CONTRIBUTION OF AGRO-BIODIVERSITY TO DIETARY DIVERSITY AND NUTRITIONAL STATUS OF WOMEN OF REPRODUCTIVE AGE IN RONGAI SUB-COUNTY, KENYA

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A thesis submitted to Graduate School in partial fulfilment for the requirements of the Master of Science Degree in Nutritional Sciences of Egerton University

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DECLARATION AND RECOMMENDATION

Declaration

I declare that this thesis is my original work and has not been previously published or presented for the award of a certificate, diploma or degree in this or any other University.

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Recommendation

This thesis has been submitted with our approval as the University supervisors.

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DEDICATION

This thesis is dedicated to my dear parents, Mr. George Gitagia and Mrs. Alice Gitagia and brother, Chris Gitagia, who inspired and supported me throughout this work.

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ABSTRACT

The causes of malnutrition among women of reproductive age are complex but it is mainly attributed to diets lacking diversity. Agro-biodiversity is widely perceived as a promising strategy to improve dietary diversity and ultimately nutritional status. The main objective of this study was to assess the relationship between agro-biodiversity, dietary diversity and nutritional status of women aged 15-49 years in two different agro-ecological zones (low and high agricultural potential areas) of Rongai Sub-County, Nakuru County, Kenya. A cross sectional research design was adopted for the study. A multi-stage cluster sampling was used to select 384 participants. Agro-biodiversity was measured using Shannon-Wiener index, species count/richness, and production diversity score. Data from the qualitative 24-hour dietary recall was used to determine minimum dietary diversity (MDD) for women of reproductive age. Weight and height were taken and used to compute body mass index of the women. All data was analysed using the Statistical Package for Social Sciences, version 20.0, 2011. Diversity of crops was significantly ($P<0.05$) higher in high (Shannon-Wiener index, 1.08 ± 0.41) than low potential area (0.93 ± 0.40), while diversity of legumes and nuts as well as domesticated animals was higher ($P<0.05$) in low (1.05 ± 0.26 and 2.29 ± 1.01) compared to high potential area (1.00 ± 0.00 and 1.93 ± 0.91). The average production diversity score was 5 food groups per farm household. Overall, women dietary diversity score was low (3.78 ± 0.99) with no significant difference ($P>0.05$) between low (3.78 ± 0.99) and high potential area (3.84 ± 1.05). A larger proportion ($P<0.05$) of women from high (19.1%) compared to low (13.9%) potential area met the MDD. Overall, 11.8% of the women were underweight; with a significant higher proportion ($P<0.05$) in low (18.5%) compared to high potential area (7.1%). In contrast, majority of overweight and obese women were from high (21.9% and 11.6%) compared to low (17.2% and 5.1%) potential area, respectively. There was no relationship ($P>0.05$) between agro-biodiversity indicators and dietary diversity. In low agricultural potential area, woman's education level positively influenced dietary diversity while in high agriculture potential area, household gender, woman's education level, woman's age and household size influenced dietary diversity. Women’s dietary diversity positively associated with nutritional status in high potential area ($\chi^2= 10.423$, $P<0.05$). In conclusion, the study demonstrated that the availability of food from the farm does not always translate to better dietary diversity. Therefore, there is a need for nutrition education and behaviour change communication to ensure that agro-biodiversity is optimally utilized to positively impact women dietary diversity and ultimately their nutritional status.

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LIST OF ABBREVIATIONS AND ACRONYMS

BMI	Body Mass Index
CBD	Convention on Biological Diversity
CDDS	Child Dietary Diversity Score
DD	Dietary Diversity
DDS	Dietary Diversity Score
FAO	Food and Agriculture Organization
HDDS	Household Dietary Diversity Score
IFPRI	International Food Policy Research Institute
KDHS	Kenya Demographic and Health Survey
Kg	Kilogram
KNBS	Kenya National Bureau of Statistics
M^2	Meters square
MDD-W	Minimum Dietary Diversity for Women of reproductive age
MoPHs	Ministry of Public Health service
SPSS	Statistical Packages for Social Sciences
SWI	Shannon-Weiner Index
UNICEF	United Nations Children's Emergency Fund
VIF	Variance Inflation Factor
WDDS	Women Dietary Diversity Scores
WFP	World Food Program
WHO	World Health Organization

CHAPTER ONE

INTRODUCTION

1.1 Background information

The United Nations General Assembly declared 2010 to be the Global Year of Biodiversity. This provided a unique opportunity to raise awareness and promote the role of agro-biodiversity in the lives of people, principally those in developing countries (FAO, 2010). This is because most people in developing countries depend majorly on own food production to improve their diets (Wispelwey and Deckelbaum, 2009). Agro-biodiversity exists at numerous levels, from the various ecosystems in which people raise crops and livestock through different varieties and breeds of the species, to the genetic variability within each variety or breed (Frison, Cherfas and Hodgkin, 2011). Agro-biodiversity has played a pivotal role in sustaining and strengthening food, nutrition, health and livelihood security (Frison, Cherfas and Hodgkin, 2011). However, there is limited quantitative data on status of agro-biodiversity globally, and indications are that the loss of agro-biodiversity is occurring throughout the world at unprecedented rates (FAO, 2011). It was estimated in 2011 that about three-quarters of the diversity found in agricultural crops has been lost over the last century, and this erosion continues. For instance, 90% of our food energy and protein is obtained from only 15 plant and 8 animal species, with alarming consequences for nutrition and food security (FAO, 2011).

The erosion of agro-biodiversity has coincided with reduction in dietary diversity (Fanzo *et al*., 2013). Dietary diversity (DD) is defined as the number of individual food items or food groups consumed over a given period of time (Ruel, 2003). It is an essential element of diet quality, and consuming a variety of foods across and within food groups is associated with adequate intake of essential nutrients and promotes good health (Waswa *et al*., 2015). Achieving a diverse diet is particularly important for women to meet their nutrient requirements for good health and productive lives (Arimond *et al*., 2010). However, limited accessibility to a variety of foods to constitute diversified diets is a predominant problem among women of reproductive age in developing countries (Chakona and Shackleton, 2017; Ochieng *et al*., 2017). Consumption of poor quality diets and generally lack of access to wide food diversity has been acknowledged as among major factors responsible for maternal malnutrition (Headey and Ecker, 2013; Arimond *et al*., 2010; Moursi *et al*., 2008).

Maternal malnutrition is recognized as a major predisposing factor for morbidity and mortality in women (Lartey, 2004). Worldwide, malnutrition is widespread among women of reproductive age where approximately 15% are underweight and 35% are overweight (WHO, 2012). In Kenya, analysis of Body Mass Index (BMI) shows that 9% of women aged 15-49 years were underweight while the proportion of overweight and obese women increased from 25% in 2008-2009 to 33% in 2015 (KNBS and ICF Macro, 2015). Micronutrient deficiencies is also prevalent among women of reproductive age where 47.9%, 52% and 40% were found to suffer from iron, zinc and vitamin A deficiency in Kenya, respectively (Kenya Ministry of Public Health, 2011). These macro and micronutrient deficiencies among women impose a huge health burden in terms of lost productivity, impaired physical and mental human development, susceptibility to various diseases and premature deaths (Lim *et al*., 2012). Therefore, securing food and nutrition is an essential investment in women that will lead to improved life, health and productivity in the long run.

Increasing agro-biodiversity is being perceived as a promising strategy to improve dietary quality and diversity and ultimately nutrition status (Sibhatu and Qaim, 2018; Kissoly *et al*., 2018; Jones, 2017; Powell *et al*., 2015; Jones, Shrinivas and Bezner-Kerr, 2014; Berti and Jones, 2013; Penafiel *et al*., 2011). The rationale is that increased agro-biodiversity (crops and livestock species production) will enhance access to a variety of food items for consumption at the household level, thereby improving the dietary diversity of women. However, there is limited empirical evidence showing the contribution of agro-biodiversity to dietary diversity and nutritional status (Sibhatu and Qaim, 2018; Jones, 2017; Powell *et al*., 2015; Sibhatu, Krishna and Qaim, 2015). In particular, evidence from diverse agro-ecological is rare (Kissoly *et al*., 2018). While several studies have analysed the links between agro-biodiversity and dietary diversity, the results are mixed, context specific and inconclusive (Sibhatu and Qaim, 2018; Kissoly *et al*., 2018; Jones, 2017; Powell *et al*., 2015; Sibhatu, Krishna and Qaim, 2015; Jones, Shrinivas and Bezner-Kerr, 2014). Essentially, besides agro-biodiversity, dietary diversity may be affected by other socio-demographic and socio-economic factors further complicating the relationship (Kissoly *et al*., 2018; Jones, 2017; Sibhatu, Krishna and Qaim, 2015). Moreover, the level of agro-biodiversity may vary depending on agro-ecological zones (Kissoly *et al*., 2018; Mburu *et al*., 2016; KC *et al*., 2016). To fill this gap, this study documented the status of agro-biodiversity and dietary diversity, and assessed the relationship between agro-biodiversity, dietary diversity and nutritional status among women of reproductive age in two different agro-ecological zones of Rongai Sub-County, Nakuru County, Kenya.

This research was part of a larger project that aimed at determining the relationship between agro-biodiversity and mother/caregiver-child nutrition parameters, to identify entry points, and barriers for diversifying farm production and diets in Rongai Sub-County. This work focused on status of agro-biodiversity, dietary diversity and nutritional status of women of reproductive age.

1.2 Statement of the problem

In Kenya, 9% of women aged 15-49 years are underweight, 33% overweight with a further 10% being obese. In Nakuru County where this study was conducted, 6.2 % of women of reproductive age are underweight while 38.5% are overweight. This double burden of malnutrition in women imposes a huge health burden to our economy through reduced productivity, increased burden of communicable and non-communicable diseases, adverse pregnancy outcomes and loss of lives. One of the underlying factors responsible for malnutrition is consumption of poor quality diets that are low in diversity. Agro-biodiversity comprises of different varieties of plants and animals, including those that are cultivated and wild species. Diversity of these crop and animal species are rich sources of nutrients and if utilized effectively, they could contribute significantly to improved dietary diversity and ultimately nutritional status of women. Therefore, it is important to understand the relationship of agro-biodiversity with dietary diversity as this could help in solving the complex issue of maternal malnutrition. However, scarce empirical evidence linking agro-biodiversity to dietary diversity and nutrition status exist in Kenya, more so in Nakuru County. To fill this gap, the study assessed contribution of agro-biodiversity to dietary diversity and nutritional status among women of reproductive age in two different agro-ecological zones of Rongai Sub-County, Nakuru County.

1.3 Objectives

1.3.1 Main objective

To assess contribution of agro-biodiversity to dietary diversity and nutritional status among non-pregnant women of reproductive age in two different agro-ecological zones of Rongai Sub-County, Nakuru County.

1.3.2 Specific objectives

i. Document the status of agro-biodiversity of smallholder farm households in Rongai Sub-County.

ii. Determine the dietary diversity scores of non-pregnant women of reproductive age in Rongai Sub-County.

iii. Assess the nutritional status of non-pregnant women of reproductive age in Rongai Sub-County.

iv. Examine the relationship between socio-demographic factors, socio-economic factors, agro-biodiversity and dietary diversity of non-pregnant women of reproductive age in Rongai Sub-County

v. Determine the association between dietary diversity and nutritional status of non-pregnant women of reproductive age in Rongai Sub-County.

1.4 Research questions

i. What is the status of agro-biodiversity of smallholder farm households in Rongai Sub-County?

ii. What is the dietary diversity score of non-pregnant women of reproductive age in Rongai Sub-County?

iii. What is the nutrition status of non-pregnant women of reproductive age in Rongai Sub-County?

iv. What is the relationship between socio-demographic factors, socio-economic factors, agro-biodiversity and dietary diversity of non-pregnant women of reproductive age in Rongai Sub-County?

v. What is the relationship between dietary diversity and the nutritional status of non-pregnant women of reproductive age in Rongai Sub-County?

1.5 Justification of the study

The double burden of malnutrition is prevalent among women of reproductive age. Both undernutrition and over nutrition have been shown to adversely affect woman's health (Hasan *et al*., 2017). Undernutrition in women is associated with a greater risk of infections, pregnancy complications, labour problems, and death (KNBS and ICF Macro, 2015). On the contrary, overweight and obese women are at higher risk of developing non-communicable diseases (NCDs) such as diabetes, hypertension, coronary heart disease and cancers (He *et al*., 2016; Aune *et al*., 2014). Intake of high diverse diets has been associated with lower rates of malnutrition (Popkin and Slining, 2013). Increasing dietary diversity of women is therefore an important approach to improve women nutritional and health outcomes. Agro-biodiversity is widely being suggested as a cost effective approach to improve dietary quality. Thus, it is critical to understand the association between agro-biodiversity and dietary diversity as this could assist in reducing the burden of malnutrition. Rongai Sub-County lies in two different agro-ecological zones and such areas are expected to have different levels of agro-biodiversity. Thus, Rongai Sub-County offered a better chance of understanding how different levels of agro-biodiversity related to dietary diversity and nutrition status of women aged 15-49 years.

1.6 Significance of the study

The findings from the study are useful in planning and implementing interventions aimed at improving the dietary diversity and nutritional status of women in Rongai Sub-County and other similar areas. The study recommendations inform stakeholders such as Ministry of Health, Ministry of Agriculture and Non-Governmental Organization on ways of improving farm and dietary diversity in Rongai Sub-County and other similar rural and sub-urban areas. The study findings also form a basis for future research.

1.7 Scope of the study

This study was carried out in Rongai Sub-County due to its diverse agro-ecological zones. It was specifically conducted in two divisions of Rongai Sub-County; Kampi ya Moto representing the low agricultural potential zone and Menengai the high agricultural potential zone. The study targeted non-pregnant women of reproductive age living in smallholder farm households from the two agro-ecological zones.

1.8 Limitations of the study

This study used a cross sectional design, therefore it was not able to capture the seasonal variation which can affect food availability and in turn influence dietary diversity. The study also targeted non-pregnant women and their pregnancy status was based on self-reports, thus the study made the assumption that all women gave correct and truthful information.

1.9 Definition of terms

Agro-biodiversity – is the biological variation exhibited among crops, animals and other organisms used for food and agriculture; in this study agro-biodiversity refers to different species of crops and animals used for food.

Agro-ecological zones (AEZs) – are geographical area exhibiting similar climatic conditions that determine their ability to support rain fed agriculture. At a regional scale, AEZs are influenced by latitude, soil, temperature, seasonality, rainfall amounts and distribution during the growing season.

Body Mass Index (BMI) – is an indicator for nutritional status that is commonly used to classify underweight, overweight and obesity in adults; it is calculated by dividing weight in kilograms by height in m^2 (Kg/m^2).

Diet quality – refers to a diet that meets requirements for energy and essential nutrients.

Dietary diversity (DD) – number of different foods or food groups consumed by an individual or household over a given reference period. In this study, DD refers to the daily consumption of food products from different recommended food groups over the previous 24 hours.

Household – a group of persons living under the same roof and sharing food from the same food pot.

Malnutrition – refers to the insufficient, excessive or imbalanced consumption of nutrients, characterized by underweight, micro-nutrient deficiencies, overweight and obesity.

Market diversity – number of different foods or food groups that are sold in market over a given reference period.

Micro-nutrient deficiency – is a condition which arises from lack of essential vitamins and minerals required in small amounts by the body for proper growth and development.

Micro-nutrients – essential food factors required in small quantities by the body e.g. vitamins and minerals for normal growth and development.

Minimum dietary diversity – is a dichotomous indicator of whether or not women aged 15-49 years have consumed at least five out of ten defined food groups the previous day or night.

Nutrient adequacy – the proportion of recommended nutrient intake attained compared to set standard.

Nutritional Status – the body condition in relation to diet intake and utilization of nutrients. In this study, body mass index was used as an indicator of nutritional status.

Obesity – is excessive fat accumulation that may impair health. In this study refers to an adult with body mass index (BMI) of 30Kg/m^2 or more.

Overweight – Weight that is higher than what is considered as a healthy weight for a given height. In this study, it refers to a woman with body mass index (BMI) >25 Kg/m^2.

Production diversity – number of different food groups that are produced by each farm household over a given reference period.

Reproductive age – women aged between 15 and 49 years.

Smallholder farmers – are those farmers who own less than 5 acres of land on which they grow subsistence crops and one or two cash crops relying almost exclusively on family labour. In this study, smallholder farmers are defined on the basis of land holdings, cultivation of less than 5 acres of land.

Socio-economic status - The status of the members of the household based on the educational levels, occupation and income (financial background).

Species – A taxonomic group of closely related organisms that are very similar to each other and are usually capable of interbreeding and producing fertile offspring.

Species richness – number of different crop and livestock species that are cultivated/reared by each household.

Undernutrition – is when the body contains lower than normal amounts of one or more nutrients i.e. deficiencies in macronutrients and/or micronutrients.

Under-weight – refers to an adult with a body mass index (BMI) of under 18.5 Kg/m^2.

Variety – a taxonomic category consisting of members of a species that differ from others of the same species in minor but heritable characteristics.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter reviews literature on agro-biodiversity, dietary diversity and malnutrition among women of reproductive age. The link between agro-biodiversity, dietary diversity and nutritional status is discussed in depth to identify the gaps in the line of study. The chapter ends with a summary of ideas that led to development of conceptual framework of the study.

2.2 Agro-biodiversity

Biodiversity is the variability among living organisms and the ecological complexes of which they are part, including diversity within species (genetic diversity), between species, and of ecosystems (United Nations Environment Programme, 2002). Agro-biodiversity a sub-component of biodiversity, is a broad term that encompasses different components of biological diversity at genetic, species and ecosystem levels that are relevant to food and agriculture (Frison, Cherfas and Hodgkin, 2011; Convention on Biological Diversity (CBD), 2008). At ecosystem level, it includes the diversity of agro-ecosystems which partially results from both agricultural and non-agricultural land and water uses. Examples of agro-ecosystems include rice paddies, pastoral systems, aquaculture systems and cropping systems (CBD, 2008). At the genetic level, it is defined as the diversity within species as a result of farmers' selection based on specific traits to meet environmental and climatic conditions. For example, different varieties of maize have been developed based on traits such as taste, height, colour and productivity (CBD, 2008). The species level encompasses the diversity of plants and animals used in agriculture as a result of human management of biodiversity for food, nutrition and medicinal purposes. For example, domesticated livestock include cattle, sheep, chicken and goat, while crop species include wheat, banana, cabbage, sweet potato and ground nuts (CBD, 2008). This study focused on species diversity.

In empirical literature, the commonly used indicators for species diversity are three these include; Shannon-Wiener index for crop species; species count/ richness combined for crops and animals species and production diversity for food groups produced (Koppmair, Kassie and Qaim, 2017; Ng'endo, Bhagwat and Keding, 2016; Malapit *et al*., 2015; Jones, Shrinivas and Bezner-Kerr, 2014). The Shannon-Wiener Index is a diversity index used in ecological studies. It is a quantitative measure that reflects both richness (species count) and evenness (distribution) (McArt *et al*., 2012; Magurran and McGill, 2011). The Shannon-Wiener index score is not bound by a definitive range and thus an increase in the score reflects greater diversity in a household farm (McArt *et al*., 2012). This index has greater impact for biodiversity as the mathematical equation is more affected by variations in species richness (McArt *et al*., 2012).

To incorporate both plants and livestock in a single farm diversity measure, a combination of crop and livestock count is used (Ng'endo, Bhagwat and Keding, 2016; Sibhatu, Krishna and Qaim, 2015; Jones, Shrinivas and Bezner-Kerr, 2014) by summing up the number of different food plant and livestock species that are cultivated/reared by each household. This single farm diversity measure is termed as species count/richness (Ng'endo, Bhagwat and Keding, 2016; Sibhatu, Krishna and Qaim, 2015; Jones, Shrinivas and Bezner-Kerr, 2014). Species count/richness indicator does not discriminate crops based on how much land they occupy, rather it considers trait differences as the most important element for diversity. The count is not bound by a definitive range thus, the higher the score the more diverse a household farm is (McArt *et al*., 2012).

Noteworthy, a species count does not necessarily reflect diversity from a dietary point of view (Koppmair, Kassie and Qaim, 2017). To better account for the dietary perspective, a number of studies have generated a production diversity score defined as the number of food groups produced by each household (Koppmair, Kassie and Qaim, 2017; Malapit *et al*., 2015). To construct the production diversity score, the 10 food groups used to calculate the women's dietary diversity score were considered (Koppmair, Kassie and Qaim., 2017; FAO, 2016; Malapit *et al*., 2015). Thus, the higher the count the greater the agro-biodiversity in a household farm (Koppmair, Kassie and Qaim, 2017; Malapit *et al*., 2015).

There is a growing realization worldwide that agro-biodiversity is fundamental for environmental conservation, food security and is a valuable ingredient for sustainable agriculture (Fanzo *et al*., 2013; FAO, 2011; CBD, 2008). However, despite the great strides in increased food production and improved food security by modern intensive agriculture, it has also greatly contributed to loss in agro-biodiversity (CBD, 2008). The FAO (2010) estimates that since the origin of agriculture, an entire 300,000 plant species have been discovered and about 10, 000 have been consumed as human food. Out of these, only a mere 150–200 species have been commercially cultivated. Of these, only four (rice, wheat, maize and potatoes) contribute to 50% of the global energy needs, while 30% of crops supply 90% of the global caloric intake (FAO, 2010). Of the estimated 15,000 species of mammals and birds, only 30 to 40 have been domesticated for food production and less than 14 species including cattle, goats, sheep, buffalo and chickens; account for 90% of global livestock production (CBD, 2008).

Lack of knowledge, poverty, the need for high yielding and uniform crop varieties and animal breeds that have high market demand are some of the factors attributed to the loss of agro-biodiversity (Jones, 2017; Khoury *et al*., 2014; Frison, Cherfas and Hodgkin, 2011). The declining diversity of agricultural production and food supplies worldwide may have important implications for global diets (Jones, 2017). In spite of the abundance of food produced by modern intensive agricultural systems, poor quality diets commonly manifested as diets lacking diversity remain a widespread challenge around the globe (Jones, 2017).

2.3 Dietary diversity

Dietary diversity (DD) is defined as the number of individual food items or food groups consumed over a given period of time (Ruel, 2003). Dietary diversity has been measured through various ways including; household dietary diversity score (HDDS), infant and young child minimum dietary diversity (CDDS) and women's dietary diversity score (WDDS) (FAO and FANTA, 2014).

The WDDS based on nine food groups has widely been used to assess the micronutrient adequacy of women's diet. Despite the usefulness of WDDS in assessment of dietary quality of women, the indicator has a drawback since it fails to provide a standard threshold for micronutrient adequacy for all contexts (Custodio, Kayitakire and Thomas, 2015). This led to development of the new global indicator; the minimum dietary diversity for women of reproductive age (MDD-W). This indicator is based on ten food groups which include; (1) starchy staples, (2) pulses; beans, peas and lentils, (3) nuts and seeds, (4) dairy products, (5) meat, poultry and fish, (6) eggs, (7) dark green leafy vegetables, (8) vitamin A rich fruits and vegetables, (9) other vegetables, (10) other fruits. Women of reproductive age who consume foods from at least five out of the ten foods are considered to have met a minimum threshold for dietary diversity (FAO, 2016).

Importantly, DD is an essential element of diet quality, and consuming a variety of foods across and within food groups is associated with adequate intake of essential nutrients and good health promotion (Arimond *et al*., 2010; Kennedy *et al*., 2009; Ruel, 2003). It is well recognized that the causes of malnutrition are complex, and high among them is a general simplification of diets. Noteworthy, even when households have access to adequate food, lack of dietary diversity has been identified as a key underlying factor contributing to malnutrition (Nguyen *et al*., 2018; Waswa *et al*., 2015; Arimond *et al*., 2010; Kennedy *et al*., 2009).

2.4 Burden of malnutrition among women of reproductive age

Malnutrition among women of reproductive age remains a critical public health problem. Globally, approximately 10-19% of women of reproductive age are underweight. This is higher in developing countries with some countries reporting critical levels of more than 35% (WHO, 2012). At the same time, the prevalence of overweight and obesity has been on rise accounting for 40% to 60% in developed countries and 30% to 40% in developing countries (Ng' *et al*., 2014; Black *et al*., 2013). In Kenya, the burden of malnutrition is also prevalent in this age group where 9% are reported to be undernourished, 33% overweight and 10% obese (KNBS and ICF Macro, 2015).

Malnutrition among women is the most important risk factor contributing directly or indirectly to morbidity and mortality, particularly in developing countries (Muller and Krawinkel, 2005). The double burden of malnutrition is prevalent among women of reproductive age, where the undernutrition is co-existing with over nutrition within the same group. Both undernutrition and over nutrition are evident to have an adverse impact on women's health (Hasan *et al*., 2017). On one hand, underweight is associated with reduced fertility and adverse pregnancy complications including low birth weight, preterm birth, small for gestational age and neonatal death (He *et al*., 2016; Razak *et al*., 2013). In addition, a chronically undernourished woman is more likely to give birth to an undernourished child, causing the cycle of undernutrition to be repeated over generations. On the other hand, overweight and obese women are at higher risks of infertility and gestational complications such as hypertensive disorders, gestational diabetes and haemorrhage (He *et al*., 2016; Aune *et al*., 2014). Furthermore, maternal obesity increases the risk of obesity in their children during childhood, early adulthood and raises the risks of diabetes and cardiovascular disease in later life (He *et al*., 2016). Thus, promoting intake of diverse diet among women is a cost effective approach to improve their diet quality and ultimately nutritional status (Keding and Cogill, 2013).

2.5 Relationship between Agro-biodiversity, dietary diversity and nutritional status

Agro-biodiversity is currently being endorsed widely as a multiple-food based intervention for improving overall diet quality through food diversification (Sibhatu and Qaim, 2018; Kissoly *et al*., 2018; Jones, 2017; Jones, Shrinivas and Bezner-Kerr, 2014; Keding and Cogill, 2013). However, relatively few studies have investigated the relationship between overall agro-biodiversity, dietary quality and nutritional status (Sibhatu and Qaim, 2018; Kissoly *et al*., 2018; Jones, 2017; Jones, Shrinivas and Bezner-Kerr, 2014; Powell *et al*., 2015; Keding and Cogill, 2013; Berti and Jones, 2013; Penafiel *et al*., 2011). A study in Kampala, Uganda examined the relationship between urban agriculture activities and household food security in 296 randomly selected households. The agro-biodiversity was assessed through the number of crops grown and livestock reared. Nutrition measures were assessed through dietary diversity and anthropometry. The study revealed a positive association between livestock production and dietary diversity but no relationship was reported with crop diversity (Yeudall *et al*., 2007).

In Kenya, a study by Ekesa *et al*. (2008) investigated the role of agro-biodiversity on dietary intake and nutritional status in 144 randomly selected household in Western Kenya. Agro-biodiversity was measured by the variety of food crops grown, animals domesticated for food and food items from natural habitats. Dietary intake was assessed through dietary diversity. The study reported a positive relationship between dietary diversity and agro-biodiversity. In contrast the study did not report the significance of the associations and showed correlations without controlling for confounding factors such as education, wealth and land size.

A similar study in Tanzania and Kenya used a mixed model approach and controlled for confounding factors such as wealth, land size, household-head age, and education (Herforth, 2010). While crop diversity was positively associated with household and individual dietary diversity in Tanzania, the association was not evident in Kenya possibly due the small sample size (n=169). In both countries, crop diversity was significantly correlated with number of servings of vitamin A rich foods, iron rich foods, fruits and vegetables. The increased consumption of traditional vegetables was attributed to acquired knowledge of medicinal importance of traditional vegetables, increased production in Kenya and more favourable attitudes in Tanzania. A systematic review (Penafiel *et al*., 2011) pointed out that there are limited studies on the contribution of edible plant and animal biodiversity to human diets. Thus, the complexity of linking agriculture and health appears to be a setback in undertaking a large comprehensive study on agro-biodiversity. In addition, there is need for multidisciplinary research which incorporates appropriate agro-biodiversity and nutritional assessment methodologies in order to have a better understanding on the contribution of agro-biodiversity to dietary diversity.

A study in Malawi, using nationally representative sample of 6623 subsistence-oriented farming households, observed a positive relationship between agro-biodiversity and dietary diversity. The relationship was consistently positive even after controlling for the effect of several covariates on household dietary diversity. The covariates adjusted for include: household size, age of household head, education level of household head, sex of household head, total cropped area of the household in the previous rainy and dry seasons combined, household food and non-food expenditures, number of different non-agricultural income sources for the household, proportion of food consumed that came from own production and intra-household control of agricultural earnings decisions (Jones, Shrinivas and Bezner-Kerr, 2014).

Powel *et al*. (2015), reviewed twelve studies investigating associations between agro-biodiversity and dietary diversity or nutritional outcomes. Of the studies which measured dietary diversity at the household or individual level, six reported a positive association with crop diversity (Jones, Shrinivas and Bezner-Kerr, 2014; Oyarzun *et al*., 2013; Keding *et al*., 2012; Powell, 2012; Herforth, 2010; Ekesa *et al*., 2008), while two reported no associations (Torheim *et al*., 2004; Remans *et al*., 2011). Moreover, a study among smallholder farming households in Kenya reported no linkages between agro-biodiversity and dietary diversity (Ng'endo, Bhagwat and Keding, 2016). The inclusion of the contribution of animal source foods in the diet by use of combined crop and livestock count contributed to this direct relationship in the Malawi study (Jones, Shrinivas and Bezner-Kerr, 2014). However, the inclusion of the indicator did not modify the relationship in the Kenyan study despite the study area being endowed with high levels of agro-biodiversity (Ng'endo, Bhagwat and Keding, 2016).

A more recent systematic review analysed associations between production diversity, dietary diversity and nutrition in smallholder farm households (Sibhatu and Qaim, 2018). The study identified 45 original studies reporting results from 26 countries using various indicators of diets and nutrition. The systematic review demonstrated that farm production diversity was positively associated with household-level and individual-level dietary diversity and nutrition in some situations, but not in others. Similarly, a number of the original studies included in the review found positive associations when using certain indicators of diets and nutrition, but not when using other indicators. The study concluded that insignificant or negative results reported in the original studies should not be ignored, even when the same studies also report positive associations under certain conditions. Focusing only on the positive results may lead to biased policy conclusions (Sibhatu and Qaim, 2018).

The consistency of a relationship between dietary outcomes and crop diversity across existing studies is notable (Sibhatu and Qaim, 2018; Jones, 2017; Koppmair, Kassie and Qaim, 2017; Sibhatu, Krishna and Qaim, 2015; Jones, Shrinivas and Bezner-Kerr, 2014; Powell *et al*., 2015; Keding and Cogill, 2013; Berti and Jones, 2013; Penafiel *et al*., 2011). The studies clearly show a relationship between agro-biodiversity and dietary diversity. It is however not unanimously evident that high farm agro-biodiversity translates to improved dietary diversity as some studies support this relationship while others refute. Therefore, more information is needed to understand the reasons for these associations as well as the impact of different study methodologies while considering seasonality and agro-ecology in these relationships (Sibhatu and Qaim, 2018; Kissoly *et al*., 2018; Powell *et al*., 2015). There is dearth information on the relationship between agro-biodiversity, dietary diversity, and nutritional status (Sibhatu and Qaim, 2018; Jones, 2017; Jones, Shrinivas and Bezner-Kerr, 2014; Powell *et al*., 2015; Keding and Cogill, 2013; Berti and Jones, 2013; Penafiel *et al*., 2011). In particular, evidence from diverse agro-ecological is rare (Kissoly *et al*., 2018). To fill this gap, based on the area's agricultural potential (low or high), the objective of this study was to assess the relationship between of agro-biodiversity, dietary diversity and nutritional status among women of reproductive age in Rongai Sub-County.

2.6 Theoretical framework

The theoretical framework on the determinants of malnutrition developed by United Nations Children's Emergency Fund (UNICEF) (1990) (Figure 1) outlines a structure for understanding how political, economic and social factors come together to have an impact on malnutrition. The framework highlights that inadequate dietary intake is an important factor caused by many other factors such as economic, infrastructures and governance. Further, it illustrates the interaction of inadequate dietary intake with disease to cause malnutrition. Although not included in this frame work, agro-biodiversity, acting through agriculture (economic resource), is another factor impacting on access to food and dietary intake (Cleghorn, 2014). Low agro-biodiversity is expected to lead to insufficient access to variety of foods which will cause inadequate dietary intake (low dietary diversity) and will eventually lead to maternal malnutrition

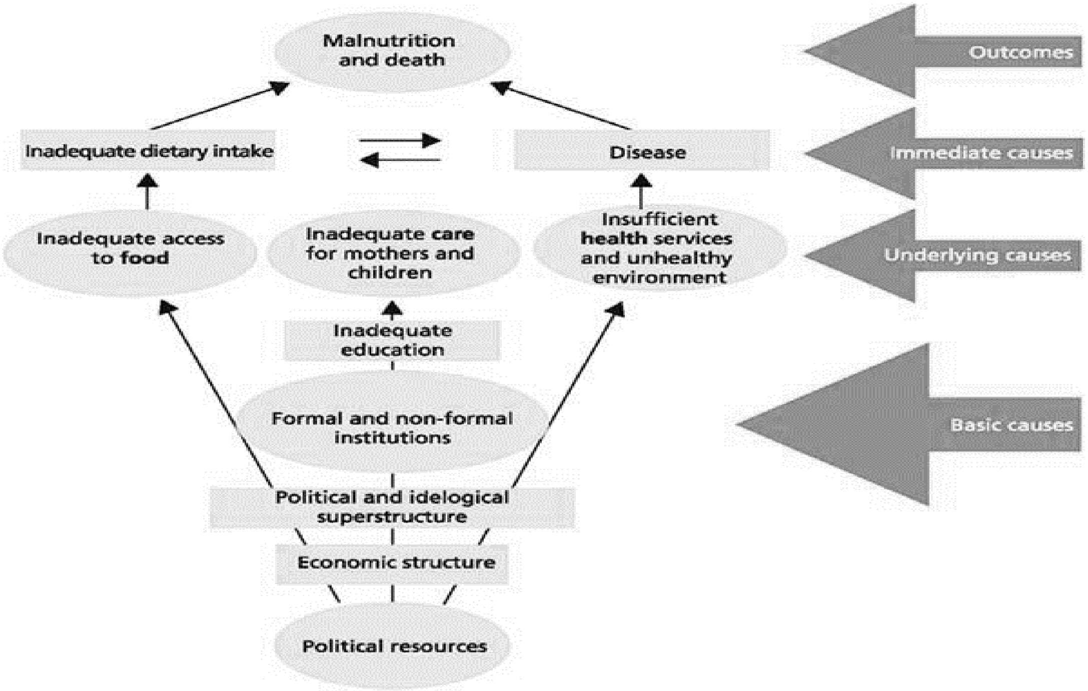

Figure 1: United Nations Children's Emergency Fund (UNICEF) theoretical frame work of determinants of malnutrition

2.7 Conceptual framework of the study

The conceptual framework adapted for this study (Figure 2) was based on the UNICEF conceptual framework of the determinants of malnutrition (UNICEF, 1990). It attempts to show how agro-biodiversity was expected to link to dietary diversity and nutritional status of women of reproductive age. The proposed main pathway is through consumption of different food crops and animal species produced by farmers. Following the argument of causal relationship between agro-biodiversity and dietary diversity, less diversified agricultural systems could result into low dietary diversity (Remans *et al*., 2011), and ultimately leading to poor nutritional status.

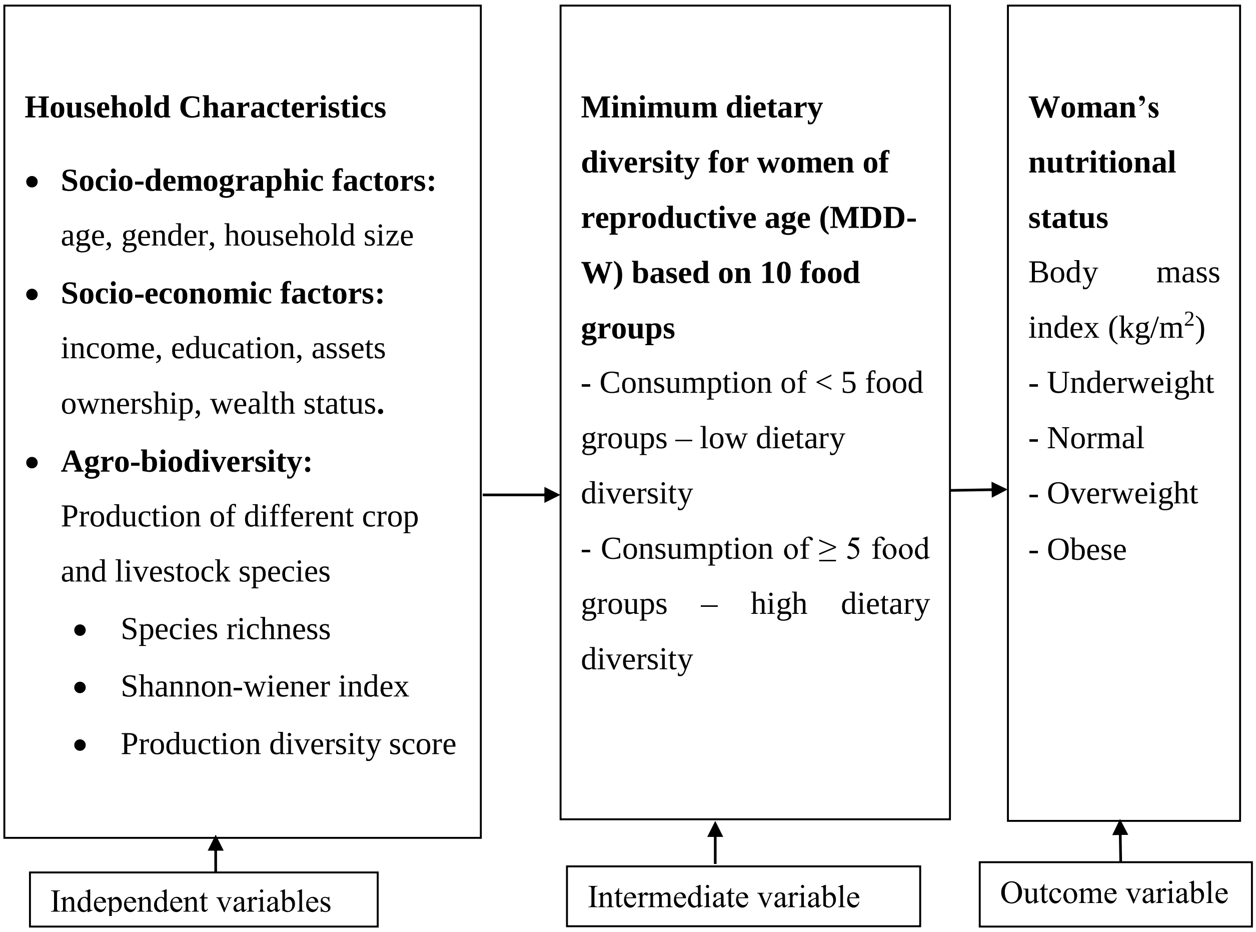

Figure 2**:** Conceptual framework of the study modified from UNICEF, 1990; Keding and Cogill, 2013; Cleghorn, 2014

The independent variables were agro-biodiversity, socio-demographic and economic factors. The indicators for agro-biodiversity were three. The first one was Shannon-Wiener index (SWI), a diversity index which reflects both richness (species count) and evenness (distribution). The higher the SWI score, the greater the diversity in a household farm (McArt *et al*., 2012). The second indicator was species richness (species count) which involved counting the total number of different species cultivated by a household (McArt *et al*., 2012). The third indicator was production diversity score defined as the number of food groups produced in a household farm. Minimum dietary diversity for women (MDD-W) was the intermediate variable. The dichotomous indicator for MDD-W recommended by FAO, 2016 was used where consumption of 5 food groups or more out of 10 was scored as high dietary diversity and below 5 as low dietary diversity. The women's nutritional status was the outcome variable and body mass index (BMI) indicator was used.

CHAPTER THREE

METHODOLOGY

3.1 Introduction

This chapter describes the methodology that was used in the study. It includes description of the research design, study area, study population, sampling frame, sample size determination, sampling procedure, data collection tools and equipment, data collection procedures, pretesting, ethical consideration and data analysis.

3.2 Research design

This study adopted a cross-sectional research design. The advantage of this design is that it is able to allow the assessment of the exposure (dietary diversity) and outcome (nutritional status) at a single point in time (Katzenellenbogen *et al.*, 2002).

3.3 Study area

This study was conducted in Rongai Sub-County (Appendix (1) which is one of the nine administrative Sub-Counties of Nakuru County. The Sub-County lies between latitude 0°12´ and 1°10´ North and longitude 35° 27´ and 35° 35´ East. It covers an estimated area of 993.1 Km^2 with 4 administrative divisions, 5 political wards, 18 locations and 27 sub-locations. The Sub-County has a total of 34, 021 households (Nakuru County Integrated Development Plan, 2013).

The Sub-County is divided into four divisions, namely: Ngata, Menengai, Kampi ya Moto and Solai. The Sub-County lies in two different agro-ecological zones: the Upper Midland II zone (low potential area) and Lower Highland II zone (high potential area) (Jaetzold et al., 2006). The low potential area experience semi-arid climate (26-30°C), lies at an altitude of 1520-1890 m and receives an average annual rainfall of 760 mm (Nakuru County Integrated Development Plan, 2013). The high potential area experience dry sub-humid equatorial climate (15-20^0 C), lies at an altitude of 1800-2400 m above sea level and receives an average annual rainfall of 760-1270 mm.

3.4 Study population

This study targeted all non-pregnant women of reproductive age (15 to 49 years), who were smallholder farmers and have lived in the study area for at least one year prior to the survey.

3.4.1 Inclusion and exclusion criteria

All women of reproductive age (15-49 years), who were smallholder farmers, living in Rongai Sub-County were eligible for inclusion into the study. For households with more than one woman meeting the inclusion criteria, one was randomly selected. Those who were excluded from the study were women with malformation that interfered with anthropometric measurements, pregnant women, women who were only visiting the households and those who were not smallholder farmers. This is because the above factors would have introduced errors during data collection, analysis and interpretation.

3.5 Sampling frame

The sample size was determined using the formula by Fischer *et al.* (1991)

$$n = \frac{Z^2 Pq}{e^2}$$

Where;

n = sample size desired

Z = the standard normal deviation, which is 1.96 set at 95% confidence interval

p = estimated prevalence of malnourished women in Nakuru county which is 38.5% (KNBS and ICF Macro, 2015).

q = 1–P, Proportion of well-nourished women 61.5%

e = desired level of precision (for example, 0.05 for ± 5%)

$$n = \frac{(1.96)^2 * 0.385 * 0.615}{(0.05)^2} = 363.83$$

Attrition rate is 10% of n = 10%*363.83= 36.38

n = 363.83 + 36.38 = 400.213

3.6 Sampling procedure

A multi-stage cluster sampling procedure was adopted to obtain an appropriate sample for the study. In the first sampling stage, Rongai Sub-County was purposively selected because it lies in two different agro-ecological zones. The Sub-County has four administrative divisions and two divisions were purposively selected from the two different agro-ecological zones; one division from low potential area (Kampi ya Moto) and the other from high potential area

(Menengai). The households list of the two divisions were obtained from the Ministry of Agriculture, Nakuru County population records. The lists indicated 7,044 and 9,966 households were from Kampi ya Moto and Menengai divisions respectively. Proportionate sampling was used to get the specific number of households from each of the two study sites as shown in Table 1. Four sub-locations were then selected randomly from each division. Thereafter villages in each sub-location were randomly selected to get a representative sample of the population. In each selected village, a list of all households with women of reproductive age and who were smallholder farmers was generated and participants randomly selected to take part in the study (Figure 3).

Table 1: Sample size distribution of households from Kampi ya Moto and Menegai division involved in the study

Division	Households	Percentage	Sample size
Kampi ya Moto	7,044	41.41	41.41% * 400 = 166
Menengai	9,966	58.59	58.59% * 400 = 234

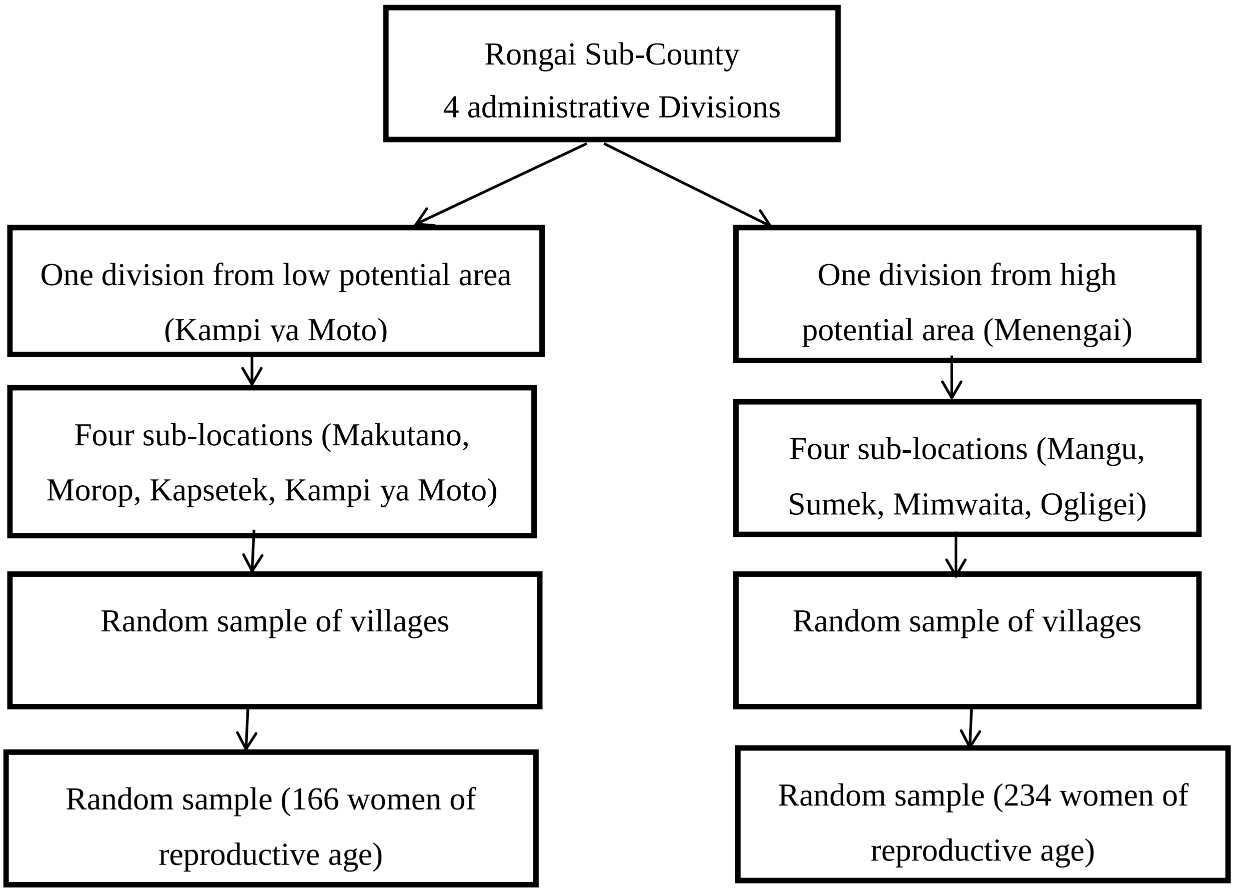

Figure 3: Multi-stage cluster sampling procedure followed in selection of women of reproductive age to participate in the study

3.7 Recruitment and training of enumerators

The data for this study was collected by the researcher and team of trained enumerators with at least university education and basic nutrition knowledge. The enumerators were fluent in English and Kiswahili, as well as the local vernacular languages (Kalenjin and Kikuyu) spoken in the study areas. Prior to the commencement of the survey, the enumerators participated in workshops where they were trained on the use and application of the survey tools and on how to take accurate anthropometric measurements.

3.8 Data collection tools

The tools that were employed to collect data included; household structured questionnaire (Appendix 2), qualitative 24 Hour Dietary Recall (Appendix 3). The information collected from 24 hour recall was used to fill dietary diversity (DD) questionnaire (Appendix 4). The other tool used was anthropometric measurements form (Appendix 5).

3.8.1 Household structured questionnaire

Household structured questionnaire was used to gather information on socio-demographic, household characteristics and assets ownership such as electricity, mobile phone, television, type of roofing materials, type of fuel and type of toilet facilities. The questionnaire was also used to gather information on food crops and animal species diversity in a household farm.

3.8.2 Qualitative 24-Hour dietary recall

The 24 Hour dietary recall was used to gather information on all foods and beverages consumed by the woman in the previous 24 hours, commencing with the first item eaten after waking up and ending with the last item eaten before going to sleep (Gibson and Ferguson, 2008).

3.8.3 Anthropometric measurements form

The anthropometric measurements form was used to record the weight and height measurements for women taken using standardized equipment. The body mass index (BMI) indicator was used to assess women's nutritional status. The BMI was calculated as a ratio between weight in kilograms and height of the respondent in meters squared (kg/m^2) and compared with internationally recommended cut-off points for nutritional status (WHO, 2006).

3.9 Data collection equipment

The study used standardized equipment; stadiometer (SECA; MD001; 1998; Germany) for height measurements and weighing scale (SECA; MD001; 1998; Germany) for weight measurements.

3.10 Data collection procedures

An informed consent was sought from the women prior to actual data collection. The questionnaires were researcher administered to women at their homes through face to face interview to ensure that questions were clarified on the spot if needed and to ensure completeness of the questionnaire.

3.10.1 Assessment of socio-demographic and economic status

The participants were asked questions on socio-demographic and economic factors. The socio-demographic part included questions on household head, number of children, woman's age, education level, marital status, religion and ethnicity. The socio-economic status information included household income, housing characteristics (type of roofing materials), basic amenities (source of drinking water, type of fuel and type of toilet facilities), and ownership of land and other valuable assets including; refrigerator, radio, television, DVD player, mobile phone, sewing machine, car/truck, motorcycle, bicycle, spade/shovel, sprayer pump, water pump, and computer.

3.10.2 Assessment of agro-biodiversity

The household agro-biodiversity data was collected using a structured questionnaire by asking the participants to list all plant and animal species present in their land (plot, kitchen garden, woodlots or farm).

3.10.3 Assessment of dietary diversity

The participants were asked to recall and describe all items consumed, including food items, beverages and snacks during the previous 24-hour period, commencing with the first item eaten after waking up and ending with the last item eaten before going to sleep. For each food item or beverage consumed by the participant, the researcher probed for additional detail on food item such as consumption time (breakfast, lunch, dinner mid-morning or afternoon snack), place of consumption (home, away from home), method of cooking (boiling, frying, stewing or raw). The information collected from 24 hour recall was used to fill DD questionnaire, by aggregating all food items consumed by the woman in the previous 24 hours period into 10 food groups recommended by FAO (FAO, 2016). These food groups include; (1) starchy staples, (2) pulses; beans, peas and lentils, (3) nuts and seeds, (4) dairy products, (5) meat, poultry and fish, (6) eggs, (7) dark green leafy vegetables, (8) vitamin A rich fruits and vegetables, (9) other vegetables and (10) other fruits (FAO, 2016).

3.10.4 Assessment of anthropometric measurements

Weight measurements of the woman were taken using standardized weighing scale (SECA; MD001; 1998; Germany) placed on levelled surface and zeroed. The participant were asked to remove their shoes, bulky clothing and stand with both feet at the centre of the platform on the scale. Weight measurements were then recorded to the nearest 0.1kg (Centers for Disease Control and Prevention, 2007). This procedure was repeated three times and the mean weight calculated and recorded in the anthropometric measurements form.

Height measurements of the woman were taken using a standardized stadiometer (SECA; MD001; 1998; Germany) placed on a firm level ground. The participants were asked to remove their shoes and stand straight on the stadiometer, with heels together and upper part of the back and the head in contact with the vertical part of the stadiometer. Then the head piece was firmly lowered down to come into contact with the vertex of the head. The height measurements were recorded to the nearest 0.1cm (Centers for Disease Control and Prevention, 2007). This procedure was repeated three times and the mean height calculated and recorded in the anthropometric measurements form.

3.11 Pre-testing of the tools

The data collection tools were pre-tested in 40 randomly selected households (10 percent of the sample size) in Kikapu village, an agricultural area in Njoro Sub-County, Nakuru County. The village is out of Rongai Sub-County but has similar farming activities as the study area. To enhance quality of data collection tools, ambiguous and unclear questions were modified before the actual data collection to ensure that the tools yielded same results consistently.

3.12 Validity and Reliability of the tools

3.12.1 Validity

Validity is defined as the degree to which a concept is accurately measured in a study (Haele and Twycross, 2015). There are two broad measures of validity; external and internal. External validity is the extent to which the findings of the study can be generalized from a sample to population. The study achieved external validity by ensuring that the participants sampled were representative of that population through random sampling. Internal validity was achieved through content validity and face validity. Content validity refers to appropriateness of the tool. That is whether the tool adequately covers the entire domain of the study variables and whether a tool measures the concept intended (Roberts *et al*., 2006). Content validity comes from opinion or judgments of people who are experts in particular field of study. The content validity of tools developed for this study were assessed by two research supervisors and other experts from the department of Human Nutrition. Face validity refers to the degree to which a tool measures the variable that it is supposed to measure (Roberts *et al*., 2006). Face validity of the study tools was tested during the pre-testing phase to assess whether questions are well constructed, meaningful and understandable by the participants.

3.12.2 Reliability

Reliability is the degree to which an assessment tool produces stable and consistent results. Reliability is concerned with the extent to which the results of a study or measure are repeatable in different circumstances (Roberts *et al*., 2006). After pre-testing, the reliability of the study tools was estimated using the Cronbach’s alpha (Heale and Twycross, 2015). The Cronbach alpha was computed using SPSS Software. The tools that scored Cronbach alpha of 0.70 or above were used for actual data collection.

3.13 Ethical approval and permissions

Approval to carry out this research was sought from the Graduate School of Egerton University (Appendix 6); this was after the approval of the research proposal by the Human Nutrition Department and Faculty of Health Sciences. Ethical clearance (Appendix 7) was thereafter obtained from Egerton Research Ethics committee and research permit from the National Commission for Science, Technology and Innovation (Appendix 8). Permission was also obtained from relevant authorities at the Sub-County, location and sub-location level prior to commencement of data collection. The researcher clarified the purpose of the study to the respondents and the questionnaires were administered upon obtaining informed consent (Appendix 9). To ensure confidentiality, names and other means of identification such as identity card number were not used during the data collection. The researcher also ensured that all information acquired was kept in strict confidence and only used for the purpose of the study.

3.14 Data management

Completed questionnaires were checked daily for accuracy and completeness in recording of responses. Editing and coding was done before data entry. Double data entry was performed at the end of the survey and the entered datasets compared and cleaned prior to data analysis.

3.15 Data analysis

This study used a comparative approach to determine if there were significant differences in low and high agricultural potential area of Rongai Sub-County. All data were analysed using the Statistical Package for Social Sciences (SPSS), version 20.0, 2011 and summarized using tables and graphs. Information collected at household level included: housing characteristics (type of roofing materials), basic amenities (source of drinking water, type of fuel and type of toilet facilities), and ownership of land and other valuable assets including (refrigerator, radio, television, DVD player, mobile phone, sewing machine, car/truck, motorcycle, bicycle, spade/shovel, sprayer pump, water pump, and computer); was used to generate a household wealth index, an indicator of household socio-economic status. Using principal component analysis, weights were assigned to each of these variable in the household, and the weighted scores summed up to come up with the household wealth index score, with a high score representing high wealth. The wealth index scores were divided into quintiles which classified the households as: poorest, poor, middle and rich (KNBS and ICF Macro, 2015). Contribution of income sources to total household income was also assessed as an indicator of socio-economic status. Sources of income were categorized into five categories; agriculture, casual labour, regular employment, business and remittances. The contribution of each sources of household income was assessed at three levels; major, medium and minor.

Agro-biodiversity was assessed using three indicators; Shannon-Wiener index, species richness and production diversity. With the assistance from an agronomist, the Shannon-Wiener Index score was calculated using the following equation;

$$\hat{H} = -\sum_{i=1}^{\hat{S}} \hat{p}_i \ln \hat{p}_i,$$

Where H´ = the Shannon diversity index.

pi = fraction of the entire population made up of species i.

S = number of species encountered.

Species information gathered from household structured questionnaire was also used to compute species richness/count and production diversity. (Koppmair, Kassie and Qaim, 2017; Malapit *et al*., 2015; McArt *et al*., 2012). To construct the production diversity score, the 10 food groups used to calculate the women's DDS (FAO, 2016) were considered. The scoring used in generating the women's DDS (FAO, 2016), was adapted to create the production diversity score. If a farm had sorghum, maize and millet (all cereals), this was counted as '1' and those farms that didn't cultivate any cereals were assigned as '0'. The same was done for the other food groups and the scores for all food groups were added to obtain the production diversity score. (Koppmair, Kassie and Qaim, 2017; Malapit *et al*., 2015).

The 10 food groups aggregated from DD questionnaire were used to compute minimum dietary diversity for women of reproductive age indicator (MDD-W). The MDD-W is a dichotomous indicator with a standard minimum threshold of consumption of 5 or more of the ten recommended food groups (FAO and FANTA, 2014). Women consuming food items from at least 5 or more of the ten food groups were regarded as having high dietary diversity and below 5 as low diversity. The mean weight and height were used to compute body mass index (BMI) an indicator for nutritional status; calculated by dividing weight in kilograms by height in m^2

(Kg/m^2). Women with BMI < 18.5 were classified as being underweight, normal 18.5 to 24.9, overweight 25.0 to 29.9 or obese ≥ 30.0 (WHO, 2006).

Means and percentages were used to describe the data. Chi-square (χ^2) test was used to compare categorical variables of two agro-ecological zones. Independent samples t-test was used to compare means of continuous variable in the two agro-ecological zones. Two independent bivariate and multivariate analysis were carried out to identify different determinants of dietary diversity across the two ecological zones. The independent variables with $P < 0.2$ with the dependent variable in bivariate analysis were fitted in to a multivariate logistic regression model to identify their independent effect on dietary diversity (Saaka and Galaa, 2018; Weldehaweria *et al*., 2016). The dependent variable was MDD-W with two categories, low and high dietary diversity. Independent variables included in the multivariate analysis were household head's gender, level of income, wealth index, family size, woman's education level and age, cultivated farm size and agro-biodiversity indicators. Multicollinearity was investigated using variance inflation factor (VIF). The VIF factor ranged from 2.480 to 4.335 which were below the suggested cut offs > 5, above which collinearity is considered a problem (Kutner *et al*., 2004). The direction and strength of association between the dependent and independent variables were assessed using regression coefficient, adjusted odds ratio with 95% confidence interval. P values < 0.05 were considered statistically significant. The summary of objectives, variables and statistical tests used are shown in Table 2.

Table 2: Summary of study objectives, independent, dependent variables and statistical test performed to analyse the data

Objectives	**Variables**	**Statistical test**
Document the status of agro-biodiversity of smallholder farm households in Rongai Sub-County	Shannon-Wiener index, Species richness, Production diversity	Descriptive statistics : means, frequencies, percentages
Determine dietary diversity score of women aged 15-49 years in Rongai Sub-County	Dietary diversity	Descriptive statistics : means, frequencies, percentages
Assess nutritional status of women of reproductive age in Rongai Sub-County	BMI; weight, height	Descriptive statistics : means, frequencies, percentages
Examine relationship between socio-demographic, socio-economic factors, agro-biodiversity and dietary diversity of women aged 15-49 years in Rongai Sub-County.	Socio- demographic and economic factors Agro-biodiversity Dietary diversity	Chi square, correlation tests, multivariate logistic regression
Determine the links between dietary diversity and nutritional status of women aged 15-49 years in Rongai Sub-County	Dietary diversity Nutritional status	Chi square, t-test, binary logistic regression

CHAPTER FOUR

RESULTS

4.1 Introduction

The aim of this study was to assess the relationship between agro-biodiversity, dietary diversity and nutritional status among women of reproductive age in the two different agro-ecological zones of Rongai Sub-County, Nakuru County. A cross-sectional study targeting 400 women aged 15-49 years was carried out in January to April 2016. However, a total of 384 women of reproductive age were included in this study with proportional to size samples from each of the agro-ecological zones; 41.41% (n = 159) from low potential area and 58.59% (n= 225) high potential area. This yielded a response rate of 96%. The non-response rate was due to migration of the sampled household out of the study area and refusal to give information on some variables such as asset ownership, size of land, crop species cultivated and livestock reared by the household.

4.2 Socio-demographic characteristics of the study population

Table 3 shows the socio-demographic characteristics of the study participants. Overall, majority of the households (81.8%) were male headed with most women being married (76.6%) and were Christians (94.0%). Approximately half of the study population (42.7%) had attained primary level of education. In the study area, a significantly higher proportion ($P < 0.05$) of the respondents interviewed were of the Kalenjin ethnic group in low potential area (73.6%) compared to high potential area (55.6%). The total number of household members was more ($P < 0.05$) in low potential area (5.78 ± 2.54) compared to high potential area (4.98 ± 2.35). Overall, each household had approximately five members (5.31 ± 2.46) and three children (2.80 ± 1.97).

Table 3: Socio-demographic characteristics of women of reproductive age in low and high potential area of Rongai Sub-County

Characteristic	Total (n=384)		Agro-ecological zones: Low potential area (n=159)		Agro-ecological zones: High potential area (n=225)		χ^2 value P value
	%	N	%	n	%	n	
HH head gender							
Male	81.8	314	82.4	131	81.3	183	0.700
Female	18.2	70	17.6	28	18.7	42	0.792
Marital status†							
Married	76.6	294	72.3	115	79.6	181	5.084
Single	20.6	79	25.2	40	17.3	39	0.166
Widow	2.1	8	1.3	2	2.7	6	
Separated	0.8	3	1.3	2	0.4	1	
Religion†							
Muslim	6.0	23	10.1	16	3.1	7	7.996
Christian	94.0	361	89.9	143	96.9	218	0.005*
Ethnicity†							
Kalenjin	63.0	242	73.6	117	55.6	125	33.618
Kikuyu	20.1	77	11.9	19	25.8	58	0.001**
Others††	16.9	65	14.5	23	18.6	42	
Education†							
None	10.9	42	10.1	16	11.6	26	2.947
Primary	42.7	164	40.3	64	44.4	100	0.400
Secondary	32.3	124	37.1	59	28.9	65	
Tertiary	14.1	54	12.6	20	15.1	34	
Age in years#	29.09 ± 9.17		28.44 ± 8.51		29.55 ± 9.59		P= 0.244
HH members number#	5.31 ± 2.461		5.78 ± 2.54		4.98 ±2.35		P= 0.002*
Number of children#	2.80 ± 1.97		2.81 ± 2.02		2.79 ± 1.93		P= 0.904

HH, Household, †characteristic of the women of reproductive age; †† other ethnic groups include Kisii, Turkana, Luhya, Meru and Mijikenda; *P < 0.05, **P<0.01 significant by χ^2 test; # data are mean ± standard deviations; *P < 0.05 significant using independent samples t-test.

4.3 Socio-economic status of the households

4.3.1 Household income and income sources in Rongai Sub-County

Overall, almost half (44.0%) of the households have an income ranging between 3,500 and 7,000 Kshs/month (Table 4). There was no significant difference (P>0.05) in the level of household income in the two agro-ecological zones. The sources of household income were not different in the two zones, however low potential area cited agricultural production (34.6%) and casual labour (35.2%) as their main sources of income while the high potential zones had regular employment (38.2%) as the major source of income and agricultural production (36.0%) as a medium source of income.

Table 4: Comparison of household income and sources in low and high potential area of Rongai Sub-County

Income and source	Total (n=384)		Agro-ecological zones: Low potential area (n=159)		Agro-ecological zones: High potential area (n=225)		χ^2 value P value
	%	n	%	n	%	n	
Household income							
< Ksh.3,500/month	25.0	96	24.5	39	24.9	56	2.550
Ksh.3,500-7,000/month	44.27	170	43.4	69	44.4	100	0.636
Ksh.7,000 ≥14,000/month	30.73	118	31.4	50	29.8	68	
Income source							
Agriculture production							
Major	27.6	106	34.6	55	22.7	51	8.040
Medium	33.9	130	30.8	49	36.0	81	0.09
Minor	7.8	30	8.8	14	7.1	16	
No contribution	29.9	115	25.2	40	33.3	77	
Casual labour							
Major	32.0	123	35.2	56	29.8	67	8.276
Medium	23.4	90	21.4	34	24.9	56	0.082
Minor	5.5	21	8.8	14	3.1	7	
No contribution	38.3	147	34.0	54	41.3	93	
Regular employment							
Major	34.4	132	28.9	46	38.2	87	3.654
Medium	3.6	14	3.8	6	3.6	8	0.455
Minor	0.5	2	0.6	1	0.4	1	
No contribution	60.4	232	65.4	104	56.9	128	

*P < 0.05 significant by χ^2 test; Income sources were categorize in to four categories major, medium, minor and no contribution.

4.3.2 Wealth index distribution

Table 5 presents wealth index distribution in Rongai Sub-County. The wealth index serves as proxy for household's long-term standards of living. Majority of households were from poorest category (61.8%). There was a significant difference (χ^2 = 9.226; P = 0.026) in wealth distribution in the two agro-ecological zones. Majority of the households in poorest category were from low potential area (69.7%) compared to high potential zones (56.3%). Overall, only 3.2% of the households were in the rich category, with a higher proportion (P<0.05) from high potential area (5%) compared to low potential area (0.6%).

Table 5: Wealth index categories in low and high potential area of Rongai Sub-County

	Total (n=377)		Agro-ecological zones: Low potential area (n=155)		Agro-ecological zones: High potential area (n=222)		χ^2 value P value
Wealth index categories	%	n	%	n	%	n	
Poorest	61.8	233	69.0	107	56.8	126	9.226
Poor	32.6	123	28.4	44	35.6	79	0.026*
Medium	2.4	9	1.9	3	2.7	6	
Rich	3.2	12	0.6	1	5	11	

*P < 0.05 significant by χ^2 test.

4.4 Status of agro-biodiversity in Rongai Sub-County

The household agro-biodiversity survey documented a total of 61 species; 45 edible plant species, 9 non-edible plant species and 7 animal species (Table 6). The category with highest species was other fruits (9 plant species) followed by other vegetables (8 plant species), dark green vegetables (7 plant species), legumes, nuts and seeds (6), vitamin A rich fruits(4 plant species) and cereals (4 plant species).

Table 6: Agro-biodiversity of cultivated/domesticated species in low and high potential area of Rongai Sub-County

Categories	Cultivated/domesticated species	Total (n=384)	Agro-ecological zones	
			Low potential area (n=159)	High potential area (n=225)
Cereals	Maize, millet, sorghum, wheat	4	3	4
White tubers	Irish potato, cassava,	2	2	2
Vitamin A rich vegetables and tubers	Pumpkin, butternut, carrot, sweet potato	4	4	4
Dark green vegetables	Kales, spinach, Jute, cowpeas(Kunde), black night shade, amaranth	7	7	7
Other vegetables	Tomato, onion, green peas, eggplant, cabbage, red pepper, coriander, green plant	8	5	8
Vitamin A fruits	Mango, pawpaw, loquat, passion fruits	4	3	4
Other fruits	Avocado, banana, lemon, oranges, watermelon, custard apple, grapes, white supporter, guavas	9	8	9
Legumes and nuts	Red beans, soya beans, black beans, ground nuts, green grams	6	6	2
Sweet	Sugar cane	1	1	1
Total edible plants species		**45**	**39**	**41**
Non-edible plants species	Napier grass, star grass, grevillea, eucalyptus, acacia, bottle brush, wattle brush, cypress	9	9	9
Animals	Chicken, cattle, goat, sheep, duck, turkey, rabbit	7	6	7
Total agro-biodiversity		**61**	**52**	**57**

Plant species were not classified into varieties in this study; therefore, foods such as maize, beans, sorghum and millet may reflect more than one variety.

4.4.1 Status of agro-biodiversity using Shannon-Wiener index indicator

The Shannon-Wiener index means for the study area was low and different in the two agro-ecological zones. The mean Shannon-Wiener index for all cultivated species (edible and non-edible) was significantly lower (P < 0.05) among households in low potential area (0.96 ± 0.48) compared to those in high potential area (1.10 ± 0.43, (Fig. 4A). While, the mean diversity of edible crop species was significantly higher in high potential area (1.08 ± 0.41) compared to low potential area (0.93 ± 0.40), (P < 0.05) (Fig. 4B).

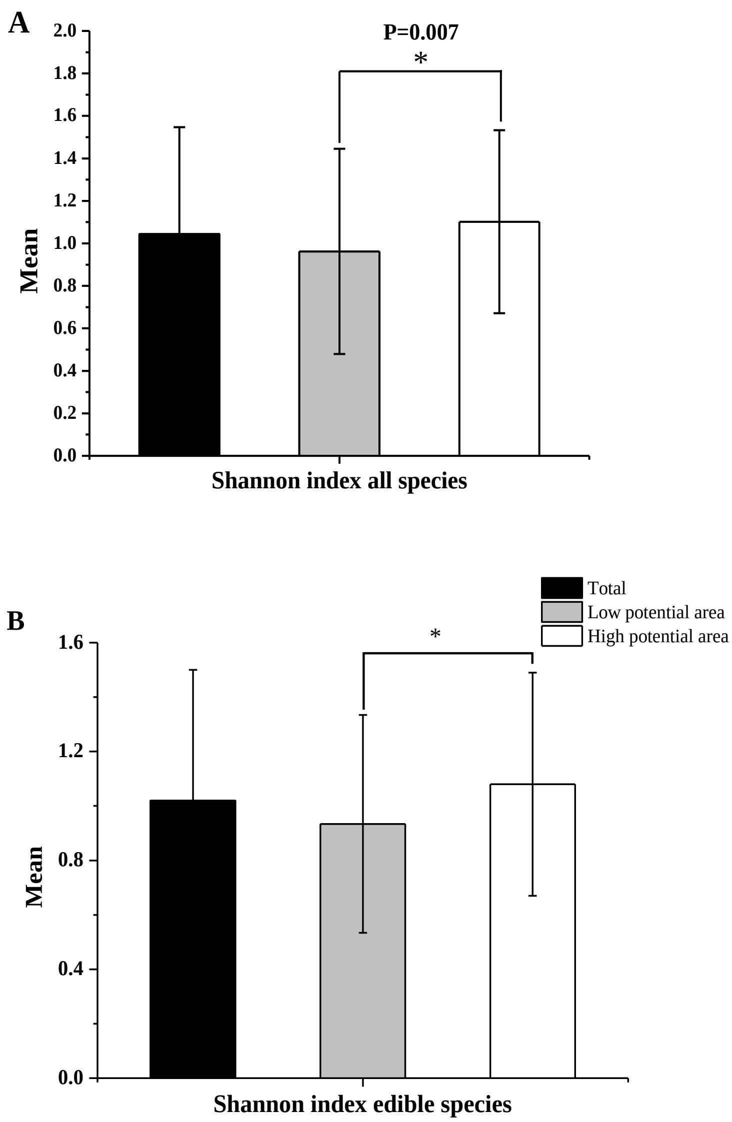

Figure 4: Shannon-Wiener index for all species and the edible species. Data are mean ± standard deviations, *P < 0.05, significant by independent samples t-test.

4.4.2 Status of agro-biodiversity using species count/ richness indicator

Overall, the mean species count/richness in Rongai Sub-County was 6.05 ± 3.03, with no difference ($P = 0.292$) in the two agro-ecological zones. However, the mean diversity of cereal, tubers and roots was larger ($P = 0.005$) (1.75 ± 0.83) in high compared to low (1.49 ± 0.86) potential area. On contrary, the mean diversity of legumes and nuts as well as domesticated animals was significantly higher ($P > 0.05$) in low than high potential area (Table 7). There were no significant difference ($P > 0.05$) in the diversity of fruits, vegetables and species richness. Although, high potential area (4.53 ± 2.22) had more ($P = 0.018$) total crop count than low potential area (3.95 ± 2.53).

Table 7: Species count/richness in the low and high agricultural potential area

Categories	Total (n=384)	Agro-ecological zones		P value
		Low potential area (n=159)	High potential area (n=225)	
Cereals, tubers and roots	1.65 ± 0.85	1.49 ± 0.86	1.75 ± 0.83	0.005*
Legumes and Nuts	1.02 ± 0.17	1.05 ± 0.26	1.00 ± 0.00	0.019*
Fruits	1.93 ± 1.14	2.18 ± 1.11	1.76 ± 1.14	0.075
Vegetables	2.27 ± 1.21	2.24 ± 1.13	2.28 ± 1.25	0.799
Domesticated animals	2.08 ± 0.99	2.29 ± 1.01	1.93 ± 0.91	0.001**
Total crop count	4.23 ± 2.46	3.95 ± 2.53	4.53 ± 2.22	0.018*
Species count/richness	6.05 ± 3.03	5.86 ± 3.40	6.19 ± 2.74	0.292

Data are mean ± standard deviations, $^{*}P < 0.05$, $^{**}P < 0.01$ significant using independent samples t-test.

4.4.3 Status of agro-biodiversity using production diversity indicator

The proportion of farms producing 10 food groups recommended by FAO, (2016) in the DDS in Rongai is shown in Table 8. A high proportion of farm households produced starchy staples (89.5%), with high potential area producing more ($P = 0.004$) starchy staples (93.3%) than low potential area (84.1 %). Overall, pulses were cultivated by 84.3 % of the households while vitamin A rich foods, other fruits, nuts, and seeds were least produced in the two agro-ecological zones. A significant higher proportion (P = 0.01) of households (30.7%) in high potential area grew other vegetables compared to low potential area 12.7%. In addition, more farm households produced dairy products in low potential area (61.6%) compared to high potential area (53.3%). The average production diversity score (number of DDS food group produced per farm) was 5 food groups per farm household, with no difference (P = 0.125) in the two agro-ecological zones.

Table 8: Proportion of households producing different food groups in low and high potential area of Rongai Sub-County

Food groups Produced †	Total (n=384)		Agro-ecological zones: Low potential area (n=159)		Agro-ecological zones: High potential area (n=225)		χ^2 value P value
	%	n	%	n	%	n	
Starchy staples	89.5	342	84.1	132	93.3	210	8.453 0.004*
Pulses	84.3	322	82.8	130	85.3	192	0.447 0.504
Nuts and seeds	0.3	1	0.6	1	0.0	0	1.437 0.231
Vitamin A rich fruits and vegetables	26.4	101	28.7	45	24.9	56	0.677 0.411
Dark green leafy vegetables	55.5	212	49.7	78	59.6	134	3.650 0.056
Other vegetables	23.3	89	12.7	20	30.7	69	16.632 0.001*
Other fruits	22.8	87	21.0	33	24.0	54	0.467 0.494
Dairy products	56.5	216	61.6	96	53.3	120	2.297 0.130
Eggs	68.1	260	67.5	106	68.4	154	0.037 0.848
Meat poultry and fish	85.6	327	85.4	134	85.8	193	0.014 0.907
Production diversity score#	5.12 ± 1.986		4.94 ± 2.258		5.25 ± 1.986		0.125

*P < 0.05 significant by χ^2 test, # data are mean ± standard deviations; *P < 0.05 significant using independent samples t-test.

4.4.4 Production of species within the ten dietary diversity food groups

a) Starch staples

Figure 5 shows the variety of starch staples grown by households in the study area. Maize was the major starchy staple grown by majority of the households in low (82%) and high potential area (89%), with no difference in the two agro-ecological zones. Potatoes were grown by significantly more ($P < 0.05$) households in high potential area (42%) compared to (6%) in low potential area. The indigenous starchy staples such as millet, sorghum and cassava were grown by less than 10% of the population.

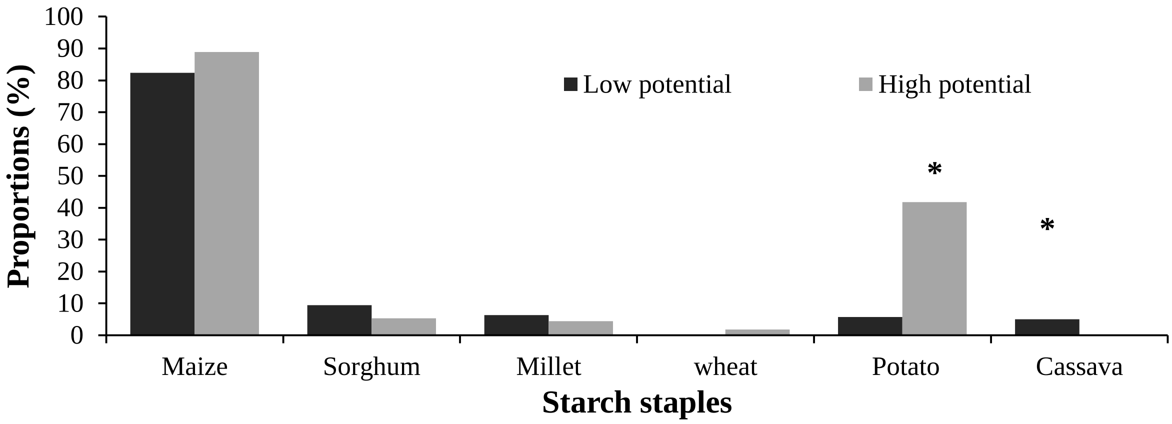

Figure 5: Starch staples grown by smallholder farm households in Rongai Sub-County; $^{*}P <$ 0.05 significant by χ^2 test.

b) **Pulses, nuts and seeds**

The most popular legume produced by households in the two agro-ecological zones was the common bean. (Figure 6). Other legumes and nuts such as soya beans, ground nuts and green grams were grown by less than 5% of the households, with no difference in the two agro-ecological zones ($P > 0.05$).

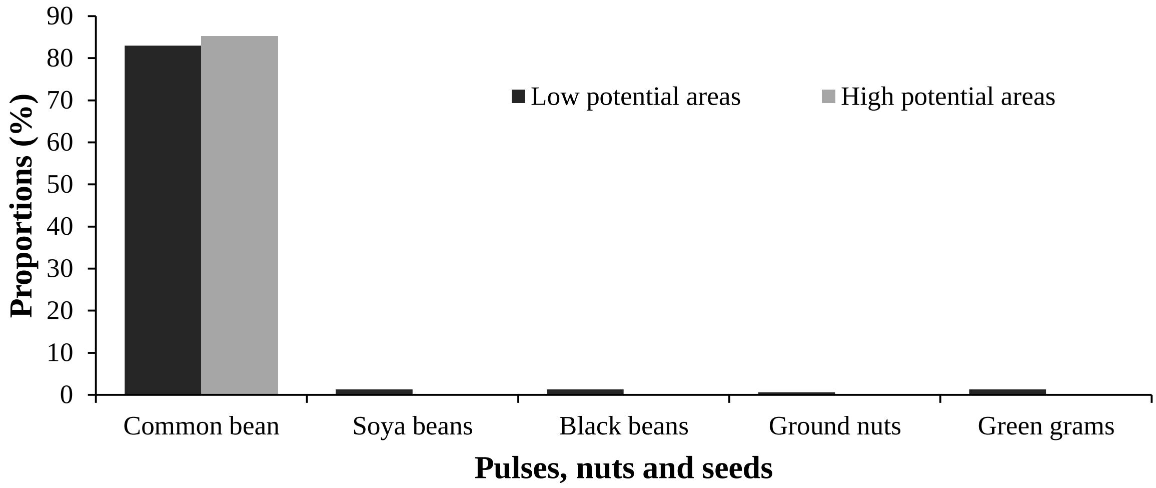

Figure 6: Legumes and nuts grown by smallholder farm households in Rongai Sub-County; $^{*}P < 0.05$ significant by χ^2 test.

c) Dark green leafy vegetables

There were only six varieties of dark green vegetable being cultivated by households in the study area (Figure 7). A larger proportion of the farm households cultivated kales as the major dark green leafy vegetables, with high potential area producing more ($P < 0.05$) kales (48%) than low potential area (32%). Spinach was produced by fewer households ($P < 0.05$) in low potential area (7%) compared to high potential area (18%). Conversely, a more households ($P < 0.05$) in low potential area (32%) cultivated cowpeas compared to high potential area (20%). Amaranth and jute mallow were the least produced dark green leafy vegetables.

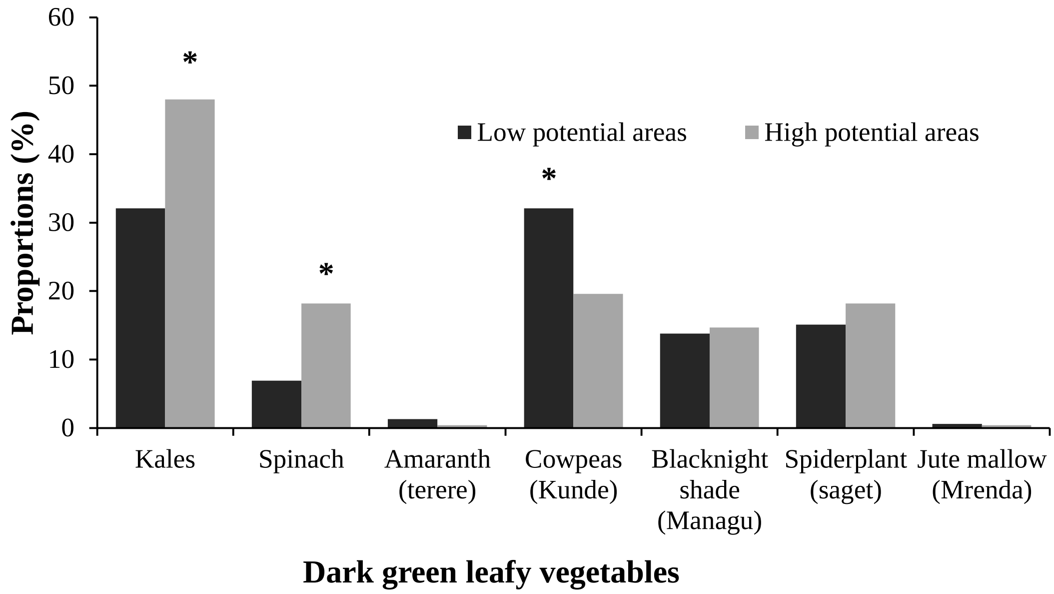

Figure 7: Dark green leafy vegetables grown by smallholder farm households in Rongai Sub-County; $^*P < 0.05$ significant by χ^2 test.

d) Vitamin A rich fruits and vegetables

Figure 8 shows different vitamin A rich foods that were produced in Rongai Sub-County, with orange-fleshed sweet potato being produced by a significantly larger proportion in low potential (16%) compared to high potential area (12%). More, households ($P < 0.05$) in low potential area grew pawpaw (11%) and mangoes (8%) compared to high potential area (2%) pawpaw and (2%) mangoes. While, more farm households in high potential area produced ($P < 0.05$) pumpkins (7%) compared to low potential area (2%).

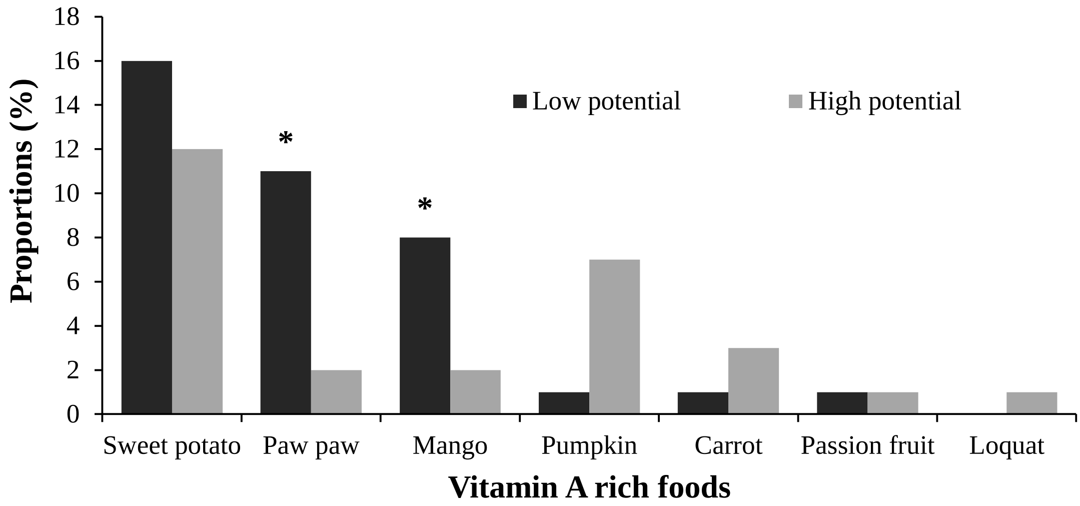

Figure 8: Vitamin A rich foods grown by smallholder farm households in Rongai Sub-County; *P < 0.05 significant by χ^2 test.

e) Domesticated animals

A total of seven animals were domesticated in the two agro-ecological zones with more than 50% of the households rearing chicken and cattle (Figure 9). A significantly higher proportion of farm households in low potential area kept goat and sheep compared to high potential area (26% and 38% vs. 12% and 27%, P < 0.05). Ducks, rabbits and turkey were the least domesticated animals.

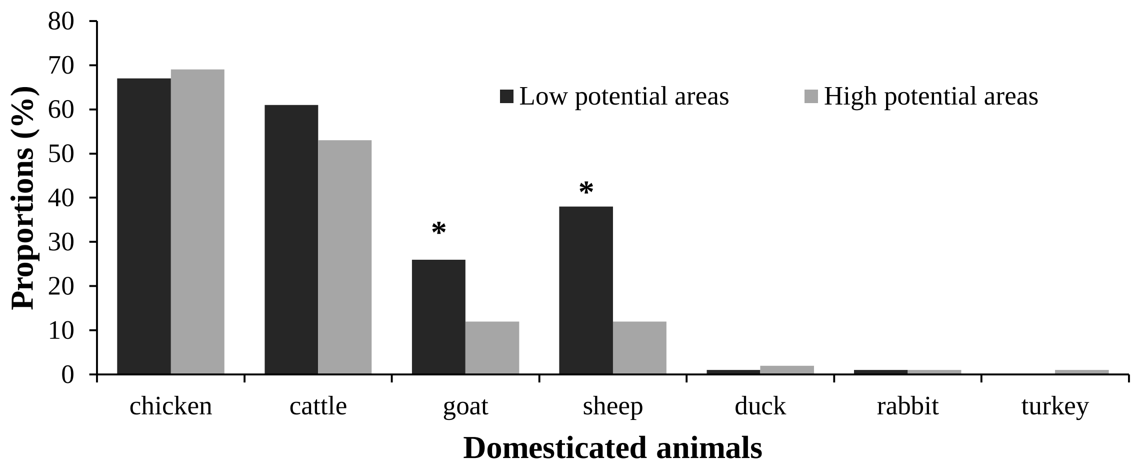

Figure 9: Domesticated animals reared by smallholder farm households in Rongai Sub-County; *P < 0.05 significant by χ^2 test.

4.5 Dietary diversity of women in the two agro-ecological zones

Overall, the dietary diversity score (DDS) of women was 3.78 ± 0.99, with no significant difference ($P > 0.05$) between women residing in low (3.78 ± 0.99) and high potential area (3.84 ± 1.05) (Figure 10A). Majority ($P < 0.05$) of the women (80.9%) consumed foods from less than five food groups, thus not meeting the MDD threshold (consumption of 5 or more food groups) (Figure 10B). However, a significantly higher proportion ($P < 0.05$) of women from high potential area (19.1%) met minimum dietary diversity (consumed 5 or more food groups) compared to 13.9% from low potential area.

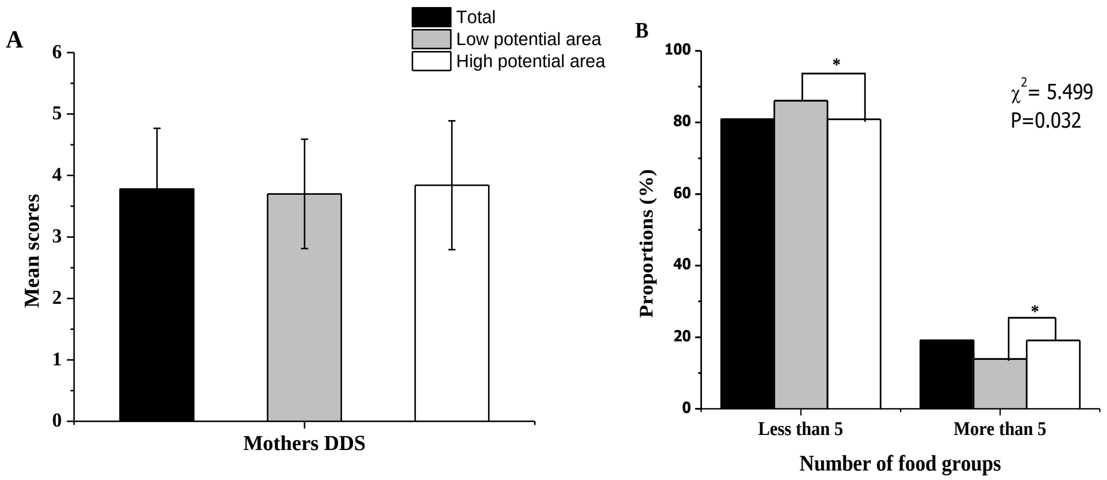

Figure 10: Women's dietary diversity scores and proportions that met minimum dietary diversity. Data are mean ± standard deviations (A), $^{*}P < 0.05$, significant by independent samples t-test and percentages (B) by χ^2 test; DDS, dietary diversity score.

4.5.1 Frequency of different foods groups consumed by women in the two agro-ecological zones

The frequency of foods consumed by women is shown in Table 9. Overall, a high proportion (99.7%) consumed starchy staples while, (42.4%) consumed pulses. Nuts and seeds, meat, poultry, fish and eggs were least consumed across the two agro-ecological zones. Vegetables formed an integral part of the main meals, with 83% of women consuming dark-green leafy vegetables and 92.0% consuming other vegetables such as cabbage, tomato, french beans and cucumbers. Consumption of vitamin A rich fruits and vegetables (e.g. pawpaw, mangoes, carrots and pumpkin) was low (14.1%) across the two agro-ecological zones. A significant larger proportion (P = 0.004) of women from high potential area (27.6%) consumed dairy products compared to those from low potential area (15.1%).

Table 9: Proportion of households consuming different food groups in low and high potential area of Rongai Sub-County

	Total (n=384)		Agro-ecological zones				χ^2 value P value
			Low potential area (n=159)		High potential area (n=225)		
Food groups[†]	%	n	%	n	%	n	
Starchy staples	99.7	383	99.4	158	100	225	1.419 0.234
Pulses	42.4	163	45.9	73	40	90	1.333 0.248
Nuts and seeds	0.3	1	0.6	1	0.0	0	1.419 0.234
Dairy Products	22.2	86	15.1	24	27.6	62	8.324 0.004*
Meat poultry and fish	9.6	37	10.1	16	9.3	21	0.057 0.811
Eggs	6.0	23	5.7	9	6.2	14	0.052 0.819
Dark green leafy vegetables	83.0	319	83.9	133	82.7	186	0.064 0.801
Vitamin A rich fruits and vegetables	14.1	54	12.6	20	15.1	34	0.494 0.482
Other vegetables	92.2	354	90.6	144	93.3	210	0.991 0.320
Other fruits	8.1	31	7.6	12	8.4	19	0.083 0.774

*$P < 0.05$ significant by χ^2 test, † Responses are consumed and not consumed, the data presented is for consumed.

The proportion of women consuming foods from various foods groups varied between those with low and high DDS (Figure 11). Starchy staples, dark green leafy vegetables and other vegetables were frequently consumed foods by women in both categories. A significant higher percentage of women with high DDS consumed pulses (65.0%), dairy products (65.0%) and vitamin A rich foods (45%) compared to women with low DDS (37.0%, 12.0%, and 7.0%, $P < 0.05$) respectively. While, a lower proportion of women with low DDS consumed meat/poultry/fish (27.0%), eggs (3.0%) and other fruits (3.0%) compared to women with high DDS (27.0%, 18.0%, and 32.0%, $P < 0.05$) (Figure 11).

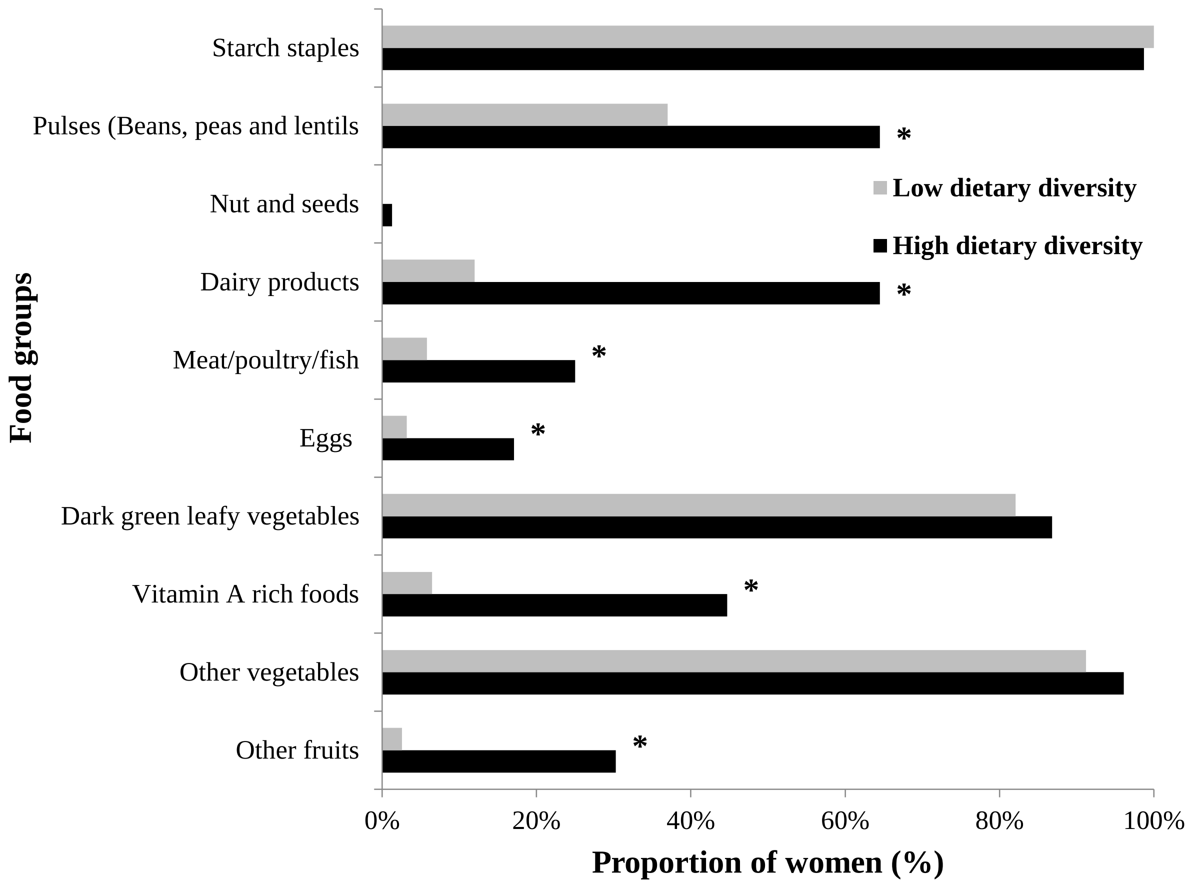

Figure 11: $^{*}P < 0.05$ significant by χ^2. Proportion of women consuming foods from each food group according to the dietary diversity categories. The threshold of 5 out of 10 food groups was considered for minimum dietary diversity for women of reproductive age (MDD-W) (FAO and FANTA, 2014).

4.6 Nutritional status of women in the two agro-ecological zones

Table 10 shows the nutritional status of women in the two agro ecological zones. In low potential a significantly higher proportion of women were underweight compared to high potential area (18.5% vs. 7.1%, $\chi^2 = 15.428$, $P = 0.001$). In contrast, a higher percentage of women were overweight and obese from high potential area compared to low potential area (21.9% and 11.6% vs. 17.2% and 5.1%, $\chi^2 = 15.428$, P = 0.001) respectively.

Table 10: Nutritional status of women in low and high potential area of Rongai Sub-County

	Total (n=384)		Agro-ecological zones: Low potential area (n=159)		Agro-ecological zones: High potential area (n=225)		χ^2 value P value
Weight#	60.09 ± 13.07		58.27 ± 13.16		61.37 ± 12.88		0.022*
Height (cm)#	159.64 ± 8.24		160.14 ± 9.80		159.28 ± 6.89		0.316
BMI	%	n	%	n	%	n	
<18.5 Kg/m²	11.8	45	18.5	29	7.1	16	15.428
18.5-24.9 Kg/m²	59.3	226	59.2	93	59.4	133	0.001*
25-29.9 Kg/m²	19.9	76	17.2	27	21.9	50	
≥ 30 Kg/m²	8.9	34	5.1	8	11.6	26	

†BMI, body mass index, #Data are mean ± standard deviations, *P < 0.05, significant by independent samples t-test; **P < 0.01, *P < 0.05 significant by χ^2 t-test.

4.7 Association of factors with dietary diversity of women of reproductive age in low and high potential area of Rongai Sub- County

4.7.1 Association of socio-demographic factors with dietary diversity of women

A Chi square test was performed to assess the association of socio-demographic factors with dietary diversity in low and high potential area (Table 11). In low potential area, women education level significantly (P = 0.018) influenced dietary diversity; larger proportion of women with high level of education attaining the recommended MDD compared to women with low level of education (33.1% vs. 57.7%, χ^2 =10.049; P < 0.018). In high potential area, women education level, (χ^2 = 27.085; P = 0.018), and household wealth category (χ^2 = 8.858; P = 0.031) positively associated with dietary diversity; with a large proportion of women with high level of education and from wealthy households meeting the recommended MDD.

Table 11: Association of socio-demographic factors with women dietary diversity in low and high potential area of Rongai Sub-County

	Agro-ecological zones					
	Low potential area			**High potential area**		
	Low DD (n=133)	**High DD (n=26)**	**χ^2 value P value**	**Low DD (n=175)**	**High DD (n=50)**	**χ^2 value P value**
Factors	**n (%)**	**n (%)**		**n (%)**	**n (%)**	
Household gender						
Male	93 (69.9)	23(88.5)	3.788	139 (79.4)	43 (86.0)	1.086
Female	40 (30.1)	3(11.5)	0.052	36 (20.6)	7 (14.0)	0.297
Woman education level						
None	16 (12.0)	0 (0.0)	10.049	25 (14.3)	1 (2.0)	27.085
Primary	58 (43.6)	6 (23.1)	0.018*	88 (50.3)	12 (24.0)	0.001*
Secondary	44 (33.1)	15 (57.7)		44 (25.1)	21 (42.0)	
Tertiary	15 (11.3)	5 (19.2)		18 (10.3)	16 (32.0)	
Household income range						
Less than 3500 Ksh/Month	34 (25.6)	5 (19.2)	2.309	47 (26.9)	9 (18.0)	6.311
3500-7000 Ksh/Month	59 (44.4)	10 (38.5)	0.679	81 (46.3)	19 (38.0)	0.177
7000 -14,000	25 (18.8)	23.1 (6)		23 (13.1)	9 (18.0)	
>14,000	14 (10.5)	5 (19.2)		23 (13.1)	12 (24.0)	
Income source Agricultural production						
Major	42 (31.6)	13 (50)	3.784	42 (24.0)	9 (18.0)	1.662
Medium	42 (31.6)	7 (26.9)	0.436	62 (35.4)	19 (38.0)	0.798
Minor	13 (9.8)	1 (3.8)		12 (6.9)	4 (8.0)	
No contribution	35 (26.3)	5 (19.2)		58 (33.1)	17 (34.0)	
Household Wealth categories						
Poorest	93 (72.1)	14 (53.8)	7.711	107 (61.5)	19 (39.6)	8.858
Poor	34 (26.4)	10 (38.5)	0.052	56 (32.2)	23 (47.9)	0.031*
Middle	2 (1.6)	1 (3.8)		3 (1.7)	3 (6.2)	
Rich	0 (0.0)	1 (3.8)		8 (4.6)	3 (6.2)	

DD, dietary diversity; P < 0.05 significant by χ^2 test.

4.7.2 Association of household size, farm size and wealth index with dietary diversity of women

Bivariate association were made between continuous variables and dietary diversity of women using spearman rank correlation across the two agro-ecological zones (Table 12). There was a negative correlation between household size and dietary diversity in high potential area (r = -0.145; P < 0.05) and not in the low potential area (r = -0.540; P = 0.497). The farm size and wealth index positively (P < 0.05) associated with dietary diversity in the two agro-ecological zones.

Table 12: Association of household size, farm size and wealth index with women dietary diversity in low and high potential area of Rongai Sub-County.

Women Dietary Diversity	**Agro- Ecological Zones**		**Household size**	**Farm size**	**Wealth index**
	Low potential area	*Spearman r Coefficient*	-0.540	0.200	0.194
		P value	0.497	0.011*	0.015*
		n	159	159	155
	High potential area	*Spearman r coefficient*	-0.145	0.186	0.143
		P value	0.030*	0.005*	0.033*
		n	225	225	222

Spearman's rho, correlation is significant at P < 0.05

4.7.3 Association of agro-biodiversity indicators with dietary diversity of women

In low potential area, species richness (r = 0.165; P = 0.038) and production diversity score (r = 0.192; P < 0.016) weakly correlated with dietary diversity (Table 13). There was no association (P > 0.05) between species richness, Shannon-Wiener index of the farm household and woman's dietary diversity in high potential area. However, production diversity positively influenced women's dietary diversity (r = 0.142; P = 0.033).

Table 13: Relationship between agro-biodiversity and dietary diversity of women in low and high potential area of Rongai Sub-County

Women dietary diversity	Agro-ecological zones		Agro-biodiversity indicators		
			Species Richness	**Shannon-Wiener index**	**Production Diversity**
	Low potential area	*Spearman r Coefficient*	0.165	0.151	0.192
		P value	0.038*	0.057	0.016*
		n	159	159	159
	High potential area	*Spearman r Coefficient*	0.114	0.100	0.142
		P value	0.087	0.135	0.033*
		n	225	225	225

Spearman's rho, correlation is significant at P < 0.05

4.8 Determinants of women dietary diversity

The factors that influenced dietary diversity were found to be different in the two agro-ecological zones (Table 14). In low potential area, only woman's education level positively (P < 0.05) influenced dietary diversity: women with high level of education were 3.65 times more likely [AOR = 3.65, 95% CI (1.21-10.99)] to have high dietary diversity than those with low level of education. The household gender, woman's education level, woman's age and family size influenced dietary diversity in high potential area. Women from male headed households were 4.15 times more likely [AOR = 4.15, (1.16-14.86), P < 0.05] to have high dietary diversity compared to those from female-headed households. Women with high level of education were 5.32 times [AOR = 5.32, 95% CI (2.27-12.46), P < 0.05] more likely to have high dietary diversity than those with low level of education. In addition, older women were more likely to have a diverse diet [AOR = 1.13, 95% CI (1.07-1.18), P < 0.05] compared to younger women. However, larger family size negatively influenced dietary diversity [(AOR = 0.77; CI (0.62-0.95), P < 0.05] in high potential area. There was no association (P > 0.05) between dietary diversity and household income, wealth index, Shannon-Wiener index, species count/richness and production diversity score across the two agricultural zone.

Table 14: Multivariate analysis of the determinants of women dietary diversity in low and high potential area of Rongai Sub-County

	Agro-ecological zones					
	Low potential zone (n =159)			High potential zone (n = 225)		
Factors	**B**	**AOR (95% CI)#**	**P value**	**B**	**AOR (95% CI)#**	**P value**
Household gender						
Female (reference)	1			1		
Male	1.046	2.85(0.68-11.88)	0.151	1.423	4.15(1.16-14.86)	0.029*
Household income						
Low income (reference)	1			1		
High income	0.300	1.35(0.46-3.95)	0.583	0.402	1.50(0.58-3.89)	0.410
Woman education level						
Low (reference)	1			1		
High	1.295	3.65(1.21-10.99)	0.021*	1.672	5.32(2.27-12.46)	0.001*
Woman age	0.050	1.05(0.99-1.12)	0.123	0.117	1.13(1.07-1.18)	0.001*
Family size	-0.125	0.88(0.71-1.09)	0.253	-0.262	0.77(0.62-0.95)	0.015*
Household wealth index	0.279	1.32(0.71-2.46)	0.379	-0.154	0.86(0.55-1.33)	0.495
Farm size (acres)	-0.089	0.92(0.58-1.45)	0.704	0.263	1.30(0.97-1.75)	0.080
Shannon-Wiener index	-1.000	0.37(0.06-2.17)	0.269	0.127	1.14(0.31-4.16)	0.848
Species count/richness	-0.055	0.95(0.81-1.11)	0.505	-0.072	0.93(0.82-1.06)	0.268
Production diversity score	0.445	1.56(0.87-2.80)	0.134	0.260	1.30(0.89-1.89)	0.174

$P < 0.05$, $P < 0.01$ significant using binary logistic regression; B, Regression coefficient; CI, Confidence Interval, AOR, Adjusted Odds Ratio.

4.10 Association between dietary diversity and nutritional status of women

As shown in (Table 15), there was a significant (P = 0.015) association between women's dietary diversity and their nutritional status in high potential area. A higher proportion of women with normal BMI met the recommended minimum dietary diversity compared to those who were underweight (44.0% versus 8.0%; $\chi^2 = 10.423$, P < 0.015). However, dietary diversity did not influence (P > 0.05) nutritional status of women in low potential area.

Table 15: Association between dietary diversity and nutritional status of women in low and high potential area of Rongai Sub-County

		Dietary diversity			
		Total	**Low**	**High**	**χ^2 value P- value**
Agro-ecological zones	**Nutritional status**	n (%)	n (%)	n (%)	
Low potential area (n=159)	Under weight	29 (18.5)	28 (21.1)	1 (4.2)	4.380
	Normal	93 (59.2)	75 (56.4)	18 (75.0)	0.223
	Over weight	27 (17.2)	23 (17.3)	7 (5.3)	
	Obese	8 (5.1)	7 (5.3)	1 (4.2)	
High Potential area (n=225)	Under weight	16 (7.1)	12 (6.9)	4 (8.0)	10.423
	Normal	133 (59.4)	111 (63.8)	22 (44.0)	0.015*
	Over weight	49 (21.9)	30 (17.2)	19 (38.0)	
	Obese	26 (11.6)	21 (12.1)	5 (10.0)	

*P < 0.05 significant by χ^2 test, BMI, body mass index.

CHAPTER FIVE

DISCUSSION

5.1 Socio-demographic and socio-economic status of the study population

Socio-demographic and socio-economic factors like age, education, occupation and income, tend to have a major influence on individual nutrition and health. Most of the households in the study area were headed by men. In Kenya, one-third of households are headed by female, with a higher proportion of rural (36%) than urban (27%) households headed by them (KNBS and ICF Macro, 2015). United Nations, (2015), report that in the few decades there has been a marked increase in female headed households in both developed and developing countries. Several factors contributing to the growth of female-headed households are; changes in social norms, education levels, demographic and economic growth which have influenced household structure resulting in increased female headship (Mwangi, 2017; Chindime and Ubomba-Jaswa, 2006).

Education is a key determinant of the lifestyle and status an individual enjoys in a society. Studies have consistently shown that educational attainment has a strong effect on health behaviors and attitudes (KNBS and ICF Macro, 2015). Education enhances women's wellbeing and gives them a greater voice in household decisions and autonomy to determine the status of their lives (Malhotra, Pande and Grown, 2003). Approximately half of the participants in the current study had attained primary level of education (42.7%). The results of this study however differ from the Nakuru County education levels statistics which indicated that 30.1% of the women of reproductive age had primary school education (KNBS and ICF Macro, 2015). The difference could be due to the method that was used to categorize education level. In this study, the education level was classified into four groups, none, primary, secondary and tertiary, while in the KDHS the education level was classified into six groups: no formal education, some primary education, primary education completed, some secondary education and more than secondary education (KNBS and ICF Macro, 2015).

The number of household members were more in low potential area compared to high potential area. Overall, each household had approximately five members. The results show that the mean size of household in Rongai Sub-County was higher than the national level of 3.9 (KNBS and ICF Macro, 2015). On average rural households tend be larger (4.4) than urban households (3.2) (KNBS and ICF Macro, 2015). Economic security could be the possible reason why the rural households tend to have more family members compared to urban households. Alam,

(2012) suggests that large families are desired by those in the lowest economic status group. This is because children are regarded as economic assets and security in old age. Family size influences household's members' wellbeing, especially in the context of developing countries where the family resources are very limited. Family size directly determines resources that could be allocated to each member. Given the constraint of family income budget and the increasing cost of raising children, resources available for the mothers are directly affected by the number of children they have. The more children a woman has, the fewer resources that could be allocated to her (Wu and Li, 2012).

The income sources were different in the two agro-ecological zones of this study, with low potential area citing agricultural production and casual labour as their main sources of income. The high potential area had regular employment as a major source of income and agricultural production as a medium source of income. Most of the women (59%) in Kenya are employed in either agriculture or domestic service (KNBS and ICF Macro, 2015). Women are the backbone of the development of rural and national economies. They comprise 43% of the world's agricultural labor force, which rises to 70% in some countries (Palacios-lopez *et al*., 2015). Overall, majority of households were from the poorest category. There was a difference in wealth distribution across the two agro-ecological zones. Majority of the households in poorest category were from low potential area compared to high potential zones. Socio-economic factors (e.g. income and financial independence) have repeatedly been shown to have an impact on the women's health (Williams, Cunich and Byles, 2013). Research has illustrated the impact of poverty on health, with many health risks discovered to be closely associated with low socio-economic status. Higher income allows individuals to easily access quality healthcare, afford more nutritious foods, and better housing, all of which are related to overall improved health status (Engel, 2017).

5.2 Status of agro-biodiversity of households' farms

Kenya has been described as a country rich in agro-biodiversity with estimated 7,500 plant species (Wambugu and Muthamia, 2009). The country's agro-biodiversity is however under serious threat due to among others; climatic change, increasing deforestation, pollution and soil degradation (Odhiambo *et al*., 2016; Mkaibi, 2014; Wemali, 2014; Abukutsa, 2010, Wambugu and Muthamia, 2009; Ekesa *et al*., 2008). The present study documented a total of 61 species; 45 of these were edible plant species, 9 non-edible plant species and 7 animal species. This demonstrated a high diversity in the study area, though low compared to an earlier study conducted in Western Kenya which documented 67 edible crop species and 12 domesticated animal species (Odour *et al*., 2016). The variation in the number of farm species documented in Western Kenya may have been due to a bigger sample size (n = 627), thereby increasing the possibility of documenting even species that are only cultivated by few households.

The level of agro-biodiversity was significantly higher in high potential area compared to low potential area (using Shannon-Wiener index). This implies that the households' farms in high potential area were more diversified in crops, because the higher the species diversity index the greater the diversity in household's farm (McArt *et al*., 2012). The variation in crop diversity could be attributed to the differences in climatic and agricultural potentials of the two agro-ecological zones. Generally, the high potential area experience a dry sub-humid equatorial climate (15-20^0 C) and receives a higher average annual rainfall of 760-1270 mm compared to the low potential area that experience semi-arid climate (26-30^0 C) and receives a lower average annual rainfall of 760 mm (Nakuru County Integrated Development Plan, 2013). Kenya agriculture production is mainly rain fed; areas with high rainfall tend to produce more food crops compared to dry areas. This could explain the high diversity in high potential area.

Starch staples was the most popular food group produced; maize and potatoes being the most common species cultivated by the households. A study by Ekesa *et al*. (2008) indicated that in Kenya maize was produced by 97% while the Kenyan traditional precolonial staples like sorghum, finger millet were grown by less than 30% of the population. This concurs with the present study findings which revealed that the production of indigenous staples such as sorghum, millet, cassava, arrowroots and yams was on decline. Frison *et al*. (2010) also indicated that traditional foods have been replaced by convenience foods. Locally available indigenous foods require some form of processing before their final use in food preparation which is usually tedious and time consuming. This has led to their replacement in the diet by crops such as maize, wheat, rice and potatoes that are easier to prepare. Convenience and commercialization of agriculture could partly be the reasons why the respondents in this study area have adopted these species as compared to indigenous species. As a result of the Green Revolution, many of those local, traditional crop species and varieties have been replaced by high-yielding staple crop cultivars (Stamp *et al*., 2012). This further corresponds with a report by Heywood, (2013) which indicated that cultivation of indigenous starchy staples like millet, sorghum, cassava, sweet potatoes and yams are now associated with being poor. The association has resulted to changes in agricultural practices leading to disruption of dietary patterns and loss of diversity.

Legumes belong to the family Leguminosae and are the next important food crop after cereals. They are sources of low-cost dietary vegetable proteins and minerals when compared with animal products such as meat, fish and egg (Olunike, 2014). Legumes therefore are an important source of affordable alternative protein to poor resource people in many tropical countries especially in Africa and Asia (Olunike, 2014). However, over the past few decades, the diversity of varieties within the legume species is currently on the decline among many communities (Zander *et al*., 2016; Nedumaran *et al*., 2015). This corresponds to the findings of the current study where common red bean was cultivated by more than 80% of the farmers while other legume species such as soybean, groundnut, chickpea, lentil and pigeon peas were cultivated by less than 10%. These other food legumes have potential which is under exploited and untapped. Many of these food legumes if exploited fully may play a vital role in protein nutrition to poor farm families especially to women and children (Olunike, 2014; Durst and Bayasgalanbat, 2014).

The current study demonstrated a deterioration in cultivation of indigenous vegetables. This concurs with an earlier study done by Ekesa *et al*. (2008) which pointed out that in Kenya, the cultivation of indigenous vegetables is declining. There were only five species of traditional vegetables being grown and cowpea leaves were the most common in this study area. This is because cowpea can withstand harsh conditions and its yield is always higher than the other indigenous vegetables. In Kenya, there are about 210 species of indigenous vegetables consumed as leafy vegetables (IPGRI, 2006). In a previous study in Western Kenya, Abukutsa (2005) observed that indigenous vegetables cultivation continue to face challenges of optimal production. Changed food habits in favor of introduced temperate vegetables has lowered the demand for indigenous vegetables due to the fact that the former fetches higher prices in local markets (Abukutsa, 2010). African indigenous food crops, particularly indigenous leafy vegetables and staples face eminent extinction due to being associated with negative perceptions which include being considered as poor people's food or famine food, and being subject to backward knowledge (Darkwa and Darkwa, 2013; Demi, 2014). Wemali, (2014) noted that Kenya is experiencing a decline in the consumption of indigenous African leafy vegetables; the main reason being lack of knowledge of correct choice of foods, hence reduced dietary diversity.

5.3 Dietary diversity of women of reproductive age

Based on various food groups, starch staples and vegetables were foods commonly consumed by households. Staples and vegetables are considered the most basic diet of rural African households (Keding *et al*., 2012, with cooked maize flour (*Ugali*) and vegetables as the socially acceptable main meal (Ohna, Kaarhus and Kinabo, 2012). The high consumption of staples may suggest that diets in the study sites were mainly based on starchy foods. Diets in developing countries have been documented to be predominantly cereal based (Ekesa, Blomme and Garming, 2011). The high consumption of starchy staples increases the risks for micronutrient deficiencies as such diets have low concentrations of micronutrients nutrients. The consequences of consuming such a diet is usually associated with impaired growth, development, and body's resistance to infections (Mbwana *et al*., 2016).

Nuts and seeds which are rich in B vitamins, unsaturated fatty acids, fiber and minerals which have unique health benefits were rarely consumed by women. The low intake of these foods could be explained by low production of nuts and seeds (0.3%) in the study area. Vitamin A rich foods were cultivated by more households (26.4%) but consumed by less participants (14.1%). The same was reflected in dairy products, eggs, meat, poultry and fish where the production of these foods was higher (Table 8) compared to consumption (Table 9). The possible explanation for this finding could be a low level of knowledge or lack of it on the utilization of locally available foods. Lack of knowledge on the locally available nutrient-rich foods, and how best to utilize them in the diet, has resulted in these foods being underutilized and neglected (Odhiambo *et al*., 2016; Waswa *et al*., 2015; Termonte *et al*., 2012; Frison *et al*., 2006).

Although the level of agro-biodiversity was different between the low and high agro-ecological zones, the dietary diversity of the women remained the same. This finding alludes to the fact that availability of food from the farm does not always translate to better dietary diversity. The study results are also similar to a previous report from DR Congo (Termote *et al*., 2012), where the researchers found that a rich biodiverse environment did not contribute substantially to better diets among rural women. This lack of association could be attributed to agro-biodiversity measures not accounting for crop failure. Crops may be cultivated but households may not harvest due to crop failure caused by factors such as unfavorable climatic change and therefore cultivated crops may end up not contributing to household diets. It is also possible that the cultivated crops or reared animals may not be consumed by household members as they may be sold to earn income to the household. Common to both wealthy and poorer households is the selling of farm produce, especially for poorer households immediately after harvest season (Leavy and Poulton, 2007).

This study demonstrated the existence of low dietary diversity among women of reproductive age which suggests poor diet quality. Similar patterns have been reported in South Africa, Ethiopia, Vietnam, Burkina Faso, and Northern Uganda; hence it is relatively evident that poor dietary diversity is a feature of many developing countries (Chakona and Shackleton, 2017; Weldehaweria *et al*., 2016; Nguyen *et al*., 2014; Labadarios *et al*., 2011; Kennedy *et al*., 2009). Poor dietary diversity is well recognized as a critical factor for maternal undernutrition. Maternal undernutrition is a major predisposing factor for morbidity and mortality in women, notably caused by inadequate food intake, poor diet quality and frequent infections (KNBS and ICF Macro, 2015; Tavuringa, Muchenje and Mushunje, 2013). Importantly, malnourished women are at higher risk of infections, pregnancy complications, labour problems, and they recover more slowly from illnesses (KNBS and ICF Macro, 2015), hence the need for interventions to diversify their diets.

5.4 Nutritional status of women of reproductive age

Maternal nutritional status plays an important role in women and children's health. In this study, 11.8% of the women were underweight, 59.3% had normal BMIs and the rest (28.8%) were either overweight or obese. The prevalence of underweight in this study is slightly higher than the national level (9%). However, the prevalence of overweight was marginally lower than that documented nationally among women of reproductive age (33%). The possible explanation for the lower level of overweight/obesity is likely because the study participants were from a rural area. Urban women are more likely to be overweight/obese (43%) than rural women (26%) (KNBS and ICF Macro, 2015). Similar trends have being documented in Ghana, for example, systematic review and meta-analysis revealed that overweight among urban women was 11% higher than rural women, while obesity was two times higher in urban relative compared to rural women (Ofori-Asenso *et al*., 2016). The increasing prevalence and trends of overweight and obesity in Africa may be attributed largely to rapid urbanization and its associated nutritional transition (Amugsi *et al*., 2017). Urbanization and nutrition transition are characterized by increased intake of energy-dense foods that are high in fat and decreased physical activity, which are documented risk factors for overweight and obesity (Yadar and Krishnan, 2008).

There were marked differences in the prevalence of undernutrition and overweight in the two study areas, with low potential area citing higher level of underweight compared to high potential area. One of the probable reason could be due to lower level of socio-economic status of low potential area compared to high potential area as indicated by wealth index. Majority of the households in poorest category were from low potential area compared to high potential zones. Thinness is more common among women in the lowest wealth quintile and is inversely related to wealth. Women in the lowest wealth quintile (22%) are 5 times as likely to be thin compared to women in the highest wealth quintile (4%) (KNBS and ICF Macro, 2015). However this is not always the case, studies suggest that the distribution of underweight by socio-economic status is changing (Amugsi *et al*., 2017; Jone-Smith *et al*., 2012). For instance, high prevalence of overweight and obesity has been documented among low socio-economic populations. A study in urban poor settlements in Nairobi, Kenya confirmed high levels of overweight and obesity among women (Kimani-Murange *et al*., 2015). Another study using data from seven African countries showed that the increase in overweight and obesity was higher among the poorest compared with the richest population group (Ziraba, Fotso and Ochako, 2009). Another possible cause of high prevalence of overweight and obesity in high potential areas could be due to physical inactivity or sedentariness. Most of the women from high potential areas were employed as compared to women from low potential areas who depended mainly on farming and casual labour. Indeed, sedentary lifestyle has been linked to the increasing burden of overweight and obesity in low-income and middle-income countries (Amugsi *et al*., 2017; Abrha, Shiferaw and Ahmed, 2016).

The prevalence of both underweight and obesity in this study is a clear manifestation of the double burden of malnutrition among women of reproductive age. This double burden of malnutrition could be explained by intake of poor quality diets that are low in diversity by women (Table 9). The trend is also evident at national level where 9% of women aged 15-49 years are underweight, 33% of the women overweight with a further 10% of them being obese (KNBS and ICF Macro, 2015). This trend is mainly attributed to changes in food production and consumption patterns; which have contributed to increased consumption of diets based on a limited number of energy-rich staples, over reliance on processed foods and greater use of edible oils and sugar-sweetened beverages (Fanzo and Mattei, 2012; Popkin *et al*., 2012). These shifts in diets consumption are major contributing factors to the escalating problems of obesity which are now increasingly found in tandem to micronutrient deficiencies and undernutrition in developing countries (Fanzo and Mattei, 2012).

5.5 Relationship between socio-demographic factors, agro-biodiversity and dietary diversity

In bivariate analysis, wealth index, farm size and agro-biodiversity indicators weakly associated with dietary diversity. However, the relationship was not revealed in multivariate analysis. This apparent lack of significant association may be because other factors in the model moderated the relationship. Multivariate logistic regression model showed that, in low agricultural potential area, only woman's education level positively influenced dietary diversity while the household gender, woman's education level, woman's age and family size influenced dietary diversity in high potential area. In the two zones, educated women were more likely to consume a diet high in diversity. Educated women assign a significantly more substantial proportion of their household food budget to nutritious foods (Morseth *et al*., 2017; Mbwana *et al*., 2016). This is mainly because they tend to have greater awareness and understanding of nutritional health benefits (Tavuringa, Muchenje and Mushunje, 2013), and are also empowered. Improvement in women's empowerment have been associated with enhancement in maternal and child nutrition outcomes (Van den Bold *et al.*, 2013). Woman's education is recognized as a critical factor for woman empowerment. This enables them to gain great access and control over financial and knowledge resources to improve their lives (Ashraf and Farah, 2007).

In high potential area, women dietary diversity was also influenced by the gender of the household head, with those headed by men having higher dietary diversity. Similar findings were reported in a study in Ethiopia (Haidar and Kogi-Makau, 2009) which assessed nutritional parameters in relation to gender differences. In that study, dietary intake was disaggregated by household type, and it was demonstrated that the nutrient intake in male-headed households was relatively better than in female-headed households. Such manifestations are usual as male-headed households have the advantage of more sources of income instead of one, especially when both partners are involved in revenue generating activities. The combined income of both spouses probably offers them better opportunities to access a variety of different food products thus increasing their dietary diversity. The increased household size negatively influenced women dietary diversity in high potential area. This could partly be explained by the fact that as the number of family members' increases, the intra-household food distribution is affected and food may become more limited which in turn would limit access to different food groups.

A positive association between farm production diversity and dietary diversity should be plausible. As smallholder farm households tend to consume a considerable share of what they produce, agro-biodiversity should then directly translate into consumption diversity and consequently improve dietary quality through this production pathway (Sibhatu and Qaim, 2018; Kissoly *et al*., 2018; Jones, 2017; Powell *et al*., 2015; Sibhatu, Krishna and Qaim, 2015). However, in this study, there was no significant association in the regression analysis between agro-biodiversity measures and dietary diversity of women in the two agro-ecological zones. This lack of connection could be attributed to market diversity, which is a major mediating factor in the relationship between agro-biodiversity and dietary diversity (Sibhatu and Qaim, 2018; Kissoly *et al*., 2018; Jones, 2017; Sibhatu, Krishna and Qaim, 2015). Taking market diversity into account, the relationship between agro-biodiversity and dietary diversity becomes more complicated (Sibhatu and Qaim, 2018; Kissoly *et al*., 2018; Jones, 2017; Koppmair, Kassie and Qaim, 2017; Sibhatu, Krishna and Qaim, 2015). Instead of producing foods from all food groups at home, farm households buy food from the market which can contribute to improving dietary diversity. However, markets can worsen dietary diversity if the households sell the nutritious food products to obtain the income to cater for the family needs like school fees. It is a typical practice in both wealthy and poor households to sell their farm produce mostly after the main harvest seasons (Ng'endo, Bhagwat and Keding, 2016). A study by Sibhatu, Krishna and Qaim. (2015) documented a negative interaction between market diversity and agro-biodiversity and confirmed that market participation by households could reduce the role of agro-biodiversity in improving dietary diversity.

The production diversity score also had no relationship with dietary diversity. Sibhatu, Krishna and Qaim. (2015) found out that when using production diversity scores instead of a simple species count, the effect on dietary quality got smaller in many cases and it turned insignificant. This intriguing finding concurred with the results of this study. The production diversity score measures the number of different food groups produced on a farm, so one could have expected the effect of production diversity on the number of food groups consumed in the farm household to be stronger. The fact that this is not the case reveals that the subsistence pathway is not the only mechanism underlying the production-consumption relationship (Kissoly *et al*., 2018; Jones, 2017; Sibhatu, Krishna and Qaim, 2015). Market diversity through purchase or sale of diverse food products seems to be another critical factor that could contribute to improving dietary quality. There is need for further research to elucidate these dynamics and to comprehend the regional-specific factors that may influence the role of markets in moderating the relationship between agro-biodiversity and dietary diversity.

The linkages between agro-biodiversity, market diversity and dietary diversity are complex (Sibhatu and Qaim, 2018; Kissoly *et al*., 2018; Jones, 2017; Koppmair, Kassie and Qaim, 2017; Sibhatu, Krishna and Qaim, 2015). For instance, in some cases, agro-biodiversity in the farm household may be high and a wide range of food crops available in the markets but does not automatically translate to higher DDS (Kissoly *et al*., 2018; Ngendo, Bhagwat and Keding, 2016; Termote *et al*., 2012). Factors such as intra-household resource and food allocation may come into the interplay further complicating this relationship. Even when the food is available in the farms or markets, the intra-household allocation of food may disfavour women access to nutritious foods due to cultural beliefs, economic constraints and low decision making. For example, in many regions of South Asia, women find themselves in subordinate positions to men, hence they tend to eat the least, or to eat leftovers after other family members have eaten (Asian Development Bank, 2013; Mathur, 2011). Also, women are largely excluded from making decisions, have limited access and control of resources and are restricted from mobility by their husbands or sometimes by in-laws (Ayesha, 2016; Fikree and Pasha, 2004). This compromised access leads women to making suboptimal decisions with regard to food choices which may subsequently cause poor dietary intake.

5.6 Association between dietary diversity and nutritional status

The present study findings showed a significant relationship between women's dietary diversity and nutritional status in high potential area. A higher proportion of women with normal BMI met the recommended minimum dietary diversity compared to those who were underweight across. This study results are in line with similar findings reported previously by Shashikantha *et al*. (2016) in India. However, a significant positive relationship was not demonstrated in low potential area. The possible explanation could be due that the low potential area had lower level of socio-economic status compared to high potential area. Dietary diversity has been shown to be strongly associated with household socio-economic status (Morseth *et al*., 2017; Ogechi and Chilezie, 2017; Amugsi *et al*., 2016; Torheim *et al*., 2004), and links between socio-economic status and nutritional status have also been established (Acharya *et al*., 2017; Amugsi *et al*., 2016).

Interpretation of associations between dietary diversity and nutritional status is therefore complicated by the fact that both are strongly linked to household socio-economic factors.

Families with greater incomes and resources tend to have more diverse diets, but they are also likely to have better access to health care, and better environmental conditions which independently improve nutritional status. The analysis of demographic health surveys (DHS) data confirms that dietary diversity is generally associated with nutritional status, and that the association remains when household wealth and welfare factors are controlled for by multivariate analyses (Arimond and Ruel, 2004). Findings of other studies confirm that there is an association between dietary diversity and nutritional status that is independent of socio-economic factors and that dietary diversity may indeed reflect diet quality (Sawadogo *et al*., 2006; Penafiel *et al*., 2011). This association has been observed in a range of countries and populations with widely different dietary patterns (Nithya and Bhayani, 2018; Ogechi and Chilezie, 2017, Amugsi *et al*., 2016; Ali, Thaver and Khan, 2014; Azadbakht and Esmaillzadeh, 2011; Azadbakht *et al*., 2005; Arimond and Ruel, 2004). Overall, it is evident that dietary diversity plays a crucial role in determining nutritional outcomes. Thus, dietary diversity should be emphasized as potential intervention to improve nutritional status.

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

6.1 Introduction

This chapter presents conclusions and recommendations made from the study findings. It also gives suggestions for further research in this area.

6.2 Conclusions

From the study results, the following conclusions were made:

i. The level of agro-biodiversity was significantly higher in high potential area compared to low potential area (using Shannon-Wiener index).

ii. The production of indigenous staples and vegetables was on the decline and there was low diversity within the legume species across the two agro-ecological zones

iii. Overall, diet quality was poor among the women as reflected by the low mean dietary diversity scores. The diets consumed by women were mainly based on starchy staples with low consumption of animal source foods, nuts and seeds, vitamin A rich foods, fruits and vegetables.

iv. Although the level of agro-biodiversity was different between the low and high agro-ecological zones, the dietary diversity of the women remained the same.

v. The double burden of malnutrition exists among women of reproductive age across the two different agro-ecological zones.

vi. Agro-biodiversity indicators did not have significant influence on the dietary diversity of women of reproductive age in the two different agro-ecological zones. However, different factors influenced dietary diversity of women in each agro-ecological zone. In low agricultural potential area, woman's education level positively influenced dietary diversity while in high agriculture potential area, household head gender, woman's education level, woman's age and household size influenced dietary diversity.

vii. Women’s dietary diversity positively associated with nutritional status in high potential area. A higher proportion of women with normal body mass index met the recommended minimum dietary diversity compared to those who were underweight across the two agro-ecological zones.

6.3 Recommendations

The following are recommendations based on study conclusions:

i. The Ministry of Agriculture and Ministry of Health in Rongai Sub-County to promote production and consumption of indigenous crops among smallholder farm households to improve their farm agro-biodiversity and dietary diversity.

ii. The Rongai Sub-County Health team and community nutritionist to promote dietary diversity and modification of diets using locally available foods to ensure that available agro-biodiversity is effectively utilized.

iii. The Sub-County Ministry of Health and community nutritionist to carry out nutrition education with a component of behaviour change to address the underlying constraints leading to intake of poor diets that are low in diversity among women.

iv. There is need of Nakuru County government and other stake holders to come up with double-duty actions and policy to reduce the risks and/or the double burden of malnutrition.

v. The Nakuru County government and other stake- holders to consider different factors affecting women's dietary diversity in each agro-ecological zone such as education level, household gender, family size and age when developing agriculture and nutrition interventions and policies.

6.4 Suggestions for further research

The following research areas should be carried out to better understand dynamics of the relationship between agro-biodiversity, dietary diversity and nutritional status;

i. Contribution of agro-biodiversity to nutrient intakes of individuals/ population groups in different agro-ecological zones.

ii. Assessment and documentation of the knowledge, practices and value of indigenous crops within households and community level.

iii. Investigation of regional-specific factors that influence the role of markets in moderating the relationship between agro-biodiversity and dietary diversity.

iv. Application of improved designs such as cluster randomized controlled trials and quasi-experimental designs that would help in controlling confounding factors to better understand the causal mechanisms and relationship between agro-biodiversity and dietary diversity.

v. Assessment of seasonal differences in farm diversity and household diets.

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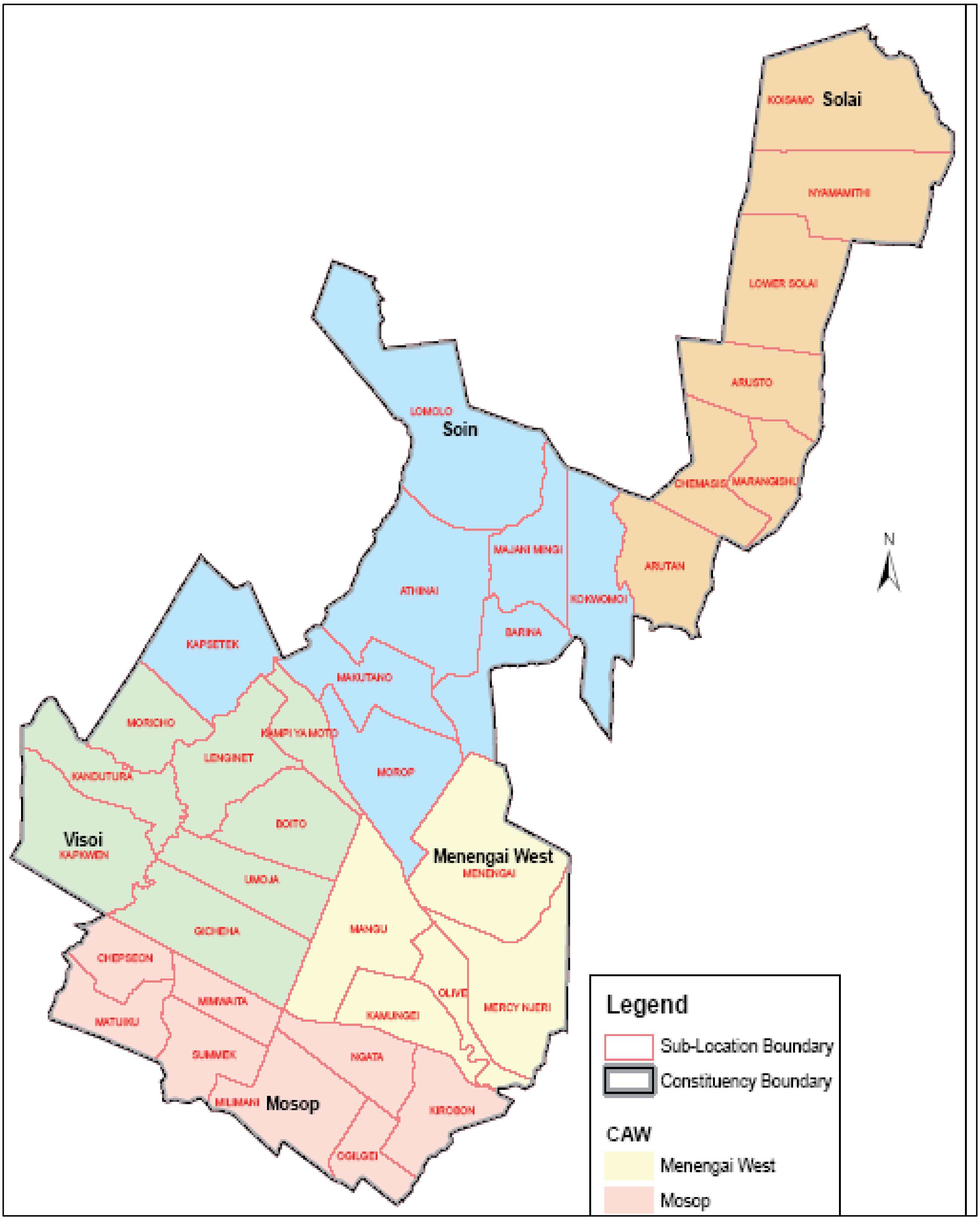
APPENDICES

Appendix 1: A map of Rongai Sub-County.



(Nakuru County Integrated Development Plan, 2013).

Appendix 2: Household Structured Questionnaire.

Agro-Biodiversity Assessment Household Questionnaire.

1. General Information		
	Household ID	
	Location	
	Sub location	
	Village	
	Date of interview (dd/mm/yyyy)	
	Household head gender *1=male; 2=female*	
	Household head age*(number)*	
	Household head years of education*1= none; 2= primary;3=secondary; 4= tertiary*	
	Household head religion *1 = Muslim; 2 = Christian; 99 = other (specify)*	
	Household head ethnicity*1 = Kalenjin; 2= Kikuyu; 3= Kisii; 99 = others (specify)*	
	Woman of reproductive age *(number)* (*if different from household head*)	
	Woman's of reproductive age-years of education (*if different from household head*) *1= none; 2= primary; 3=secondary; 4= tertiary*	

2. Number of Household Members					
Age group	Female	Male	Age group	Female	Male
0-5			18-60		
6-18			60+		

In the past 12 months, has a member of the household (only members that were counted in the table above) lived or migrated outside the Sub-County? *(1=Yes, 2=No)*	

3.1 Farming land information						**HHID____________**
Ask the farmer to draw their farm(s)/plots/ kitchen gardens and give a code (letter) to each land used for farming (Only the land that is/can be used for farming, also fallow or grazing land!!, do NOT inventory land that is used for building or land that is rented out); Identify the land type (farm; plot used for farming; kitchen garden, woodlot).;Assign land codes as F1, F2, etc. (for the farm lands) ; P1, P2, P3, etc. (for the plot lands used for farming)HG1, HG2, HG3, etc. (for the kitchen gardens) and W1, W2,W3 for the woodlands; Ask the farmer to identify for each land used for farming whether it was cultivated/harvested during the long rains season 2015 and/or during the short rains season 2015. For kitchen gardens/woodlots the other harvest column (S3) might be more appropriate as they do not necessarily follow the agricultural seasons.						
Land type *(farm; plot; home garden; forest)*	**Land code** (F1,F2,F3 ; P1,P2,P3; HG1,2,3; W1, W2, W3))	**Long rains season April-June 2015** ***(Season Code = S1)*** **Land cultivated ?** *1 = yes; 2= no*	**If not cultivated during long rains 2015, what was the use of the land?** *1= fallow; 2 = grazing land; 3 = other (specify)*	**Short rains season Sept – Nov 2015** ***(Season Code =S2)*** **Land cultivated?** ***1 = yes; 2= no***	**If not cultivated during short rains 2015, what was the use of the land?** *1= fallow; 2 = grazing land; 3 = other (specify)*	**Other harvest cycle?** ***(Season Code =S3)*** *1 = year round* *2 = other (specify)*

4.1 Useful species grown on farm, by land and season Season ___________code:_________Land code:____________ HHIDS:___________							
Tell respondent "Please list all useful species - that were grown during the long rains season 2015 on [land X1]. Useful species are those that are used for food, animal feed, fuel, construction, or other purposes". Record each species in a separate column in the row 'Species Name' and add the language in which the species name was cited in brackets. Ask "Are there any other species grown on that plot in that season?" Record species and language in brackets. And then ask "Are there any useful perennial species that are harvested on or bordering this plot during the long rains 2015?" Record each species. Use additional sheets of section 4.1 to accommodate number of species on the plot in the season, if necessary. Subsequently, ask all the questions in the table hereunder for each species. Use Code '88' if the respondent does not know the answer. Begin a separate sheet 4.1 for the next land (farm, plot, home garden) in the same season S1 until covering all the lands that were cultivated in that season. Subsequently, take a separate sheet 4.1 for each land that was cultivated in the second season S2 (short rains season 2015) and finally do the same exercise for all home gardens that fell under category S3 in the former table.							
	Species Name + (language)*						
	If species is not a tree, What is the total area per plot the species planted? (#, unit)						
	If species is a tree, How many trees are on or bordering the plot? (number)						
	What is the species used for? *(1=Food, 2=animal feed, 3=Medicine, 4=Fuel,5= Mulch, 6=Construction material, 99=other (specify))*						

5.Domesticated animal species maintained by the household **HHID:______________**							
Ask respondent "Please list all useful animal species that you maintain on farm (including birds and, insects). Useful animal species are those that are used for food, fuel, fertilizer, or any other use". *Record each species in a separate column in the row 'Name of Animal Species'. Use additional sheets to accommodate the number of species collected. Code '88' for "do not know".*							
	Name of animal species + (language)						
	How many animals of this species do you currently own? *(number)*						
	How is the animal or animal product used? *(1=Food, 2=Dung Fuel, 3=Fertilizer, 4=sale; 5=smearing;99= Other (specify)*						
	If milk produced, what is it used for? *(1=household consumption, 2=sale, 3=both, 4=not produced, 99=others (specify))*						
	If meat produced, what is it used for? *(1=household consumption, 2=sale, 3=both, 4=not produced, 99=others (specify))*						

6 Household Income	**HHID_________**
	Ask respondent "Could you please indicate which bracket best represent your total household income [read out each income bracket]". *Circle the corresponding income range.*
	Less than 3500 Kshs/month
	Between 3500 and 7000 Kshs/month
	Between 7000 and 14000 Kshs/month
	More than 14000 Kshs/month

7 HH sources of income		
	For each item below ask "What is the contribution of [Income source] to total household income - is it a major, medium, or minor contribution?" *Code '88' for "do not know".*	
	Income source	**Code**
	Sale of agricultural products *(1=Major, 2=Medium, 3=Minor,4= does not contribute)*	
	Off-homestead Agriculture labour and/or irregular employment *(1=Major, 2=Medium, 3=Minor,4= does not contribute)*	
	Regular employment *(1=Major, 2=Medium, 3=Minor,4= does not contribute)*	
	Business self-employed *(1=Major, 2=Medium, 3=Minor,4= does not contribute)*	
	Remittance *(1=Major, 2=Medium, 3=Minor,4= does not contribute)*	
	Others *(1=Major, 2=Medium, 3=Minor,4= does not contribute)*	

8 Household characteristics		
Where possible interviewer to directly observe and respond.		
	What is the floor of your main residence made of?*(1=Earth floor; 2=stone; 3=cement;4= tile; 5=wood; 99= other (specify))(1ANSWER)*	
	What are the walls of your main residence made of?*(1=Wood; 2=earth wall; 3=iron sheet; 4=stone; 5=brick; 6=cement; 99=others (specify)(1ANSWER)*	

	What is the roof of your main residence made of?*(1=Straw/grass; 2=iron sheet; 3=tile; 4=cement; 5=bamboo; 99=others (specify))(1ANSWER)*	
	What kind of toilet facility does your household use?*(1=No facility/bush/field, 2=open pit/traditional pit latrine, 3=improved pit latrine (VIP), 4=pour flush latrine, 5=flush toilet, 99=other (specify))*	
	Is your toilet facility located within your dwelling, or yard or compound? *(1=Yes, 2=No)(1ANSWER)*	
	Is there electricity in the house? *(1=Yes, 2=No)(1ANSWER)*	
	What type of fuel does your household mainly use for cooking? *(1=Electricity, 2=LPG/Natural gas, 3=Biogas, 4=kerosene, 5=coal/lignite, 6= charcoal, 7=firewood/straw, 8=dung, 99=other (specify))*	

Asks the respondent "Do you own a [asset name] ___?" Record 1=Yes, 2=No.

	Asset name	Yes/No		Asset name	Yes/No
	Cooker/gas stove			Car/truck	
	Refrigerator			Motorcycle	
	Radio			Bicycle	
	Television			Hoe	
	DVD player			Spade/shovel	
	Mobile phone			Plough	
	Sofa set			Sprayer pump	
	Sewing machine			Water pump	
	Computer			Wheelbarrow	
	Generator			Kerosene stove	
	Solar panel			Other _____________	
	Car battery			Other _____________	
	Improved modern jiko			Other _____________	

Appendix 3: Qualitative 24 Hour Recall Questionnaire.

Quantitative 24-hour recall Household ID------------Date--------

Interview Date:		Day of the week for recall:	
Household ID		Recall number: 1 2	
Was yesterday a celebration or feast day where you ate unusual foods?1=Yes 2= No			|_|
Were you unwell yesterday? 1=Yes 2= No			|_|

If yes stop there and proceed to another household

Quick list for the respondent

Time	Dish/food

a. **Age in years_________ Recall No._____________ Day of Recall ______________**

Page _____of ________

Time	**[1]Meal code**	**[2]Place of preparation**	**Dish**		**Ingredients**				[3]Preparation method
			Description of dish/food	Description	Description	Description	**[4]Source**	**[5]Wild**	

[1]Meal code: 1=before breakfast 2=breakfast 3=midmorning 4=lunch 5=afternoon 6=dinner/supper 7=before sleep 8=during night

[2]Place: 1=home 2=outside home

[3]Preparation 1=raw 2=boiled 3=steamed 4=fried 5=roasted 6=others (specify)

[4]Source: 1=own production 2=purchase 3=Purchased (unprocessed) 4=gifts/aid 5=others (specify)

[5]Wild: 1=yes 2=no

Appendix 4: Women dietary diversity questionnaire.

	Food Group	EXAMPLES	**YES(1) /NO (0)**
1	Grains, white roots and tubers, and plantains	Cereals; Bread, *mandazi* or any food made from millet, oats, sorghum, maize, rice, wheat (e.g. *ugali*, rice porridge) spaghetti or other foods made from grains, Tubers;White potatoes, white yams, cassava, arrowroot/nduma, green banana	
2	Pulses (beans, peas and lentils)	Mature beans or peas (fresh or dried seed), lentils or bean, green grams/*ndengu*, cowpea, soyabean, black bean/*njahi*	
3	Nuts and seeds	Any tree nut, groundnut/peanut or certain seeds, or nut/seed, macadamia	
4	Dairy Products	Milk, cheese, yoghurt or other milk products, fermented milk/*mursik*	
5	Meat, poultry and fish	Liver, kidney, heart or other organ meats or blood-based foods, including from wild game, Beef, tripe/*matumbo*, blood sausage/ *mtura*, pork, lamb, goat, rabbit, wild game meat, chicken, duck or other bird, Fresh or dried fish, shellfish or seafood, *omena*	
6	Eggs	Eggs from chicken, duck, guinea fowl or any other egg	
7	Dark green leafy vegetables	Dark green leafy vegetables, including wild ones locally available e.g. cassava leaves, beans leaves, sweet-potato leaves, *kanzira kales/sukumawiki*, *managu*, *saget*, *spinach, terere, nderema/nderemek, mrenda, mito*	
8	Other vitamin A-rich fruits and vegetables	Vitamin A rich fruits; e.g. pawpaw, ripe mango, loquat, passion fruit (ripe), tree tomato Vitamin A rich vegetables; e.g. carrots, pumpkin Vitamin A rich tubers; e.g. sweet potatoes (orange fleshed)	
9	Other vegetables	Other vegetables; e.g. cabbage, tomato, French beans, cucumbers, eggplant/*bringanya*, garlic, green pepper/*hoho*, onion	
10	Other fruits	Other fruits; e.g. oranges, avocados, guavas/*mapera*, apples, ripe banana, coconut flesh, grapes, lemon, pineapple, pears, plum, strawberry, tangarine, watermelon	

Appendix 5: Anthropometric Measurements Recording Form.

Household ID_________ Individual ID______ Assessment date________

Anthropometric Measurements Recording form

1. **Age _____________________**

	1st reading	2nd reading	3rd reading	Average
Height (cm)				
Weight (Kg)				

Notes:

Appendix 6: Approval Letter from Graduate School Egerton University.

EGERTON UNIVERSITY

Tel: Pilot: 254-51-2217620
254-51-2217877
254-51-2217631
Dir.line/Fax: 254-51-2217847
Cell Phone

P.O. Box 536 - 20115
Egerton, Njoro, Kenya
Email: bpgs@egerton.ac.ke
www.egerton.ac.ke

OFFICE OF THE DIRECTOR GRADUATE SCHOOL

Ref: HM18/71519/14

Date: 27th June, 2017

Ms. Maureen Wanjiru Gitagia
Dept. of Human Nutrition
Egerton University,
P. O. Box 536,
EGERTON.

Dear Ms. Gitagia

RE: CORRECTED PROPOSAL

This is to acknowledge receipt of two copies of your corrected proposal entitled **"Contribution of Agro-Biodiversity to Dietary and Nutritional Status of Women of Reproductive Age in Rongai Sub-County, Kenya."**

You are now at liberty to commence your fieldwork. However note the following: -

1. You must register each semester.
2. Pay your fees every semester.
3. Submit progress reports every four (4) months (Masters) or six (6) months (PhDs). Without this, your thesis/project will not be accepted. Forms are available at the Board.
4. You are expected to publish one (1) paper (Masters) or two (2) papers (PhD) in peer-reviewed journal and present them before issuance of "Intent to Submit Thesis/Project" form by the Board.

Thank you.

Yours sincerely

BOARD OF POST GRADUATE STUDIES
27 JUN 2017
EGERTON UNIVERSITY P.O. Box 536, EGERTON

Prof. P.K. Cheplogoi
DEPUTY DIRECTOR, BOARD OF POSTGRADUATE STUDIES

c.c. Dean, Health Science
COD, Human Nutrition

Supervisors

PKC/vk

Transforming Lives Through Quality Education
Egerton University is ISO 9001:2008 Certified

Appendix 7: Ethical Clearance from Egerton Research Ethics Committee.

EGERTON **UNIVERSITY**

TEL: (051) 2217937
FAC: 051-221792

P. O. BOX 536
EGERTON

20th November 2015

Ref: EU/DVRE/009

Dr. Maureen Cheserek
Food & Nutrition Dept.
EGERTON UNIVERSITY

RE: APPLICATION FOR ETHICAL APPROVAL OF RESEARCH PROJECT

Reference is made to your application for Ethical clearance of your Research Project entitled ***"Agrobiodiversity and dietary diversity for improved nutrition status of mother infant dyads in Rongai Sub-county*** The Egerton University Research Ethics Committee met on 10th November 2015 and considered your application.

It was observed that:

1. A similar topic had been cleared earlier by the EUREC (REF: - EU/DVC/RE/009 of 22nd July 2013).
2. Methodology: there is inconsistency in the sample size. It is not clear whether the FGD of 10 groups and approx. 10 individuals includes the 800 indicated in section 4(b). There is also mention of 400 HH in section 4.4.
3. There is no evidence of intrusive and extractive sampling as the study is limited to interviews. There is need for an informed consent/assent as appropriate (This form is not attached in the application form)
4. The application should also be explicit in ensuring privacy and confidentiality of the information collected.

It was decided that the Project be approved for implementation.

Please further note that the Standard Operating Procedures (SOPs) requires that you submit progress reports of your study to the Committee. You are also required to obtain Research permit from NACOSTI.

Prof. J. K. Kipkemboi
CHAIRMAN – RESEARCH ETHICS COMMITTEE

cc. DVC (R&E)] to see in file
Director Research]

JKK/pao

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Appendix 8: Research Authorization from National Commission for Science, Technology and Innovation.

NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY AND INNOVATION

Telephone: +254-20-2213471, 2241349, 310571, 2219420
Fax: +254-20-318245, 318249
Email: secretary@nacosti.go.ke
Website: www.nacosti.go.ke
When replying please quote

9th Floor, Utalii House
Uhuru Highway
P.O. Box 30623-00100
NAIROBI-KENYA

Ref: No. **NACOSTI/P/16/48994/9498**

Date: **15th February, 2016**

Dr. Maureen Jepkorir Cheserek
Egerton University
P.O. Box 536-20115
EGERTON.

RE: RESEARCH AUTHORIZATION

Following your application for authority to carry out research on ***"Agrobiodiversity and dietary diversity for improved nutritional status of mother infant dyads in Rongai Sub County"*** I am pleased to inform you that you have been authorized to undertake research in **Nakuru County** for a period ending **15th February, 2017.**

You are advised to report to **the County Commissioner and the County Director of Education, Nakuru County** before embarking on the research project.

On completion of the research, you are expected to submit **two hard copies and one soft copy in pdf** of the research report/thesis to our office.

DR. M. K. RUGUTT, PhD, HSC.
DIRECTOR-GENERAL/CEO

Copy to:

The County Commissioner
Nakuru County.

The County Director of Education
Nakuru County.

Appendix 9: Introductory letter and consent form

Contribution of Agro-biodiversity to Dietary Diversity and Nutritional Status of Women of Reproductive Age in Rongai Sub-County, Kenya

Hello, my name is Maureen Gitagia, a student from Egerton University. I will conduct a survey on contribution of agro-biodiversity to dietary diversity and nutritional status of women of reproductive age in Rongai Sub-County, as part of my university degree. The study will document the locally available food varieties in this area, the dietary diversity and nutritional status of women. You have been selected to represent the women in the village for this study. I will ask questions about the food species that are produced in your household's farms or gathered from wild and the foods that you consume. Your height and weight will be taken and recorded. The questionnaire will take 45-60 minutes. Whatever information you shall provide will be kept strictly confidential and will not be shown to any other persons.

This study carries no physical or emotional risk to you, your household or the community. Your participation in this study is voluntary and there will be no direct benefit. However, the information that will be gathered from this research will be used to inform policy makers of sustainable interventions to improve the quality of women's dietary diversity and nutritional status in your sub- county.

This study does not interfere with your rights in any way; you can decide to participate in this study or not to. You are also free not to answer any questions and to withdraw from the interview at any stage of the interview. If you have any questions, comments, or complaints about the study, please contact Maureen Gitagia 0715660350.

Participant consent:

I have read and understood the above information. I agree to participate in the research study.

Participant

Name____________________________ Sign ___________________ Date_________________

Confirmation of consent;

Researcher: Maureen Gitagia

Name____________________________ Sign ___________________ Date_________________

Appendix 10: A harvested maize farm in Makutano sub-location in low potential area of Rongai Sub-County.

Appendix 11: A banana farm in Mangu sub-location in the high potential area of Rongai Sub-County.

Appendix 12: Publication

Gitagia, M. W., Rose Chepchirchir Ramkat, D. M. M., Termote, C., Covic, N., and Cheserek, M. J. (2019). Determinants of dietary diversity among women of reproductive age in two different agro-ecological zones of Rongai Sub-County, Nakuru, Kenya. *Food and Nutrition Research*, *63*.