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Smallholder dairy farming land use in the Nairobi metropolitan region, Kenya

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SMALLHOLDER DAIRY FARMING LAND USE IN THE NAIROBI METROPOLITAN REGION, KENYA

A thesis submitted in candidature for the degree of Doctor of Philosophy

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ABSTRACT

This study examines the characteristics of small scale dairy farmers practicing zero-grazing (stall-feeding) within the city Nairobi and the immediate surrounding areas in Kiambu district. The levels of dairy land use intensifications are compared among the urban, peri-urban and rural areas and the results are discussed for land use theory, policy and future research and development. Two conceptual frameworks on coupled human-environment land use systems and the urban-rural gradient guided the study. Data were collected from a stratified random sample of 327 dairy farmers between 2006 and 2007. Semi-structured questionnaire provided information on household and dairy farm characteristics. Systematic methods including factor analysis, cluster analysis and one-way analysis of variance were utilized to enhance the reliability of the findings. More than 43% of the farmers indicated that dairy farming was the most important source of income and some have been practicing it for the last 50 years. When asked about the future plans for their dairy farming, less than 2% of all the farmers expected to discontinue. Results of analysis showed that there are statistically significant differences in the levels of dairy land use intensification between the urban and rural farmers. Farmers in the urban areas kept more heads of dairy cattle per unit area of land and also obtained higher milk yields per cow each day compared to rural farmers. However, there were no significant differences between the peri-urban and urban or rural farmers. The findings suggests that the new Nairobi metropolitan development strategy should consider smallholder dairy farming in projects aimed at reducing urban poverty, food insecurity and waste management.

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CHAPTER 1
INTRODUCTION

1.1 Background

Developing countries are urbanizing more rapidly than any other part of the world, with worsening urban poverty, food security, and environmental degradation. Urban and peri-urban agriculture is a common land use activity with the potential to address some of these challenges in the Sub-Saharan Africa. However, urban agriculture land use has been an invisible and an overlooked issue in development academics and policy but it is now an area of interest. There is a need for better understanding of the status and trends of urban and peri-urban agriculture before it becomes a component of sustainable urban and regional development theories and policies. The present study analyses the changes in smallholder dairy farming land use in the urban, peri-urban and rural areas in Nairobi, Kenya.

1.1.1 Challenges of Urban Poverty, Hunger and Environmental Degradation

The world's population is becoming increasingly urbanized due to both natural increases and rural to urban migration. The United Nations World Urbanization Prospects (UN, 2004 and 2008) indicates that the proportion of world population that is urban will rise to 61 percent by 2030. During the same period, the proportion urban residents in Sub-Saharan Africa will reach 47 percent. This implies the need to transport large quantities of food into urban areas and may result in traffic congestion, air, and water pollution. Estimates indicate that Nairobi city population will require 8 million metric tons of food in the year 2020 compared to about five million tons consumed in the year

2000 (Argenti, 2000). Furthermore, the urban poor will pay more for the food because of the higher transport cost as the main component of food price. There are also unnecessary food swaps between countries, with large amounts of same product being imported and re-exported. For example, in the year 2002 Kenya exported 141 million Kenya Shillings (KShs) worth of liquid milk and imported 135 million KShs worth of powdered milk (GoK, 2007), resulting in large number of unnecessary road and rail movements.

Recent studies show that urbanization in Africa is growing along with environmental degradation, worsening poverty and hunger, unlike other parts of the world (Devereux and Maxwell, 2001; Koc *et al.*, 1999; Smith, 1998). Historically, poverty and food insecurity have been rural problems, but now they are increasingly becoming urban issues (Iaquinta and Drescher, 2003; Koc *et al.*, 1999). This gloomy evidence of future urbanization in Sub-Saharan Africa require that the focus of research development for the coming decades should be on urban regions since that is where the majority of the poor and the hungry will live. Therefore, there is an urgent need to explore and understand the possible opportunities available to address the issues of urban poverty, food security, and environmental degradation. Urban and peri-urban agriculture may play an important role in addressing these challenges. However, it is through better understanding of the extent and trends of agricultural land use in the urban regions that we can achieve reasonable policies and programmes design and implementation to influence future development.

1.1.2 The Role of Urban Agriculture

Urban Agriculture has been defined as an industry located within or on the fringe of a town, which raises, processes and distributes food and non-food products, (re-)using mainly resources, inputs and services found in and around that urban area, and in turn outputs and services largely to that urban area (Mougeot, 2000). He further notes that urban agriculture cannot be differentiated from rural agriculture only on the basis of its location close to the city, but only if it is integrated into urban ecosystem. This implies that urban and peri-urban agriculture is part of urban food supply and distribution, urban transport, urban land use management, urban waste management, urban water, urban population, urban labour market, urban politics, urban social networks and urban environment. Urban and peri-urban agriculture consist of very many different activities but the main sectors include forestry, livestock, horticulture, floriculture, and aquaculture (FAO, 1999). The present study will focus on livestock production, specifically on milk production from dairy cattle by small-scale farmers.

Many urban residents in Sub-Saharan Africa are practising urban agriculture (Mougeot, 1994; 1998; 1999 and 2000). A study commissioned by UNDP estimated that 800 million people were engaged in urban agriculture globally, of these 200 million were considered to be market producers employing 150 million people full time (Smit *et al.*, 1996). The same report projected that in the year 2005 urban agriculture would provide between 23 and 33 percent of vegetables, meat and fish as well as 50 percent of dairy products consumed in cities. The benefits of urban agriculture include: provision of cheap, fresh and nutritious food; less need for packaging, storage and long distance transportation of food; reduced cost of urban waste management since organic waste is composted and used as nutrients; and potential creation of jobs and income (FAO, 1996; Smit *et al.*, 1996; Mougeot 1998 and 2002). The environmental benefits of urban agriculture include improved microclimate, conservation of biodiversity, and environmental awareness among the urban inhabitants. In developed countries the benefits of urban agriculture focus on environmental conservation, leisure, cultural, historic and educational purposes (Deelstra and Girardet, 2000; Bryant, 2005).

1.2 Statement of the Research Problem

Urban agriculture has now become an important issue for research and development attention as an essential part of the strategy for sustainable urban and regional development (Mougeot, 1994). However, despite the growing statistics and expressed concerns, our understanding of the patterns and trends of agricultural land use activities in the urban and peri-urban areas remains limited. Recent studies from developed countries have focused on issues of urban sprawl and conversion of agricultural land indicating decline in agricultural activities with increasing urbanization (Johnson 2002; Bernstein, 1995). However, studies from developing countries indicate that agricultural activities in urban and peri-urban areas are intensifying with increasing urbanization (Koc *et al.*, 1999; Mougeot, 2000; Jacobi *et al.*, 2000). How can we describe and explain the changing agricultural land use patterns and intensities in and around the rapidly expanding third world cities?

Recent analysis of urban agriculture case studies have concluded that urban agricultural activities have to intensify or specialize in order to generate profit and compete with non-agricultural land use activities (Mougeot, 2000). This hypothesis points to the relationship between the level of urbanization and urban agricultural land use change. While this hypothesis indicates that increase in the levels of urbanization will result in intensification of urban agricultural land use activities, no case study has tried to empirically explain why this is so.

A survey in Kenyan six towns including Nairobi estimated that there were 1.4 million heads of livestock worth 17 million (US$) in urban areas (Lee-Smith *et al.*, 1987). The survey showed that about 29 percent of the total households interviewed in Nairobi practised some urban agriculture while 17 percent kept some livestock. A recent regional scoping study, commissioned by the UK Department for International Development, in Nairobi, Kampala, Dar es Salaam and Addis Ababa confirms that many urban households keep livestock as a response to limited alternative livelihood options and food security (Guendel, 2002). The scoping study recommended further research to provide detailed information that could contribute to the development and promotion of livestock keeping by the urban poor.

Results of a national characterization survey of dairy farming system has indicated that smallholder dairy farms represent half of the total milk production in Kenya and there is rapid intensification especially in the peri-urban areas of Nairobi (Omore *et al.*, 1999; Staal *et al.*, 1997 and 2001). The studies identified constraints and opportunities for future research and development. However, the focus was on rural agriculture and rural development with little analysis of the urban dairy production. Although the issues identified in the rural and peri-urban smallholder farmers may apply in urban areas, the urban dairy farmers may face very different challenges and opportunities. Therefore, there is a need to analyse the status and trends of smallholder dairy land use intensification from both rural and urban perspective. It might be of interest to explore the influence of urbanization on urban and peri-urban smallholder dairy land use intensification.

1.3 Research Objectives and Questions

The present study examines the status and trends of urban agricultural land use changes in the urban, peri-urban and immediate rural areas of Nairobi, Kenya. The aim of the study is to provide information and improve our understanding of dairy land use dynamics and implications for future research and development. The main objectives are to:

1. Describe the characteristics of smallholder dairy farming with respect to household profile, dairy management practices and milk marketing;
2. Analyse and compare the levels of dairy intensification in the urban, peri-urban and rural areas and try to explain the difference; and
3. Discuss the implications for land use theory, policy and future research and development.

The following research questions guided the study:

1. What are the social and economic characteristics of households keeping dairy cattle under zero grazing?
2. What are the nature of dairy management practices in terms of cattle housing, feeding, health, breeding, milking and milk marketing channels?

3. How do the above characteristics differ among urban, peri-urban and rural areas?

4. What factors influence the observed differences?

5. How can we group the dairy enterprises into uniform categories?

6. What indicators can define the categories?

7. What challenges and opportunities do different categories of dairy enterprises face?

8. What are some of the possible future research, policy, and action required at the national, regional, and local levels in order to improve dairy production?

9. What contribution can the case study contribute to land use theory?

1.4 Significance of the Study

Although there have been many studies on agricultural land use change in urban regions, most studies were in developed countries and have concentrated on agricultural land conversion and urban sprawl or environmental degradation. In contrast, theoretically grounded agricultural intensification studies in developing countries have focused on rural areas with little account on the influence of urbanization on intensification. Instead, most studies focus on population density or economic factors such as transportation cost and distance to urban markets for maximization of profits. Although some studies on the effects of urbanization on agricultural intensification exist for developed countries, especially United States and Europe (Bryant *et al.* 1982; Bhadra and Brandao, 1993), the results are not applicable in Sub-Saharan Africa where the contexts of urbanization are very different. Previous studies on agricultural land use change and intensification exist, however, there have been no case studies focusing on the effects of urbanization on urban and peri-urban smallholder dairy intensification from Sub-Saharan Africa reported in the literature.

Therefore, the present study will provide empirical data that describe and explain the extent and trends in dairy land use intensification in the urban and peri-urban areas of Nairobi, which are currently unknown or approximated. By using the empirical data to test the theoretical basis of land use change, we hope that the study will contribute to advancement of knowledge in agricultural land use change in the urban regions. We hope that the improved knowledge might contribute to informed decision-making in policy, research, and implementation of development projects in urban and peri-urban areas aimed at reducing urban poverty, food security, and environmental degradation. The experience gained in this study can be adapted and applied to other urban regions in Africa.

On the broader global perspective, there is a growing interest in land use and land use change. Studies in the earth systems and global environmental change have recognized land use and land use change as both cause of global change and also as influenced by global change (Briassoulis, 2000; Aspinall, 2006). Detailed information on land use and land use changes are required by climate change scientists in order to better understand and model climate change (DeFries *et al.* 2002). Although urban land use occupy only less than 2% of the earth surface it is one of the most important driver of global land use change (GLP, 2005). However, empirical case studies focusing on urbanization and land use change are very few and far apart. The present study seeks to address the above gaps in our knowledge.

1.5 Outline of the Thesis

The three objectives posed above helps in the arrangement of chapters in this thesis. The next chapter reviews the literature that analyses the effects of urbanization on agricultural land use change. Then chapter 3 provides the context of the study area by examining the human and environmental factors, at the local, regional, national levels, that may help to explain the differences in the levels of dairy land use; and introduces the method for collecting and analyzing the empirical data. Chapter 4 describes the detailed characteristics of the farm households, farmland, dairy cattle population, feed resources, dairy farm facilities and services, and milk production and marketing, concluding with opportunities and constraints facing dairy farming in the Nairobi urban region. Chapter 5 compares the level of dairy land use intensity in terms of inputs and outputs among the urban, peri-urban and rural farmers. Finally, chapter 6 summarizes the results, compares the results with results obtained in the previous studies and draws some conclusions

CHAPTER 2

LITERATURE REVIEW

This chapter begins by defining some concepts in urbanization and agricultural land use change as well as their representation in theory and how they are measured in practice. This is followed by description of two conceptual frameworks which provide the theoretical and analytical background to the study. The urban-rural gradient is a spatial model that provides for the logical division of the urban region into urban peri-urban and rural zones. It has no explanatory or predictive context but purely a descriptive generalization. On the other hand, the coupled human-environment land use system provides some theoretical foundation. It is a representation of the drivers of land use change at multiple institutional, temporal and spatial scales based on systems theory.

2.1 The Urbanization Literature

2.1.1 Challenges of the Urbanizing World

More than a half of the world population now live in urban areas and this is projected to reach 60 % by 2030 (UNFPA, 2007) and 70% by 2050 (UN, 2008). This will be particularly notable in developing countries in Africa and Asia, where people in towns and cities will likely increase from 44% in 2007 to 67% in 2050 (Figure 2.1 and 2.2). The projected urban population growth, particularly in Africa, is a major challenge in the face of increasing poverty, food and nutrition insecurity, and environmental degradation. In its Fourth Assessment report of 2007, the Intergovernmental Panel on Climate Change (IPCC, 2007) has warned that Africa is particularly vulnerable to projected future climate change and variability. It is projected that reduction in agricultural yields in some African countries could be as much as 50 percent by the year 2020. The Report concludes that the small-scale farmers would face the worst impact which would adversely affect agricultural production and food security. As a result more people will be expected to migrate into urban areas in search of better livelihoods.

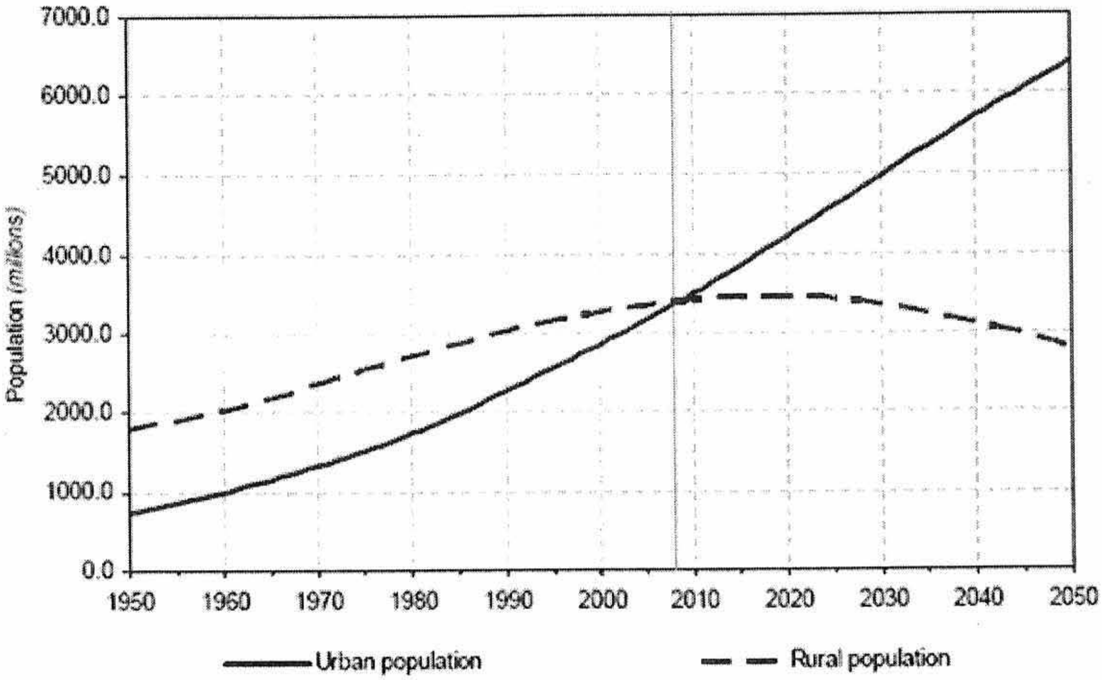


Figure 2.1 Global Urban and Rural Populations, 1950-2050 (UN, 2008)

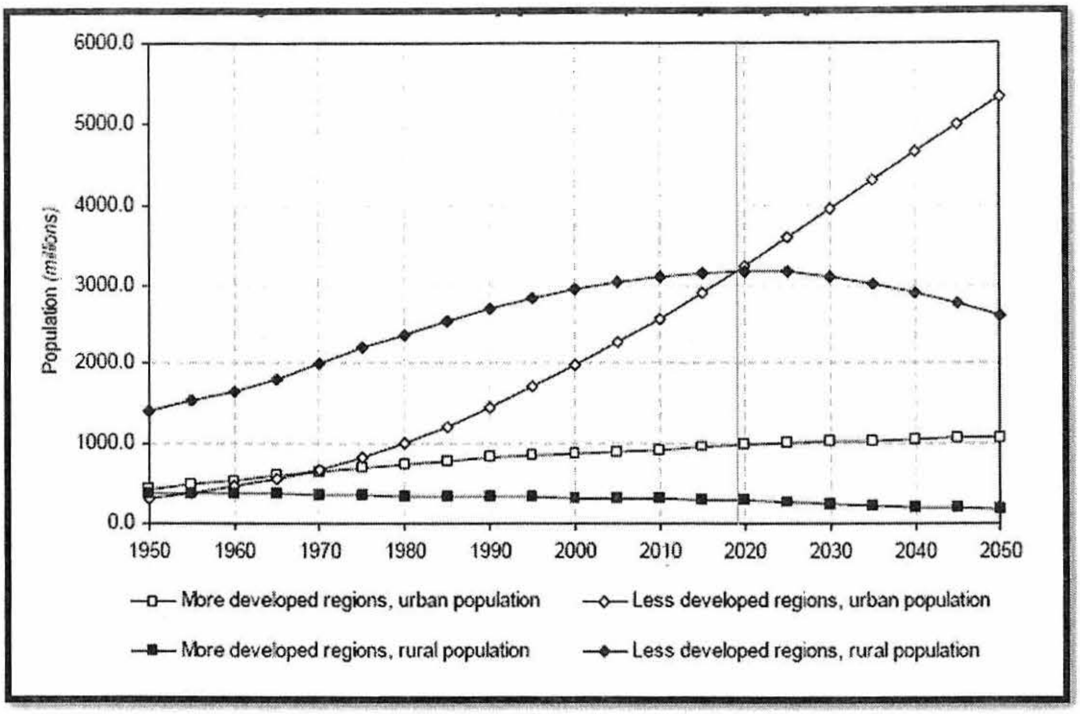


Figure 2.2 Urban and Rural Populations for Developed and Developing Countries, 1950-2050 (UN, 2008)

Poverty has long been associated with rural settlements while urban areas have been associated with high standards of living and access to services. However, poverty is now being urbanized. UNFPA (2007) notes that more than half of urban population in Africa now live below the poverty line, as measured by the number of people earning less than one USA dollar in a day. In many urban areas, rates of economic growth and infrastructure development have lagged behind spatial urban expansion, resulting in unemployment and inadequate services. According to ILO (1995), the modern sector has failed to generate sufficient jobs and this has contributed to expansion the informal sector which is now a major urban employer.

Urban agriculture is one of the informal activities in which some of the vulnerable urban people participate. Although well-established in some cities, urban agriculture is often illegal and excluded from statistics and development activities. The official information systems do not indicate the existence of urban agriculture, especially the urban dairy. Therefore, we do not know the extent of urban dairy or where they are located. However, in order to ensure improved urban livelihoods, strategies are now needed for cities to build on their comparative and local advantages (UNFPA, 2007). There is need for updated and reliable information and analysis of local urban dairy land use activities. This could improve informed decision-making in such areas as policies for poverty reduction, vision for sustainable urban development as well as allowing policy makers to decide where to act.

2.1.2 Definitions and Measures of Urbanization

Despite wide acknowledgement that managing urbanization is one of the key challenges of the 21st century, there is no common technical definition of the term urban that can apply to all types of research and policy situations (McIntyre *et al.*, 2000; Theobald, 2004). The definitions of urban areas vary between and within different countries both in time and with the settlement characteristics. For example in the United Kingdom, areas are described as urban or rural depending on whether the majority of the population fall inside a settlement of 10,000 population or more (Office for National Statistics, 2005). In contrast, The Central Bureau of Statistics of Kenya has adopted the population census and national statistical concept of classifying as urban all settlements with a population of at least 2,000 people (GoK, 2002). Therefore, a settlement in Kenya belongs to the urban area, or a rural if it is not. Globally, the United Nations (UN, 2004) accepts the definitions of urban used by each nation. However, most the official definitions of urban areas are based on policy needs and cannot serve specific research goals (McIntyre *et al.*, 2000; McConnell and Keys, 2005).

In order to overcome some of these problems in defining urban areas, ecologists have proposed the concept of an urban-rural gradient (McDonnell and Pickett, 1990). The urban-rural gradients are not physical linear transects on the ground but rather abstract classification of changes in land use, land cover, human activities and other environmental processes as one moves outwards beyond the city centre from predominantly urban to predominantly rural areas beyond the city limits. In general, there is a non-linear and a non-uniform gradient of urban influence in the surrounding areas (McGregor *et al.*, 2006). The urban-rural gradients represent unique natural experimental conditions with varying levels of urbanization which researchers can exploit in studying urban systems (McIntyre *et al.*, 2000).

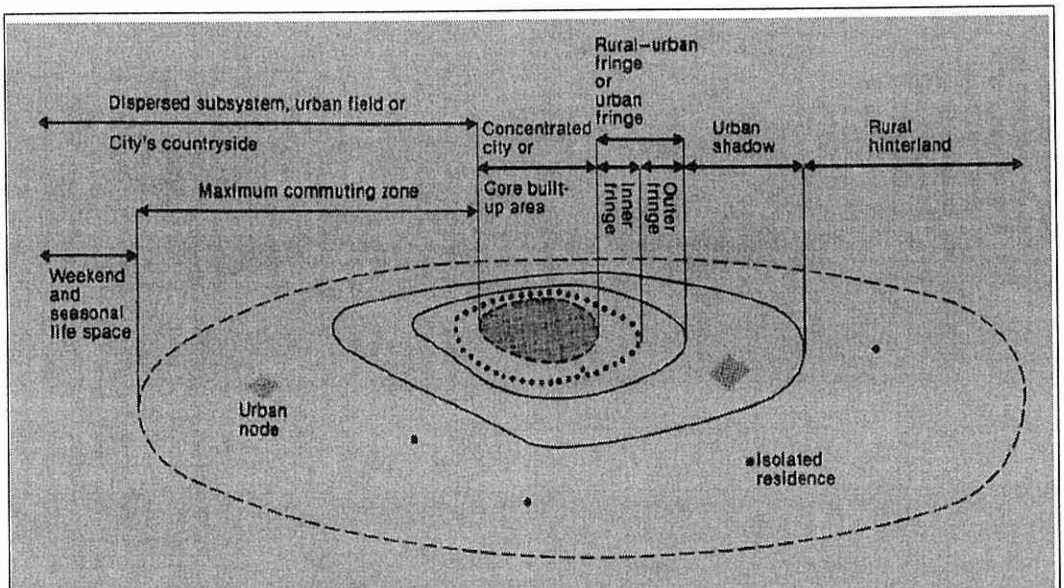
The use of the urban-rural gradient has recently gained popularity as a useful tool in studying ecological changes across urbanizing regions. For example, McKinney (2008) provides the most comprehensive meta-analysis of recent studies on the impact of urbanization on ecological processes. In clarifying urban-rural gradient in ecological studies, Theobald (2004) proposes the use of the degree to which the natural processes are controlled by human, as well as the degree to which the landscape patterns are natural or artificial. However, there is a high variability in how the urban components of the gradient are defined. The nature of data available and the objectives of the study has determined the exact measures used in defining the urban-rural gradient. Theobald (2004) further notes that the commonly used measures include: subjective, based on qualitative descriptions; distance from the city centre, using transects; mapping land cover, such as using the vegetation or impervious surface cover; population density or; building density such as housing density or density of roads.

An ecological study in Melbourne, Australia, used principal components analysis to define the urban-rural gradients (Hahs and McDonnell, 2006). The main ecological measure that captured most of the variability and thus representing the best measure of the urban-rural gradient included: human population density, dominant land cover and landscape patterns. Siri *et al.* (2008) have also used principal components analysis and cluster analysis to produce a quantitative classification of urban-rural gradients for malaria epidemiology research in Kisumu City, Kenya. The resulting urban zones were found to be more logical measure of the urban-rural gradient compared with those from population density or administrative boundary of urban by census data.

Socio-economics, environmental and agricultural variables have also been used in cluster analysis to quantitatively define urban-rural gradients within the peri-urban areas in Kumasi, Ghana (Adam 2001). The variables used included: reported decline in soil fertility; reduced fallow period; increase in agrochemical use; increase in cultivation of cereals and home-gardens; decline in cultivation of cocoa; increase in cultivation of vegetables and keeping of poultry; reported high costs of inputs and; introduction of modern farming methods such as use of fertilizer. All the villages studied had a process of change linked to Kumasi but with different levels of change. The degree of changes in the villages was influenced by many factors other than the distance to the city centre. This confirms that there is no single indicator for the urban-rural gradient.

2.1.3 The Urban-Rural Gradient Model

Bryant *et al.* (1982) provided the general spatial model of the urban-rural gradient as a basis for defining the areas around any city. Although no two cities are exactly the same in their patterns, quite often we can detect zones around the city centre that can be found in many cities. Its principle elements are presented in Figure 2.3. The different zones are classified according to the degree to which they are influenced by the urban centre. Right in the middle is the core built-up area, commonly called the central business district (CBD), consisting of the commercial and administrative buildings.



The form of the regional city (from Bryant et al. 1982)

Figure 2.3 Urban-Rural Gradients (The Countryside Agency, 2003)

The areas next to the CBD are identified as the urban fringe, which can be further subdivided into the inner fringe and the outer fringe. The urban fringe can be considered as the thin strip of land around the core built-up area, where rural land uses are being taken over by the urban land uses. This is followed by the urban shadow that often consists of scattered non-agricultural residential houses with decreasing number of daily commuters to the city centre. Finally the rural hinterland has predominantly agricultural land uses but with some commercial and commuting links to the city centre. Peri-urban is the general term for all these areas of mixed land use with influence from the urban centre. According to Caruso *et al.* (2001), the two most distinguishing characteristics of the peri-urban areas are: functional link to the city centre and; rural land use due to presence of large areas of agriculture, forestry or conservation with resulting low human population density.

It is now widely acknowledged that peri-urban areas are not restricted to their normal association with areas surrounding the city centre but can occur in a range of settings. A recent study in Melbourne, Australia, has refined the spatial model of peri-urban areas to include areas: adjacent to metropolitan centre; adjacent to non-metropolitan regional centre; adjacent to an urban centre within the non-urban commuter hinterland of a metropolitan or regional centre and; a peri-urban along a growth corridor or transport network (Buxton *et al.*, 2006). This detailed spatial representation of the peri-urban is indicated in Figure 2.4 below. However, this detailed classification of peri-urban areas would be only useful for a study dedicated to peri-urban areas, unlike the present study that explores the urban, peri-urban and rural areas

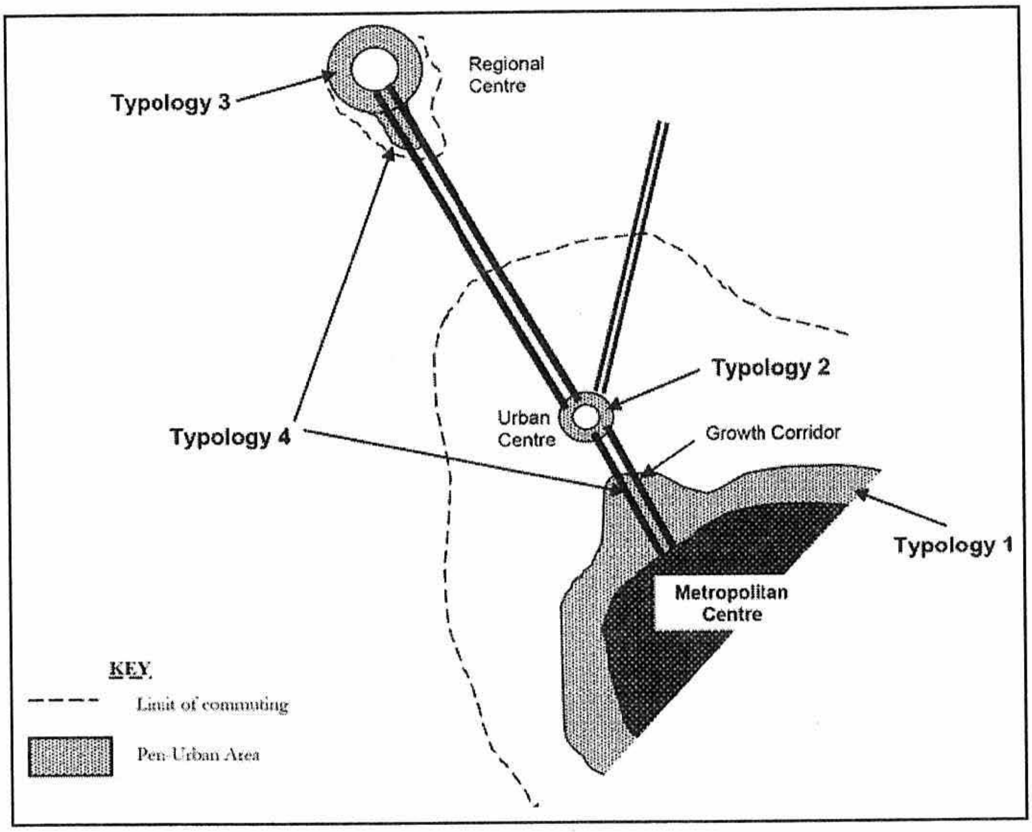


Figure 2.4 Peri-Urban Areas (Choy, 2006 Modified from Buxton *et al.,* 2006)

In summary, urbanization can be conceptualized in terms of the shifting spatial influence of the city centre on the surrounding areas over time. Within this continuum we can identify the core urban centre, the peri-urban and the rural hinterland, each having different human and environmental characteristics. However, McIntyre *et al.* (2000)

noted that there is no need for a single uniform definition of the urban-rural gradient because the key variables will depend on the objective of the research and available data. Therefore, for the purpose of comparisons between studies, it is always recommended to quantify the criteria used in defining the urban-rural gradients. The general spatial representation of the urban rural gradient (Bryant *et al.*, 1982) will be useful in identifying the urban, peri-urban and the immediate rural areas in Nairobi.

2.2 Land Use Change Literature

2.2.1 Background to Land Use Change

Land use change occurs locally and is now acknowledged to be the most prominent form of global environmental change. The effects of local land use changes are cumulative and attain a global importance because of their outcomes in the global ecosystem (Turner and Meyer, 1991; Turner and Meyer, 1994; Turner *et al.,* 1994, 1995 and 2004). It is estimated that more than a half of the earth's surface has been transformed by human-induced land use change and this is expected to get worse for the next several decades (GLP, 2005; MEA, 2005; Vitousek *et al.*, 1997). The increasing intensity of land management has contributed to: modified rates of biogeochemical cycles, loss of biodiversity, soil erosion, climate change and variability, and impacts on other ecosystem goods and services for human needs and subsequently influencing sustainable development. There is urgent need to improve our understanding and knowledge on the land use changes, the underlying processes, and how to mitigate the effects on environment and human. Patterns, extent and rates of land use change need to be identified in order to focus research, policy and management in the affected areas (Lambin *et al.,* 1999; Verburg *et al.*, 2004; Lambin and Geist, 2006). In response to these trends, national and international organizations have called for accelerated studies in land use change.

The scientific community called for the study of land use change during the 1972 Stockholm Conference on Human and Environment and again in 1992 United Nations Conference on Environment and Development (UNCED, 1992). In 1994 an international and interdisciplinary project on land use and land cover change (LUCC) was launched. The project was initiated by the International Geosphere-Biosphere Program (IGBP) in collaboration with the International Human Dimensions Program (IHDP) on Global Environmental Change (Turner *et al.*, 1995; Lambin *et al.*, 1999). The LUCC project sponsored several studies at the global, national and local levels aimed at improving our understanding on land use change focusing on human-environment interactions. The Implementation Strategy of the LUCC project provided the guidelines for priorities in land use change research during the period 1994 to 2005 (Turner *et al*, 1995; Lambin *et al.*, 1999). The approach was based on interdisciplinary and combined the three epistemological approaches of inductive, deductive and mixed approaches.

At the end of LUCC project in 2005, there was still no comprehensive explanation of land-use changes, although much progress had been made in understanding the causes and processes at play (Lambin and Geist, 2006). The LUCC synthesis report has stressed that that urbanization is likely to become the dominant factor in land use change in the decades to come. Over the past decade during the LUCC project, land use change research has been recognized as a heterogeneous, dynamic, non-linear and complex system (Turner *et al.*, 2007). In this dominant paradigm, the new Global Land Project (GLP) took over from the LUCC project, still under the joint leadership of IGBP and

IHDP. The Global Land Project research priorities on major challenges facing land use change for the period 2005-2015 are set out in its Science Plan and Implementation Strategy (GLP, 2005). GLP has asserted that, presently and for the next several decades, land use change is a key determinant in global environmental change. GLP calls for analysis of land use changes, particularly across the urban-rural-wilderness gradients. In line with the new thinking in land use change research, some definitions are provided in the next section.

2.2.2 Definitions and Measures of Land Use Change

Land use, land cover, land use change and agricultural land use intensification are all contested terms, each with a multiple of meanings. Therefore it would be useful to clarify their meanings in this section so that we can apply them uniformly in the present study. Land cover refers to the physical surface characteristics of the earth's surface that may include vegetation, bare soils, water or human structures (Turner *et al.*, 1995) Land use has been defined as the human activities which are directly related to land, making use of land resources or having an impact on them (FAO, 1995). Therefore land use refers to the function or purpose for which land is utilized, and may include for example raising cattle, road networks, recreational parks or urban settlement. The description of land use usually involves specifying the mix of land use types, the particular pattern of these land use types, the areal extent and intensity of use associated with each type and the land tenure status. Land use change occurs when the user of land decides to employ land resources towards different purposes. According to Briassoulis (2000) land use change is usually taken to mean quantitative changes in the conditions, magnitude and pattern of a given land use type.

Land use change can further be conceptualized into land use conversion and land use modification Land use modification denotes the slow and gradual change affecting a particular land use type, While land conversion indicates complete replacement of one land use by another (Turner *et al.*, 1995). Land use conversion involves change from one land use type to another which may include changes in the mix and pattern of land use in an area. In contrast, land use modification involves alterations of structure and function without a complete change from one land use type to another. The widely discussed land use conversions in literature are the changes from forestry to agriculture and from agriculture to urban land use. Most of the recent studies on land use change in the urban and peri-urban areas have focused on conversion of rural agricultural land to urban land use or urban sprawl and the negative impacts (Bernstein, 1995; Johnson, 2002). Detailed conceptualization of land use change is provided by Briassoulis (2000).

In the proposed study the focus is on land use modification and not on land use conversion. Modification of a particular land use may involve change in the intensity of land use as well as alteration of its characteristic qualities. Turner and Doolittle (1978) defined agricultural intensity as the amount of output or input per unit area per unit time. Therefore, the more intensive agricultural systems are those with higher outputs per unit area per unit time. The unit of measurement of land area can be a plot, farm unit, an acre, hectare or any other unit, while time can be measured in days, months, years, cropping seasons or any other units. Assessing the monetary values would make these inputs and output comparable, however due to limited data and variation of price in time and space, sometimes it becomes necessary to use surrogates for agricultural intensity (Turner and Doolittle, 1978; Shriar, 2000 and 2005). According to Hunt (2000), the term agricultural intensification is too vague to be used as an empirical variable. Hunt argues that several components of agricultural land use can be used for intensification, for example modifying the type of technology, amount of labour, land, or any other input will have completely different meanings. A recent meta-analysis of agricultural land use change in the tropics confirms that agricultural intensification involves several processes and therefore concludes that a single definition is not useful (Keys and McConnell, 2005). The main processes captured in the meta-analysis included: adoption of new field crops; development of horticulture and; planting of trees on the farms. Herzog *et al.* (2006) used amount of nitrogen fertilizer applied on crops, density of livestock units; and number of agrochemical applications as indicators of agricultural intensity in Europe. In the present study, dairy intensification will be measured in terms of inputs or outputs such as number of milking cows, milk output or sales per unit area over time, levels of labour input, and types or amount of animal feed inputs. This will imply considering dairy farming system with comparable technology, while keeping the other variables under control

2.2.3 Approaches to Land Use Change Research

Several approaches and theories have been advanced to describe and explain land use changes. The modern pioneers of the study of land use change can be traced back to John Heinrich von Thunen (Briassoulis, 2000; Turner *et al.*, 1990). The work of von Thunen was first published in 1826 in German and later translated into English by Hall (1966). In his book "Isolated State", von Thunen analysed the location of agricultural land as a function of distance to market centre and transport cost. According to von Thunen, agricultural intensity decreases with increasing distance from the market centre. Although it overlooks other biophysical and institutional factors influencing land use change, many of the current urban economics and agricultural economics literature draw their explanation from von Thunen theory (Bryant *et al.*, 1982; Briassoulis, 2000, Browder, 2002).

Malthusian theory emphasizes that population growth is the main cause of land use change (Ehrlich and Ehrlich, 1990). Boserup's theory maintains that population growth increases agricultural land use change as innovation and technological shifts occur and allows for growing population (Boserup, 1965 and 1981). However, the literature indicates that land use change is a result of a complex interaction between natural and human factors operating on multiple spatial, temporal and institutional scales, and can not be explained by a single theory. The role of economics and population factors alone are not specific and cannot explain land use change (Lambin and Geist, 2006, Keys and McConnell, 2005).

Recent comprehensive reviews have evaluated and summarized the alternative ways in which explanatory theory of land use change has been approached (Briassoulis, 2000 and 2005; Lambin *et al.*, 2003; Parker *et al.*, 2003). Briassoulis (2000) uses discipline based typology to classify land use theories into three main categories: natural sciences, social sciences and interdisciplinary research. The conclusion is that although there are many theories that have been put forward to explain land use changes, there is no single theory that can comprehensively describe and explain land use changes. Instead different theories specialize on different spatial and temporal levels while focusing on specific driving factors. Natural science based theories have placed excessive focus on biophysical factors while ignoring or assigning a secondary role to other factors such as institutional, political and economics. Other theories have emphasized economic profit maximization while others have only focused on demographic without considering the effect of the other driving factors.

Therefore it is now widely accepted that the study of land use change is problem oriented and in practice should not be restricted to a specific single theory but should combine different theories at different temporal and spatial scales (Lambin *et al.*, 1999; Briassoulis, 2000). Each theory has its particular merits and limitations. The multidisciplinary nature of land use change is widely recognized in both the natural and social sciences, however, the institutional powers of disciplines remain strong and multidisciplinary science that cut across disciplines is not yet well developed (Agarwal *et al.*, 2002). At the empirical level, there have been three basic methodological approaches in land use change studies: the narrative, agent-based and mixed or systems approach (Turner *et al.*, 1999; NAS, 2002; Lambin *et al.*, 2003).

The narrative perspective uses qualitative methods and seeks depth of understanding through historical details and interpretation (Klepeis and Turner, 2001). It tells the land use change story for a specific locality while recognizing that it is difficult to understand the dynamics of land use change at a point in time without analysis in the context of long histories of nature-human interaction. It is especially beneficial in identifying random events that significantly affect land use change but might be missed out in approaches employing less expansive time horizon or temporary sampling procedures (Batterbury and Bebbington, 1999; Lambin *et al.*, 2003). The narrative approach is illustrated in the empirical contribution of Guyer and Lambin (1993), and Olson *et al.* (2004a and 2004b).

The narrative approach may help to identify land use driving factors that are consistently important over long-term, thereby providing an empirical and interpretative baseline by which to assess the validity and accuracy of the other approaches. Case studies have shown that historic approach requires triangulation of data from different methods such as oral history, household surveys and archival work (Batterbury and Bebbington, 1999). The limitation of the narrative approach is that it requires long term studies, availability of longitudinal data and expertise, but these rarely exist since land use change studies have started only recently.

The agent-based approach seeks to explain the general nature and rules of land use decision-making by individuals. There are many forms of explanation ranging from the rational decision making in economics to household, gender, class or other dimensions. The agent-based approach represents the motivation behind decisions and external factors that influence decisions on land use (Lambin *et al.*, 2003). Most of the agent based case studies have been informed by neoclassical economic or demographic perspectives (Lambin *et al.*, 2003, Browder, 2002). The economic framework emphasizes rationality and utility maximization concepts and assumes that any parcel of land in any location is to be allocated to the land use activity that earns the highest rent (Chomitz and Gray, 1996). The demographic and human ecology frameworks focus on household scales with farm family as the unit of analysis. The common limitation of agent-based approaches is that they often focus on one level of analysis exclusively without considering the range of other alternatives (Browder, 2002; Lambin *et al.*, 2003). For example, the institutional and political factors external to the household originating from regional, national or global scales normally escape treatment.

Most recent case studies have also been criticized for focusing on simplistic economic frameworks which assume that decision-makers will maximize the present value of their land resources (Briassoulis 2000; Anthony, 2004). The value of land is usually defined in economic terms, but economic value should not be the only criterion important for decision making. The environmental, political, social and cultural factors that are not quantifiable are very important but have rarely been captured in most of the agent-based land use change models that use an economic framework (Anthony, 2004).

The alternative approach is to view land use change as a dynamic complex system of human-environment interactions operating at local, regional and global levels. The systems approach is based on comprehensive and trans-disciplinary problem-solving process that is oriented towards real-world issues such as global environmental change, capitalism or globalization (Hadon *et al.*, 2005). Klein (2005) argues that a systems approach is a reaction to the scientific system that is highly fragmented into sub-disciplinary fields and is therefore unable to deal with the complex real-world problems. In order to address the pressing real-world problems in a comprehensive manner, the systems approach recognizes the need to combine different theories, concepts and methods from many different fields. In land use change studies, systems approach has been used in political ecology chain of explanation (Blaikie and Brookfield, 1987; Campbell and Olson, 1991; Olson *et al.*, 2004a) and in land use change science (Turner *et al.*, 1995; Lambin *et al.*, 1999 and 2003; Young 2002).

The different approaches of understanding follow different lines of explanation of the processes and causes of land use changes because each focuses on specific temporal, spatial and organizational levels. The narrative or historic approach adopts long-term vision and focuses on critical events and abrupt transitions, whereas the agent-based approach deals with individual land user's foreseeable future at the household levels and the systems approach tend to focus on gradual and progressive processes at the global and national scales. Both the agent-based and systems approaches depend on explicit model development and empirical testing. The best way forward would be to pick the most realistic principles from each approach and combine them in a case study of land use change (Briassoulis, 2000; Overmars and Verburg, 2005; Lambin and Geist 2006)

Therefore, land use change analysis requires conceptual frameworks and analytical methods that are both comprehensive enough to capture the dynamics of the interactions at different scales and flexible enough to accommodate the temporal dynamics of these processes (Campbell, 1998; Briassoulis, 2000; Lambin and Geist, 2006). In this study, in order to be comprehensive and flexible, the narrative, agent-based and systems approaches will be combined in various ways without being constrained by a particular theory (Lambin *et al.*, 2001 and 2003; Serneels and Lambin, 2001).

2.2.4 Land Use Change Analysis Framework

The foundation of the land use change analysis framework is the coupled human-environment system that refers to the interaction between the human and environmental factors that determine land use change. The key elements of the human subsystem may include: economics factors such as markets and infrastructure; population factors such as growth, density, labour force, age or gender; socio-culture factors such values and beliefs, lifestyle; technology such as animal feed, breeding, milk transportation and processing.

The environment components may consist of: biogeochemical cycles such soil nutrients, carbon balance; physical characteristics such as landforms, topography, altitude and geology; biodiversity such as animal and fodder crop genetics and; natural processes such climate change and variability, droughts, floods, livestock pest and diseases.

The analytical framework was articulated by the LUCC project (Turner *et al.*, 1995; Lambin *et al.*, 1999). The approach maintains that land use change is a complex and dynamic non-linear process driven by multi-factors at different temporal, spatial and institutional levels. A modified model of the framework is shown in Figure 2.5 (Le, 2005). The framework draws on complex systems theory that combines the three epistemological approaches of deductive, inductive and mixed research methods. It combines perspectives of understanding in order to meet the need to scale up, down and across levels of space, time and institutions. The framework also encourages use more than one method for data collection and analysis (Young, 2002 and Lesschen *et al.*, 2005). The coupled human-environment framework is based on the following key principles (Turner *et al.*, 1995; Lambin *et al.*, 1999):

1. Involves explicit integration of environmental (or natural) and human (or social) processes as active driving forces of land use change.
2. Use of historical time frame relevant to understanding the temporal dimensions of past, current and future patterns of land use change.
3. Recognizing that different driving factors have different temporal characteristics, some are long-term processes while others are short-term.

4. Explicit examination of feedback mechanisms among processes and the connections across factors. This is represented in Figure 2.5 by the arrows of interactions between factors and between scales.
5. Examination of interactions over space by recognizing that events in one area can have impacts in other areas.
6. Derived from theory and empirical studies.
7. Applicable and relevant to a wide range of land use change situations.

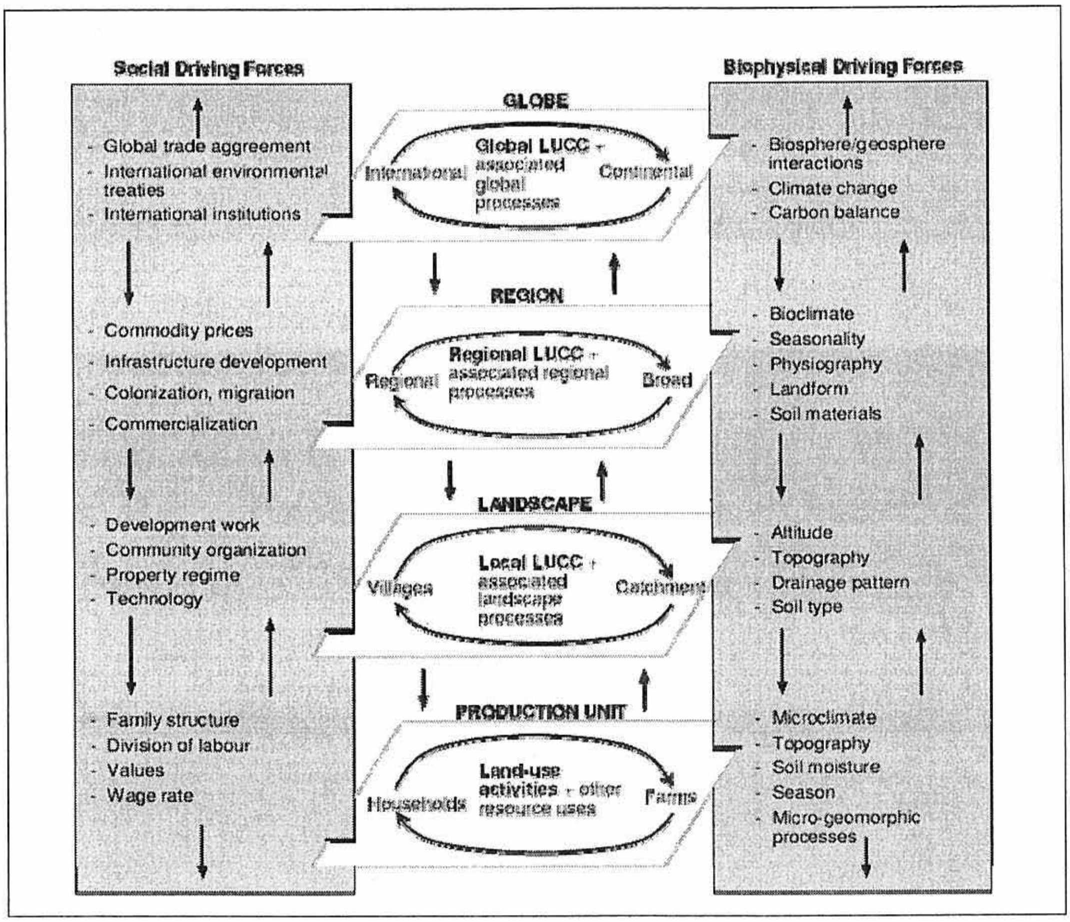


Figure 2.5 Coupled Human-Environment Land Use Systems Framework (Le, 2005)

In practice, case studies rarely include all the above elements either because the local or regional context renders them irrelevant or a single specific link is of the greatest importance to the research. In the present study the influence of urbanization on agricultural land use change is critical and will be emphasized at the local level. At the global level, influence of globalization and trade liberalization might be considered. At the national and urban regional levels it might be possible to consider the policy and practice in urban development, agriculture, livestock and dairy industry. Population, climate, soils, hydrology, geology and topography will also be considered at the local levels. The next section describes and gives selected examples of how the key elements of the framework interact to influence land use change.

2.3 Driving Factors of Land Use Change

Driving factors are the forces that influence the process of land use change. Land use change is influenced by a number of natural and human factors operating at different spatial and temporal levels and interacting in complex relationships (Briassoulis, 2000 and 2005 Lambin and Geist, 2006 and 2007). What is identified as a driving factor of land use change is determined by the spatial, temporal and institutional scale of the land use system being studied (Lambin *et al.*, 2003; Burgi *et al.*, 2004). Human or socioeconomic factors include: demography; technology; economy; political and social institutions; culturally determined attitudes, beliefs and behaviour; and information and its flow. Among the biophysical factors are: climate, rainfall, temperatures, weather conditions, surface and underground hydrology, landforms, geology, soils, vegetation, animal communities, and natural hazards (Briassoulis, 2000). The relative importance of biophysical to socioeconomic drivers of land use change varies with location and through time. The influence of biophysical factors on land use change has been well addressed in the literature unlike the influence of socioeconomic factors which is less well developed.

The human driving forces are further distinguished into underlying forces, proximate forces and mitigating forces (Turner *et al.*, 1994; Ojima *et al.*, 1994; Briassoulis, 2005; Lambin and Geist, 2007). Proximate causes of land use change constitute human activities or immediate actions at the local level that originate from intended land use decisions. They involve direct physical action such as decision making by the land user to shift from one land use type to another. The underling or root causes, on the other hand, are those main, deep rooted societal forces that underpin the more proximate causes of land use change (Lambin *et al.*, 2003). The proximate causes generally operate at the local scales such as at the household, individual farm or community levels. By contrast, underlying causes may originate from the regional or global levels. Therefore underlying causes of land use change are often exogenous to the community and decision-makers. Human mitigating forces counteract the negative impacts of proximate and underlying human driving forces and they include both formal and informal regulations, market changes and technology innovations. Sometimes the mitigating forces become underlying root causes of land use change to cope with the negative impacts of past land use change (Briassoulis, 2005)

The driving forces form a complex system of dependencies, interactions, and feedback loops and they affect several temporal, spatial and organizational levels

(Lambin *et al.*, 2003). However, understanding the influence and interaction among different factors that drive land use change is complicated therefore it is difficult to analyse and represent them effectively. Frequently certain driving forces are emphasized over others. The detection, measurement and explanation of land use changes usually depend on the spatial, temporal and institutional level of analysis (Briassoulis, 2005). Small changes cannot be detected at high levels of spatial and temporal details. Similarly, long-term trends of land use change cannot be detected within a short time horizon and small spatial units. Therefore driving forces have to be interpreted in a nested or hierarchical scale of explanation (Briassoulis, 2000; Blaikie and Brookfield, 1987).

The biophysical factors are the natural characteristics and conditions of the land that define the capacity for different land uses. These factors act as potentials or constraints to planned changes in land use and determine the range of choices considered and final decision by the land users. The biophysical factors vary among localities and regions and the most important ones include: Climate and weather, geology, topography, underground and surface hydrology and natural hazards (Briassoulis, 2005). The influence of biophysical factors on land use changes are well documented, especially at the local levels (FAO, 1976 and 2007; Davidson, 2002). Therefore the available knowledge will be used and these factors will be treated as control variables at the local level of analysis.

Changes in population size, composition and distribution have important impact on land use change. Natural population growth and migration as well as urbanization have been shown as important factor causing land use change in a time scale of a couple of decades (Geist and Lambin, 2002; NAS, 2002; Briassoulis, 2005). However, population factors alone have not been confirmed as a major determinant of land use change, because demographic explanations often ignore the influence and interactions of other parameters (Briassoulis, 2005). A report on case studies from India, China and United States of America indicates that the limitation in most formulas relating population to land use change is that the role of socio-economics and political organization and institutions is overlooked (NAS, 2002). The report indicates that government policies and globalization have more influence than simple numerical population increases (NAS, 2002). The policies identified to directly or indirectly affect land use change include: environmental policies; population policies; foreign investment regulations, economic price control on agricultural inputs and outputs; resettlement incentives; taxation and privatization; and reforestation and infrastructure support programs. The report concludes that any understanding of the interaction between land use change and population will depend on taking into account the external and global forces.

Cultural factors also influence land use change. Land users have different beliefs, personal histories, attitudes, collective memories and individual perceptions that influence their land use decisions (Lambin *et al.*, 2003). The formal and informal organizations and institutions of society establish opportunities and constraints on land use decision making (Young, 2002). The institutions link the local conditions to the national and global processes and vice versa. Institutions such as government or transnational corporations operate interactively at different spatial and temporal scales while community institutions and organizations operate at the local levels

Recent research indicates that at the timescale of decades or less, land use changes mostly result from individual and social responses to changing economic conditions mediated by other factors (Lambin *et al.*, 2001). Economic factors and market forces define the range of variables that have direct impact on decision making by the land users (Lambin *et al.*, 2003). Access to transport infrastructure and market for output and input also influence land use change (Briassoulis, 2005).

Globalization has been defined in various ways by different people depending on the context in which it is used. The term globalization basically implies increase in linkages across national boundaries and the spread of goods, ideas, practices, communication and technologies across the world (Smith and Smith, 2002). In relation to land use change, globalization is not a driving force but is a process that accelerates or reduces the impact of the other driving forces of land use change (Lambin *et al.* 2003). For example a case study on urbanization and land use change in Pearl River Delta in China has indicated that the demand for industrial land did not originate from the region itself but other parts of China and the world (NAS, 2002). The case study indicates that the demand from developed countries for electronic goods and textile products was more influential than local demand for food and housing. Within the present study, globalization is operationalized in terms of trade liberalization and adoption of international urban development planning system.

2.4 Urbanization and Agricultural Land Use Change.

Land use change research has generally concentrated in rural areas focusing on deforestation, agricultural intensification and desertification. Urban areas have been neglected in recent land use change studies. On the other hand, urban studies have concentrated on urban sprawl and conversion of agricultural land into urban land use. For example the only recent comprehensive literature reviews, using meta-analysis of recent case studies of land use change, exist for: deforestation (McConnell and Keys, 2005; Geist and Lambin, 2001 and 2002), desertification (Geist and Lambin, 2004), and agricultural crop intensification (Keys and McConnell, 2005).

Lambin *et al.* (2000) echoed this need for land use change research to pay more attention to agricultural intensification, especially in the urban-rural transition zones of the developing countries. Similarly, the Millennium Ecosystem Assessment report (MEA, 2005) and Global Land Project (GLP, 2005) have identified urbanization and urban areas as research areas where significant knowledge gaps exist. According to Browder (2002) the influence of urbanization on land use change has not been properly conceptualized and this explains why urbanization has not been considered as a driving factor in recent land use change studies. Browder further argues that in the few land use change studies where urbanization is considered, urban factors are narrowly defined using population size or distance to urban centre or a dummy indicator.

Elsewhere, comprehensive national surveys in Kenya indicate that milk price and level of smallholder dairy land use intensification is influenced by high market accessibility around the two main urban areas of Nairobi and Nakuru (Thys *et al.*, 2006; Bebe, 2003; Staal *et al.*, 2002; Baltenweck *et al.*, 1998). The market accessibility was measured as the total time to travel to the nearest urban areas, measured from topographic map distance and grouped by type of road (Staal *et al.*, 2002). These variables do not represent the current concepts of urbanization and its influence on land use change.

Recent case studies in land use change studies have emphasized the need to pay more attention to selection of appropriate accessibility measures instead of simple distance to road or market (Lambin *et al.*, 2000; Verburg *et al.*, 2004). This calls for adequate conceptualization of urbanization as a factor influencing land use change. Apart from identifying land use change in the urban areas as the critical area of research, the land use change research community has also identified the need to develop their own definitions of urban areas (GLP, 2005). Meanwhile, the Global Land Project (GLP, 2005) recommends the use of urban-rural gradient concepts in studying land use changes in urban regions.

CHAPTER 3

THE STUDY AREA AND RESEARCH METHODS

This chapter provides the context of the study area and describes the research methods. It starts by examining the human and environmental factors, at the local, regional, national levels, that may help to explain the differences in the levels of dairy land use. The next section introduces the method for collecting and analysing the empirical data.

3.1 Description of the Study Area

3.1.1 The National Context of Kenya

3.1.1.1 The Environment and Physical Features

Kenya lies across the Equator on the eastern coast of Africa, between latitudes 5 degrees south and 5 degrees north and longitudes 25 degrees and 31 degrees east. Kenya shares common border with Somalia in the northeast, Ethiopia in the north, Sudan in the northwest, Uganda in the west, Tanzania in the south and the Indian Ocean in the southeast. The total land area is about 536,000 square kilometres of which 45,240 square kilometres is under wildlife conservation and 13,400 square kilometres consist of water bodies. Altitude varies from sea level to 5,199 meters above sea level on Mount Kenya. Climate in Kenya ranges from warm and humid tropical climate in the coastal areas to cool temperate climate in the highlands. The annual rainfall varies from 200 mm in the arid north to over 2,000 mm in the central highlands. There are generally two seasons with short rains from October to December and long rains from April to June. About 20 percent of the land area consists of high to medium agricultural potential areas that support 80 percent of the total population. The remaining 20 percent of the population live on 80 percent of the land that is arid or semi-arid.

The agricultural land potentials closely follow the agro-ecological and climatic zones that fall into three broad regions (Jaetzold and Schmidt, 1983; Ominde, 1988). The high potential areas with an annual rainfall of more than 750 mm cover the central Kenya highlands, the Rift Valley, western Kenya and the coastal strip. Commercial dairy production is concentrated in these areas. The medium potential areas with annual rainfall of more than 625 mm but less than 750 mm are located in part of eastern Kenya and neighbouring the high potential coastal strip. The low potential areas with annual rainfall of less than 625 mm cover 80% of Kenya and run from north and north-eastern Kenya to the southern parts bordering Tanzania.

3.1.1.2 Population

Kenya has eight administrative provinces: Nairobi, Central, Rift Valley, Eastern, North-eastern, Western, Nyanza and Coast. A group of sub-locations, the smallest administrative units, form the locations, division, districts and the province. The population of Kenya is currently about 35 million people, growing at an annual rate of about 2.5 percent from 28.7 million people during the 1999 population census (GoK, 2001). Kenya has high and growing urban population and is one of the most rapidly urbanizing countries in Sub-Saharan Africa (UN-Habitat, 2005). In the year 2000, about 33 percent of the total population lived in urban areas and this is projected to reach 54 percent by the year 2030 (Table 3.1). The majority of the urban population is poor and live in the informal settlements without appropriate infrastructure and services (UN-Habitat, 2001).

Table 3.1 Estimates of Urban and Rural Population of Kenya (UN-Habitat, 2001; 2005)

Population Statistics	Year 2000	Year 2015	Year 2030
Total National Population	30,080,000	37,611,000	49,916,000
National Growth Rates (%)	2.8	1.5	1.0
Urban Population	9,957,000	16,752,000	23,696,000
Level of Urbanization (%)	33.1	44.5	54.0
Urban Annual Growth Rates (%)		3.5	2.5
Rural Annual Growth Rates (%)		0.2	-0.2

3.1.1.3 Economy and Development Challenges

Kenya's economy is diverse and based on tourism, mining, manufacturing, agriculture, art and craft, finance and investment, and commercial services. Agriculture is the backbone of the Kenyan economy and currently contributes directly 26 percent of the GDP and further 27 percent indirectly through linkages manufacturing and other service sectors (GoK, 2007). Agriculture accounts for 80 percent of rural employment, 60 percent of foreign exchange earnings and 45 percent of annual government earnings. The sector further contributes over 75 percent of the industrial raw materials and contributes to national food security. Livestock sub-sector contributes about 40 percent of the agricultural GDP and employs 50 percent of the agricultural labour force (GoK, 2007). The dairy industry is the largest in the livestock industry and accounts for 33 percent of the agricultural GDP and supports about 600,000 households (Omore *et al.*, 1999; Muriuki *et al.*, 2003; Staal *et al.*, 2003). During the past decade, Kenya's economy has stagnated, per capita income has declined while poverty and food insecurity have increased. The number of people living below the national poverty line has risen from 48 percent in 1990 to 56 percent in the year 2001 (GoK, 2001). Urban poverty increased from 29 percent to 49 percent over the same period.

The Government of Kenya has responded to the above development challenges in the Economic Recovery Strategy (ERS) for wealth and employment creation for the period 2003-2007 (GoK, 2004). The strategy identified agriculture, trade, industry and tourism as the key sectors that focus for economic growth. Poverty Reduction Strategy Paper (PRSP) also emphasizes growth as a critical element in reduction of poverty and hunger. The Government has also developed the Strategy for Revitalising Agriculture (SRA) during the period 2004-2014 (GoK, 2004). The SRA aims at providing the policy and institutional framework that is conducive to increasing agricultural productivity and encouraging the private sector involvement in agribusiness. Specifically, the SRA paper proposes to review and harmonise the legal, regulatory and institutional arrangements such as combining all legislations for agricultural sector under one Agricultural Act. In 2008 Government of Kenya unveiled the Kenya Vision 2030 as the successor development program of the above mentioned ERS (GoK, 2008a). The new vision aims to make Kenya a globally competitive and successful country with a high quality of life by the year 2030. The vision has identified planning and management of both rural and urban areas as critical for Kenya's development.

All the above national development strategies call for intensifying crop and livestock production and a shift towards high-value farm enterprises. Intensive smallholder dairy production is one of the pathways for eradication of poverty and hunger. Therefore, there is an urgent need to focus research and development activities on smallholder dairy in Kenya, especially the urban and peri-urban smallholder dairy. The following section provides background information on the dairy industry in Kenya.

3.1.2 Smallholder Dairy Farming Systems in Kenya

3.1.2.1 Introduction

Kenya's dairy industry is one the most developed and the largest in Sub-Saharan Africa (Muriuki *et al.*, 2003; Ngigi, 2005; Staal *et al.*, 2004). Milk consumption in Kenya is also one of the highest in developing countries, averaging 100 litres per person annually (ILRI, 2006). About 60 percent of the milk is available in the markets while 40 percent is for home consumption by the farming households and the calves. Cattle produce 84 percent of the total milk, while camel 12 percent and goats 4 percent (Omore *et al.*, 1999). There were about 3.3 million improved dairy cattle producing 3.6 billion litres of milk in 2006 (GoK, 2007). The improved exotic breeds and their crosses contribute 70 percent while the local zebu cattle contribute the rest of the total milk output. The improved dairy herd is mainly composed of pure breed Friesian-Holstein, Ayrshire, Guernsey, Jersey and their crosses. The crosses constitute about 50 percent of the total herd while Friesian-Holstein and Ayrshire dominate the pure breeds. The small-scale farmers (smallholders) dominate milk production, accounting for 80 percent of the total marketed milk (Staal *et al.,* 2001).

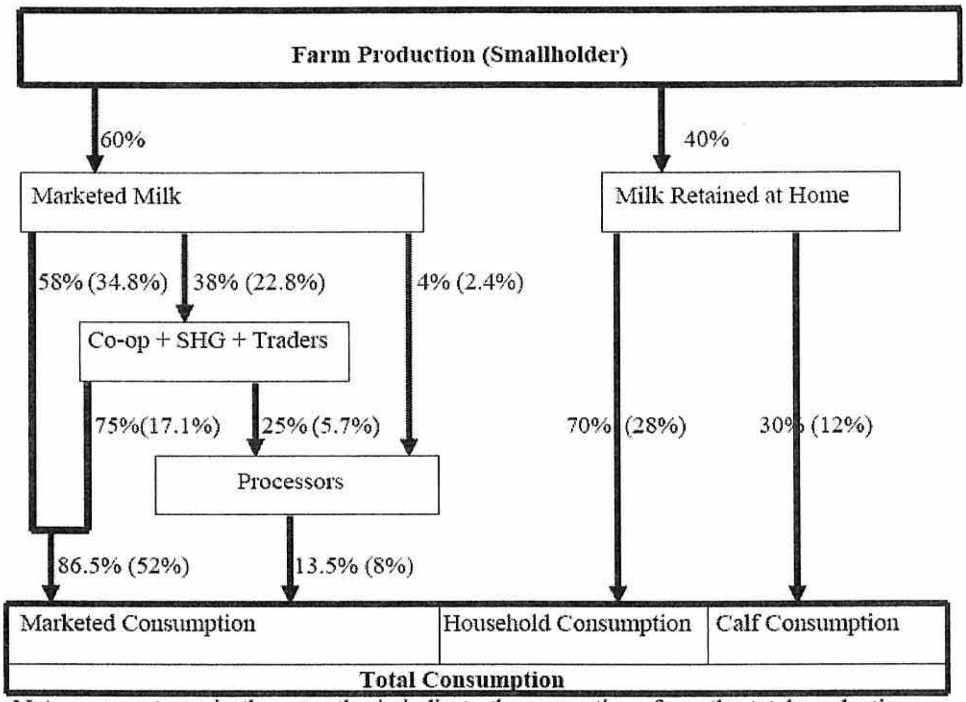
3.1.2.2 Categories of Dairy Farming Systems

The dairy production systems in Kenya fall into large-scale or small-scale and are further subdivided into intensive and semi-intensive. The large-scale systems are mostly in the central highlands. They vary from semi-intensive production systems with local zebu cattle to highly intensive production systems with pure breed exotic or crossbreed dairy cattle. The cattle feed on irrigated fodder supplemented with commercial concentrate feeds. The large-scale system accounts for 25 percent of the total national cow milk production but account for only 4 percent of the cattle population (Peeler and Omore, 1997). The semi-intensive smallholder dairy production systems have large herd of local zebu cattle grazing natural pasture and milked once a day. These are common in medium agricultural potential areas of western Kenya. Usually the investments and operating costs are low as well as production levels compared to intensive systems.

The intensive smallholder dairy production systems are mainly in the high potential central highlands and the Rift Valley. A typical smallholder owns about one hectare of land and keeps about three improved dairy cattle fed on planted fodder and purchased commercial feeds (Peeler and Omore, 1997). The farmer hand milks the cow twice a day, feed using cut and carry fodder in modern cow housing, and recycle manure for growing Napier grass fodder. The stall-feeding or zero-grazing systems increased from 29 percent to 48 percent between 1990 and 2000 (Staal *et al.*, 2004). Intensive smallholder dairy system accounts for 20 percent of all cattle but contribute more than 66 percent of the national milk production (Peeler and Omore, 1997).

3.1.2.3 Milk Marketing

The farming households retain about 40 percent of the total milk produced for home consumption and feeding the calves. The remaining 60 percent go through various market channels. Direct unprocessed milk sales from producers to consumers comprise 58 percent and cooperatives and small milk traders handle about 38 percent of the marketed unprocessed milk (Figure 3.1). Less than 15 percent of that marketed is processed and packaged. Most consumers in Kenya prefer boiled fresh unprocessed milk compared to other dairy products (Omore, 2000; Ouma *et al.*, 2003). There have been debate on health risks posed by sale of unprocessed milk but studies have shown that the risks are not much when compared to processed and packaged milk (Muruiki *et al.*, 2003; Omore, 2000).



Note: percentages in the parenthesis indicate the proportions from the total production and the others from the source;
SHG = self help groups; KCC = Kenya Co-operative Creameries.

Figure 3.1 Milk Marketing Channels in Kenya (Muruiki *et al.*, 2003)

There are about 50 private companies and cooperative societies licensed by the Kenya Dairy Board to process and market milk products in Kenya (GoK, 2007). About

35 processors were active with installed capacity of 2.5 million litres but only handling 1 million litres each day. Some of the companies export dairy products to the regional and international markets. The dairy products exported include skimmed milk, powdered milk, long life milk, butter, ghee, yoghurt and cheese.

3.1.3 The Nairobi Metropolitan Region Context

This section presents the description of study area covering part of Nairobi City and the immediate surrounding areas in Kiambu District (Fig.3.2). The natural environment including climate, geology and soils is almost uniform for the selected areas in Kiambu and Nairobi. The selected study area is very dynamic in terms of land use changes because Nairobi is the largest town in Kenya and is rapidly expanding into the surrounding Kiambu District. Most areas in Kiambu are of high agricultural potential with high human population density comparable with some parts of Nairobi. The study area covers a rectangular transect of about 50 km wide and 100 km long running from the city centre towards northwest into Kiambu District.

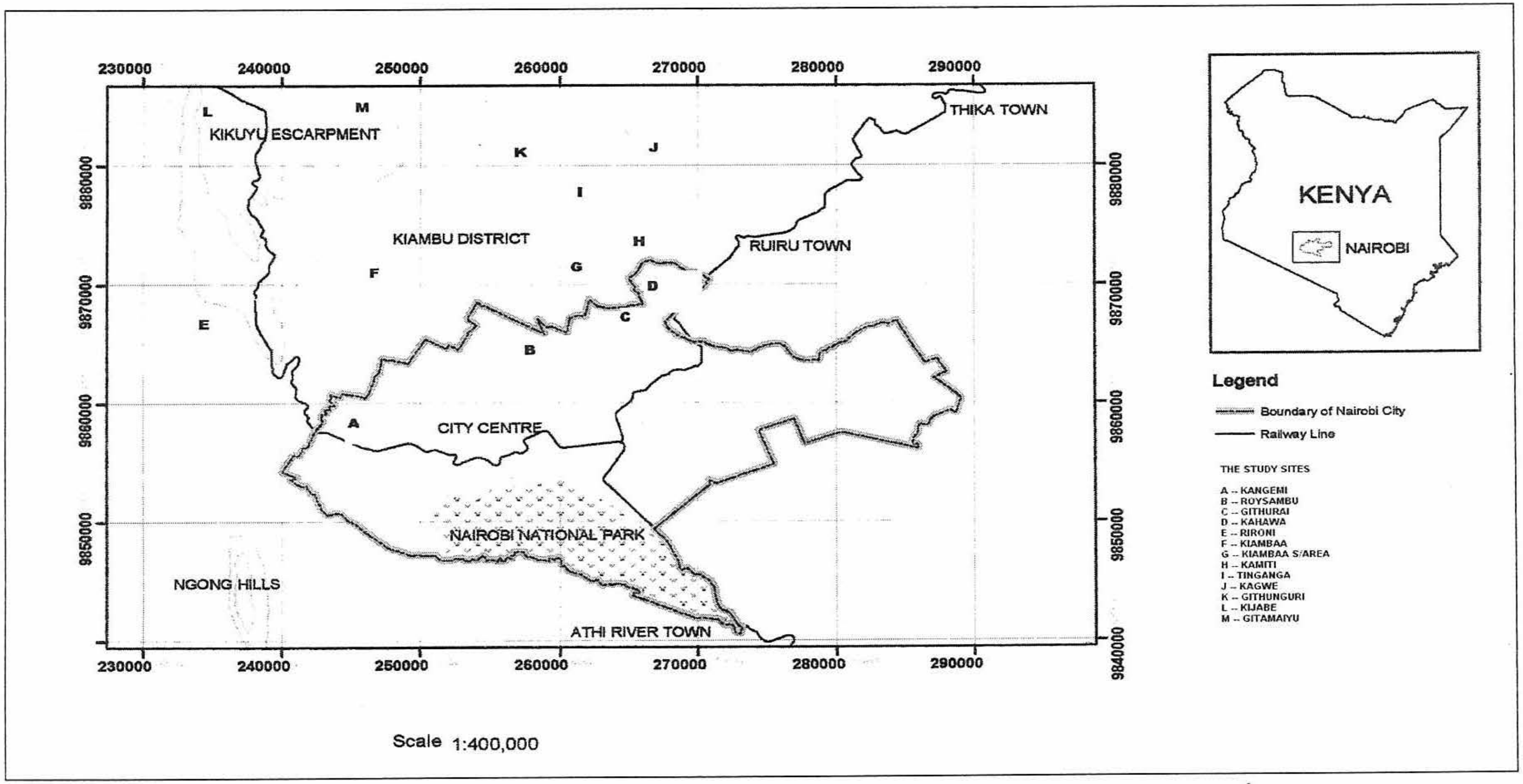


Figure 3-2 The Study Area (Compiled from Survey of Kenya, 2003)

3.1.3.1 Location, Population and Administration

Nairobi is the capital and the largest town in Kenya with current population of about 3 million people and projected to reach 5.5 million by the year 2020 (UN-Habitat, 2005), see Table 3.2. The official city boundary currently covers about 680 square kilometres located on the southeast highlands of Kenya. Nairobi neighbours Kiambu District to the west and northwest and Thika District to the north, both traditional lands of Kikuyu people. To the east and the south are the semi-arid Machakos and Kajiado districts, traditional homeland to the Akamba and pastoral Maasai people. Nairobi is a cosmopolitan city with a hub of roads; rail and air transport networks connecting eastern, central and southern Africa. The city generates 45 percent of the national GDP, employs 25 percent of Kenyans and 45 percent of all urban workers in Kenya (UN-Habitat, 2006). Economically, Kiambu District is more developed compared to other rural districts in Kenya. The district has good roads, electricity, piped water and other services and is a popular residential area for many workers in Nairobi.

With respect to central government, Kiambu District is one of the seven districts that form the Central Province. The district has a total area of 1,324 square kilometres and is the smallest district in the province (GoK, 2002). Kiambu has seven administrative divisions including Kiambaa, Limuru, Ndeiya, Githunguri, Kikuyu, Lari and Kiambu Municipality (Table 2) with 37 locations and 112 sub-locations. In terms of local government, the district is composed of two townships, two municipalities and one county council. In 1999 population census, Kiambu had a population of 744,010 projected to reach 824,077 by the year 2010 (GoK, 2006b).

Table 3.2 Population of Kiambu (Source: GoK, 2001)

Division	Area (km^2)	Population	Density	Locations	Sub-locations
Municipality	99.4	71,928	724.0	5	11
Kiambaa	91.1	116,127	1,275.0	5	17
Limuru	155.5	89,870	577.9	5	12
Ndeiya	125.2	23,708	189.4	1	4
Githunguri	175.2	136,554	779.4	6	20
Lari	441.1	111,302	252.3	9	22
Kikuyu	236.4	194,521	822.8	6	26
Total	1,323.9	744,010	562.0	37	112

3.1.3.2 The Physical Environment

The study area has three broad topographic regions of the Upper Highlands, the Lower Highlands and the Upper Midlands (Sombroek *et al.*, 1982). The Upper Highlands in the northwest corner of the study area, around Kijabe and Gitamaiyu and Uplands, represented by symbol 1 in Figure 3.3, are foot ridges with flat bottom valleys extending from the Aberdare Ranges and Kikuyu Escarpment. The altitudes are in the range of 2280-2550 metres above sea level with cool temperatures (Jaetzold and Schimdt, 1983). The climate is humid with average annual rainfall in the range of 1100-2000mm (Figure 3.4).The Lower Highlands cover the areas west of Kiambu town extending from Githunguri, through Limuru towards the southwest corner of the study area. The landscape is characterized by long narrow foot ridges separated by narrow winding valleys at altitudes in the range of 1820-2280 metres above sea level with fairly cool temperatures (20-22° C). The climate is sub-humid with average rainfall in the ranges of 1000-1600 mm per year.

The Upper Midlands occupy the largest part of the study area and are composed of gentle sloping foot slopes, plateaus and flat plains. The broad volcanic ridges, plateaus and their foot slopes extend east of Kiambu town from Ruiru through Nairobi City centre to the south and southwest corner of the study area. The altitudes are in the range of 1520-1820 metres above sea level with cool temperate temperatures (22-24° C). The climate is semi-humid with average annual rainfall in the range of 800-1400 mm.

The areas to the east and southeast of Nairobi city centre have characteristic flat plains with occasional low hills. The altitudes are in the range of 1360-1520 metres with warm temperate temperatures (24-26° C). The climate is semi-arid with average annual rainfall in the range of 450-900 mm. The rainfall in the whole of the study area is bimodal with long rains falling in April and May while the short rains come from October to November (Jaetzold and Schmidt, 1983).

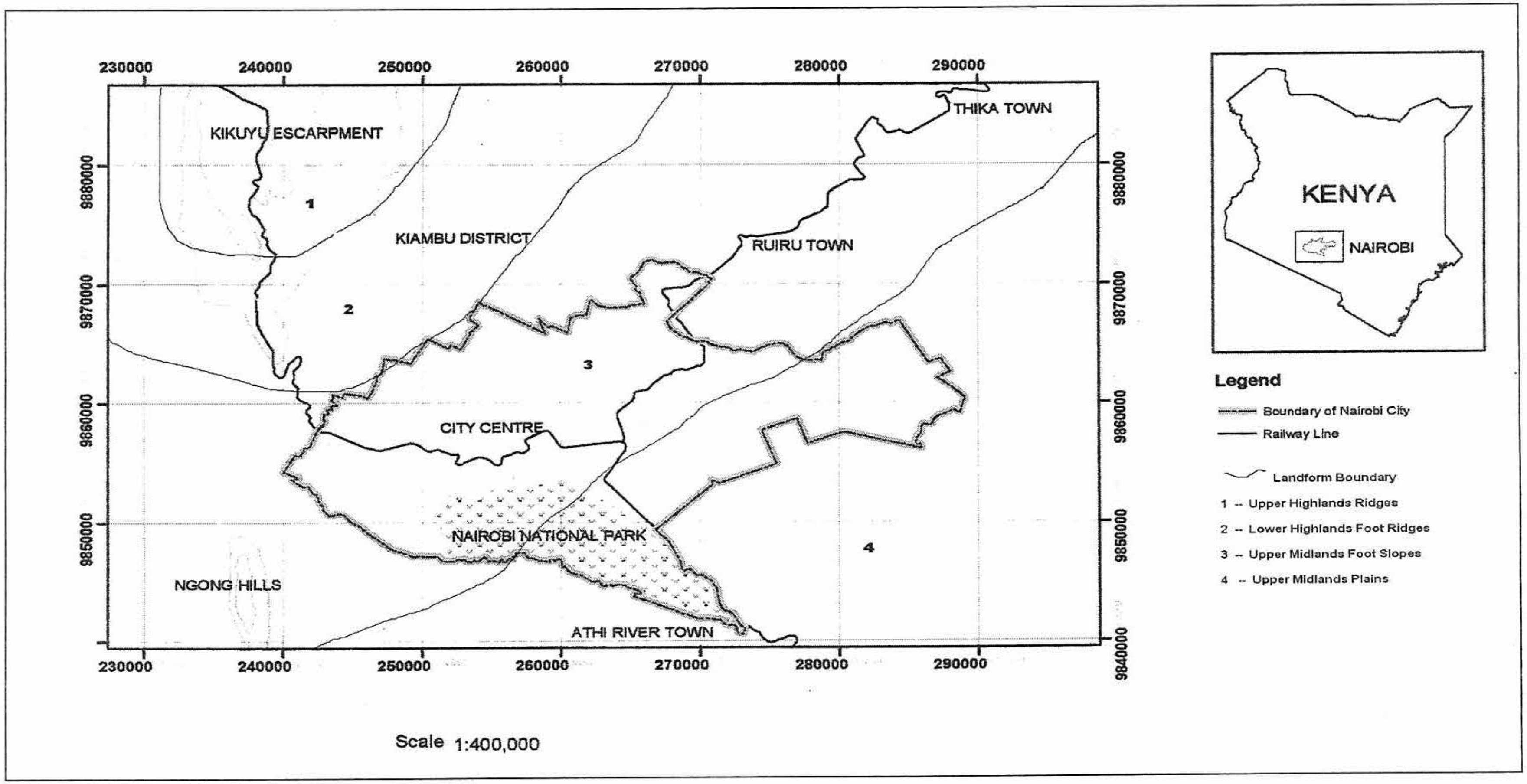
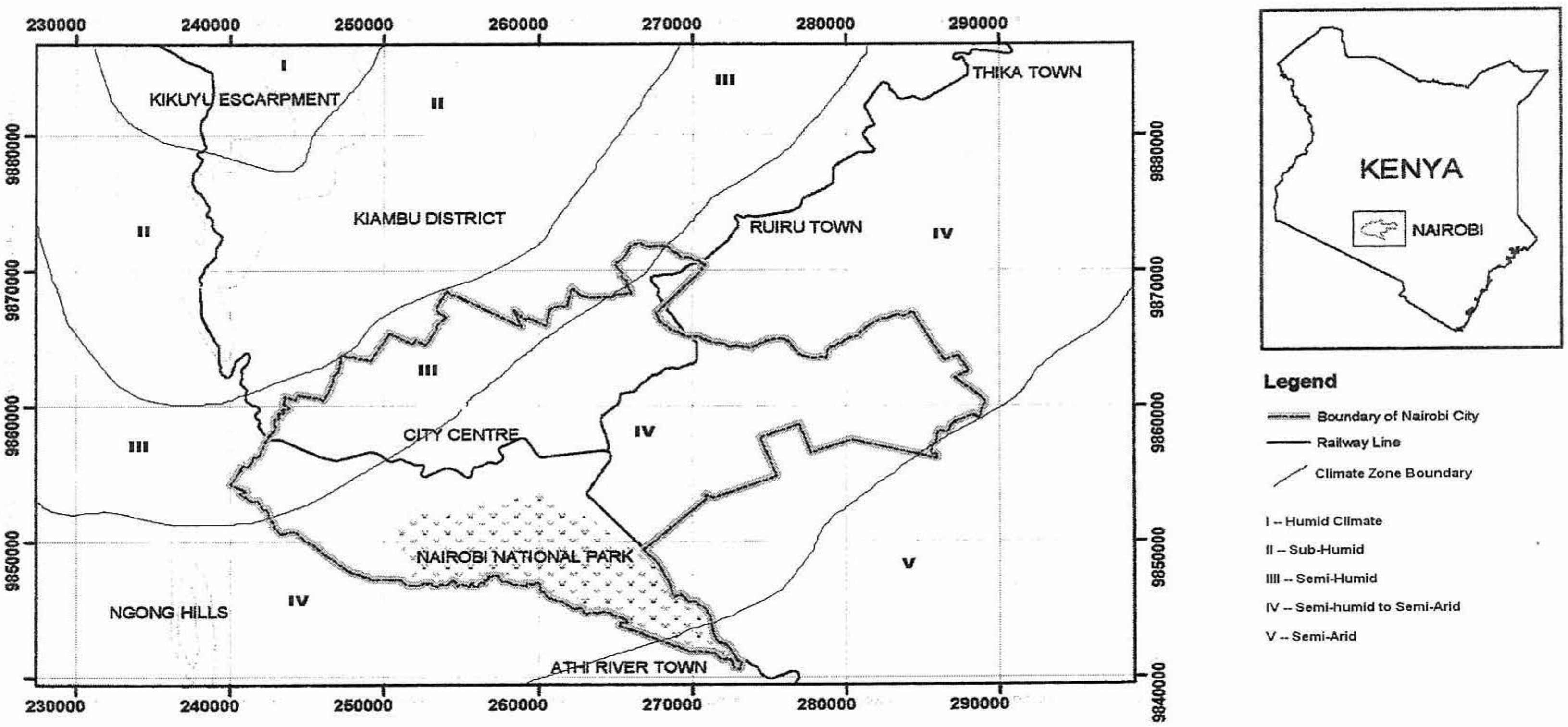


Figure 3.3 Landforms Map (Compiled from Sombroek et al., 1982)



Scale 1:400,000

Figure 3.4 Climate Map (Compiled from Sombroek *et al*, 1982; Jaetzold and Schmidt, 1983)

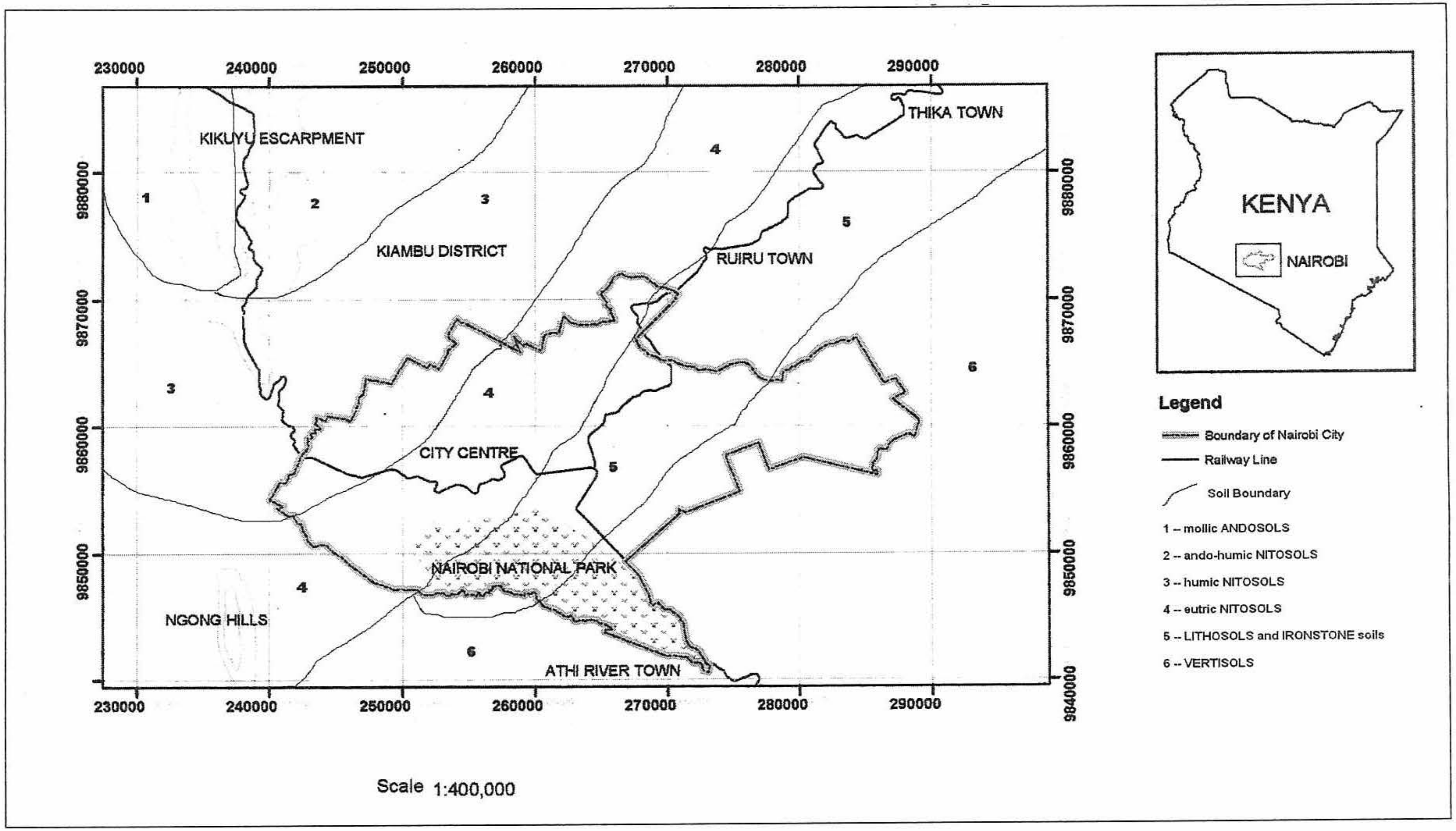


Figure 3.5 Soil Map (Compiled from Sombroek *et al.*, 1982)

The study area has three broad categories of soils that are associated with landforms. Figure 3.3, extracted from Sombroek *et al.* (1982), shows the distribution of the soils. All the soils have high natural fertility. The soils of the Upper Highlands are mollic Andosols developed from volcanic rocks. These soils have good drainage, fertile, deep, dark brown and silty clay loam. The upper foot ridges of the Lower Highlands have with similar soils but slightly smeary clay with acidic humic topsoil. These are found in Gatamaiyu area and consist of ando-humic Nitosols and humic Andosols.

A large parts of the study area covering Tinganga, Kiambaa, Githunguri, Limuru and Rironi are covered with humic Nitosols. Symbol 3 in Figure 3.5 represents these soils with good drainage, extremely deep, dark reddish brown friable clays. Similar soils but with underlying rocks are found the south west of Kiambu town running into northwest parts of Nairobi. These are eutric Nitosols and chromic Acrisols. According to FAO (1977), Acrisols are old soils with low base saturation, while the chromic term denotes the red colour. A complex of Lithosols and Ironstone soils cover the areas from the Nairobi National Park, through the city centre up to Ruiru and Thika. These are soils with good drainage, shallow, yellowish red to dark yellowish brown gravely clay over rocks. Lithosols are shallow soils over rock while Ironstone soils are soils with massive ironstone layers starting from 50 cm of the surface.

The flat plains to the southwest corner of the study area covering most the areas east of Nairobi contain Vertisols, commonly called the black cotton soils. These soils have poor drainage, very deep, dark grey to black and strongly cracking clays with calcareous and slightly saline deeper sub-soils. Along the river valleys and swamps, there are vertic Gleysols that are also cracking black clays but with mottles caused by water logging.

3.1.3.3 Population and Land Use in Kiambu

Kiambu is one of the districts in Kenya with highest density of human populations. The district had a population of 744, 010 people with 189,706 households in the national census of 1999 (GoK, 2001). The population is forecast to reach 817, 891 in 2008 and 824,077 by the year 2010 (GoK, 2006b). The current population translates into 618 persons per square kilometre. Therefore, there is high land pressure in the district resulting in low average farm size. The main land use classes in the district include smallholder mixed farming, large-scale coffee and tea farming and conservation forestry (Okoth, 2003). The most common land use is subsistence smallholder mixed farming that involves keeping livestock and growing crops. Smallholder farmers in Kiambu grow maize, beans, yams, potatoes, cabbages onion, tomatoes and other vegetables, usually intercropped with tea or coffee. Napier grass is the common fodder crop for feeding cattle. The average smallholder farm size is about three acres (1.2 ha) and crops grow under natural rainfall without any irrigation.

There are also large-scale farms with single crop of coffee or tea depending on the agricultural, ecological and climatic zone. Tea grows in the humid highland areas around Limuru, Gitamaiyu and Githunguri. Coffee, on the other hand, grows in sub-humid midlands around Kiambu town, Kagwe, Tinganga, and Githunguri. Most of the large-scale farms are more than ten acres under irrigation and belong to individuals or firms. Some large-scale farms have patches of natural grass, usually *Themeda triandra,* harvested by smallholder dairy farmers after paying a fee. Some large-scale farms also grow cut flowers under greenhouses.

3.1.3.4 Population and Land Use in Nairobi

Nairobi started in 1896 as a railroad camp during the construction of the Kenya-Uganda Railways from Mombasa to Kisumu, before it was made the headquarters of the railways in 1899 (Morgan, 1967; Obudho, 1997). Nairobi had a population of 128,794 people in the census of 1948 and increased to over 2 million people in 1999 census (Table 3.3). Population projections indicate that Nairobi will have more than five million people by 2020 (UN-Habitat, 2001). The rapid urban population growth in Nairobi has taken place without accompanying economic growth resulting in high unemployment and poverty. About 60 percent of the total population lives in informal settlements without appropriate infrastructure and services (UN-Habitat 2001).

Currently Nairobi has a population of about 3 million people with the official city boundary but the Nairobi City Council does not have a long-term development strategy. The 1973 Nairobi Metropolitan Growth Strategy did not reach the implementation stages. Therefore, the 1948 Master Plan is the only long-term plan that is still in use. However, in the year 2005, the National Economic and Social Council (NESC) commissioned a study that recommended a preparation of a new Nairobi Metropolitan Regional Development Plan (GoK, 2008a). In December 2008 the Nairobi Metropolitan Development Strategy was officially launched (GoK, 2008b). The proposed new Nairobi Metropolitan Region will cover an area of 32,000 square kilometres with a population of about 6 million people. The new Ministry of Nairobi Metropolitan Development is currently in the process of preparing a new land use plan for the Nairobi Metropolitan Region.

Table 3.3 Population of Nairobi, 1948-2020 (Adapted from UN-Habitat, 2001)

Year	Population	Growth Rates
1948	128,794	--
1962	343,500	6.6
1969	509,286	6.4
1979	827,775	6.9
1999	1,327,000	4.8
1989	2,137,000	6.2
2010	3,750,435	4.7
2020	5,552,305	4.0

3.2 Research Methods

3.2.1 General Research Design

This chapter presents the methods used in selecting the study sites, sampling of farmers, and data collection and analysis. This study is based on a cross-sectional field survey to compare the similarities and differences among smallholder dairy farmers in the urban, peri-urban and rural areas. The case study uses Nairobi, the capital city of Kenya and the immediate surrounding areas in Kiambu district, as the field site. The study is exploratory in that there is no record available with the list of farmers, therefore the population of dairy farmers in Nairobi is not known. Furthermore, previous studies have rarely compared the characteristics of smallholder dairy farmers along the urban rural gradient.

Literature review was performed in order to identify what variables to consider in the study. The two conceptual frameworks for land use change and for urban-rural gradient, as described in chapter two, were useful in define the information needs of the study. The study draws on a combination of secondary and primary data. At the national and regional levels, the information on current status, extent, trends and location of smallholder dairy farming systems as well as factors influencing land use change was collected from existing literature. At the local household level, the primary data were gathered through observation, group discussions, key informants, and using semi-structured questionnaire in field survey of 327 farmers. The field research activities covered a ten months period from July 2006 to April 2007. The selection criteria for farmers consisted of: identifying administrative areas in the urban, peri-urban and rural areas; randomly selecting two neighbourhoods (villages) from each administrative unit, and; randomly selecting farmers from the chosen villages.

3.2.2 The Study Sites

The selection of the study sites was informed by theory and previous empirical studies from the region. The choice, of the western and north-western areas of Nairobi City and the bordering Kiambu District areas, was based on the ecological and socio-economic considerations. First, most of the Kiambu and western parts of Nairobi have almost similar climate, soils, geology and population density at the general regional level, this can be expected to minimize within and between group differences in some of the variables that have important influence on land use changes. Second, among all the districts bordering Nairobi city, Kiambu has a long history of well established smallholder dairy farming system documented in several studies.

There was no information on dairy farmers within Nairobi city limits, and it was difficult to locate them. Instead, this study began by visiting the Kenya Breweries factory in Nairobi, where dairy farmers regularly go to purchase the brewers' spent grain for use as animal feed. A list was compiled containing the name of the farmer and the area where their dairy farm is located. The list contained about 1,000 people, including farmers who purchased the feed for their own farms as well as some individual who purchased the feed in bulk and resell it in small quantities to other farmers. The list served as an indicator of the location of dairy farmers in the neighbourhoods of Nairobi.

Recent studies, at the national and regional scales, have characterized the dairy farming systems in the Kenya highlands that supply milk to Nairobi (Staal *et al.*, 1997; 2001; 2002). The studies covered Kiambu and Nairobi; however the focus was on dairy development in rural areas with limited mention of peri-urban dairy farming. In contrast, the present study focuses on group comparison among the urban, peri-urban and rural dairy farmers. The most important conclusions from these previous studies in the region that informed the present study can be summarized below.

First, the majority of the dairy farmers in the metropolitan areas of Nairobi, especially in Kiambu, are small-scale (smallholder) farmers who practice zero-grazing (stall-feeding) dairy management system. The dairy cattle are usually housed in a simple cowshed and dairy feeds are purchased or fodder harvested in the fields and carried to the shelter for the cattle. Most of the previous studies have indicated that the most important constraint to smallholder dairy farming is the access and availability of animal feeds both in terms of good quantity and quality.

Second, distance to the city centre has influence on the availability and access to market for milk sales, dairy feed and other inputs. Staal *et al.* (2002) estimated that this influence of urbanization on dairy farming fades at about 75 km from Nairobi city centre. Another important lesson from previous studies was that random sampling using national population census data did not yield enough samples on dairy farmers in Nairobi (Staal et al., 2001). Finally, the recent studies have developed comprehensive methods and tools for charactering smallholder dairy farming systems in Kenya, especially in the peri-urban areas (Staal *et al.*, 1997 and 2001).

On the basis of the urban-rural gradient framework, as discussed in the previous chapter, it was possible to identify three distinct zones within the study area. The grouping of the dairy farmers into urban, peri-urban and rural location was based on whether they are located within or outside the jurisdiction of the city government, dominance of agricultural or urban land use, and distance to the city centre using public road transport (Table 3.4). Some of the general regional characteristics of the urban, peri-urban and rural areas are outlined in Table 3.5. Four administrative units were randomly selected from each of the three zones, making a total of twelve study sites. This was followed by random selection of two neighbourhoods (villages) from each of the administrative units. The village characteristics are presented in Table 3.5 below.

Table 3.4 General Characteristics of the Urban, Peri-Urban and Rural Areas

Urban-Rural Gradients	Descriptions
Urban	• Within the city boundary • High urban land use • Low agricultural land use • Within 30 km from the city centre •
Peri-Urban	• Outside the city boundary • Mixed urban and agricultural land uses • Variable distance from the city centre • High daily commuting to the city centre •
Rural	• Outside the city boundary • Low urban land use • High agricultural land use • Over 40 km from the city centre • Low daily commuting to the city centre • Limits of reach for Brewer's Spent Grain

Table 3.5 Study Sites in Relation to Central Business District (CBD) and Kenya Breweries Factory (KBF)

	Distance to CBD (km)	Distance to KBL (km)	Population Density
Urban			
Roysambu (Roysambu, Garden)	11 - 15	1 - 5	1,356
Kangemi (Gichagi, Uthiru)	11 - 15	21 - 25	5, 432
Githurai (Kamuthi, Njathiani)	16 - 20	6 - 10	1,882
Kahawa (Kahawa West, Kiwanja)	21 - 25	11 - 15	2,054
Peri-urban			
Settled Area (Thindigwa, Kiamumbi)	16 - 20	6 - 10	337
Kamiti (Anmer, Kamiti)	26 - 30	16 - 20	172
Kiambaa (Kiambaa, Njiku)	26 -30	26 - 30	1,875
Tinganga (Tinganga, Kagongo)	31 - 35	21 - 25	1,526
Rural			
Rironi (Rironi, Gatimu)	36 - 40	46 - 50	1,261
Ngewa (Kimathi, Nyaga)	41 - 50	31 - 40	1,019
Kijabe (Magina, Bathi)	61 - 70	71 - 80	1,506
Gatamaiyu (Kagwe, Kamuchege)	71 - 80	61 - 70	485

3.2.3 Dairy Farmers Survey

The selected villages were visited in the company of village elder and extension staff from Ministry of Livestock. The main road that crosses each village was identified and farmers chosen randomly from both sides of the road to participate in the survey. Each farmer was asked about the dairy farm characteristics and the answers recorded in a semi-structured questionnaire. The questionnaire was designed based on the one used by Staal *et al.* (2001) with modifications. The questionnaire covered both quantitative and qualitative information grouped into the following categories: household characteristics; farm characteristics; dairy feed resources and management; herd size and structure; dairy health and breeding management; milk production and marketing, and future plans for the dairy enterprise. A copy of the questionnaire is attached in Appendix 1 at the end of the thesis.

The farmers were identified by the village elders or the government livestock extension staff who accompanied the researcher during some parts of the field work. The criterion for selection was that the farmer must own at least one dairy cow kept under zero-grazing management on the day of the survey. A total of 327 farmers were interviewed with 109 each in the urban, peri-urban and rural areas. On arrival at the farm, the village elder or the extension staff, who was known by the local farmers, would normally introduce the researcher to the farmers. The researcher would then give background information about the survey to the farmers and request for their participation. The farmers were informed that their participation was voluntary and that they had the right to withdraw from the survey at any time. The farmers were also assured by the researcher that the data would be anonymized so that personal identifiable records are removed so that the data can no longer be traced to an individual. In some occasions the researcher attended farmers' group meetings such as farmers training and exhibition sessions, during which links with the farmers were made and appointments made to visit the individual farms.

Each of the farm interviews lasted for about 2 hours. During the interview the farmer was encouraged to continue with the on-going work such as milking, replenishing dairy feed or cleaning the cowshed. Most of the interviews were held in Kiswhili, the local national language, usually with the head of the household responsible for decision-making in the dairy enterprise. This was usually the mother or the father in the household. In the case where a hired worker was found managing the dairy cattle, an appointment was made to go back later and interview the owner of the dairy enterprise. This was a major problem in the urban areas where most of the dairy farm owners worked in Nairobi during the week days. Therefore appointments would be made for the author to revisit the farm over the week-ends in order to fill the questionnaire. There was no questionnaire left behind to be filled by the farmer.

3.2.4 Data Analysis

The field data were reduced, coded and entered into database followed by checking for errors, missing or abnormal data. This quality check was done on weekly basis so that where problem was identified it was possible to revisit the farmer to confirm the information. Data analysis utilized the Statistical Package for Social Sciences (SPSS) version 15.0 (SPSS, 2006). In order to answer the first research question, descriptive statistics such as frequency, percentage, mean, mode, median, standard deviation, skewness and range were calculated for the most informative variables. These are reported for all the farms and for the farms grouped across the urban-rural gradient. The outcomes are presented in tables, figures and narrative text.

Principal components analysis (PCA) was applied to the data to reduce the variables and identify important variables representing levels of dairy intensity and urban-rural gradient. The resulting variables were used in cluster analysis to group the farmers into clusters whose group means were compared using. One-way analysis of variance (ANOVA) was used to compare the group means in the level of dairy intensity among the urban, peri-urban and rural smallholder dairy farmers. The results of initial ANOVA were followed by contrast tests to compare pairs of means in order to determine significant differences. The groups were considered significantly different at 95 percent level of confidence for mean levels of dairy intensification. To validate and confirm the results, cluster analysis was used to group the farmers based on the factors identified by the principal component analysis, resulting group means were compared. The next chapter will present the results obtained using the methods.

CHAPTER 4

DAIRY FARMING SYSTEM CHARACTERISTICS

As stated in chapter one, this study examines the characteristics of smallholder dairy farming and compares the levels of dairy land use intensity across the urban, peri-urban and rural areas. This chapter describes the detailed characteristics of the farm households, farmland, dairy cattle population, feed resources, dairy farm facilities and services, and milk production and marketing, concluding with opportunities and constraints facing dairy farming in the Nairobi urban region.

4.1 The Dairy Farm Households

The respondents were fairly equally distributed between men and women for the 327 dairy farmers sampled (Table 4.1). About 26 percent of the farmers in urban areas were female-headed households, compared with 7 per cent in rural areas. In urban and peri-urban areas, more women than men were the principal decision-makers in the dairy management activities. The mean age of the farmers was 52 years (Table 4.2). The average age of the farmers in urban and rural areas were almost the same but younger than those in the peri-urban areas. The youngest farmer was 30 years while the oldest was 82 years old. The age distribution indicates a concentration of respondents in the 41-60 years age group.

Information on the highest level of education achieved by each of the farmers is shown in Table 4.3. The results indicate that the farmers are mostly between the level of secondary and primary education. It is observed that the farmers who progressed past secondary education are concentrated in urban areas. Figure 4.1 revealed that the majority of the farmers who had attended secondary and college education were male, whereas the majority who had attended primary level of education and below are women.

Overall, the sample farmers have managed their dairy farming for 15 years on average (Table 4.4). About 60 percent of all the farmers have dairying experience for over 10 years. Rural farmers have 18.5 years of dairy farming experience on average, which is higher than peri-urban and urban farmers. A maximum of 50 years of experience was observed in peri-urban farmers, compared to 49 and 33 years in rural and peri-urban farmers, respectively.

When asked about the most important source of income for the household, 43.4 percent of all the farmers indicated that it was dairy farming (Table 4.5). This proportion was particularly higher in rural and peri-urban areas. A high percentage of the urban farmers indicated that off-farm activities were their main source of income. The distribution of the other sources of income for the dairy farm households is examined in Table 4.6. Income from formal and informal business activities showed overall lead, followed by paid employment and pig or poultry farming. Rental residential housing was a major source of income for the urban farmers. In contrast, a substantial proportion of income was derived from coffee farming by farmers in peri-urban areas and from tea and vegetable farming by farmer in the rural areas (due to the location of the main coffee and tea growing areas). Included in the others are incomes from pensions, savings and inheritances. Most of the paid employment was found in Nairobi urban areas (Figure 4.2).

All the 327 dairy farms sampled were owned and operated by the family. Family members provided labour and made decisions concerning the dairy activities. Table 4.7 presents the number of family members who actively participated in dairy farming activities. As a generalization, most farms had two or one family member actively involved with dairy farming activities. In rural areas the numbers reached three and even one farmer reported six members of the family regularly involved in dairy farming. In addition, more than a half of all the farmers hired labour on temporary or regular basis to work on the dairy (Table 4.8). Most farms employed one external person; however a few managed to employ two people. In urban areas four farms employed three people and one farm reported employing four people to help in feeding and milking the cows.

Table 4.1 Gender (% farmers)

Gender	Urban	Peri-Urban	Rural	Mean
	Respondent			
Male	54.1	44	59.6	52.6
Female	45.9	56	40.4	47.4
	Household Head			
Male	74.3	77.1	92.7	81.3
Female	25.7	22.9	7.3	18.7
	Dairy Decisions			
Male	25.7	21.2	34.9	27.2
Female	40.4	35.8	22.0	32.7
Both	33.9	43.1	43.1	40.1
N	109	109	109	327

Table 4.2 Ages of the Respondents (% farmers)

Age (Years)	Urban	Peri-Urban	Rural	Mean
30-40	10.1	15.6	14.7	13.5
41-50	36.7	24.8	34.9	32.1
51-60	44.0	38.5	33.9	38.8
61-70	9.2	12.8	13.8	11.9
71-82	0	8.3	2.8	3.7
Mean	51.6	53.7	51.7	52.3

Table 4.3 Level of Education (% farms)

Education	Urban	Peri-Urban	Rural	Mean
None	5.5	12.8	2.8	7.0
Primary	21.1	27.5	41.3	30.0
Secondary	46.8	50.5	44.0	47.1
College	26.6	9.2	11.9	15.9

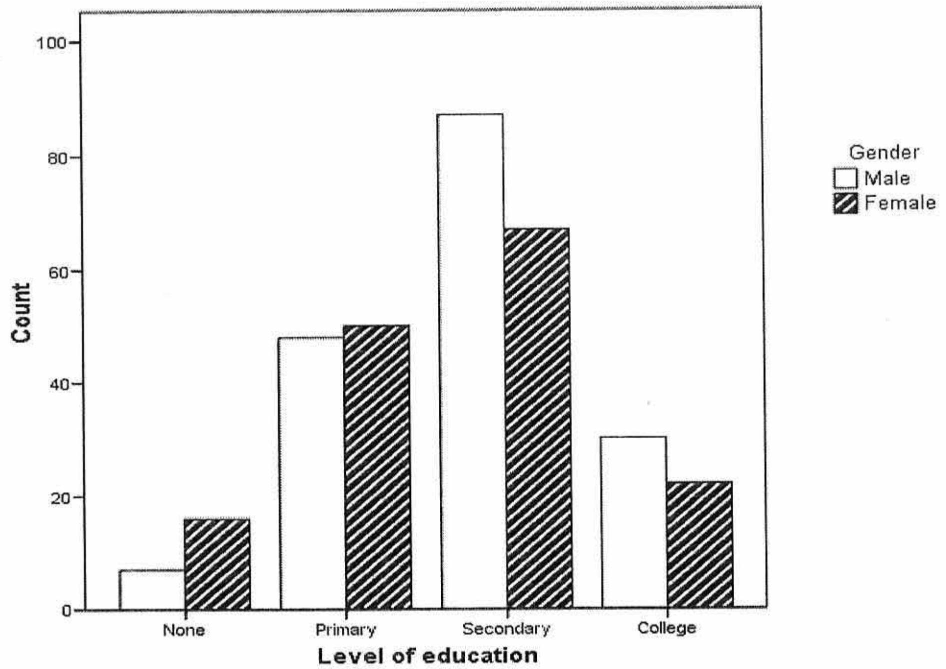


Figure 4.1 Gender Disaggregated Level of Education (% farmers)

Table 4.4 Years of Dairy Farming Experience (% farmers)

Experience(Years)	Urban	Peri-Urban	Rural	Overall
1-10	45.0	53.7	23.9	40.8
11-20	39.4	14.8	38.5	31.0
21-50	15.6	31.5	37.6	28.2
Maximum	33	50	49	50
Mean	12.5	14.8	18.5	15.3

Table 4.5 Main Source of Income (% farmers)

Source	Urban	Peri-Urban	Rural	Overall
Off-farm	62.4	36.6	29.4	42.8
Other farming	9.2	17.4	14.7	13.8
Dairy farming	28.4	45.9	56.0	43.4

Table 4.6 Other Sources of Income (% farmers)

Source	Urban	Peri-urban	Rural	Overall
Business	27.7	37.9	23.9	27.9
Employment	19.8	24.1	20.7	20.1
Pig/Poultry	16.8	6.9	21.7	14.4
Housing	41.6	9.2	3.3	17.8
Coffee	1.0	24.1	9.8	10.4
Tea	0	0	16.3	5.0
Vegetable	0	2.3	7.2	3.0
Others	0	2.3	2.2	1.3

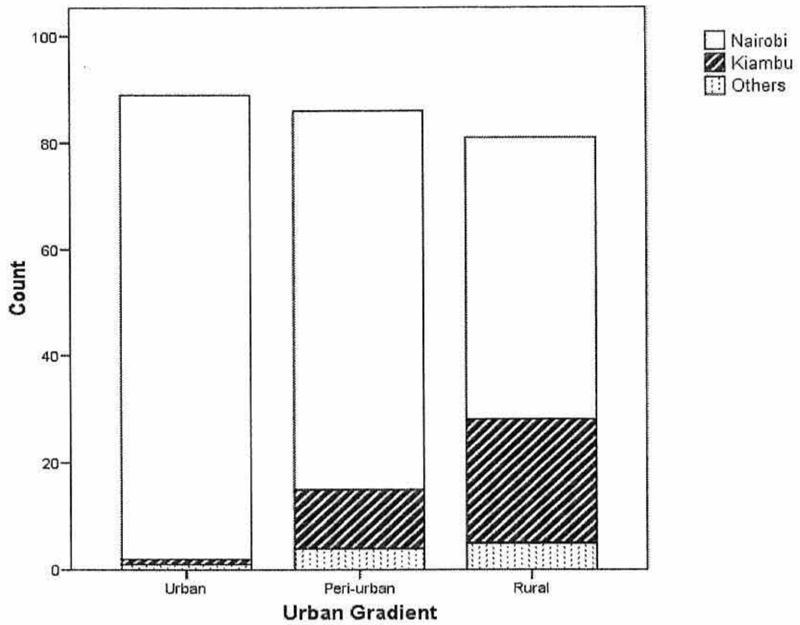


Figure 4.2 Place of paid employment (Number of farmers)

Table 4.7 Number of Family Members Engaged in Dairy

People	Urban	Peri-Urban	Rural	Sum
1	30	40	16	86
2	57	46	44	147
3	10	9	36	55
4	3	4	10	17
5	0	3	2	5
6	0	0	1	1
N	100	102	I09	311

Table 4.8 Number of Non-Family Hired Labour for Dairy

People Hired	Urban	Peri-Urban	Rural	Sum
1	64	58	38	160
2	20	10	11	41
3	4	0	0	4
4	1	0	0	1
N	89	68	49	206

4.2 Dairy Farm Land

The mean values of dairy farm area across the urban-rural gradient are presented in Table 4.9. The overall mean land size was 1.6 acres (0.6 hectares), while the largest land size was 12 acres (4.9 hectares) reported in the rural area. Over 56 per cent of the farms were 1 acre or less, while over 75 per cent were 2 acres or less. Mean land size varied along the urban-rural gradient. The rural farms had a mean land size of 2.5 acres compared to 1.1 and 1.3 acres in the urban and peri-urban areas, respectively.

The most common land tenure systems in the study area were freehold and leasehold (Table 4.10). Leasehold systems were mainly in urban areas while freehold systems were in peri-urban and rural, although a few farmers in Kangemi within urban area also held land under freehold. Many of these farmers had their land title deeds, but some farmers, in areas where land was recently subdivided, were still waiting for their title deeds. Other farmers had inherited thief land from their families under traditional land tenure system with joint ownership, especially in rural areas. Some farmers rented their land from the land owners, while a few farmers informally used public land such the road reserves.

The majority of the dairy famers sampled dedicated part of their land for growing forage crops to feed the cattle. On average, farmers planted 0.74 acres (0.3 hectares) of their land for forage (Table 4.11).The rural farmers allocated more land for forage compared to the urban and peri-urban farmers. The maximum land size allocated for forage was 4, 3 and 6 acres in urban, peri-urban and rural areas, respectively. The farmers owning small land size tended to hire extra land from their neighbour for growing forage.

About 47 percent of all the farmers sampled hired extra land (Figure 4.3). In urban areas, 56 percent of the farmers hired extra land compared to 46 and 39 percent in peri-urban and rural areas respectively. Table 4.12 indicates that the overall average size of the extra land hired for forage was 0.9 acres (0.36 hectare). Eighty per cent of all the farmers did not hire more than one acre of land. The maximum size of hired land was 13 acres (5.3 hectares) reported in the peri-urban area. The results indicate that it was cheaper for farmers to hire land in the peri-urban areas compared to urban and rural areas (Table 4.13). The rural farmers paid the highest minimum, average and maximum prize of hired land at 750, 3840, and 16000 Kenya shillings (KShs) annually, respectively. Only 65 per cent of the rural farmers paid an annual land hiring fee of less than 3000 KShs, compared to 80 and 85 percent of the farmers in the peri-urban and urban areas.

The results indicate that it was generally more expensive to buy land in urban areas than in rural areas (Table 4.14). Most farmers were unwilling to sell their land irrespective of how much money the buyer was offering. The mean price for buying farm land was 1.8 million KShs for one acre over the whole study area but about 2.9 million KShs in the urban areas. About 99 percent of the farmers in rural areas quoted less than 1.3 million KShs per acre of land. However, 96 per cent of the farmers in urban areas quoted between 2.5 and 5 million KShs for each acre of land.

Table 4.9 Owned Land Size (% farms)

Size (Acres)	Urban	Peri-Urban	Rural	Overall
0.125-0.50	45.5	36.7	14.7	32.1
0.51-1.00	29.4	26.6	16.5	24.2
1.01-2.00	15.6	21.1	21.1	19.3
2.01-12.00	10.1	15.6	47.7	24.5
Mean	1.1	1.3	2.5	1.6

Table 4.10 Land Tenure Systems (% farmers)

Tenure	Urban	Peri-Urban	Rural	Overall
Freehold/Lease	88.1	88.1	71.6	82.6
Traditional/Family	8.3	11.0	26.6	15.3
Rental Plot	2.8	0.9	0.9	1.5
Public Land	0.9	0.0	0.9	0.6

Table 4.11 Own Land Size Allocated for Fodder (% farms)

Size (Acres)	Urban	Peri-Urban	Rural	Mean
0.125-0.250	51.2	47.4	12.2	36.3
0.251-0.500	23.3	17.5	36.7	26.0
0.501-1.000	17.4	18.6	33.7	23.5
1.001-6.000	8.1	16.5	17.3	14.2
Mean	0.59	0.64	0.96	0.74
N	86	97	98	281

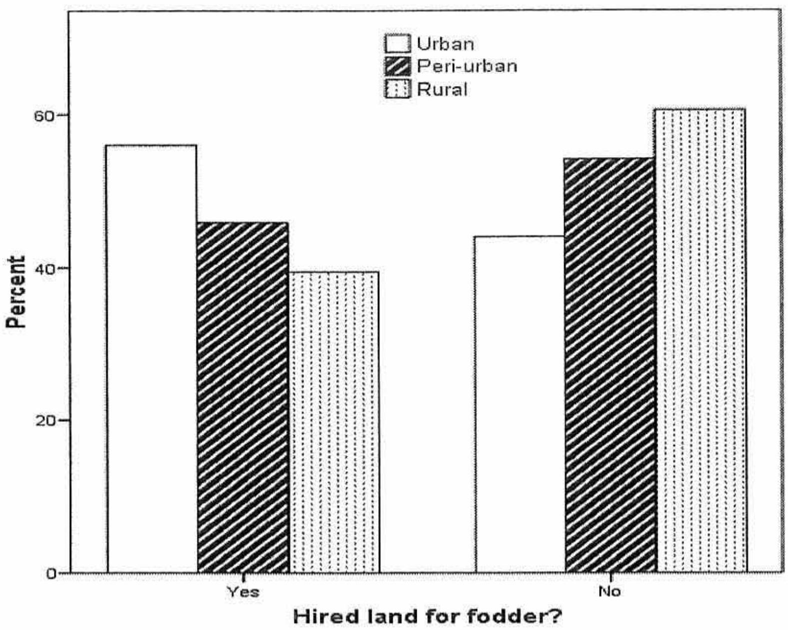


Figure 4.3 Hired Land for Planting Fodder (% farmers)

Table 4.12 Hired Land Size (% farms)

Land (Acres)	Urban	Peri-Urban	Rural	Mean
0.125-0.500	82.5	60.0	25.6	59.6
0.501-1.000	11.1	28.0	34.9	23.1
1.001-13.00	6.3	12.0	12.0	17.3
Mean	0.5	1.0	1.4	0.9
N	63	50	43	156

Table 4.13 Cost of Hired Land (KShs/Year)

Statistic	Urban	Peri-Urban	Rural	Overall
Mean	2691	2508	3840	2950
Minimum	700	100	750	100
Maximum	15000	10000	16000	16000

Table 4.14 Price of Buying Farm Land (% farms)

Price (mKShs/Acre)	Urban	Peri-Urban	Rural	Mean
0.30-0.70	0.0	10.1	75.2	28.4
0.71-1.30	3.7	38.5	23.9	22.0
1.31-2.50	45.0	33.9	0.9	26.6
2.51-8.00	51.4	17.4	0.0	22.9
Minimum	1.0	0.3	0.5	0.3
Mean	2.9	1.8	0.7	1.8
Maximum	5.0	8.0	1.5	8.0

4.3 Dairy Cattle Population

A total of 2040 heads of dairy cattle were kept by the 327 sample farmers. Table 4.15 indicates that the mean herd size was 6.24 heads of dairy cattle in the whole of the study area. The dominant dairy cattle breed were Friesian (75%) and Ayrshire (25%), composed of both cross breed and pure breed. The average heads of dairy cattle per farm were 6.66, 6.12 and 5.95 in the urban, peri-urban and rural areas, respectively. The overall herds are composed mostly of cows (56%), while cows together with heifers accounted for 85 per cent of the herds. The overall average number of lactating cows was 2.84. Only one mature bull was observed and that was in the urban area. Many farmers complained that calves conceived from Artificial Insemination were predominantly male, whereas they would have preferred female calves.

To create an aggregate value of herd size, Tropical Livestock Unit (TLU) was calculated. The Tropical Livestock Unit is the common unit for measuring and comparing the livestock numbers of different categories of ages, sizes and species. The average weight of adult cattle in tropical areas varies from 200 to 400 kilograms. Therefore a tropical livestock unit has been defined as an animal with an average live weight of 250kg. In this approach, a bull represents 1TLU, a cow is 0.7 TLU, a heifer is 0.5 TLU, while a calf is 0.2 TLU. The overall herd size in the study area was 3.67 TLU (Table 4.15). These values were 3.90, 3.62 and 3.50 in the urban, peri-urban and rural areas, respectively.

Table 4.15 Mean Herd Size (and Number of farms)

	Urban	Per-Urban	Rural	Overall
Friesian Cows	2.89 (105)	2.86 (97)	2.71 (105)	2.82 (307)
Ayrshire Cows	1.68 (69)	1.52 (63)	1.44 (52)	1.56 (184)
All Cows	3.83 (109)	3.42 (109)	3.30 (109)	3.52 (327)
Lactating Cows	3.11 (109)	2.75 (109)	2.66 (108)	2.84 (326)
Heifers	2.16 (92)	2.36 (77)	2.26 (87)	2.26 (256)
Female Calves	1.38 (29)	1.18 (17)	1.39 (18)	1.33 (64)
Male Calves	1.20 (20)	1.31 (26)	1.31 (13)	1.27 (59)
Immature Bulls	1.62 (29)	1.49 (39)	1.43 (35)	1.50 (103)
Bulls	1.00 (1)	0 00 (0)	0 00 (0)	1.00 (1)
Total Herd	6.66 (109)	6.12 (109)	5.95 (109)	6.24 (327)
TLU*	3.90 (109)	3.62 (109)	3.50 (109)	3.67 (327)

*TLU= Tropical Livestock Unit: Bull=1.0, Cow=0.5, Heifer/Immature Bull=0.5, Calf=0.2 TLU

4.4 Dairy Cattle Feed Resources and Management

All the 327 sampled farmers practiced zero-grazing (stall-feeding) and their dairy cattle were fed on variety of feed stuff (Table 4.16). Napier grass was the most popular animal feed used by all the farmers in the study area. Most farmers grow their own Napier grass although many buy extra fodder from their neighbours especially during the dry seasons. The other main feed resources, in order of rank, were maize stover, dairy meal, banana pseudo-stem and Kikuyu grass. In addition Themeda grass, harvested from fallow patches within the coffee plantations, was a major fodder used by urban and peri-urban farmers.

The observed feed resources can be grouped into four general categories: fodder, crop residue, commercial concentrates and by-products. Among the fodder are: Napier grass (*Pennisetum purpureum*), Kikuyu grass (*Pennisetum clandestinum*), Themeda grass (*Themeda triandra*), Star grass (*Cynodon nlemfuensis*), Grevillea tree (*Grevillea robusta*), and legumes such as *Desmodium species*, *Calliandra species*, *Leucaena species*, and hay made from various grasses. Among the crop residues were included: green and dry maize stover, banana pseudo-stem and leaves, vegetable refuse. The commercial concentrates included: dairy meal, fish meal, cotton seed cake and mineral salt lick. The common by-products used as animal feed were: wet brewers' grain, wheat bran, maize germ, maize bran, chicken manure, molasses, wheat pollard, and sunflower bran. Wet brewers' grain was a distinctly by-product used by many farmers and is discussed in more details in section 4.1.5 below.

The main means of transporting feed in the study area was manual (Table 4.17). It is a common practice to see women carry fodder on their backs balanced by a string across their head. Wheelbarrows were the second most important means of transporting fodder, particularly common in urban areas. In urban and peri-urban areas, many farmers used their personal vehicle, usually a one-tonne open body pick-up truck. Donkey-drawn carts and bicycles were also used in transporting feed in rural and peri-urban areas. However, hand carts were found in peri-urban and urban areas.

Over 80 per cent of all the sample farmers reported experiencing feed shortages, especially lack of fodder during the dry seasons (Figure 4.4). Only 16.9 per cent of the farmers in urban areas did not face feed shortages, compared to 21.1 per cent in peri-urban and rural areas. Table 4.18 examines the emergency sources of dairy feed. During feed shortages, all farmers reported purchasing fodder from local farmers; concentrate from commercial dairy feed shops; using their own stored feed stock or; purchasing wet brewers' grain. Farmers in urban and peri-urban areas also purchased Themeda grass from the coffee plantations, and freely collected grass from communal land such along the roads reserves or riversides and in the swamps. Commercial feeds were also available in cooperative shops, mainly for peri-urban and rural farmers. Finally, rural farmers had the advantage of going into the nearby forest reserve to cut grass for free during periods of feed shortage.

Table 4.16.Common Dairy Feed Resources (% farms) feed quality

Feed	Urban	Peri-urban	Rural	Mean	DM[1]	CF[2]	CP[3]
Napier Grass	100	100	100	100	282	200	100
Maize Stover	91.7	100	97.2	96.6	190	289	89
Dairy Meal	57.8	56.9	64.2	59.6	-	-	-
Banana Stem	35.8	69.7	26.6	44.0	-	-	-
Kikuyu Grass	36.7	38.5	49.5	41.6	282	200	110
Maize Germ	32.1	44.0	41.3	39.1	900	39	262
Hay	43.1	29.4	43.1	38.5	900	298	110
Brewers Grain	38.5	35.8	19.3	31.2	262	179	234
Themeda Grass	37.6	33.0	19.3	30.0	282	200	100
Wheat Bran	30.3	19.3	39.4	29.7	880	114	170
Maize Bran	6.4	33.0	21.1	20.2	-	-	-
Legume	10.1	2.8	24.8	12.5	240	300	171
Star Grass	29.4	2.8	0.9	11.0	282	200	100
Chicken Manure	6.4	6.4	7.3	6.7	-	-	-
Fish Meal	11.9	0.9	4.6	5.8	915		699
Molasses	7.3	5.5	0.9	4.6	737	0	55
Cotton Seed	0.9	2.8	7.3	3.7	900	248	231
Mineral Salt	5.5	5.5	0	3.7	-	-	-
Wheat Pollard	2.8	0.9	4.6	2.8	880	74	178
Vegetables	3.7	0.9	2.8	2.4	150	160	160
Sunflower Bran	1.8	0.9	0.9	1.2	900	134	430
Others	9.2	3.7	1.8	4.9	-	-	-

1- DM = dry matter (g/kg), 2- CF = crude fibre (g/kg), 3- CP = crude protein (g/kg on dry matter basis). Note that composition of a particular feed is variable therefore the figures should be regarded as representative examples (McDonald *et al.* 2002)

Table 4.17 Dairy Feed Transportation (% farms)

Transport	Urban	Peri-urban	Rural	Mean
Manual	71.7	70.1	77.1	73.0
Wheelbarrow	74.5	43.0	29.4	48.8
Vehicle	23.6	24.3	11.9	19.9
Donkey Cart	0.9	14.0	27.5	14.3
Bicycle	0	4.7	1.8	2.2
Hand Cart	0.9	3.7	0	1.6

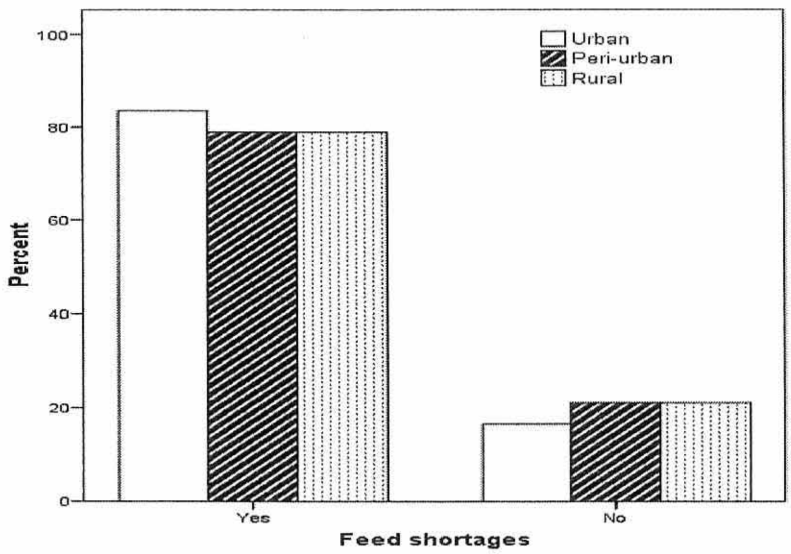


Figure 4.4 Feed Shortages (% farms)

Table 4.18 Source of Emergency Feed (% farms)

Source	Urban	Peri-urban	Rural	Mean
From Farmers	73.3	69.4	59.3	67.4
Feed Shops	35.6	41.2	54.7	43.7
Coffee Estates	23.3	45.9	4.7	24.5
Stored Stock	25.6	11.8	27.9	21.8
Brewery	23.3	10.6	15.1	16.5
Forest Reserve	0	0	48.8	16.1
Cooperatives	1.1	11.8	16.3	9.6
Roadside	17.8	2.4	0	6.9
Riverside	12.2	5.9	0	6.1
Swamp	6.7	1.2	0	2.7
Others	4.4	0	1.2	1.9

(Multiple Response)

4.5 Brewer's Spent Grain (BSG) as Dairy Feed

Inadequate fodder is one of the constraints limiting dairy production in the study area, especially during the dry seasons. To overcome this obstacle, dairy farmers have opted to use alternative dairy feed resources that are cheap and locally available. Brewers' spent grain (BSG), the material that remains after grains have been fermented during the beer making process, is readily available in large quantities throughout the year in Nairobi. Dairy farmers in the study area purchase BSG from one dominant factory located 10 km to the northeast of Nairobi city centre. Commercial dairy feeds are becoming increasingly expensive, and BSG provides a viable alternative.

Out of the 327 sample farmers, 49.5 percent (162) were using BSG as an alternative dairy feed (Table 4.19). The proportion of farmers using BSG was higher in the urban areas (64.2%) compared with rural areas (29.4%). Table 4.20 indicates that the average farmer has 7.8 year of experience in using BSG as dairy feed. The maximum years of experience in using BSG was 44 years reported in the urban area. In rural areas, 96% of the farmers had less than 10 years of experience in using BSG, with a maximum of 19 years. In contrast, over 30% of the urban farmers had experience of more than 10 years in using BSG. The beer factory sells a minimum unit of 100 kg of BSG at around KShs 200 (US$1=KShs75 in 2006/7). Most farmers purchased BSG on a weekly or fortnightly basis, transporting it using their personal pick-up cars, hire commercial transport pick-up, or use middlemen who purchase the material in bulk and sell in small quantities. The cost of transporting BSG varied from a minimum of KShs 100 for each trip in the urban areas to a maximum of KShs 2500 in rural areas (Table 4.21).

Most farmers stored the wet BSG inside specially constructed cemented tanks (Table 4.22). Others used plastic drums, plastic bags or metallic drums to store the material. The wet BSG is usually mixed with chopped fodder and fed to the cattle two to three times in a day (Table 4.23). On average, farmers use 15.9 kg of wet BSG on each day for each tropical livestock unit on the farm (Table 4.24). The maximum records were 38, 52 and 35 Kg of BSG each day for each TLU in the urban, peri-urban and rural areas, respectively. Fifty seven per cent of all the farmers used between 11 and 20 kg of BSG each day. Farmers use various methods to minimize spoilage and deterioration in quality of the wet BSG (Table 4.25). About 47% of the farmers added nothing to the stored wet BSG but only covered the surface with plastic paper or other material. Common table salt was added to the wet BSG by 14.4% of all the farmers, while 38.3% added water.

After using BSG for many years, dairy farmers have identified the limitations and side effects of using the material as dairy feed as well as learnt how to overcome the problems. These disadvantages of BSG are discussed below under four major categories: feed quality, effects on the cow and milk output, available feed quantity, and financial and human costs involved (Table 4.46). Many farmers reported that the cows become addicted to the BSG resulting in drastic reduction in milk production on withdrawal of the material from the feed mixture. Therefore the sale value is very low for cows depended on BSG, especially in rural areas where the cost of transporting BSG is high. The farmers also complained about the variable quality of the BSG. The material comes in different consistency, colour, texture, nutritive value and water content; depending on the type of grain used and type of alcohol brewed at the factory. The farmers argue that the factory should be able to standardize the BSG by mixing the different qualities and maintaining regular water content. Additionally, BSG has short shelf-life and can not be stored for more than 10 days without growing moulds or becoming sour. Therefore farmers have resolved to purchase BSG on a weekly basis or add salt and water in order to prevent the spoilage. Since wet BSG is corrosive it damages the body of the transport vehicle and requires special storage facility on the farm.

Farmers have recognized that BSG can sometimes give milk an alcoholic odour, and that this off-flavour can be avoided by feeding the cows after they have been milked but not before milking. Similarly, farmers noted that milk produced by cows fed on BSG is more dilute and has shorter shelf-life compared to milk from cows not fed on BSG. Furthermore, farmers have learnt that warm wet BSG can cause bloated stomach in cows. Therefore BSG is not fed to cows immediately on arrival from the factory; instead it is stored for some hours in order to cool down.

The farmers are normally allowed to purchase minimum of 100 kilograms of wet BSG at the factory. Although, they can purchase any maximum quantity of BSG, it is not possible because the material cannot be stored on-farm for a long time. However, during the dry seasons, the demand for BSG becomes very high and the factory has to limit the maximum quantity that each farmer can purchase. During these periods, farmers have to wake up early and start lining up at the factory gate, in order to be assured of getting some BSG. Unfortunately, sale of BSG is a monopoly of one factory and farmers have no alternative when the factory decides to increase price of feed or when the factory temporary closes down for annual maintenance services. In recent years, the factory has been increasing the price of buying BSG therefore the farmers who have been using BSG for many years now perceive it to be more expensive. Besides, the wet BSG is bulky and expensive to transport for long distances. Therefore, the rural farmers complained of expensive transport cost since they ate charged about KShs 2500 for each trip, compared to some urban farmers who pay only KShs 100. Finally, the farmers concluded that special knowledge and skills in feed management is necessary in order to handle BSG, therefore it is difficult for new farmers to start using BSG. The new farmer will also need high financial capital in order to purchase BSG on cash at regular intervals.

Despite above drawbacks, dairy farmers still find it convenient to use BSG. Over 90% of all the farmers who use BSG reported increase in milk production when the material is introduced on the dairy ration (Table 4.27). Another merit of BSG reported by farmers is that it is palatable and readily consumed by cattle. No feed is usually left uneaten when BSG is in the mixture, even with dry fodder. Many farmers reported that

BSG replaces almost a third of the fodder requirement in cattle diet. In addition, the price of buying BSG is very low compared to the price of commercial dairy feeds. BSG is also available throughout the year, unlike green fodder that becomes scarce during the dry seasons. Other merits attributed to BSG include shiny skin and body conformation as well as elimination of intestinal worms from the cattle.

Table 4.19 Utilization of Brewers Spent Grain (BSG) (% Farmers)

BSG	Urban	Peri-Urban	Rural	Overall
Users	64.2	55.0	29.4	49.5
None Users	35.8	45.0	70.6	50.5
N	109	109	109	327

Table 4.20 Years of BSG Experience (% farmers)

Years	Urban	Peri-Urban	Rural	Overall
1-5	30.0	55.0	46.9	42.6
6-10	38.6	16.7	40.6	30.9
11-44	31.4	28.3	12.5	26.9
Mean	8.2	8.2	6.2	7.8
Maximum	26	44	19	44

Table 4.21 Cost of Transporting BSG (% farms)

Cost (KShs/Trip)	Urban	Peri-Urban	Rural	Overall
100-600	46.4	14.7	22.0	28.2
601-800	35.7	38.2	0	32.4
801-1000	17.9	17.6	0	15.5
1001-2500	0	29.4	77.8	23.9
Mean	698	896	1444	887
Maximum	1000	1500	2500	2500

Table 4.22 Storage of Brewer's Spent Grain (% farms)

Storage	Urban	Peri-Urban	Rural	Overall
Plastic Drums	20.0	26.7	12.5	21.0
Plastic Trough	2.9	3.3	0	2.5
Polythene Bag	10.0	10.0	0	8.0
Metallic Drum	5.7	8.3	3.1	6.2
Cement Tank	40.0	40.0	59.4	43.8
Cement Trough	21.4	15.0	25.0	19.8
Cement Room	1.4	0	0	0.6

Table 4.23 Number of Times of BSG Feeding Each Day (% Farms using BSG)

Timing	Urban	Peri-Urban	Rural	Overall
Once	0	3.3	0	1.2
Twice	68.6	85.0	87.5	78.4
Thrice	31.4	11.7	12.5	20.4
N	70	60	32	162

Table 4.24 Amount of BSG per TLU (% Farms)

BSG (kg/d)	Urban	Peri-Urban	Rural	Overall
3-11	18.6	30.0	15.6	22.2
11-20	62.9	46.7	65.6	57.4
21-52	18.6	23.3	18.6	20.4
Mean	15.7	15.9	16.1	15.9
Maximum	38.0	52.0	35.0	52.0

Table 4.25 Methods for Preserving BSG (% farms)

Adding	Urban	Peri-Urban	Rural	Overall
Salt	14.1	0	41.4	14.4
Water	50.0	30.4	27.6	38.3
Nothing	35.9	69.6	31.0	47.7
N	70	60	32	162

Table 4.26 Disadvantages of Using BSG (% farmers)

Disadvantages	Urban	Peri-urban	Rural	Overall
Reduced Milk	41.2	72.2	56.7	55.3
Addiction	64.7	42.6	53.3	54.6
Feed Quality	33.8	38.9	23.3	33.6
Feed Quantity	32.4	25.9	40.0	31.6
Expensive	25.0	16.7	30.0	23.0
Odour in Milk	22.1	24.1	13.3	21.1
High Transport	19.1	16.7	23.3	19.1
Feed Shelf life	8.8	18.5	6.7	11.8
Dilute Milk	7.4	7.4	6.7	7.2
Time Wasting	10.3	3.7	3.3	6.6
Milk Shelf life	5.9	7.4	3.3	5.9
Corrosive	11.8	1.9	0	5.9
Cow Value	2.9	0	10.0	3.3
Bloats	0	1.9	6.7	3.3
Monopoly	5.9	0	0	2.6
Foot Rot	4.4	1.9	0	2.6
Financial Cap.	0	3.7	0	1.3
Uneconomical	0	1.9	3.3	1.3
Skill Needed	2.9	0	3.3	0.7
Min. Quantity	1.5	0	0	0.7

Table 4.27 Advantages of Using BSG (% farmers)

Advantage	Urban	Peri-Urban	Rural	All
Milk Stimulant	91.4	91.4	96.9	92.5
No Leftovers	48.6	46.6	46.9	47.5
Nutritive	65.7	34.5	25.0	46.3
Cheap	44.3	53.4	37.5	46.3
Body Conformation	30.0	50.0	65.6	44.4
Feed Replacer	34.3	29.3	18.8	29.4
Deworming	5.7	8.6	3.1	6.3
Appetizer	1.4	0	3.1	1.3
All Seasons	2.9	0	0	1.3
Others	1.4	5.2	3.1	3.1

4.6 Dairy Management Practices, Services and Facilities

Table 4.28 indicates that mastitis, pneumonia and East Coast Fever (ECF) were the most common diseases affecting dairy cattle in the study area. In addition, intestinal worm infection, diarrhoea in calves, abortion and foot rot were also reported. All farmers indicated that they use curative veterinary services from the private practitioners (Table 4.29). Farmers in rural areas also used veterinary services from the cooperative societies, while peri-urban areas used government veterinary services as an alternative. Although the government has left most of the veterinary services for private veterinary clinics where they are established, there are still some strategic services such as disease control and vaccination still provided by government.

Artificial Insemination (AI) services were readily available to all the farmers in the study area. Out of the 327 sample farmers, only 4 farmers in the peri-urban areas reported using communal natural bull services for mating the cows. Overall, majority of the farmers received artificial insemination from private practitioners (Table 4.30). However cooperative societies also provided AI services in peri-urban and rural areas.

The charges for AI services averaged 1127 KShs for each service irrespective of successful conception (Table 4.31). The cost depended on the grade and milk production records of the sire, with a maximum of 8500 KShs for one service reported in peri-urban area. About 80 percent of all the farmers reported their cows failing to conceive after AI services. Table 4.32 indicates that many farmers attributed the conception failure to inaccurate detection of cows on heat. Other farmers blamed reproductive disease of the cows and possible use of expired semen by untrustworthy AI service providers. Table 4.33 shows some of factors that influenced the decision by farmers regarding their choice of veterinary or AI service provider. Overall, many farmers were affected by the availability or monopoly of one type of service provider. The farmers in the rural and peri-urban areas were also influenced by reduced wholesale prices and the credit facilities provided by their cooperative societies

Calving interval ranged from 10 to 31 months, with an average of 14.5 months (Table 4.34). This was calculated by subtracting the second last calving date from the last calving date. Over 57 per cent of the farmers, who kept dairy breeding records, indicated calving interval of 14 months or less. Table 4.35 suggests that most farmers culled their cows any time based on financial needs or health problem. Farmers also indicated low milk production and old age as the other reasons for culling their dairy cows. The culled cow was usually replaced by another cow raised within the herd or purchased from other farmers. About 60 percent of all of the farmers raised their own replacement cows, with a higher percentage in the urban areas (Table 4.36). The average cost of buying good dairy cow in the study area was 28342 KShs for one cow (Table

4.37). The urban farmers were willing to pay more but the maximum price of 60000 KShs paid for a dairy cow was recorded in peri-urban area.

All the sample farmers practiced zero grazing in which the cows are housed throughout the year while feed and water provided inside the stall or cattle shed. The cowshed is usually partitioned so that each cow has its own stall for sleeping with separated or common feeding and watering troughs. The dairy stalls consist of a simple structure with corrugated iron sheet roof covering the cattle sleeping area, milking area but leaving some open areas where the animals can walk around. The walls are constructed from cemented masonry stones or timber with space left for ventilation and light. Table 4.38 shows that most of the floors are partly cemented, covered with masonry stone or timber. Some stall floors are also covered with hardened soil, especially in peri-urban areas. About 60 per cent of the farmers in peri-urban areas used water from on-farm boreholes for dairy and domestic use (Table 4.39). In contrast, 93.6% of the farmers in urban areas had access to municipal piped water. In some rural areas farmers harvested and stored rain water for use in their dairy farming.

Table 4.28 Common Dairy Cow Health Problems (% farms)

Disease	Urban	Peri-Urban	Rural	Mean
Mastitis	50.9	40.4	47.6	46.3
Pneumonia	45.4	27.5	35.2	36.0
ECF	34.3	24.8	28.6	29.2
Worms	15.7	9.2	9.5	11.5
Diarrhoea	2.8	0.9	1.9	1.9
Abortion	0.9	0.9	0	0.6
Foot Rot	2.8	8.3	3.8	5.0
Others	1.9	0.9	2.9	1.9

(Multiple Response) ECF=East Coast Fever

Table 4.29 Veterinary Service Provider (%)

Veterinary Services	Urban	Peri-Urban	Rural	Mean
Private	99.0	76.3	78.2	84.9
Cooperatives	0	5.4	21.8	9.0
Government	1.0	18.3	0	6.0
N	105	93	101	299

Table 4.30 Artificial Insemination (AI) Service Provider (% farmers)

AI Services	Urban	Peri-Urban	Rural	Mean
Private	96.3	56.9	58.7	70.6
Cooperative	3.7	43.1	41.3	29.4

Table 4.31 Cost of Artificial Insemination (KShs)

Cost	Urban	Peri-Urban	Rural	Mean
Mean	1279	1110	990	1127
Minimum	100	100	400	100
Maximum	3000	8500	3000	8500

Table 4.32 Explanation Given for Cow Misconception (% farmers)

Reasons	Urban	Peri-Urban	Rural	Mean
Timing	90.7	75.6	72.3	79.8
Disease	30.2	25.6	26.5	27.5
Expired Semen	5.8	5.1	22.9	11.3
Untrustworthy	9.3	5.1	36.1	17.0
Others	5.8	9.0	0	4.9

(Multiple Response)

Table 4 33 Reasons for Preferred Veterinary/AI Services (% farmers)

Reasons	Urban	Peri-Urban	Rural	Mean
Availability	48.6	23.9	38.0	37.5
No Alternative	25.7	33.0	6.0	21.2
Familiarity	19.0	26.1	16.0	20.1
Reliability	14.3	22.7	21.0	19.1
Credit Facility	3.8	10.2	18.0	10.6
Cheap	0	11.4	19.0	9.9

Table 4.34 Calving Interval (Months)

Statistic	Urban	Peri-Urban	Rural	Mean
Mean	14.5	14.6	14.5	14.5
Minimum	10	10	12	10
Maximum	21	31	17	31

Table 4.35 Times for Culling Cows (% farmers)

Time	Urban	Peri-Urban	Rural	Mean
Low Milk	14.7	5.5	22.0	14.1
Any Time	55.0	62.4	42.2	53.2
After 2-5 Calves	1.8	8.3	7.3	5.8
After 6-8 Calves	28.4	23.9	28.4	26.9

Table 4.36 Source of Culled Cow Replacement (% farmers)

Source	Urban	Peri-Urban	Rural	Mean
Raised	74.3	49.5	56.0	59.9
Purchased	25.7	50.5	44.0	40.1
N	109	109	109	327

Table 4.37 Cost of Last Purchased Cow (KShs/cow)

Statistic	Urban	Peri-Urban	Rural	Mean
Mean	32314	26855	27729	28342
Minimum	2800	3000	8000	2800
Maximum	50000	60000	50000	60000

Table 4.38 Cowshed Floor Type (% farms)

Floor Type	Urban	Peri-Urban	Rural	Mean
Cemented	37.6	18.3	20.2	25.4
Semi-Cement	42.2	59.6	38.5	46.8
Mason Stone	13.8	7.3	9.2	10.1
Semi-Stone	0	0	15.6	5.2
Timber	0	0.9	2.8	1.2
Semi-Timber	0	0	6.4	2.1
Earth	6.4	13.8	7.3	9.2

Table 4.39 Water Supply for the Dairy (% farms)

Source	Urban	Peri-Urban	Rural	Mean
Piped	93.6	44.0	69.7	69.1
Borehole	6.4	60.6	34.9	33.9
Rain	0.9	4.6	10.1	5.2
Others	2.7	2.7	0	1.5

4.7 Milk Production and Marketing

All the sample farmers used hand milking, commonly early in the morning and late in the afternoon. A number of farmers milked their cows three times in a day, although three farmers in urban area reported milking four times in a day. The average milk produced by one cow in a day in the sample dairy farms was 13.6 litres (Table 4.40). Urban farmers had higher average than that for peri-urban and rural farmers. The maximum reported was 32 litres per day by a farmer in peri-urban area. Results indicate that over 90 per cent of all the cows produced less than 20 litres of milk per day. The combined average total milk from all cows per farm was 39 litres per day (Table 4.41). However, the urban farmers achieved an average of 46 litres per day, compared to 35 litres per day from peri-urban and rural farmers. Most farmers were concentrated in the 11 to 50 litres per day band. The maximum recorded was 205 litres per day by a rural farmer.

Table 4.40 Milk Produced by Each cow per Day (% farms)

Milk (l/d)	Urban	Peri-urban	Rural	Mean
1-10	31.2	42.2	43.1	38.8
11-20	52.3	51.4	50.8	50.8
21-32	16.6	6.4	10.4	10.4
Mean	15.5	12.6	12.7	13.6

Table 4.41 Milk Produced in Each Farm per Day (% farms)

Milk (l/d)	Urban	Peri-urban	Rural	Mean
1-10	10.1	16.5	15.6	14.4
11-50	54.1	62.4	66.1	60.9
51-100	29.4	16.5	11.9	19.3
101-205	6.4	4.6	6.4	5.8
Mean	46.4	34.5	34.9	38.6

Four main milk marketing channels, through which the smallholder dairy farmers sell their milk in the Nairobi urban region, were identified from the survey, and they include direct to consumers, cooperatives, hotels and traders (Table 4.2).The sample farmers supplied a total of 4485 and 3887 litres of fresh milk per day to the cooperative and directly to consumer respectively. Farmers in rural and peri-urban supplied equal total amount of milk per day to the markets, which was less compared to that of farmers from urban areas. Most dairy farmers sell their milk to more than one outlet. The farmers can sell their milk directly to their neighbours and other households in the rural market centres and in the urban areas. More than 51 per cent of all the sample dairy farmers sold some of their milk directly to the consumers. In the urban areas, 90 per cent of the farmers sold their milk directly to consumers, compared to only 9 per cent of the farmers in rural areas. Farmers' dairy cooperative societies were the second largest market channel, especially in the rural areas where 81 per cent of the farmers channelled their milk. Hotels and restaurants mostly served urban farmers and a few rural farmers who had their own means of transporting milk directly to the urban areas.

The most common means of transporting milk is by manually carrying it to the market at no extra costs (Table 4.43). Traders visit the farms or milk collection points to pick the milk and transport it to urban areas. Some consumers also collect their milk from neighbouring farmers. Other farmers use bicycles or wheelbarrows to transport the milk to collection points or directly to the customers. Those farmers who have their own vehicles use them to transport the milk, while those who do not own personal vehicle use public road transport. In rural areas, some farmers use donkey-drawn carts.

Farm gate price received for fresh milk sales varied from 14 to 36 Kenya Shillings (KShs) per litre (US$1= KShs75 in the year 2006/2007). The minimum price of 14 was paid by traders in rural areas while a maximum of 36 KShs was paid by hotels and restaurants in urban areas (Table 4.44). Overall, the cooperatives paid the lowest average price of 18 KShs per litre while the hotels paid the highest average price of 28 KShs per litre of fresh milk. When selling their milk to different milk market channels, the farmers did not only consider the price paid but also the reliability of the market system.

Kenyans are ranked among the highest in per capita milk consumption among the developing countries. Table 4.45 examines the amount of milk consumed by the households. Overall, 60 per cent of the farms used up to two litre of fresh milk each day for home consumption. The average was 2.5 litres per day. Some milk was also fed to the calves that had not reached the age of weaning.

Table 4.42 Milk Marketing Channels (% of farmers)

Market	Urban	Peri-urban	Rural	Mean
Consumers	90	54	9	51
Cooperatives	12	43	81	45
Hotels	28	6	8	14
Traders	51	33	36	40
N	109	106	107	322

(Multiple Response)

Table 4.43 Milk Transportation (% of farms)

Transport	Urban	Peri-urban	Rural	Mean
Manual	41.3	58.1	63.6	54.2
Bicycle	32.1	31.4	21.5	28.3
Collected	19.3	10.5	7.5	12.5
Personal Vehicle	7.3	4.8	8.4	6.9
Wheelbarrow	3.7	1.9	2.8	2.8
Public Vehicle	1.8	1.9	0.9	1.6
Donkey Cart	0	0	2.8	0.9

Table 4.44 Milk Prices Paid to Farmers (KShs/Litre)

Market	Minimum	Maximum	Mean
Consumers	16	31	27
Cooperatives	15	28	18
Hotels	17	36	28
Traders	14	30	22

Table 4.45 Milk Consumption in Each Household (% farms)

Milk (l/d)	Urban	Peri-urban	Rural	Mean
1-2	50.5	59.8	69.7	60.0
3	26.6	19.6	15.6	20.6
4-10	22.9	20.6	14.7	19.4
Mean	2.8	2.9	2.5	2.6

4.8 Opportunities and Constraints

Table 4.46 presents the proportion of farmers who mentioned specific constraints they face in relation to dairy farming in the study area. The small farm land size and shortage of fodder especially during the dry seasons were the main constraints reported by over 50 percent of the farmers. Increasing human population pressure and high price for buying agricultural land were also reported as major constraints. Land tenure also surfaced through out the study area because many farmers are still waiting for several years to obtain their land title deeds after applying to the Ministry of Lands. The other general problem was lack of financial capital to expand the dairy enterprise. All the farmers, especially in the urban areas complained that there were few committed and experienced people willing to be employed in the dairy farms.

In the urban areas, a large number of farmers reported the negative effects of increasing residential houses and road traffic. In addition, there were public health regulations by the Nairobi City Council that were assumed to prohibit the keeping of dairy cattle within the urban areas. Cattle manure disposal was also a problem for the urban farmers because they did not have cropped land to apply the manure. On the contrary, the rural farmers reported fodder pests, competition for land with cash crops especially tea and vegetable, and poor road and unreliable public transport. Many roads in the rural study areas used to be all-weather roads but have deteriorated because they have not been repaired for many years. In peri-urban areas, 50 percent of the farmers reported lack of piped water. Many of the peri-urban farmers were recent settlers; therefore, they have not been supplied with municipal piped water.

In relation to milk marketing (Table 4.47), 49.1 per cent of the urban farmers agreed that they were selling their milk at high prices. In contrast, 51.4 per cent of the rural farmers complained that they were selling their milk at low prices. All the sampled farmers agreed that there was high demand for milk and were optimistic that future demands will improve with expected increase in urbanization.

When asked about the future plans for their dairy farm, less than 2 per cent of all the farmers expected to discontinue their dairy farming activities (Table 4.48). The remaining 98 percent expected to expand or continue with business as usual. Most farmers in the urban areas expected to upgrade their cross breed cows through breeding management in order to improve the milk yields, but not to expand the herd size. In the peri-urban areas, 30.2 per cent of the farmers expected to expand their herd size. In the rural areas, 34 per cent of the farmers were satisfied with the existing situation while 37.6 expected to upgrade their cross-bred cows through breeding management.

Table 4.46 Constraints to Dairy Farming (% farmers)

Problem	Urban	Peri-Urban	Rural	Mean
Small Land Size	63.5	78.0	48.6	63.3
Fodder Shortages	47.6	57.8	46.7	50.8
Human Population	39.8	25.7	41.1	35.4
Land Tenure	35.0	28.4	23.4	28.8
Piped Water	13.6	50.5	7.5	24.1
High Land Price	32	28.4	10.3	23.5
Fodder Pests	4.9	3.7	27.1	11.9
Urban Settlements	26.2	8.3	0.9	11.6
Committed Labour	11.7	7.3	9.3	9.4
Cash Crops Comp.	1.0	7.3	18.7	9.1
Residential Houses	12.6	4.6	3.7	6.9
Vet. Expenses	3.9	6.4	8.4	6.3
Poor Roads	2.9	2.8	11.2	5.3
Health Regulations	12.6	0.9	2.8	5.3
Manure Disposal	8.7	2.8	0.9	4.1
Cattle Theft	7.8	0.9	2.8	3.8
Poor Soils	3.9	1.8	3.7	3.1
Pigs/Poultry Comp.	1.0	0.9	0.0	0.6
Others	19.4	12.8	35.5	22.8

Table 4.47 Farmers' Opinion on Milk Marketing (% farmers)

Issues	Urban	Peri-urban	Rural	Mean
High Price	49.1	31.2	9.2	29.8
Low Price	10.2	22.9	51.4	28.2
Medium Price	23.1	42.2	33.0	32.8
High Demand	79.6	78.9	89.0	82.8
Low Demand	5.6	9.2	0	4.9
Med. Demand	6.5	8.3	1.8	5.5

Table 4.48 Future Plans for the Dairy Enterprise (% farmers)

Plans	Urban	Peri-Urban	Rural	Mean
Upgrade Cows	52.3	22.6	37.4	37.6
Expand	8.3	30.2	15.0	17.7
Upgrade/Expand	13.8	19.	12.	15.2
As Usual	23.9	26.4	33.6	28.0
Discontinue	1.8	0.9	1.9	1.6

4.9 Summary

All the 327 dairy farms sampled were owned and operated by the family. Family members provided labour and made decisions concerning the dairy activities. Most farms had two or one family member actively involved with dairy farming activities. In addition, more than a half of all the farmers hired labour on temporary or regular basis to work on the dairy. Most farms employed one external person; however a few managed to employ two people to help in feeding and milking the cows. The respondents were fairly equally distributed between men and women for the 327 dairy farmers sampled. The mean age of the farmers was 52 years. Overall, the sample farmers have managed their dairy farming for 15 years on average. Rural farmers have 18.5 years of dairy farming experience on average, which is higher than peri-urban and urban farmers. A maximum of 50 years of experience was observed in peri-urban farmers, compared to 49 and 33 years in rural and peri-urban farmers, respectively.

About 43% of the farmers indicated that dairy farming was the most important in source of income for their households. The proportion was particularly higher in rural and peri-urban areas. A high percentage of the urban farmers indicated that off-farm activities were their main source of income. The rural farms had a mean land size of 2.5 acres compared to 1.1 and 1.3 acres in the urban and peri-urban areas, respectively. In urban areas, 56% of the farmers hired extra land compared to 46% and 39% in peri-urban and rural areas respectively. The results indicate that it was cheaper for farmers to hire land in the peri-urban areas compared to urban and rural areas

A total of 2040 heads of dairy cattle were kept by the 327 sample farmers. The mean herd size was 6.24 heads of dairy cattle in the whole of the study area. The dominant dairy cattle breeds were Friesian (75%) and Ayrshire (25%), composed of both cross breed and pure breed. All the 327 sampled farmers practiced zero-grazing (stall-feeding) and their dairy cattle were fed on variety of feed stuff. Many farmers reported feed shortages as a major constraint, especially during the dry seasons when the green fodder is scarce. Out of the 327 sample farmers, 49.5 percent (162) were using brewers' spent grain (BSG) as an alternative dairy feed. BSG is available through out the year at a reasonable price but transport cost is high especially for farmers located at a long distance from the city centre. The proportion of farmers using BSG was higher in the urban areas (64.2%) compared with rural areas (29.4%). Over 90% of all the farmers who use BSG reported increase in milk production when the material is introduced on the dairy ration.

All the farmers use hand milking early in the morning and late in the evening. The average milk produced by one cow in a day is 13.6 litres. However, the urban farmers had higher average milk yields compared with the peri-urban and rural farmers. The maximum reported was 32 litres per day by a farmer in peri-urban area. Over 60% of the farmers use up to two litre of milk for home consumption. The farmers use four main milk marketing channels: direct to consumers, cooperatives, hotels and traders. Most farmers sell their milk to more than one outlet. In the urban areas, 90 per cent of the farmers sold their milk directly to consumers, compared to only 9 per cent of the farmers in rural areas.

When asked about the future plans for their dairy farm, less than 2% of all the farmers expected to discontinue their dairy farming activities. In the peri-urban areas, more than 30% of the farmers expected to expand their herd size. In contrast, most of the urban farmers have no plans to expand their herd size instead they have plans to genetically upgrade their dairy herd by selective breeding for high milk yield potential. Therefore it seems that dairy farming in Nairobi metropolitan region has a bright future.

CHAPTER 5

LEVELS OF DAIRY LAND USE INTENSIFICATION

The second major question of this thesis was addressed by comparing the levels of dairy intensification amongst the urban, peri-urban and rural farmers using a multivariate analysis approach. The descriptive results discussed in the previous section indicated that the farm characteristics are quite heterogeneous, and most of the scale variables are skewed and non-normally distributed. In order to reduce the data and identify the main variables indicating dairy intensification levels, principal components analysis (PCA) was applied and the resultant factor scores for each case used as the input for subsequent: (1) comparison of mean level of dairy intensity among the urban, peri-urban and rural farmers; (2) ranking of farmers into three categories of dairy intensity, and (3) classification of the farmers using cluster analysis. One-way between-groups analysis of variance (ANOVA) was used to test if the mean level of dairy intensity differed significantly among the farmers in the urban, peri-urban and rural areas.

5.1 Principal Component Analysis of all the Farmers

5.1.1 Background

Principal component analysis (PCA) is one of a suite of factor analysis methods for reducing a large number of variables into a few relatively independent components linked with a set of specific variables (Child, 2006; Norusis, 2007). In this way the most important variable accounting for the variability in a set of data can be identified. The factor scores for each case is usually standardized and can be saved and used as a variable in further analysis. This method has been used in related dairy farming system studies in Kenya (Staal *et al.* 2001 and 1997; Bebe *et al.*, 2008). Usai *et al.* (2006) applied principal component analysis to classify goat farming systems in Sardinia, Italy.

In Poland, Chapin *et al.* (2007) used similar methods to identify groups of small-scale farmers facing similar constraints to diversification. Similarly, in Mexico, Espinoza *et al.* (2007) used related methods to characterize small-scale dairy farmers in order to analyse effects on poverty levels and family income.

5.1.2 Selecting the Variables for PCA

Based on the conceptual framework discussed in chapter three and previous studies and descriptive analysis discussed in chapter four, 30 variables were initially identified to represent dairy land use intensity in this study. However, the variables that were not answered by all the 327 dairy farmers, those with little variability and those which were highly correlated with each other were excluded, as recommended by Kobrich *et al.* (2003). The remaining nine variables were judged suitable for principal components analysis. In order to utilize both quantitative and qualitative variables it was necessary to transform the quantitative variables into qualitative classes. The quantitative variables were divided into four categories using the quartile positions with respect to their means. This provided the frequency of cases that were within less than 25%, between 25% and 50%, between 50% and 75%, and higher than 75% of the mean value of each variable. A list of variable used in principal component analysis is presented in Table 5.1 and elaborated below. This method of classification is not subjective as noted by Solano *et al.* (2000) and Milan *et al.* (2003 and 2006).

Table 5.1 Variables and their Categories Used in Principal Component Analysis

Variables	category1	category2	category3	category4
Milking Cow Density (heads/acre)	< 1	2	3-4	>5
Total Milk Productivity (l/day/acre)	< 10	11-30	31-50	>51
Milk Yields (l/cow/day)	< 9	10-12	13-18	19-32
Cost of AI (KShs/service)	100-700	701-800	801-1500	1501-8500
Age of the Farmer (years)	30- 46	47-52	53-58	59-82
Dairy Experience (years)	1-7	8-12	13-21	22-50
BSG Use	No	Yes		
Main Income Source	Others	Farming	Dairy	
Owned Farmland Size (acres)	< 0.5	0.5-1.0	1.1-2.0	2.1-12.0

The milking cow density represents the ratio between the total numbers of lactating cows on the farm owned farmland size. Owned farmland size is the total area of land owned and operated by the dairy farmer. Note that many dairy farmers in the study area rented extra land for growing fodder, but this is presented as a different variable called rented land and was not suitable for used in this analysis. Land price is the cost of buying one acre of agricultural land in the neighbourhood. Milk yields represent the average daily milk produced by each lactating cow as measured by the farmer the day before the survey. The total milk productivity is the ratio between the total milk produced on the farm each day and the owned farmland size. Cost of artificial insemination refers to the price paid by the farmer for each service. The artificial insemination services in the study area were either provided by private practice or by the dairy farmers' cooperative society. Dairy experience represents the number of years that the farmer has been practicing dairy farming. BSG use indicates whether the farmer utilizes the brewers spent grain (BSG) as an alternative dairy feed or not. Tropical livestock unit was used as a common measure of dairy cattle of different ages and size. The tropical livestock units used in calculation were 0.2 for calves, 0.5 for young bulls and heifers, 0.7 for cows and 1.0 for bulls. Finally, cattle density was estimated as the ratio between the TLU and the owned farmland size.

5.1.3 Correlation Matrix and Rotation

Initial stages of the analysis involved assessing the validity of using two tests each indicating that the data were appropriate. The Kaiser-Meyer-Olkin (KMO) measure of sample adequacy is 0.68 indicating that the data matrix has sufficient correlation to justify principal components analysis. Bartlett's test of sphericity produced a high value and statistically significant, further supporting the analysis. The principal component analysis revealed the presence of three components with eigenvalues exceeding 1.0. Inspection of the scree plot indicated a clear break after the third component, indicating the existence of three components (Figure 5.1). To help in the interpretation of the three components, several rotations were performed. Varimax rotation resulted improved loading of the variable the best interpretation of the components. The three components explained a total of 69.3% of the variance in the data, with the first, second and third components contributing 28.1%, 24.7% and 16.5% respectively. The factor loadings of the variables on the three components are presented on Table 5.2 below.

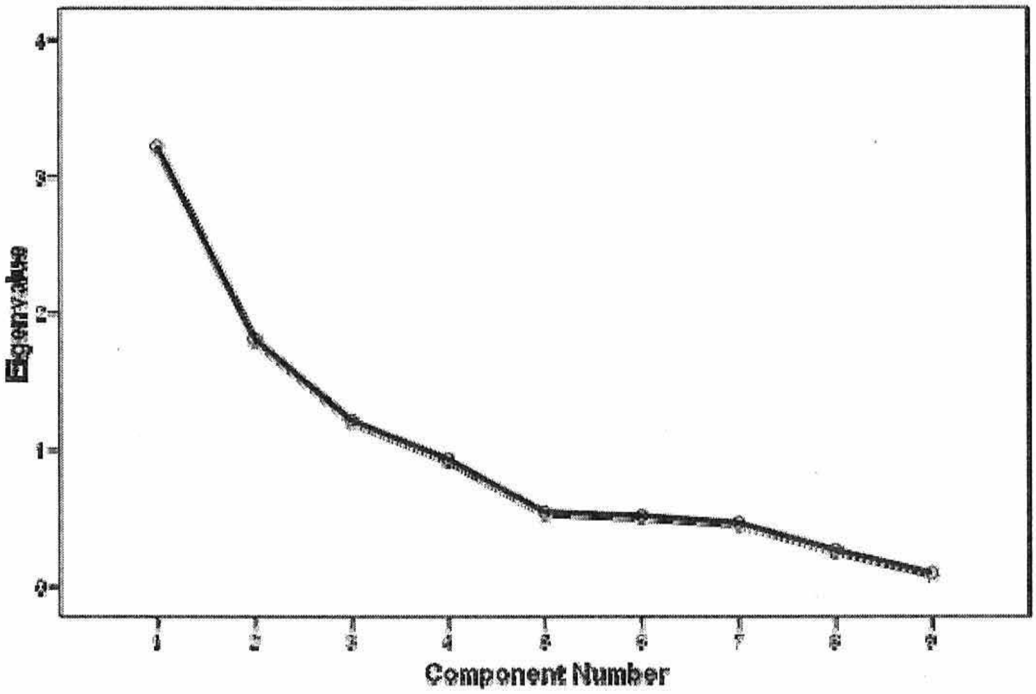


Figure 5.1 Scree plot for Principal Component Analysis

Table 5.2 Principal Component Analysis Results for all the Farmers

Variables	PC1	PC2	PC3	Communalities
Milking Cows Density (heads/acre)	0.906			0.876
Total Milk (l/day/acre)	0.831			0.888
Owned Farmland Size (acres)	-0.871			0.830
Milk Yields (l/cow/day)		0.829		0.698
Cost of AI (KShs/service)		0.806		0.655
BSG Usage (Yes/No)		0.762		0.611
Age of the Farmer (years)			0.746	0.611
Dairy Experience (years)			0.708	0.653
Main Income Source			0.614	0.412
Eigenvalues	3.219	1.807	1.209	
Total Variance (%)	28.141	24.654	16.481	
Cumulative Variance (%)	28.141	52.795	69.275	

5.1.4 Interpretation

The principal component analysis of the nine original variables led to selection of three components that reflect different dimensions of dairy intensification in the study area. The first component can be interpreted as the land intensification and has high positive correlation with milking cow density and total milk productivity. However, it has high and negative association with owned farmland size. This land intensification component explained the highest variance of 28.1% in the data. The second component can be interpreted as breeding intensification and explained another 24.7 of the variance in the data. The breeding intensity is positively correlated with milk yield per cow, cost of artificial insemination and use of brewers' spent grain as an alternative dairy feed.

The third component can be interpreted as human intensification and contributes 16.5% of the variance in the data. Human intensification is positively related to the age of the farmer, number of years the farmer has been in dairy farming and whether dairy is the main source of income. The three component scores for each case were saved as new variables for further analysis. However, four cases (farms) were automatically dropped as outliers while 323 cases remained as valid.

5.2 Principal Component Analysis of BSG Farmers

The same procedure of principal components analysis was applied to only 165 farmers who use brewers spent grain (BSG) as an alternative dairy feed. This is because utilization of BSG by farmers was considered to be a possible strong indicator of urban or peri-urban tendencies, as shown by its inclusion in the final list of variables the PCA (Table 5.2). A list of variables and their measurement scales are presented in Table 5.3. The analysis reduced final eight variables into three principal components with one of them representing the urban-rural gradient dimension. In this second series of analysis, the Kaiser-Meyer-Olkin measure of sampling adequacy was 0.6 and Bartlett's test of sphericity was statistically significant. This suggests that the data are adequate for the principal component analysis. The results are presented in Table 5.4 below.

Table 5.3 Variables and their Classes Used in PCA for BSG Farmers

Variables	category1	category2	category3	category4
Cattle Density (TLU/acre)	< 1.4	1.5-2.8	2.9-5.6	>5.7
Land Price (mKShs/acre)	0.3-0.7	0.71-1.3	1.31-2.5	2.51-8.0
Milk Yields (l/cow/day)	< 9	10-12	13-18	19-32
Cost of AI (KShs/service)	100-700	701-800	801-1500	1501-8500
Dairy Experience (years)	1-7	8-12	13-21	22-50
AI Service Provider	Private	Coops		
Main Income Source	Others	Farming	Dairy	
Owned Farmland Size (Acres)	< 0.5	0.5-1.0	1.1-2.0	2.1-12.0

Table 5.4 Principal Component Analysis Results for BSG Farmers Only

Variables	PC1	PC2	PC3	Communalities
Cattle Density (TLU/acre)	-0.891			0.803
Owned Farmland Size (Acres)	0.872			0.831
Dairy Experience (years)	0.545			0.401
AI Service Provider		0.742		0.642
Main Income Source		0.732		0.656
Land Price (KShs/acre)		-0.695		0.640
Milk Yields (l/cow/day)			0.863	0.746
Cost of AI (KShs/service)			0.832	0.729
Eigenvalues	2.339	1.866	1.242	
Total Variance (%)	26.388	21.382	20.322	
Cumulative Variance (%)	26.388	47.770	68.092	

The first component can be interpreted as land intensification as the highest loading variable being the ratio between the cattle population and land size. This component is negatively correlated with cattle density but positively correlated with owned farmland size and years of dairy farming experience. The component accounted for 26.3% of the variation in the data. The second component can be interpreted as the urban-rural gradient. It is positively associated with the provider of artificial insemination (AI) services and whether dairy farming is the main source of income for the farmer. The component is negatively correlated with the price of land in the neighbourhood. The urban-rural gradient component accounted for 21.3% of the variance in the data. The third component can be interpreted as breeding intensity and is positively related to milk yields and cost of artificial insemination. It contributed 20.3% of the variance. The three components together cumulatively contributed 68% of the variation in the data.

The land and breeding dimensions of dairy intensification have already been identified in the large sample of all the farmers. Therefore the two components are not discussed further for this sub-sample. Only the factor scores for the urban-rural gradient were saved as a new variable in each case for further analysis. Five cases out of the 165 farmers using BSG were automatically discarded as outliers resulting in 160 valid cases.

5.3 Ranking the Farmers on the Level of Dairy Intensification

The principal component analysis factor scores were used as the basis for dividing the whole set of 323 farmers (excluding four outliers) into three categories of dairy intensification. The PCA factor scores are usually standardised with a mean value of 0 and standard deviation of 1.0. The land intensity factor score ranged from -0.802 to 1.828, breeding intensity from -1.665 to 1.919 and human intensity from -2.175 to 2.281 (Table 5.5). Based in the factor scores all the cases were sorted on ascending order and grouped using quartile positions into three categories of high, medium and low intensity levels. The low intensity category consists of farmers with intensity factor score less than 25%, the medium intensity include those with factor score in the range of 25-75%, while high intensity category is comprised of farmers with factor score of more than 75%.

Table 5.5 PCA Factor Scores and Their Classes of Dairy Intensity

PCA Factor	Low Intensity	Medium Intensity	High Intensity
Land Intensity	-1.802- -0.900	-0.899-0.832	0.833-1.828
Breeding Intensity	-1.665- -0.860	-0.859-0.943	0.944-1.919
Human Intensity	-2.175- -0.690	-0.689-0.809	0.810-2.2281

The percentage of farmers in the three categories of dairy intensity across the urban-rural gradient (as determined by the author) is presented in Table 5.6. For land intensity, 89% of all the urban and peri-urban farmers fall under high and medium intensity class. In contrast, 89% of the rural farmers fall under low and medium intensity categories. This indicates that urban and peri urban farmers practice higher levels of dairy land use intensity compared to the rural farmers. A similar trend is observed in breeding intensity levels. In breeding intensity, 80% and 75% of urban and peri-urban farmers respectively are classified in the high and medium intensities. In contrast 82% of the rural farmers are grouped under low and medium intensity. Human intensity indicates reversed the trend with 80% and 75% of the rural and peri-urban farmers respectively falling under high intensity. In urban areas, 86% of the farmers lie in low human intensity. This indicates that rural and peri-urban farmers tend to be old and well-established farmers whereas urban farmers are young in age and recent entrants in dairy farming activities.

Table 5.6 Percentage of Farmers in Each Dairy Intensity Category

Intensity Factors	Intensity Levels	Urban	Peri-Urban	Rural
Land intensity				
	High	34	30	11
	Medium	55	58	37
	Low	11	12	52
Breeding Intensity				
	High	35	21	17
	Medium	45	54	52
	Low	20	25	30
Human Intensity				
	High	14	31	30
	Medium	56	44	50
	Low	30	25	20

5.4 Test of Significant Difference in Levels of Dairy Intensification

This section presents the results of statistical significance test of the difference in the group mean levels of dairy intensity among the urban, peri-urban and rural farmers. One-way analysis of variance (ANOVA) was applied to the three intensity factors scores derived from principal component analysis for all the 323 farmers. The factor scores from principal components analysis are already standardized; therefore meet the normality assumption for ANOVA. Residual plots and the Levene test of homogeneity of variance were used to check the equal variance assumption (Fry, 1996).

Results of the initial one-way between-groups analysis of variance indicated that there are significant differences between the mean levels of dairy intensity between the urban, peri-urban and rural farmers (Table 5.6). The ANOVA results for land intensity revealed highly significant differences ($p<0.001$) in the mean levels of dairy intensity among the urban, peri-urban and rural farmers ($F = 36.65$, $p<.001$). Breeding intensity was significantly different ($p<0.01$) between the groups ($F = 7.62$, $p=.001$), while human intensity was also statistically different ($p<0.05$) between the groups ($F = 3.87$, $p<.022$). ANOVA was followed by least significant differences (LSD) test in order to differentiate which means are different from each other. The results from the multiple comparisons are presented in Table 5.7 below.

Table 5.7 Overall Result of ANOVA Based on PCA Factor Score Means

Intensity Factor	Urban	Peri-Urban	Rural	F Statistics[a]	Significance
Land Intensity	0.338	0.273	-0.605	36.65	***
Breeding Intensity	0.290	-0.074	-0.213	7.62	**
Human Intensity	-0.216	0.104	0.115	3.87	*

*-$p<0.05$, **-$p<0.01$, ***-$p<0.001$ a = (df. 2, 320)

Table 5.8 Results of Multiple-Comparison Using Least Significance Difference (LSD)

Intensity Factor	Contrasts	Significance
Land Intensity		
	Urban and Peri-Urban	ns
	Urban and Rural	***
	Peri-Urban and Rural	***
Breeding Intensity		
	Urban and Peri-Urban	**
	Urban and Rural	***
	Peri-Urban and Rural	ns
Human Intensity		
	Urban and Peri-Urban	*
	Urban and Rural	*
	Peri-Urban and Rural	ns

*-p<0.05, **-p<0.01, ***-p<0.001, ns-Not significant at p=0.05

In the land intensity there was no statistical differences between the urban and peri-urban farmers ($p<0.05$), but these were both different from rural farmers ($p<0.001$). For breeding intensity there were no differences between peri-urban and rural farmers ($p<0.05$), but these were both different from urban farmers ($p<0.01$). The human intensity showed no statistical difference between peri-urban and rural farmers ($p<0.05$), however these were both significantly different from urban farmers ($p<0.05$). The ANOVA results indicate that there is a clear difference in the level of dairy intensity between urban and rural farmers. The pattern between the peri-urban with either urban or rural is not so straight forward.

5.5 Classification of all the Farmers by Cluster Analysis

In order further explore the differences in the level of dairy intensification among the farmers, two series of cluster analyses were applied to the data. The first cluster analysis was conducted using factor scores from principal components analysis for all the 323 dairy farmers, while the second cluster analysis was conducted only for 160 dairy farmers who utilize brewers spent grain (BSG) as an alternative dairy feed. Cluster analysis is a method of identifying a set of homogeneous groups with minimum within group variations and maximum between group variations (Norusis, 2007). A hierarchical cluster analysis by Ward's method using squared Euclidean distance was combined with k-means cluster analysis. Several iterations were tried until the best clusters were produced. The first analysis of all the farmers produced four distinct groups with different levels of dairy intensification. The second cluster analysis of only BSG-using farmers revealed five clear groups of dairy farmers at different degrees along the urban-rural gradient.

Table 5.9 presents the four well-defined clusters using all 323 farmers together with the calculated means of the original variables which are significantly different between the groups. Farmers in clusters 1 and 4 both have high level of diary land use intensity, while those in clusters 2 and 3 have low levels of intensity. Farmers in clusters 1 and 3 are relatively older in age and have been practising dairy farming for a long period compared with farmers in clusters 2 and 4. On the size of land owned, the farmers in clusters 3 and 4 have relatively larger land compared to those in clusters 1 and 2. About 84% of the farmers in cluster 1 depend on dairy farming as their main source of income and only 55% the farmers use BSG as an alternative source of dairy feed. In cluster 4, about 92% of the farmers use BSG and their main source of income is from off-farm activities such as business or employment.

There is no clear distribution of the clusters along the urban-rural gradient (Table 5.10). However, 43% of the urban farmers are in cluster 4, while 51% of the rural farmers are in cluster 3. The farmers in peri-urban areas are distributed in all the clusters although 34% are grouped in cluster 2.

Table 5.9 Mean Characteristics of the Clusters of All Dairy Farmers

Characteristic	Cluster1	Cluster2	Cluster3	Cluster4
Number of farmers	51	98	81	93
Dairy Experience (years)	20	9	24	12
Age of Farmer (years)	60	45	58	51
Number of cattle	8	4	5	9
Number of lactating cows	4	2	2	4
Milk yields (l/cow/day)	14	11	10	20
Milk production(l/day)	44	21	22	68
Cost of AI (KShs/service)	1200	800	800	1600
Cost of last cow (KShs)	25000	27000	27000	35000
Owned land size (acres)	0.75	0.50	2.84	1.88

Table 5.10 Number of all Farmers in Each Cluster

Clusters	Urban	Peri-Urban	Rural	Total
1	15	28	8	51
2	40	37	21	98
3	7	20	54	81
4	46	23	24	93
Total	108	108	107	323

5.6 Classification of BSG Farmers by Cluster Analysis

Five groups of farmers were differentiated by cluster analysis of the 160 farmer who use BSG as an alternative dairy feed (Table 5.11). Cluster 1 and 3 are mostly located in the rural areas while clusters 2 and 4 are mostly located in the urban areas (Table 5.12). Most of the farmers in the peri-urban areas are evenly distributed in all the clusters. Farmers in cluster 5 are located in all the areas. Farmers in cluster 3 are located at relatively longer distance from the city centre, have less experience in use of BSG, pay more for transporting BSG, but own larger land areas compared to rural farmers in cluster 1. Urban farmers in cluster 2 are relatively young and use more BSG compared to those in cluster 4.

Table 5.11 Characteristics of the Clusters of BSG Farmers (mean)

Characteristic	Cluster1	Cluster2	Cluster3	Cluster4	Cluster5
Number of farmers	26	24	25	42	43
Dairy experience (years)	21.0	10.4	19.2	11.6	11.2
BSG Experience (years)	12.35	7.58	6.20	7.50	6.58
BSG fed (kg/farm/day)	80	76	76	56	75
BSG Transport cost (KShs/trip)	1300	800	972	711	870
Land price (mKShs/acre)	0.92	2.88	1.41	3.12	2.50
Hired land size (acres)	0.81	1.04	0.70	0.58	0.56
Age of Farmer (years)	55.9	49.4	53.9	51.8	48.7
Number of all cattle	8.81	7.71	8.92	6.60	8.44
Number of family labour	2.12	1.50	2.16	1.79	1.98

Table 5.12 Number of BSG Farmers in Each Cluster along the Urban-Rural Gradient

Clusters	Urban	Peri-Urban	Rural	Total
1	0	15	11	26
2	13	10	1	24
3	4	9	12	25
4	31	10	1	42
5	21	15	6	43
Total	69	60	31	160

5.7 Summary

Principal component analysis identified three factors that represent different dimensions of dairy intensification in the study area. The three factors were interpreted as land, breeding and human intensification. One-way analysis of variance results indicate that there is statistically significant differences in the levels of dairy land use intensification between the urban and rural farmers. However, there are no clear-cut differences between the peri-urban and urban or rural farmers. Using cluster analysis, all the 323 smallholder dairy farmers were grouped into four clusters based on the level of dairy land use intensity. Additionally, using only 160 dairy farmers who utilize brewers spent grain as an alternative dairy feed, cluster analysis established five distinct groups of farmers along the urban-rural gradient.

CHAPTER 6
SUMMARY AND DISCUSSION

This final chapter of the thesis starts by recapitulating the knowledge gap addressed in this study and highlighting the key methods used in the study. The main sections of this chapter summarize the key findings and discuss their implications for the literature, public policy and future research.

6.1 Introduction

6.1.1 Restatement of the Research Problem

Previous studies show that urbanization in Africa is growing along with environmental degradation, worsening poverty and hunger, unlike most other parts of the world (Devereux and Maxwell, 2001; Koc *et al.*, 1999; Smith, 1998). Historically, poverty and food insecurity have been rural problems, but now they are increasingly becoming urban issues (Koc *et al.,* 1999; Iaquinta and Drescher, 2003). This gloomy view of future urbanization in Sub-Saharan Africa requires that the focus of development research for the coming decades should be on urban regions since that is where the majority of the poor and the hungry will live. Therefore, there is an urgent need to explore and understand the possible opportunities available to address the issues of urban poverty, food security, and environmental degradation. Urban and peri-urban agriculture may play an important role in addressing these challenges. Moreover, it is through better understanding of the extent and trends of agricultural land use in the urban regions that we can achieve realistic policies and programme design and implementation to influence future development.

Urban agriculture has now become an important issue for research and development attention as an essential part of the strategy for sustainable urban and regional development (Mougeot, 1994). However, despite the growing statistics and expressed concerns, our understanding of the patterns and trends of agricultural land use activities in the urban and peri-urban areas remains limited. Recent studies from developed countries have focused on issues of urban sprawl and conversion of agricultural land indicating decline in agricultural activities with increasing urbanization (Johnson 2002; Bernstein, 1995). However, studies from developing countries have reported that agricultural activities in urban and peri-urban areas are intensifying with increasing urbanization (Koc *et al.*, 1999; Mougeot, 2000; Jacobi *et al.*, 2000). How can we describe and explain the changing agricultural land use patterns and intensities in and around the rapidly expanding third world cities? Building on the synthesis of existing literature on agricultural land use change and urbanization, this study explores the dynamics of smallholder dairy land use changes in the urban region of Nairobi, the capital of Kenya.

6.1.2 Overview of the Research Methods

As explained in chapter 3, the study reported in this thesis was a cross-sectional case study of smallholder dairy farmers practising zero-grazing within Nairobi City and the immediate surrounding Kiambu district in highlands of Kenya. The two conceptual frameworks for land use change and urban-rural gradient, as described in chapter two, helped to define the information needs of the study. The study draws on a combination of secondary and primary data. At the national and regional levels, the information on current status, extent, trends and location of smallholder dairy farming systems as well as factors influencing land use change was collected from existing literature. At the local household level, the primary data were gathered through observation, group discussions, key informants, and using semi-structured a questionnaire in the field survey of 327 farmers. The field research activities covered a ten months period from July 2006 to April 2007. The selection criteria for farmers consisted of: identifying administrative areas in the urban, peri-urban and rural areas; randomly selecting two neighbourhoods (villages) from each administrative unit, and; randomly selecting farmers from the chosen villages.

Data analysis utilized the Statistical Package for Social Sciences (SPSS) version 15.0 (SPSS, 2006). Descriptive statistics were calculated for the most informative variables for all the farms and for the farms grouped across the urban-rural gradient. Principal components analysis (PCA) was applied to the data to reduce the variables and identify those variables important in representing levels of dairy intensity and urban-rural gradient. The resulting variables were used in cluster analysis to group the farmers into clusters whose group means were subjected to one-way analysis of variance (ANOVA) to compare the group means in the level of dairy intensity among the urban, peri-urban and rural smallholder dairy farmers. The results of initial ANOVA were followed by contrast tests to compare pairs of means in order to determine significant differences. The groups were considered significantly different at 95 percent level of confidence for mean levels of dairy intensification. To validate and confirm the results, cluster analysis was used to group the farmers based on the factors identified by the principal component analysis, resulting group means were compared.

6.2 Summary of the Main Findings

The most surprising result of this study is the high number of intensive smallholder dairy farmers in the urban areas of Nairobi. However these farmers are not recognized in any official statistics of the local government or central government. The intensive dairy land use in the urban region poses both opportunities and constraints for sustainable urban and regional development. Since these farmers are not in any record, they are not planned for, not regulated and assumed not to exist. This is a constraint in that there is no control and in case of an emergency such as zoonotic disease outbreak, the public officials do not know where the dairy farmers are located. However the urban smallholder dairy farming activities are source of income for the farmers from sale of milk; source of employment for labourer on the farm, for those providing services and farm inputs; as well as those involved in transporting, processing and marketing of milk. The milk from these urban farms is sold unprocessed directly to the consumers at half the price of processed milk. Therefore low income people in Nairobi are able purchase some milk for their improved diet. By recycling the brewers' spent grain (BSG) that would have otherwise ended up in an expensive landfill, dairy farmers are helping in urban waste management.

All the 327 dairy farms sampled were owned and operated by the family. Family members provided labour and made decisions concerning the dairy activities. Most farms had two or one family member actively involved with dairy farming activities. In addition, more than a half of all the farmers hired labour on a temporary or regular basis to work on the dairy. Most farms employed at least one external person; however a few managed to employ two people to help in feeding and milking the cows. The respondents were fairly equally distributed between men and women for the dairy farmers sampled. The mean age of the farmers was 52 years. Overall, the sample farmers have managed their dairy farming for 15 years on average. Rural farmers have 18.5 years of dairy farming experience on average, which is higher than peri-urban and urban farmers. A maximum of 50 years of experience was observed in peri-urban farmers, compared to 49 and 33 years in rural and urban farmers, respectively.

More than 43% of the farmers indicated that dairy farming was the most important in source of income for their households. The proportion was particularly higher in rural and peri-urban areas. A high percentage of the urban farmers indicated that off-farm activities were their main source of income. The rural farms had a mean land size of 2.5 acres compared to 1.1 and 1.3 acres in the urban and peri-urban areas, respectively. In urban areas, 56% of the farmers hired extra land compared to 46% and 39% in peri-urban and rural areas respectively. The results indicate that it was cheaper for farmers to hire land in the peri-urban areas compared to urban and rural areas

A total of 2040 heads of dairy cattle were kept by the 327 sample farmers. The mean herd size was 6 heads of dairy cattle including 3 lactating cows in the whole of the study area. The dominant dairy cattle breeds were Friesian (75%) and Ayrshire (25%), composed of both cross breed and pure breed. All the sampled farmers practiced zero-grazing (stall-feeding) and their dairy cattle were fed on variety of feed stuff. Many farmers reported feed shortages as a major constraint, especially during the dry seasons when the green fodder is scarce. Out of the 327 sample farmers, 49.5 percent (162) were using brewers' spent grain (BSG) as an alternative dairy feed. BSG is available through out the year at a reasonable price but due to its high moisture content transport cost is high especially for farmers located at a long distance from the city centre. The proportion of farmers using BSG was higher in the urban areas (64.2%) compared with rural areas (29.4%). Over 90% of all the farmers who use BSG reported increase in milk production when the material is introduced on the dairy ration.

All the farmers use hand milking early in the morning and late in the evening. The average milk produced by one cow in a day is 13.6 litres. However, the urban farmers had higher average milk yields compared with the peri-urban and rural farmers. The maximum reported was 32 litres per day by a farmer in peri-urban area. Over 60%

of the farmers use up to two litre of milk for home consumption. The farmers use four main milk marketing channels: direct to consumers, cooperatives, hotels and traders. Most farmers sell their milk to more than one outlet. In the urban areas, 90 per cent of the farmers sold their milk directly to consumers, compared to only 9 per cent of the farmers in rural areas.

When asked about the future plans for their dairy farm, less than 2% of all the farmers expected to discontinue their dairy farming activities. In the peri-urban areas, more than 30% of the farmers expected to expand their herd size. In contrast, most of the urban farmers have no plans to expand their herd size instead they have plans to genetically upgrade their dairy herd by selective breeding for high milk yield potential. Therefore it seems that dairy farming in Nairobi metropolitan region has a bright future.

Principal component analysis identified three components in the data using all the 327 farmers. The first component was interpreted as the land intensification and has high positive correlation with milking cow density and total milk productivity. However, it has high and negative association with owned farmland size. The second component was interpreted as breeding intensification and is positively correlated with milk yield per cow, cost of artificial insemination and use of brewers' spent grain as an alternative dairy feed. The third component was be interpreted as human intensification and is positively related to the age of the farmer, number of years the farmer has been in dairy farming and whether dairy is the main source of income.

Using only 160 dairy farmers who utilize brewers spent grain as an alternative dairy feed, principal component analysis identify three distinct components, one of which could be interpreted an indicator of the urban-rural gradient. The urban-rural gradient component is positively associated with the provider of artificial insemination (AI) services and whether dairy farming is the main source of income for the farmer, but negatively correlated with the price of land in the neighbourhood. One-way analysis of variance results for all the sample dairy farmers in Nairobi Metropolitan Region indicate that there are statistically significant differences in the levels of dairy land use intensification between the urban and rural farmers. However, there are no clear-cut differences between the peri-urban and urban or rural farmers.

6.3 Implications of the Findings for Existing Literature

The aim of this study was to contribute to a better understanding of agricultural land use change in a rapidly urbanizing region. The current literature on agricultural land use change in urban regions generally leads to mixed conclusions. The purpose of this section is to demonstrate how this study contributes to correct some of the misunderstandings and fills in some of the gaps in existing literature.

The findings of this study corroborate the results of previous studies which have concluded that agricultural intensity along the urban-rural gradient can increase, decrease or both in a complex way depending on the local context. For example, Mougeot (2000) and Koc *et al., (*1999) concluded that agricultural activities in the peri-urban areas will intensify with increasing urbanization. Silverside (2000) compared dairy intensity along the urban rural gradient in three towns of Sylhet, Mymensing and Pabna in Bangladesh and concluded that dairy intensity levels were higher in urban areas followed by peri-urban areas but lower in rural areas. In the Gangetic Middle Plains of India, dairy cattle intensity was higher in urban areas than peri-urban areas but lower in rural areas (Singh *et al.*, 2008). In Quinta do Anjo located within the Lisbon metropolitan areas, intensity of indigenous sheep production for milk has increased in the recent years (Rodriguez, 2007). This increase has been due to regulations protecting the indigenous sheep breed that is endemic to the Lisbon region and is currently protected under national agricultural reserve and integrated in the European Common Agricultural Policy.

Ma *et al.*, (2007) estimated that 54% of Chinese dairy production that supplied Beijing, Tianjin and Shanghai in the year 2000 occurred in the peri-urban areas.

However the Chinese dairy production in the peri-urban areas increased during 1980-1990s but started decreasing in the 2000s, due to shifting concentration in the rural areas. The increased peri-urban production during the early stages was attributed to: high milk demand by the expanding urban populations and expanding urban-based milk processing facilities; favourable government policies and subsidies; national and international investment in modern dairy technologies and high performance dairy cattle breeds in large scale concentrated intensive dairy farms. The subsequent decline in peri-urban dairy was due to: rising price of land and labour costs in the peri-urban; improved infrastructure and communication reduced the cost of transporting milk from rural areas: new regulations were instituted to reduce pollution from new dairy establishments.

In London there was intensive dairy production within the city in early 19th century until 1870s when it started to decrease (Atkins, 1977). The early success of intensive dairy in London has been explained by the following: availability of cheap brewer's spent grain; use of family labour and cheap immigrant labour; cheap manual carts were used in transporting fodder from the rural areas; regular culling of dry and low production cows sold as beef; availability of ready milk market especially in the West-End London where many dairy shops were located; availability of fallow land for planning pasture. However, the intensive urban dairy production in London declined drastically to when there was only one dairy farmer remaining in London in 1949, compared to an estimated 4,000 dairy farmers in 1851 (Francis-Jones, 1984). The reasons for decline included strict regulations and high cost of production compared to cheap imported products (Atkins, 1977).

In Nairobi, the level of dairy intensity seems to be riding along a rising wave but we can expect that sooner or later it may start declining. The results of the present study indicate that dairy farmers in the Nairobi metropolitan area have been operating without any regulations. However, in the near future the implementation of the new Nairobi Metropolitan Development Strategy may pose some strict regulations on dairy farming.

The results of this study as discussed in chapter 5 indicate that the level of smallholder dairy intensification can be measured in three different dimensions of land, breeding and human intensity. Hunt (2000) notes that several components of agricultural land use can represent intensification, for example modifying the type of technology, amount of labour, land, or any other input. A recent meta-analysis of agricultural land use change in the tropics confirms that agricultural intensification involves several processes and therefore concludes that a single definition is not useful (Keys and McConnell, 2005). The main processes captured in the meta-analysis included: adoption of new field crops; development of horticulture and; planting of trees on the farms. Elsewhere researchers have used amount of nitrogen fertilizer applied on crops, density of livestock units; and number of agrochemical applications as indicators of agricultural intensity in Europe (Herzog *et al.*, 2006).

Existing literature indicates difficulty in identifying the indicators of the urban-rural gradient. The present study identified the following components as representing the urban-rural gradient: price of land in the neighbourhood, whether dairy is the main source of income for the farmer, utilization of brewers' spent grain as an alternative dairy feed and the main artificial insemination service providers. Therefore the present study adds to the pool of knowledge on measuring urban-rural gradient. An ecological study in Melbourne, Australia, used principal components analysis to define the urban-rural gradients (Hahs and McDonnell, 2006). The main ecological indicators that captured most of the variability and thus representing the best measure of the urban-rural gradient included: human population density, dominant land cover and landscape patterns. Siri *et al.*, (2008) have also used quantitative classification of urban-rural gradients for malaria epidemiology research in Kisumu City, Kenya. The resulting urban malaria infection zones were found to be a more logical indicator of the urban-rural gradient compared with those from population density or urban administrative boundary by official census data.

Different variables have also been used to quantify urban-rural gradients within the peri-urban areas in Kumasi, Ghana (Adam, 2001). The variables used included: reported decline in soil fertility; reduced fallow period; increase in agrochemical use; increase in cultivation of cereals and home-gardens; decline in cultivation of cocoa; increase in cultivation of vegetables and keeping of poultry; reported high costs of inputs and; introduction of modern farming methods such as use of fertilizer. All the villages studied had a process of change linked to Kumasi but with different levels of change. The degree of changes in the villages was influenced by many factors other than the distance to the city centre. This confirms that there is no single indicator for the urban-rural gradient.

Current literature has stressed that urbanization is likely to become a dominant phenomenon influencing land use change and consequently global environmental change. However few land use change studies have used the level of urbanization as a distinct variable. The coupled human-environmental systems conceptual framework as discussed in chapter 2 did not indicate urban influence as an important factor in land use change. Hence it is suggested that urbanization should be included as a key component in the land use change conceptual framework and in modelling global environmental change.

6.4 Implication for Public Policy

If the policy makers cannot beat the smallholder dairy farmers in Nairobi then they should join them to develop the dairy industry in Kenya. Without any support, the smallholder dairy farmers in Nairobi have discovered how to cope with constraints of dairy feed shortages. The smallholder dairy farmers in Nairobi have detailed knowledge on the advantages and disadvantages of using brewer's spent grain (BSG) as an alternative dairy feed. The policy makers and livestock research need to come to the aid of smallholder dairy farmers in Nairobi. For example, new technologies should be promoted that can be used to dry the BSG so that it can be cheaply transported and stored for a long period of time.

Secondly, BSG should be recognized in the national animal feed standards and regulations. It is noteworthy that the quality assurance for the BSG in the beer processing factory is very high compared to commercially available dairy feeds in Nairobi. Smallholder dairy land use should be incorporated in the new Nairobi Metropolitan land use plan that is under preparation. Smallholder dairy farming needs to be recognized and promoted in both rural and urban development program in the Nairobi metropolitan region.

6.5 Directions for Future Research

The existing literature on smallholder dairy land use change in urban regions is fragmented and needs a major review. This study found that a lot of good information exists but in inaccessible grey literature. Therefore it is recommended that a meta-analysis on this topic would improve our knowledge. While large scale agricultural land use change and urbanization have been extensively studied, especially in America and Europe, limited studies have looked at the smallholder dairy at the household level.

Additional research at the local level seems needed on the smallholder dairy in the whole of the area covered by the new expanded Nairobi metropolitan region. This would cover parts of Thika, Kajiado and Machakos districts, all having different cultures and environmental conditions from the small area covered by the present study.

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APPENDIX 1: NAIROBI DAIRY SURVEY QUESTIONNAIRE SAMPLE

Recent studies have indicated that many Kenyans depend on dairy farming for their livelihood. What remains unknown is the extent and trends of land use changes as farmers adopt alternative land uses, especially in urban and peri-urban areas. This survey seeks to determine the intensity and changes in dairy land use activities. The survey will be completed by the person with primary decision-making authority on the farm. The information obtained from this survey will guide farmers, researcher and decision makers to plan and improve the efficiency of dairy production. ***Note that all information given by the farmer will be kept strictly confidential.***

Section I: General Information

Code Number: ....

Date of Interview: ....

Name of Respondent: ....

Respondents Position in household:-...............

Farm Location

District: .... Division: ....

Location: .... Sub-location: ....

Estate/Village: ....

Section I I: Dairy Feed

1. Which are the main sources of feed for the dairy cows?

Type of Feed	Source	Feed unit	Quantity/ Animal/ day	cost per unit	Comments(Dry, Wet season, All year availability
Fodder					
Commercial feeds					
By-products					

2. How is on-farm fodder transported? ....

3. Is there any dairy feed that you were using in the past but no longer use presently?

....

4. Is there any dairy feed you presently use but you were not using in the past?

....

5. Do you normally experience feed shortages on the farm?

Yes ......, No ....

6. If yes, what are your sources for emergency feed supplies?

....

7. Do you currently utilize Brewers' Spent Grain as source of dairy feed?
   Yes ……, No ………(If No go to Q22)
8. If yes, in which year did you begin to utilize Brewers' Spent Grain (BSG) as a source of dairy feed? ....
   9. How frequent do you feed the cows? ……………………………………
   10. At what time of the day do you feed the cows?
   ………………………………………………………………………………
11. On average what quantities of BSG do you currently feed to your cows in a day?
   ……………..
   12. How do you transport BSG from the source to the farm?
   ……………………………………………………………………………………
   13. What is the cost of transporting BSG? …………………………………
14. Do you mix BSG with other feeds on the farm before feeding the cattle? Yes ……, No ………
   15. If yes, what other feeds is it mixed with?
   ....
   ……………………………………………………………………………………..
   ……………………………………………………………………………………..
   16. What proportions of BSG is mixed with the above feeds?
   ………………………………………………………………………………
   ………………………………………………………………………………
   17. How do you feed the cows? Ad-lib …… Rationed……………
   18. What methods do you use for preserving BSG for use?
   ……………………………………………………………………………………………
   ……………………………………………………………………………..
   19. How is BSG stored on your farm?
   ....
   20. What is the disadvantage of using BSG?
   ....
   ....
   ....
   21. What is the advantage of using BSG?
   ....
   ....
   ....
   22. Reason for not using BSG as a source of feed:
   ……………………………………………………………………………………
   ………………………………………………………………………………………………
   ………………………………………………………

Section III: Milk Production and marketing

1. How many times do you milk your cows in a day? ....
2. What is the average quantity of milk production per cow per day? ....
3. What is the total amount of milk produced on the farm per day? ....
4. Quantity of milk consumed in the household per day ....
5. Quantity of milk fed to calves ....
6. Provide the following information for a maximum of three cows

Cow No.	Last calving Date	Second Last Calving Date	Milk Production		
			At Calving	**Current**	**When stopped Milking**
1					
2					
3					

7. What is the average lactation length for the above cows? ....

8. What is the total milk yield per lactation period? ....

9. Milk sales outlet and prices received

Milk Outlet type	**Quantity**	**Price / litre**
Direct to consumer		
Traders/Milk bars		
Hawkers/middlemen		
Cooperatives		
Hotels and restaurants		
Others		
Processors		

10. What is the distance to the main place where milk is sold? ....
11. How is the milk transported to the market? ....
12. What are the main issues in relation to marketing and storage of milk?

....

....

Section IV: Dairy cattle population

1. Total number of dairy cattle kept on the farm ....

2. How many milking cows do you currently have on the farm? ....

3. Details of the cattle types and breed types kept on the farm

Cattle Type						
Breed Type	Bulls (>3yrs)	Immature Males (<3yrs)	Cows	Heifers	Pre-weaning males	Pre-weaning females

Friesian (pure)						
Friesian(cross)						
Ayrshire (pure)						
Ayrshire (cross)						
Jersey(pure)						
Jersey(cross)						
Guernsey (Pure)						
Guernsey (cross)						
Other						

4. If you can remember, what was the total number of dairy cattle on the farm ten years ago? (1996) ....

Section V: Dairy Housing and Manure Management

1. Please specify the type of dairy housing on the farm?
a) Type of roof........., b) Floor type.........., c) Type of wall.......
2. How do you manage animal waste on your farm?
a) Turn into manure: ......, b) Discarded: ...... c) Not collected: ......, d) Others, please specify ....
3. If turned into manure, please specify the form?
Liquid or slurry: ..... , Semi-solid: ...., Solid: ....
4. What are the main sources of water for the cows?
....

Section VI: Breeding and health management

1. What is the most common health problems experienced on the farm?
....
2. Are veterinary services available locally?
Yes .... , No ....
3. If yes, do you use the services? Yes .... , No ....
4. Who provides the services?
a) Government: ..... , b) Private: ...., c) Cooperative: ..... , d) Others: ...
5. Reasons for preferred in service provider
4. What is the main source of breeding?
a) Bulls: ...., b) Artificial Insemination (AI): ....
5. Who are the main providers of the Artificial insemination (AI) services?
a) Government: ..... , b) Private: ...., c) Cooperative: ..... , d) Others: ...
6. What is the cost of breeding? ....
7. Have you experienced the situation where your cow fails to conceive? Yes .... , No ....

8. If yes, what are the causes? ....
....
9. How often do you replace your cows? .....
10. Do you raise dairy replacement animals on the farm?
a) Yes .... , b) No ...., c, Both
11. If No, how do you obtain your dairy replacement animals? a) Purchased ...., b) Others, please specify ....
12. If purchased, the amount paid per animal in the last purchase?
....
....

Section VII: Household characteristics

1. Household Head: Sex .... Age ....

2. What is the level of education attained by the head of the house hold?

(a)None ...... (b) Primary level education ....
(c)Secondary school level ..... (d)College level ....

3. Are you involved in any other income generating activities? No...... Yes ......

4. If yes, then specify: ....

5. Who is responsible for making most decisions concerning the dairy enterprise?
....

6. How many family members work on the dairy enterprise? ....

7. What role does each of the above family members play in the dairy enterprise?
....
....
....

8. How many non-family member employees work on the dairy enterprise?
....
9. Do you have any members of your household with off-farm employment? No...... Yes ......
10. If yes, then specify place of work: Nairobi..... , Kiambu..., Others......

11. What is the most important income source for the household?
(a) Off farm Income ....
(b) On farm income ....
(c) Dairy Cattle ....
(d) Others ....

Section VIII: Farm Characteristics

1. What is the current total size of your land? ....
2. Current land ownership: own...... family...... Rented.......
3. Land ownership in 1996: own...... family...... Rented.......
4. What is the land tenure System? Freehold......, Leasehold ....

5. What is the size of your land that is currently allocated for fodder?

6. Do you hire extra land for fodder? Yes ......, No ....

7. If yes, what size? ....

8. How much do you pay for the hired land? ....

9. System of dairy grazing:
Zero grazing ..... , Semi Zero grazing ......, Tethering ....
Road side grazing ...., Paddock/Improved grazing ....

10. What was the total size of your land in 1996? ....

11. What is the current average price of land in the neighbourhood? ......

12. In which year did you start your dairy enterprise? ....
13. What was the size of your land when you started? ....

14. How many cows did you begin with? ....

15. What are the main land-related issues that affect dairy enterprise?
....
....
....

Any other general comments from the dairy farmer, including future plans: