuring similar characteristics for cases and controls, it is believed that there might be a correlation and collinearity to some extent between these variables. Therefore, inter-correlation and collinearity tests were applied and the results showed that there was a very strong correlation and collinearity between the presence of livestock and the distance between housing units and livestock shelters, where the correlation coefficient value was 0.928 and the associated P value with the correlation was <0.0001. Apart from this, no other variables were found to be strongly correlated. Additionally, the collinearity values were 8.466 for the presence of livestock and 7.982 for the distance between housing units and livestock shelters.

It was planned to subsequently undertake multivariate modelling, so having these two strongly correlated variables would make it difficult or even impossible to isolate their individual effects on the independent variable. In the literature, several approaches have been used to overcome the matter of correlation between variables such as increasing the sample size, adding new variables, transforming the functional relationship or dropping one of the highly correlated variables (Black, 2007; Baltagi, 2008; Baltagi and Li, 1991). However, in this research some approaches cannot be applied such as increasing the samples or the variables as it is impossible to conduct another fieldtrip to the area being studied. Therefore, one of the two correlated variables needed to be eliminated from the modelling and kept in consideration for the following interpretations. In the correlated variables here, the location of keeping the livestock depends mainly on the presence of the livestock. Therefore, the former was eliminated from the regression modelling. This elimination has resulted in reducing the collinearity value for the presence of the livestock to 1.261 which was in the acceptable level and was less than 5.0 (Hair et al., 1995; Kennedy, 1992; Neter et al., 1989).

7.4. Characteristics of Exposure of Cases to CL:

The second part of the applied questionnaire survey was designed to collect some information for CL cases and their previous exposure to the disease seeking to underline some fundamental characteristics that might be related to their exposure. Seven aspects were covered, which are: which areas did the case visit three months prior to the exposure, where does the case think he / she was bitten by a sandfly, how many times was the case exposed to CL and how many times did he / she report, the reason of not reporting all the exposures to CL if applicable, in which part of the body did the case have the ulcer/s and finally how long did the ulcer/s last for. All these information were summarized in Table 7.4.

Table 7.4: Characteristics of CL Cases

Questions	Population class	All interviewed cases (125 cases)	All interviewed Saudis cases (79 cases)	All interviewed non-Saudi cases (46 cases)	All cases in urban areas (72 cases)	All cases in rural areas (53 cases)
Which areas did you visit three months prior to the exposure?	Group 1*	84	61	23	53	31
	Group 2*	18	7	11	5	13
	Group 3*	12	4	8	6	6
	Group 4*	11	7	4	8	3
Where do you think you were bitten by a sandfly?	Home	67	47	20	46	21
	Farm	22	8	14	3	19
	Country side or desert	9	5	4	5	4
	Green areas	4	2	2	3	1
	Not sure	23	17	6	15	8
How many times did you have CL?	Once	95	59	36	55	40
	Twice	18	14	4	9	9
	3 or more	12	6	6	8	4
How many times did you report the exposure?	All times	113	73	40	66	47
	Not all times	12	6	6	6	6
Why did not you report all exposures?	Difficult access	3	1	2	1	2
	Treatment dissatisfaction	5	4	1	3	2
	cost issue	3	0	3	1	2
	Side effect	1	1	0	1	0
In which part of the body did you have the CL ulcers?	Low limbs	85	55	30	50	35
	High limbs	27	16	11	16	11
	Face & neck	10	6	4	4	6
	Back	3	2	1	2	1
How long did the ulcer last for?	< one month	0	0	0	0	0
	Between 1 and 3 months	6	4	2	3	3
	More than 3 months	119	75	44	69	50

Group 1: visited settlement areas only, Group 2: visited farms, Group 3: visited countryside or desert and Group 4: do not remember

During the conducted questionnaire survey, all interviewed people visited settlement areas three months prior to the exposure to CL. Therefore, the answers to the first question were showing other visited places. From Table 7.4, it was found that 67% of all interviewed people did not visit any other places apart from settlement areas. This percentage was found fluctuating in the population classes between 73.5% (all people in urban areas) and 58% (people in rural areas) meaning the majority of the interviewed people did not visit any other places. It was also found that 14.5% of the total population visited farms besides settlement areas and these percentages were found varying slightly between population classes based on nationality and living in areas. More non-Saudis (17.5%) visited farms than Saudis (8%) and more people in rural areas (24.5%) than in urban (7%). With regards to people who visited countrysides or desert, the distribution pattern was not enormously different from people who visited farms where 9.5% of the total population visited such areas three months prior to having the disease. Additionally, nationality and living areas were found influencing the answers where non-Saudis (22%) and people in rural areas (11%) visited such areas more than Saudis (2.5%) and people in urban areas (8.5%). Due to the long time interval between the exposure to CL and time of interview (might be up to two years), some people (8.5% of the total population) did not remember the visited areas in the stated period.

With regards to the expected places where cases think they might have been bitten by an infected sandfly, home was the answer by the majority of people (53.5%). Not surprisingly, the majority of Saudis (59%) thought they might have been bitten by a sandfly at home as they spend more time indoors than non-Saudis (43.5%) and also people in urban (64%) more than in rural areas (36%). These differentiations in answers between people in urban and rural areas were believed to be due to the distribution of non-Saudis who spend more time outdoors than indoors and also mostly concentrated in rural areas. This can be seen much clearly in incriminating farms to be the expected place to come in contact with sandfly where only 10% of the Saudis cases believed they might have been bitten in farms and this percentage was tripled with 31% for non-Saudis. Similarly, 4% of the cases in urban areas and in contrast to that percentage value, 36% in rural areas thought they came in contact with sandflies in farms. A moderate number of interviewed people (18.5%) were not sure where they might have been bitten by an infected sandfly due to the long time between the exposure and the time of interview.

Table 7.4 also shows that, three quarters of the interviewed people (76%) have the exposure for the first time with no strong variations in the numbers based on nationalities and living areas. Additionally, 113 out of 125 cases reported all the exposures to the local health authorities and only 12 did not. Four main reasons were found behind not reporting all exposures which are:- difficult access to health services (3 cases), not happy with the treatment in terms of either healing progress or followed procedures based on experiences of a previous individual or other known person who got exposed to CL (5 cases), could not afford the cost of the treatments (3 cases) and finally one case had some side effects resulting in not receiving any further treatments. With regards to the location of the ulcer, 68% of the cases had the ulcers in the lower limbs (leg, feet and toes), 21.5% in the upper limbs (shoulder, arm, palm and fingers), 10% on face or neck and only 2.5% on the back. The location of the ulcers seems to be associated with the physical distance from the ground and whether the body parts were covered or not. As mentioned in

Chapter 2, sandflies do not fly and cannot reach high areas from the ground which can be seen from the answers as the majority of ulcers were in the lower limbs which were physically touching the ground and they were mostly uncovered. Fewer ulcers were found in the upper limbs which are not generally covered most of the time and while sitting or sleeping those body parts might have been close to the ground while getting bitten. Ulcers in faces occurred most likely while sleeping as they were not covered and finally the lowest number of ulcers was on people's backs with only 3 cases as they covered most of the time. 95% of the ulcers took more than three months to heal which was the average time found in literature for CL ulcer to heal as mentioned in Chapter 2 and only 5% took between one and three months to heal which might be due to miscounting the time or due to some other biological factors.

In short, from Table 7.4 some points can be stated. The majority of interviewed people did not visit other places except settlement areas and they also believed that the expected location where they might have been bitten by an infected sandfly were homes. Nationality and living areas were found influencing the answers as more Saudis and people in urban areas visited only settlement areas and the incriminated locations for the bites were at home, while non-Saudis and people in rural areas visited other types of areas, such as farms, countrysides and deserts that were incriminated to be the locations for the bites. 75.5% of the interviewed cases had CL for the first time, 14.5% for the second time and 10% had the disease for third time or more. The majority of people (90.5%) have reported all of the exposures which might be due to either their confidence of getting medically treated or due to having no other options because of their first time experience of CL. On the other hand, 9.5% of the cases did not report all the exposures due to either learning about past experiences of known individuals and their dissatisfaction over the treatment procedure or due to some other difficulties regarding either accessibility or the cost of the treatment in the case of non-Saudis as not all non-Saudis received free medical treatments. The physical contact with the ground and covering up the body well enough were the factors found distinctly influencing in the location of developing the ulcers. Most of the ulcers were found in the lower limbs (68%) that were touching or were close to the ground and not covered while the lowest numbers were in the backs (2.4%) as they were mostly far from the ground and covered. 95% of the ulcers took more than three months to heal which was matching with what have been found in literature. However, the remaining 5% said it took between one and three months to heal which was either due to miscounting the time or other biological factors such as weak *Leishmania* parasite or strong immunity system of cases.

7.5. Regression Modelling:

As discussed earlier, the 5 socio-economic and demographic factors (after eliminating the location of keeping livestock due to the multicollinearity) with the strongest association with the incidence of CL will be used for further analysis and regression modelling. Multivariable models were constructed using conditional stepwise logistic regression to assess the extent to which these variables are associated with the disease occurrence for each of the five population groups in turn. Besides these six variables, distances from several land use / land cover patterns that were found associated with CL in Chapter 6 were added too. So, each model included 8 variables which were:

1. Presence of livestock.
2. Presence of green areas within the household boundaries.
3. Awareness level about the seasonality of CL.
4. Taking protective measures against insects in the household.
5. Methods of household waste disposal.
6. Distance from livestock.
7. Distance from any type of vegetation.
8. Distance from construction waste disposal sites.

At an early step, it was found that transforming the distance variables into natural logarithms (Ln) improved the fit of the model. Thus, distance variables were used in their transformed forms while the other risk factors were added to the model in their original conditions. Afterward, the five regression models for the population types of the study will be listed and discussed in turn.

7.5.1. Regression Model for All Interviewed People:

The result of the conducted conditional logistic regression for all interviewed people (125 cases / controls) is shown in Table 7.5

Table 7.5: Multivariate model for all interviewed people

Variables	Coefficient	OR	*P* value
Presence of livestock	1.405	4.075	.015
Presence of green areas within the household boundaries	2.497	12.151	.001
Taking protective measures against insects	-0.713-	0.490	.036
Distance from livestock (Ln)	-0.770-	0.463	.025
Distance from vegetation (Ln)	-1.158-	0.314	.004

Pseudo R^2= 0.352

The first step in the interpretation was to assess the model fit. Even though the Pseudo R^2 was not perfectly equivalent to the R^2 statistic of the linear regression model, a Pseudo R^2 of 0.3 in a logistic regression models with unadjusted data was approximate to an R^2 in the range between 0.6 to 0.7 in an ordinary least square regression (Hensher et al., 2005; Louviere et al., 2000; Lilavanichakul and Boecker, 2013). Thus, this model fit with R^2 of 0.352 was in an acceptable level of fit according to Louviere et al. (2000) who stated that Pseudo R^2 in the range between 0.2 and 0.4 was acceptable for choice models.

In this model as well as in the other four, socio-economic and demographic variables were deliberately mixed up with the selected environmental variables and the results showed that both types were significantly associated with CL transmission and with correlation coefficients following the anticipated general epidemiological direction. From the model for all interviewed people, the presence of green areas within the household boundaries was identified as a risk factor with the strongest association with the incidence of CL with a *P* value of .001. Additionally, the relationship was found positive, meaning that the more the presence of vegetation within the household boundaries the more likely people were to develop the disease. The OR emphasises this correlation as people who have such land use were approximately 12.2 times at higher risk of contracting CL than people who have not. Presence of livestock was also significantly associated with CL with a *P* value of .015. The direction of the relationship was positive, so as the presence of livestock increases the probability of contracting CL increases too. The OR stated that people who have livestock were approximately at 4.1 times higher risk of developing CL than people who don't have livestock. The distance from both vegetation (including house gardens, house vegetable plots, large farms and natural vegetation cover) and livestock were also risk factors significantly associated with the incidence of the disease with *P* values of .004 for the former and .025 for the latter. The relations were found inverse as anticipated where the further people located from the risk factors the less likely they develop the disease.

From the logistic regression model for all survey respondents, a predicted probability (PP) risk measure was generated. The PP values are the ratios of the number of occurrences to the total of possibilities (Sweet and Martin, 2010). The outcome values are ranging between 0.0 and 1.0 based on either one or many variables (Sayad, [No date]). The value 0.5 was considered as the cut off point in this study where people less than this value were predicted to be free of CL (controls) and people above this value (≥.50) were predicted to be exposed to the CL (cases). The result of the generated PP is summarised in Table 7.6.

Table 7.6: Predicted probability summary

Predicted probability classes	Level of PP	PP values	Total people in this band	% of total 250 interviewed people	Numbers per each category	% of cases or controls in each class
Low PP 0 to <0.50	Lowest	0.0012	133	53.2%	94 controls	70.7%
	Highest	0.4968			39 cases	29.3%
High PP ≥ 0.50	Lowest	0. 5017	117	46.8%	31 controls	26.5%
	Highest	0. 9811			86 cases	73.5%

From Table 7.6, the PP values were ranging between 0.0012 as the lowest and 0.9811 as the highest values out of 1.0. Ideally, it is supposed that there should be an equal number of 125 CL controls in the band < 0.50 and 125 CL cases in the band ≥ 0.50. However, the numbers were not equally distributed as 133 people were in the first band and 117 people were in the second. Considering the PP value of 0.5 as the cut off point where people less than this values were expected to be controls and people higher than this value were expected to be cases, 72% of the interviewed people (180 people) were well predicted. On the other hand, 28% of the interviewed people (70 people) were poorly predicted as 31 of the controls (26.5%) were predicted to be cases and 39 of the reported cases (29.3%) were predicted to be controls (see Figure 7.3). Thus, it was required to investigate more the reasons behind this misprediction. In the first place, 10% tolerance rate was allotted for both controls and cases. In other words, controls in the PP range between 0.50 and 0.60 and cases in the range between 0.50 and 0.40 were ignored. This was conducted as such values were just above or below the cut off point and might be influenced by any factors that might mislead the investigation. This conducted step reduced the misclassified numbers to 29 cases and 20 controls after removing 10 cases and 11 controls.

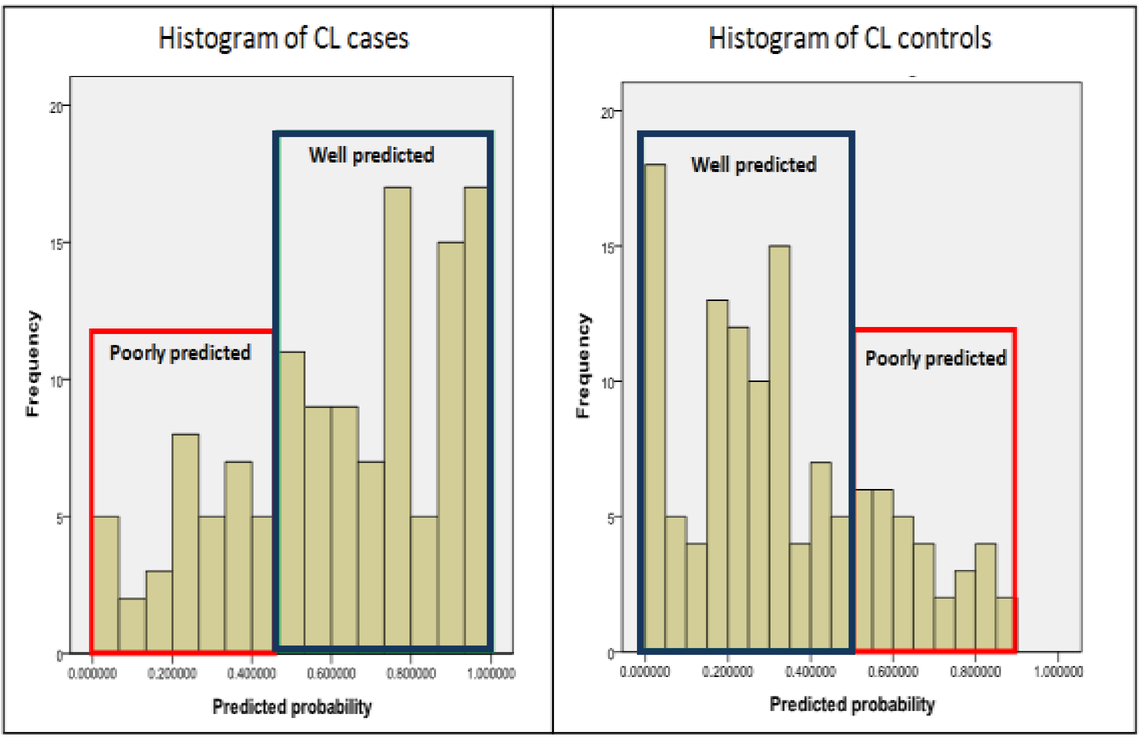


Figure 7.3: Predicted probability distribution

With the remaining 49 poorly predicted people, other socio-economic and demographic variables that were not included in the regression modelling were looked at closely. These new probable risk factors are:

1. Living area (urban or rural)
2. Housing type (modern, traditional or farm house)
3. Domestic animal presence and if yes then where do they keep them
4. Regular activities from dusk to dawn
5. Gender of cases / controls
6. Visited places three months prior to the exposure (cases) or the interview (controls)

All these possible risk factors for the 49 poorly predicted people are summarised in Tables 7.7 and 7.8:

Table 7.7: Other socio-economic and demographic variables for cases predicted to be controls

Live in areas		Housing types		Do you have domestic animals?		If you have domestic animals, where do you keep them?	
Urban	7	Modern	13	Yes	7	In / close from house	5
Rural	13	Traditional	4	No	13	Far	2
		Farm house	3			N/A	13
Activities from dusk to dawn				**Gender**		**Visited areas 3 months prior to exposure/interview**	
No special activities			13	Male	14	Settlements only	14
Sit/ sleep outdoor			4	Female	6	Farms and green areas	3
Deal with animas			2			Countryside, grazing or desert	3
Visit green areas			1				

Table 7.8: Other socio-economic and demographic variables for controls predicted to be cases

Live in areas		Housing types		Do you have domestic animals?		If you have domestic animals, where do you keep them?	
Urban	7	Modern	23	Yes	5	In / close from house	5
Rural	22	Traditional	2	No	24	Far	0
		Farm house	4			N/A	24
Activities from dusk to dawn				**Gender**		**Visited areas 3 months prior to exposure/interview**	
No special activities			12	Male	19	Settlements only	20
Sit/ sleep outdoor			11	Female	10	Farms and green areas	3
Deal with animas			2			Countryside, grazing or desert	6
Visit green areas			4				

From both tables, some numbers stood out strikingly and might be the reasons for the poorly predicted cases. The most obvious number was that 35 people (71.5%) were living in rural areas at the same time as only 14 (28.5%) were living in urban areas. Rural areas were described as having higher level of diversity in their ecological variables with noticeable higher presence of risk factors in them in comparison to urban areas as discussed before. From Tables 7.3 and 7.4, almost all the mentioned risk factors that were included in the regression models apart from vegetation within the household boundaries were found occurring much far away more in rural than urban areas. Additionally, population characteristics were found varying significantly between urban and rural areas in terms of nationality, activities and behaviours in favour of rural areas. In addition, from both tables, 15 people were found sitting or sleeping outdoor between dusk and dawn which is the peak activity and biting time for sandflies. Furthermore, 15 people visited extremely risky areas three months prior to the CL exposure for cases or prior to the interview for the controls. And finally, 10 people were found having domestic animals in or close to their household increasing the probability of coming in contact with sandflies, as domestic animals are described to be the possible secondary food source for female sandflies (Garner and Saville, [No date]). So, these variations and occurrences of other risk factors might have led to such misprediction especially in the case of CL cases than in controls. It is worth mentioning that all these variables were considered to be included in the regression models but they were either insignificant if included or strongly multicollinear with other more important variables. Therefore, they were not added.

With 72% of all interviewed people accurately predicted, the PP measure can be stated as fairly good measure. This PP scale will be used to evaluate to which extent do the changes in some socio-economic, demographic and environmental variables influence the probability of contracting CL. In other words, small number of people sharing the same characteristics in all risk factors apart from the one that aimed to be evaluated will be selected as a case study and the obtained PP will be contrasted and used for the interpretations. From the first regression model, distance from livestock and vegetation cover were found significantly and inversely associated with contracting CL. To assess to which extent does distance from both risk factors influence the probability of CL development, two small groups of people sharing the same characteristics namely presence of livestock, presence of vegetation within the household boundaries, awareness level about the seasonality of CL, taking protective measures against insects and methods of household waste disposal but varying only in their proximities from vegetation and livestock were selected. Then the PP values were plotted against their distances from both risk factors as shown in Figures 7.4.A and 7.4.B

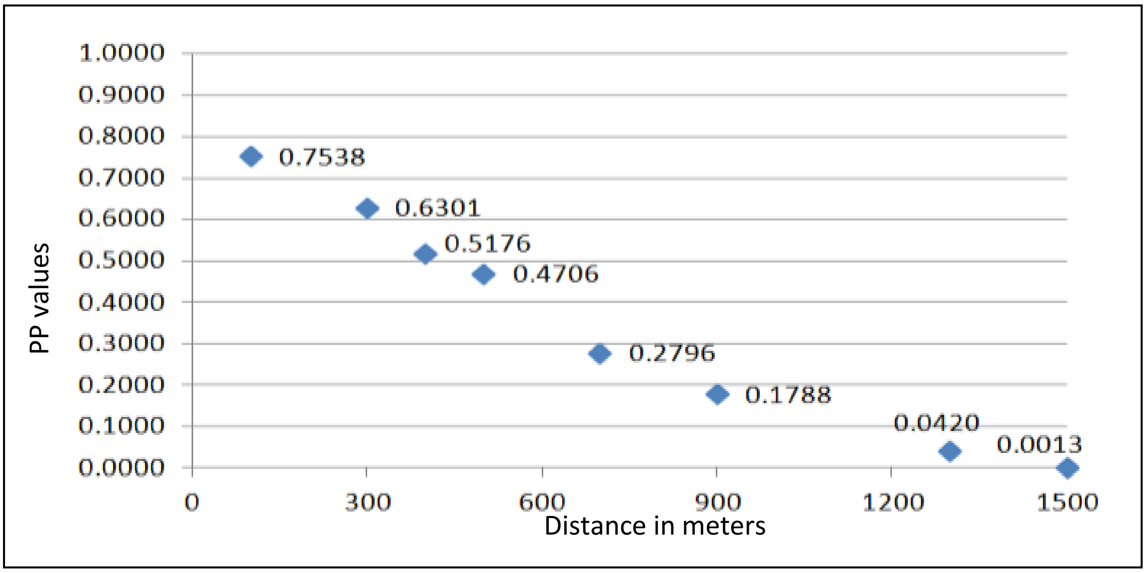


Figure 7.4.A: PP values against distance from vegetation cover

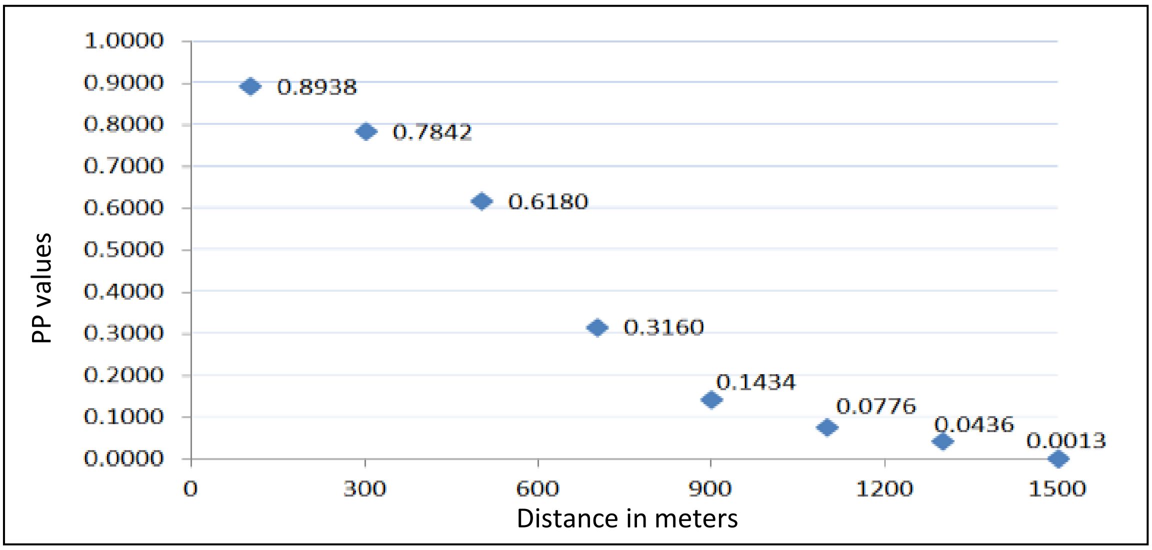


Figure 7.4.B: PP values against distance from livestock shelters

From both Figures 7.4 A and 7.4 B, the influences of the distance upon the PP is very obvious, the closer people from vegetation and livestock the higher probability for them developing CL. The most noticeable increase in the PP values from vegetation cover and livestock occurred in the distances of approximately 600 metres where the increase in both figures was slightly sharper. These findings were consistent with other findings from Chapter 6 as <100 to 500 metres from various vegetation covers and <100 to 200 metres from livestock were found to be the critical distances and people located closer than these distances were at very high risk of contracting the disease.

With such risk factors in the surrounding living areas, the use of protection in the household against sandflies and rodents was also significantly associated with CL incidence with a *P* value of .036 and with an inverse relationship direction as the more protection used in the household the less likely people would develop CL. The PP value suggests that, people who did not taking protective measures against insects in their households had almost 9 times higher probability of developing CL than those who used protection.

7.5.2. Regression Model for Interviewed People Based on Nationality (Saudis and Non-Saudis):

The influence of nationality on risk factors was investigated by identifying a multivariate regression model for the interviewed Saudis (79 cases / 79 controls) and for the interviewed non-Saudis (46 cases / 46 controls). The results are shown in Tables 7.9 and 7.10.

Table 7.9: Multivariate model for interviewed Saudis

Variables	Coefficient	OR	*P* value
Presence of Livestock	1.726	5.619	.003
Presence of green areas within the household boundaries	2.084	8.038	.009
Awareness level about the seasonality of CL	-1.199-	0.301	.027
Distance from Livestock (Ln)	-0.832-	0.435	.035
Distance from vegetation (Ln)	-.0395-	0.492	.007

Pseudo R^2= 0.305

Table 7.10: Multivariate model for interviewed non-Saudis

Variables	Coefficient	OR	*P* value
Presence of Livestock	3.117	22.575	.019
Taking protective measures against insects	-2.081-	0.125	.032
Distance from livestock (Ln)	-1.094-	0.796	.047
Distance from vegetation (Ln)	-1.052	0.995	.042

Pseudo R^2= 0.337

Even though the number of risk factors associated with CL in the model for Saudis was as the same as the previous model for all interviewed people with five variables in each model, the resulted R^2 was slightly weaker. Also, it is slightly weaker in comparison to the R^2 from the model for non-Saudis which has fewer significant risk factors associated with CL. These slight variations might be a result from the differences in the presence and the distribution pattern of the risk factors. However, the obtained R^2 from the Saudis (0.305) and non-Saudis (0.337) regression models were still in an acceptable model fit as discussed before.

In both models, the presence of livestock was found as the strongest risk factor associated with CL. However, the coefficient values showed that influence of presence of livestock was much stronger with non-Saudis (3.117) in comparison to Saudis (1.726). Additionally, in the case of non-Saudis, the OR showed that people who have livestock were 22.57 times at higher risk of contracting CL than non-Saudis who do not have livestock, while the value was almost 5.6 for Saudis. This strong variation in the OR might be a result from other factors that were associated with the presence of livestock such as occupation and housing condition. Distance from livestock in both models was also significantly and inversely associated with CL where the increase in the distance decreases the probability of developing the disease.

The presence of green areas within the household boundaries was only significant in the first model and not in the second. This was basically because such risk factor was more common in the case of houses of the Saudis than those of non-Saudis as discussed before. The correlation was found to be positive as with the increase in the presence of vegetation within the household boundaries the possibility of contracting CL increases too. Saudis who have green areas within their household boundaries were found to be at approximately 8 times higher risk of developing CL than those who did not have such vegetation. Distance from vegetation (including all vegetation types) was also significantly and inversely associated with CL for both models as discussed earlier.

Awareness level about the seasonality of CL was significantly associated with the incidence of CL in the case of the model for Saudis with a *P* value of 0.027, while it was not in the case of the non-Saudis. As noted earlier from Table 7.1 in this chapter, Saudi controls were found to have fairly better CL awareness level than Saudi cases and therefore this variation has resulted in the significant value. On the other hand, non-Saudis were found to be less aware of CL with low variation between cases and controls.

This low variation resulted in the insignificant association with the CL exposure in the case of model for non-Saudis. The relationship between the awareness level about the seasonality and the incidence of CL was found inverse. This might be the consequences of the awareness level as highly aware people generally avoid activities and behaviours bringing them in possible contact with sandflies. From the PP values, people unaware of the seasonality of CL had almost 6 times higher probability of developing CL than those who were aware.

As mentioned earlier, non-Saudis were generally found living on the outskirts of the cities and in rural areas. Such areas were known of having and interacting with more risk factors than urban areas. Example of such risk factors is being in closer proximity to natural vegetation and dumping areas, as well as being in lower hygiene level with poorer housing conditions. In such areas, the density of sandflies and rodents were presumably high with the availability of their preferable habitats. For these reasons, using protection was found significantly and inversely associated with the incidence of CL in the model for non-Saudis and not in that of the Saudis'. The more protections used in the household the less probable people contract with CL.

7.7.3. Regression Model for Interviewed People based on Living Areas (urban and rural):

The association between the highlighted 8 risk variables and the incidence of CL in urban (72 cases / controls) and rural areas (53 cases / controls) were conducted. The results are shown in Tables 7.11 and 7.12.

Table 7.11: Multivariate model for interviewed people in urban areas

Variables	Coefficient	OR	*P* value
Presence of livestock	1.103	3.013	.014
Presence of green areas within the household boundaries	2.473	11.859	.024
Distance from vegetation (Ln)	-.964-	.381	.004

Pseudo R^2: 0.237

Table 7.12: Multivariate model for interviewed people in rural areas

Variables	Coefficient	OR	*P* value
Presence of livestock	2.330	9.618	.022
Taking protective measures against insects	-1.458-	0.233	.019
Distance from livestock (Ln)	-2.568	0.779	.036
Distance from vegetation (Ln)	-1.526-	0.591	.021

Pseudo R^2= 0.590

From these two regression models, the weakest and the strongest model fit among the others have appeared. In the model for people in urban areas, the Pseudo R^2 value of 0.237 is considered to be the weakest while the model for people in rural areas had the goodness of fit value of 0.590, which is the strongest. Even though the numbers of risk factors were not hugely different as they were three in the first and four in the second, the difference in the Pseudo R^2 was more than double. This massive difference was most likely caused by the distribution of the risk factors and people in rural areas and the larger interaction between them. It rather implies that there was a more pronounced gradient of risk factors in rural than urban areas due to the nature of both areas. All the mentioned risk factors were stated to be more common in the latter than the former apart from the vegetation within the household boundaries factor. However, the goodness of fit for the model for people in urban areas can be described as an acceptable model fit based on the discussions earlier and for the rural area model the fit can be described as very well fitted.

The distribution of risk factors differs in their presence and densities between urban and rural areas as can be seen from both regression models. The presence of livestock was found significantly and positively associated with CL in both models. The presence of livestock have stronger influences on people in rural areas and its nature than in urban areas as people who have livestock in the former is at approximately 9.2 times higher risk of developing CL than people who don't have livestock while it was about 3 times higher in urban areas. This difference is believed to be due to the significant variations in other socio-economic, demographic and environmental aspects in each area. Even though presence of livestock was significantly associated with CL in both models, the distance from such risk factor was only significantly and inversely associated with CL in the model for people in rural areas only and not in the urban one. The reason behind this is believed to be due to the low distance variation of keeping livestock in urban areas as most people keep them within the household boundaries and they cannot be kept out or far away because of the nature of the built up areas.

The presence of green areas within the household boundaries was found significantly and positively associated with CL in the model for people in urban areas only and not in the rural one as discussed before. With the lack of the presence of many other risk factors in urban areas in contrast to rural areas, vegetation within the household boundaries in urban areas was found playing a very significant rule in CL transmission where people who have such areas were almost at 12 times higher risk of developing CL than people who do not have such vegetations. Distance from all types of vegetations was found significantly and inversely associated with CL for both models. The farther the people were located from such risk factor, the less likely they were to contract the disease. Since the extent of risk factors for CL were much larger in rural than in urban areas and activities and behaviours of people in rural areas can easily interact with sandflies, rodents and their habitats, taking protective measures against insects in the household was found to be significantly and negatively associated with CL transmission in the model for people in rural areas while it was not so in the urban model.

7.8. Discussion:

The significant risk factors from the five regression models were combined in Table 7.13 which includes the coefficient values and in Table 7.14 which shows the OR in order to support the overall discussion, comparison and conclusion.

Table 7.13: Summary of five multivariate regression models with the coefficient values

Variables		All people	All Saudis	All non-Saudis	People in urban areas	People in rural areas
Presence of Livestock	Coeff	1.405	1.726	3.117	1.103	2.330
Presence of green areas within the household boundaries	Coeff	2.479	2.084		2.473	
Taking protective measures against insects	Coeff	-0.713		-2.081		-1.458
Awareness level about the seasonality of CL	Coeff		-1.199			
Distance from livestock (Ln)	Coeff	-0.770	-0.832	-1.094		-2.586
Distance from vegetation (Ln)	Coeff	-1.158	-0.395	-1.052	-.946	-1.526
Pseudo R^2		0.352	0.305	0.337	0.237	0.590

Significant risk factors

Table 7.14: Summary of five multivariate regression models with the OR values

Variables		All people	All Saudis	All non-Saudis	People in urban areas	People in rural areas
Presence of Livestock	OR	4.075	5.619	22.575	3.013	9.618
Presence of green areas within the household boundaries	OR	12.151	8.038		11.859	
Taking protective measures against insects	OR	0.490		0.125		0.233
Awareness level about the seasonality of CL	OR		0.301			
Distance from livestock (Ln)	OR	0.463	0.435	0.796		0.779
Distance from vegetation (Ln)	OR	0.314	0.492	0.995	0.381	0.591

Significant risk factors

The general lifestyle in Al-Dawadmi Governorate is bedouins and farmers with wide interactions with the largely distributed livestock (sheeps, camels and cows). Livestock shelters are rich of organic materials, provided with food, crops and with walls full of cracks and gaps. Such characteristic make these places very suitable for both Leishmaniasis vectors and reservoirs and consequently increases the risk for people in the surrounding areas of developing CL (El naiem and Ward, 1990; Dhiman et al., 1983; Alexander, 2000; Ximenes et al., 1999; Dye et al., 1991). The wide distribution of livestock in Al-Dawadmi Governorate has resulted in making the presence of them significantly and positively associated with CL in all five classes in the population.

From Tables 7.13 and 7.14, the influence of livestock was found varying between Saudis and non-Saudis and between urban and rural areas. Generally speaking, non-Saudis were more likely to have and interact more with livestock than Saudis (see Table 7.2). This was basically because of the type of occupations they were involved in as well as the influence of other socio-economic and demographic factors. Also, people in rural areas were more likely to have and interact with livestock more than people in urban areas (see Table 7.2) because of the nature of their living areas. This strong variation can be seen from the coefficient and OR. The coefficient was almost doubled in the case of non-Saudis (3.117) than in Saudis (1.726). Additionally the OR showed that the impact of livestock was far stronger on non-Saudis than Saudis. Non-Saudis who have livestock were at 22.57 times higher risk of contracting CL than non-Saudis who do not have livestock. In the case of Saudis, the OR was also high but not as high as the previous one where Saudis who have such risk factors were almost at 5.6 times higher risk of developing CL than Saudis who do not have. In rural areas the coefficient was also found to get almost doubled in comparison to urban areas. The OR stated that people in rural areas who have livestock were almost at 9.6 times higher risk of contracting CL than people who have not while the figure was almost 3 in the case of people in urban areas.

There is a strong distance-decay in the influence of several risk factors following Tobler's first law of geography, "*Everything is related to everything else, but near things are more related than distant things*", (Tobler, 1970). The influence of presence of livestock on CL incidence was found much stronger in closer proximities and decreases with the increase in the proximity. In Chapter 6, most risky distance from livestock were found between <100 up to 200 metres based on different population groups. Also, the generated PP values showed that there was a dramatic positive change in the probability of developing CL in the distance less than 600 metres far away from such risk factor (see Figure 7.4.B). From the conducted five regression models, the distance from livestock was significant in the case of all people, Saudis, non-Saudis and people in rural areas where cases were closer in proximity to livestock than controls. Distance from livestock in urban areas was not significantly associated with the incidence of CL which was also discussed earlier.

In Chapter 2, vegetation was stated as a main food source for male sandflies as well as food and natural shelters for rodents (Wasserberg et al., 2003; Ben Salah et al., 2000; Thompson et al., 2002; Killick-Kenderick and Killick-Kenderick, 1987). Three types of vegetation were found in the areas being studied which were house gardens or vegetable plots, large farms and natural vegetation covers. The presence of vegetation within the household boundaries (house gardens or vegetable plots) was found playing a significant rule in CL transmission in three classes in the population who were believed having such risk factor: all people, all Saudis and people in urban areas. Since Saudis and people in urban areas often have fewer preferable habitats for sandflies and rodents in their houses and surrounding areas due to the nature of their living areas, the presence of such risk factor was found playing a very important rule in the transmission of CL. Saudis who have such areas were almost at 8 times higher risk of contracting CL in contrast to Saudis who do not have, and people in urban areas were almost at 12 times higher risk of contracting CL than people who do not have such areas.

The influence of the existence of all types of vegetation including house gardens, vegetable plots, farms and natural vegetation was following the same epidemiological trend as people in closer proximities were at higher risk than people who stay far away. From Chapter 6, the main findings stated that people within 300 metres from natural vegetation cover and 500 metres from vegetable, crop and fodder farms were at really high risk of contracting CL. Furthermore, the generated risk prediction probability showed steady increase in the probability of CL development in areas just less than 600 metres distance from vegetation as shown in Figure 7.4.A. In the five regression models, the distance from vegetation covers were found significantly and inversely associated with CL in all population groups due to the wide existence of such risk factors. The distance factor in the distribution patterns of vegetation and people showed stronger influence on non-Saudis and people in rural areas in comparison to Saudis and people in urban areas as observed from the coefficient and OR.

The use of protective measures against insects in the household was notably associated with CL in all interviewed people, non-Saudis and people in rural areas. These population groups were believed to be living in areas with surrounding environment that has higher density of sandflies and rodents and thus there are more interactions between people and risk factors in comparison to Saudis and people in urban areas. So, protecting the households was found as an important key factor in keeping sandflies away and thus less likely of developing the disease (Yatich, 1995; Harrat et al., 1998; Kamhawi et al., 2000). The models showed that the more protections used in the households the less probable it was for people to contract CL. The awareness level about the seasonality of CL was only significant in the interviewed Saudis group. The seasonality awareness level was believed to be influencing people's behaviour and activities as they might consider and avoid possible risk factors, risk areas, risk times as well as increasing protections in households during the hazard time (Kassiri et al., 2013). The regression coefficients indicated that the more people were aware of the seasonality of the disease the less probable for them to develop CL.

The obtained Pseudo R^2's were in an acceptable fit level as discussed before in four regression models which are: all people, interviewed Saudis, interviewed non-Saudis and interviewed people in urban areas. The goodness of fit was found very well fitted in the case of model for people in rural areas. The R^2 showed that there was much stronger differentiation of risk factors in rural than in urban areas and in the case of the non-Saudis than that of the Saudis. However, the different risk pattern was much stronger between urban and rural areas than between Saudis and non-Saudis and very obviously far more distinct in rural areas than in urban areas.

7.9. Conclusion:

In conclusion, from the conducted five regression models, some points stood out strikingly and will be emphasized either by risk factor or population group. In the first place, both presence of livestock and distance from vegetation cover patterns were found to be significantly associated with the incidence of CL in all population groups. For the former, the relationship was positive and as the presence of livestock increases, the probability of developing CL increases too. The risk factors were found much higher for non-Saudis in contrast to Saudis and for people in rural areas versus people in urban areas. This higher probability resulted from the distribution pattern of livestock as more livestock was found to be present among non-Saudis community and in rural areas than in Saudis communities and in urban areas. For the latter, the wide occurrence of all considered types of vegetation (house gardens or vegetable plots, large farms, natural vegetations) has resulted in these remarkable positive significances for all classes in the population. When only green areas within the household boundaries was considered, all people, Saudis and people in urban areas were significantly associated due to the distribution of such land use patterns as discussed before. The distance from livestock was significantly and inversely associated with CL in four out of five classes in the population. The only population class for which the distance from livestock was insignificant was people in urban areas and this is believed due to low distance variation as most people in urban areas keep their livestock within the household boundaries as explained earlier. The previous four risk factors can be described as natural hazards with wide distribution all over the area being studied and with more concentration in rural than in urban areas where most of the non-Saudis live.

Broadly speaking, living areas of the non-Saudis are often at a lower level of hygiene with poor housing conditions. In such areas, protective measures in the household against CL vectors and reservoirs were found to be the fundamental aspects of developing CL. The regression models showed that, all people in general, non-Saudis and people in rural areas who undertake protective measures in their household were at lower risk probability of contracting CL than people who do not undertake such measures. Finally, the awareness level about the seasonality of CL is believed to be controlling activities and behaviour of people during the period of higher risk of contracting CL at risky areas. Even though the general awareness level of the Leishmaniasis was found to be very poor as described previously, the aware people were at lower risk of contracting CL than the unaware ones.

So, the final proclamation that can be stated is that both local environment and behaviour of household members were found to play an important role in CL transmission. Additionally, obvious patterns of risk factors were found associated more with non-Saudis than Saudis and in rural areas than in urban areas. However, the risk distribution pattern was found to be much stronger between urban and rural areas than between Saudis and non- Saudis. Therefore, living area of people was found to be influencing the exposure to CL most strongly, more than any other socio-economic and demographic factors.

Chapter Eight: Unreported CL Cases in Al-Dawadmi Governorate:

8.1. Introduction:

It is widely recognized in many areas of public health and epidemiological research that under-reporting of conditions is a common problem worldwide (PAHO and WHO, 2000; Durić and Ilić, 2012; Negri, 2009; Doyle et al., 2002). In Chapter 2, it was noted that there are many factors which might prevent people exposed to CL from reporting their illness. These include individual preferences, travel and financial cost, socio-cultural and organizational factors. In addition, from the exploratory field trip to Al-Dawadmi Governorate, it was found that there were very strong variations in different aspects such as distances of populations from health facilities, lifestyle, income and the nature of the surrounding environment. All these factors may influence reporting and might be anticipated to result in some CL cases not being reported to the official authorities, especially when considering the fact that CL is not a vital disease and drug treatment is not always necessary (Davies et al., 2003; Herwaldt ,1999; Norton et al., 1992; Anders, 2003). So, with the possibility of having under-reporting of CL cases in the study area it is difficult for health authorities and policy makers to evolve a suitable control strategy for eliminating or even eradicating the disease. Therefore, this chapter is going to investigate the reporting issue and the reasons why it occurs by answering one of the main research questions which is:

"Is there evidence of under-reporting of CL cases in the study area? If so, do the characteristics of the officially reported cases differ from those that were not reported?"

In order to answer this question, a search for CL cases that were not reported to the local authorities was conducted during the field trip. This search resulted in finding 41undre-reported cases; the procedures followed to find them were discussed extensively previously in Chapter 4. It should be noted that the identification of cases that had not been officially reported was based on the observations from the survey team as well as the answered questions and not on any medical examination as none of the research team were medically qualified.

From the found 41 under-reported cases, it is difficult to say what proportion do they represent as the total number of unreported cases is unknown. However, it is reasonable to assume that they represent a minor proportion as they were the easiest to find and interview, with the searched area restricted to the previously selected 6 communities and the time involved was comparatively short (less than 9 working days). Nevertheless, it is also thought that the 41 cases at least provide a cross-section of unreported examples as the sample includes both Saudis and non-Saudis, people close and remote from health facilities and in different age groups and professions. The 41 unreported CL cases were spatially located and face-to-face interviews were carried out (a distribution map of unreported cases attached in the Appendix H). The same questionnaire that was used in collecting the socio-economic and demographic information discussed in Chapter 4 was also used in these interviews.

So, at an early stage, a straightforward and short answer for the first part of the question above can be given which is: Yes, there is evidence of under-reporting of CL cases in Al-Dawadmi Governorate based on the 41 cases identified. In regard to the second part of the question which is about the differences in the characteristics of unreported and officially reported CL cases, some comparisons are needed. These comparisons were applied between two groups namely the unreported 41 cases and the reported 125 cases and the main differences between these two groups will be highlighted that might be the key factors behind not reporting the exposures. This comparison covers three main aspects which are:

- Socio-economic and demographic variables
- Accessibility and utilization of heath care centres
- The experience of unreported and reported cases regarding their CL exposures.

A total of 15 questions were asked for both groups and some preliminary tests were applied to the collected data. The results of the preliminary tests showed that these data are not normally distributed. Thus, non-parametric tests were preferred. Even though the number of interviewed people in the two groups was not equal (41 unreported vs. 125 reported cases) the Kolmogorov–Smirnov test (KS) was selected for use. KS is one of the most useful non-parametric tests for comparing the distribution and the shape for two samples even if the sample size is not the same as the comparison will be carried out on the basis of the relative frequency distributions for each group (Buja et al., 2009; Steinskog et al., 2006). The three aspects will be discussed in turn and the main differences will be highlighted.

8.2. Characteristics of the Survey Respondents:

8.2.1. Socio-economic and Demographic Variables:

In the first place, the main socio-economic and demographic characteristics of reported and unreported interviewed people are summarized in Figures 8.1.A to 8.1.H. Additionally, the results of the KS tests are shown in Table 8.1

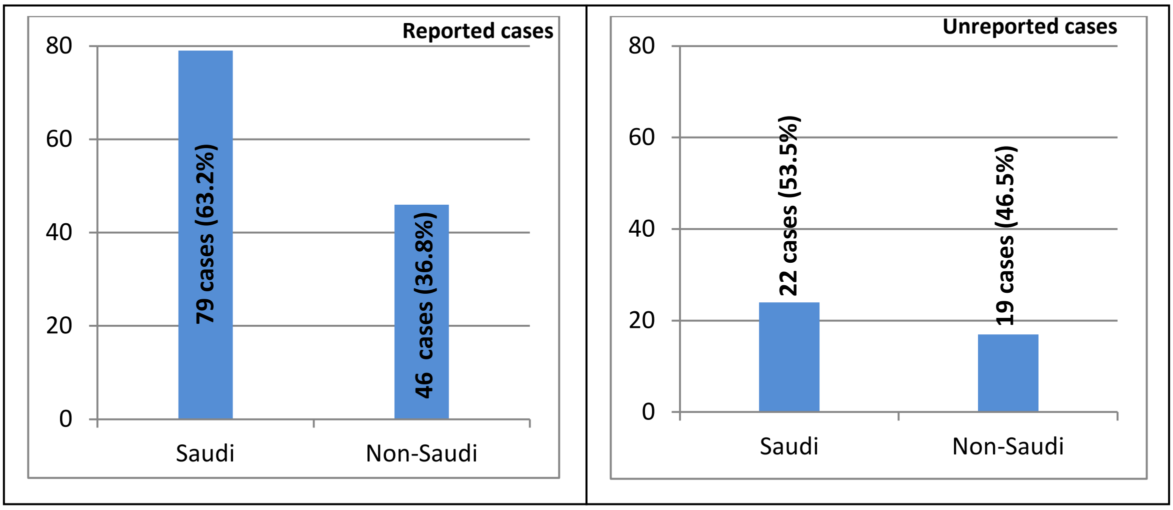


Figure 8.1.A: Distribution of reported and unreported CL cases based on nationality

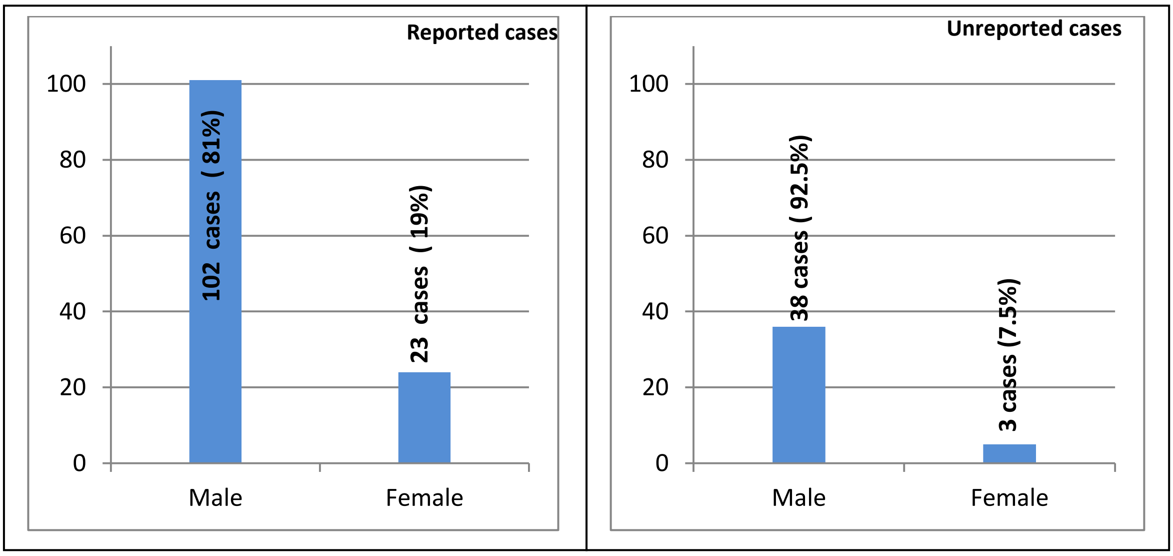


Figure 8.1.B: Distribution of reported and unreported CL cases based on gender

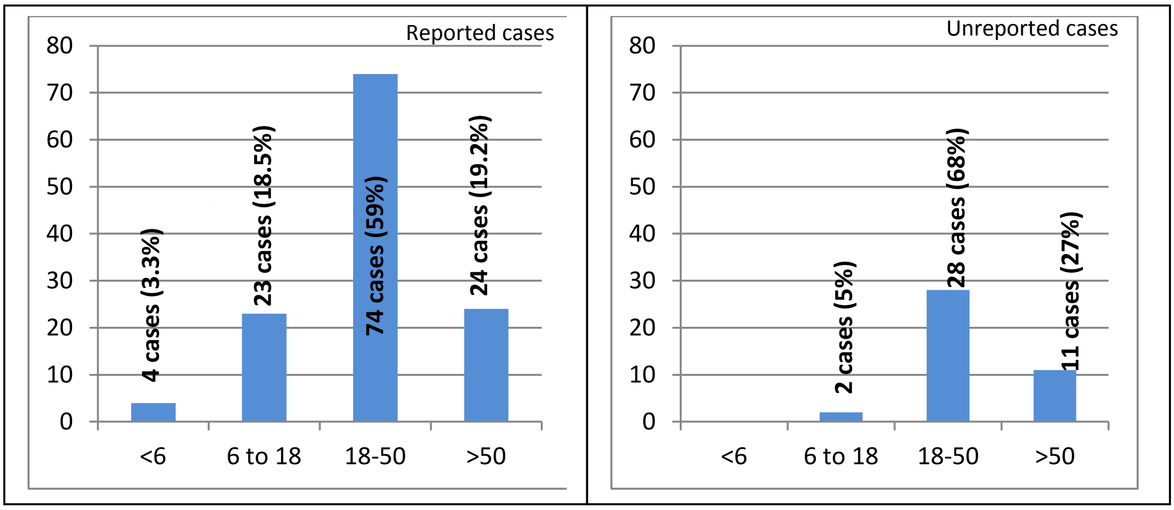


Figure 8.1.C: Distribution of reported and unreported CL cases based on age group

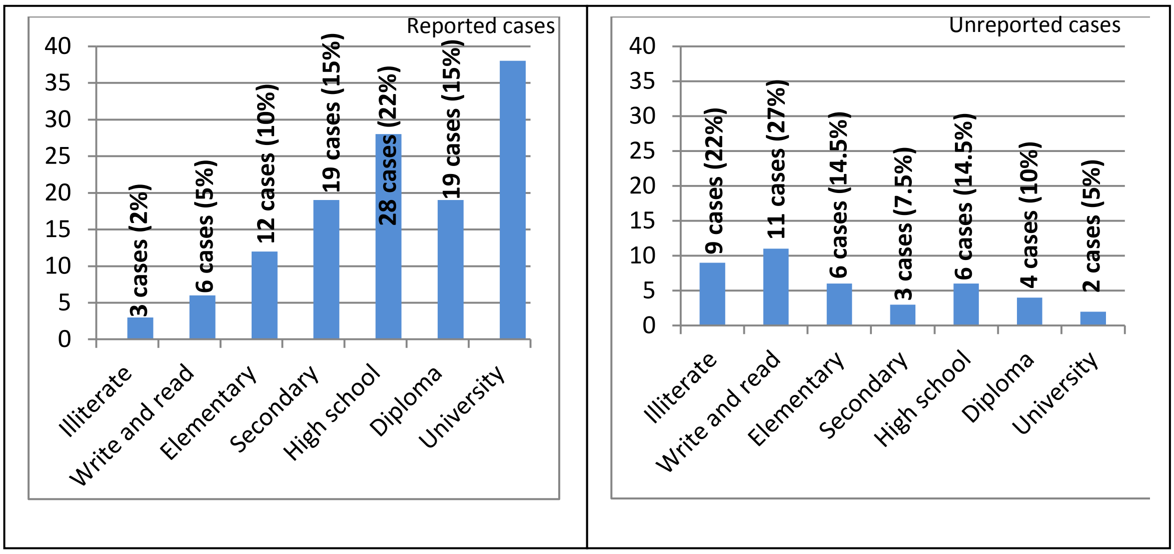


Figure 8.1.E: Distribution of reported and unreported CL cases based on educational level

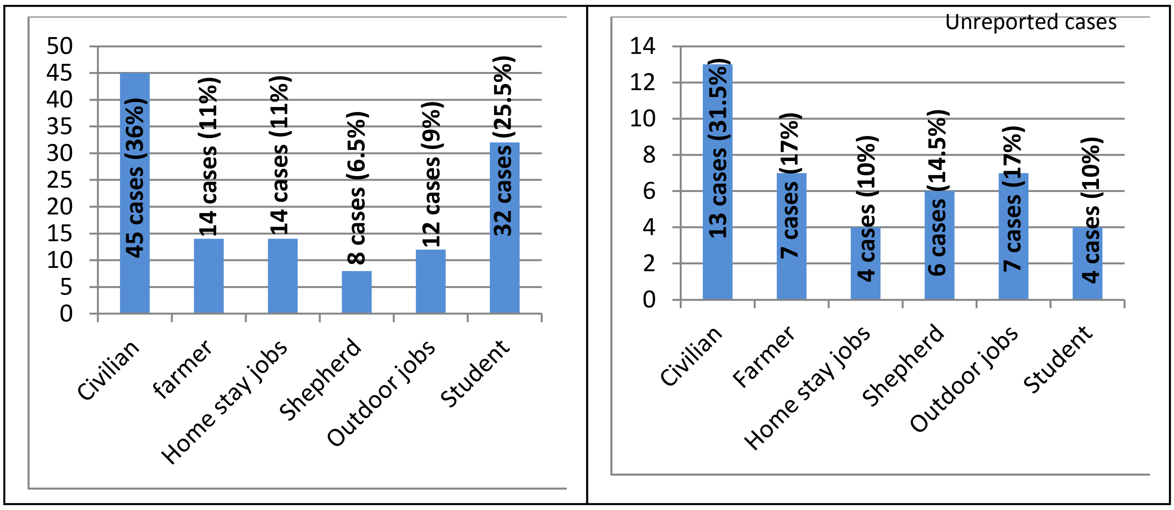


Figure 8.1.F: Distribution of reported and unreported CL cases based on occupation

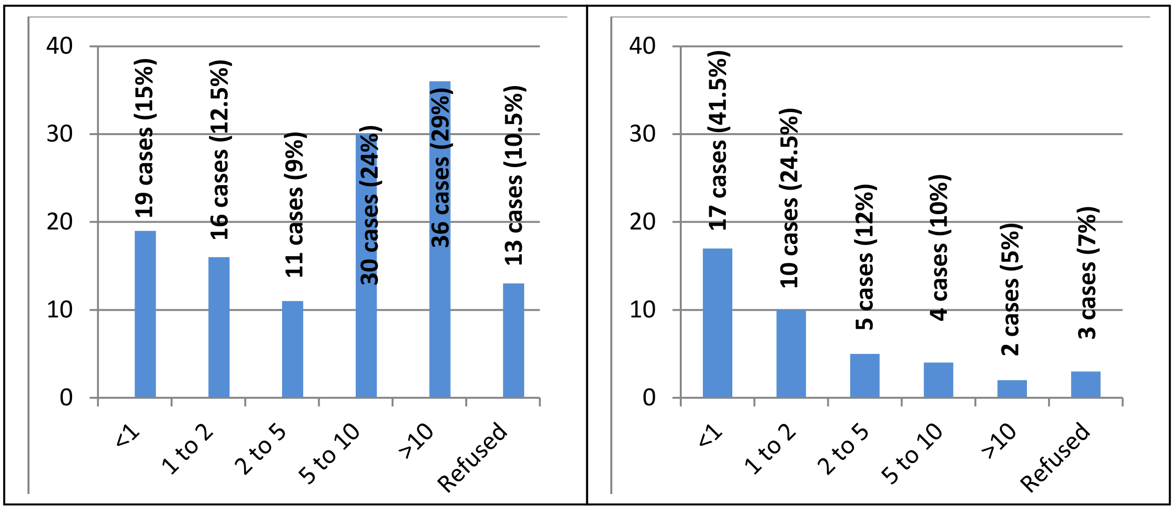


Figure 8.1.G: Distribution of reported and unreported CL cases based on monthly income in 1000 Saudi riyals

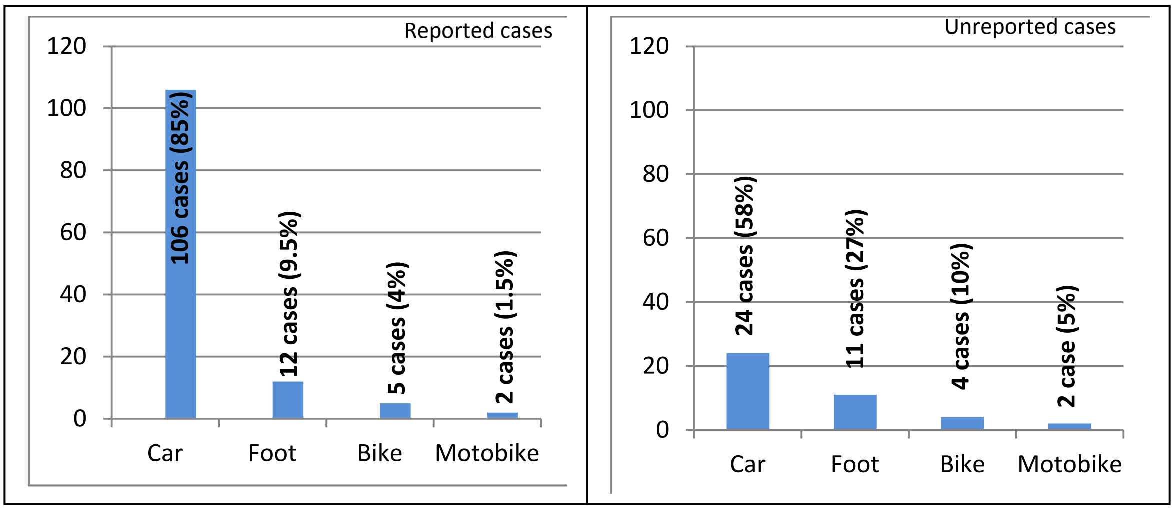


Figure 8.1.H: Distribution of reported and unreported CL cases based on transportation method

Table 8.1: KS test results of some socio-economic and demographic factors

Variables	Case nationality	Case gender	Case age	Case educational level	Case occupation	Household monthly income	Household transportation method
Z value	0.530	0.616	0.929	2.590	0.745	1.854	1.459
P value	0.941	0.843	0.354	< 0.001	0.636	0.002	0.028

The above figures and table showed that there are strongly significant differences between reported and unreported CL cases particularly in terms of educational level, household monthly income and household transportation methods. It was found that there were very clear tendencies for the unreported cases to be more common in lower educational level, lower income and the availability of transportation methods in comparison to reported cases. These differences might be fundamental factors behind not reporting the exposure in the study area a topic which will be discussed later.

8.2.2. Accessibility and Utilization of Health Care Facilities:

Secondly, the differences in the level of accessibility and utilization of primary health care centers (PHCCs) and general hospitals (GHs) between reported and unreported CL cases are presented in Figures 8.2.A to 8.1.D and the results of the KS test are summarized in Table 8.2.

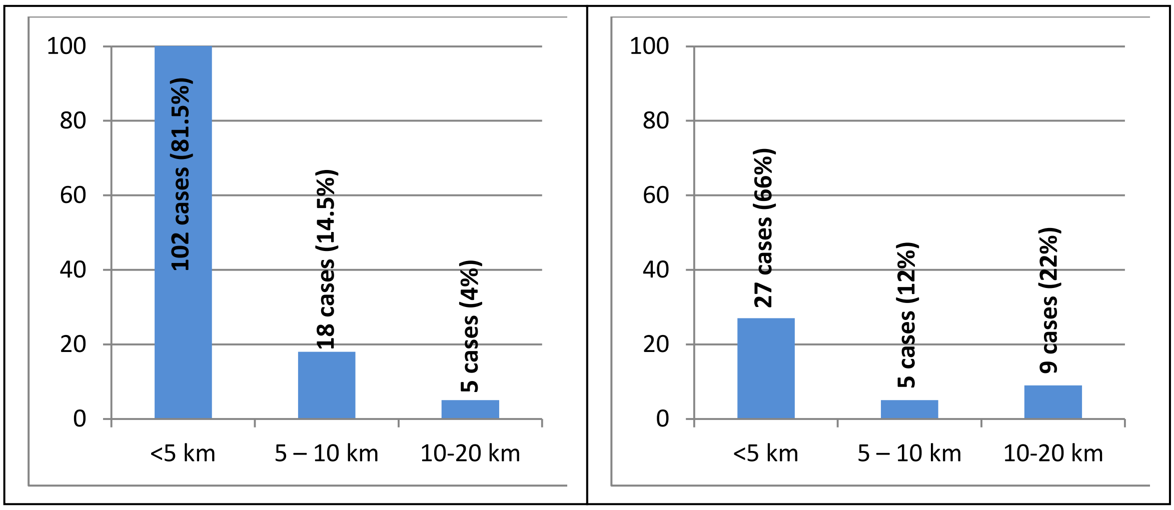


Figure 8.2.A: Distribution of reported and unreported CL cases based on distance to the nearest PHCC

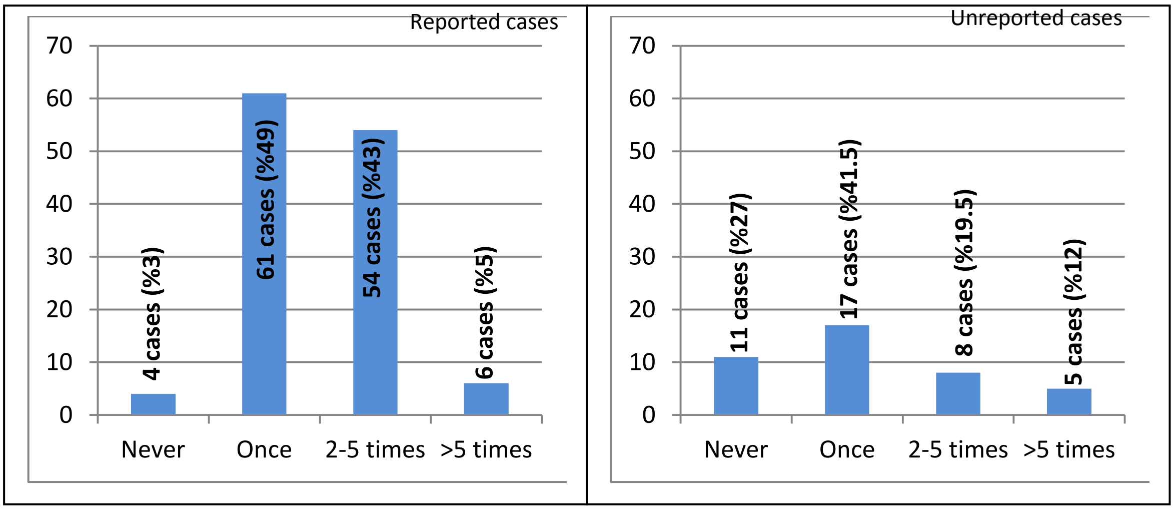


Figure 8.2.B: Distribution of reported and unreported CL cases based on their utilization of the nearest PHCC in the past 12 months prior the interview.

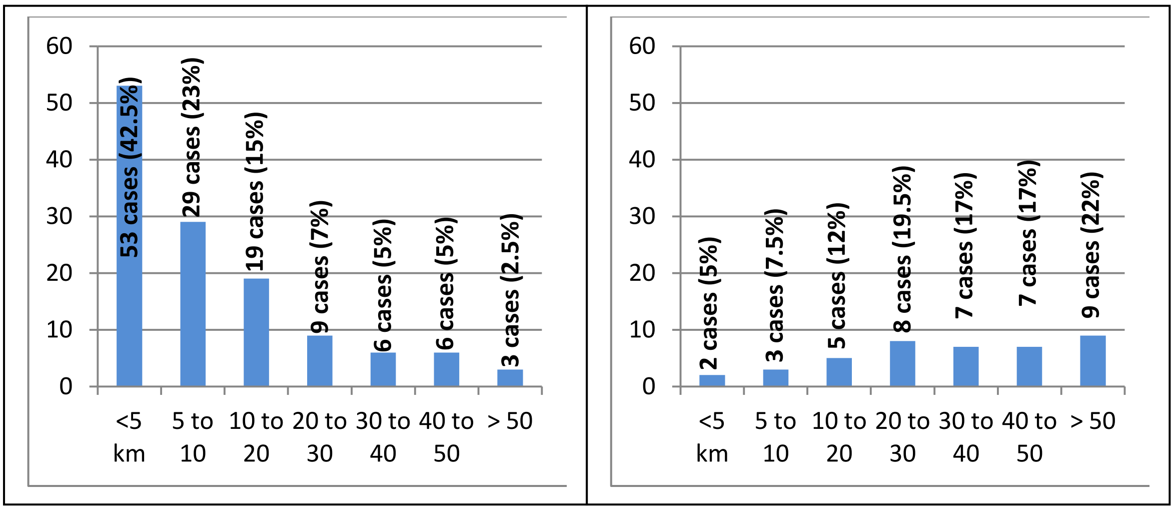


Figure 8.2.C: Distribution of reported and under reported CL cases based on distance to the nearest GH

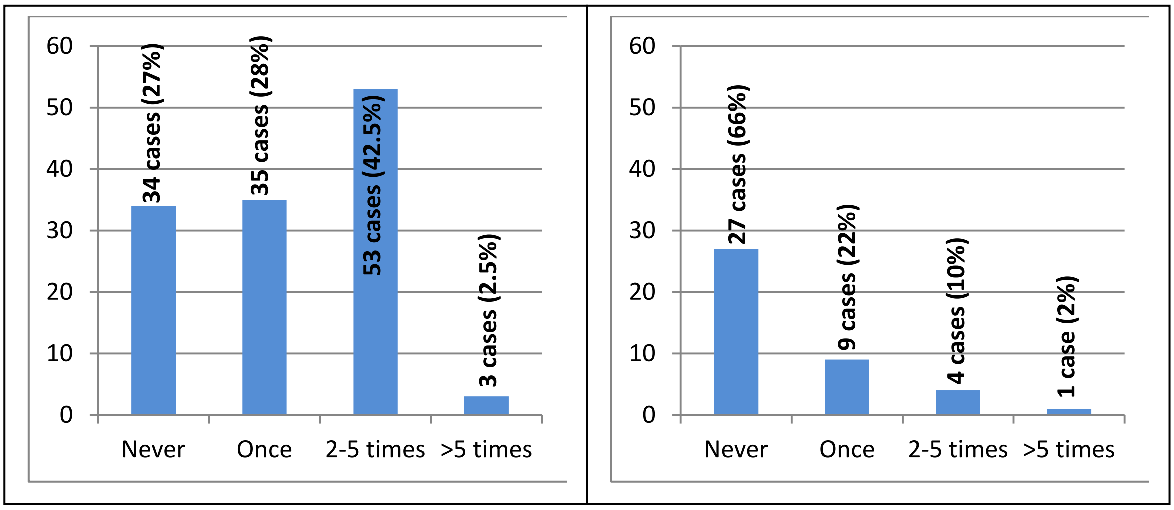


Figure 8.2.D: Distribution of reported and unreported CL cases based on their utilization of the nearest GH in the past 12 months prior the interview.

Table 8.2: KS test results of accessibility and utilization of primary health care centres and general hospitals.

Variables	How far is the nearest PHCC from your residence	How many times did any of your household members visit the nearest PHCC in the past 12	How far is the nearest GH from your residence	How many times did any of your household members visit the GH in the past 12 months
Z value	0.997	1.313	3.134	2.354
P value	0.273	0.064	< 0.001	< 0.001

From the above figures and table it can be seen that there were no strong differences in the distribution and the utilization between reported and unreported cases in regards to PHCCs. However, it is also apparent that there were higher frequencies of unreported CL cases in further distances from GH in comparison to the reported cases which were concentrated at closer distances. Distance-related differences in the utilization of GHs were also evident.

8.2.3. The Experience Regarding Previous CL Exposures:

Thirdly, the experience of reported and unreported cases regarding their previous exposures to CL are summarized in Figures 8.3.A to 8.3.D and the KS results are summarized in Table 8.3:

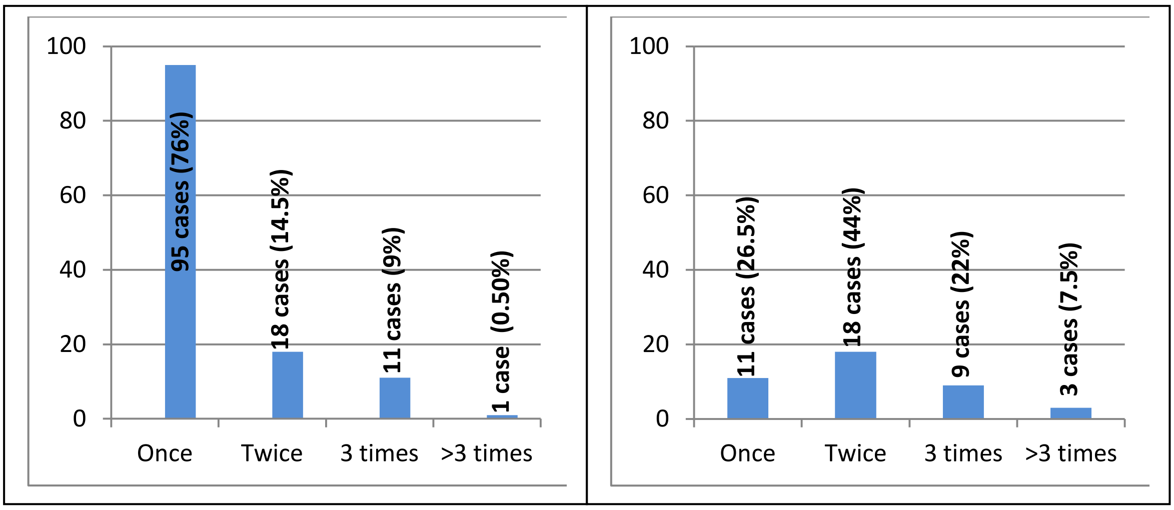


Figure 8.3.A: Distribution of reported and unreported CL cases based on the number of exposures to CL in the past 10 years

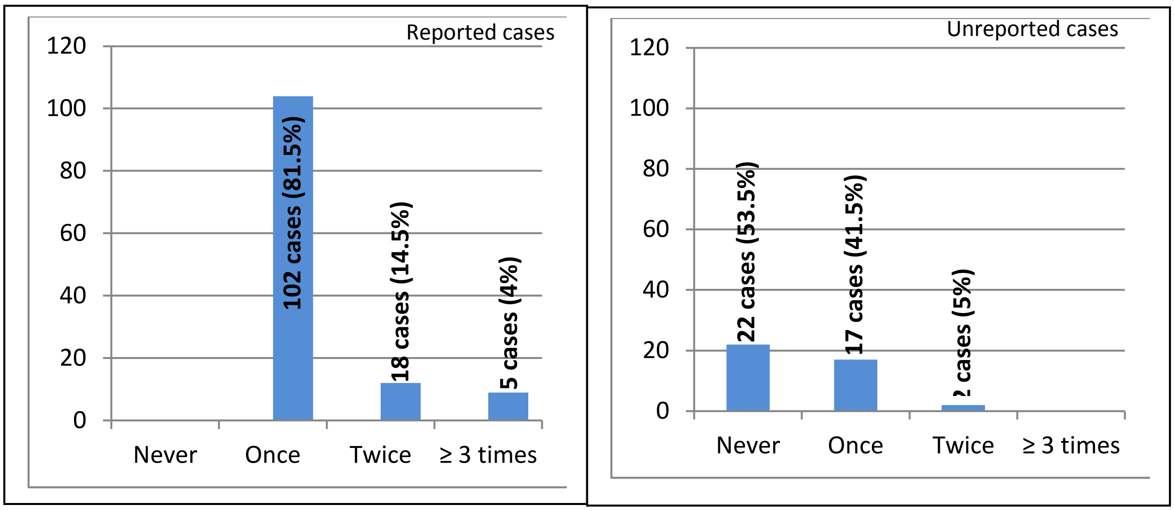


Figure 8.3.B: Distribution of reported and unreported CL cases based on the number of reported exposures to the local health authorities.

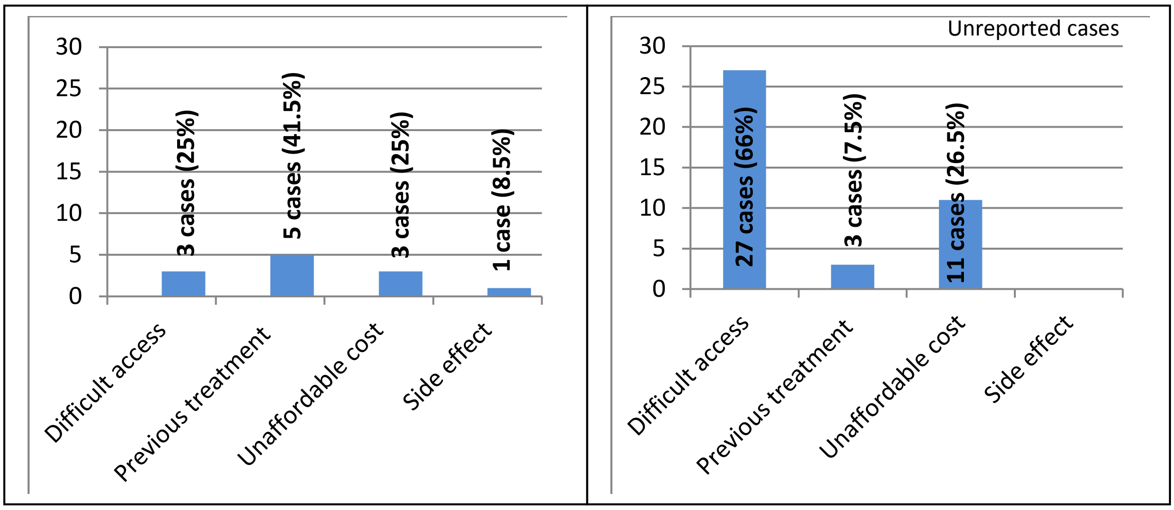


Figure 8.3.C: Distribution of reported and unreported CL cases based on the reasons behind not reporting any of the exposures to local health authorities.

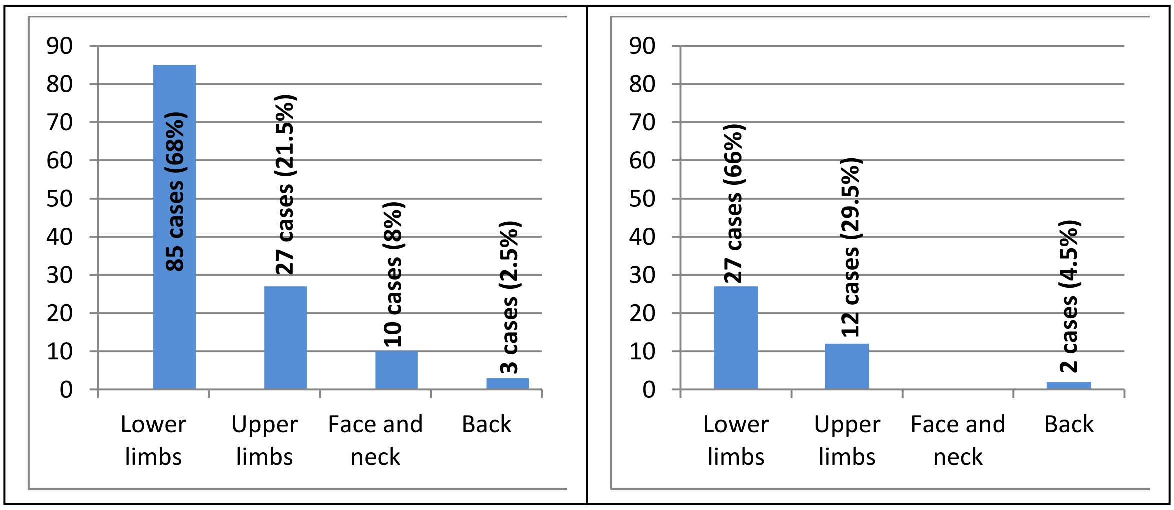


Figure 8.3.D: Distribution of reported and unreported CL cases based on the part of the body where the CL ulcer/s occurred.

Table 8.3: KS test result of reported and unreported CL cases regarding their exposure to CL

Variables	How many times have you exposed to CL in the past 10 years?	How many times did you report your exposure/s to the local health authorities?	What was the reason/s behind not reporting any or all the CL exposures?	In which part of the body did you have the CL ulcer/s?
Z value	2.461	2.981	2.711	1.000
P value	< 0.001	< 0.001	< 0.001	0.307

From Figures 8.3.A to 8.3.D and Table 8.3, it can be seen that there are obvious differences between reported and unreported CL cases in terms of their answers regarding to their previous exposure to CL. It can be seen that more of the reported cases had their exposure for the first time and reported it, while for unreported cases many had experienced CL previously and most of these exposures were not reported. The reasons behind not reporting all or some of the exposures were found to vary significantly between the two groups as well as the location of having the CL ulcer/s. All these differences are discussed further below.

8.3. Discussion:

The first analysis compared some socio-economic and demographic variables between reported and unreported CL cases. It can be seen that no significant differences between the two groups were found based on nationality, gender, age group and occupation. It can be noted that most of the interviewed people were Saudis as they are relatively easier to find and interview due to living mostly in urban areas whereas non-Saudis are harder to locate as they live mostly in rural areas, farms and grazing lands. Additionally, the great majority of interviewed people from each population class were males. This occurred basically for two main reasons; firstly, the interview team was selective and more males were selected to be interviewed rather than females as interviewing the former is far easier and faster. Secondly, it is believed that finding unreported males is much easier as females often reported their exposures and get treated for cosmetic purposes.

Additionally, it was believed that local people were more likely to inform the research team of unreported males more than females for reasons related to cultural values as discussed in Chapter 7.

In regards to the age group, no significant differences were found between reported and unreported cases as the majority were aged between 18 and 50 years old. However, it was noted that there was a very low number of unreported cases in the age group between 6 to 18 years, with only 2 cases compared to 23 reported cases. Additionally, no unreported cases were found in the age group < 6 years old whilst there were 4 reported cases in the same group age. The reason for these low numbers of unreported cases in these two age groups might be associated with other factors such as younger and highly educated parents that would seek medical treatment for their children in comparison to older individuals in other age groups.

On the subject of the education level, the frequencies were found significantly different between reported and unreported cases with a *P* value of <0.001. There were very clear tendencies for the unreported cases to be more common in lower education level categories. It was noted that 63.5% of the unreported cases had elementary education level or less, 86% of the reported cases had high school education level or higher. This significant difference is not surprising as the level of education affects several aspects such as beliefs in the importance of health care treatments if exposed to CL, occupation and income. The distribution of reported and unreported CL cases based on the type of occupation was not significantly different with a *P* value of 0.636 which might be due to the limited variation in frequencies in both groups.

Similar to education level is that of monthly income. It was found that the distribution between reported and unreported CL cases was significantly different with a *P* value of 0.002. Most of the unreported people were in the lower monthly income group, while most of the reported were in higher income levels. Monthly income is often associated with many aspects that can be anticipated to influence reporting such as education level and the affordability of reporting as discussed previously in Chapter 7. From Figure 8.1.G it was observed that 32 out of 41 unreported cases (78%) have a monthly income of less than 5000 SR which can be considered as a moderately low income and only 14.5% had a monthly income of ≥ 5,000 SR. In contrast, 37% of the reported cases were in the specified low income class and 53% were in the high monthly income class. Even though almost a third of the reported cases were in the specified low income class (<5.000 SR), other factors might influence their participation in reporting such as the type of occupation and the level of accessibility. In Saudi Arabia, non-Saudis working in domestic jobs such as drivers, house guards and maids are medically treated free of charge while other jobs including farmers, shepherds and hand laborers are not. So, the low income reported cases are probably domestic non-Saudis workers who could afford the travel cost to health care facilities.

The final socio-economic aspect was the type of transportation used in the household. From Figure 8.1.H and Table 8.1 it was noted that the distribution was significantly different between the two groups with a *P* value of 0.028. It can be seen that 24 out of 41 unreported cases used cars, but they did not report even with the availability of a convenient transportation method suggesting that other factors were influential such as financial cost, accessibility, and their willingness to be treated.

Differences between reported and unreported cases in terms of proximity and utilization of PHCCs and GHs were also compared. In Al-Dawadmi Governorate there are 68 widely distributed PHCCs in cities, towns, villages and even small group of houses if they meet the required minimum population size in their catchment areas to have such service (a distribution map of PHCCs is attached in the Appendix J). Patients normally visit a PHCC initially to be examined by a general doctor and if further treatment is needed then they will be referred to a GH. In the study area only 3 of the 68 PHCCs had dermatologists who could treat Leishmaniasis. If a patient was diagnosed with CL in any of the other 65 PHCCs then they would have been referred to one of the main five GHs in the governorate that are located in Al-Dawadmi City, Nifi, Albijadiah, Algmsh and Sajer (a distribution map of GHs is attached in the Appendix K).

It can be seen from Table 8.2.A that most reported and unreported CL cases were at relatively short distances from PHCCs, with 81.6% of the former and 66% of the latter were within 5km from a PHCC. Additionally, 14.5% of the reported cases and 12% of the unreported cases were between 5 and 10 km from a PHCC. Only a very few reported cases (4%) were between 10 and 20 km from a PHCC (which can be considered as moderately far), whilst the proportion for unreported cases was much higher at 22%. The distribution of reported and unreported cases based on distance to PHCCs was not found to be significantly different.

In regards utilizing PHCCs, even though there were some clear differences in the utilization between the two groups, no significant difference was found with the *P* value was just above the significance level at 0.064. From Figure 8.2.B it was observed that only 3% of the reported cases or anybody in their household did not visit a PHCC in the past 12 months before the interview, while the share was far higher at 27% for unreported case. In addition, 49% of the reported cases visited a PHCC once and 43% visited a PHCC 2 to 5 times in the past 12 months prior the interview whilst 41.5% and 19.5% of the unreported cases visited such a health clinic once and 2 to 5 times respectively. So, the majority of both groups visited a PHCC at least once in the past 12 months prior the interview. However, even though the level of accessibility to PHCCs was fairly good (66% of the unreported cases were within 5 km), most such facilities cannot confirm the exposure as they do not have dermatology clinics and general doctors might misdiagnose CL with other similar symptoms as well because they cannot treat exposed patients.

Very strong and significant variation can be seen between reported and unreported cases in the distances from their residences to GHs with a *P* value of <0.001. From Figure 8.2.C, it can be seen that 65.5% of reported cases were within 10 km of a GH, but only 12% of unreported were in the same distance band. Furthermore, only 12% of the reported cases were located further than 30 km from a GH whereas the majority of the unreported people (65%) were in such a distance band.

The utilization of GH between reported and unreported CL cases was found to be significantly different with a *P* value of <0.001. Figure 8.2.C shows that 27% of the reported cases did not visit a GH in the past year prior the interview whilst the proportion was far higher for unreported cases at 66%. There are several factors that can be anticipated to influence utilization which are travel distance, travel cost, individual preferences and the level of health care treatment needed as PHCCs normally deal with non-urgent cases. As mentioned earlier, there are only 3 PHCCs in the governorate can receive and treat CL cases. These 3 PHCCs are located all in Al-Dawadmi City meaning that any exposed person to CL must travel to any of the 5 GHs in the region or any of these 3 PHCCs. So, as found in the literature as the travel distance to health care facilities increases the likelihood of utilizing these services decreases (Joseph and Phillips, 1984; Posnett, 1999; Jones at al., 1999). In short, the level of accessibility and utilization of PHCCs were not significantly different between reported and unreported cases and are not anticipated to influence reporting, but the proximity to a GH does.

Several key points can be made regarding the comparison between reported and unreported cases based on their previous experience of CL. It is apparent from Figure 8.3.A that the distribution between the two groups based on the number of exposures to CL was significantly different with a P value of <0.001. The majority of reported cases (76%) had CL for the first time, while the majority of unreported cases (73%) had had CL more than once. So, the reason for not reporting the exposure might be influenced by the previous experience of developing CL in various ways. For example, they might were not able to afford the travel or the treatment cost for their first exposure and used alternative treatment methods such as traditional medication or even left it untreated and they were satisfied with the results to some extent and so continued not to report subsequent exposures. Another possibility is that they might have sought treatment for their exposure the first time and at some point they were not satisfied with the medication, duration of healing, cost or process, so they preferred not to report the following exposure.

Figure 8.3.B shows the distribution of the two groups in terms of the number of reported exposures to local health authorities which is significantly different with a P value of <0.001. The figure for the unreported class shows that 22 people never reported any of their exposures which suggests they could not afford the costs or preferred not to report for other reasons. Also the distribution shows that 17 of these people reported once and 2 people had done so twice previously. It is also apparent that even reported cases did not report all their exposures in the past. The reasons behind this are illustrated in Figure 8.3.C, with 3 identifying difficulties in accessing GHs either due to not having a convenient transportation method or being very remote from such facilities. About two thirds of the unreported cases mentioned they did not report their exposures because of the same reason. Accessibility features strongly as several visits are needed to a GH (at least 3 to 5 times) to complete the treatment cycle which make it even much harder for

some remote populations. This long treatment procedure and the long healing period was also the direct reason for 8 people not to report their exposures.

Another reason for not reporting exposures is the financial cost. The most affected population class in this respect is non-Saudis who are not working in domestic jobs where they can be treated for free. Most of the non-Saudis were in the low economic class with monthly incomes varying between \$250 and \$500, compared to a CL treatment cost of up to \$400 if all treatment cycles are completed. The final aspect that was compared was the location of the ulcer. Generally speaking, people are anticipated to care more if ulcers occur on visible places such as the face, neck and hands. Even though the differences between reported and unreported cases in this respect were not significantly different with a P value of 0.307, some contrasts were apparent in the frequencies of Figure 8.3.D. It was found that 66% of the unreported cases had their ulcers on lower limbs, 29.5% on upper limbs and only 4.5% on the back. However, no unreported case had their ulcers on the face or neck as people who have such ulcers are more likely to report even with higher cost as not treating ulcers might lead to permanent disfiguration and in some cases to be rejected from their communities as mentioned earlier in Chapter 2.

8.4. Conclusion:

From the above results and discussion, it suggests that from the socio-economic and demographic variables, the level of education influences the likelihood of reporting. The more people are educated the more likely they are to report their exposures due to their belief in the importance of reporting on the individual level by minimize the disfiguration and also on the community level by helping local authorities to assess the size of infected population. In addition, as reporting the exposure might involve high costs in traveling to one of the scattered 8 dermatologists, monthly income and the availability of a convenient transportation method were found significant. So, in the light of this, people should be educated more about CL including the disease vectors, reservoirs, preferable habitats, seasonality and the benefit of reporting the disease if exposed. Also, local authorities should work to reduce the reporting cost by increasing the number of dermatologists at least in highly endemic areas for CL. Also, the cost of treating exposed non-Saudis to CL should be considered seriously as it appears there are a large number of them not reporting their exposure and consequentially health authorities and decision makers may be underestimating the prevalence of the disease in Al-Dawadmi Governorate.

In addition, previous experiences were found to influence reporting. From the analysis and discussion above, one of the main issues is dissatisfaction with previous treatments. For instance, 46.5% of the unreported cases had reported CL exposure previously and due to their dissatisfaction they did not report other exposures. This dissatisfaction includes the level of accessibility, treatment procedure, healing time and treatment cost. Most of these could be improved by increasing the number of dermatologists and educating people about the treatment procedures and the expected time for an ulcer to heal as it is relatively long in comparison to other ulcers. Also, the importance of the long procedures before treatment that involve filling in some forms including personal and household information should be explained clearly. This explanation should emphasize that based on the answers some sandfly eradication patrol teams might be asked to visit the neighbourhood to destroy sandfly and rodent habitats and so reduce the disease risk. Also, the dissatisfaction with the cost for non-Saudis should be considered by the health authorities.

So, the final conclusion is that many factors were found influencing reporting behaviour including socio-economic, demographic, level of accessibility and dissatisfaction with treatment for previous exposures. In order to improve the level of reporting some effort is needed. In the first place, the government should educate local populations more about CL vectors, reservoir habitats, seasonality and the benefits of reporting the disease if exposed. Also the long healing time and the reasons for the administrative procedures should be explained and justified. And finally, the distribution of dermatologists and the cost issue of treating non-Saudis should be reviewed by the Ministry of Health and decision makers.

Chapter Nine: Conclusion and Recommendations:

9.1. Introduction:

The research presented in this thesis has highlighted a number of findings that need to be carefully considered in order to develop strategies to reduce the prevalence of CL in Al-Dawadmi Governorate. Chapter 9 includes four main aspects which are firstly: an integrated summary of the research findings from the four analytical chapters (five to eight). Secondly, the implications of the analysis. Thirdly, a section specifies the encountered difficulties during this study and finally, possible future research regarding CL in Al-Dawadmi Governorate and in Saudi Arabia more generally.

9.2. Summary of the Research Findings:

This research aimed to answer four main questions that were presented in Chapter 2 and, for convenience, are re-stated and answered here in turn:

Question 1: How does CL vary according to climate conditions in the selected study area?

This question was answered in Chapter Five which focused on understanding the influence of climate phenomenon upon the incidence of CL in Al-Dawadmi Governorate. No sandfly trap data were available so it was not possible to define ideal climatic conditions. However, the number of reported CL cases could be related to meteorological data from the study area. As anticipated from the literature, the results showed that temperature was the climate phenomenon with strongest association with CL incidence rate with P values of <0.05 for both maximum and minimum temperature and <0.001 for the mean temperature. Rainfall was also found significantly associated with the incidence of CL with a P value of <0.1 if combined with maximum or minimum temperature and with a P value of <0.05 if combined with the mean temperature. The findings from Chapter 5 suggest that if the temperature in the previous two or three months was suitable for sandflies then more CL cases will occur. Also, if the rain in the previous one or two months was such that sandflies and rodents were more active and there was more probability for local people to visit the countryside or farms then more CL cases are anticipated to occur. Because Al-Dawadmi Governorate is an arid region, relative humidity (which is generally low) was not significantly associated with the incidence of CL.

One of the main findings from this study that does not appear to have been identified in any previous research concerns the amount of rain required for a severe CL outbreak. The analysis suggests that if the amount of rain was 40 mm or more in the previous one or two months and the temperature was suitable in the previous two to three months then there was a very high probability of a severe CL outbreak as recorded in October 2008 and February 2010. These findings can be used by the local authorities as an early warning system to reduce the risk of the disease by increasing their eradication activities in such circumstances.

Question 2: Does the prevalence of CL in particular communities vary according to the local environment and proximity to different types of land use / cover?

This question was answered in Chapter Six which investigated the association between the incidence of CL and the surrounding land use / cover. Six selected communities were examined that represented a range of urban and rural settings including a city, towns, villages and small groups of houses. A comparison exercise was carried out between two population groups (cases and controls) and the surrounding environments. The results showed that there were seven types of land uses / covers strongly associated with the incidence of CL. The associations were found to vary according to nationality (Saudis vs. non-Saudis) and living area (urban vs. rural) where the levels of interaction with the surrounding environments differ. The land uses / covers with the strongest association with the incidence of CL were natural vegetation cover (both very dense and dense) and livestock shelters within 1500 m. In urban areas the existence of construction waste disposal sites, abandoned and mud houses within the same radius also put people at greater risk of developing CL. Finally, vegetable, crop and fodder farms that were more common in rural areas caused the same risk for people in these regions, particularly non-Saudis.

Another aspect of land use / cover investigated in this chapter was whether the highlighted land uses / covers had similar effects on risk with distance. Although the influence of the studied land uses / covers was anticipated to follow Tobler's (1970) first law of geography *''everything is related to everything else, but near things are more related than distant things''* some critical distances were found for certain land use / cover types. In regard to the very dense natural vegetation cover the critical distance was found to be 300 metres. Similarly, from the less dense natural vegetation the threshold distance varied between ≤100 and 200 metres. So, it can be said that people within ≤100 and 300 metres from natural vegetation cover are at high risk of developing CL. Based on these findings and in order to reduce the exposure risk in the governorate, local authorities should consider these distances in their elimination and eradication strategies. Regarding livestock shelters the critical distance was found to be ≤100 metres, while 500 metres was identified as the threshold from vegetable, crop and fodder farms where people within these distances were at higher risk of contracting CL.

Question 3: Do CL cases vary according to socio-economic and demographic characteristics of local populations?

This question was investigated in Chapter Seven by testing the associations between the prevalence of CL and a series of socio-economic and demographic variables. A comparison was carried out between the answers from CL cases and controls that were collected through a questionnaire survey in order to identify the main differences in their characteristics which might be the key factors in developing the disease. These investigated factors included awareness of CL, housing conditions, demographic and socio-economic variables and the activities of household members. These characteristics varied appreciably according to nationality (Saudi vs. non-Saudis) and area of residence (urban vs. rural) so these sub-groups were examined separately.

In terms of CL awareness, the results showed that there were not that many significant differences between cases and controls as the general awareness level was very poor. However, differences were observed in awareness of disease seasonality and in taking protective measures against sandflies with controls being better informed than cases in all population classes. Also, the data indicated that CL controls, Saudis and people in urban areas had higher awareness of CL in general than CL cases, non-Saudis and people in rural areas. Regarding housing condition, the answers of cases and controls were found to be significantly different in terms of availability of livestock, the locations they were kept in, the presence of vegetation within household boundaries and the methods of disposing of house wastes. Similar to awareness, CL cases, non-Saudis and people in rural areas were found living in housing conditions that were more associated with the prevalence of CL than CL controls, Saudis and people in urban areas respectively.

The five socio-economic and demographic variables most strongly associated with the incidence of CL were combined with the highlighted land uses and covers from Chapter Six in some multivariate modelling. These models were applied to four different population subsets based on nationality and areas of residence. Based on nationality, the presence of livestock was significantly associated with the incidence of CL for both Saudis and non-Saudis but with much stronger influence upon non-Saudis than Saudis. Distance from livestock and vegetation cover were also found strongly associated with the disease for both population classes with closer people at higher risk of contracting the disease. The presence of vegetation within the household boundaries and the awareness level of CL in the case of Saudis and the use of protective measures against sandflies in the case of non-Saudis were also found to be associated with risk of developing CL.

For area of residence, the multivariate models showed that the presence of livestock and the distance from any type of vegetation were strongly associated with the incidence of CL, with much stronger influence upon people in rural areas compared to urban locations. The presence of vegetation within the household boundaries was found to affect the incidence of CL in urban areas, while the use of protection measures against sandflies and the distance from livestock shelters were strongly associated with CL in rural areas.

Overall, the results suggest that both the local environment and behaviour of residents were found to play an important role in disease incidence. Also, the strongest patterns of risk factors were associated more with non-Saudis than Saudis, and in rural areas compared to in urban ones. However, the contrasts in the highlighted risk factors were much stronger between the areas of residence (urban vs. rural) than between nationality (Saudis vs. non-Saudis). So, it can be suggested that area of residence influences the incidence of CL more than any other socio-economic and demographic factor.

Question 4: Is there evidence of underreporting of CL cases in the study area? If so, do the characteristics of the officially reported cases differ from those that were not reported?

This question was answered in Chapter Eight through an investigation of CL under-reporting in Al-Dawadmi governorate. The first part of the question can be answered briefly; yes there is evidence of un-reported CL cases based on 41 examples found in the time available. The second part was answered by comparing the main characteristics between reported (125 cases) and unreported exposures (41 cases). The comparison covered three main aspects including some socio-economic and demographic factors, level of accessibility and utilization of health services and finally the experience of unreported and reported cases with respect to previous CL exposures.

Considering the socio-economic and demographic characteristics, the level of education was found strongly associated with reporting. The study found that the more people were educated the greater the likelihood that they would report their exposure to the local health authorities. Another factor that was found causing non-reporting was the level of income. Lower income population classes, particularly non-Saudis, were found more likely not to report their exposures because of the expected high travel and treatment costs.

Since the number of dermatologists was comparatively low (8 clinics) and remote people need to travel for some substantial distances, the availability of a convenient transportation method was associated with the probability of reporting. Most PHCCs (65 out of 68) are not equipped to treat CL exposures and no significant association was found between access to these facilities and reporting. However, the distance to PHCCs was found to influence the utilization of such services to some extent with a *P* value of 0.065. The strongest influence of the distribution of health facilities upon utilization was seen in the case of GHs. The majority of unreported CL cases (65%) were located further than 30 km from a GH compared to only 12% of reported cases. Consequently, distance to GHs was found strongly associated with reporting CL exposures at a *P* value of <0.001.

The third comparison between reported and unreported CL cases was regarding their previous exposure to CL. 76% of the reported cases concerned first exposures to CL, while the proportion was only 26.5% for the unreported cases. This indicated that there was some level of dissatisfaction among the unreported cases that have had previous exposure (73.5%). This dissatisfaction was looked at closely, 66%, 26.5% and 7.5% of unreported cases were not happy with the level of accessibility to GHs, could not afford the treatment cost or were not happy with previous treatments respectively. These three dissatisfaction factors were also found among the reported cases as 12 out of 125 said they had not reported some previous exposures for such reasons. Lastly, the role of the location of the ulcer was examined. People were found to be seeking health treatment even if higher cost were involved if the ulcers occurred on visible parts of the body like face and neck as no single unreported case had had the ulcer in such parts. In contrast, people were less concerned if the ulcers occurred on the lower or upper hidden limbs where 95% of unreported cases had their ulcers.

9.2. The Implications of the Study:

The findings from this study may have a variety of implications that can be used in multi-dimensional strategies in order to reduce the prevalence of CL in general and particularly in Al-Dawadmi Governorate. These multi-perspective implications will be discussed at four different levels.

In the first place, weather cannot be controlled, but understanding the association between climate phenomenon and activities by the sandfly vector can be used to reduce the risk of disease occurrences. From this study, the association between climate phenomenon and particularly temperature and precipitation with the incidence of CL is quite clear. Based on this, an early warning system could be provided by the local authorities in the governorate to keep local residents regularly informed about the anticipated sandfly population and activity levels. For example, four risk bands could be defined which are extremely high, high, moderate and low. This information would help local residents manage their day-to-day activities and be aware of the extent to which protection methods are needed in their households. For instance, if the temperature in the previous two or three months was in an ideal range for sandflies to develop and to be active and the amount of rain in the previous one or two months was at a level expected to increase sandfly and rodent activities as well as allowing people to visit outdoor areas then a high risk of developing CL can be announced. Likewise, if the ideal temperature occurs in combination with more than 40 mm or more of rain then the alert level should be raised to extremely high risk as a severe CL outbreak can be anticipated and so forth.

On the second level, local authorities need to work in reducing risky land uses / covers close to settlements in different buffer zones. Settlements' surrounding areas should be free of any type of natural vegetation cover and particularly *Haloxylon salicornicum*, *Citrullus colocynthi*s and *Lycium shawii* which are the most preferable types of natural vegetation for rodents in the study area (Naeem et al., 2000; Yan et al., 2004; Feulner, 2002; Woldewahid, 2003). Creating a 300 metre buffer zone around settlements with no natural vegetation is the suggested minimum distance based on findings from this study. This elimination of natural vegetation is anticipated to reduce food sources for rodents and resting or breeding sites for sandflies which will affect their population and activities. This approach has been used successfully in some other countries and resulted in reductions in the prevalence of CL. For example, natural vegetation cover and rodents burrows in the Northern Jordan Valley in Jordan and Sidi Bouzid town in Tunisia (endemic zones for CL) were removed by deep ploughing the areas around houses. This approach resulted in a dramatic decrease in the CL reservoir and vector population and so the number of CL cases dropped very significantly by almost 90% in Tunisia and by an unstated percentage in Jordon (Anders, 2008; Ben Salah et al., 2007). However, removing natural vegetation around all communities might be ecologically unacceptable for local people and also very expensive to do and maintain. This issue can be overcome by working only on eradicating rodents from the surrounding areas and destroying their burrows. This method was applied in both China and Russia; when they realized controlling sandflies was not possible they turned to destroying rodent burrows and preventing re-colonization which resulted in noticeably reducing CL cases (Stanford University, [no date] c). In respect of other land uses / covers that are hard to remove far such as livestock shelters and farms, local authorities should educate locals about the levels of risk associated with certain distances from different land uses and covers. Also, they should be educated about the best ways to protect their household from sandflies and rodents in the surrounding environments.

The third dimension concerns socio-economic and demographic factors. The main priority should be to improve the awareness of local residents regarding CL seasonality, vector, reservoir, and preferable habitats. From the research findings it was clear that people were poorly aware of these aspects which is likely to be a substantial cause of the high level of CL exposure in the governorate. Local authorities could use schools, colleges, universities, publicity campaigns and local media to raise the awareness. More education effort is needed in rural areas and particularly for non-Saudis that are more vulnerable to developing the disease. Also the level of cleanliness in some remote areas should be improved by the local municipality providing waste disposal containers and collecting them on at least a weekly basis.

Another aspect that needs to be improved is to make people more aware of the importance of using protection measures against sandflies and rodents. All residents, particularly in rural areas and non-Saudis who have lower neighbourhood cleanliness combined with generally poorer housing condition should be encouraged to use more protection methods against sandflies. Also, local authorities should inform people about the best protection methods as sandflies differ from other insect species in terms of size, attractive habitats and periods of the year where they are most active. It would be also be helpful if protective methods were made more affordable since prevention is better than cure.

The final aspect that needs to be considered is the degree of CL underreporting in the governorate. Because of this issue, the real size of problem in the governorate is unknown and endemic areas for the disease might be ignored. From this research, local residents' dissatisfaction with the provided health services is the main reason for not reporting exposures. Dissatisfaction about travel distance should be minimized by increasing the number of dermatologists in the governorate especially in deprived areas such as Al-Fegarah and Afgrah. Also, many non-Saudis do not report their exposures because of the relatively high cost of treatment. The Ministry of Health should consider the issue of cost and exclude CL exposed non-Saudis in the treatment cost scheme. This extension of coverage would be really beneficial in the long term as it will help local authorities better understand the epidemiology of the disease in the governorate which is basis for improving eradication strategies.

Overall, a key conclusion from this study is that both natural hazards and human factors were found to influence the incidence of CL. Climate conditions cannot be controlled, but prevention strategies can be applied to reduce the influence of the climate. This can be achieved by making people aware of the disease seasonality throughout an early warning system. Another natural hazard is the highlighted types of land uses / covers such as natural vegetation cover. Trying to change or maintain the land use is not the best solution as it will be very expensive and probably will not be totally effective. So, it is believed that it would be very beneficial if local residents had better awareness about CL seasonality, vector, reservoir and habitats. This action should help positive behaviour changes so that fewer CL exposures occur.

9.3. Limitations of the Study:

During this study, several difficulties were encountered. These difficulties occurred at several stages including data availability, requesting access to CL report forms, the landscape digitizing exercise and interviewing people. All these difficulties are discussed below.

Generally speaking, access to data is limited in Saudi Arabia, especially for academic use. The main difficulties faced by the researcher in this work can be summarised in following points:

- Most, if not all, of the governmental and non-governmental institutions in Saudi Arabia follow very long bureaucratic procedures for data access.
- Most of the provided data were in a hard copy format requiring additional work to transform them into digital formats.
- Most of the available data were not up-to-date which affected the depth and accuracy of the study.
- Some institutions only allowed reviewing their data inside their premises or library and borrowing or copying was not allowed at all.
- Some important data, such as comprehensive census data for Al-Dawadmi governorate, could not be found which limited how certain aspects could be further investigated.

The process of having permission to access CL reporting forms was the longest and most complicated part of the data collection process. It started by submitting the request to the

Ministry of Health office in Al-Dawadmi Governorate, then going throughout five other different departments and committee meetings at the Ministry of Health, ending up with the Associate Agency for Preventive Health that approved the request and provided the data. All these procedures took more than five months to be completed and without such data the research would not have been possible.

Regarding the digitizing exercises, difficulties were experienced due to the nature of the governorate and the time when the field work took place, these were:

- The landscape digitizing exercises were carried out between the end of May and early August 2012 which is a very hot period of the year where the temperature can reach up to 57 ℃ under the sun in the afternoon, making the long time period required for digitizing in the outdoors very risky due to possibilities of heatstroke and acute dehydration.
- As most of the areas around settlements are privately owned land and farms, it took a long time to get permission to access these fenced areas and to discover the nature of the land use / land cover patterns inside.
- Some parts of the governorate were difficult to access or impassable on foot or even with a normal car, forcing the research team to hire four-wheel-drive vehicle for some days.
- Some residents in rural areas were not comfortable with the digitizing team working in their locality which resulted in many disruptions and some limitations on detail and accuracy.

Difficulties encountered while interviewing people were:

- Locating people who had reported CL was not easy, as no postcode system exists in the country to date. Some records had descriptive addresses of their houses which required a lot of time to locate.
- Hospitality shown by the local population increased the interviewing time to some extent as normally people would only answer questions after serving the interview team with some welcoming coffee or tea and in some cases a large feast and turning down their hospitality would have been culturally inappropriate.

- Some of the interviewed locals were actually misdiagnosed with CL. Normally, this situation only became apparent with their answers to questions regarding their symptoms and healing period.
- Interviewing adult females was very difficult for cultural reasons, especially in the case of the Bedouins and conservative people. This social obstacle forced the interviewing team to be selective in interviewing which influenced the coverage of the study to a certain extent.
- Respondents varied in their co-operation with the research. Some interviewed people did not finish the questionnaire and withdrew when they considered that some questions, such as relating to occupation, information about the female members or income were getting too personal.
- Communication with non-Arabic or non-English speakers was quite difficult which led to longer time requirements for explanation.
- Unpunctuality of the interviewee.

All these difficulties were anticipated to some degree at the beginning of the research and some complications are justifiable, especially the procedures required to have access to CL reporting forms as they include lots of personal information like national ID number, address, occupation, housing type and details about family members. Nevertheless, the difficulties were considerable and without co-operation and help from several ministries and local residents the research would not have been completed.

9.4. Scope of Future Studies:

Further research should extend the investigation of the prevalence of CL in Al-Dawadmi governorate. Possible projects include the following:

- In Al-Dawadmi Governorate, the local authority decided in October 2013 to remove the main livestock market (approximately 60 shelters) from the southern part of Al-Dawadmi City which was within about 200 metres of the settlements to a newly built market 5 km further south west of the city (see Appendix L 1 and 2). This removal of one of the main causes of the disease incidence in the city is likely to change the exposure rate significantly and more investigation could be carried out on this aspect.

- In recent years, the local authority and the Ministry of Health in Al-Dawadmi Governorate have been working on improving awareness among the local residents about the CL vector, reservoir and preferable habitats by means of awareness campaigns, schools and smart device apps (see Appendix M). The effects of these efforts on the exposure rate in the governorate needs to be studied again and compared with the results of this study.
- The local municipality of Al-Dawadmi Governorate has also started including some farms close to settlements with additional services. This step started by making and distributing new waste containers free of charge (see Appendix N). This action is believed to have increased the level of cleanliness and hygiene in such areas and the new exposure rates could be compared with the main findings of this study**.**
- From June 2013 the Field Epidemiology Training Program (FETP) started distributing some protective materials against sandflies on request. These materials include liquid sandfly killer and rat traps for low socio-economic classes like farmers and shepherds (see appendix O). Such protective measures might result in reducing the number of exposures among such population classes. The impact of this intervention merits further investigation.
- As sandflies are very adaptable species, they might get used to the ecological changes. So more studies are needed to investigate other undiscovered possible habitats. This could be achieved by using sandfly traps around suspected land use / land cover patterns.
- With the issue of climate change, the identified association between sandflies and climate variables might change over time. So, further investigations are required after a few years in Al-Dawadmi Governorate.

Although this study has certain limitations, the researcher believes that the main findings from it are relevant from a public health perspective to better understand the epidemiology of CL. The study has confirmed the complexity of the disease as it is sensitive to climate variables, affected by the local environment and strongly associated with socio-economic and demographic variables. The findings of the research are also applicable to similar CL endemic areas in Saudi Arabia, particularly Al-Qaseem, Hael, Medinah and Al-Ahsa regions that share similar climate conditions, landscape and population characteristics and should therefore help to inform measures that would help reduce the prevalence of CL in Saudi Arabia.

References

ABPI (The Association of the British Pharmaceutical Industry), [No date]. *Pathogens cause disease.* [Online]
Available at:
http://www.abpischools.org.uk/page/modules/infectiousdiseases_pathogens/pathogens7.cfm?coSiteNavigation_allTopic=1
[Accessed 13 5 2014].

Abranches, P., Lopes. F. J., Silva, F. M., Ribeiro, M. M. & Pires, C. A.,1983. Kala-azar in Portugal. III. Results of a survey on canine Leishmaniasis performed in the Lisbon region. Comparison of urban and rural zones. *Ann Parasitol Hum Comp,* **58**(4), pp. 307-315.

Acha, P. N. & Szyfres, B., 1989. *Zoonoses et maladies trasmissibles communes à l'homme et aux animaux.* Paris: Office International des Epizooties.

ACPHD (Alameda County Public Health Department), [No date]. *Communicable Disease.* [Online]
Available at: http://www.acphd.org/communicable-disease.aspx
[Accessed 2 7 2014].

Adler, N. b., Boyce, T., Chesney, M., Folkman, S. & Syme, S., 1993. Socioeconomic inequalities in health: No easy solution. *Journal of the American Medical Association,* **269**(24), p. 3140–3145.

Adler, S. & Theodor, O., 1957. Transmission of disease agents by phlebotomine sand flies. *Annual Review of Entomology,* **2**, pp. 203-226.

AFPMB (Armed Forces Pest Management Board), 2014. *Armed Forces Pest Management Board.* [Online]
Available at: http://www.flickr.com/photos/afpmb/
[Accessed 3 3 2014].

Ahmadi, N. A., Modiri, M. & Mamdohi, S., 2013. First survey of cutaneous Leishmaniasis in Borujerd county, western Islamic Republic of Iran. *East Mediterr Health J,* **19**(10), pp. 847-853.

Ahmad, I., Owais, M., Shahid, M. & Aqil, F., 2010. *Combating Fungal Infections: Problems and Remedy.* New edition ed. New York: Springer.

Alahmed, A. M. & Al-Dawood, A. S., 2001. Rodents and their ectoparasites in Wadi Hanifah, Riyadh City, Saudi Arabia.. *J Egypt Soc Parasitol,* **31**(3), pp. 737-743.

Albejaidi, F. M., 2010. Healthcare System in Saudi Arabia: An Analysis of Structure, Total Quality Management and Future Challenges. *Journal of Alternative Perspectives in the Social Sciences,* **2**(2), pp. 794-818.

Al-Dahhan, A., Alzahrani, M. & Emarah, S., 2012. *Leishmaniasis* [Interview] (19 6 2012).

Al-Dawadmi Governorate' website, 2010. *Information about the governorate.* [Online]
Available at: http://www.alduwadimi.gov.sa/Pages/TheGovernor.aspx
[Accessed 7 11 2012].

Alriyadh.gov (Alriyadh Governorate), 2008. *Riyadh's climate.* [Online]
Available at: http://urbplandep.alriyadh.gov.sa/ARA/art.asp?id=30
[Accessed 7 10 2012].

Alexander, B., 2000. Sampling methods for phlebotomine sandflies. *Med Vet Entomol,* **14**(2), pp. 109-122.

Alexander, B., Agudelo, L. A., Navarro, F., Ruiz, F., Molina, J., Aguilera, G. & Quiñonez, M.L., 2001. Phlebotomine sandflies and Leishmaniasis risk in Colombian coffee plantations under two systems of cultivation. *Med Vet Entomol*, **15**, pp. 364-373.

Alexander, B. & Young, D., 1992. Dispersal of phlebotomine sand flies (Diptera: Psychodidae). *Mem Inst Oswaldo Cruz,* **403**, pp. 378-379.

Alexander, J. B., 1987. Dispersal of phelobotomine sand flies (Diptra: Psychodidae) in a Colombian coffee plantation. *J. Med. Entomol*, **24**, pp. 552-558.

Aliro, E., Getaz, L., Stoll, B., Chappuis, F. & Loutan, L., 2010. Urbanisation and infectious diseases in a globalised world. *Lancet Infect Di*, **10**, pp. 131-141.

Al-Shahrani, H., 2004. *The Accessibility and Utilization of Primary Health Care Services in Riyadh, Kingdom of Saudi Arabia.* Norwich: University of East Anglia.

Alvar, J., Velez, I, D., Bern, C., Herrero, M., Desjeux, P., Cano, J., Jannin, J. & Den Boer, M., 2012. Leishmaniasis Worldwide and Global Estimates of Its Incidence. *plosone,* **7**(5), pp. 1-12.

Alvar, J., Yactayo, S. & Bern, C., 2006. Leishmaniasis and poverty.. *Trends Parasitol*, 22(12), pp. 552 - 557.

Analysights, 2011. *Posts Tagged 'autocorrelation'.* [Online]
Available at: https://analysights.wordpress.com/tag/autocorrelation/
[Accessed 9 4 2013].

Anders, G., 2003. *PCR Diagnosis of Leishmaniasis in Israel and the West Bank.* Berlin: Universität zu Berlin.

Annimer, A., 992. *State health centres services in Khartoum: their development, and spatial distribution.* Riyadh: King Saud University.

Armstrong, G., 1999. Trends in Infectious Disease Mortality in the United States During the 20th Century. *The Journal of the American Medical Association,* **281**(1), pp. 61-66.

Ashford, D., David, J. R., Freire, M., David, R. & Sherlock, I., 1998. Studies on control of visceral Leishmaniasis: impact of dog control on canine and human Visceral Leishmaniasis in Jacobina, Bahia, Brazil. *he American journal of tropical medicine and hygiene*, **59**, pp. 53-57.

Ashford, R. W., 1996. Leishmaniasis reservoirs and their significance in control. *Clin. Dermato,* **14**, p. 523–532.

Ashwan, M. S. S., 1990. *The population growth of Riyadh city in Saudi Arabia.* Durham,: University of Durham.

Athas, W. F., Adams-Cameron, M., Hunt, W. C. & Amir-Fazli, A., 2000. Travel distance to radiation therapy and receipt of radiotherapy following breast conserving surgery. *J Natl Cancer Inst,* **92**, pp. 269-271.

Australasian National Statistical Service, [No date] *Sample size calculation.* [Online] Available at: www.nss.gov.au
[Accessed 27 1 2013].

Balasegaram, M., Balasegaram, S., Malvy, D. & Millet, P., 2008. Neglected Diseases in the News: A Content Analysis of Recent International Media Coverage Focussing on Leishmaniasis and Trypanosomiasis. *Neglected tropical diseases,* **2**(5), pp. 1-5.

Baltagi, B. H., 2008. *Econopmetric Analysis of Panel Data, Forth ed.* New York: John Wiley.

Baltagi, B. H. & Li, Q., 1991. A Transformation That Will Circumvent the Problem of Autocorrelation in an Error Component Model. *Journal of Econometrics,* **48**, pp. 385-393.

Barnes, D. S., 1995. *The Making of a Social Disease: Tuberculosis in Nineteenth-Century France.* New edition ed. Berkeley: University of California Press.

Barnett, P. G., Singh, S. P., Bern, C., Hightower, A. W. & Sundar, S., 2005. Virgin soil: the spread of Visceral Leishmaniasis into Uttar Pradesh, India. *Am J Trop Med Hyg,***73**, pp. 720-725.

Basu, S., [No date]. *Eradicating Malaria in Poor Nations:The Potential of Vector Control Measures and Vaccine Development.* [Online]

Available at: http://www.africantechnologyforum.org/MalariaHTML.htm
[Accessed 2 7 2014].

Beier, J.C., Sawaf, B. M., El Merdan, A. I., El Said, S. & Doha, S., 1986. Sand Flies (Diptera: Psychodidae) Associated with Viscral Leishmaniasis in El Agamy, Alexandria Governorate, Egypt. *Journal of Medical Entomology,* **23**(6), pp. 600-608.

Belal, A. M. & Al-Hinai, H. G., 2009. Community-Based Initiatives for prevention of non-communicable diseases: Nizwa Healthy Lifestyle Project planning and implementation experience in Oman.. *Sudanese journal of public health,* **4**(1), pp. 225-228.

Belsky, A. J., 1989. Landscape Patterns in a Semi-Arid Ecosystem in East Africa. *Journal of Arid Environments,* **17**(2), pp. 265-270.

Ben Salah, A. B., Ben Ismail, F., Amri, S., Chlif, F., Ben Rzig, H., Kharrat, H., Hadhri, M &. Dellagi, K., 2000. Investigation of the spread of human Visceral Leishmaniasis in central Tunisia. *Trans. R. Soc. Trop. Med. Hyg,* **94**, pp. 382-386.

Bentley, M. D. & Day, J. F., 1989. Chemical Ecology and Behavioral Aspects of Mosquito Oviposition. *Annual Review of Entomology,* **34**, pp. 401-421.

Bern, C., Joshi, A. B., Jha, S. N., Das, M. I., Hightower, A. & Thakur, G. D., 2000. Factors associated with Visceral Leishmaniasis in Nepal: bednet use is a strongly protective. *American Journal of Tropical Medicine and Hygiene,* **63**(3-4), pp. 184-188.

Bettencourt, B. A., Schlegel, R. J., Talley, A. E. & Molix, L. A., 2007. The breast cancer experience of rural women: a literature review. *Psycho-oncology,* **16**(10), pp. 875-887.

Bhar, L. M., [No date]. *Multicollinearity: causes, effects and remedies.* [Online] Available at: http://www.iasri.res.in/seminar/AS-299/ebooks%5C2005-2006%5CMsc%5Ctrim2%5C3.%20Multicollinearity-%20Causes,Effects%20and%20Remedies-Ranjit.pdf
[Accessed 9 1 2013].

Biraben, J. N. & Goff, J. L., 1975. *The plague in the early middle ages.* Baltimore: The Johns Hopkins University Press.

Black, K., 2007. *Business Statistics: Contemporary Decision Making.* New York: John Wiley & Sons.

Bonita, R., Beaglehole, R. & Kjellstrom, T., 2006. *Basic Epidemiology.* 2nd ed. Geneva: World Health Organization.

Bounoua, L., Kahime, K., Houti, L., Blakey, L., Ebi, K. L., Zhang, P., Imhoff, M. L., Thome, K. J., Dudek, C., Sahabi, S. A., Messouli, M., Makhlouf, B., El-Laamrani, A. & Boumezzough, A., 2013. Linking Climate to Incidence of Zoonotic Cutaneous Leishmaniasis (L. major) in Pre-Saharan North Africa. *Int J Environ Res Public Health*, **10**(8), p. 3172–3191.

Boussaa, S., Guernaoui, S., Pesson, B. & Boumezzoug, A., 2005. Seasonal fluctuations of phlebotomine sand fly populations (Diptera: Psychodidae) in the urban area of Marrakech, Morocco. *Acta Trop,* **95**, p. 86–91.

Boussery, G., Boelaert, M., Peteghem, V., Ejikon, P. & Henckaerts, K., 2001. Visceral Leishmaniasis (kala azar) outbreak in Somali refugees and Kenyan shepherds, Kenya. *Emerg Infect Dis,* **7**, pp. 603-604.

Bower, S. M., McGladdery, S. E. & Price, L. M., 1994. Synopsis of infectious diseases and parasites of commercially exploited shellfish. *Annual Review of Fish Diseases,* **4**, pp. 1-199.

Braverman, Y., 1994. Nematocera (Ceratopogonidae,Psychodidae, Simuliidae and Culicidae) and control methods. *Revue Scientifique Et Technique De L`office International Des Epizooties,* **13**(4), pp. 1175-1199.

Breslow, N. E. & Day, N. E., 1980. *Statistical Methods in Cancer Reseach.* Lyon: IARC Scientific Publications.

Brown, D., 2011. Noncommunicable diseases may prove harder to control than other ailments. *The Washington Post*, 19 9, p. 1.

Budd, G., 1857. *On disease of the liver. First* ed. London: Churchikk.

Büttiker, W. & Lewis, D. J., 1983. Insects of Saudi Arabia some ecological aspects of Saudi Arabian Phlebotomine sand flies (Diptera: Psychodidae). *Fauna Saudi Arabia,* **5**, pp. 479-530.

Buja, A. Cook, D., Hofmann, H., Lawrence, M., Lee, E. K., Swayne, D. F. & Wickham, H., 2009. Statistical Inference for exploratory data analysis and model diagnostics Phil. *Phil. Trans. R. Soc. A*, **367**, pp. 4361-4383.

Bunnett, W. D., 1979. location – Allocation study for primary health care centres: A survey of Doctored and un-Doctored population in the Lansing ,Michigan Area. *Journal Royal of Health,* pp. 164-171.

Byrne, J. P., 2012. *Encyclopedia of the Black Death.* First edition ed. Santa Barbara: ABC-CLIO.

Byron, C., Correa, M. A., Tesh, R. B. & Johnson, K. M., 1974. Horizontal and vertical movements of Phlebotomine sandflies in a Panamanian rain forest. *Journal of Medical Entomology,* **11**(3), pp. 369-375.

Calvet, F. E., Jmoaa, I., Zaafouri, B., Ashford, R. W., Ben-Ismail, R. & Delattre, P., 2000. The spatio-temporal distribution of a rodent reservoir host of Cutaneous Leishmaniasis. *Journal of Applied Ecology,* **37**, pp. 603-615.

Calvopina, M., Gomez, E. A., Sindermann, H., Cooper, F. J. & Hashiguchi, Y., 2006. Relapse Of New World Diffuse Cutaneous Leishmaniasis Caused By Leishmania (Leishmania) Mexicana After Mil Ttefosine Treatment. *Am J Trop Med Hyg,* **75**(6), pp. 1074 - 1077.

Cardenas, R., Sandoval, C. M., Rodríguez-Morales, A. J. & Franco-Paredes, C., 2006. Impact of climate variability in the occurrence of Leishmaniasis in northeastern Colombia. *Am J Trop Med Hyg,* **75**(2), pp. 273-277.

Carpenter, P. A. & Bishop, P. C., 2009. A review of previous mass extinctions and historic catastrophic events. *Futures,* **41**(10), p. 676–682.

Casanova, C., Costa, A. I. & Natal, D., 2005. Dispersal pattern of the sand fly Lutzomyia neivai (Diptera: Psychodidae) in a cutaneous Leishmaniasis endemic rural area in Southeastern Brazil. *Mem Inst Oswaldo Cruz,* **100**(7), pp. 719-724.

Casanova, C., Mayo, R. C., Rangel, O., Mascarini, L. M., Pignatti, M. G., Galati, E. B. A. & Gomes, A. C., 1995. Natural Lutzomyia intermedia (Lutz & Neiva) infection in the Valley of Mogi-Guaçu River, State of São Paulo, Brazil.. *Bol Dir Malariol y San Amb,* **35**(1), pp. 77-84.

CDC (Centers for Disease Control and Prevention), 2003. *Vital Statistics of the United States: 1980-2003.* [Online]
Available at: http://www.cdc.gov/nchs/data/TechApp03_1-09.pdf
[Accessed 14 7 2014].

CDC (Centers for Disease Control and Prevention), 2012a. *Malaria.* [Online]
Available at: http://www.cdc.gov/malaria/about/history/uscurves.html
[Accessed 2 7 2014].

CDC (Centers for Disease Control and Prevention), 2012. *Glossary of Terms.* [Online]
Available at: http://www.cdc.gov/hantavirus/resources/glossary.html
[Accessed 13 5 2014].

CDC (Centers for Disease Control and Prevention), 2013b. *Parasites - Leishmaniasis.* [Online]

Available at: http://www.cdc.gov/parasites/Leishmaniasis/biology.html
[Accessed 9 8 2013].

CDC (Centers for Disease Control and Prevention), 2013c. *Leishmaniasis FAQs.* [Online]
Available at: http://www.cdc.gov/parasites/Leishmaniasis/gen_info/faqs.html
[Accessed 18 3 2014].

CDC (Centers for Disease Control and Prevention), 2014a. *World Health Day – Vector-Borne Diseases.* [Online]
Available at: http://www.cdc.gov/features/worldhealthday2014/
[Accessed 1 7 2014].

CDC (Centers for Disease Control and Prevention), 2014b. *Impact of Malaria.* [Online]
Available at: http://www.cdc.gov/malaria/malaria_worldwide/impact.html
[Accessed 14 5 2014].

CDC (Centers for Disease Control and Prevention), 2014c. *Malaria.* [Online]
Available at: http://www.cdc.gov/malaria/about/facts.html
[Accessed 9 8 2014].

CDC (Centers for Disease Control and Prevention), 2014d. *Parasites - Leishmaniasis.* [Online]
Available at: http://www.cdc.gov/parasites/Leishmaniasis/health_professionals/
[Accessed 1 8 2014].

CDC (Centers for Disease Control and Prevention), 2014e. *Resources for Health Professionals.* [Online]
Available at: http://www.cdc.gov/parasites/Leishmaniasis/health_professionals/
[Accessed 3 3 2014].

CDC (Centers for Disease Control and Prevention), 2013a. *Parasites - Leishmaniasis.* [Online]
Available at: http://www.cdc.gov/parasites/Leishmaniasis/
[Accessed 5 5 2014].

CDSI (Central Department of Statistics and Information), 1974. *Annual Statistics Book.* [Online]
Available at: http://www.cdsi.gov.sa/2010-08-08-05-41-26
[Accessed 2 12 2013].

CDSI (Central Department of Statistics and Information), 1980. *Annual Statistics Book.* [Online]
Available at: http://www.cdsi.gov.sa/pdf/yb16-20.rar
[Accessed 9 12 2012].

CDSI (Central Department of Statistics and Information), 1985. *Annual Statistics Book.* [Online]
Available at:
http://www.cdsi.gov.sa/english/index.php?option=com_content&view=article&id=84&Itemid=172
[Accessed 4 11 2012].

CDSI (Central Department of Statistics and Information), 1992. *Annual Statistics Book.* [Online]
Available at: http://www.cdsi.gov.sa/2010-08-08-05-41-26
[Accessed 2 12 2013].

CDSI (Central Department of Statistics and Information), 1995. *Annual Statistics Book.* [Online]
Available at:
http://www.cdsi.gov.sa/english/index.php?option=com_content&view=article&id=84&Itemid=172
[Accessed 9 11 2012].

CDSI (Central Department of Statistics and Information), 2000. *Annual Statistics Book.* [Online]
Available at:
http://www.cdsi.gov.sa/english/index.php?option=com_content&view=article&id=84&Itemid=172
[Accessed 10 12 2012].

CDSI (Central Department of Statistics and Information), 2003. *Annual Statistics Book.* [Online]
Available at:
http://www.cdsi.gov.sa/english/index.php?option=com_content&view=article&id=84&Itemid=172
[Accessed 9 11 2012].

CDSI (Central Department of Statistics and Information), 2005. *Annual Statistics Book.* [Online]
Available at: http://www.cdsi.gov.sa/2010-08-08-05-41-26
[Accessed 2 12 2013].

CDSI (Central Department of Statistics and Information), 2009. *Annual Statistics Book.* [Online]
Available at:
http://www.cdsi.gov.sa/english/index.php?option=com_content&view=article&id=84&Itemid=172
[Accessed 10 11 2012].

CDSI (Central Department of Statistics and Information), 2010. *Annual Statistics Book.* [Online]
Available at: http://www.cdsi.gov.sa/2010-08-08-05-41-26
[Accessed 2 12 2013].

CDSI (Central Department of Statistics and Information), 2011. *Annual Statistics Book.* [Online]
Available at: http://www.cdsi.gov.sa/yb47/
[Accessed 14 12 2012].

CDSI (Central Department of Statistics and Information), 2012a. *The Detailed Results of Housing Census by Administrative Area.* [Online]
Available at: http://www.cdsi.gov.sa/2010-07-31-07-00-05/doc_download/1454-----1431-2010---
[Accessed 16 11 2013].

CDSI (Central Department of Statistics and Information), 2012. *Annual Statistics Book.* [Online]
Available at: http://www.cdsi.gov.sa/2010-08-08-05-41-26
[Accessed 10 6 2013].

CDSI (Central Department of Statistics and Information), 2013. *Annual Statistics Book.* [Online]
Available at: http://www.cdsi.gov.sa/2010-03-23-04-53-18/326-nday34
[Accessed 23 7 2013].

Chahed, M. K., 2010-2011. *Addressing Leishmaniasisin Tunisia's changing climate,* Tunisia: Climate Change Adaptation in Africa Program.

Chance, M. L., 1995. New developments in the chemotherapy of Leishmaniasis. *Annals of Tropical Medicine and Parasitology,* **89**, pp. 37-42.

Chaniotis, B. N., Correa, M. A., Tesh, R. D. & Johnson, K. M., 1974. Horizontal and vertical movements of phlebotomine sand flies in a Panamanian rain forest. *J Med Entomol,* **11**, pp. 363-375.

Chaniotis, B. & Tselentis, Y., 1996. Water wells as a habitat of sand fly (Diptera: Psychodidae) vectors of Visceral Leishmaniasis in Greece. *J Med Entomol,* **33**(2), pp. 269-270.

Chappuis, F., Sundar, S., Hailu, A., Ghalib, H., Rijal, S., Peeling, R. W., Alvar, J. & Boelaert, M., 2007. Visceral Leishmaniasis: what are the needs for diagnosis, treatment and control?. *Nature reviews no* 11, **5**, pp. 57-66.

Chatterjee, S. & Hadi, A. S., 2013. *Regression Analysis by Example (Wiley Series in Probability and Statistics).* 5th edition ed. New York: Wiley.

Chaudhary, S. A., 1999. *Flora of the Kingdom of Saudi Arabia.* New edition ed. Riyadh: Ministry of Agriculture and Water.

Chaves, L. F. & Pascual, M., 2006. Climate Cycles and Forecasts of Cutaneous Leishmaniasis, a Nonstationary Vector-Borne Disease. *journal pmed,* **3**(8), pp. 1320-1328.

CIESIN (Center for International Earth Science Information Network), [No date]. *hanges in the incidence of vector-borne diseases attributable to climate change.* [Online]
Available at: http://www.ciesin.org/TG/HH/veclev2.html
[Accessed 1 7 2014].

Claborn, D. M., 2014. *Leishmaniasis - Trends in Epidemiology, Diagnosis and Treatment.* Rijeka: InTech.

Claborn, D., Masuoka, P., Morrow, M. & Keep, L., 2008. Habitat analysis of North American sand flies near veterans returning from leishmania-endemic war zones. *International Journal of Health Geographics,* 7(65), pp. 1 - 8.

Cornwell, J., 1984. *Hard Earned Lives. Accounts of Health and Illness from East London.* New ed. London: Tavistock.

Connelly, C. R., 2005. *University of Florida, Entomology and Nematology Department.* [Online]
Available at: http://entnemdept.ufl.edu/creatures/aquatic/biting_midges.htm
[Accessed 22 1 2013].

Coombes, Y. J., 1993. *A Geography of the New Public Health.* London: Queen Mary & Westfield College, University of London.

Cortes, S., Odete, A. M., Campino, A. & Campino, L., 2007. Stray dogs and Leishmaniasis in urban areas, Portuga. *Emerg. Infect. Dis,* **13**, pp. 1431-1432.

Croft, S. L., Sundar, S. & Fairlamb, A. H., 2006. Evolutionary and geographical history of the Leishmania donovani complex with a revision of current taxonomy. *Clinical Mirobiology Reviews,* 19(1), p. 111–126.

Cox, F. E., 2002. History of Human Parasitology. *Clin. Microbiol.,* **15**(4), pp. 595 - 612.

Croft, S. L. & Coombs, G. H., 2003. Leishmaniasis - current chemotherapy and recent advances in the search for novel drugs. *Trends Parasitol,* **19**, pp. 502-508.

Cross, E. R. & Hyams, K. S., 1996. The potential effect of global warming on the geographic and seasonal distribution of Phlebotomus papatasi in southwest Asia. *Environ Health Perspect,* **104**(7), p. 724–727.

Crown, W. H., 1998. *Statistical Models for the Social and Behavioral Sciences: Multiple Regression and Limited-Dependent Variable Models.* First ed. Westport: Praeger Publishers.

Crum-Cianflone, N. F., 2008. Bacterial, Fungal, Parasitic, and Viral Myositis. *Clin Microbiol Rev,* **21**(3), p. 473–494.

Curson, P., 1984. *Geography Epidemiology, and Human Health in Clarke J J (Ed) Geography and Population.* New ed. Oxford.: Pergamon Press.

Davies, C. L., Llanos-Cuentas, E. A. & Campos, P., 2000. Spraying houses in the Peruvian Andes with lambda-cyhalothrin protects residents against cutaneous Leishmaniasis. *Trans R Soc Trop Med Hyg,* **94**, p. 631–636.

Davies, C. R., Kaye, P., Croft, S. L. & Sundar, S., 2003. Leishmaniasis: New approaches to disease control. *JBM,* **326**, pp. 377-382.

De Long, L. & Burkhart, N., 2013. *General and Oral Pathology for the Dental Hygienist.* New York: Lippincott Williams & Wilkins.

Deloria, P. & Salisbury, N., 2004. *A Companion to American Indian History.* New edition ed. New York: Wiley-Blackwell.

Department of Defence in USA., 2001. *Regional Disease Vector Ecology Profile: Central Europe.* Washington: DIANE Publishing.

Derryberry, R. D., Conover, S. B. & Conover, W. J., 2010. Teaching Rank-Based Tests by Emphasizing Structural Similarities to Corresponding Parametric Tests. *Journal of Statistics Education,* **18**(1), pp. 1-19.

Derryberry, R. D., Conover, S. B. & Conover, W. J., 2010. Teaching Rank-Based Tests by Emphasizing Structural Similarities to Corresponding Parametric Tests. *Journal of Statistics Education,* 18(1), pp. 1-19.

Desjeux, P., 2004. Leishmaniasis: current situation and new perspectives. *Comparative Immunology, Microbiology & Infectious Diseases,* **27**(5), p. 305–318.

Despommier, D. D., Robert, W., Hotez, G. & Hotez, P., 1994. *Parasitic Diseases: Third Edition.* New York: Springer-Verlag.

Dhiman, R. C., Shetty, P. S. & Dhanda, V., 1983. Breeding habitats of phlebotomine sandflies in Bihar, India. *Indian Journal of Medical Research,* 77(1), pp. 29-32.

Dodani, S., Mistry, R., Khwaja, A., Farooqi, M. & Qureshi, R., 2005. Prevalence and awareness of risk factors and behaviors of coronary heart disease in an urban population of Karachi, the largest city of Pakistan: a community survey. *J Public Health*, **27**, pp. 309-310.

Doha, S. A. & Samy, A. M., 2010. Bionomics of phlebotomine sand flies (Diptera: Psychodidae) in the province of Al-Baha, Saudi Arabia. *Mem Inst Oswaldo Cruz,* **105**(7), pp. 850-856.

Doha, S., Shehata, M. G., El Said, S. & El Sawaf, B., 1991. Dispersal of Phebotomus papatasi (Scopoli) and P. langeroni Nitzulescu in El Hammam, Matrouh Governorate, Egypt. *Ann Parasitol Human Comp,* **76**, p. 66.69.

Donovan, J., 1986. *We Don't Buy Sickness, It Just Comes.* New ed. Aldershot: Gower.

Dossin, F.M., Dufour, A., Dusch, E., Siqueira-Neto, J. L. & Moraes, C. B., 2008. Automated nuclear analysis of Leishmania major telomeric clusters reveals changes in their organization during the parasite's life cycle. *PLoS One,* **3**(6), pp. 1-16.

Doyle, T. J., Glynn, M. K. & Groselclose, S. L., 2002. Completeness of notifiable disease reporting in the United States: an analytical literature review. *American Journal of Epidemiology,* **155**, pp. 866-874.

Drancourt, M. & Raoult, D., 2002. Molecular insights into the history of plague. *Microbes and Infection,* **4**(1), p. 105–109.

Draper, N. R. & Smith, H., 2003. *Applied regression analysis,.* 3ed edition ed. New York: Wiley,.

Droomers, M. & Westert, G. T. P., 2004. Do lower socioeconomic groups use more health services, because they suffer from more illnesses?. *European Journal of Public Health,* **14**(3), pp. 311-313.

Dryden, M. W., 1988. *Evaluation of certain parameters in the bionomics of Ctenocephalides felis felis.* West Lafayette: Purdue University.

Dryden, M. W., 1993. Biology of fleas of dogs and cats. *Comp Cont Educ Pract Vet,* **15**, pp. 569-579.

Dubin, R. A., 1998. Spatial Autocorrelation: A Primer. *Journal of Housig Economics,* **7**, pp. 304-327.

Dujardin, J. C., Campino, L., Cañavate, C., Dedet, J. P., Gradoni, L., Soteriadou, K., Mazeris, A., Ozbel, Y. & Boelaert, M., 2008. Spread of Vector-borne Diseases and Neglect of Leishmaniasis, Europe. *Emerg Infect Dis,* **14**(7), p. 1013–1018.

Duque, P., Vélez, I. D., Morales, M. & Sierra, D., 2004. Sand flies fauna involved in the transmission of cutaneous Leishmaniasis in Afro-Colombian and Amerindian communities of Choco, Pacific Coast of Colombia. *Neotropical Entomology,* **33**(2), pp. 255-264.

Durić, P. & Ilić, S., 2012. Participation of infectious disease surveillance in primary health care. *Sri Lanka Journal of Infectious Diseases,* **2**(2), pp. 37-46.

Dye, C., Davies, C. R. & Lainson, R., 1991. Comunication among phlebotomine sandflies: a field study of domesticated Lutzomyia longipalpis populations in Amazonian BraziL. *Anim Behav,* **42**, pp. 183-192.

EI-Badry, A. A., Eassa, A. H. A. & EI-Kheir, D. I., 2008. Nocturnal Activity and Biting Rhythm of Sand Flies (Diptera; Psychodidae)in AI-Agool, AI-Madinah AI-Munawarah, Saudi Arabia. *Parasitologists United Journal,* **1**(2), pp. 93-100.

El Naiem, D. A. & Ward, D. R., 1990. An oviposition pheromone on the eggs of sandflies (Diptera: Psychodidae). *Trans R Soc Trop Med Hyg,* **5**, pp. 87-91.

El Shabrawi, A., 1992. A study of Patient satisfaction as an evaluation for utilizing health care facilities. *Journal Royal of Health,*, pp. 64-67.

El-Badry, A. A., Al-Juhani, A. M., El-Kheir, D. I. & Al-Zubiany, S. F., 2009. Sand Flies distribution and Bionomics, in Al-Madinah Al-Munawarah. *Journal of Parasitology,* pp. 1-11.

El-Beshbishy, H. A., Al-Ali, K. H. & El-Badry, A. A., 2013. Molecular characterization of cutaneous Leishmaniasis in Al-Madinah Al-Munawarah province, western Saudi Arabia. *International Journal of Infectious Diseases,* **17**(5), pp. 334-338.

Elliott, J., 1863. *Report on epidemic and remittent fever occurring in parts of Burdwan and Neddea divisions,* Calcutta: Bengal Secretarial Office.

El-Sibae, M. M., Eesa, N. M. & Morsy, T. A., 1994. Rodents and cutaneous Leishmaniasis in Qasim, Saudi Arabia. *Journal of the Egyptian Society of Parasitology,* **23**(3), pp. 667-673.

Eyles, J. & Woods, K. J., 1983. *The Social Geography of Medicine and Health.* New ed. London: Croom Helm.

Faber, W. R., Hay, R. J. & Naafs, B. eds., 2013. *Imported Skin Diseases.* Chichester: Wiley-Blackwell.

Faiman, R., Kirstein, O., Freund, M., Guetta, H. & Warburg, A., 2011. Exclusion of phlebotomine sand flies from inhabited areas by means of vertical mesh barriers. *Trans R Soc Trop Med Hyg,* **105**, p. 512–518.

Fairlamb, A., 2012. *CLS Researchers identify Potential New Treatment for Leishmaniasis (Image courtesy of WHO/TDR Image Library).* [Online]
Available at: http://www.lifesci.dundee.ac.uk/news/2013/aug/20/cls-researchers-identify-potential-new-treatment-Leishmaniasis-image-courtesy
[Accessed 3 3 2014].

FAO (Food and Agriculture Organization), [No date]. *The arid environments.* [Online]
Available at: http://www.fao.org/docrep/t0122e/t0122e03.htm
[Accessed 19 1 2012].

Faraj, T. K., 2011. *Influence of Climate Variables upon selected Infectious Diseases in Asir Region, Saudi Arabia.* Norwich(Norfolk): UEA.

Farrar, J., Hotez, P., Junghanss, T., Kang, G., Lalloo, D. & White, N., 2008. *Manson's Tropical Diseases: Expert Consult Basic.* 22 edition ed. Amsterdam: Saunders Ltd.

Farrell, J P;, 2002. *Leishmania (World Class Parasites).* North CArolina: Kluwer Academic Publishers.

Feliciangeli, D. M. & Rabinovich, J., 1998. Abundance of Lutzomyia ovallesi but not Lu. gomezi (Diptera: Psychodidae) correlated with cutaneous Leishmaniasis incidence in north-central Venezuela. *Medical and Veterinary Entomology,* **12**(2), p. 121–131.

Fernando, R. J., Fernando, S. S. & Leong, A. S. Y., 2001. *Tropical Infectious Diseases: Epidemiology, Investigation, Diagnosis and Management.* London: Greenwich Medical Media.

Ferrari, G. R. F., 1990. *Listening to the Cicadas: A Study of Plato's Phaedrus.* New edition ed. Cambridge : Cambridge University Press.

Ferro, C., Cardenas, E., Corredor, D., Morales, A. & Munstermann, L. E.,1998. Life cycle and fecundity analysis of Lutzomyia shannoni (Dyar) (Diptera: Psychodidae). *Memórias do Instituto Oswaldo Cruz,* **93**, pp. 195-199.

Ferro, C., Morrison, A., Torres, M., Pardo, P., Wilson, M. & Tesh, R. B., 1995. Species Composition and Relative Abundance of Sand Flies of the Genus Lutzomyia (Diptera: Psychodidae) at an Endemic Focus of Visceral Leishmaniasis in Colombia. *Journal of Medical Entomology,* **32**(4), pp. 527-537.

Feulner, G., 2002. *Dubai founas.* [Online]
Available at: http://www.enhg.org/Dubai/Gazelle/Mar2002.aspx
[Accessed 14 7 2014].

Fisher, R. A. & Yates, F., 1948. *Statistical tables for biological, agricultural and medical research (3rd ed.).* London: Oliver & Boyd.

Fletcher, R. W. & Fletcher, S. W., 2005. *Clinical Epidemiology: The Essentials.* 4th ed. Baltimore: Lippincott Williams & Wilkins .

Fortney, J. C., Booth, B. M., Blow, F. C. & Bunn, J. Y., 1995. The effects of travel barriers and age on the utilization of alcoholism treatment aftercare. *AmJ Drug Alcohol Abuse,* **21**, pp. 391-406.

Franke, C. R., Ziller, M., Staubach, C. & Latif, M., 2002. Impact of the El Nino/southern oscillation on Visceral Leishmaniasis. *Brazil. Emerg Infec Dis,* **8**, p. 914–917.

Gail, M. H. & Benichou, J., 2000. *Encyclopedia of Epidemiologic Methods (Wiley Reference Series in Biostatistics).* New edition ed. Chichester: Wiley-Blackwell.

Galati, E. A. B., Fonseca, M. B., Marassá, A. M. & Bueno, E. F. M., 2009. Dispersal and survival of Nyssomyia intermedia and Nyssomyia neivai (Diptera: Psychodidae: Phlebotominae) in a cutaneous Leishmaniasis endemic area of the speleological province of the Ribeira Valley, state of São Paulo, Brazil. *Mem Inst Oswaldo Cruz, Rio de Janeiro,* **104**(8), pp. 1148-1158.

García, A. L. et al., 2009. Leishmaniases in Bolivia: Comprehensive Review and Current Status. *Am. J. Trop. Med. Hyg,* 80(5), pp. 704 - 711.

Garner, G. & Saville, P., [No date]. *Reference Guide for Animal Health Staff.* [Online]
Available at:
https://www.spc.int/lrd/ext/Disease_Manual_Final/b501__Leishmaniasis.html
[Accessed 4 3 2014].

Gavgani, A. S., Hodjati, M. H., Mohite, H. & Davies, C. R., 2002. Effect of insecticide-impregnated dog collars on incidence of zoonotic Visceral Leishmaniasis in Iranian children: a matched-cluster randomised trial. *Lancet,* **360**(3), pp. 374-379.

Ghazanfar, F. A. & Fisher, M., 1998. *Vegetation of the Arabian Peninsula.* Dordrecht: Kluwer Academic Published.

Githeko, A. K., Lindsay, S. W., Confalonieri, U. E. & Patz, J. A., 2000. Climate change and vector-borne diseases:a regional analysis. *Environment and Health,* 78(9), pp. 1136-1147.

Glennie, K., 1987. Desert sedimentary environments, present and past: a summary. *Sedimentary Geology,* pp. 135 - 165.

González, U., Pinart, M., Reveiz, L. & Alvar, J., 2008. *Interventions for Old World cutaneous Leishmaniasis (Review),* New York: John Wiley & Sons.

Goodman, D. C., Fisher, E., Stukel, T. A. & Chane, C., 1997. The distance to community medical care and the likelihood of hospitalization: Is closer always better?. *The distance to community medical care and the likelihood of hospitalization: Is closer always better?,* **87**, pp. 1144-1150.

Gossage, S. M., 2004. *Molecular and Cellular Biology of Leishmania Development.* Liverpool: University of Liverpool.

Green, S. B. & Salkind, N. J., 2008. *Using SPSS for Windows and Macintosh (5th Edition).* London: Pearson.

Griffiths, J. K., 1998. Human Cryptosporidiosis: Epidemiology, Transmission, Clinical Disease, Treatment, and Diagnosis. *Advances in Parasitology,* **40**, p. 37–85.

Grogl, M., Daugirda, G. L., Hoover, D. L., Magill, A.J. & Berman, J. D., 1993. Survivability and infectivity of viscerotropic Leishmania tropica from operation Desert Storm participants in human blood products maintained under blood bank conditions. *Am J Trop Med Hyg,* **49**, pp. 308-315.

Guerin, P. J., Olliaro, P., Sundar, S., Boelaert, M., Croft, S.L., Desjeux, P., Wasunna, M.K. & Brycesonf, A. D., 2002. Visceral Leishmaniasis: current status of control, diagnosis, and treatment, and a proposed research and development agenda. *The Lancet Infectious Diseases,* **2**(1), pp. 494-501.

Guernaoui, S., Boussaa, S., Pesson, B. & Boumezzough, A., 2006. Nocturnal activity of phlebotomine sandflies (Diptera: Psychodidae) in a cutaneous Leishmaniasis focus in Chichaoua, Morocco. *Parasitol Res,* **98**, p. 184–188.

Gulliford, M., Figueroa-Munoz, J., Morgan, M. & Hughes, D., 2002. What does 'access to health care' mean?. *J Health Serv Res Policy,* **7**, p. 186–188.

Hair, J. F., Anderson, R. E., Tatham, R. L. & Black, W. C., 1995. *Multivariate Data Analysis (3rd ed).* New York: Macmillan.

Hamer, L., 2004. *Improving patient access to health services:a national review and case studies of current approaches,* London: NHS.

Hanafi, A. H., Fryauff, D. J. & Modi, G. B., 2007. Bionomics of Phlebotomine sand flies at a peacekeeping duty site in the north of Sina. *Egypt Acta Trop,* **101**(2), pp. 106-114.

Harandi, M. F. Moazezi, S. S., Saba, M., Grimm, F., Kamyabi, H., Sheikhzadeh, F., Sharifi, I. & Deplazes, P., 2011. Sonographical and Serological Survey of Human Cystic Echinococcosis and Analysis of Risk Factors Associated with Seroconversion in Rural Communities of Kerman, Iran. *Zoonoses and Public Health,* **58**(8), p. 582–588.

Harhay, M. O., Olliaro, P. L., Costa, D. L. & Nery Costa, C. H., 2011. Urban parasitology: Visceral Leishmaniasis in Brazil. *Trends in Parasitology,* **27**(9), pp. 403-409.

Harrat, Z., Pratlong, F., Benikhlef, R., Lami, P., Belkaid, M. & Dedet, J. P., 1998. Leishmania major MON-74 as a causative agent of cutaneous Leishmaniasis in Burkina Faso. *Trans. R. Soc. Trop. Med Hyg,* **92**, pp. 355-367.

Hashighushi, Y. & ELaundries, E. G., 1991. A review of Leishmaniasis in Equador. *Bulletin of PAHO,* **25**(1), pp. 64-76.

Hasker, E., Singh, S. P., Malaviya, P., Picado, A. & Gidwani, K., 2012. Visceral Leishmaniasis in rural bihar, India. *Emerg Infect Dis,* **18**, pp. 1662-1664.

Hassana, M. M., Banagab, A. O., Ehab, A. M. F. & Bakri, Y. M. N., 2012. Assessment of Knowledge, Attitude and Practice about Sandfly and Visceral Leishmaniasis Control Activities in Rural Area of GedarifState, Sudan in May 2008. *Neelain Medical Journal,* **2**(4), pp. 1-18.

Harvard University, [No date]. *Tuberculosis in Europe and North America, 1800–1922.* [Online]
Available at: http://ocp.hul.harvard.edu/contagion/tuberculosis.html
[Accessed 14 5 2014].

Heimgartner, E. & Heimagartner, V., 1976. Experience with endemic dermatological diseases in the Peruvian wilderness: mucocutaneous Leishmaniasis and Brazilian foliaceous pemphigus. *Medicina Cutanea Ibero-latino-americana,* **4**(1), pp. 1-6.

Hensher, D. A., Rose, J. M. & Greene, W. H., 2005. *Applies choice analysis: A primer.* Third ed. Cambridge: Cambridge Unviersity Press.

Herrington, J. S., 1987. *Factors Affecting US Oil & Gas Outlook.* New edition ed. Washington,: National Petroluem Council.

Herwaldt, B. L., 1999. Leishmaniasis. *Lancet,* **354**, pp. 1191-1199.

Higgs, G. & Gould, M., 2001. Is there a role for GIS in the New NHS?. *Health and Place,* 7(3), pp. 247-259.

Hiwat, H. & Bretas, G., 2011. Ecology of Anopheles darlingi Root with respect to vector importance: a review. *Parasites & Vectors,* **4**, pp. 1-13.

Hoare, C. A., 1938. Early discoveries regarding the parasite of oriental sore. *Transactions of the Royal Society of Tropical Medicine and Hygiene*, **32**(1), pp. 67 - 92.

Hotez, P. J., 2013. *Forgotten People, Forgotten Diseases: The Neglected Tropical Diseases and their Impact on Global Health and Development.* Second edition ed. Herndon: ASM Press.

Hubálek, Z., 2003. Emerging Human Infectious Diseases: Anthroponoses, Zoonoses, and Sapronoses. *Emerg Infect Dis*, **9**(3), pp. 403 - 404.

Hunter, P. R., 2003. Climate change and waterborne and vector-borne disease. *Journal of Applied Microbiology Symposium Supplement*, **94**, p. 37–46.

IAMAT (International association for medical assistance to travellers), [No date], *Leishmaniasis.* [Online]
Available at: http://www.iamat.org/disease_details.cfm?id=50
[Accessed 10 4 2014].

Ibrahim, E. M., Mustafa, M. B., Al AmrI, S. A., Al-Seghayer, S. M., Hussein, S. M. & Meriones, G. L., 1994. possible reservoir host of zoonotic cutaneous Leishmaniasis in Riyadh province, Saudi Arabia.. *oc Trop Med and Hyg* , pp. 88-139.

IOM, (International Organization for Migration), 2008. *Migration and Climate,* Geneva: International Organization for Migration.

IPCC, (Intergovernmental Panel on Climate Change), 2013. *Long-term Climate Change: Projections, Commitments and Irreversibility,* Cambridge: Cambridge University Press.

IPCC, (Intergovernmental Panel on Climate Change), 2001. *Climate change 2001: The scientific basis,* Cambridge: Cambridge University Press.

Jaber, S. M., Ibbini, J. H., Hijjawi, N. S., Amdar, N. M., Huwail, M. J. & Al-Aboud, K., 2013. Exploring recent spatial patterns of cutaneous Leishmaniasis and their associations with climate in some countries of the Middle East using geographical information systems. *Geospatial Health*, **8**(1), pp. 143-158.

Johnston, R. J., Gregory, D. E. & Smith, D. M., 1986. *The Dictionary of Human Geography.* New ed. Oxford: Basil Blackwell.

Jones, A. P. & Bentham, G., 1995. Emergency medical service accessibility and outcome from road traffic accidents. *Public Health,* **109**, p. 169–177.

Jones, A. P., Bentham, G. & Horwell, C., 1999. Health service accessibility and deaths from asthma. *International Journal of Epidemiology,* **28**, pp. 101-105.

Jones, K. & Moon, G., 1987. *Health Disease and Society An introduction to medical Geography.* New ed. London: Routledge and Kegan Paul.

Jörg, B. H. & Steinkohl, F., 2004. Origin of winter precipitation in the central coastal lowlands of Saudi Arabia. *Journal of Arid Environments,* **57**(1), pp. 101-115.

Joseph, A. & Phillips, D., 1984. *Accessibility and Utilization-geographical perspectives on health care delivery.* New edition ed. New York: Harper and Row.

Judith, N. W. & Aral, S. O., 1996. The Dynamic Topology of Sexually Transmitted Disease Epidemics: Implications for Prevention Strategies. *The Journal of Infectious Diseases,* **174**(2), pp. 201-213.

Jürgen, H. P. & Hoffmeyer, Z., 2008. Harmonisation of Demographic and Socio-Economic Variables in Cross national Survey Resear. *Bulletin de méthodologie sociologique,* **98**, pp. 1-15.

Júnior, N. R., Pinheiro, F. G., Naiff, M. D. E., Souza, E., Souza, L. D., Castro, L. M., Menezes, M. P. & Franco, A. M. R. 2009. Case series study of American cutaneous Leishmaniasis in Rio Preto da Eva municipality, Amazonas State, Brazil. *Revista de Patologia Tropical,* **38**(2), pp. 103-114.

Jutting, J. P., 2004. Do community-based health insurance schemes improve poor people's access to health care? Evidence from rural Senegal. *World development,* **32**(2), pp. 273-288.

KAIR, (King Abdul Aziz Ibn Saud Information Resource), [No date]. *Kingdom of Saudi Arabia founded.* [Online]
Available at: http://www.ibnsaud.info/main/020.htm
[Accessed 21 5 2012].

Kolaczinski, G. H. et al., 2008. Risk factors of visceral leishmaniasis in East Africa: a case-control study in Pokot territory of Kenya and Uganda. *International Journal of Epidemiology,* pp. 1-9.

Koplow, D. A., 2003. *Smallpox: The Fight to Eradicate a Global Scourge.* New ed. California : University of California Press.

Kamhawi, S., Belkaid, Y., Modi, G., Rowton, E. & Sacks, D., 2000. Protection against cutaneous Leishmaniasis resulting from bites of uninfected sand flies. *Science,* pp. 1351-1354.

Kanjanopas, K., Siripattanapipong, S., Ninsaeng, U., Hitakarun, A., Jitkaew, S., Kaewtaphaya, P., Tan-ariya, P., Mungthin, M., Charoenwong, C. & Leelayoova, S., 2013. Sergentomyia (Neophlebotomus) gemmea, a potential vector of Leishmania siamensis in southern Thailand. *BMC Infectious Diseases,* **13**, pp. 313-333.

Karakis, I., Gandacu, D., Alpert, P., Shafir, H., Baharad, A., Anis, E. & Grotto, I., 2013. *Cutaneous Leishmaniasis in Israel and Correlation over Time with Average Ambient Temperature.* Basel, s.n., pp. 1-12.

Kasap, O. E. & Alten, B., 2005. Laboratory estimation of degree-day developmental requirements of Phlebotomus papatasi (Diptera: Psychodidae). *Journal of Vector Ecology,* **30**(2), pp. 328-333.

Kassiri, H., Javadian, E. & Sharififard, M., 2013. Monthly activity of Phlebotominae sand flies in Sistan- Baluchistan Province, Southeast Iran. *Journal of Insect Science,* 1-13. **13**.

Kaul, M. S., 1991. Phlebotomine sandflies (Dipera : Psycbodidae) from Khandwa and Hoshangabad District of Madhya Pradesh, India. *J. Com. Dis,* **23**(4), pp. 257-262.

Kean, B. H., Mott, K. E. & Russell, A. J., 1978. *Tropical medicine and parasitology: classic investigations.* New York: Cornell University Press.

Keeling, M. & Rohani, P., 2007. *Modeling Infectious Diseases in Humans and Animals.* First ed. Princeton : Princeton University Press.

Kelly, D. W. & Dye, C., 1997. Pheromones, kairomones and the aggregation dynamics of the sandfly Lutzomyia longipalpis. *Anim Behav,* **53**, pp. 352-355.

Kennedy, P., 1992. *A Guide to Econometrics.* Oxford: Blackwell.

Khan, S. J. & Muneeb, S., 2005. Cutaneous Leishmaniasis in Pakistan. *Dermatology Online Journal ,* **11**(1), pp. 1-4.

Khasnis, A. A. & Nettleman, M. D., 2005. Global Warming and Infectious Disease. *Archives of Medical Research,* **36**(1), pp. 689-696.

Killick-Kenderick, R. & Killick-Kenderick, M., 1987. Honeydew of aphids as a source od sugar for Phlebotomous ariasi. *Med. & Vet. Entomol.,* **1**(3), pp. 293-302.

Killick-Kendrick, R., 1990. Phlebotomine vectors of the Leishmaniasis: a review. *Med Vet. Entomol,* **4**, pp. 1-24 .

Killick-Kendrick, R., 1999. The biology and control of Phlebotomine sand flies. *Clinics in Dermatology,* **17**(3), p. 279–289.

Killick-Kendrick, R., Killick-Kendrick, M., Focheux, C., Dereure, J., Puech, M. P. & Cadiergues, M. C., 1997. Protection of dogs from bites of phlebotomine sandflies by deltamethrin collars for control of canine Leishmaniasis. *Medical and veterinary entomology,* **11**(2), pp. 105-111.

Killick-KendrIck, R. & Molyneux, D. H., 1981. Transmission of Leishmaniasis by the bite of phlebotomine sandflies:Possible mechanisms.. *Transactions of the Roval Societv of Tropical Medicine and Hygiene,* **75**, pp. 152-154.

Killick-Kendrick, R., Rioux, J. A., Bailly, M., Guy, M. W., Wilkes, T. J., Guy, F. M., Davidson, I., Knechtli, R., Ward, R. D., Guilvard, E., Perieres, J. & Dubois, H., 1984. Ecology of Leishmaniasis in the South of France. 20 - Dispersal of Phlebotomus ariasi Tonnoir, 1921 as a factor in the spread of the Visceral Leishmaniasis in the Cévennes. *Ann Parasitol Hum Comp,* **59**, pp. 555-572.

Kolaczinski, G. H., Reithinger, R., Worku, D. T., Ocheng, A., Kasimiro, J., Kabatereine, N. & Brooker, S., 2008. Risk factors of Visceral Leishmaniasis in East Africa: a case-control study in Pokot territory of Kenya and Uganda. *International Journal of Epidemiology,* pp. 1-9.

Korpi, H., 2011. *Mortality from diseases in 1936 to 2010.* [Online]
Available at: http://www.stat.fi/til/ksyyt/2010/ksyyt_2010_2011-12-16_kat_003_en.html
[Accessed 28 6 2014].

Kovats, R. S., Edwards, S. J., Charron, D., Cowden, J., D’Souza, R. M., Ebi, K. L., Gauci, C., Gerner-Smidt, P., Hajat, S. & Hales, S., 2005. Climate variability and campylobacter infection: an international study. *International Journal of Biometeorology,* 49(4), pp. 207-214.

Lainson, R. & Shaw, J. J., 1987. *Evolution, classification and geographical distribution. In: Peters W, Killick-Kendrick R, editors. The leishmaniases in biology and medicine..* London: Academic Press;.

Lane, R. P., 1993. *Sandflies (Phlebotominae).* London: Chapman and Hall.

Lane, R. R., 2003. *hlebotomine Sandflies In: Manson P, Cook GC, Zumla A, eds. Manson’s Tropical Diseases.* 21st ed. London: Saunders.

Langmuir, A. D., 1962. Medical importance of measles. *Am J Dis Child,* **103**, pp. 54-56.

Larson-Hall, J., 2010. *A Guide to Doing Statistics in Second Language Research Using SPSS.* New York and London: Routledge.

Last, J. M., 1988. *A Dictionary of Epidemiology.* Second edition ed. New York: Oxford Ubiversity Press.

LCCS (Library of Congress Country Studies), 1992. *Saudi Arabia, climate.* [Online]
Available at: http://lcweb2.loc.gov/cgi-bin/query/r?frd/cstdy:@field(DOCID+sa0034)
[Accessed 11 1 2012].

LCCS (Library of Congress Country Studies), 2006. *Country profile: Saudi Arabia.* [Online]
Available at: http://lcweb2.loc.gov/frd/cs/profiles/Saudi_Arabia.pdf
[Accessed 19 9 2012].

Lemon, S. M., Sparling, P. F., Hamburg, M. A., Relman, D. A., Choffnes, E. R. & Mack, A., 2008. *Vector-Borne Diseases: Understanding the Environmental, Human Health, and Ecological Connections, Workshop Summary,* Washington (DC): National Academies Press.

Lewis, D. J., 1975. Functional morphology of the mouth parts in New World phlebotornine sandflies (Diptera: Psychodidae). *Transactions of the Royal Society of Entomology,* **126**, pp. 497-532.

Lewis, D. J. & Büttiker, W., 1980. Insects of Saudi Arabia, Diptera Fam. Psychodidae, Subfam. Phlebotominae. *Fauna Saudi Arabia,* **2**, pp. 252-285.

Lilavanichakul, A. & Boecker, A., 2013. Consumer Acceptance of a New Traceability Technology: A Discrete Choice Application to Ontario Ginseng. *the International Food and Agribusiness Management Association,* **16**(4), pp. 25-49.

Lima, A. P., Minelli, L., Teodoro, U. & Comunello, E., 2002. Tegumentary leishmaniasis distribution by satellite remote sensing imagery, in Paraná State, Brazil. *Lima, Minelli, Teodoro & Comunello,* 77(7), pp. 681-692.

Lindsay, S. W. & Birley, M. H., 1996. Climate change and malaria. *Annals of Tropical Medicine and Parasitology,* **90**, p. 573–588.

Longnecker, M. T. & Ott, R. L., 2004. *A First Course in Statistical Methods.* 04 edition ed. Belmont: Cengage Learning.

Louviere, J., Hensher, D. & Swait, J., 2000. *Stated Choice Methods. Analysis and Application.* Cambridge: Cambridge University Press.

Lovett, A., Haynes, R., Sunnenberg, G. & Gale, S., 2002. Car travel time and accessibility by bus to general practitioner services: a study using patient registers and GIS. *Soc.Sci. Med,* **55**, pp. 97-111.

LSTM (Liverpool School of Tropical Medicine), [No date]., *Super'kalazar'banana.* [Online]
Available at: http://www.lstmliverpool.ac.uk/lambanana/
[Accessed 19 5 2014].

Lundberg, L., Johannesson, M., Dag, I. & Borgquist, L., 1998. Effects of user charges on the use of prescription medicines in different socioeconomic groups. *Health Policy,* **44**, pp. 123-134.

Mackenbach, J. P., Looman, C. W. N. & Meer, V. D., 1996. Differences in the misreporting of chronic conditions, by level of education: the effect on inequalities in prevalence rates. *Am J Pubic Health,* **86**(5), pp. 706-711.

Magill, A. J., 2000. *Leishmaniasis.* First ed. Philadelphia: W.B. Saunders Company.

Magill, A. J., Ryan, E. T., Hill, D. & Solomon, T., 2012. *Hunter's Tropical Medicine and Emerging Infectious Disease: Expert Consult.* 9th ed. Amsterdam: Saunders.

Mahboudi, F., Abolhassani, M., Tehrani, S. R., Azimi, M. & Asmar, M., 2002. Differentiation of old and new world leishmania species at complex and species levels by PCR. *Scand J Infect Dis,* **34**(10), pp. 756 - 758.

Mandaville, J. P., 1986. Plant life in the Rub' al-Khali (the Empty Quarter), south-central Arabia. *Proceedings of the Royal Society of Edinburgh. Section B. Biological Sciences,* **89**, pp. 147-157.

Mandaville, J. P., 1990. *Flora Of Eastern Saudi Arabia.* New edition ed. New York: Routledge.

Mann, C. J., 2003. Observational research methods. Research design II:cohort, cross sectional, and case-control studies. *Emerg Med J,* **20**, pp. 54-61.

Mansour, A. & Al-Osaimy, M., 1996. A study of health centres in Saudi Arabia. *International journal of nurse studies,* **33**, pp. 309-315.

Marco, J., Bhutto, A., Soomro, F. R., Baloch, J. H., Barroso, P. A., Kato, H., Uezato, H., Katakura, K., Korenaga, M., Nonaka, S. & Hashiguchi, Y., 2006. Multilocus enzyme electrophoresis and cytochrome B gene sequencing–based identification of leishmania isolates from different foci of cutaneous Leishmaniasis in Pakistan. *Am. J. Trop. Med. Hyg,* **75**(2), pp. 261-266.

Markell, E. K., David, T., Krotoski, J. A. & Krotoski, W. A., 1999. *Markell and Voge's Medical Parasitology, Eighth Edition.* Philadelphia: Saunders.

Martinez, S., Gonzalez, M. & Vernaza, E., 1997. Treatment of Cutaneous Leishmaniasis with Allopurinol and Stibogluconate. *Department of Internal Medicine,* **24**, pp. 165-169.

Mathews, T. J. & MacDorman, M. F., 2013. Infant Mortality Statistics from the 2010 Period Linked Birth/Infant Death Data Set. *NVSS*, **62**(8), pp. 1-27.

Mayer, J. D., 1981. Medical Geography: some unsolved problems',. *Prof. Geog,* 34(3), pp. 261-269.

MCI (Ministry of Commerce and Industry), 2012. *The Kingdom of Saudi Arabia regions.* [Online]
Available at: http://www.mci.gov.sa/AboutKingdom/Pages/KingdomRegions.aspx
[Accessed 10 9 2012].

McLeod, K. S., 2000. Our sense of Snow: the myth of John Snow in medical geography.. *Soc Sci Med.,* 50(7 - 8), pp. 923 - 935.

Meade, M., Florin, J. & Gesler, W., 1988. *Medical Geography.* New ed. New York: The Guilford Press..

Mechanic, D., 1978. *Illness behaviour. In: Medical sociology. A comprehensive text.* 2nd edition ed. New York: The free press.

MEP (Ministry of Economy and Plannin), 2006. *Human Development Report.* [Online]
Available at:
http://www.mep.gov.sa/inetforms/themes/clasic/file/download.jsp;jsessionid=212951F12482B85A3982FE553E8FAB5A.beta?DownloadTranslation.ObjectID=1254&FileAttribute=DownloadTranslation.Content&TableName=DownloadTranslation.
[Accessed 29 4 2013].

MEP (Ministry of Economy and Plannin), 2012a. *Annual Statistics Book.* [Online]
Available at: http://www.cdsi.gov.sa/yb48/
[Accessed 11 8 2013].

MEP (Ministry of Economy and Plannin), [No date]a. *Development Plans.* [Online]
Available at:
http://www.mep.gov.sa/themes/GoldenCarpet/index.jsp;jsessionid=BE86A69E245F45592B1B171B7EB9833B.alfa?event=SwitchLanguage&Code=AR#1410414851657
[Accessed 7 3 2012].

MEP (Ministry of Economy and Plannin), [No date]b. *Saudi Arabia - Economic Indicators (2007 - 2013).* [Online]
Available at:
http://www.mep.gov.sa/inetforms/themes/clasic/file/download.jsp;jsessionid=1C619D5DB55C33AC45638CB94AFB3CD3.alfa?DownloadTranslation.ObjectID=306&FileAttribute=DownloadTranslation.Content&TableName=DownloadTranslation
[Accessed 11 7 2012].

Meteorologocal Office, 2014. *What is climate change?.* [Online]
Available at: http://www.metoffice.gov.uk/climate-guide/climate-change
[Accessed 22 5 2014].

MHRA (Medicines and Healthcare products Regulato Agency), 2003. *Disease Awareness Campaigns Guideines.* London: Medicines and Healthcare products Regulatory Agency.

Miller, A. G. & Cope, T. A., 1996. Flora of the Arabian Peninsula. *Socotra,* **1**, pp. 1-144.

Miller, L. & Zawistowski, S., 2013. *Shelter Medicine for Veterinarians and Staff.* Second edition ed. Ames: Wiley-Blackwell.

Mitchell, K. J., Fritschi, L., Reid, A., McEvoy, S., Ingram, D. M., Jamrozik, K., Clayforth, C. & Byrne, M, J., 2006. Rural-urban differences in the presentation, management and survival of breast cancer in Western Australia. *Breast (Edinburgh, Scotland),* **15**(6), pp. 769-776.

Mittra, B. & Andrews, N. W., 2013. IRONy OF FATE: role of iron-mediated ROS in Leishmania differentiation. *Trends in Parasitology,* **29**(10), p. 489–496.

MOA (inistry of Agriculture), 2009. *Annual statistic book.* [Online]
Available at:
http://moa.gov.sa/webcenter/faces/oracle/webcenter/page/scopedMD/s8bba98ff_4cbb_40b8_beee_296c916a23ed/businessRolePages/Page48.jspx?wc.contextURL=%2Fspaces&wc.contextURL=%2Fspaces&wc.originURL=%2Fspaces%2Fsystem%2Fpage%2F%25D8%25A7%25D9%2584%25D8%25B3%25
[Accessed 11 6 2012].

MOFA (Ministry of Foreign Affairs), 2012. *Agriculture And Water Resources.* [Online]
Available at:
http://embassies.mofa.gov.sa/sites/india/EN/AboutKingdom/KingdomAchievments/Pages/Agriculture-And-Water-Resources.aspx
[Accessed 11 4 2013].

MOH (Ministry of Health), 2002. *Annual statistic book for 2002.* [Online]
Available at: http://www.moh.gov.sa/Ministry/Statistics/Book/Pages/default.aspx
[Accessed 15 9 2012].

MOH (Ministry of Health), 2006. *Annual statistic book for 2006.* [Online]
Available at: http://www.moh.gov.sa/Ministry/Statistics/book/Documents/1427.rar
[Accessed 11 9 2012].

MOH (Ministry of Health), 2007. *Annual statistic book for 2007.* [Online] Available at: http://www.moh.gov.sa/Ministry/Statistics/book/Documents/1428.rar [Accessed 2012 9 2012].

MOH (Ministry of Health), 2008. *Annual statistic book for 2008.* [Online] Available at: http://www.moh.gov.sa/Ministry/Statistics/book/Documents/1429.rar [Accessed 11 9 2012].

MOH (Ministry of Health), 2009. *Annual statistic book for 2009.* [Online] Available at: http://www.moh.gov.sa/Ministry/Statistics/book/Documents/1430.rar [Accessed 15 9 2012].

MOH (Ministry of Health), 2010. *Annual statistic book for 2010.* [Online] Available at: http://www.moh.gov.sa/Ministry/Statistics/book/Documents/1431.rar [Accessed 13 9 2012].

MOH (Ministry of Health), 2012. *Annual statistic book for 2012.* [Online] Available at: http://www.moh.gov.sa/Ministry/Statistics/book/Documents/1433.pdf [Accessed 4 2 2013].

MOHE (Ministry of Heigher Education), M. o. H. E., 2006. *educational system in saudi arabia.* New edition ed. Washington,DC: Ministry of Higher Education.

Mohscn, Z. H., 1983. Biting activity, physiological age and vector potential of Phlebotomus papatasi scopoli (Diptera:Phlebotornidaei) in central Iraq. *J BioI Sci,* **14**, pp. 79-94.

Mokyr, J., 2003. *The Oxford Encyclopedia of Economic History.* New edition ed. New York: Oxfor University Press USA.

Molina, J. A., Mario, I. O. & Felipe, G., 2007. Seasonality of Lutzomyia fairtigi (Diptera: Psychodidae: Phlebotominae), a species endemic to Eastern Colombia. Parasitologia Tropical. *Rio de Janeiro,* **103**(5), pp. 477-482.

Momeni, A. Z. & Aminjavaheri, M., 1994. Clinical picture of cutaneous Leishmaniasis in Isfahan, Iran.. *Int J Dermatol,* **33**(4), pp. 260-265.

Mondzozo, A. E., Musumba, M., McCarl, B. A. & Wu, X., 2011. Climate Change and Vector-borne Diseases: An Economic Impact Analysis of Malaria in Africa. *Int. J. Environ. Res. Public Health,* **8**, pp. 913-930.

Montoya-Leram, J., 1996. *The Biology of Visceral Leishmaniasis Vectors in the San Andres de Sotavento Focus, Cordoba, Colombia.* London: University of London.

Morrison, A. C., Ferro, C., Morales, A., Tesh, R. B. & Wilson, M. L., 1993. Dispersal of the sand fly Lutzomyia longipalpis (Diptera:Psychodidae) at an endemic focus of Visceral Leishmaniasis in Colombia. . *J Med*

MRCRC (Mackay Regional Council and Reef Catchments), 2013. *Coasts and Communities Town and Far Beach, Beach Plan,* Mackay: Queensland Government.

Mukhopadhyay, A. K., Rahaman, S. J. & Chakravarty, A. K., 1990. *Effect of flood on immature stages of sandflies in a flood-prone kala-azar endemic village of North Bihar, India. Effect of flood on immature stages of sandflies in a flood prone kala azar endemic village of North Bihar, India,* Geneva: WHO.

Mukhopadhyay, R., Dey, S., Gaget, D., Lightbody, J., Xu, N., Ouellettet, M. & Rosen, P., 1996. Trypanothione overproduction and resistance to antimonials and arsenicals in Leishmania. *Proc. Natl. Acad. Sci,* **93**, pp. 10383-10387.

Murray, P. R., Rosenthal, K. S. & Pfaller, M. A., 2012. *Medical Microbiology: with student consult online access.* 7th edition ed. Philadelphia: Saunders.

Mutinga, M. J., Kamau, C. C., Basimike, M., Mutero, C. M. & Kyai, F. M., 1992. Studies on the epidemiology of Leishmaniasis in Kenya: flight range of phlebotomine sandflies in Marigat, Baringo District.. *East Afr Med J,* **69**, pp. 9-13.

Mutinga, M. J., Kamau, C. C. & Kyai, F. M., 1986. Investigations on the epidemiology of leishmaniases in Kenya—IV: Breeding habitat of Phlebotomus duboscqi (Diptera: Psychodidae), a vector of Leishmania major in Marigat, Baringo District, Kenya. *International Journal of Tropical Insect Science,* **7**(6), pp. 727-729.

Myler, P. J. & Fasel, N., 2008. *Leishmania: After the Genome.* Norfolk: Caister Academic Press.

Naeem, M., Bader, S., Ashraf, Y. & Roa, A. R., 2000. Status of flora in Lai Sohanra (Cholistan) forest preseres. *Pakistan journal of biological science* , **3**(11), pp. 1838-1846.

Najera, L., 1946. Observaciones sobre la ecologia de los phlebotomos en su fase larvaria pi-incipalnu'ntc. *Rev Iberica Parasitol,* **6**(1,2), pp. 139-158.

Narvaez, F. J. A., Silvia, B. C. L., Nicole, R. V., Eduardo, A. R. Z., Alberto, V. G. & Nelly, E. A. A., 2003. Seasonal transmission of Leishmania Mexicana in the state of Campeche. *Mem Inst Oswaldo Cruz, Rio de Janeiro,* **98**(8), pp. 995-998.

Nattinger, A. B., Kneusel, R. T., Hoffmann, R. G. & Gilligan, M. A., 2001. Relationship of distance from a radiography facility and initial breast cancer treatment. *J Natl Cancer Inst,* **93**(17), pp. 1344-1346.

Naucke, T. J., Menn, B., Massberg, D. & Lorentz, S., 2008. Sandflies and Leishmaniasis in Germany. *Parasitol Res,* **103**(1), pp. 65-68.

Nayyar, G. M., Newton, P. N. & Herrington, J., 2012. Poor-quality antimalarial drugs in southeast Asia and sub-Saharan Africa. *Lancet Infectious Diseases,* **12**(6), p. 488–496.

Negri, S., 2009. Food Safety and Global Health: An International Law Perspective. *Global health governance,* **3**(1), pp. 1-26.

Neter, J., Wasserman, W. & Kutner, W., 1989. *Applied Linear Regression Models.* Irwin: Homewood.

Nimri, L., Soubani, R. & Gramiccia, M., 2002. Leishmania species and zymodemes isolated from endemic areas of cutaneous Leishmaniasis in Jordan. *Kinetoplastid Biol Dis,* **1**, pp. 1-9.

Norton, M. A., Frankenburg, S. & Klaus, S. N., 1992. Cutaneous Leishmaniasis acquired during military service in the Middle East. *Arch. Dermatol,* **128**, pp. 83-87.

Novikova, N. M., 1970. Drawing up a preliminary vegetation map of Arabia [in Russian]. *Geobotanicheskos Kartografirovanie,* **1970**, pp. 61-71.

NRC (National Research Council), 2001. *Under the weather: climate, ecosystems, and infectious disease,* Washington, DC: National Academy Press.

O'Brien, R. M., 2007. A Caution Regarding Rules of Thumb for Variance Inflation Factors. *Quality & Quantity,* **41**(5), pp. 673-690.

Pacholi, S., 1993. *Medical geography of malaria in Madhya Pradesh.* New ed. New Delhi: Northern Book Co .

PAHO and WHO (Pan-American Health Organization and World Health Organization), 2000. *An integrated approach to Communicable Disease Surveillance.* [Online]
Available at: http://www1.paho.org/english/sha/eb_v21n1-vigil.htm
[Accessed 6 8 2014].

Pankhurst, C. & Coulter, W., 2009. *Basic Guide to Infection Prevention and Control in Dentistry (Basic Guide Dentistry Series).* First edition ed. Hoboken: Wiley-Blackwell.

Parrott, L., Donatien, A. & Beguet, M., 1921. Transmission du clou de Biskra par le phlebotome (Phlebotomus papatasi Scop.). *Soc. Biol,* **73**, pp. 1030 - 1032.

Parry, M. L., Rosenzweig, C., Iglesias, A., Livermore, M. & Fischer, G., 2004. Effects of climate change on global food production under SRES emissions and socio-economic scenarios. *Global Environmental Change,* **14**(1), p. 53–67.

Patz, J. A., Githeko, A. K., McCarty, J. P., Hussein, S. and de Wet, N., [No date]. *Climate change and infectious diseases.* [Online]
Available at: http://www.who.int/globalchange/publications/climatechangechap6.pdf
[Accessed 22 6 2014].

Patz, A. J., Graczyk, T. G., Geller, N. & Vittor, A. Y., 2000. Effects of environmental change on emerging parasitic diseases. *Int. J. Parasitol,* **30**, pp. 1395-1405.

Perfil'ev, P. P., 1968. Fauna of U.S.S.R. Diptera. Phlebotomidae (sandflies). *Acad. Sci. U.S.S.R. Zool,* 3(2).

Peters, W., Bryceson, A. & Evans, D. A., 1990. Leishmania infecting man and wild animals in Saudi Arabia. The influence of prior infection with Leishmania arabica on challenge with L. major in man.. *Trans R Soc Trop Med and Hyg,* p. 84.

Petrisheva, A. & Izyamkaya, N. G., 1941. On the breeding places of Phlebotomines in Sebastopo. *Rev Appl Entomol,* **21**, pp. 98-101.

PHAC (Public Health Agency of Canada), 2006. *Diphtheria.* [Online]
Available at:
http://www.collectionscanada.gc.ca/webarchives/20071121073753/http://www.phac-aspc.gc.ca/publicat/ccdr-rmtc/00vol26/26s3/index.html
[Accessed 28 7 2014].

PHE (Public Health England), 2013. *General Information on Healthcare associated infections (HCAI).* [Online]
Available at:
http://www.hpa.org.uk/Topics/InfectiousDiseases/InfectionsAZ/HCAI/GeneralInformationOnHCAI/
[Accessed 2 7 2014].

PHE (Public Health England), 2014. *Measles notifications and deaths in England and Wales, 1940-2013.* [Online]
Available at:
http://www.hpa.org.uk/web/HPAweb&HPAwebStandard/HPAweb_C/1195733835814
[Accessed 21 7 2014].

Philadelphia, P. A., Williams, L. & Wilkins, L., 2006. *Head & neck surgery - otolaryngology.* New York: Brooklyn.

Phillips, D., 1981. *Contemporary Issues in the Geography of Health Care.* New ed. Norwich: Geo Books.

Philo, C., 1995. Journey to the asylum: a medical-geographical idea in historical context. *Journal of Historical Geography,* 21(2), pp. 148-168.

Pita-Pereira, D., 2008. Detection of natural infection in Lutzomyia cruzi and Lutzomyia forattinii (Diptera: Psychodidae:Phlebotominae) by Leishmania infantum chagasi in an endemic areaof Visceral Leishmaniasis in Brazil using a PCR multiplex assay. *Acta Trop,* **107**, p. 66–69.

PME (Presidency of Meteorology and Environment), 2014a. *The climate of Saudi Arabia.* [Online]
Available at: http://www.pme.gov.sa/popups1.6.pdf
[Accessed 31 7 2014].

Posnett, J., 1999. Is bigger better? Concentration in the provision of secondary care. *British Medical Journal*, **319**, p. 1063–1065.

Quate, L. W., 1964. Phlebotomus sandflies of the Paloich area in the Sudan. *J Med Ent*, **68**, pp. 201-213.

Quinnell, R. J. & Dye, C., 1994. An experimental study of the peridomestic distribution of Lutzomyia longipalpis (Diptera:Psychodidae). *Bull Ent Res*, **84**, pp. 379-382.

Quintana, M. G., Salomón, O. D. & De Grosso, M. S., 2010. Distribution of phlebotomine sand flies (Diptera: Psychodidae) in a primary forest-crop interface, Salta, Argentina.. *J Med Entomol,* **47**(6), pp. 1003-1010.

Ready, P. D., 2008. Leishmaniasis emergence and climate change. *Rev. sci. tech. Off. int. Epiz,* **27**(2), pp. 399-412.

Reithinger, R., Mohsen, M. & Leslie, T., 2010. Risk Factors for Anthroponotic Cutaneous Leishmaniasis at the Household Level in Kabul, Afghanistan. *PLoS Negl Trop Dis,* **4**(3), pp. 1-8.

Relman, D. A., Hamburg, M. A., Choffnes, E. R. & Mack, A. eds., 2009. *Microbial Evolution and Co-Adaptation.* Washington DC: National Academies Press.

Reyburn, H., Ashford, R., Mohsen, M., Hewitt, S. & Rowland, M., 2000. A randomized controlled trial of insecticide-treated bednetsand chaddars or top sheets, and residual spraying of interior rooms for the prevention of cutaneous Leishmaniasis in Kabul, Afghanistan. *Trans R Soc Trop Med Hyg,* **94**, pp. 361-366.

Ricketts, T., Savitz, L. A. & Gesler, W. M., 1994. *Geographic Methodsfor Health ServIces Research: A Focus on the Rural-Urban Continuum.* New ed. New York and London: Lanham

Roscoe, M. S., 2009. *Environmental Predictors of Cutaneous Leishmaniasis in Afghanistan: A Spatial Epidemiologic Study.* California: TUI University Cypress.

Ross, E. & Deverell, A., 2010. *Health, illness and disability – Psychosocial approaches.* Hatfield: Van Schaik.

Rozendaal, J. A., 1997. *Vector control, Methods for use by individuals and communities.* Geneva: World Health Organization.

Russell, A., 1756. *The Natural History of Aleppo.* London: A. Millar in the strand.

Ryan, J. R. et al., 2006. Spatial Clusteringand Epidemiological Aspects of Visceral Leishmanasisin Tow Endmic Villages, Baringo District, Kenya. *Am. J. Trop. Med. Hyg,* 74(2), p. 308–317.

Sabra, M., Hala, A. & faddan, A., 2013. Cutaneous Leishmaniasis in Gharyan – Libya – a Case-Control Study. *Life Science Journa,* **10**, pp. 826-834.

Saf'janova, V. M., 1971. Leishmaniasis control. *Bull World Health Organ,* **44**, pp. 561-566.

Safyanova, V. M., 1946. Laboratory Cultivation of Sandflies (Diptra : Phlebotominae). *Bull. Wid Hlth Org,* **31**, pp. 573-576.

SAHealth (Governoment of South Australia), 2014. *Ways infectious diseases spread.* [Online]
Available at:
http://www.sahealth.sa.gov.au/wps/wcm/connect/public+content/sa+health+internet/health+topics/health+conditions+prevention+and+treatment/infectious+diseases/ways+infectious+diseases+spread
[Accessed 13 5 2014].

Saliba, E. K., Disi, A. M., Ayed, R. E., Saleh, N., Al-Younes, H., Oumeish, O. & Al-Ouran, R., 1994. Rodents as reservoir hosts of cutaneous Leishmaniasis in Jordan. *Ann Trop Med Parasitol,* **88**(6), pp. 617-622.

Saliba, E. K. & Oumeish, O. Y., 1999. Reservoir hosts of cutaneous Leishmaniasis. *Clin Dermatol,* **17**, pp. 275-277.

Salomón, O. D., Quintana, M. G., Mastrángelo, A. V. & Fernández, M. S., 2012. Leishmaniasis and Climate Change—Case Study: Argentina. *Journal of Tropical Medicine,* **2012**, pp. 1-11.

Sanchez-Tejeda, G., Rodríguez, N., Parra, C. I., Hernandez-Montes, O., Barker, D. C. & Monroy-Ostria, A., 2001. Cutaneous Leishmaniasis caused by members of Leishmania braziliensis complex in Nayarit, state of Mexico. *Mem Inst Oswaldo Cruz,* **96**, pp. 15-19.

Sangiorgi, B., Miranda, D. N., Oliveira, D. F., Santos, E. P., Gomes, F. R., Santos, E. O. & Barral, A., Miranda, J. C., 2012. Natural Breeding Places for Phlebotomine

Sand Flies (Diptera: Psychodidae) in a Semiarid Region of Bahia State, Brazil. *Journal of Tropical Medicine,* **2012**, pp. 1-5.

Sawalha, S. S., Shtayeh, M. S. & Khanfar, H. M., 2003. Phlebotomine sand flies (Dip iero : Psychodidae) of the Palestinian WestBank: potential vectors of Leishmaniasi. *J Med Entomol,* **40**(3), pp. 321-328.

Sayad, S., [No date]. *Logistic Regression.* [Online]
Available at: http://www.saedsayad.com/logistic_regression.htm
[Accessed 26 3 2014].

Schenkel, K., Rijal, S., Koirala, S., Koirala, S., Vanlerberghe, V., Stuyft, P. V., Gramiccia, M. & Boelaert, M., 2006. Visceral Leishmaniasis in southeastern Nepal: A cross-sectional survey on Leishmania donovani infection and its risk factors. *Tropical Medicine and International Health,* **2**(12), p. 1792–1799.

Schimpff, S. C., 2012. *The dramatic change in the causes of death.* [Online]
Available at: http://www.kevinmd.com/blog/2012/07/dramatic-change-death.html
[Accessed 8 8 2014].

Schlein, Y., Bonat, S. & Jacobson, R. C., 1990. Oviposition, diapause and other factors affecting the egg-laying of Phlebotomus paptasi in the laboratory. *Med.Vet Entomal,* **4**, pp. 76-78.

Schlein, Y. & Jacobson., R. L., 1999. Sugar meals and longevity of the sandfly Phlebotomus papatasi in an arid focus of Leishmania major in the Jordan Valley. *ed. Vet. Entomol,* pp. 65-71.

Schlein, Y., Jacobson, R. L. & Müller, G. C., 2001. Sand fly feeding on noxious plants: a potential method for the control of Leishmaniasis. *Am J Trop Med Hyg,* **65**(4), pp. 300 -303.

Schlein, Y. & Muller, G., 1995. Assessment of plant tissue feeding by sandflies (Diptera: Psychodidae) and mosquitoes (Diptera: Culicidae). *J Med Entomol,* 32(6), pp. 882-887.

Schlipköter, U. & Flahault, A., 2010. Communicable Diseases: Achievements and Challenges for Public Health. *Public Health Reviews,* **32**(1), pp. 90-119.

Schlesselman, J. J., 1982. *Case-Control Studies; Design, Conduct, Analysis..* New ed. Oxford: Oxford University Press.

SCO (Saudi Commercial Office), [No date]. *Introducation.* [Online]
Available at: http://www.saudicommercialoffice.com/introducation.htm
[Accessed 9 4 2012].

Sergey, C., Agarval, R., Singh, R. B., Wilzynsca, A. & De Meester, F., 2011. Can Environmental Factors Predispose Noncommunicable Diseases?. *The Open Nutraceuticals Journal,* **4**, pp. 45-51.

SGS (Saudi Geological Survey), 2012. *Saudi Arabia, facts and numbers.* [Online] Available at: http://www.sgs.org.sa/arabic/news/sgsnews/pages/%D8%AD%D9%82%D8%A7%D8%A6%D9%82%20%D9%88%D8%A7%D8%B1%D9%82%D8%A7%D9%85.aspx [Accessed 10 4 2013].

Sharma, M. & Majumdar, P. K., 2009. Occupational lifestyle diseases: An emerging issue. *Indian J Occup Environ Med,* **13**(3), p. 109–112.

Sharma, U. & Singh, S., 2008. Insect vectors of Leishmania: distribution, physiology and their control. *J Vector Borne Dis,* **45**, p. 255–272.

Shevchenko, F. I., 1929-1930. Vneshnyaya morfologiya lichinok moskitov. P. papatasi, P. chinensis, P. sergenti (The external morphology of sandfly larvae (P. papatasi, P. chinensis, P. sergenti)). *Meditsinskaya Mysl' Uzbekistana I Turkmenistana,* **7/8**, pp. 67-83.

Shil, S., Acharya, G. C., Paul, S. C. & Paul, S., 2013. Trend analysis and forecasting coconut production in Assam. *Jpurnal of Plantation Crops,* **41**(2), pp. 238-241.

Shobokshi, O. A., 1999. The development of health services in Kingdom of Saudi Arabia. *Al-Ageeg,* **21**, pp. 81-86.

Shope, R. E., 1999. Infectious Diseases and Atmospheric Change. *Global Atmospheric Change and Public Health,* **1999**, pp. 47-54.

Shuman, E. K., 2011. Global Climate Change and Infectious Diseases. *the ijoem,* **2**(1), pp. 11-19.

Silva, J. M., Zacarias, D. A., De Figueirêdo, L. C., Soares, M. R., Ishikawa, E. A., Costa, D. L. & Costa, C. H., 2014. Bone marrow parasite burden among patients with New World kala-azar is associated with disease severity. *Am J Trop Med Hyg,* **90**(4), pp. 621-626.

Silverman, J., Rust, M. K. & Reierson, D. A., 1981. Influence of temperature and humidity on survival and development on the cat flea, Ctenocephalides felis (Siphonaptera: Pulicidae). *J Med Entomol,* **18**, pp. 78-83.

Silvia, I. D. S., 1999. *Cancer Epidemiology: Principles and Methods.* Lyon: IARC Library.

Simard, R. & L'Ecuyer, P., 2011. Computing the Two-Sided Kolmogorov-Smirnov Distribution. *Journal of Statistical Software,* **39**(11), pp. 1-18.

Singh, K., 1999. Studies on the role of climatological factors in the distribution of phlebotomine sandflies (Diptera: Psychodidae) in semi-arid areas of Rajasthan, India. *Journal of Arid Environments,* **42**, p. 43–48.

Singh, S., 2006. New developments in diagnosis of Leishmaniasis. *Indian J Med Res,* **123**, pp. 311-330.

Singh, S. & Sivakumar, R., 2003. Recent advances in the diagnosis of Leishmaniasis. *J Postgrad Med,* **49**, pp. 55-60.

Siriwardana, H. V., Noyes, H. A., Beeching, N. J., Chance, M. L., Karunaweera, N. D. & Bates, P. A., 2007. Leishmania donovani and Cutaneous Leishmaniasis, Sri Lanka. *Emerg infect dis,* **13**(3), pp. 476-478.

Song, M. D. & Chung, K. C., 2010. Observational Studies: Cohort and Case-Control Studies. *Plast Reconstr Surg,* **126**(6), p. 2234–2242.

Spencer, S. H., 2006. 2 Million Displaced By Storms. *Washington Post*, 13 January.

Stauch, A., Duerr, H. P., Picado, A., Ostyn, B., Sundar, S., Rijal, S., Boelaert, M., Dujardin, J. C. & Eichner, M., 2014. Model-Based Investigations of Different Vector-Related Intervention Strategies to Eliminate Visceral Leishmaniasis on the Indian Subcontinent. *Negl Trop Dis,* **8**(4), pp. 1-9.

Stanford University, [No date]a. *History.* [Online]
Available at:
http://web.stanford.edu/group/parasites/ParaSites2006/Leishmaniasis/history.htm
[Accessed 7 2 2014].

Stanford University, [No date]b. *Mucocutaneous Leishmaniasis.* [Online]
Available at:
http://www.stanford.edu/class/humbio103/ParaSites2006/Leishmaniasis/Mucocutaneous.htm
[Accessed 3 3 2014].

Stanford University, [No date]c. *Public Health Interventions.* [Online]
Available at:
http://www.stanford.edu/class/humbio103/ParaSites2003/Leishmania/publichealth.html
[Accessed 2 4 2014].

Steinskog, D. J., Tjostheim, D. B. & Kvamsto, N. G., 2006. Notes and correspondence A Cautionary Note on the Use of the Kolmogorov–Smirnov Test for Normality. *American Meteorological Society,* **135**, pp. 1151-1157.

Strauss, W. M., Shah, M. S. & Shobrak, M., 2008. Rodent trapping in the Saja/Umm Ar-Rimth Protected Area of Saudi Arabia using two different trap types. *Zoology in the Middle East,* **43**, pp. 31-39.

Sutherst, R. W., 2004. Global change and human vulnerability to vector borne diseases. *Clin Microbiol. Rev,* **17**, pp. 136-173.

SWA (Saudi Wildlife Authority), 2012. *Reports.* [Online]
Available at: http://www.swa.gov.sa/index.php/2013-04-11-14-26-14
[Accessed 7 11 2012].

Sweet, S. A. & Martin, K. A. G., 2010. *Data Analysis with SPSS: A First Course in Applied Statistics [Paperback].* 4th ed. New Jersey: Pearson.

Tabachnick, B. G. & Fidell, L. S., 2012. *Using Multivariate Statistics.* Cambridge: Pearson.

Tayeh, A., Jalouk, L. & Al-Khiami, A. M., 1997. *A cutaneous Leishmaniasis control trial using pyrethroid-impregnated bednets in villages near Aleppo, Syria,* Geneva: World Health Organization.

Tayeh, A., Jalouk, L. & Cairncross, S., 1997b. Twenty years of cutaneous Leishmaniasis in Aleppo, Syria.. *Trans R Soc Trop Med Hyg,* **91**(6), pp. 657-659.

Thesiger, W., 1947. A Journey Through the Tihama, the 'Asir, and the Hijaz Mountains. *The Geographical Journal,* **110**(4/6), pp. 188-200.

The Public Health Department Government of Maharashtra., [No date]. *Disease Information:Japanese Encephalitis(JE).* [Online]
Available at: http://www.maha-arogya.gov.in/diseasesinfo/je/modeoftransmission.htm
[Accessed 17 8 2012].

The World Bank., [No date]a. *Population growth (annual %).* [Online]
Available at:
http://data.worldbank.org/indicator/SP.POP.GROW/countries/SA?display=graph
[Accessed 11 7 2012].

Thomson, M. C., Firth, E., Jancloes, M., Mihretie, A., Onoda, M., Nickovic, S., Bertherat, S. & Hugonnet, S., 2011. *Climate and Public health- The MERIT initiative: a climate and health partnerships to inform public health decision makers,* New'York: MERIT.

Tibayrenca, M. & Ayalab, F. J., 2012. Reproductive clonality of pathogens: A perspective on pathogenic viruses, bacteria, fungi, and parasitic protozoa. *PNAS,* **109**(84), p. 19523–19524.

Tienda, M. & Mitchell, F. eds., 2006. *Hispanics and the Future of America.* 1st Edition ed. Atlanta: National Academies Press.

TIH (Tropical International Health), 2000. *Topics in international Health series (Leishmaniasis) Multimedia CD review.* s.l.:Welcome Trust.

Tobler, W., 1970. A computer movie simulating urban growth in the Detroit region. *Economic Geography*, **46**(2), pp. 234-240.

Tomlinson, R., 1998. *Locality-Based Services for the Elderly: A case Study of south Manchester.* Manchester: Manchester University.

Twigg, L., 1992. *Geographical Information Systems: An Approach to the Integration of Official Health Statistics.* London: Univeristy of London.

UN (United Nations), [No date]b. *Saudi Arabia.* [Online]
Available at: https://data.un.org/CountryProfile.aspx?crName=Saudi%20Arabia
[Accessed 26 3 2013].

UN (United Nations), [No date]. *United Nations - Administrative committee on coordination - subcommittee on nutrition (ACC/SCN).* [Online]
Available at:
http://www.unsystem.org/scn/archives/rwns02vol1/ch08.htm#TopOfPage
[Accessed 6 8 2014].

UN (United Nations), 2011. *Non-communicable diseases deemed development challange of 'epidemic proportions'.* New York: UN Press.

USDS (United State Department of State), 2012. *Human Rights Reports: Saudi Arabia.* [Online]
Available at: http://www.state.gov/j/drl/rls/hrrpt/2011/nea/186447.htm
[Accessed 12 7 2012].

Uthman, M. A., Satir, A. A. & Tabbara, K. S., 2005. Clinical and histopathological features of zoonotic cutaneous Leishmaniasis in Saudi Arabia. *J Eur Acad Dermatol Venereol*, **19**(4), pp. 431-436.

Vellakkal, S., 2013. Impact of Private Health Insurance on Lengths of Hospitalization and Healthcare Expenditure in India: Evidences from a Quasi-Experiment Study. *Indian Journal of Economics & Development,* **1**(1), pp. 24-28.

Viana, G. M. C., Nascimento, M. D. S., Rabelo, E. M. F., Neto, J. A. D., Júnior, J. R. B., Santos, A. C., Júnior, O. M. S., Oliveira, R. A. S. & Guimarães, R. S., 2011. Relationship between rainfall and temperature: observations on the cases of Visceral Leishmaniasis in São Luis Island, State of Maranhão, Brazil. *Revista da Sociedade Brasileira de Medicina Tropical,* **44**(6), pp. 722-724.

Vieira, V. P., Ferreira, A. L., dos Santos, C. B., Leite, G. R., Ferreira, G. E. M. & Falqueto, A., 2012. Peridomiciliary Breeding Sites of Phlebotomine Sand Flies (Diptera: Psychodidae) in an Endemic Area of American Cutaneous Leishmaniasis in Southeastern Brazil. *Am J Trop Med Hyg,* **87**(6), p. 1089–1093.

Vijayakumar, L., 2007. Suicide and its prevention: The urgent need in India. Indian. *Indian J Psychiatry,* **49**, pp. 81-84.

Vincent, P., 2008. *Saudi Arabia: An Environmental Overview.* New edition ed. London/New : Taylor & Francis.

Volf, P. & Volfova, V., 2011. Establishment and maintenance of sand fly colonies. *Journal of Vector Ecology,* **36**(1), pp. 1-9.

Wachoider, S., Silverman, D. T., McLaughlin, J. K. & Mandel, J. S., 1992. Selection of Controls in Case-Control Studies. *American JounaJ of Epidemiology ,* 135(9), pp. 1042 - 1050.

Wallace, P., Killick-Kendrick, E. & Killick-Kendrick, R., 1987. *The Leishmaniases in Biology and Medicine.* London: Academic Press.

Wasserberg, G. & Rowton, E. D., 2011. Sub-additive effect of conspecific eggs and frass on oviposition rate of Lutzomyia longipalpis and Phlebotomus papatasi. *Journal of Vector Ecolog,* **36**, pp. 138-143.

Wasserberg, G., Yarom, I. & Warburg, A., 2003. Seasonal abundance patterns of the sandfly Phlebotomus papatasi in climatically distinct foci of cutaneous Leishmaniasis in Israeli deserts. *Medical and Veterinary Entomology,* **17**, p. 452–456.

Webber, R., 2009. *Communicable Disease Epidemiology and Control: A Global Perspective (Modular Text Series).* 3ed edition ed. Wallingford: CABI Publishing.

Weber, M. d., leemis, L. M. & Kincaid, R. K., 2006. Minimum Kolmogorov–Smirnov test statistic parameter estimates. *Journal of Statistical Computation and Simulation,* **76**(3), pp. 195-206.

West, I., Hampshire, R. & Al-Mulla, M., 2013. *Qatar - Sabkha, Salt Lakes and Other Desert Environoments.* [Online]
Available at: http://www.southampton.ac.uk/~imw/Qatar-Sabkhas.htm
[Accessed 11 3 2013].

Whelan, P., 2003. Biting midges or "sandflies" in the NT. *The Northern Territory Disease Conrtol Bulletin,* **10**(3), pp. 1-12.

Whitley, E. & Ball, J., 2002. Statistics review 6: Nonparametric methods. *PMCID,* **6**(6), pp. 509-513.

WHO (World Health Orginazation), [No date]a. *Genes and noncommunicable diseases.* [Online]
Available at: http://www.who.int/genomics/public/geneticdiseases/en/index3.html
[Accessed 21 7 2014].

WHO (World Health Orginazation), [No date]b. *Malaria, other vectorborne and parasitic diseases.* [Online]
Available at: http://www.wpro.who.int/mvp/climate_change/en/
[Accessed 8 7 2014].

WHO (World Health Organisation), [No date]**c**. *Mucocutaneous Leishmaniasis.* [Online]
Available at: http://www.who.int/Leishmaniasis/mucocutaneous_Leishmaniasis/en/
[Accessed 3 3 2014].

WHO (World Health Organisation), 1990. *WHO Technical Report Series, Control of Leishmaniasis No.793,* Geneva: WHO.

WHO (World Health Orginazation), 1991. *Control of the Leishmaniasis. Technical report series No.793,* Geneva: WHO.

WHO (World Health Organisation), 1997. *WHO.* [Online]
Available at: http://www.who.int/whr/1997/media_centre/50facts/en/
[Accessed 28 6 2014].

WHO (World Health Organisation), 2003. *Climate change and human health.* [Online]
Available at: http://www.who.int/globalchange/publications/climchange.pdf?ua=1
[Accessed 20 5 2014].

WHO (World Health Organisation), 2004. *Global strategic framework for integrated vector management.* [Online]
Available at: http://www.emro.who.int/rbm/PDF/GlobalStratFrameIVM.pdf
[Accessed 1 7 2014].

WHO (World Health Organisation), 2005. *Climate and health.* [Online]
Available at: http://www.who.int/globalchange/news/fsclimandhealth/en/
[Accessed 26 5 2014].

WHO (World Health Organisation), 2006. *Pesticides and Teir application for the control of vectors and pets of publick health importance,* Geneva: WHO.

WHO (World Health Organisation), 2007. *The top ten causes of death.* [Online]
Available at: http://www.who.int/mediacentre/factsheets/fs310.pdf
[Accessed 14 5 2014].

WHO (World Health Organisation), 2008a. *Noncommunicable diseases now biggest killers.* [Online]
Available at: http://www.who.int/mediacentre/news/releases/2008/pr14/en/
[Accessed 21 7 2014].

WHO (World Health Organisation), 2010a. *Essential Leishmaniasis maps.* [Online]
Available at: http://www.who.int/Leishmaniasis/Leishmaniasis_maps/en/
[Accessed 4 2 2014].

WHO (World Health Organisation), 2010b. *Control of the leishmaniases, Report of a meeting of the WHO Expert Committee on the Control of Leishmaniases,* Geneva: WHO.

WHO (World Health Organisation), 2012. *What is the deadliest disease in the world?.* [Online]
Available at: http://www.who.int/features/qa/18/en/
[Accessed 30 6 2014].

WHO (World Health Organization), 2013a. *Noncommunicable diseases.* [Online]
Available at: http://www.who.int/mediacentre/factsheets/fs355/en/
[Accessed 30 6 2014].

WHO (World Health Organisation), 2013b. *Sustaining the drive to overcome the global impact of neglected tropical diseases, Second WHO report on neglected tropical diseases,* Geneva: WHO.

WHO (World Health Organisation), 2013c. *Leishmaniasis, Burden and distribution.* [Online]
Available at: http://www.who.int/Leishmaniasis/burden/en/
[Accessed 9 7 2014].

WHO (World Health Organisation), 2014a. *Genes and human disease.* [Online]
Available at: http://www.who.int/genomics/public/geneticdiseases/en/index3.html
[Accessed 7 7 2014].

WHO (World Health Organisation), 2014b. *The top 10 causes of death.* [Online]
Available at: http://www.who.int/mediacentre/factsheets/fs310/en/
[Accessed 21 7 2014].

WHO (World Health Organisation), 2014c. *Leishmaniasis.* [Online]
Available at: http://www.who.int/mediacentre/factsheets/fs375/en/
[Accessed 3 3 2014].

WHO (World Health Organisation), 2014d. *Climate change and health.* [Online]
Available at: http://www.who.int/mediacentre/factsheets/fs266/en/
[Accessed 14 7 2014].

WHO (World Health Organisation), 2014e. *Global Alert and Response (GAR).* [Online]
Available at:
http://www.who.int/csr/resources/publications/CSR_ISR_2000_1leish/en/
[Accessed 9 1 2014].

WHO (World Health Organisation), 2014f. *Clinical forms of the leishmaniases.* [Online]
Available at:
http://www.who.int/Leishmaniasis/clinical_forms_leishmaniases/en/index1.html
[Accessed 11 5 2014].

Wilkinson, D. & Cameron, K., 2004. Cancer and cancer risk in South Australia: what evidence for a rural-urban health differential?. *The Australian Journal of Rura Health,* **12**(2), pp. 61-66.

Willett, W. C., Koplan, J. P., Nugent, R., Dusenbury, C., Puska, S. & Gaziano, T. A., 2006. Prevention of Chronic Disease by Means of Diet and Lifestyle Changes. In: *Disease Control Priorities in Developing Countries..* Washington DC: The World Bank Press, pp. 833-850.

Wilson, M. L., 2001. *Ecology and infectious disease, in Ecosystem Change and Public Health: A Global Perspective.* First ed. Baltimore: Johns Hopkins University Press.

Wolcott, S. & Hanes, C., 2013. Understanding Aging During the Epidemiologic Transition. *Research in Economic History,* **29**, pp. 1-69.

Woldewahid, G., 2003. *Habitats and spatial pattern of solitarious desert locusts (Schistocerca gregaria Forsk.) on the coastal plain of Sudan.* Wageningen: Wageningen University.

Wondimeneh, Y., Takele, Y., Asmamaw, A., Ferede, G. & Muluye, D., 2014. Trend Analysis of Visceral Leishmaniasis at Addis Zemen Health Center, Northwest Ethiopia. *BioMed Research International,* **2014** , pp. 1-5.

Ximenes, M. F., Souza, M. F. & Castellón, E. G., 1999. Density of Sand Flies (Diptera: Psychodidae) in Domestic and Wild Animal Shelters in an Area of Visceral Leishmaniasis in the State of Rio Grande do Norte, Brazil. *Mem Inst Oswaldo Cruz,* pp. 427-432.

Yaghoobi, E. & Akhavan, A. A., 1999. Entomological survey of sandflies (Diptera: Psychodidae) in a new focus of zoonotic cutaneous leishmaniosis in Iran. *Acta Tropica,* **73**, p. 321–326.

Yan, S., Weihong, Z., Kequan, P. & Keping, M., 2004. Population genetic structure of a dominant desert tree, Haloxylon ammodendron (Chenopodiaceae), in the southeast Gurbantunggut desert detected by RAPD and ISSR markers. *Acta Botanica Sinica,* **46**(6), pp. 675-681.

Yatich, J. K., 1987. *A review of the control of phlebotomine sandflies (Diptera: psychodidae) and a survey of responses on managment of viscral leishmniasis by residents living in a focus of the disease in Marigat, Kenya.* Nairobi: University of Nairobi.

Yatich, J. K., 1995. *A review of the control of phlebotomine sandflies (diptera: psychodidae) and a survey of responses on management of Visceral Leishmaniasis by residents living in a focus of the disease in Marigat, Kenya.* s.l.:Simon Fraser University.

Young, D. G. & Arias, J. R., 1991. Phlebotomine sandflies in the Americas. *Pan American Health Organization.,* **24**, pp. 1-26.

Young, D. G. & Fairchild, B. G., 1974. *Studies Of Phlebotomine Sand Flies (Annual Report),* Florida: Department of Entomology & Nematology.

Zahran, M. A., 2010. *Climate - Vegetation: : Afro-Asian Mediterranean and Red Sea Coastal Lands.* 5th edition ed. London / New York: Springer.

Zarins, J. & Zahrani, A., 1985. Recent Archaeological Investigations in the Southern Tihama Plain (The Sites of Athar, and Sihi, 1404/1984). *Atlas,* **10**, pp. 65-107.

Zijlstra, E. E. & El-Hassan, A. M., 2001. Leishmaniasis in Sudan. Visceral Leishmaniasis. *Trans R Soc Trop Med Hyg,* **95**, pp. 27-58.

Appendix

Appendix A: The obtained ethical approval from the International Development Ethics Committee of the University of East Anglia.

12	04	03
Official use only – ref. number		

PART B – Review report and decision.

To be completed by the applicant:

Name of applicant:	Hamad Aldossari
Student ID no. (if applicable)	4587596/3
Supervisor (if applicable)	Andrew Lovett
Project Title:	A spatial analysis of Cutaneous Leishmaniasis in Al-Dawadmi region, Saudi Arabia

To be completed by the Ethics Committee:

Reviewer's recommendation (✓):

Accept	✓
Request modifications	
Reject	

Reviewers' checklist	Delete as appropriate	
Risks and inconvenience to participants are minimised and not unreasonable given the research question.	✓	
All relevant ethical issues are acknowledged and understood by the researcher.	✓	
Procedures for informed consent are sufficient and appropriate	✓	

Reviewers' Comments

The points raised in the 28th April 2012 review have been addressed largely.

We were not suggesting that the researcher necessarily move with a lone female interviewer himself – we know that would not be appropriate. He might keep this under review and ensure he finds the best way to gather information from women (two female interviewers moving together or with a family member?).

The information on the consent form is still very brief. Do look at the example on the DEV intranet and see if there is additional information on how you will care for the data, what benefits (or not) may come from your research etc.

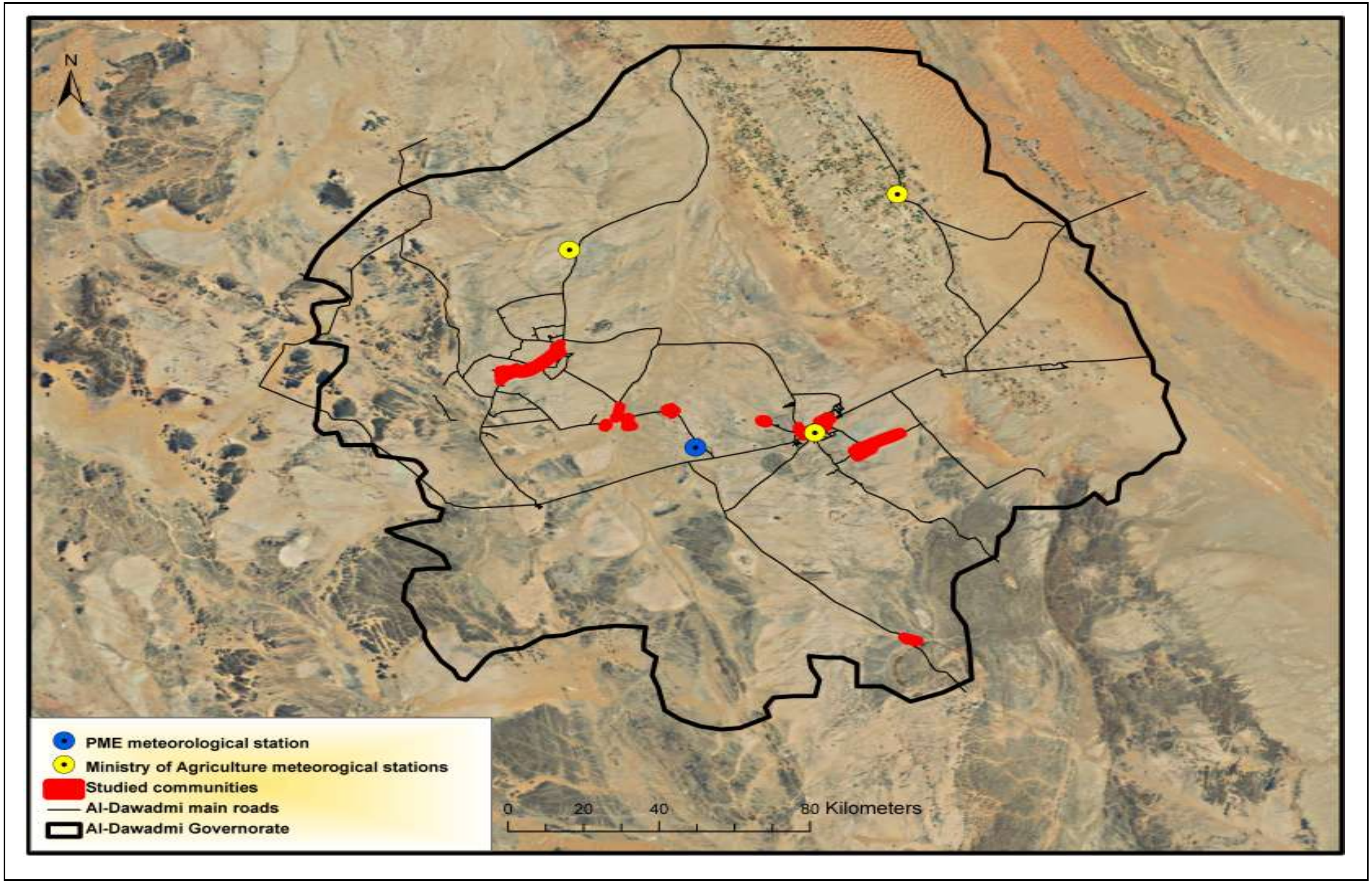
Committee's recommendation:

Ethical approval granted

Signature (Chair of the International Development Ethics Committee)	
Date	25th August 2012

Ethical Approval Form –November 2011 Page 1

Appendix B: A distribution map of the meteorological stations in Al-Dawadmi Governorate.



Appendix C: A sample of CL reporting form.

13-JAN-2008 14:59 FROM:

المملكة العربية السعودية

وزارة الصحة

المديرية العامة للشئون الصحية بمنطقة الرياض

إدارة الرعاية الصحية الأولية

الرقم :

التاريخ :

الموضوع :

استقصاء وبائي لحالة ليشمانيا جلدية

السجل المدني/الملف الصحي ....

تاريخ الفحص ....

المنطقة/ المحافظة ....

القطاع ....

المدينة/القرية ....

المستشفى/ المركز الصحي ....

العمر/ .... سنة/شهر

اسم المريض/ [redacted]

الإقامة/ مقيم بالمنطقة .... غير مقيم بالمنطقة ....

الجنس/ ذكر أنثى

الجنسية/ سعودي غير سعودي

العمل/ المهنة ....

مكان الإقامة ....

العنوان بالتفصيل ....

رقم التليفون/ الجوال [redacted]

مكان الإصابة المتوقع ....

أماكن التواجد في آخر ثلاثة أشهر من تاريخ تشخيص الإصابة ....

....

نوعية الأماكن التي زارها المريض : ☐ حضر - ☑ ريف - ☐مزارع .

عدد القرح .... مكان القرحة .... Left leg

شكل القرح ☑جافة - ☐ رطبة - ☐وجود التهابات ثانوية .

وجود أشخاص آخرين في نفس محل الإقامة أو العمل لديهم تقرحات جلدية ☐ نعم ☑ لا

آخر مركز صحي راجعه المريض للعلاج من الليشمانيا الجلدية ....

العلاج الذي أعطي للمريض بالمركز ....

إسم المراقب الصحي وتوقيعه [redacted] إسم الطبيب المعالج وتوقيعه ....

Dr. M... A. Alam

ختم المركز الصحي ....

Appendix D: Household questionnaire:

بسم الله الرحمن الرحيم

أخي الفاضل / أختي الفاضلة السلام عليكم و رحمة الله و بركاته

أتمنى من العلي القدير أن تكون / تكوني بأفضل حال. أنا حمد بن منصور الدوسري أحد طلاب الدكتوراه في كلية علوم البيئة بجامعة إيست أنقليا بمدينة نورج , المملكة المتحدة, و أقوم برحلة علمية لمنطقة الدوادمي الإدارية لجمع بعض المعلومات المهمة لإكمال دراستي عن العلاقات المكانية و الزمانية بين البيئة المحلية و ظهور مرض اللشمانيا الجلدية في المنطقة.

البيانات التي سيتم جمعها ستستخدم من الباحث لغرض الدراسة فقط و لن يتم استخدامها في دراسات من جهات أخرى ولن تنشر أي بيانات شخصية في جميع الدراسات. المدة المتوقع إكمال الإستبانة فيها تتراوح ما بين 15 و 30 دقيقة و موافقتكم على إجراء هذه المقابلة إختيارية و لن يترتب عليها أي مقابلات أخرى في المستقبل و يمكن الاعتذار عن إكمال المقابلة في أي وقت.

تعاونكم أو اعتذاركم في مكان التقدير.

هل ترغب في إجراء المقابلة؟
نعم ( )
لا ( )
التاريخ ....
الرقم المرجعي للحالة........................

Dear Sir,

My name is Hamad Aldossari and I am a PhD candidate in the School of Environmental Sciences at the University of East Anglia, UK. This survey is a part of my study about cutaneous Leishmaniasis in Al-Dawadmi region, Saudi Arabia. Your help to answer these questions which will take approximately between 15 to 30 minutes would be very appreciated for my research. Your information will be treated as confidential, used only for my study and no personal details will be reported in my thesis. Participating in this study is entirely optional and you can withdraw at any time. No other interviews will be needed in the future.

Please do I have your consent to continue?

Yes ( )
No ( )
Date: ....

Survey Number : ....

To begin with, I would like to ask you some questions about your background knowledge of CL.

1- For CL there is a key insect which is responsible for transmitting the diseases, do you know which insect it is?




[ ] bug [ ] sandfly [ ] mosquitoes [ ] spider
[ ] other insect, please specify.............. [ ] do not know

2- For CL there are reservoirs or hosts for Leishmania parasite, what do you think these reservoirs are?




[ ] Humans [ ] Rats and gerbils [ ] Dogs and foxes [ ] Poultry
[ ] other, please specify? [ ] I do not know

3- Sandflies have preferred habitats for resting and breeding, which of the following do you think are suitable habitats for them?

[ ] Livestock houses [ ] Mud houses
[ ] Dumping areas [ ] Water wells
[ ] Mammals skin or wool [ ] Tree trunks
[ ] Bare sand [ ] Bird nests
[ ] Dark wet areas [ ] Rodent burrows
[ ] Sunny places [ ] Water bodies
[ ] Wall cracks [ ] Abandoned houses
[ ] Clay or wet soil [ ] poultry houses

4- What do you think the approximate size of an adult sandfly is?

[ ] 3mm [ ] 7mm [ ] 1cm [ ] larger than 1cm [ ] I do not know

5- In which season do you think the number of sandflies is highest?

[ ] summer [ ] autumn [ ] winter [ ] spring [ ] I do not know

6- How do your household members protect themselves from insects?

[ ] insect repellent oil or spray [ ] Insecticide
[ ] eliminate water bodies [ ] spilling burned oil around the house
[ ] Do not care [ ] removing some type of vegetation species
[ ] Bed net [ ] others, please specify…...............

Thank you for your answerers, now I would like to ask you some questions about your utilizations of health care facilities in your local area.

7- How far is the nearest general hospital to your residence?

[ ] less than 5 km [ ] 5-10 km [ ] 11-15 [ ] 16-20
[ ] 21-30km [ ] 31-50 km [ ] more than 50 km.

8- How often have you or member of your household visited the general hospital in the past 12 months?

[ ] never [ ] once [ ] two to five times [ ] more than five times

9- How far is the nearest primary heath care centre from your residence?

[ ] less than 5 km [ ] 5-10 km [ ] 11-15 [ ] 16-20
[ ] 21-30km [ ] 31-50 km [ ] more than 50km.

10- How often have you or member of your household visited the primary health care centre in the past 12 months?

[ ] never [ ] once [ ] two to five times [ ] more than five times

Thank you for your answers, the following part asks some questions about your household and household members.

11- Where do you live?

....

12- How many people are there in the household?

[ ] living alone [ ] 2-4 residents [ ] 5-7 residents
[ ] 8-10 residents [ ] more than 10 residents.

13- What are the ages and genders of your household members including yourself and non-Saudis?

ID	Gender		Age	Nationality		ID	Gender		Age	Nationality	
1	M	F		Sau	Non	7	M	F		Sau	Non
2	M	F		Sau	Non	8	M	F		Sau	Non
3	M	F		Sau	Non	9	M	F		Sau	Non
4	M	F		Sau	Non	10	M	F		Sau	Non
5	M	F		Sau	Non	11	M	F		Sau	Non
6	M	F		Sau	Non	12	M	F		Sau	Non

14- In what kind of residence do you live?

[ ] villa [ ] traditional house [ ] farm house or room
[ ] Mud house [ ] tent [ ] others, please specify...........

15- How long have you lived in your residence or in the community?

[ ] less than one year [ ] 1-10 years [ ] more than 10 years

16- Do you have cattle?

[ ] Yes, [ ] No, if No move to question 17

16B) Where do you keep them, [ ] inside the house [ ] nearby animal house
[ ] far from the house [ ] other, please specify.....

17- Do you have domestic animals?

[ ] Yes, [ ] No, if no move to question 18

17B) Where do you keep them, [ ] inside the house [ ] nearby pets cages
[ ] far from the house [ ] other, please specify....

18- Do you have a garden or a field in your residence?

[ ] Yes [ ] No

19- What kind of water supply does your residence have?

[ ] Mains [ ] Vehicle [ ] Well [ ] Others, please specify.....……

20- What kind of sewerage does your residence have?

[ ] Mains [ ] Septic tank [ ] others, please specify..........……

21- How do you dispose of your household waste?

[ ] Collected by city municipality [ ] Bury [ ] Burn
[ ] Others, please specify …...…..................

22- What activities do your household members often do between dusk and dawn?

[ ] setting or resting indoor [ ] setting or resting outdoor
[ ] visiting green areas [ ] feeding animals
[ ] sleeping outdoor [ ] others, please specify...................................

23- What kind of transport do you have in your residence?

[ ] Car [ ] motorbike [ ] bicycle [ ] on foot
[ ] others, please specify …....

24- How much is your family monthly income?

[ ] less than 1,000 SR [ ] 1,000-2,000SR [ ] 2,001-5,000 SR
[ ] 5,001-10,000 SR [ ] more than 10,000 SR [ ] refused.

Thank you very much for your answers, the last part of this interview is about exposure to CL in your household.

25- Has any member of your household had exposure to CL?

[ ] Yes, move to question 26
[ ] No, move to question 28.

26- Who of the listed people in question 13 has had exposure to CL?

Give the ID number for all cases please [, , ,].

27- When was the case bitten by a sandfly (exact or approximate date of discovering the bite)...

28- What is the educational level of the case / control?

[ ] Illiterate [ ] Elementary school [ ] High school
[ ] University or higher degree [ ] other, please specify.............

29- What is the occupation of case / control?

[ ] child [ ] student [ ] civilian [ ] officer
[ ] farmer [ ] retired [ ] Shepherd [ ] house wife
[ ] unemployed [ ] Maid [ ] others, please specify…..........

30- Which areas has the case / control been to in the last three months before the bite / interview?

[ ] urban [ ] farms [ ] countryside
[ ] desert [ ] others, please specify.........

31- During the past three months before the bite / interview, other than regular activity, did the case / control participate in any physical activities?

[ ] Yes, if yes, please specify.......................
[ ] No [ ] Do not remember

*** For controls: Thank you very much for your time and your cooperation is really appreciated**

32- Where does the case think he or she was bitten by a sandfly?

[ ] house [ ] farm [ ] countryside [ ] leisure camp (Estrahah)
[ ] do not know [ ] others, please specify.....................

33- Was the case reported to your local health authorities?

[ ] Yes [ ] No

34- How many times has the case been exposure to CL in the last six years?

[ ] once [ ] twice [ ] three times [ ] more than three times

35- How many times has the case report the CL cases?

[ ] never [ ] once [ ] twice [ ] three times
[ ] more than three times.

36- Why did not the case report the exposures to CL to the local health authorities if applicable?

[ ] difficult in accessibility [ ] could be treated individually
[ ] unsatisfied with previous treatment [ ] long procedures
[ ] other reasons, please specify.........

37- In which part of the body did you have the ulcer/s?

[ ] Arms [ ] nick or face [ ] legs
[ ] trunk or back [ ] other, please specify ....

38- For how long did the ulcer/s last for?

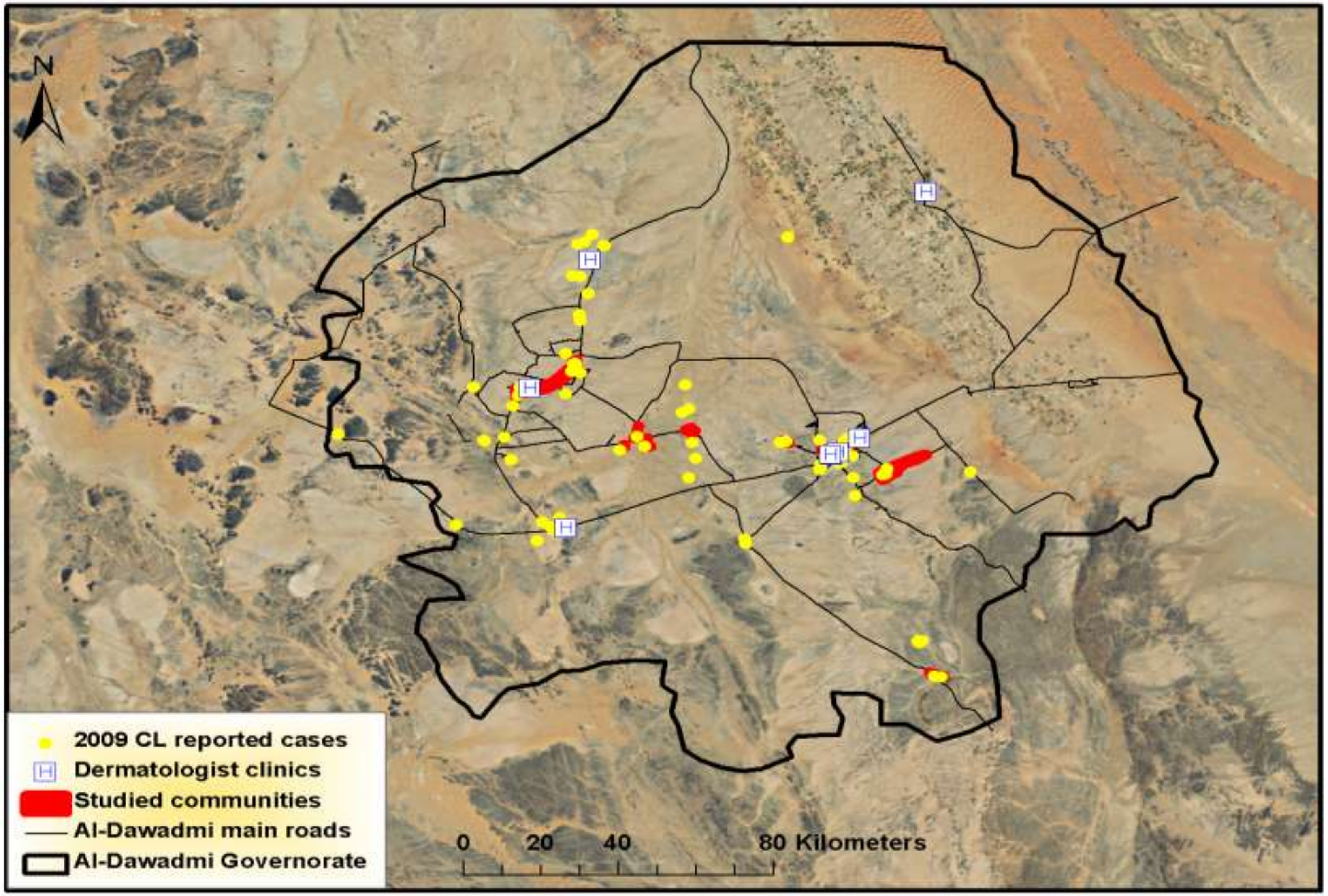
[ ] less than a week [ ] from one to four weeks
[ ] between one and three months [ ] more than three months

39- How did the case treat the ulcer?

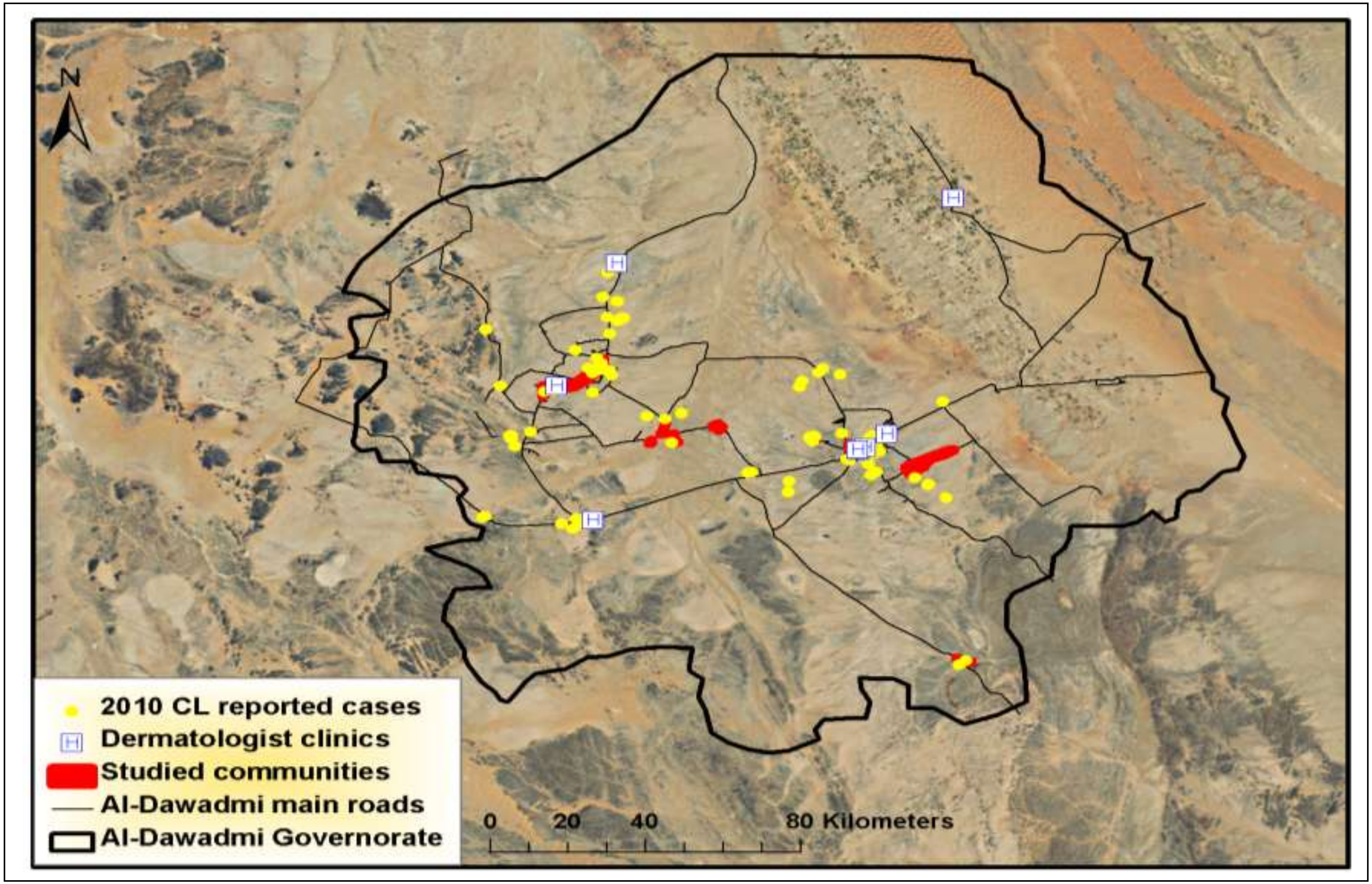
[ ] traditional medicines [ ] cooling or heating the sores [ ] untreated
[ ] recommended medicine [ ] other, please specify........................

We have come to the end of our interview and I would like to thank you very much for your co-operation and help which are really appreciated.

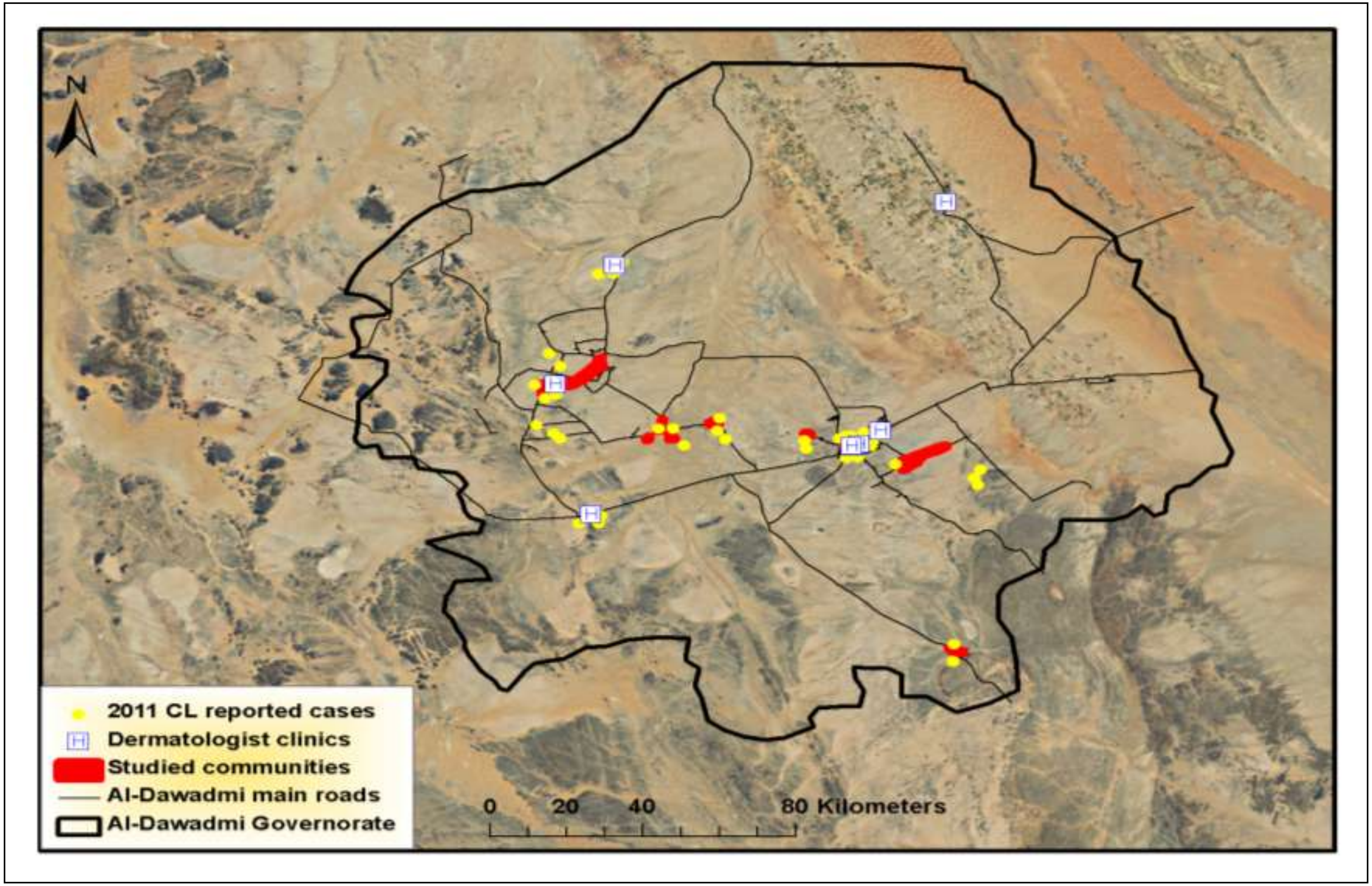
Appendix E: The distribution of CL reported cases in 2009



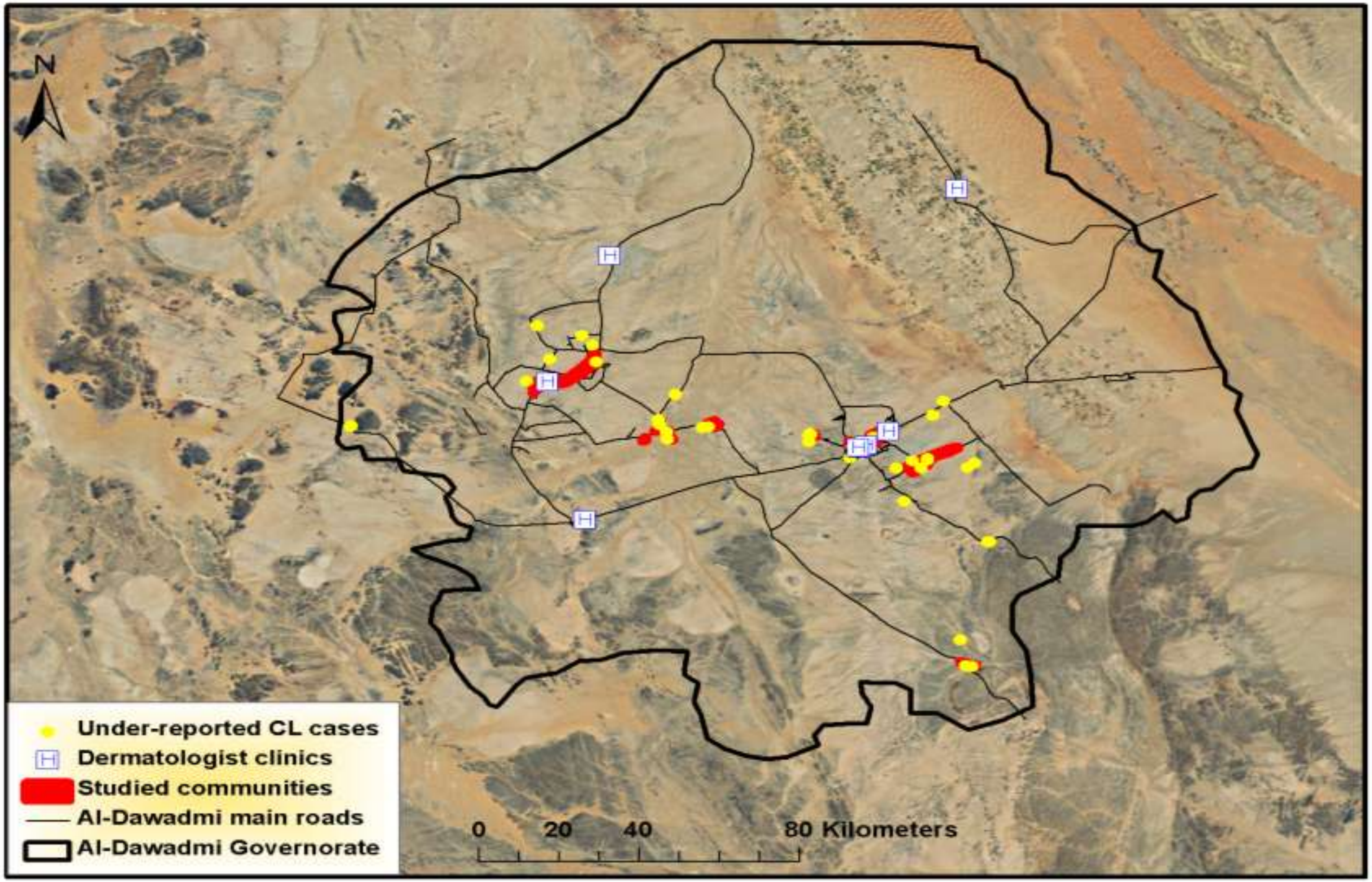
Appendix F: The distribution of CL reported cases in 2010



Appendix G: The distribution of CL reported cases in 2011



Appendix H: The distribution of interviewed CL unreported cases



Appendix I 1: The number of interviewed Saudis within the selected distance intervals (79 cases / 79 controls).

Land use	Distances intervals	100m	200m	300m	400m	500m	1000m	1500m
Very dense vegetation cover	Cases	18	37	56	69	76	78	78
	Controls	14	27	49	64	71	78	78
	Odd ratio	1.37	1.8598	2.087	1.6172	2.8545	1	1
	P value	0.4295	0.056	0.0235	0.2785	0.1323	1	1
Dense vegetation cover	Cases	15	32	45	54	59	70	72
	Controls	15	32	42	56	59	69	72
	Odd ratio	1	1	1.166	0.8871	1	1.1272	1
	P value	1	1	0.6315	0.7294	1	0.8068	1
Abandoned or mud houses	Cases	0	5	10	14	28	44	65
	Controls	0	5	9	14	27	45	65
	Odd ratio	1	1	1.1272	1	1.0574	0.9498	1
	P value	1	1	0.8068	1	0.8674	0.8726	1
Construction waste disposal sites	Cases	5	8	10	14	17	29	48
	Controls	2	5	8	12	14	27	45
	Odd ratio	2.6014	1.6676	1.2862	1.2026	1.273	1.117	1.1699
	P value	0.262	0.3891	0.6172	0.6681	0.5484	0.7395	0.6278
Livestock shelters	Cases	16	28	37	54	58	78	78
	Controls	10	23	34	51	55	76	78
	Odd ratio	1.7524	2.7873	1.166	1.1859	1.2052	3.0789	1
	P value	0.2015	0.0076	0.6315	0.6134	0.5971	0.3348	1
Vegetable and crop farms	Cases	3	5	8	9	12	17	30
	Controls	1	3	7	7	9	16	28
	Odd ratio	3.0789	1.7117	1.159	1.3224	1.393	1.0796	1.1152
	P value	0.3348	0.4726	0.7862	0.5988	0.4833	0.8449	0.7414
Fodder fields	Cases	3	8	14	22	25	47	66
	Controls	3	6	12	19	23	45	63
	Odd ratio	1	1.3521	1.2026	1.2188	1.1272	1.1097	1.2894
	P value	1	0.5936	0.6681	0.5864	0.7294	0.747	0.5381
Palm farms	Cases	6	10	14	20	24	38	40
	Controls	2	9	15	20	25	37	40
	Odd ratio	3.1644	1.1272	0.919	1	0.9425	1.0521	1
	P value	0.1665	0.8068	0.8372	1	0.8634	0.8734	1
Mixed vegetation	Cases	1	1	2	4	4	13	28
	Controls	0	1	2	3	4	17	30
	Odd ratio	3.0382	1	1	1.3511	1	0.7184	0.8967
	P value	0.4982	1	1	0.7	1	0.4183	0.7414
Built up areas	Cases	75	78	78	78	78	79	79
	Controls	77	77	77	77	78	78	79
	Odd ratio	0.487	2.026	2.026	2.026	1	3.0382	1
	P value	0.4142	0.5676	0.5676	0.5676	1	0.4982	1

Appendix I 2: The number of interviewed non-Saudis within the selected distance intervals (46 cases / 46 controls).

Land use	Distances intervals	100m	200m	300m	400m	500m	1000m	1500m
Very dense vegetation cover	Cases	9	15	25	30	36	39	41
	Controls	1	4	6	18	24	34	40
	Odd ratio	10.9459	5.0806	7.9365	2.9167	3.3	1.9664	1.23
	P value	0.0263	0.0078	0.0001	0.0133	0.01	0.2023	0.7483
Dense vegetation cover	Cases	9	16	20	22	25	35	36
	Controls	6	11	15	18	20	26	35
	Odd ratio	1.6216	1.697	1.5897	1.4259	1.5476	2.4476	1.1314
	P value	0.3999	0.2544	0.2842	0.4009	0.298	0.0497	0.8039
Abandoned or mud houses	Cases	0	2	6	6	8	23	27
	Controls	0	0	1	2	5	18	28
	Odd ratio	1	5.2247	6.75	3.3	1.7263	1.5556	0.9107
	P value	1	0.2902	0.0831	0.1578	0.3731	0.2953	0.8288
Construction waste disposal sites	Cases	0	0	2	5	6	15	19
	Controls	0	1	1	2	2	12	22
	Odd ratio	1	0.3262	2.0455	2.6829	3.3	1.371	0.7677
	P value	1	0.4962	0.5648	0.2535	0.1578	0.4928	0.5295
Livestock shelters	Cases	23	29	34	36	38	40	42
	Controls	1	2	10	17	22	28	35
	Odd ratio	45	37.5294	10.2000	6.1412	3.0536	4.2857	3.3
	P value	0.0003	< 0.0001	< 0.0001	0.0001	0.0234	0.0062	0.0569
Vegetable and crop farms	Cases	2	3	4	4	5	21	29
	Controls	0	0	3	4	5	13	26
	Odd ratio	5.2247	7.4828	1.3651	1	1	2.1323	1.3122
	P value	0.2902	0.1874	0.6951	1	1	0.0863	0.5239
Fodder fields	Cases	3	5	11	14	18	27	36
	Controls	1	1	2	3	4	14	30
	Odd ratio	3.1395	5.4878	6.9143	6.2708	6.75	3.2481	1.92
	P value	0.3299	0.1273	0.0158	0.0067	0.0016	0.0072	0.1677
Palm farms	Cases	3	4	7	11	16	25	29
	Controls	2	5	9	12	15	20	24
	Odd ratio	1.5349	0.781	0.7379	0.8905	1.1022	1.5476	1.5637
	P value	0.6477	0.7261	0.5831	0.8098	0.8254	0.298	0.2926
Mixed vegetation	Cases	5	5	7	9	9	14	22
	Controls	4	6	7	9	10	11	17
	Odd ratio	1.2805	0.813	1	1	0.8757	1.392	1.5637
	P value	0.7261	0.7483	1	1	0.7968	0.4828	0.2926
Built up areas	Cases	21	28	30	33	35	40	41
	Controls	26	28	34	35	36	39	40
	Odd ratio	0.6462	1	0.6618	0.7978	0.8838	1.1966	1.23
	P value	0.298	1	0.366	0.6352	0.8039	0.7649	0.7483

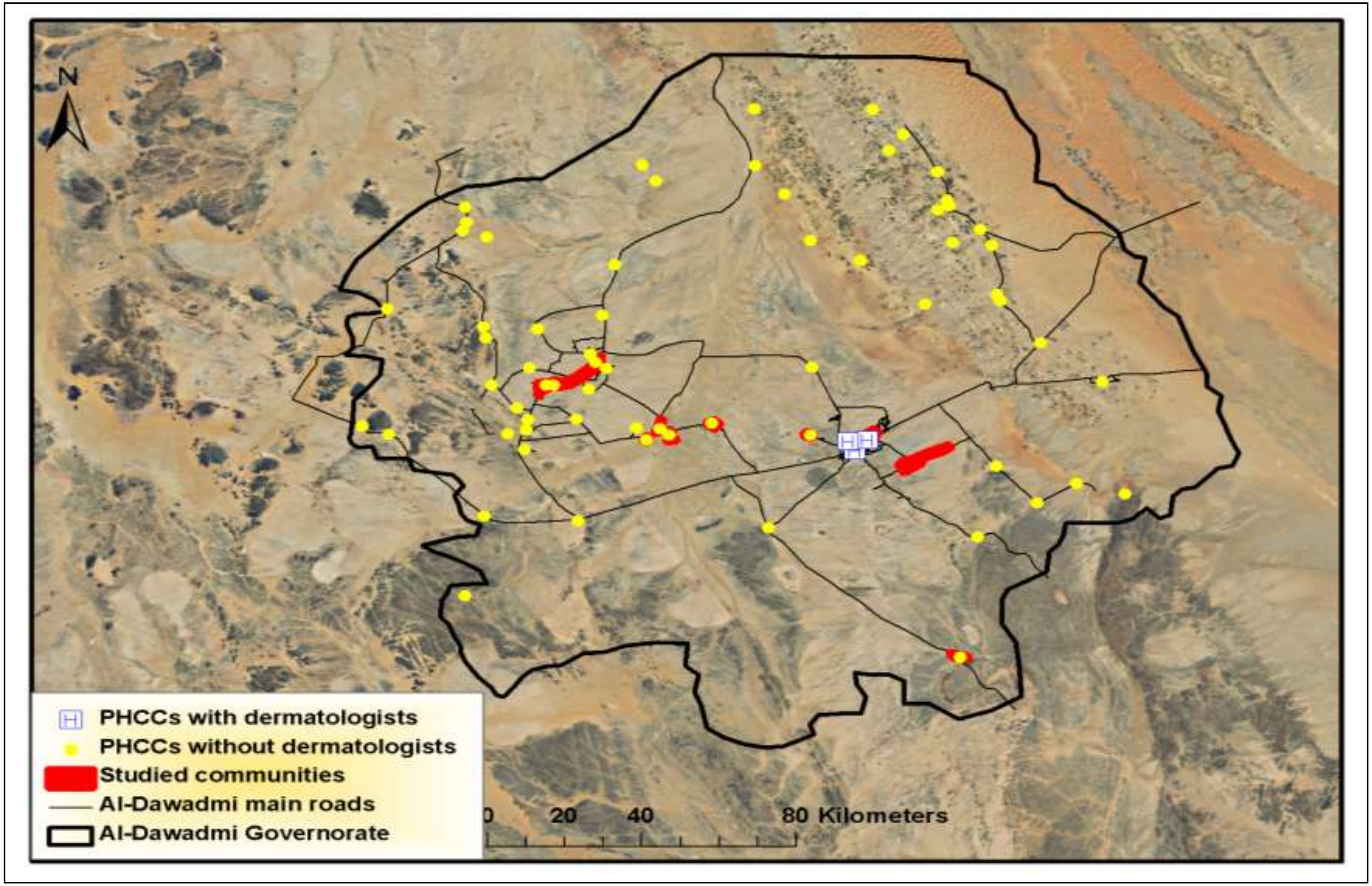
Appendix I 3: The number of interviewed people in urban areas within the selected distance intervals (72 cases / 72 controls).

Land use	Distances intervals	100m	200m	300m	400m	500m	1000m	1500m
Very dense vegetation cover	Cases	18	38	55	63	69	71	71
	Controls	10	21	37	55	64	72	72
	Odd ratio	2.0667	2.7143	3.0604	2.1636	2.875	0.3287	0.3287
	P value	0.096	0.0044	0.0021	0.0875	0.1308	0.4979	0.4979
Dense vegetation cover	Cases	27	47	50	60	65	70	70
	Controls	17	33	43	54	57	63	68
	Odd ratio	1.9412	2.2218	1.5328	1.6667	1.1667	5	2.0588
	P value	0.0724	0.0197	0.2237	0.2208	0.6949	0.0445	0.4133
Abandoned or mud houses	Cases	1	6	13	20	27	54	67
	Controls	0	4	8	12	26	45	67
	Odd ratio	3.042	1.5455	1.7627	1.9231	1.0222	1.8	1
	P value	0.4979	0.5148	0.2418	0.1119	0.949	0.1075	1
Construction waste disposal sites	Cases	2	6	10	14	16	33	46
	Controls	2	6	8	12	14	28	51
	Odd ratio	1	1	1.2903	1.2069	1.1837	1.3297	0.7285
	P value	1	1	0.6149	0.6651	0.6817	0.3995	0.3749
Livestock shelters	Cases	20	32	42	51	59	69	71
	Controls	6	15	24	43	47	66	69
	Odd ratio	4.2308	3.04	2.8	1.6379	2.4141	2.0909	3.087
	P value	0.004	0.003	0.0029	0.1628	0.0253	0.3108	0.3341
Vegetable and crop farms	Cases	0	0	0	0	0	17	26
	Controls	0	0	1	1	2	6	20
	Odd ratio	1	1	0.3287	0.3287	0.1945	3.4	1.4696
	P value	1	1	0.4979	0.4979	0.2933	0.0162	0.2846
Fodder fields	Cases	1	3	10	20	24	42	59
	Controls	2	4	9	15	18	44	68
	Odd ratio	0.493	0.7391	1.129	1.4615	1.5	0.8909	0.267
	P value	0.5672	0.6993	0.8056	0.3327	0.2726	0.734	0.0274
Palm farms	Cases	2	6	10	15	24	39	53
	Controls	1	6	10	16	21	32	34
	Odd ratio	2.0286	1	1	0.9211	1.2143	1.4773	3.1176
	P value	0.5672	1	1	0.8394	0.5898	0.244	0.0014
Mixed vegetation	Cases	0	0	0	0	0	0	17
	Controls	3	3	3	4	4	4	16
	Odd ratio	0.1369	0.1369	0.1369	0.105	0.105	0.105	1.0818
	P value	0.1912	0.1912	0.1912	0.133	0.133	0.133	0.8429
Built up areas	Cases	66	68	68	70	71	71	71
	Controls	66	66	70	71	71	71	71
	Odd ratio	1	1.5455	0.4857	0.493	1	1	1
	P value	1	0.5148	0.4133	0.5672	1	1	1

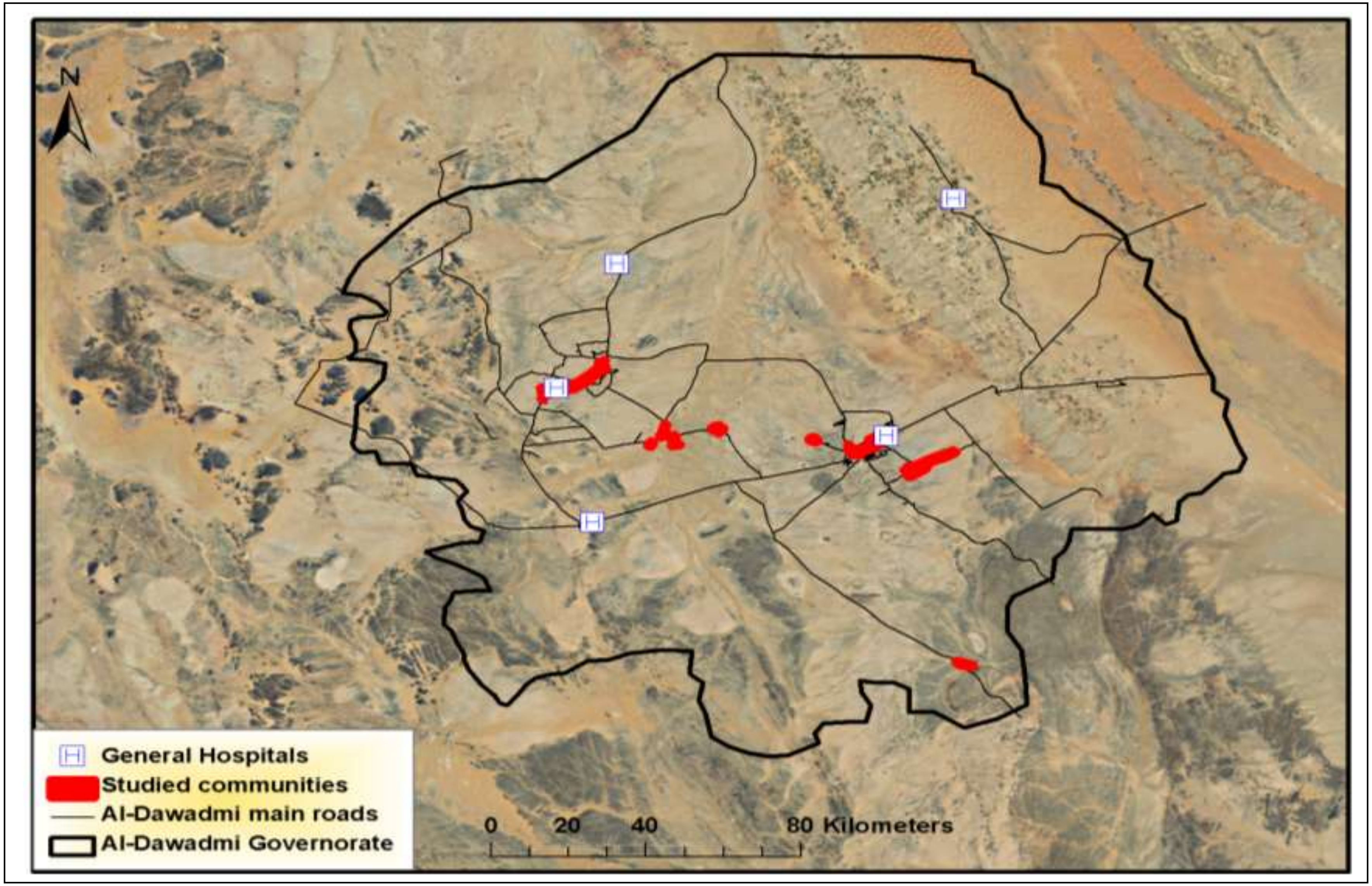
Appendix I 4: The number of interviewed people in rural areas within the selected distance intervals (52 cases / 52 controls).

Land use	Distances intervals	100m	200m	300m	400m	500m	1000m	1500m
Very dense vegetation cover	Cases	15	27	37	40	43	46	48
	Controls	5	10	18	27	31	40	46
	Odd ratio	3.7895	4.4654	4.4965	2.963	2.1836	2.1357	1.4609
	P value	0.0174	0.0008	0.0003	0.0099	0.0654	0.1416	0.5415
Dense vegetation cover	Cases	2	10	17	18	23	36	38
	Controls	4	10	14	20	22	32	39
	Odd ratio	0.4804	1	1.3155	0.8486	1.0803	1.3897	0.9094
	P value	0.4095	1	0.5223	0.6855	0.8442	0.4185	0.8276
Abandoned or mud houses	Cases	0	1	5	6	8	16	24
	Controls	0	1	2	4	6	18	26
	Odd ratio	1	1	2.6563	1.5638	1.3926	0.8408	0.8594
	P value	1	1	0.2562	0.509	0.5673	0.6774	0.6972
Construction waste disposal sites	Cases	3	3	3	4	5	10	15
	Controls	0	0	1	2	2	11	16
	Odd ratio	7.4158	7.4158	3.12	2.0816	2.6563	0.8879	0.9128
	P value	0.1888	0.1888	0.3314	0.4095	0.2562	0.8075	0.8309
Livestock shelters	Cases	30	36	39	42	44	49	49
	Controls	5	10	20	29	35	38	44
	Odd ratio	12.5217	9.1059	2.3054	4.2764	3.7481	4.8355	2.5057
	P value	< 0.0001	< 0.0001	0.0448	0.0009	0.004	0.0089	0.1485
Vegetable and crop farms	Cases	5	8	12	13	17	30	36
	Controls	1	3	9	10	12	23	34
	Odd ratio	5.4167	2.963	1.4309	1.3975	1.6134	1.7013	1.1834
	P value	0.1292	0.1247	0.466	0.4806	0.2779	0.1752	0.6818
Fodder fields	Cases	4	8	14	19	23	27	34
	Controls	2	3	5	7	9	15	25
	Odd ratio	2.0816	2.963	3.4462	3.6723	3.7481	2.4014	2.0042
	P value	0.4095	0.1247	0.0282	0.0088	0.004	0.031	0.08
Palm farms	Cases	8	9	12	17	18	29	32
	Controls	3	8	14	16	19	25	30
	Odd ratio	2.9630	1.3926	0.8153	1.092	0.9203	1.3533	1.1683
	P value	0.1247	0.5673	0.6519	0.8339	0.8386	0.4375	0.6935
Mixed vegetation	Cases	6	6	9	13	13	27	36
	Controls	1	4	6	8	10	24	31
	Odd ratio	6.6383	2.1277	1.6023	1.8281	1.3975	1.2548	1.5028
	P value	0.0849	0.3048	0.4059	0.2268	0.4806	0.56	0.3149
Built up areas	Cases	30	38	40	41	42	48	49
	Controls	37	39	41	41	43	46	48
	Odd ratio	0.564	0.5456	0.9006	1	0.8879	1.4609	1.276
	P value	0.1603	0.1339	0.8191	1	0.8075	0.5415	0.728

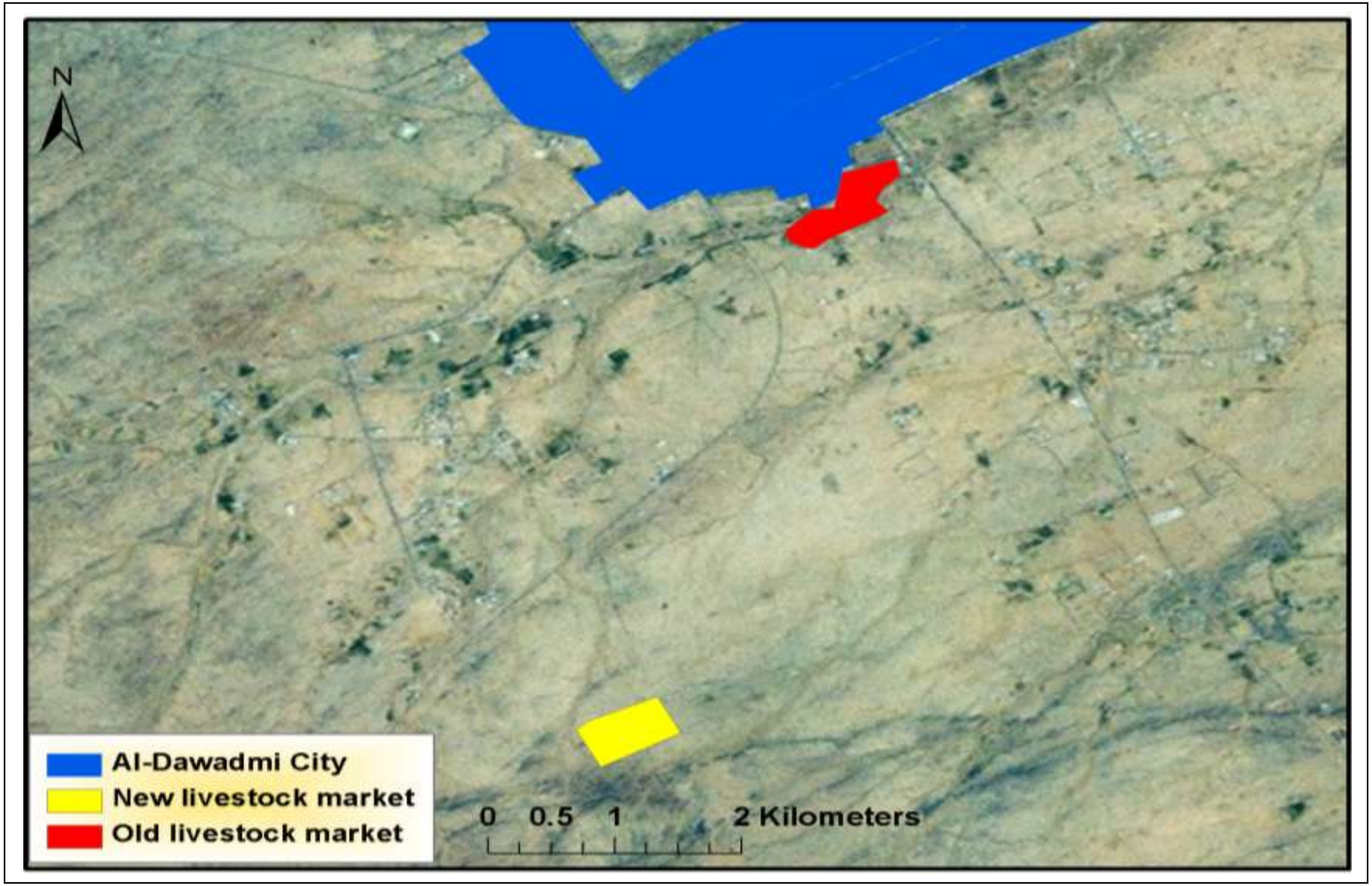
Appendix J: The distribution of PHCCs in Al-Dawadmi Governorate



Appendix K: The distribution of GHs in Al-Dawadmi Governorate



Appendix L 1: The locations for both the old and new livestock markets in Al-Dawadmi City



Appendix L 2: The removal action for the old livestock market and the new built one in Al-Dawadmi City

Appendix M: Some of the local authority's efforts to increase local resident's awareness about CL

Appendix N: Some of the local authority's efforts to provide waste disposal containers in farms close from settlements.

Appendix O: Distributed protection methods against CL vector and reservoir by the Field Epidemiology Training Program in Al-Dawadmi Governorate.