Relationships between agrobiodiversity, dietary diversity and nutritional status in Tanzania

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The candidate confirms that the work submitted is her own and that appropriate credit has been given where reference has been made to the work of others.

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Abstract

Background: Agrobiodiversity is important for biodiversity conservation and sustainable agriculture. Increasing agrobiodiversity may also improve dietary diversity and nutritional status in low income countries but research is lacking in this area. To fill this knowledge gap, this study explores relationships between agrobiodiversity, dietary diversity and nutritional status in Tanzania. The research investigates 1) the relationships between agrobiodiversity, dietary diversity and nutritional status in children in two villages in rural Tanzania and 2) the relationships between land cover, dietary diversity and nutrition in under five year olds in a nationally representative sample in Tanzania.

Methods: A cross-sectional survey was conducted in 122 randomly selected households in Minyenye village, Singida district and Mbwei village, Lushoto district. Female heads of households were interviewed to collect quantitative and qualitative data on demographics, livelihoods, complementary feeding and household food sources. Dietary diversity was calculated from 24 hour dietary recalls which were collected for the respondent and their oldest child under five. Agrobiodiversity data were systematically collected using the point intercept method. All plants, both intentional crops and other plants, growing on the household's farms at the time of data collection were measured and Shannon Biodiversity Indices were calculated. In addition to these indices, the food sources section of the questionnaire was used to calculate household crop and animal diversity scores. Heights and weights were measured in all family members and MUAC was collected for all children under 15 years old. Relationships between these factors were explored using regression analyses. At the national level relationships between land cover, from GlobCover 2009, and dietary diversity and nutrition, from the 2010 Tanzanian Demographic and Health Survey (DHS), were investigated using spatial and regression analyses.

Results: No significant associations were seen between dietary diversity and nutritional status in either village and dietary diversity was negatively associated with height for age z-scores in the DHS analyses. No significant associations were seen between agrobiodiversity and dietary diversity. Agricultural, but not forest, land cover was associated with dietary diversity. Associations between both agrobiodiversity and land cover and child nutritional status are complex. In Minyenye, agrobiodiversity was positively associated with children's height for age while in Mbwei these were negatively associated with children's body mass index (BMI) z-scores. More agricultural and forest land cover was associated with higher weight for height, however more agricultural land cover was associated with lower height for age. Positive associations were seen between eating and rearing animals and dietary diversity but negative or no associations were seen with nutritional status. Selling crops was positively associated with dietary diversity but showed mixed associations with nutritional status at the local village scale.

Conclusion: Study results provide a word of caution for those attempting to increase agrobiodiversity to improve diet and nutritional status. The effectiveness of agricultural interventions aimed at improving nutrition through improvements in agrobiodiversity can only be evaluated in light of the multiple determinants of nutritional status. The current study's results illustrate the complexity of the pathway from food production through consumption to nutrient utilization in low income countries.

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List of Abbreviations

BMI	Body Mass Index
CI	Confidence Interval
COSTECH	Commission for Science and Technology
DDS	Dietary Diversity Score
DHS	Demographic and Health Survey
EA	Enumeration Area
ESA	European Space Agency
ENVISAT	ESA Environmental Satellite
FANTA	Food And Nutrition Technical Assistance project
FAO	Food and Agriculture Organization
FFQ	Food Frequency Questionnaire
FVS	Food Variety Score
GIS	Geographic Information System
GNI	Gross National Income
GPS	Global Positioning System
HAZ	Height for age z-score
IMF	International Monetary Fund
LAZ	Length for age z-score
LCCS	Land Cover Classification System
MAR	Missing At Random
MDG	Millennium Development Goals
MERIS	Medium Resolution Imaging Spectrometer Instrument
MICE	Multiple Imputations using Chained Equations
MUAC	Mid Upper Arm Circumference

MODIS	Moderate Resolution Imaging Spectroradiometer
NBS	National Bureau of Statistics
NDVI	Normalised Difference Vegetation Index
OR	Odds Ratio
RCT	Randomised Controlled Trial
SD	Standard Deviation
SE	Standard Error
SI	Shannon Index
SPOT	Probationary System of Earth Observation
VEO	Village Executive Officer
VCF	Vegetation Continuous Fields
WAZ	Weight for age z-score
WEO	Ward Executive Officer
WHO	World Health Organisation
WHZ	Weight for height z-score
WLZ	Weight for length z-score

Chapter 1:
Introduction

1.1 Chapter summary

This first chapter introduces the background to this research and the national and regional context in which it took place. This chapter briefly summarises food security issues and nutritional status in sub-Saharan African and the relevance and measurement of dietary diversity as a marker for nutritional status. It defines agrobiodiversity and introduces the potential relevance to dietary diversity and nutritional status. Specifically, the reasons for investigating the relationships between agrobiodiversity, dietary diversity and nutritional status and research into these intersecting areas are discussed. Information is included on food security, nutrition and foods eaten in Tanzania. This introductory chapter ends with an outline of the thesis structure and a summary of the key academic contributions achieved in each chapter.

1.2 Aim and objectives

This thesis reports a study that aimed to **investigate the relationship between agrobiodiversity, dietary diversity and nutritional status in Tanzania**. Broadly, the research investigates 1) the relationships between agrobiodiversity, dietary diversity and nutritional status in children in two villages in rural Tanzania and 2) the relationships between land cover, dietary diversity and nutrition in under five year olds in a nationally representative sample in Tanzania. As a means to fill the knowledge gap on how agrobiodiversity relates to diet and health in subsistence agriculture and to improve understanding of food security in sub-Saharan Africa.

The specific objectives of this study are to:

1. Review, design and pilot a conceptual framework and suite of appropriate measurement tools to accurately measure agrobiodiversity, dietary diversity and nutrition in an Eastern Sub-Saharan Africa context.

2. Systematically assess the diversity and abundance of both cultivated and wild plants growing on household agricultural land in two villages in rural Tanzania and investigate how this is related to dietary diversity in under five year old and nutritional status in children in these villages.

3. Measure household crop and animal diversity, dietary diversity of respondents and children under five and nutritional status of children living in these villages, determine whether household produce is sold and investigate how these factors are related.

4. Investigate basic socio-demographic factors affecting dietary intake of children under five and nutrition outcomes in children in these villages.

5. Investigate the socio-demographic determinants of dietary diversity and nutritional status and explore the relationships between land cover, dietary diversity and nutritional status in children under five years at a national level, in Tanzania.

6. Integrate outcomes from this multi-scale investigation of the relationships between agrobiodiversity, dietary diversity and nutritional status, to draw conclusions that inform understandings of food security in sub-Saharan Africa.

Objectives 2, 3 and 4 were met through the primary data collection presented in chapters 4, 5 and 6. Each of these chapters, as well as chapter 7, had specific objectives to ensure they met the overall thesis objectives:

Chapter 4:

Objective 4A: To present descriptive data on the demographic, social, dietary diversity and nutritional status variables in this population to set the context for the analyses.

Objective 4B: To investigate whether dietary diversity and food variety are associated with nutritional status in under five year olds.

Objective 4C: To investigate whether complementary feeding and sanitation are associated with nutritional status in these villages.

Chapter 5:

Objective 5A: Present descriptive data on habitat, species present, farm characteristics, cross-sectional plant agrobiodiversity and crop and vegetable diversity scores in the two villages.

Objective 5B: Investigate whether plant agrobiodiversity and crop/vegetable diversity scores are associated with dietary diversity and nutritional status in children.

Objective 5C: Investigate whether selling staple crops, vegetables, fruit and other produce is associated with dietary diversity and nutritional status in children.

Chapter 6:

Objective 6A: To assess animal diversity and present descriptive data on animal product consumption and animal rearing practices in the two villages.

Objective 6B: To examine whether eating animals and animal products and animal diversity are associated with dietary diversity in respondents and under five year olds and nutritional status in children.

Objective 6C: To examine whether selling animals and animal products is associated with dietary diversity in respondents and under five year olds and nutritional status in children.

Chapter 7:

Objective 7A: To investigate whether demographic, social, agricultural and dietary factors are associated with dietary diversity and nutritional status in under five year olds in Tanzania.

Objective 7B: To investigate whether dietary diversity is associated with nutritional status in under five year olds in Tanzania.

Objective 7C: To investigate whether dietary diversity and nutritional status in under five year olds vary spatially in Tanzania.

Objective 7D: To investigate whether land cover is related to dietary diversity and nutritional status in under five year olds in Tanzania.

1.3 Food security

Much of the research in the area of food security cite the Food and Agriculture Organisation (FAO) definition for food security published in 1996: "Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life" (FAO, 1996). This definition is of global significance where many low income countries are perhaps first aiming to meet their dietary needs. Food security is often expressed in three levels: Availability, access and utilization (FAO, 1996). Since Sen's essay on entitlement to food was published in 1981 (Sen), food security research in the social sciences has shifted from food production to food access (Webb et al., 2006, Coates et al., 2006). Workshops held by the Food and Nutrition Technical Assistance (FANTA) project in 2004 and 2005 agreed on the following domains of food insecurity: Anxiety/uncertainty about and actual depletion of the household food supply; Insufficient quality, which includes variety, preferences and social acceptability; Insufficient food intake and its physical consequences; Coping strategies to increase household resources (FANTA, 2004).

The International Scientific Symposium "Biodiversity and Sustainable Diets: United Against Hunger" organised by FAO and Bioversity International in 2010 proposed a definition of sustainable diets which encompass concepts of environmental sustainability and food security: "Sustainable diets are those diets with low environmental impacts which contribute to food and nutrition security and to healthy life for present and future generations. Sustainable diets are protective and respectful of biodiversity and ecosystems, culturally acceptable, accessible, economically fair and affordable; nutritionally adequate, safe and healthy; while optimizing natural and human resources" (Burlingame and Dernini, 2012). This shift in the view of food security is essential to ensure food security into the future. Achieving both food security and food systems sustainability simultaneously requires a change in perspective when considering availability and access from agriculture and markets through to consumption and utilization by the individual (Prosperi et al., 2014).

The global food system is under great pressure due to the increasing global population combined with stronger competition for land, water and energy under the largely unknown effects of climate change (Foresight, 2011). Globally there are two billion people who are not getting enough food (Foresight, 2011). These pressures are felt most strongly in low income countries, which are defined as countries with gross national income (GNI) per capita of $1,035 or less (lower middle income, $1,036 - $4,085; upper middle income, $4,086 - $12,615; and high income, $12,616 or more) (The World Bank, 2014). Food security needs to be addressed at the same time as reducing the impact of food production on the environment (McMichael, 2005). The Millennium Development Goals (MDG) highlight both these areas with "end poverty and hunger" and "ensure environmental sustainability" being two of their eight goals (United Nations, 2014). Researchers are talking about the importance of reducing malnutrition and environmental degradation simultaneously (McMichael, 2005) and sustainable agriculture has a large part to play in this. Increased understanding of the complex relationships between nutrition, agriculture and the environment is essential.

The relationships between agriculture and nutrition are no more relevant globally than in sub-Saharan Africa where 26% of the world's undernourished people live; approximately 239 million people (UNFAO, 2010b). Self employment in agriculture is the most important activity for the rural labour force in sub-Saharan Africa (The World Bank, 2008). In sub-Saharan Africa agriculture and its associated industries are essential to growth and to reducing mass poverty and food insecurity (The World Bank, 2008). The landscape in East Africa is mainly arid and semi-arid, with some sub-humid, desert and highland areas (Barry et al., 2006). These land types characteristically have low uneven rainfall and infertile soils which have led to problems in the food supply of these areas (Barry et al., 2006).The challenge of improving both the quality and amount of food produced is key for the improvement of quality of life for those living in East sub-Saharan Africa. Much research has been conducted on increasing food production in sub-Saharan Africa on the assumption that increasing food production will increase food security (Larson and Frisvold, 1996). The relationship between food production and consumption is complex and there is concern that an increase in food production will not necessarily lead to an increase in food security (Sen, 1981).

1.4 Nutritional status

Individuals are malnourished if their diet does not provide adequate calories, protein and other essential nutrients for growth or they are unable to use the food they eat due to illness. They are also malnourished if their energy intake exceeds their energy requirements resulting in overweight (UNICEF, 2006). Nutritional status in this thesis refers to undernutrition, which is defined by UNICEF as "the outcome of insufficient food intake and repeated infectious diseases". It includes being underweight or too short for one's age, being too thin for one's height as well as deficiencies in vitamins and minerals (UNICEF, 2006). Nutritional status can be measured in four main ways; through dietary intake, biochemical indices, anthropometry and physical assessment.

Table 1.1. Methods used to measure nutritional status, their definition, pros and cons

Measure	Definition
Dietary intake	
Nutrient adequacy	Meeting the requirements for energy and all essential nutrients (Ruel, 2003). Can be measured using a variety of dietary assessment tools e.g. Food diaries, 24 hour recall or food frequency questionnaires.
Pros:	Describes current nutritional status;
Cons:	Short term; Subject to bias; Does not take absorption or utilisation of nutrients in the body into consideration.
Biochemical indices	
Biochemical indices	Laboratory assessment of nutrients or other markers of nutritional status in body fluids, most commonly blood and urine (Simko et al., 1995).
Pros:	Objective.
Cons:	Invasive; Requires specialised equipment and expertise including refrigeration and access to laboratories; Expensive; Usually specific to individual nutrients.
Anthropometry	
Height for age z-scores (stunting)*	Moderate to severe stunting is below minus two standard deviations (SD) from the median height for age of the reference population (UNICEF, 2014). Reflects failure to reach linear growth potential due to suboptimal health/nutritional conditions (de Onis et al., 1997).
Weight for age z-scores (underweight)*	Moderate and severe underweight is below minus two SD from the median weight for age of the reference population (UNICEF, 2014). Reflects body mass relative to age and is influenced by both height and weight (de Onis et al., 1997).
Weight for height z-scores (wasting)*	Moderate and severe wasting is below minus two SD from the median weight for height of reference population (UNICEF, 2014). Typically indicates a recent and severe process of weight loss (de Onis et al., 1997).
BMI for age z-scores*	Used as a marker of thinness, especially for children and adolescents between 5 and 19 years of age (Cole et al., 2007).
Mid Upper Arm Circumference (MUAC)*	Provides estimates of arm soft tissue and wasting (Simko et al., 1995).
Pros:	Easy to obtain; Objective; Systematic; Reliable; Repeatable.
Cons:	Potential for measurement error.
Physical assessment	
Physical assessment	Observation, inspection and measurement of an individual (Simko et al., 1995).
Pros:	Provides detailed and broad nutritional status information.
Cons:	Requires medical expertise; Potentially invasive; Time consuming.

*Methods employed in this study to reflect nutritional status.

Table 1.1 outlines these main categories used to define nutritional status and the pros and cons associated with each method, with five more specific sub-categories under anthropometry. More detail is included for this technique as nutritional status in this thesis refers to the anthropometric measurements of height for age, weight for age, BMI for age, weight for height and MUAC.

The nutritional status of people in sub-Saharan Africa remains poor. These countries have considerably higher rates of stunting, wasting and underweight (WHO, 2010b, Onis et al., 2000) and shorter life expectancies than people living in high income countries (Mathers et al., 2001). Rates of stunting are highest in Eastern Africa (Percentage stunted: 50.0 (95% CI: 42.3-57.9) compared to the rest of Africa, Asia and Latin America (Black et al., 2008). Combined statistics from Ghana, Senegal, Guinea Bissau, the Philippines, India, Nepal, Bangladesh and Pakistan show that children who are severely stunted (< -3 Standard Deviations (SD) below World Health Organisation (WHO) Child Growth Standards) have 4.1 (2.6-6.4) greater odds of dying and 4.6 (2.7-8.1) greater odds of dying from diarrhoea compared to children with height for age z-scores above -1 (Black et al., 2008). Malnourished children are also more likely to perform poorly academically (Alderman et al., 2006, Victora et al., 2008, Adair et al., 2013) and have lower capacity for work (Haas et al., 1996) compared to children who are not malnourished.

There is evidence that many different socio-demographic, economic and health factors contribute to the nutritional status of children under five years of age. These include household income (Yang et al., 2012), parental employment (El-Ghannam, 2003), parents' literacy (Fernandez et al., 2002) and maternal education (Kabubo-Mariara et al., 2009, Abuya et al., 2012). Vaccinations (Dancer et al., 2008) sanitation (Fink et al., 2011, Kikafunda et al., 1998), distance to a source of drinking water (Pickering and Davis, 2012) and having crowded living conditions (Yang et al., 2012) are also associated with child nutritionals status in low income countries. The type of complementary foods introduced into an infant's diet (Onyango et al., 1998, Obatolu, 2003) contributes to child growth in young children. The gender dynamics within the household and community also have an important effect on child nutritional status (Khatun et al., 2004). These impact through women's decision making power (Smith et al., 2005), the low value that is placed on women's knowledge (Awumbila, 2003) and maternal education, income and access to resources (Chilton et al., 2007).

In addition, diarrhoea (Victora et al., 1990) and other infection (Fernandez et al., 2002) impacts on nutritional status but being malnourished puts children at increased risk of getting an infection; a dangerous cycle in low income countries (Bhaskaram, 2002). Examples of these cycles are seen with HIV, tuberculosis and malaria in sub-Saharan Africa which, along with diarrhoeal diseases and respiratory infections are responsible for the highest number of deaths from infectious diseases in Africa (WHO, 2004). Children with HIV are likely to be more severely malnourished (Prazuck et al., 1993) and malnourished children with HIV are more likely to die than those without HIV (Fergusson and Tomkins, 2009). Malnutrition is more common in children with tuberculosis (Karyadi et al., 2000) and malnourished children were more likely to die from tuberculosis (Zachariah et al., 2002) and malaria (Müller et al., 2003) than those that are not malnourished.

A conceptual framework on the determinants of malnutrition developed by UNICEF (1990) (Figure 1.1) outlines a structure for understanding how these and other 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 and illustrates that this interacts with disease to cause malnutrition. Although not included in this frame work, agrobiodiversity, acting through dietary diversity, is potentially another factor impacting on access to food and dietary intake. A limitation of this framework is that it makes no reference to environmental or agricultural factors and their impact on access to adequate food, income and exposure to health risks.

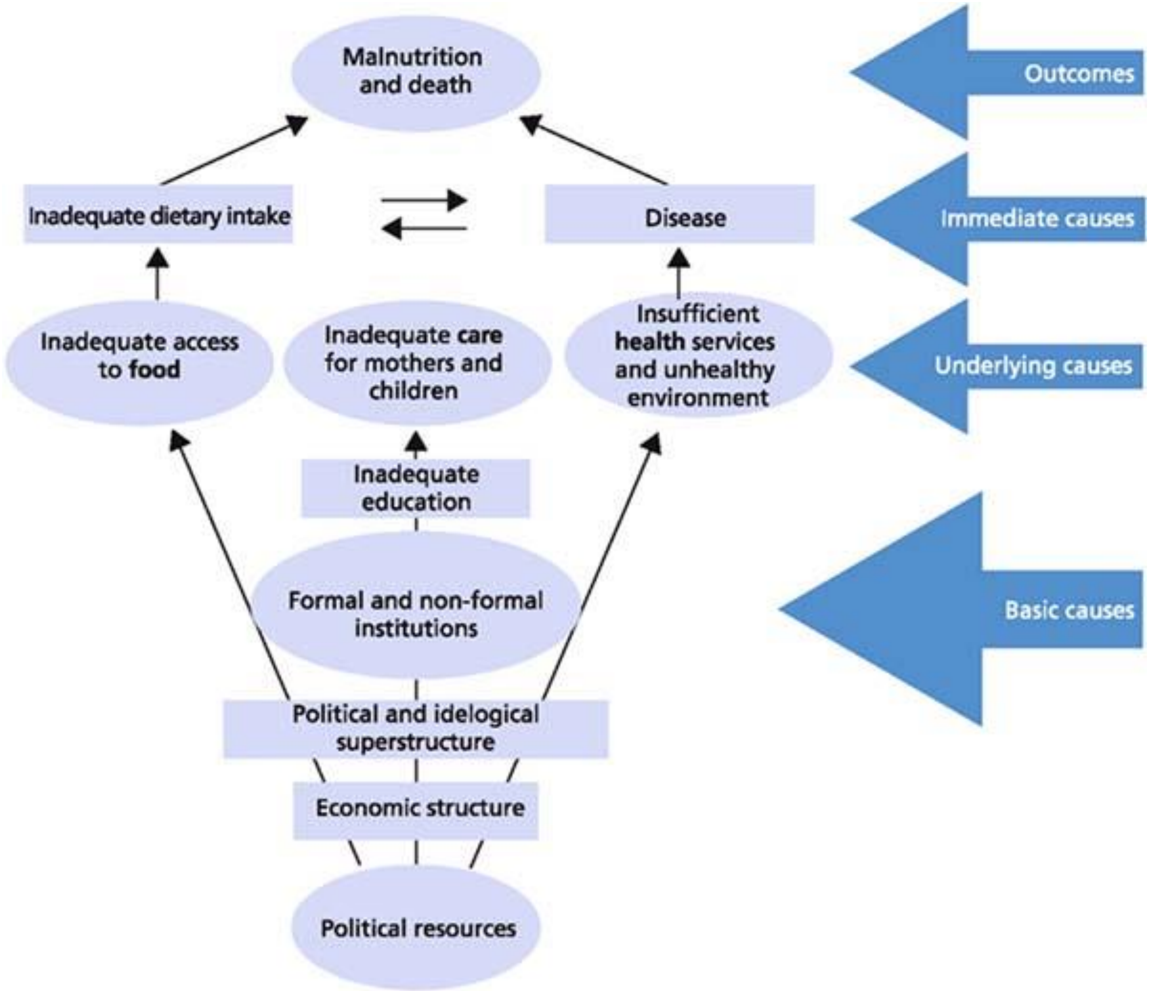


Figure 1.1. UNICEF conceptual framework of the determinants of malnutrition (UNICEF, 1990)

Much research has been conducted in low income countries into potential ways of improving food and nutrient intake in order to improve heath in these communities. Accurately measuring food security and nutrient adequacy in a low income country context is an essential step towards improving health outcomes (Keenan et al., 2001) and the associated benefits on educational attainment (Alderman et al., 2006, Victora et al., 2008, Adair et al., 2013) and productivity (Haas et al., 1996). Without a relatively accurate idea of people's access to food and nutrient intake it is difficult to plan and implement interventions that could lead to improvements in nutritional status and health. One of the ways that the quality of the diet is often represented in low income countries is by estimating the diversity in an individuals diet. This is based on the idea that a more diverse diet will provide a wider variety of nutrients to a growing child.

1.5 Dietary diversity

Dietary diversity has been defined as "the number of different foods or food groups consumed over a given reference period" (Ruel, 2003), page 3912S). Dietary diversity is important as the more different kinds of foods an individual consumes the more likely they are to get all the nutrients they need for healthy growth, development and function (Gibson and Anderson, 2009). This is especially true in low income countries where dietary intake is based on starchy staples and the consumption of different food groups such as vitamin A rich fruit and vegetables, meat and eggs are typically low (Arimond, 2004).

Capturing measurements of dietary diversity - the number of different food groups consumed, or food variety - the total number of different foods consumed, over a defined period of time (often 24 hours), as proxies for food security, nutrient adequacy and nutritional status have become popular in low income countries (Ruel, 2003). Dietary diversity scores has been shown to be significantly positively associated with food security (Bukusuba et al., 2007), nutrient adequacy (Arimond, 2004, Ogle et al., 2001, Moursi et al., 2008, Daniels et al., 2007, Hatloy et al., 1998, Kennedy et al., 2007, Torheim et al., 2004, Ponce et al., 2006) and nutritional status in a number of studies (Arimond, 2004, Corbett et al., 1992, Steyn et al., 2006, Garg and Chadha, 2009, Nti and Lartey, 2007, Savy et al., 2005, Savy et al., 2006).

1.6 Agrobiodiversity, dietary diversity and nutritional status

Agrobiodiversity has been defined as the biological diversity on lands used for agricultural purposes (Brookfield and Stocking, 1999). This includes the diversity of plants, animals and micro-organisms at species and ecosystem levels (Cromwell et al., 1999) and covers both cultivated crops and wild plants. The term agrobiodiversity is used to mean plant agrobiodiversity in some studies (Remans et al., 2011a) and both plant and animal agrobiodiversity in others (Ekesa et al., 2008, Walingo and Ekesa, 2013). The focus of this thesis is primarily on plant agrobiodiversity with secondary analysis on a simple measure of animal agrobiodiversity.

Biodiversity has been highlighted as an important factor for sustainable agriculture (Srivastava et al., 1996). It can have a positive effect on soil health which in turn has a positive effect on agricultural output (Chivian, 2002). There have been a number of papers encouraging the agriculture and nutrition (Welch and Graham, 1999, Hawkes and Ruel, 2006) and nutrition and biodiversity fields (Johns and Sthapit, 2004, Frison et al., 2006) to work closer together.

Agriculture, biodiversity and nutrition are all interrelated and a number of publications have investigated how these three areas intersect.

1.6.1 Agriculture and nutrition

In Hawkes and Ruel's (Hawkes and Ruel, 2006) conceptual framework of the links between agriculture and health (Figure 1.2) agriculture is linked with health through labour, environmental change, income generation and access to food, water, land and health related services leading to undernutrition as well as a number of other health outcomes.

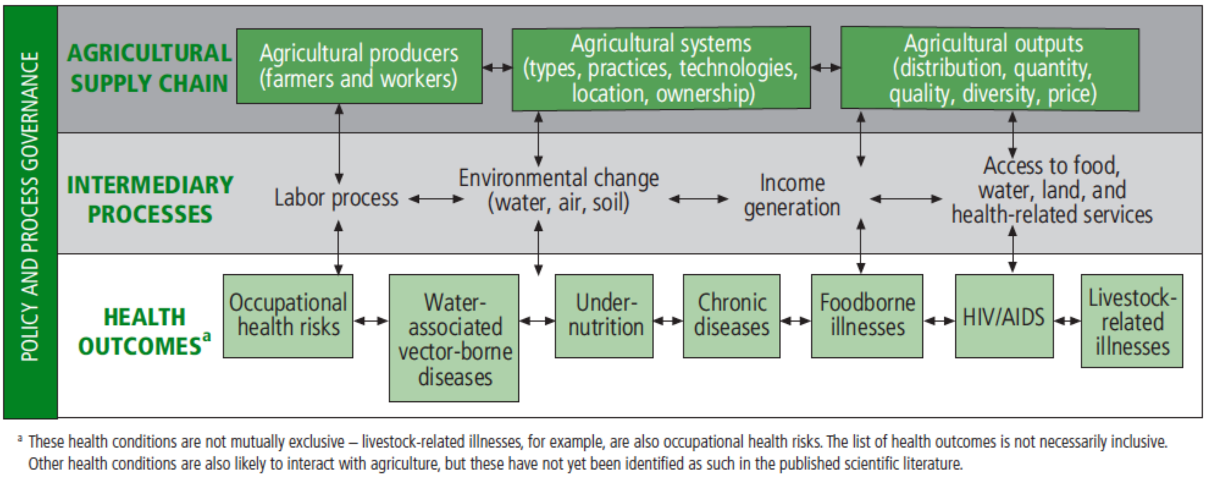


Figure 1.2. Conceptual framework of the links between agriculture and health (Hawkes and Ruel, 2006)

Despite acknowledgement that agriculture and nutrition are linked (Lipton and Kadt, 1988), research in these two fields have run in parallel for many years (Hawkes and Ruel, 2006). In order to improve food security ("Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life" (FAO, 1996)), much agricultural research has focused on increasing yields, attempting to fulfil the *availability* aspect of food security (Sen, 1981). While nutrition research has attempted to address the *utilization* aspect of food security. Since Sen's essay on food entitlement in 1981 focus in food security research has turned to include people's *access* to food, addressing some of the complex issues that link food production to consumption (Coates et al., 2006, Webb et al., 2006). Research into the effects of agricultural interventions on nutrition and health outcomes has increased from the 1990's onwards (Berti, 2004). Berti et al (2004) reviewed 30 agricultural interventions that measured impact on nutritional status. They found that most agricultural interventions increased food production and two thirds of these improved nutrition outcomes in household members.

1.6.2 Agriculture and biodiversity

Except for research looking at conservation of genetic diversity for food production, research into biodiversity has also remained relatively separate from agricultural research until recently (Frison et al., 2011). Agricultural practices can have varying affects on the biodiversity of flora & fauna. These range from concerns about the negative impact of large cash crop farming on biodiversity (Srivastava et al., 1996, Green et al., 2005) to the positive effects agricultural practices can have on biodiversity when sustainable practices are employed (Thrupp, 2000). In the past three decades the concept of agrobiodiversity has been introduced which provides an opportunity for the agriculture and biodiversity research areas to work more closely together.

1.6.3 Biodiversity and nutrition

Very little data is available on the relationship between biodiversity, nutrition and health in low income countries (Frison et al., 2004, Frison et al., 2011). Discussions about the links between biodiversity and nutrition are on the increase (Frison et al., 2004, Johns and Eyzaguirre, 2007, Nakhauka, 2009) and the Food and Agriculture Organisation (FAO) recently published an expert consultation on nutrition indicators for biodiversity (UNFAO, 2010a). Wahlqvist & Specht (1998) outline the many reasons why biodiversity is so important for human health including a diverse food supply and increased resilience.

Frison et al. (2011) highlights the importance of agricultural biodiversity in the sustainable delivery of a more secure food supply. The discussion paper states that more diverse farming systems and crops are more resilient to shocks and changes in the climate (Frison et al., 2011). Additionally, biodiversity influences nutrition through ensuring the sustainable productivity of soils (Chivian, 2002).

1.6.4 Agriculture, biodiversity and nutrition

Few good quality papers have linked agricultural biodiversity with diet and nutrition outcomes. Akrofi (2010) found that the Shannon index (a measure of the number of different plant species and the abundance of these species (Pla, 2004)) of cultivated plants in home gardens was not significantly related to the household dietary diversity score in Ghana. Crop diversity was positively associated with dietary diversity in one of the two populations assessed in

Mexico (Dewey, 1981). Higher agrobiodiversity, as assessed by the number of crops grown by the household, was found to be linked with higher dietary diversity in a large nationally representative sample in India (Bhagowalia et al., 2012) and in two smaller cross-sectional studies in Kenya (Walingo and Ekesa, 2013, Ekesa et al., 2008), although the significance of the associations were not reported in either of the Kenyan papers.

Evidence of an association between agrobiodiversity and nutritional status is even more limited. Shack et al. (Shack et al., 1990) found no association between the number of food crops grown in household gardens and anthropometric measures in children in a cross sectional survey in Papua New Guinea. Crop diversity was significantly correlated with height for age in children in one out of the two villages studied by Dewey (Dewey, 1981) but weight for height was not associated with agrobiodiversity in either village.

A number of discussion papers have outlined how agriculture, biodiversity and nutrition are related. Johns and Sthapit (Johns and Sthapit, 2004) propose the following conceptual framework (Figure 1.3) to illustrate the complex links between biodiversity and health. This framework takes into consideration income generation and socio-cultural traditions and attempts to capture some of the complexity of the pathways between biodiversity and nutrition.

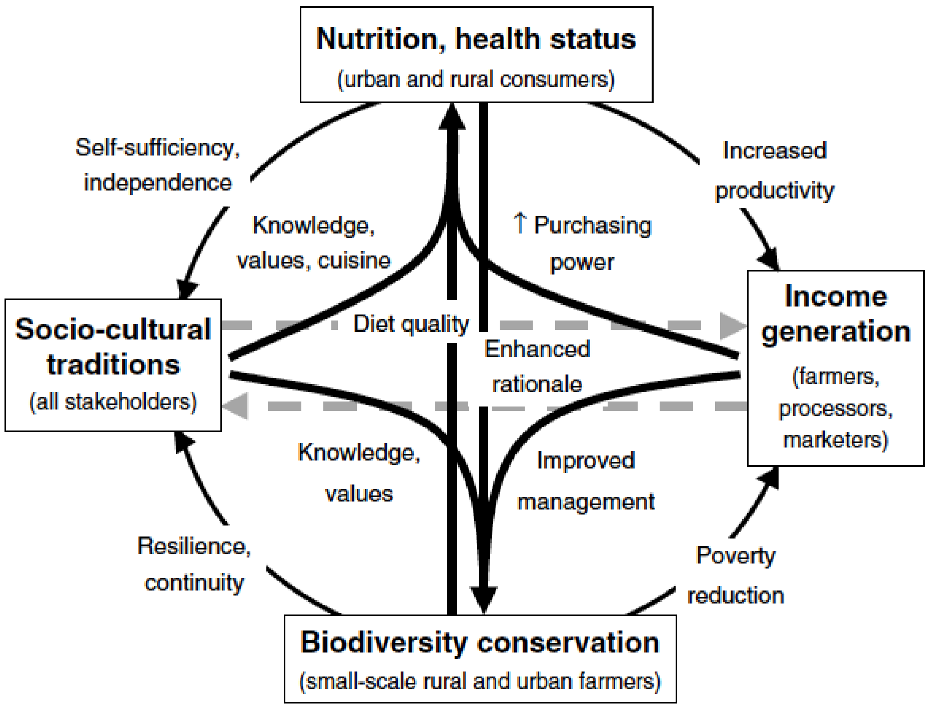


Figure 1.3. Conceptual framework linking biodiversity conservation and human nutrition in low income countries (Johns and Sthapit, 2004)

A number of key authors (Bélanger and Johns, 2008, Wahlqvist, 2003, Johns and Eyzaguirre, 2006, Frison et al., 2011) have discussed the ways in which agriculture, biodiversity and nutrition are potentially related. Wahlqvist (2003) states that “while biodiversity is essential for sustainable food diversity, it does not guarantee it” and Johns and Eyzaguirre (2006) call for empirical evidence to prove the association between biodiversity and dietary diversity and health. In much of the other literature in this area there is an underlying assumption, that higher agrobiodiversity will lead to higher dietary diversity (Frison et al., 2005, Frison et al., 2006, Johns, 2003, Deckelbaum et al., 2006, Hillocks, 2011). This assumption appears logical but perhaps does not acknowledge the complexity of the pathway from food production to consumption in Eastern sub-Saharan Africa and globally.

1.7 Food security and nutritional status in Tanzania

A high proportion of the Tanzanian population lack food security, especially those living rurally. Approximately 23% of people were categorised as moderately food secure and 48% as severely food insecure in a study in rural Iringa in Tanzania (Knueppel et al., 2010). The study identified insufficient food quality and insufficient food intake as the two main factors contributing to this food insecurity. Approximately a quarter of surveyed households in Tanzania reported often or always having problems satisfying food needs in the past year in the 2010 DHS survey (Tanzanian NBS and ICF Macro, 2011). High levels of malnutrition among children persist in Tanzania. Recent data show that 44.4% of children in Tanzania below five years of age are stunted and 16.7% are underweight (Gollogly, 2009). There is clearly a need for research into factors that could improve food security and nutritional status in Tanzania.

1.8 Foods eaten in Tanzania

Only approximately 50% of rural households in Tanzania consume three or more meals per day, compared to almost 80% in urban households (Tanzanian NBS and ICF Macro, 2011). The frequency of meals varies depending on the season with less meals being consumed in the rainy season (Kinabo et al., 2006). There has been some initial evidence that Tanzania is moving into the nutrition transition in urban (Njelekela et al., 2002, Bovet et al., 2002) and even rural areas (Keding et al., 2011). However undernutrition still remains the most important component of malnutrition in Tanzania (Abrahams et al., 2011).

The typical meal eaten in Tanzania is *ugali*, a starchy staple made into a stiff porridge. It is mostly made from maize flour but it can also be made from other flours such as cassava

(Mazengo et al., 1997, Kinabo et al., 2006). People consuming *ugali* as their main energy source rely on accompaniments for nutrients such as protein, vitamins and minerals. It is common for people to consume *ugali* with a vegetable dish consisting of green leafy vegetables, boiled or fried with onions and tomatoes (Vainio-Mattila, 2000) and sometimes beans, meat or fish (Kinabo et al., 2006). Meat and fish are not commonly consumed; 60% of households in the 2010 DHS survey for Tanzania consumed no meat in the past week and 50% consumed no fish (Tanzanian NBS, 2011). Traditional diets consumed in rural Tanzania are often not nutritionally adequate; insufficient energy, protein and micronutrient intakes are common (Ecker et al., 2010, Mazengo et al., 1997).

Maize (*Zea Maize Gramineae*) is a very important crop for those living in Tanzania. The area cultivated with maize occupies an area 4.25 times larger than cassava which has the second largest planted area (Tanzanian NBS et al., 2006). A local level study conducted in Katumba ward in Tanzania demonstrated that the local population preferred maize meals and could obtain almost 70% of their energy and over 80% of their required protein through maize meals (Mboya et al., 2011).

In addition to maize, cassava (*Manihot Aspera Crantz Euphorbiaceae*) has become an important crop for food security in Tanzania for a number of reasons. Cassava is a root crop and can be left in the ground until needed for up to three years (Romanoff and Lynam, 1992). This means that, with planning, it can be available when other crops fail (Prudencio and Al-Hassan, 1994). It can grow in poor conditions with limited input and is unusually tolerant to drought compared to other crops grown in sub-Saharan Africa (El-Sharkawy, 2004). However, it requires appropriate processing before consumption to remove cyanide and other anti-nutritional factors (Padmaja and Steinkraus, 1995).

The use of wild foods is also important in many rural environments across sub-Saharan Africa, including Tanzania. Harris and Mohammed (2003) found the majority of wild foods used in Northern Nigeria to be leaves used for side dishes to the main starchy staple but they also included foods not normally eaten except while waiting for harvest or in times of famine. In Mali, Nordeide et al (1996) report the consumption of wild green leafy vegetables and wild fruit in both rural and urban environments. In Tanzania, Johns et al (1996) and Vainio-Mattila (2000) report that consumption of wild species are common among the Batimi people in Ngorongoro district and the Sambaa people in the Usambara Mountains. *Mlenda* (*Corchonus Tritocularies Tillaceae*), is an example of a wild food which is an important source of nutrients, such as iron and calcium (Kinabo et al., 2006), in some parts of sub-Saharan Africa. These are some specific examples which illustrate the importance of wild food sources throughout Tanzania.

1.9 Outline of thesis and summary of research contributions

Chapter 2 summarises the available literature relating dietary diversity and food variety to nutritional status as well as agrobiodiversity to dietary diversity/nutritional status in low income countries. The literature review presents strong evidence that measures of dietary diversity and food variety are positively associated with nutritional status in children in low income countries, however the evidence from Eastern Africa is less comprehensive. This chapter also reveals a large gap in the literature relating agrobiodiversity to dietary diversity and nutritional status, it shows that there is very little good quality research that addresses the aim of this thesis.

Chapter 3 of the thesis outlines the methods for the primary data collection; the design of the methodology, the selection of the villages the study took place in and the data collection methods. The results from the primary data collection are reported in chapters 4, 5 and 6. Chapter 4 explores the associations between dietary diversity and food variety and nutritional status in the two villages as well as how additional factors such as complementary feeding and sanitation impact on nutritional status in these communities. The chapter found that neither dietary diversity nor food variety was associated with any of the measures of nutritional status in children in these villages. These results contradict much of the literature outlined in the literature review in chapter 2 highlighting that a positive association between dietary diversity and nutritional status cannot be assumed in all contexts. The chapter also contributes additional knowledge about the importance of appropriate complementary feeding and sanitation in improving nutritional status in low income countries.

Chapter 5 presents the main results of the thesis; how plant agrobiodiversity is related to dietary diversity and nutritional status in children. The results show that in the majority of cases agrobiodiversity is not associated with dietary diversity or nutritional status. It was, however, positively associated with height in Minyenye and negatively associated with BMI in Mbwei. The mixed results of this chapter suggest that simply increasing agrobiodiversity may not be an effective strategy to improve nutritional status. This is only the second piece of research that measures biodiversity in the household farms and relates these measures to both dietary diversity and nutritional status in the household children. It is therefore an important addition to the literature.

Chapter 6 presents data on animal diversity, as measured by the number of animals raised by the household, and how this relates to dietary diversity and nutritional status in household children. The results show that the more different types of animals eaten and raised in the households the poorer the nutritional status of the household children were. Additionally, households selling animals and animal products had children with the same or worse nutritional status than households not selling these products. This contributes to the literature on how raising animals is related to nutritional status and highlights the complexity of the determinants of diet and health in low income countries.

Chapter 7 links nationally representative dietary diversity data to nutrition outcomes and dietary and nutrition data to national land cover data in Tanzania. This chapter found that dietary diversity was not significantly associated with nutritional status in children. More agricultural land cover in the surrounding area was associated with higher dietary diversity and weight for height but lower height for age. More forest land cover was associated with higher weight for height. There is little research linking land cover and nutritional outcomes and these results provide important information on how these are related. Chapter 8 discusses the overall findings of the thesis, bringing together the primary data collection and national data, and summarises the thesis's main findings. The main conclusions of the thesis are presented in chapter 9.

Due to the constraints on land use and the continuing growth in population worldwide (Godfray et al., 2010) it is important, now more than ever, to establish and attempt to quantify how a greater diversity in agrobiodiversity affects nutrition and health outcomes in a low income country context. This study provides information that is beneficial to researchers interested in health and food security and the overlaps of agricultural and health research. Research that makes links between environment and agricultural practice, food intake and health is rare. Looking at these factors simultaneously has shown the complexities in how these factors are related and suggests these relationships should not be assumed in different contexts. It provides evidence in support of broad, locally driven interventions. This thesis therefore contributes new empirical insights from Tanzania to improve understanding of the relationships between agrobiodiversity, dietary diversity and nutritional status which are important for agricultural, food security, dietary and nutritional research.

Chapter 2: Literature reviews of the associations between agrobiodiversity, dietary diversity and nutritional status

2.1 Chapter summary

Chapter 1 introduced the rationale for investigating associations among agrobiodiversity, dietary diversity and nutritional status, while this chapter summarises published literature on these associations. The chapter presents two narrative synthesis reviews which have used a systematic style approach: the first summarises literature linking dietary diversity with nutritional status in children (Part 1), while the second presents research on the relationships agrobiodiversity has with dietary diversity and nutritional status (Part 2). The main finding presented in part 1 of this chapter is that dietary diversity and food variety are associated with nutritional status in children in low income countries. Part 2 showed that there is limited good quality research on the associations between agrobiodiversity and either dietary diversity or nutritional status. The review reveals a gap in the literature on the relationship between agrobiodiversity and both dietary diversity and nutritional status that this thesis aims to fill.

2.2 Introduction

Measures of dietary diversity have been used in low income countries to reflect diet quality and nutritional status for a number of years. It is generally accepted that more diverse diets in low income country contexts are more nutritionally adequate (Ruel, 2003, Daniels et al., 2007, Hatloy et al., 1998). There is much literature showing that more diverse diets are also associated with better growth outcomes but this is not always the case. Linking agrobiodiversity to dietary diversity and nutritional status is a relatively new area of enquiry and there are limited publications showing associations between these factors. These narrative synthesis reviews summarise all the available literature linking agrobiodiversity, dietary diversity and nutritional status, as measured through anthropometry, in a low income country context.

2.3 Part 1: Dietary diversity and nutritional status in children

2.3.1 Methods

This review focuses on research presenting associations between dietary diversity and nutritional status, as measured by anthropometry, in children in low income countries. Interventions investigating these associations, longitudinal, case control and cross-sectional studies are included in the review.

2.3.1.1 Search strategy

In order to find the maximum number of papers using measures of dietary diversity in low income countries different search techniques were used. Firstly the following electronic databases were searched in February 2014:

- Embase Classic and Embase 1947 to 2014 March 05
- Global Health 1910 to 2014 Week 08
- Ovid Medline 1946 to February Week 4 2014
- Psychinfo 1806 to March Week 1 2014

The following search terms were used, the numbers on the right represent how many papers were identified with each search term from all databases combined.

1	diet$ divers$.mp.	1655
2	diet$ variet$.mp.	562
3	food divers$.mp.	352
4	food variet$.mp.	504
5	food group divers$.mp.	23
6	food group variet$.mp.	33
7	**1 or 2 or 3 or 4 or 5 or 6**	**2797**
8	nutritional status.mp.	110250
9	growth.mp.	2956808
10	stunt$.mp.	15608
11	wast$.mp.	321553
12	underweight.mp.	20248
13	undernutrition.mp.	17619

14	malnourish$.mp.	25669
15	malnutrition.mp.	126573
16	**8 or 9 or 10 or 11 or 12 or 13 or 14 or 15**	**3452136**
17	africa$.mp.	711961
18	low income countr$.mp.	7773
19	developing countr$.mp.	823802
20	**17 or 18 or 19**	**1340313**
21	**7 and 16 and 20**	**440**
22	limit 21 to English language	401
23	limit 22 to humans [valid in Embase and Ovid Medline only]	394
24	limit 23 to yr="1980 -Current"	394

2.3.1.2 Criteria for inclusion

Titles and abstracts were first screened to identify potentially relevant references. The full journal articles of these potentially relevant references were obtained, where possible, and these were then checked for final inclusion in the review. Papers that met the following inclusion criteria were included in the review:

- English language
- Human
- Children under the age of 20 years
- Study relates dietary diversity or food variety to nutritional status as measured by anthropometry
- Based in a low income country as defined by the International Monetary Fund (IMF)

2.3.1.3 Included references

Three hundred and ninety four references were identified through the database searches containing 341 unique references. Based on the titles and abstracts 83 papers were identified as potentially relevant. Thirteen papers were unable to be located. These have been excluded from the review. An additional 25 were excluded because they did not meet the inclusion criteria when full papers were examined. Thirty-five papers were included in the review from this process. Relevant review papers, books and reports were used to obtain two additional relevant references, these are referred to in the inclusion flowchart (figure 2.1) as hand searched references. A total of 37 references are included in the review.

Papers were summarised and details of how dietary diversity and food variety were measured are included. The associations between dietary diversity and nutritional status are summarised in Table 2.1 and food variety and nutritional status in Table 2.2. In keeping with the language used in the papers reviewed this review uses the terms 'dietary diversity (DD)' and dietary diversity score (DDS)' to mean diversity estimated from the number of food groups individuals, or households, have consumed over a particular reference period. The review uses the terms 'food variety (FV) and 'food variety score (FVS)' to mean the number of individual food items individuals, or households, have consumed over the reference period. The FVS is larger than the DDS when people consume more than one different food type within a food group. For example, if both tomatoes and onions are consumed one DD point will be added to the DDS and two FV points will be added to the FVS.

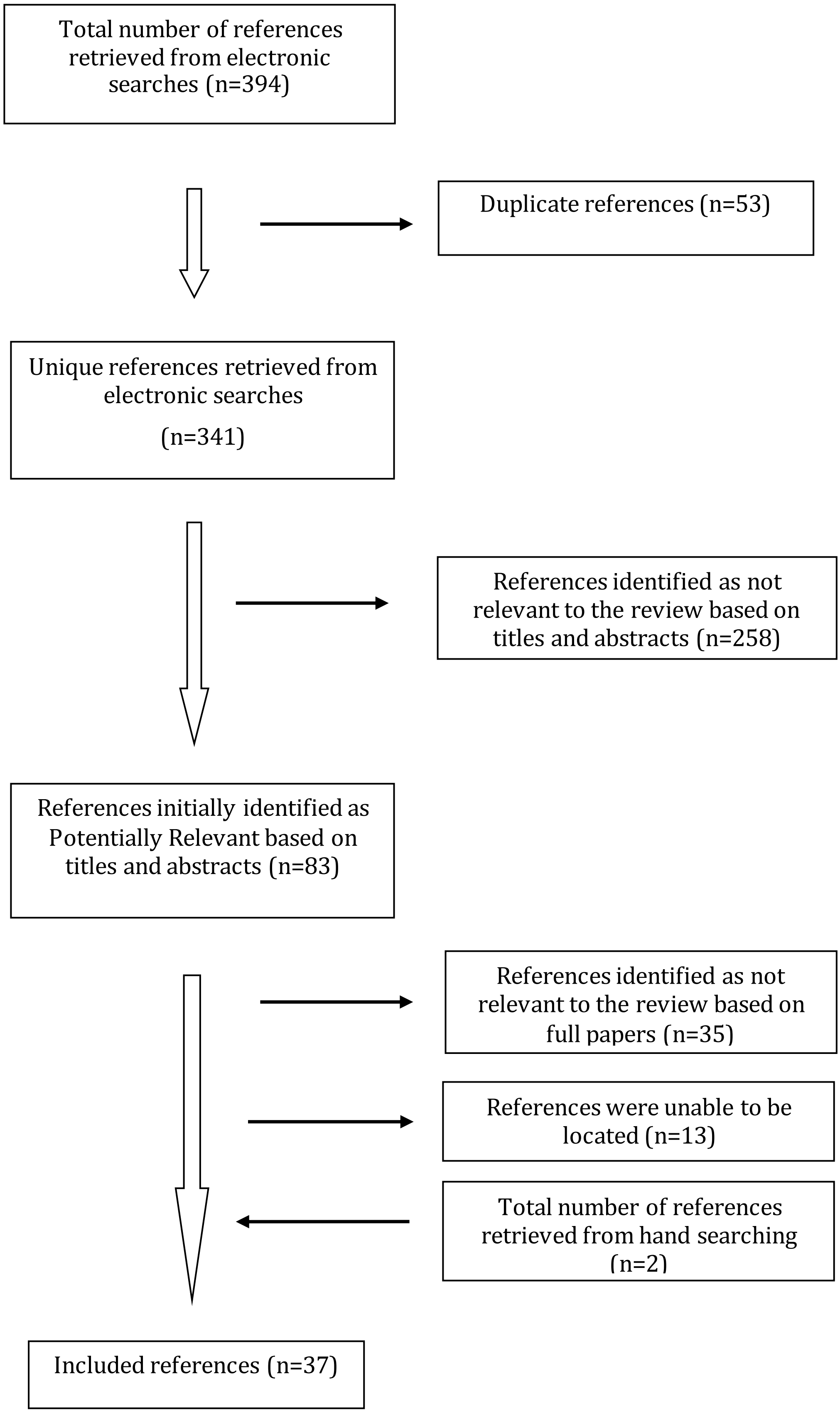


Figure 2.1. Flowchart of inclusion for part 1: Dietary diversity and nutritional status

2.3.2 Results and discussion

Thirty-two studies reported associations between dietary diversity and anthropometric measures in children (Table 2.1). Twenty-five of these studies were cross-sectional, five were longitudinal studies and two were interventions. The first, non-randomised, intervention study found an improvement in dietary diversity and weight gain in the intervention arm of the study, in female children only (Kilaru et al., 2005). The second intervention study, which had a randomised cluster design, found that the improved dietary diversity of the younger children in the intervention group was not accompanied by an increase in length for age z-scores (LAZ) (Aboud et al., 2013).

Out of the five longitudinal studies, one found DDS to be higher in children who had better growth (Nti and Lartey, 2007), one found DDS to be positively associated with weight but not length gain (Alvarado et al., 2005), two found DDS to be positively associated with height or length for age z-scores (HAZ/LAZ) (Bork et al., 2012, Ma et al., 2012) and one study found that DDS was not related to the development of kwashiorkor (Lin et al., 2007). Twenty of the cross sectional studies show positive associations between dietary diversity and either LAZ, HAZ, weight for age z-scores (WAZ) or weight for length/height z-scores (WLZ/WHZ) and five found no associations (Hillbruner and Egan, 2008, Nungo et al., 2012, Sullivan et al., 2006, Tessema et al., 2013, Aboussaleh and Ahami, 2009).

The results showing positive associations between dietary diversity and nutritional status are often not entirely conclusive. Some of these 20 cross sectional studies also found no association in particular geographic areas (Dewey, 1981, Ekesa et al., 2011), in rural areas (Hatloy et al., 2000), in girls (Eckhardt et al., 2005) and in some age groups (Benefice et al., 2007, Garg and Chadha, 2009, Sawadogo et al., 2006). Additionally, within these studies dietary diversity was not always associated with both height and weight.

Seven cross- sectional studies, one longitudinal study and one non RCT intervention study reported the association between food variety and nutritional status in children in low income countries (Table 2.2). Gibson et al (2003), whose intervention focused on dietary diversification, found that food variety was not associated with HAZ, WHZ, triceps skinfold z-scores or arm fat area z-score after 12 months but MUAC z-scores and arm muscle area z-scores were significantly higher in the intervention group. In the longitudinal study, Bork et al (2012) found food variety to be associated with HAZ cross-sectionally but not with height gain over the six months.

Three of the cross-sectional studies found significant positive associations between food variety and nutritional status (Novotny, 1987, Onyango et al., 1998, Steyn et al., 2006).

Additionally, one found positive associations in urban but not rural areas (Hatloy et al., 2000), another found that food variety was positively associated with HAZ in under 23 month olds and WAZ in just 9-11 month olds (Sawadogo et al., 2006) and another found food variety to be associated with the duel burden of malnutrition (overweight mother/underweight child) (Saibul et al., 2009). There was only one cross-sectional study that found no association between food variety and nutritional status (Lamontagne et al., 1998). As with dietary diversity, the evidence suggests that food variety is associated with nutritional status in children in low income countries.

All four studies with samples sizes of over 10 000 children found significant associations between DDS and/or FVS and HAZ (Arimond, 2004), rates of stunting (Li et al., 2011, Marriott et al., 2012, Rah et al., 2010) and rates of underweight (Marriott et al., 2012). These results are supported by seven out of the eight studies with between 1000 and 10 000 participants that were carried out in different countries in Africa and Asia. All of the studies with over 10 000 participants and four other papers (Disha et al., 2012, Eckhardt et al., 2005, Steyn et al., 2006, Zongrone et al., 2012) reported on nationally representative samples. All showed significant associations between dietary diversity and anthropometric outcomes, although Eckhardt et al (2005) found associations in boys only. Studies using large, nationally representative samples are less prone to selection bias than smaller studies and these large studies provide evidence of a true association between dietary diversity and nutritional status. However, these studies were all cross-sectional so cause and effect cannot be implied.

The statistical methods used in the majority of studies compared dietary diversity scores between malnourished children and those that were not malnourished and/or presented the correlation between the diversity indices or assessed association using regression analyses. Almost all of the papers reported the significance of the statistical tests that were carried out. Regression analysis gives the amount of change expected in the dependent variable with each unit change in the independent variable (Montgomery et al., 2012). It is therefore the best statistical method to show how dietary diversity and nutritional status are related cross-sectionally, ideally controlled for potential confounders. Twenty-five of the 37 studies used multivariable regression to control for confounders. That such a high number of studies employed these methods indicates the reported results are more reliable.

The type of dietary diversity score and the way it was collected did not alter the relationships seen between dietary diversity and nutritional status. Five out of the 32 studies used household dietary diversity, one of these showed no association but the other four, and the one paper reporting household food variety, found significant associations between the diversity scores and anthropometric measures. The majority of the papers reported collecting dietary diversity through a 24 hour recall (19/32 dietary diversity studies and 7/9 food variety studies), the other studies used food frequency questionnaires (FFQ), seven day diet recalls, questionnaires, interviews and observation. The size and direction of the results from studies using these other methods were not different from those using 24 hour recalls. The results from this literature review show that the 24 hour recall is the most appropriate method to measure dietary diversity in the current study.

The number of food groups in the dietary diversity scores varied from 6 to 23, the majority of papers used between 7 and 12 food groups. For comparison between studies and across countries it would be useful for studies to use the same number of food groups. Nine food groups (Cereals; roots & tubers; vitamin A rich fruit & vegetables; other fruit; other vegetables; legumes & nuts; meat, poultry & fish; fats & oils; dairy; eggs) were recommended by the FAO workshop in Rome, Italy in October 2004 (FAO/WHO/IFPRI, 2004), however only one study included in this literature review used this grouping (Steyn et al., 2006).

There was, however, some variation by geographic region. There were only 15 studies conducted in Africa, 11 of these conducted in Eastern Africa (in Malawi, Kenya, Tanzania, Ethiopia, Zambia, Burundi). The one dietary diversification intervention study (Gibson et al., 2003), in Malawi, found no association effect on height or weight z-scores. The one longitudinal study (Lin et al., 2007), again in Malawi, found that dietary diversity was not associated with Kwashiorkor. Of the nine cross-sectional studies conducted in Eastern Africa, six found positive associations (Onyango et al., 1998, Corbett et al., 1992, Cordeiro et al., 2012, Disha et al., 2012, Walingo and Ekesa, 2013, Ekesa et al., 2011) and three found no associations (Nungo et al., 2012, Tessema et al., 2013, Sullivan et al., 2006) in Kenya, Ethiopia and Malawi. The evidence in this part of the world is not as convincing as the literature as a whole. This provides evidence towards the relationship between dietary diversity and nutritional status being contextual and suggests that more research into this association in Eastern Africa would be beneficial.

Assessing the combined evidence of the cross-sectional, longitudinal and intervention studies shows that dietary diversity scores and food variety scores are positively associated with growth in children in low income countries. This was the case for both dietary diversity and food variety, using the 24 hour recall to collect the data or other similar methods, using individual or household diversity scores, with a range of food group categories. That results were consistent over these different methods indicates that this is a strong and repeatable association. The association was seen with growth measures in children in a number of different countries and contexts, although the evidence was not as strong in Eastern Africa.

Looking at all the evidence, it is reasonable to hypothesise that dietary diversity and nutritional status, as measured by anthropometry, will be associated in the current study.

Table 2.1. Studies investigating the associations between dietary diversity based on number of food groups and nutritional status based on anthropometric measures

Author and year	Country Population subgroup	DDS method Individual or household DDS Intervention/study design details	Number of food groups: Food groups used in DDS	Results
Interventions				
(Aboud et al., 2013)	Bangladesh Children, 4-14 mo at recruitment Intervention N=226, control N=237	24 hr diet recall Individual DDS Parenting intervention on health, nutrition, communication and play. Randomised stratified cluster design with control group. 15 mo follow up	7: Grains; legumes; fish & meat; egg; vegetables; fruit; milk.	No significant difference in DD or LAZ between the 2 groups. DD improved in younger age group but LAZ did not.
(Kilaru et al., 2005)	India Infants 5-11 mo	24 hr diet recall Individual DDS Nutrition education	7: Dairy; cereal; protein; fruit; vegetables; oil & fat; sugar & savoury snacks.	Percentage feeding at least 5 different food groups was significantly higher in the intervention group (42%) than the control group (19%), p=0.01. Weight velocity was 77g/mo greater in the female children between 6-10

	Intervention N=69, control N=69	with increasing DD as 1/5 focuses, with control group (not an RCT). 1 year follow up		mo of age in the intervention group compared to the control group (Multivariable regression).
Longitudinal studies				
(Bork et al., 2012)*	Senegal Children, 6-36 mo N=1060	List based FFQ, 24 hours. Individual DDS 2 visits, 6 mo apart	7: Animal milk products; animal-based foods; cereals & tubers; pulses & nuts; fruit & vegetables; vitamin A–rich foods; food with fat added.	DDS significantly positively associated with HAZ at 6-12 mo, 12-18 mo and 12-18 mo. DDS not associated with length/height increments (mixed models with adjustments).
(Ma et al., 2012)	China Children 5-7 mo N=180	7 day diet recall Individual DDS 3 visits every 6 mo over 12 mo	8: Starchy staples; legumes & nuts; dairy; meat, poultry & liver/organ meats; fish, shrimp & crabs; eggs; fruits; vegetables.	DDS at visit 1 was not significantly associated with LAZ, WAZ or WLZ at visit 3. DDS at visit 3 was significantly associated with LAZ at visit 3 (regression coefficient: 0.156, p=0.036) (Multivariable regression).
(Lin et al., 2007)	Malawi Children, 1–3yrs N=1651	2 mo FFQ Individual DDS Followed for 10 wks	7: Starchy staples; legumes; dairy; meat, fish & eggs; vitamin A rich foods; other fruits & vegetables; foods rich in fats. (minimum portion size: 1 serving)	DDS was not associated with the development of Kwashiorkor over the 10 weeks (Multivariable regression).
(Nti and Lartey, 2007)	Ghana Children, 6-12 mo	Monthly behavioural observation visit	10: Cereal & cereal products; roots, tubers & plantain; meat products; fish & seafood; eggs; milk & milk products; margarine; legumes, nuts & pulses; fruits;	Positive deviant children (growth above the norm) had significantly higher DDS (mean (SD): 6.3 (0.6)) than negative deviant children (growth below the norm) (3.7

	N=100	Individual DDS Over 6 mo	soups & stews.	(1.1)) (p=0.001, independent t-test).
(Alvarado et al., 2005)	Columbia Afro-Columbian Children 5-7 mo at baseline N=133	Week FFQ Individual DDS Followed for 18 mo	21: intake frequency of food/beverages in previous week. Score represents both food frequency and food diversity.	DDS positively related to weight gain in non-breastfed children (regression coefficient: 0.14kg/mo, p=0.03). No significant association with length gain. (multivariable regression)
Cross sectional surveys and case control studies				
(Tessema et al., 2013)	Ethiopia Children 0-23 mo N=575	24 hr diet recall Individual DDS	Not stated	No significant difference in odds of being stunted between those with DDS<4 and those with DDS>4. Crude Odds Ratio (OR) (95% Confidence Intervals (CI)): 0.90 (0.53, 1.3) (Multivariable regression).
(Walingo and Ekesa, 2013)	Western Kenya Youngest pre-school child, 12-60 mo N=164	24 hr diet recall Individual DDS	23 food items within 8 food groups: Cereals; roots & tubers; pulses & nuts; vegetables; fruits & vegetables; meat, fish & meat products; milk & milk products; fats & oils. Based on only the first 23 healthy foods consumed over a period of 2 mo, established using food checklists.	DDS was positively associated with stunting (r2 = 0.036, significance not reported) and significantly associated with wasting (r2 = 0.081).

(Cordeiro et al., 2012)	Tanzania Adolescents 10-19 yrs. N=670	24 hr diet recall Household DDS	12: Cereals; fish and seafood; roots and tubers; pulses, legumes, nuts; vegetables; milk and milk products; fruits; oil, fats; meat, poultry, offal; sugar, honey; eggs; miscellaneous.	Each additional food group consumed at the household level decreased the odds of an adolescent being undernourished by 14% (OR = 0.86 (95%CI: 0.74, 0.99); P < 0.05) (multivariable regression). Undernutrition defined as BMI < 5^{th} percentile.
(Disha et al., 2012)	Ethiopia and Zambia Children, 0-23 mo N=4322	24 hr diet recall Individual DDS DHS	7: grains, roots, tubers; legumes & nuts; dairy products; flesh foods; eggs; vitamin A-rich fruits & vegetables; other fruits & vegetables.	DDS was associated with HAZ (OLS regression coefficient: 0.23, p<0.001) and WAZ (0.17, p<0.001) in Ethiopia and with HAZ (0.12, p<0.01) in Zambia. DDS was not associated with WHZ in either country. (Multivariable regression)
(Marriott et al., 2012)	14 low income countries Children 6-24 mo Weighted N=79 423	24 hr diet recall Individual DDS DHS	6: Grains, roots, tubers; legumes & nuts; dairy products; meat & eggs; vitamin A-rich fruits & vegetables; other fruits & vegetables.	DDS was significantly associated with stunting (OR: 0.79 (0.72, 0.86), p<0.001) and underweight (0.78 (0.71, 0.86), p<0.001) (Multivariable regression).
(Nungo et al., 2012)	Kenya Children under 5 yrs N=232	24 hr diet recall Household DDS	12: Not stated	There was no significance correlation between DDS and nutrition status.
(Paudel et al., 2012)	Nepal Children 6-60	Not stated Not stated	Not stated	DD below the WHO standard was associated with stunting. Unadjusted OR: 7.28 (4.09-12.94), adjusted OR: 4.06 (1.70, 9.67) (Multivariable regression).

	mo Cases N=118, Control N=236	Case control study		
(Zongrone et al., 2012)	Bangladesh Youngest children N=2096	24 hr diet recall Individual DDS DHS	6: Grains, roots & tubers; legumes & nuts; dairy products; flesh foods & eggs; vitamin-A rich fruits & vegetables; other fruits & vegetables.	DDS was significantly associated with HAZ (0.08, p= 0.006) and WAZ (0.04, p= 0.045) (Multivariable regression).
(Ekesa et al., 2011)	Burundi and Democratic Republic of Congo (DRC)	24 hr diet recall (validated by FFQ) Household DDS	12: Cereals; root, tubers, bananas; pulses & legumes; milk & milk products; eggs; meat & offal; fish & sea foods; oil & fats; sugar &honey; fruits; vegetables; spices & condiments.	There were no significant relationships between DDS and HAZ, WHZ or WAZ in DRC. DD was significantly related to HAZ and WAZ in Burundi but the coefficients of determination were very small (r2 = 0.051 and 0.030 respectively).
(Li et al., 2011)	China Children, 2-17 yrs N=13 770	3 consecutive days of 24 hr diet recalls Individual DDS China National Nutrition and Health Survey	13: Rice and products (0.5); wheat & products (0.5); corn, coarse grains & products (0.5); starchy roots & products (0.5); red meat & products (0.5); poultry & game (0.5); egg (0.5); fish & shellfish (0.5); legumes & products (1.0); milk & dairy products (1.0); dark-coloured vegetables (1.5); light-coloured vegetables (1.0); fruit (1.5). Weighting in brackets for a total of 10. (25g minimum portion size)	Children with normal weight and height had significantly higher DDS (Mean (Standard Error (SE)): 4.18 (0.01)) than those who were stunted (3.77 (0.03)) and those who were stunted and overweight (3.75 (0.14)) and significantly lower DDS than those who were overweight (4.53 (0.05)) (p<0.05 for all associations) (Multivariable regression).
(Niranjala	Sri Lanka	24 hr diet recall	18: Not stated	50.5% of those with DD <5 had BMI below the 5th

and Gunawardena, 2011)	Females 13 to 16 yrs N=525	Individual DDS		percentile for age compared to 36.4% of those with DD>5 (p=0.01).
(Rah et al., 2010)	Bangladesh Children 6-59 mo N=165 111	Interview Individual DDS National Surveillance Project	9: Rice; lentils; green leafy vegetables; yellow/orange fruits; eggs; fish; chicken; meat other than chicken; milk. Number of days that each of these food groups were consumed in the previous week.	After adjusting for all potential confounders high DDS was associated with reduced odds of being stunted among children aged 6–11 mo (OR (95% CI): 0.85 (0.76–0.94), 12–23 mo (0.74 (0.69–0.79) and 24–59 mo (0.69 (0.66–0.73) (Multivariable regression).
(Aboussaleh and Ahami, 2009)	Morocco School aged children N=263	7 day FFQ Individual DDS	12: Meat; poultry; fish; legumes; green & other vegetables; fruits that are a source of vitamin C; other fruits; cereals & derivatives; dairy products; fats; sweets & sweetened tea.	Mean (SD) DDS was significantly higher in stunted (8.06±0.96) than in non-stunted (7.75±1.08) children when fats, sweets and sweetened tea was excluded (p=0.03). This association disappeared when area of residence or parent education were controlled for. No significant relationship was seen with wasting (t-test).
(Garg and Chadha, 2009)	India Infants, 6-12 mo N=151	24 hr diet recall Individual DDS	6: Cereals, grains & tubers; pulses; milk; green leafy vegetables & vitamin A rich fruits; eggs; other.	DD of infants 9-12 months had significant associations (p<0.01) with WAZ, LAZ and WLZ. No associations in the 6-8 month olds were seen (Multivariate regression).
(Zhang et al., 2009)	China Children 6-11 mo. N=501	24 hr diet recall Individual DDS	6: Cereals & tubers; beans; animal milk; egg; meat & fish; other foods. 1-3 FG: 1 point 4-6 FG: 2 points	No association was seen between DDS and LAZ. DDS was significantly positively associated with WAZ (p=0.026) and WLZ (p=0.017) (Multivariable regression).

(Hillbruner and Egan, 2008)	Bangladesh Children, 6-72 mo N=555	24 hr diet recall Individual DDS	9: Cereals; pulses; vegetables; fruit; meat; fish; dairy; eggs; miscellaneous.	No significant association between DD and wasting (OR: 1.2: 0.8-1.8) or not achieving expected growth (OR: 0.95: 0.65-1.39) (logistic fixed-effects modelling).
(Benefice et al., 2007)	Bolivia Children, 0-15 yrs N=452	24 hr diet recall and questionnaire on the frequency of foods consumed on a daily and weekly basis. Household DDS	7: Fish(4); cereals(3); tubers (1); plantain (1); fruits (2); meat & milk (4). Weighted scores in brackets.	No difference in DDS in normal weight and overweight groups of children. DDS associated with HAZ in 0-5 yrs only (regression coefficients): 0-5 yr olds: (0.07, p=0.05), 5-10 yr olds: (0.04, ns), >10 yr olds: (0.03, ns) (multivariable regression).
(Sawadogo et al., 2006)*	Burkina Faso Children, 6-35 mo N=2466	24hr diet recalls Individual DDS	8: Cereals; roots & tubers; nuts & pulses; fruits & vegetables; meat & fish; eggs; milk & dairy products; fats.	DDS was significantly positively associated with HAZ in 6-11 (p=0.002) and 12-23 (p=0.0003) mo olds, this association was not significant in 24-35 mo olds. DDS was not significantly associated with WAZ at any age (Multivariable regression).
(Steyn et al., 2006)*	South Africa Children, 1-8 yrs N=2200	24 hr diet recall Individual DDS National Food Consumption Study	9: Cereals; roots & tubers; vitamin A rich fruit & vegetables; other fruit; other vegetables; legumes & nuts; meat, poultry & fish; fats & oils; dairy; eggs (tea, sugar & sweets not included)	DDS was significant correlated with HAZ r=0.19, (p<0.0001), WAZ r=0.21, (p<0.0001) and WHZ r=0.1, (p<0.0001).
(Sullivan et al., 2006)	Malawi Children, under 5 yrs Case N=145,	FFQ Individual DDS Case control study	7: Starchy staples; legumes; dairy; meat, fish & eggs; vitamin A-rich foods; other fruits & vegetables; foods rich in fats. (minimum portion size: 1 serving/day)	DDS was not significantly different in children with Kwashiorkor (Mean (SD)): (5.02 (1.10)) compared to children with Marasmus (5.06 (0.99)), which acted as a control group.

	control N=46			
(Eckhardt et al., 2005)	Philippines Children, repeated measures at 8.5, 11.5, 15.5, & 18.5 yrs N=2029	Usual intake questionnaire Individual DDS Cebu Longitudinal Health and Nutrition Study	8: Fish; animal source foods; staple cereals; other starches; vegetables; fruits; beans & nuts; dairy.	DDS significantly associated with height in boys (regression coefficients (SE) 0.33 (0.06), p<0.05) but not girls (-0.01 (0.05), NS) (Multivariable regression).
(Arimond, 2004)	11 across Africa, S/SE Asia and Latin America/Caribbean Children, 6-23 mo N=22 065	7 day diet recall Individual DDS DHS	7: Starchy staples; legumes; dairy; meat, poultry, fish & eggs, vitamin A rich fruit & vegetables; other fruit & vegetables; foods made with oil, fat or butter. Included in DDS if consumed on 3 or more of the past 7 days	Significant association between DDS and HAZ was found in 9/11 countries. This association was seen in 7/11 countries when SES was controlled for (multivariable regression).
(Hatloy et al., 2000)*	Mali Children, 6-59 mo N=2315	24 hr FFQ Household DDS	10: Staples; vegetables; oil & sugar; fruit; nuts & pulses; Meat, milk; fish; leaves & gathered foods; eggs.	Compared to those with the highest DDS, children from households with the lowest DDS had increased risk for being underweight (OR (95% CI): 2.4 (1.3-4.6) or stunted (2.2 (1.1, 4.2) in urban but not rural areas. DD was not related to the prevalence of wasting in either urban or rural areas (multivariable regression).
(Corbett et al., 1992)	Kenya Children, 5-24	Questionnaire on consumption over	7 : Standard diet = any combination of	HAZ was significantly greater in those who reported the consumption of ‘non-standard’ food during the

	yrs N=362	the past 7 days Individual DDS	maize, pulse, vegetables & milk. Non standard diet = additional elements such as animal protein (excluding milk) rice or bread.	previous week. No significant association was seen with WHZ and skinfold thickness (ANOVA).
(Dewey, 1981)	Mexico Children, 2-4 yrs N=149	2 24 hr diet recalls Individual DDS	Number of food groups not stated: DDS was calculated using an adaptation of a commonly used index of species diversity (Shannon index) using calories contributed by food category/total calories consumed.	DD significantly correlated with WHZ (r=0.36, p<0.05) but not HAZ in one village. No significant associations were seen in the other village.

*used both food groups and food items and is reported in table 2.1 and 2.2.

Mo: Months; Hrs: Hours; Yrs: years; Wk: Weeks; DD: Dietary Diversity; DDS: Dietary Diversity Score; LAZ: Length for age z-score; HAZ: Height for age z-score; WAZ: Weight for age z-score; WHZ: Weight for height z-score; BMI: Body mass index; FFQ: Food frequency questionnaire; SD: Standard deviation; SE; Standard error; CI: Confidence interval; OR: Odds ratio; S/SE; South/South East; DRC: Democratic Republic of Congo; WHO; World Health Organisation.

Table 2.2. Studies investigating the association between food variety based on number of food items and nutritional status based on anthropometric measures

Author and year	Country Population subgroup	Food variety method Individual or household food variety score Intervention/study design details	Number of individual food items (Mean (SD))	Results
Intervention studies				
(Gibson et al., 2003)	Malawi Stunted children, 30-90 mo Intervention N=200, control N=81	2 validated interactive 24 hr diet recall Individual FVS Community based dietary diversification /modification intervention. Quasi-experimental design with a non equivalent control group (not RCT).	Mean (1st, 3rd quartile) FVS Intervention: 6 (5,7) Control: 5 (4,7)	No significant difference between 2 groups after 12 months in HAZ; WHZ; triceps skinfold z-scores; arm fat area z-score. MUAC z-score and arm muscle area z-score were significantly higher in intervention group ($p<0.001$). (Multivariable regression).
Longitudinal studies				
(Bork et al., 2012)*	Senegal Children 6-36 mo N=1060	List based FFQ, 24 hrs. Individual FVS 2 visits, 6 mo apart	The FVS included 20 individual foods or food groups (fresh milk, powered milk, sour milk, fresh fish, dried or smoked fish, eggs, meat, organ meats, chicken, groundnuts, other	FVS was significantly positively associated with HAZ at 6-12 mo, 12-18 mo and 12-18 mo. FVS not associated with length/height increments (Multivariable regression).

			legumes, vegetables, leaves, fruit, vitamin A–containing food, tubers, roots, millet gruel, milk-based millet gruel, millet couscous, millet porridge, rice, fat-containing foods, bread, biscuits) & “other foods”.	
Cross sectional surveys				
(Saibul et al., 2009)	Malaysia Children, 2-9 yrs N=284	3 24hr diet recalls Individual FV	Children: 6.9(1.9)	Duel burden of malnutrition (overweight mother/underweight child) was significantly associated (Adjusted odds ratio and 95% CI) with children’s FVS, 0.71 (0.51-0.95) (Multivariable regression).
(Sawadogo et al., 2006)*	Burkina Faso Children, 6-35 mo N=2466	24 hr diet recalls Individual FVS	Total: 16 items	FVS was significantly positively associated with HAZ in 6-11 (p=0.0001) and 12-23 (p=<0.0001) mo olds, this association was not significant in 24-35 mo olds. FV was significantly negatively associated with WAZ in 6-11 (p=0.01) mo olds but was not significantly associated with WAZ at age 12-23 and 24-35 month olds (multivariable regression).
(Steyn et al., 2006)*	South Africa Children, 1-8 yrs N=2200	24hr diet recall Individual FVS National Food Consumption Study	5.5(2.5)	Significant correlation between FVS and HAZ (r=0.21, p<0.0001), WAZ (r=0.23, p<0.0001) and WHZ (r=0.1, p<0.0001).

(Hatloy et al., 2000)*	Mali Children, 6-59 mo N=2315	24hr FFQ Household FVS	Urban: 19.6 (6.1) Rural: 14.3 (5.2)	Compared to those with the highest FVS, children from households with the lowest FVS had increased risk for being underweight (OR (95% CI): 2.3 (1.3-4.0) or stunted (1.7 (1.0, 3.1) in urban but not rural areas. FVS was not related to the prevalence of wasting in either urban or rural areas (Multivariable regression).
(Lamontagne et al., 1998)	Nicaragua Children, 12-18 mo N=80	Observation and recall combined to give 24hrs of intake Individual FVS	Not reported	No significant correlations between FVS and HAZ, WAZ, WHZ were found.
(Onyango et al., 1998)	Kenya Children, 12-36 mo N=154	3 24 hr diet recall Individual FVS	Mean (SE): 6.0 (0.2)	FVS was significantly and positively associated with WAZ (regression coefficient: 0.19, p=0.001), HAZ (0.17, p=0.008), WHZ (0.12, p=0.01), triceps skinfolds (0.24, p=0.05) & MUAC (0.17, p=0.006) (Multivariable regression).
(Novotny, 1987)	Ecuador Children 12 mo - 5 yrs N=146	24 hr diet recall Individual FVS	7 (3) Range 2-16	FVS significantly associated with HAZ (regression coefficient): 0.159, p<0.05) and WAZ (0.232, p<0.05) (Multivariable regression).

*used both food groups and food items and is reported in table 2.1 and 2.2.
SD: Standard deviation; SE; Standard error; CI: Confidence interval; OR: Odds ratio; Mo: Months; Hrs: Hours; Yrs: years; FFQ: Food frequency questionnaire; FV: Food variety; FVS: Food variety score; HAZ: Height for age z-score; WAZ: Weight for age z-score; WHZ: Weight for height z-score; MUAC: Mid upper arm circumference.

2.4 Part 2: Agrobiodiversity and dietary diversity/nutritional status

2.4.1 Methods

This second review focuses on research presenting associations between plant or plant and animal agrobiodiversity and either dietary diversity or nutritional status, as measured by anthropometry, in low income countries. Due to the limited amount of research available in this area research in both children and adults is included. Interventions investigating these associations, longitudinal, case control and cross-sectional studies are included.

2.4.1.1 Search strategy

The same methodology was followed for part 2 of this chapter. The following electronic databases were searched in February 2014:

- Embase Classic and Embase 1947 to 2014 February 14
- Global Health 1973 to 2014 Week 06
- Ovid medline 1946 to February week 1 2014
- Psychinfo 1806 to February Week 2 2014

The following search terms were used. The numbers on the right represent how many papers were identified with each search term from all databases combined.

1	diet$ divers$.mp.	1635
2	diet$ variet$.mp.	557
3	food divers$.mp.	350
4	food variet$.mp.	500
5	food group divers$.mp.	23
6	food group variet$.mp.	33
7	**1 or 2 or 3 or 4 or 5 or 6**	**2769**
8	nutritional status.mp.	107066
9	growth.mp.	2884272
10	stunt$.mp.	14925
11	wast$.mp.	313836
12	underweight$.mp.	19545
13	undernutrition.mp.	16079

14	malnourish$.mp.	24195
15	malnutrition.mp.	116572
16	**8 or 9 or 10 or 11 or 12 or 13 or 14 or 15**	**3360729**
17	**7 or 16**	**3362592**
18	agrobiodiversity.mp.	93
19	biodiversity.mp.	48164
20	**18 or 19**	**48194**
21	**17 and 20**	**7031**
22	africa$.mp.	651952
23	low income countr$.mp.	7651
24	developing countr$.mp.	705500
25	**22 or 23 or 24**	**1209473**
26	**21 and 25**	**568**
27	limit 26 to English language	546
28	limit 27 to humans [valid in Embase and Ovid Medline only]	317

2.4.1.2 Criteria for inclusion

Titles and abstracts were first screened to identify potentially relevant references. Where possible, the full journal articles of these potentially relevant references were obtained and these were checked for final inclusion in the review. Papers that met the following inclusion criteria were included in the review:

- English language
- Human
- Measures plant agrobiodiversity or number of crops grown
- Study relates agrobiodiversity to dietary diversity or measure of nutritional status
- Based in a low income country as defined by the IMF

2.4.1.3 Included references

Database searches identified 317 references of which 295 were unique (figure 2.2). Based on the titles and abstracts 32 papers were identified as potentially relevant. Four papers were unable to be found and have been excluded from the review (authors were emailed where contact details could be found). On review of the full journal articles 25 were excluded as they did not meet the inclusion criteria. Three papers were included in the review from those found through database searches. An additional four hand-searched references were identified through Google scholar and the reference lists of included papers, relevant review papers, books and reports. A total of seven references are included in the review.

Papers were summarised and research relating agrobiodiversity to dietary diversity or food variety are presented in Table 2.3, those relating agrobiodiversity to nutritional status are presented in Table 2.4. Agrobiodiversity is used to reflect the diversity of plants, the diversity or crops grown or the diversity of both crops grown and animals raised depending on the different definitions used by the researchers. These different definitions are outlined in the tables.

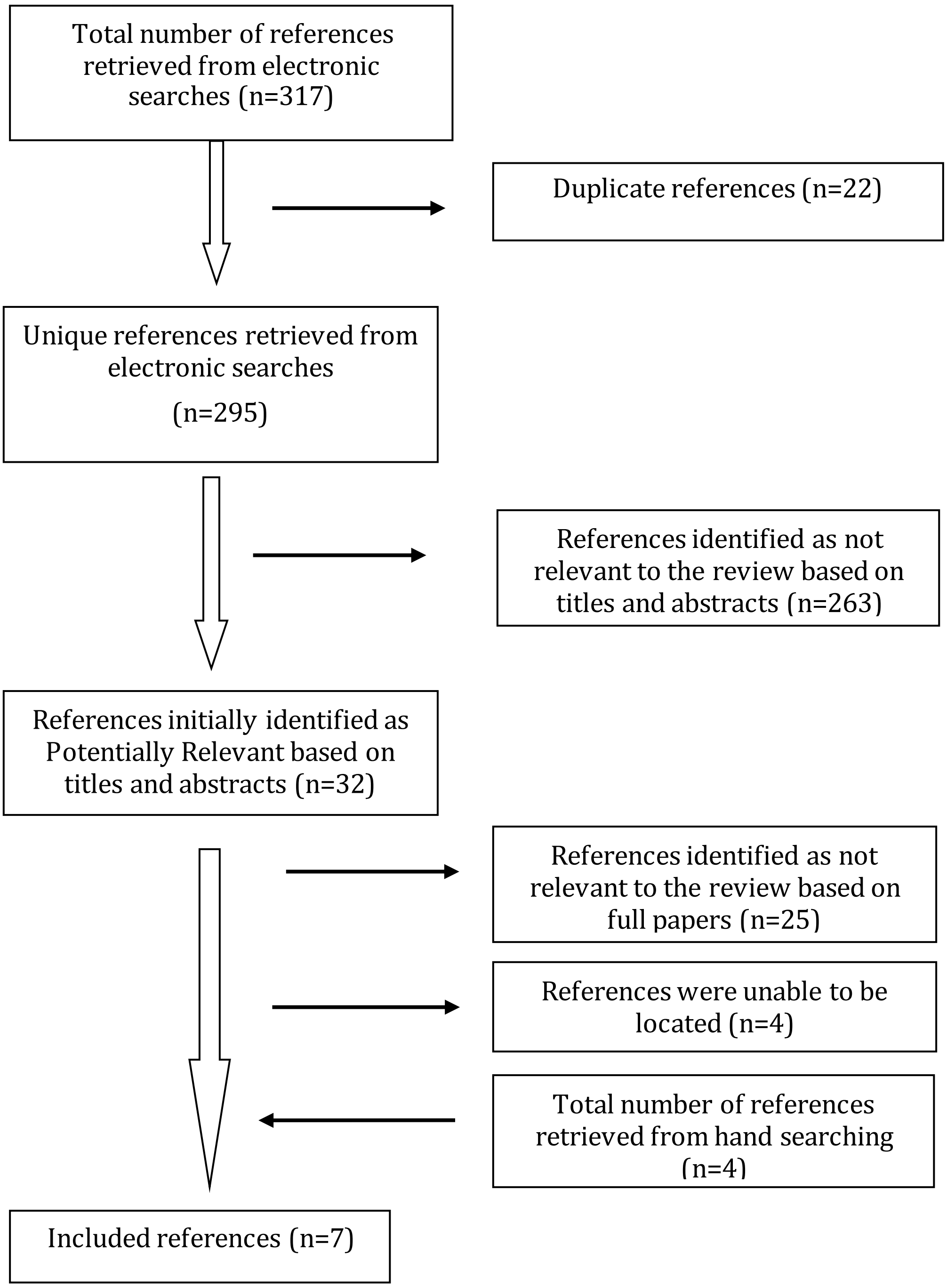


Figure 2.2. Flowchart of inclusion for part 2: Agrobiodiversity and dietary diversity/nutritional status

2.4.2 Results and discussion

All six references presented in table 2.3 were cross-sectional surveys assessing associations between agrobiodiversity and dietary diversity at one time point. Four studies defined agrobiodiversity as the diversity of plants or crops and two based their definitions of agrobiodiversity on both plant foods and animals. Four of the six studies showed some positive association between agrobiodiversity and dietary diversity (Walingo and Ekesa, 2013, Dewey, 1981, Bhagowalia et al., 2012, Ekesa et al., 2008). Of these studies, Walingo and Ekesa (2013) were the only ones to use a biodiversity index of plants and animals and showed that agrobiodiversity was positively associated with child dietary diversity (coefficient of determination: 0.496). Despite using a biodiversity index, the methods on how the agrobiodiversity data was collected and what this index reflects was not reported. Additionally, the quality of this study was lowered by the statistical methods used and the omission of information on statistical significance. Ideally regression analysis adjusting for potential confounders would have been used, with associated p-values or confidence intervals reported.

Ekesa et al (2008) also used a count of both food crops grown and animals reared in their definition of agrobiodiversity. A positive correlation between agrobiodiversity and dietary diversity was reported but no indication of whether this was significant was given (Ekesa et al., 2008). Dewey (1981) found the farm crop diversity (details not presented) to be significantly correlated with child dietary diversity in one out of two areas studied. Again details of how crop diversity was measured were not reported making it difficult to understand the associations reported.

The final paper showing a positive association between agrobiodiversity and dietary diversity use a count of crops grown as reported by a household member to represent agrobiodiversity. A count of crops grown over a reference period may be a useful tool in determining food availability but it is not agrobiodiversity which is defined as the biological diversity on lands used for agricultural purposes; it includes the diversity of plants, animals and micro-organisms at species and ecosystem levels and covers both cultivated crops and wild plants (Brookfield and Stocking, 1999, Cromwell et al., 1999). Never the less, a large, nationally representative survey in India found the reported number of crops grown to be significantly associated with the number of food groups the household had consumed in the previous 30 days (Bhagowalia et al., 2012). Regression analysis was used but no potential confounders were adjusted for so the associations seen could be affected by the socio-economic status of the household, the education of the household members or a number of other factors. As this was a large, nationally representative sample using mainly appropriate statistical methods this paper provides important evidence on the association between the number of crops the household grows and dietary diversity. As a result of weak methodology and statistical methods, the overall evidence of an association between agrobiodiversity and dietary diversity provided by these four references is poor.

Two papers found no association between agrobiodiversity and dietary diversity (Remans et al., 2011a, Akrofi et al., 2010). Akrofi et al (2010) found no significant correlation between home garden Shannon biodiversity indices and household dietary diversity. The details reported on the methods used to assess agrobiodiversity were limited and agrobiodiversity was not measured in the household farms. Remans et al (2011a) found no significant correlation between nutritional functional diversity of the farm (the diversity of nutrients provided by the farm) and household dietary diversity. Although the methodology of this paper was high quality and well reported, this study measured something slightly different from agrobiodiversity. It provides evidence that suggests there is no association between agrobiodiversity and dietary diversity but does not address the question directly. The six studies linking agrobiodiversity to dietary diversity are collectively inconclusive.

Two studies employed a cross sectional design to link plant agrobiodiversity with nutritional status (Table 2.4) (Dewey, 1981, Shack et al., 1990). The first found no association between the number of food crops grown in household gardens and children's nutritional status using multivariable regression (Shack et al., 1990). The study did, however, find a significant association between agrobiodiversity and the mothers BMI. Agrobiodiversity was recorded directly by a researcher but it appears that it is a count of food crops grown in the household gardens, rather than a method capturing the diversity of plants grown in the garden. The second found a significant correlation between crop diversity and height for age in children in one of the two villages studied. Interestingly it was not the village that had a significant correlation between agrobiodiversity and dietary diversity (Dewey, 1981).

In addition to the cross sectional studies presented in table 2.3 and 2.4 Talukder et al (2010) reported on a Helen Keller International intervention to improve vegetable gardens in Bangladesh, Cambodia, Nepal and the Philippines. It compared the frequency of consumption of vegetables in households with no garden, traditional (seasonal with a few traditional fruits and vegetables), improved (produce more varieties of fruits and vegetables) and developed (produce a wide variety of fruits and vegetables that are available year round) vegetable gardens after the intervention. Children from households with developed gardens consumed vegetables 5/week compared to 4/week in households with improved gardens and 3/week in those with traditional or no vegetable gardens (significance not stated). There was no significant difference in anaemia prevalence between the program and the control communities. Similar results were seen in the pilot study of this project published in Talukder et al (2000).

Land cover has previously been used as a proxy for biodiversity (Skidmore et al., 2003, Walker et al., 1992, Tucker and Sellers, 1986), details of this are presented in section 7.2, chapter 7. Two papers were identified which looked at land cover and dietary diversity or nutritional status. Johnson et al (2013) presented the Vegetation Continuous Fields (VCF) and the Normalized Difference Vegetation Index (NDVI) measured using satellites in Malawi. They found that communities experiencing loss in forest cover over the previous ten years, based on these two indices, were 19% less likely to have a diverse diet (OR: 0.813, p=0.05) but were no more likely to be stunted (OR: 1.113, p=0.64) than children living in areas with no change in forest cover. The odds of having poor dietary diversity and of being stunted did not vary depending on the current percentage forest cover. Tree cover and NDVI were measured in the East-Usambara mountains in Tanzania using Landsat eTM+ satellite images by Powell et al. (2011). This data was not directly related to dietary diversity in mothers and their youngest child between the ages of two and five years. They did, however, report that households with greater nearby tree cover were more likely to consume forest foods and individuals using forest foods had higher dietary diversity.

Overall there is very little published data on the association between agrobiodiversity and dietary diversity or nutritional status. The data that is available is inconclusive and the quality of the literature is relatively poor. The methodological limitations in how agrobiodiversity was assessed and the statistical methods used to assess these associations make it difficult to compare the results of the studies and to assess the reliability of the results and conclusions of the studies. There is some evidence from a large intervention study that improvements in agrobiodiversity lead to improvements in vegetable consumption but unfortunately this was not linked to measures of dietary diversity. There is also limited data showing associations between more biodiverse land cover and dietary diversity but not child growth. This review identified four potentially relevant papers that could not be located. In addition to these it is likely that there is other relevant work on improving nutrition through agrobiodiversity that has not been published in peer reviewed journals. This review, therefore, may not cover all the research in this area. The conclusions are based on the small number of papers obtained and it is possible that this additional research would alter the conclusions of the review. Additional limitations of both this review and the dietary diversity and nutritional status review are those commonly associated with narrative synthesis reviews. These reviews included no formal quality assessment. There is a greater likelihood of bias than in a systematic review following strict protocols. These reviews do, however, have transparent methods which would allow replication of these results.

To the students knowledge, there has been no published literature using both systematic observations of the biodiversity of household farms and reliable statistical methods to assess the association between agrobiodiversity and dietary diversity or nutritional status to date. It appears that none of the published studies have assessed the biodiversity of both the crops grown and wild plants present in the gardens or on the farms. Additionally, those studies directly observing crops grown focused on vegetable gardens rather than household farms. Due to the limited number of relevant studies and the quality of these studies, the literature to date is inconclusive. This literature review has revealed a substantial gap in the literature on how agrobiodiversity is related to dietary diversity and nutritional status that the current project aims to address. The gaps in the literature found by this literature review consolidated the decision to measure agrobiodiversity of household farms systematically rather than relying on counts of foods grown.

Table 2.3. Studies investigating the associations between agrobiodiversity and dietary diversity

Author and year	Country Population subgroup	Agrobiodiversity measurement	Dietary diversity score details	Results
(Walingo and Ekesa, 2013)	Western Kenya Individual DDS (Youngest child, 12-60 mo) N=164	Agrobiodiversity was measured by assessing the variety of food plants grown and animals reared by households. A Shannon Index (SI) was calculated to reflect species diversity.	Qualitative 24 hr diet recall. The score was based on only the first 23 healthy foods consumed over a period of 2 months, established using food checklists. 8 : Cereals; roots & tubers; pulses & nuts; vegetables; fruits & vegetables; meat & meat products (included fish); milk & milk products; fats &oils.	Agrobiodiversity was positively associated with DDS (r2 = 0.496). (significance was not reported).
(Bhagowalia et al., 2012)	India India Human Development Survey Household DDS N=19 000	Number of crops grown by the household, information collected through the survey.	Number of food groups consumed over the past 30 days.	Number of crops grown by the household is significantly associated with dietary diversity (regression coefficient: 0.32 (p<0.01). Associations remain significant when farms are broken down into their different sizes ranging from <0.5 hectares to >5 hectares.
(Remans et al., 2011a)	Malawi, Kenya and Uganda Household DDS	All crop, plant and tree species on the farms and vegetable gardens cultivated by the household were documented. Only plants that were	24 hr diet recall. 15: Cereals; vitamin A rich vegetables & tubers; white tubers, roots & plantains; green leafy vegetables; other vegetables;	Correlations between nutritional functional diversity and household dietary diversity were not significant.

	N=170	edible and consumed in the village were considered for this study. Species richness was defined by the number of identified edible species per farm. Nutritional functional diversity summarises the diversity of nutrients provided by the farm. It was calculated based on farm species composition and species nutritional composition using 17 nutrients from 77 crops.	vitamin A rich fruits; other fruits; legumes & nuts; oils & fat; meat; fish; eggs; milk; sweets; spices & tea.	
(Akrofi et al., 2010)	Ghana HIV positive and HIV negative households Household DDS N=80	An inventory of the cultivated plant species was compiled for home gardens. The number of individual plants of each species recorded. Shannon index (SI) was calculated based on these cultivated species. Plant species were categorised as human food, medicine and animal feed. Livestock reared in the gardens was also recorded.	Household DDS as food groups based on 24 hr qualitative diet recall. 14: Cereals; vitamin A-rich vegetables & tubers; white tubers & roots; dark green leafy vegetables; other vegetables; vitamin A-rich fruits; other fruits; organ meat (iron rich); flesh meats; eggs; fish; legumes, nuts & seeds; milk & milk products; oils, fats & red palm products.	There was no significant correlation between the home garden SI and the household DDS (r = 0.17, p = 0.14).
(Ekesa et al., 2008)	Eastern Kenya Individual DDS (Pre school children)	Variety of food crops grown, animals reared for food and wild food items collected through gathering, hunting and trapping. Total number of food	7 day food variety score. 7: Breads & cereals; roots & tubers; pulses & nuts; vegetables & fruits; meat & meat	The number of animals kept and plants grown was correlated with children's DDS (r=0.697) (significance

	N=144	types, plant and animal combined, were used.	products (included fish); milk & milk products; fats & oils.	was not reported).
(Dewey, 1981)*	Mexico Socios: an area of organised farming Nearby village: Tecominoacan Individual DDS (Children, 2-4 yrs) N=149	Crop diversity in family plots (number of species). Further details not presented.	2 24 hr diet recalls DDS was calculated using an adaptation of a commonly used index of species diversity (SI) using calories contributed by food category/total calories consumed.	Socios: Households with >=5 crops in the family plot had higher DDS. R=0.25 (p<0.05) Tecominoacan: no relationship between crop diversity and DDS.

*presented associations with both dietary diversity and nutritional status and is reported in table 2.3 and 2.4.

DDS: Dietary diversity score; SI: Shannon index; Hr: Hour; Yrs: Years.

Table 2.4. Studies investigating the associations between agrobiodiversity and nutritional status as measured by anthropometry

Author and year	Country Population subgroup	Agrobiodiversity measurement	Nutritional status measurement	Results
(Shack et al., 1990)	Papua new Guinea Mothers and their youngest non-breastfed child 2-6 yrs N=56	Number of food crops grown in the household gardens as observed by a researcher.	Weight, height, arm circumference, and triceps and subscapular skinfolds in mothers and children.	The number of different types of crops planted in the garden was not related to nutritional status in the children. The number of different types of crops planted was positively associated with the mothers BMI (Regression coefficient 0.002, p<0.05) (Multivariable regression).
(Dewey, 1981)*	Mexico Socios: an area of organised farming. Nearby village: Tecominoacan. Children, 2-4 yrs N=149	Crop diversity in family plots (number of species). Further details not presented.	Height for age and weight for height in children were reported.	Socios: no significant correlation between crop diversity and HAZ or WHZ. Tecominoacan: Crop diversity was significantly correlated to HAZ in children: r=0.29 (p<0.05) but not WHZ.

*presented associations with both dietary diversity and nutritional status and is reported in table 2.3 and 2.4.

HAZ: Height for age z-scores; WHZ; Weight for height z-scores; Yrs: Years; BMI: Body mass index.

2.4 Conclusion

Current research indicates that dietary diversity and food variety are associated with nutritional status as measured using anthropometry in children in low income countries. There were a number of papers using methods that varied in the way the data was collected and presented which found dietary diversity and food variety to be related to these anthropometric measures. The results seen from studies carried out in Eastern Africa do not show such a clear cut association and further research in this area would be beneficial. The associations between agrobiodiversity and both dietary diversity and nutritional status are less clear. There is limited research in this area and, due to methodological limitations, the results seen to date are inconclusive. This literature review has revealed a substantial gap in current knowledge about the relationships between agrobiodiversity and dietary diversity and nutritional status in low income countries.

Chapter 3:
Pilot, village selection and methods for the project's primary data collection.

3.1 Chapter summary

This chapter describes the overarching methodological approach and outlines the research design employed to investigate the relationships between agrobiodiversity, dietary diversity and nutritional status in Tanzania. This chapter describes the design and application of the methodological tools used during the primary data collection phase of the project. The project described is a cross-sectional survey in two villages which collected data through household interviews, anthropometry and a systematic agrobiodiversity survey. Important aspects of the research process, including sampling design, piloting methods, ethical procedures, training of research assistants, randomisation and participant recruitment are described. Information on the two villages where this project collected data is presented. Methodological specifics, particularly the analytical approach, associated with each empirical chapter (chapters 4, 5 and 6) are covered subsequently in these chapters. The methods used to investigate the relationships between land cover, dietary diversity and nutrition, the DHS and land cover analysis phase of the project, are described in chapter 7.

3.2 Research design

This research was conducted in four phases of work (Figure 3.1). Phase 1 involved literature review, design of methodological tools and piloting of these tools to meet objective 1. Phase 2 involved selection of study site villages, primary data collection and analysis of data to investigate the relationships between agrobiodiversity, dietary diversity and nutritional status in rural Tanzania to fulfil objectives 2, 3 and 4. Phase 3 involved analysis of Demographic and Health Survey (DHS) data and land cover data to investigate the relationships between land cover, dietary diversity and nutritional status and fulfil objective 5. Phase 4 involved the integration of outcomes from the empirical and analytical work conducted in phases 2 and 3 to generate discussion and conclusions (chapters 8 and 9) that inform understanding of food security in sub-Saharan Africa and thus fulfil objective 6.

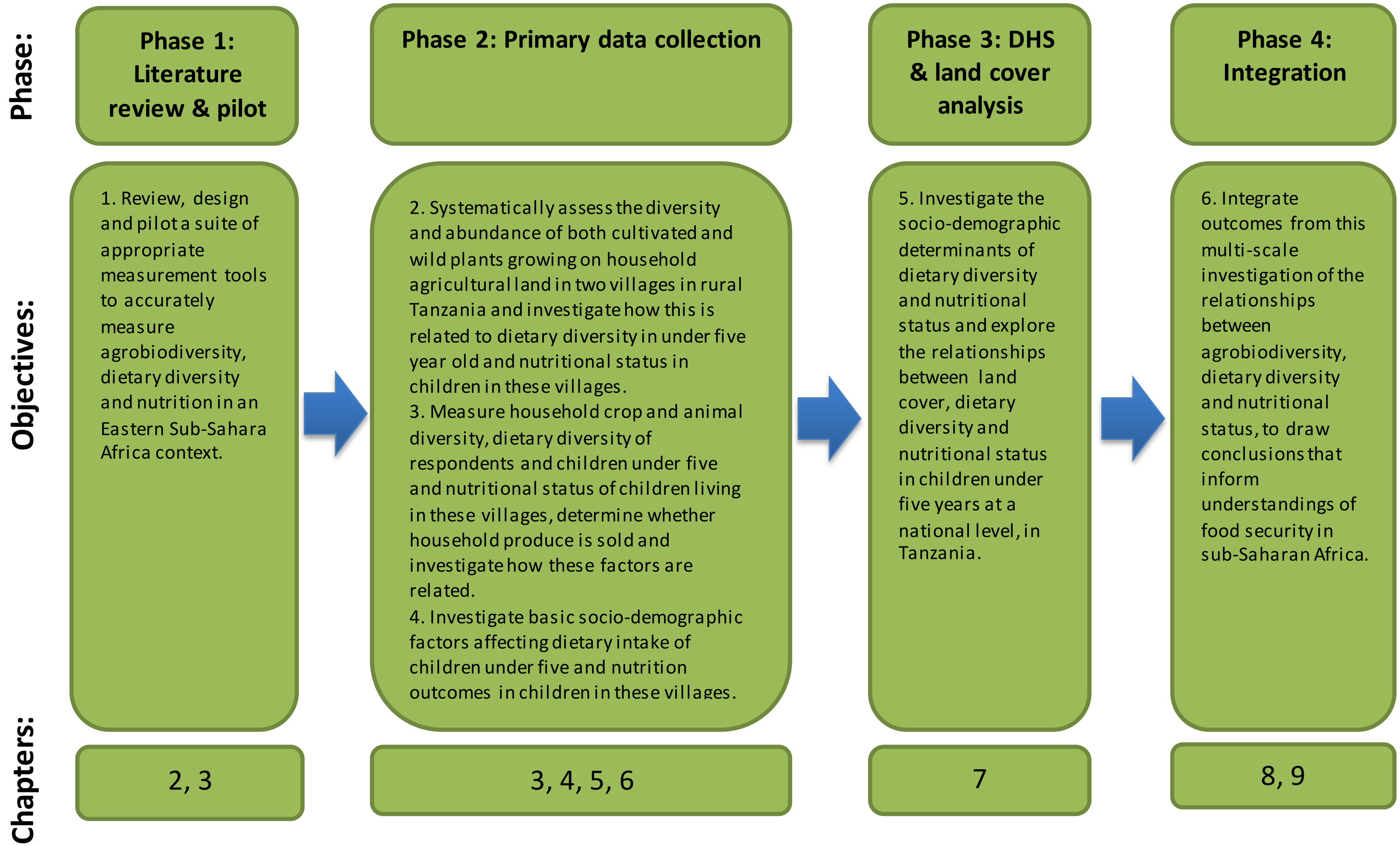


Figure 3.1. Overall research design, the objectives each phase fulfils and the chapters these are presented

The conceptual framework was designed using other relevant conceptual frameworks presented in section 1.4, 5.1 and 6.1 ((UNICEF, 1990, Altieri, 1999, Leroy and Frongillo, 2007) and attempts to graphically display a simple representation of how agrobiodiversity would be expected to be associated with individual dietary diversity and childhood nutritional status. The main three pathways illustrated are its potential relationship to individual dietary diversity, to household income and to production, through improvements to ecosystem functioning (Figure 3.2a)).

The impact agrobiodiversity potentially has on dietary diversity and household income through improvements in ecosystem functioning leading to increased production is beyond the scope of this study. The relationships between agrobiodiversity and dietary diversity/nutritional status and between dietary diversity and nutritional status are addressed through both the literature reviews presented in chapter 2 and the primary data collection. These relationships are also explored at a national level relating average group dietary diversity and nutritional status and land cover surrounding these geographically clustered groups.

Figure 3.2 b) illustrates the elements of the framework that the empirical study addresses. The main focus of the primary data collection are the relationships between agrobiodiversity, dietary diversity and nutritional status. Data was also collected on specific socio-demographic characteristics and whether households produce was sold in order to see if household income from these practices influenced child dietary diversity and nutritional status. As these factors are not the primary focus of the thesis, these are displayed less prominently in the framework (figure 3.2 b)).

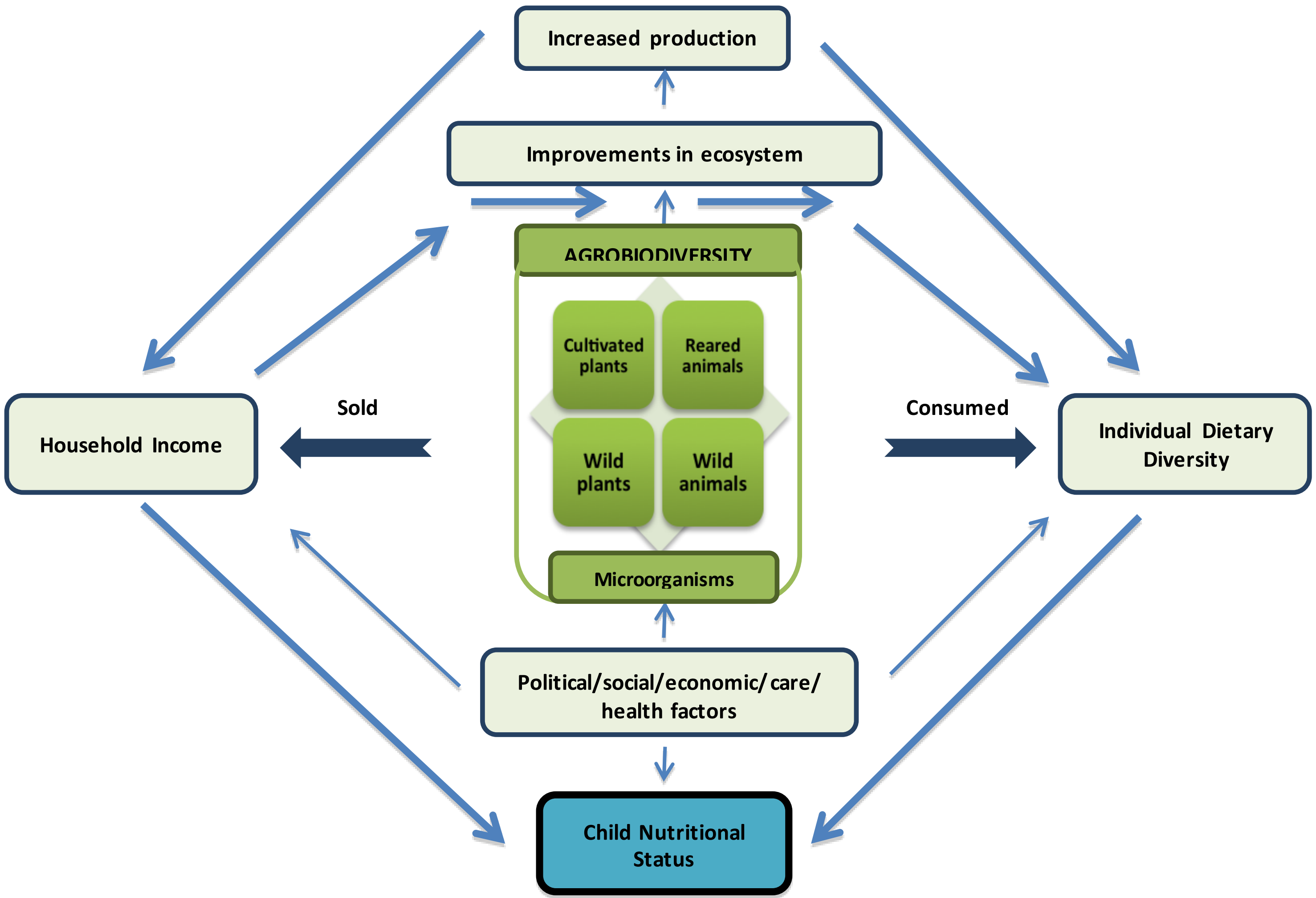


Figure 3.2 a). Conceptual framework for the relationships between agrobiodiversity, dietary diversity and nutritional status

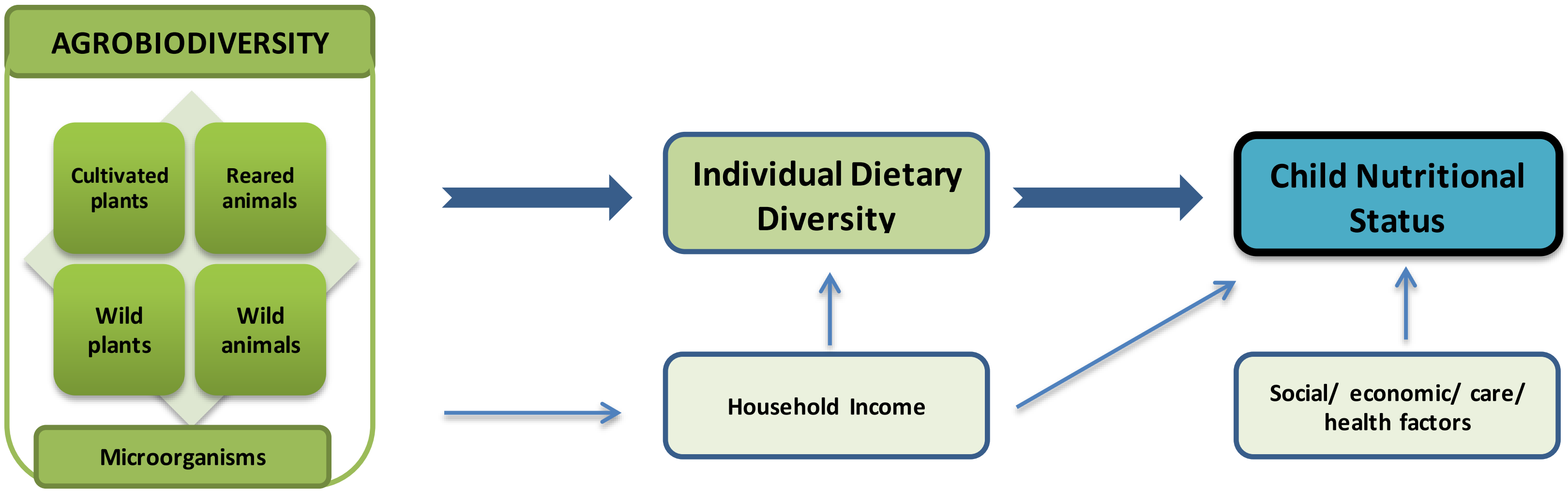


Figure 3.2 b). Section of the conceptual framework for the relationships between agrobiodiversity, dietary diversity and nutritional status which forms the focus of this thesis

3.3 Village selection for primary data collection

Two villages were selected in rural Tanzania for collection of primary data. Areas where the population were, on average, likely to be malnourished were selected, as explained below, to allow for factors associated with malnutrition to be more easily identified. Areas with different biophysical (eg. soil, vegetation type and topography and thus land cover) and climate characteristics are likely to have different levels of agrobiodiversity (Hadgu et al., 2009). Differing contexts allow for contrasting relationships between agrobiodiversity, dietary diversity and nutritional status to be investigated. One site in an area of high biodiversity with two rainfall seasons and one site in an area of low biodiversity with one rainfall season were selected. The following sections outline the criteria that were used for selecting Enumeration Areas (EA), areas defined by the census, with high proportions of malnourished children in high and low biodiversity areas.

Areas of poor nutritional status were determined using data from the 2010 Demographic and Health Survey (DHS) obtained free from the DHS program (The DHS Program, 2014b). Age, sex, height and weight of children under the age of five years were used to calculate their individual height and weight z-scores. These scores were added to ArcGIS, a piece of software based on geographic information systems (GIS) for working with mapped data and analysing geographic information. Scores averaged by EA were added using the Global Positioning System (GPS) co-ordinates that were collected at the centre point of each EA cluster. ArcGIS was then used to select those EA clusters that had both average height and weight z-scores below negative 2. These cut offs were used to identify EA that had a high prevalence of malnutrition.

Of 474 EA included in the 2010 DHS survey, 61 had average weight z-scores below negative 2 and 36 had average height z-scores below negative 2. Twenty had both height and weight z-scores below negative 2. Due to the agricultural focus of this project, rural environments were the most appropriate areas to collect data. EA that were classed as urban in the DHS survey were therefore excluded leaving 18 classed as rural and malnourished. The land cover data used, GlobCover2009, was obtained from the European Space Agency (ESA) GlobCover Portal (European Space Agency, 2010) for free. This data was added to ArcGIS, the 18 EA classified as malnourished were then added and a map generated (Figure 3.3). Five km buffers around each of these 18 EA were created and land cover classifications within these boundaries assessed to determine areas of high and low biodiversity.

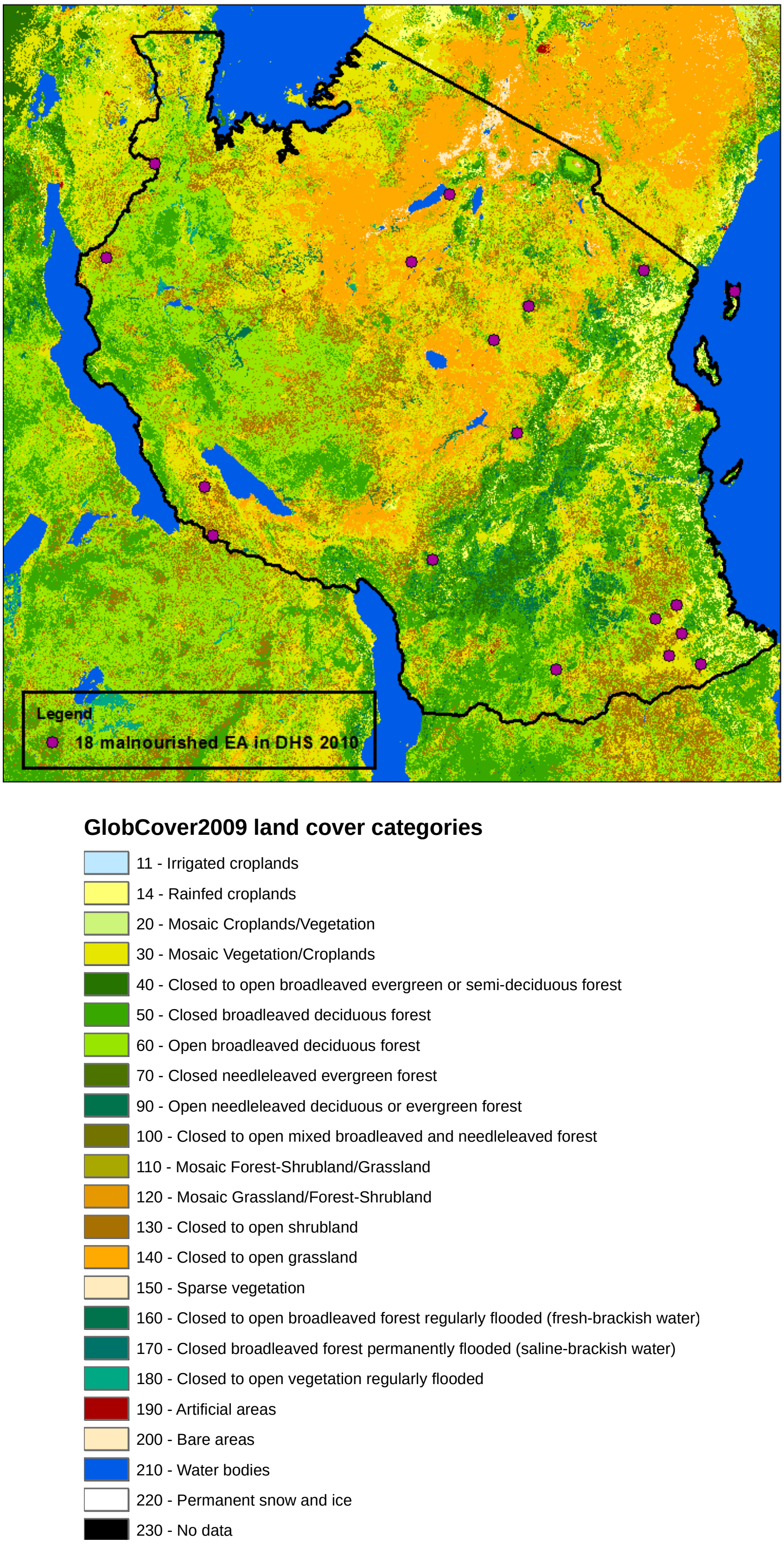


Figure 3.3. A map of the 18 potential enumeration areas determined as malnourished in relation to land cover classification (GlobCover2009) in Tanzania. The key outlines 22 different land cover categories determined in the GlobCover2009 data

The GlobCover2009 project was able to differentiate between different types of land cover with 67.5% accuracy (Bontemps et al., 2011). Land cover classification characteristics were used as a proxy for biodiversity. Previous research has shown that satellite imagery can identify biodiverse forested areas (Skidmore et al., 2003, Walker et al., 1992, Tucker and Sellers, 1986) (Austin et al., 1996, Homer et al., 1993, Miller and Conroy, 1990). Due to the focus on agrobiodiversity in this project, sites of high biodiversity were defined as areas including both 'Croplands' and 'Forests' in the buffer surrounding the EA (Box 3.1).

Box 3.1 Land use types used to classify high biodiversity sites

Croplands

The following land cover types were included in the definition of 'Croplands' in land cover assessment. These correspond to the Land Cover Classification System (LCCS) of 'cultivated terrestrial areas and managed lands':

1) Post-flooding or irrigated croplands

2) Rainfed croplands

3) Mosaic Cropland (50-70%) / Vegetation (grassland, shrubland, forest) (20-50%)

4) Mosaic Vegetation (grassland, shrubland, forest) (50-70%) / Cropland (20-50%)

Forests

The following land cover types were included in the definition of 'Forests' in land cover assessment. These match the LCCS of 'Natural and semi-natural terrestrial vegetation – Woody-Trees' and 1 of the classes of 'natural and semi-natural aquatic vegetation'.

1) Closed to open (>15%) broadleaved evergreen and/or semi-deciduous forest (>5m)

2) Closed (>40%) broadleaved deciduous forest (>5m)

3) Open (15-40%) broadleaved deciduous forest (>5m)

4) Closed (>40%) needleleaved evergreen forest (>5m)

5) Open (15-40%) needleleaved deciduous or evergreen forest (>5m)

6) Closed to open (>15%) mixed broadleaved and needleleaved forest (>5m) (100)

7) Mosaic Forest/Shrubland (50-70%) / Grassland (20-50%)

8) Mosaic Grassland (50-70%) / Forest/Shrubland (20-50%)

9) Closed (>40%) broadleaved forest regularly flooded - Fresh water

Sites of low biodiversity were defined as areas with land cover types that were not associated with high biodiversity and did not include 'Croplands' or 'Forests' (Box 3.1). Box 3.2 summarises the land use types used to classify low biodiversity sites.

Box 3.2 Land use types used to classify low biodiversity sites

Low diversity

The following land cover types were included in the definition of 'Low diversity' in land cover assessment. These correspond to the LCCS of 'Natural and semi-natural terrestrial vegetation – shrub and herbaceous' and 'artificial surfaces' and 'bare areas':

1) Closed to open (>15%) shrubland (<5m)

2)Closed to open (>15%) grassland

3) Sparse (>1. 5%) vegetation (woody vegetation shrubs, grassland)

4) Artificial surfaces and associated areas (urban areas >50%)

5) Bare areas

6) Permanent snow and ice

Two villages, representing areas of low nutrition with 1) high and 2) low biodiversity were chosen from maps that were produced for each of the 18 potential EA. These decisions were made by examining the maps to find the most diverse land cover and the least diverse land covers by comparing the proportion of land that fell into 'Cropland', 'Forest' and 'Low diversity' categories. No strict cut-offs were used in the distance from the centre point of the EA as EA vary in size depending on population size. The following criteria, obtained through the 2010 Tanzanian DHS and Google maps, were also considered to determine suitable sites: agro-ecological zone, how close the nearest villages and main roads were, how close protected areas were, which districts they fell in, elevation, percentage of population with agricultural land, average hectares of agricultural land, accessibility by public transport, whether they were in a protected area and wealth index.

For each site, three areas, ranked as first, second and third choices, were chosen based on their land cover and this additional information. The location of the six potential sites are shown in Figure 3.4. The land cover surrounding the six potential EA which was used to help decide on the final two sites are shown in figures 3.5 to 3.10. The figures on the left (Figure 3.5, 3.7 and 3.8) are the high diversity sites and the figures on the right (Figure 3.6, 3.8 and 3.10) are the low diversity sites.

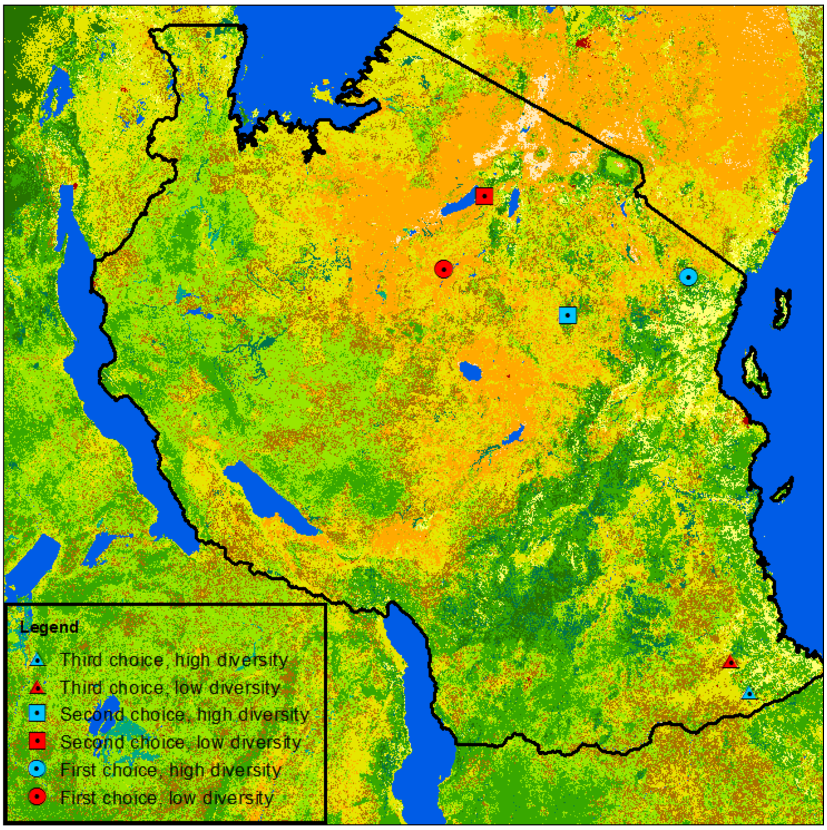


Figure 3.4. Location of top 6 potential sites, first, second and third choices for the high and low diversity sites.

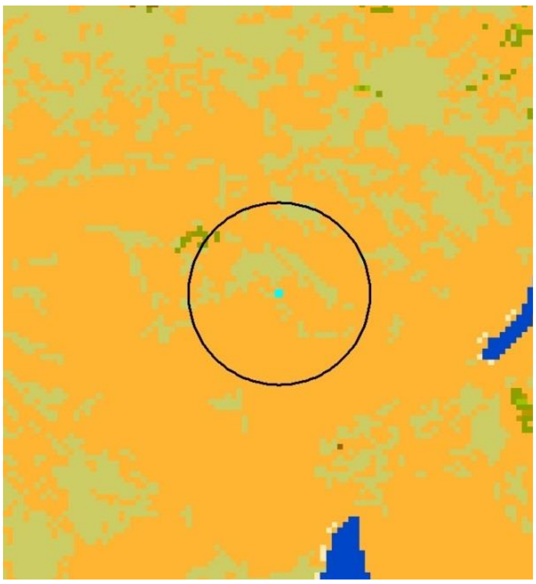
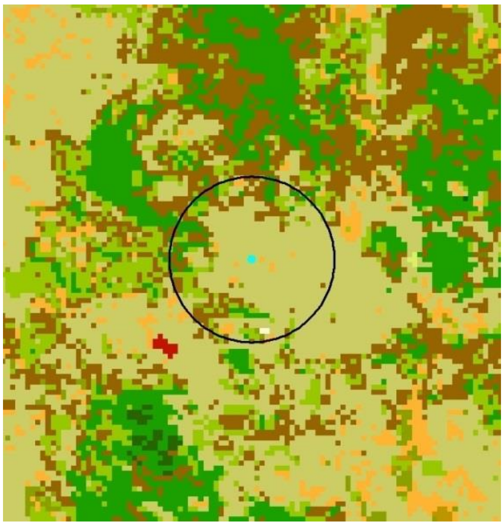


Figure 3.5. Land cover around EA 62, in Tanga, Northern Tanzania, one of the

Figure 3.6. Land cover around EA 232, in Singida, Central Tanzania, one of the

three potential high diversity EA

three potential low diversity EA



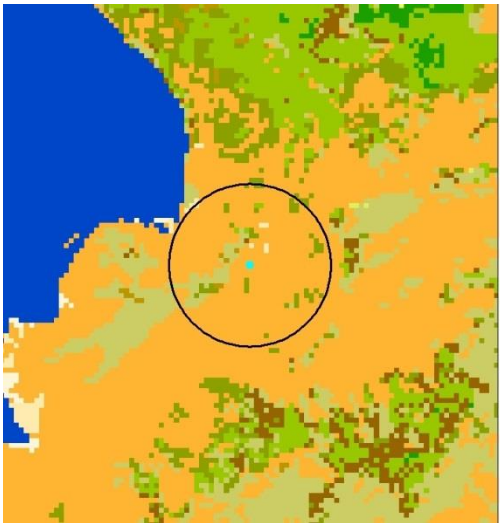
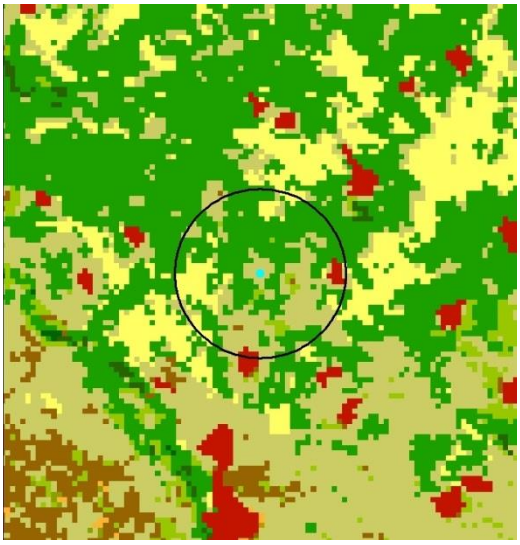


Figure 3.7. Land cover around EA 376, in Manyara, Northern Tanzania, one of the three potential high diversity EA

Figure 3.8. Land cover around EA 34, in Arusha, Northern Tanzania, one of the three potential low diversity EA



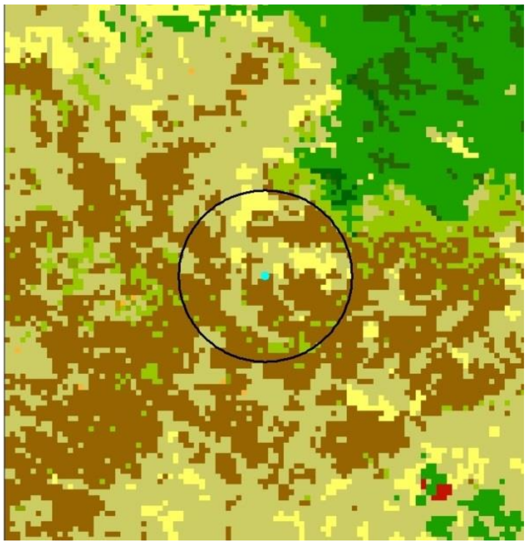


Figure 3.9. Land cover around EA 160, in Mtwara, Southern Tanzania, one of the three potential high diversity EA

Figure 3.10. Land cover around EA 149, in Lindi, Southern Tanzania, one of the three potential low diversity EA

The borders of the six potential EA were obtained from the Director of AfricaScope (Africascope, 2014). These EA borders and their identifying numbers were taken to the Bureau of Statistics in Dar es Salaam, Tanzania. The GIS expert who worked on the DHS 2010 linked this information with the original paper copies of the census which defined these borders and the villages within the borders were identified. Based on the information obtained from the

Bureau of Statistics and information obtained from pre data collection visits to the two villages, the first choice areas were confirmed as the data collection sites.

The low diversity EA in Singida covered one sub-village of a village called Minyenye which was made up of five different sub-villages. Five different EAs covered these five sub-villages. Each EA did not correspond to a sub-village and the edge of the EA would be difficult to locate on the ground. As the rest of the village was unlikely to significantly differ in nutritional status it was decided to collect data in the whole of Minyenye. Similarly for the high diversity EA in Lushoto, five EA made up Mbwei village but it was decided that data collection would take place in all of the seven sub-villages.

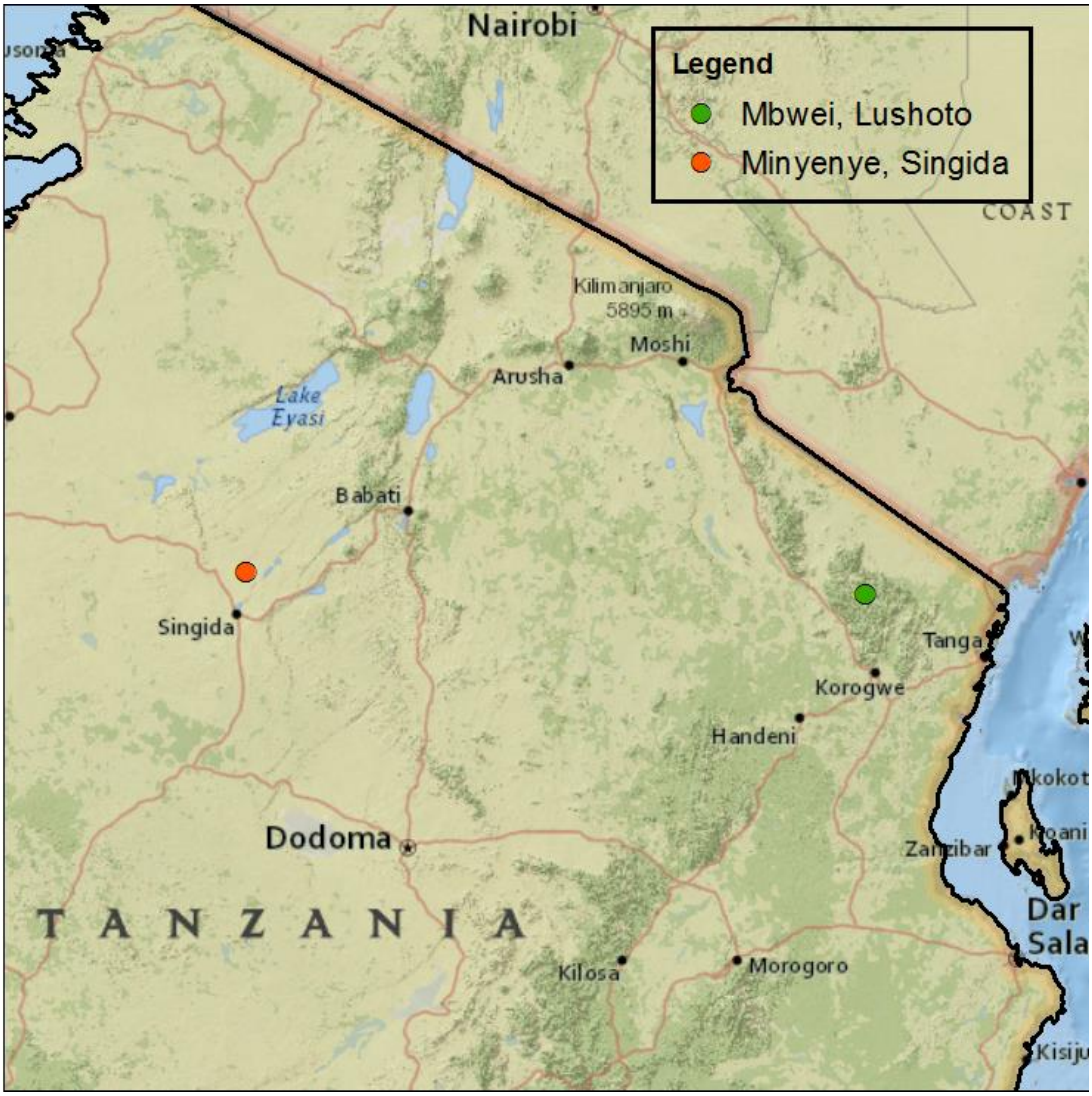


Figure 3.11. Map of Tanzania with Minyenye, Singida and Mbwei, Lushoto

3.4 Study site description

The low biodiversity village was Minyenye in Singida district, Singida region, located in the central plains of Tanzania (Figure 3.11). The village identified as a high biodiversity area was Mbwei in Lushoto district, Tanga region, situated in the West Usambara mountains close to the coast of Tanzania.

3.4.1 Minyenye village, Singida district, Singida region

Figure 3.12. A typical house and surrounding area in Minyenye village, Singida district (photo taken during data collection, June 2012, dry season)

Minyenye is situated in the relatively flat region of Singida, in central Tanzania (Figure 3.13). The region of Singida lies 1200m to 1500m above sea level, is semi-arid and experiences low rainfall, short rainy seasons and commonly drought (Tanzanian NBS and Singida Regional Commissioner's Office, 2005). Singida's average rainfall is 700mm a year (Tanzanian NBS and Singida Regional Commissioner's Office, 2005) and the average maximum temperature in June is 26.5 degrees Celsius (National Bureau of Statistics, 2011). The long dry season typically lasts from April to November followed by the short rainy season from December to March (Tanzanian NBS and Singida Regional Commissioner's Office, 2005). Data was collected in Minyenye in June of 2012; the dry season (Figure 3.12).

Singida has a high average land area per capita (4.5 hectares) (Tanzanian NBS and Singida Regional Commissioner's Office, 2005). Agriculture is the main economic activity in the region producing 60% of the areas goods and services (Tanzanian NBS and Singida Regional Commissioner's Office, 2005). Ninety percent of the people of Singida region rely on agriculture as their main livelihood (Tanzanian NBS and Singida Regional Commissioner's Office, 2005). The main food crops are maize, sorghum, bullrush millet, sweet potatoes and beans and the main cash crops are sunflower, groundnut, simsim, pigeon peas, onion and cotton (Tanzanian NBS and Singida Regional Commissioner's Office, 2005). People here rely on sorghum and maize as their main staples with bullrush millet and sweet potatoes also used as starchy foods (Tanzanian NBS and Singida Regional Commissioner's Office, 2005).

The average household size in Singida region 2002 was 5.0 people (Tanzanian NBS and Singida Regional Commissioner's Office, 2005). Thirty three percent of the households in this region were in the lowest quintile for wealth index of the country and only 6% were in the highest quintile (Tanzanian NBS and ICF Macro, 2011). In Singida region, approximately 14% of the female heads of households had no education and the median years of education was 6.3 (Tanzanian NBS and ICF Macro, 2011). Regionally, 75% of women were literate, 93% were currently employed and 83% worked in agriculture (Tanzanian NBS and ICF Macro, 2011). Nine percent of male heads of households had no education and the median years of education for men was 6.4 (Tanzanian NBS and ICF Macro, 2011). Eighty-two percent of the male heads of households were literate, 99% were currently employed and 92% were employed in agriculture (Tanzanian NBS and ICF Macro, 2011).

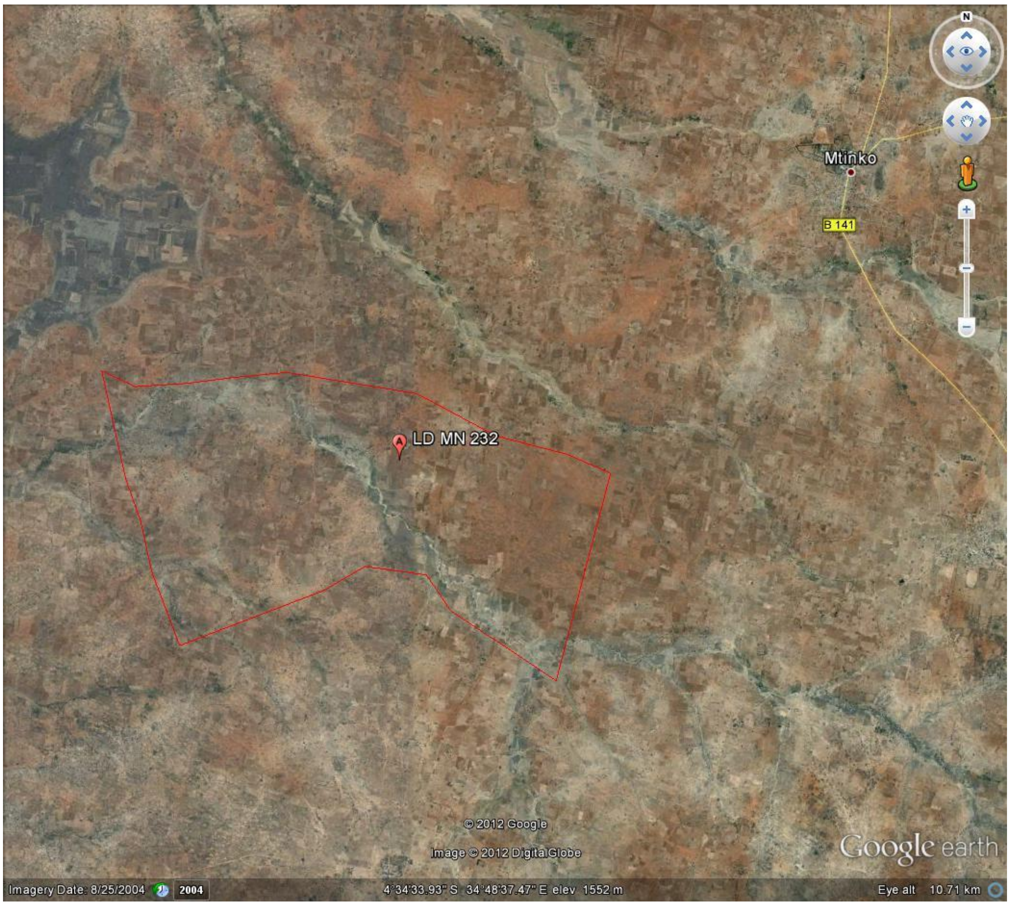


Figure 3.13. Google Earth image of the area surrounding Minyenye village (August 2004, dry season) illustrating flat, largely un-vegetated orange land and seasonal rivers/streams. The DHS centre point is marked by the A flag, the red outline is the border of the enumeration area from the DHS (2010)

3.4.2 Mbwei village, Lushoto district, Tanga region

Figure 3.14. The hilly landscape of Mbwei's sub-villages (on the opposite hills) with the fertile valley in view (Photo taken during data collection, July 2012, dry season)

Mbwei is in the West Usambara mountains and is situated in Lushoto district in Tanga region (Figure 3.15). The Usambara mountains rise to a maximum altitude of 2300 meters above sea level (National Bureau of Statistics, 2011). In the mountainous zone, where Mbwei lies, temperature ranges between 21 and 28 degrees and the rainfall ranges between 800 and 2000mm. In contrast to Minyenye village's single rainy season, there are two rainy seasons in Mbwei. In the North and Costal regions of Tanzania, the short rains typically fall in November to April and the long rains in March to May (Tanzanian NBS and ICF Macro, 2011). Data was collected in Mbwei in July of 2012; the dry season (Figure 3.14). In 2010, 40.9% of the agricultural land in Tanga region was planted in the short rainy season (National Bureau of Statistics, 2011). Mbwei village therefore had one additional planting season each year compared to Minyenye. The main crops grown in the mountainous zone of Tanga region are coffee, tea, cardamom, maize, round potatoes, banana, beans, spices, fruits and vegetables (Tanzanian NBS and Tanga Regional Commissioner's Office, 2008).

The average household size for Tanga region in 2002 was 4.6 people (Tanzanian NBS and Tanga Regional Commissioner's Office, 2008). Only 16% of households in this region were in the lowest quintile of wealth index nationally and 25% were in the highest wealth index (Tanzanian NBS and ICF Macro, 2011) suggesting Mbwei residents would be less poor than Minyenye residents. In Tanga region, 19.6% of female heads of households and 5.5% of male heads of households had no education (Tanzanian NBS and ICF Macro, 2011) . The median years of completed education for this region was 6.4 for both woman and men (Tanzanian NBS and ICF Macro, 2011), similar to Singida region. Seventy percent of the women were literate, 71% were currently employed and 48% worked in agriculture compared to 83% literacy in men, 82% currently employed and 59% employed in agriculture (Tanzanian NBS and ICF Macro, 2011). Mbwei's region had a lower rate of employment overall and in agriculture compared to Minyenye's.

Figure 3.15. Google Earth image of area surrounding Mbwei village (April 2007, Rainy Season). Illustrating mountainous terrain and largely green vegetated lands. The DHS centre point is marked by the A flag, the red outline is the border of the enumeration area from the DHS (2010)

3.5 Mixed method approach

During phase 2, an interview based, mixed methodology approach was used to collect primary data. Four key methods were applied; household questionnaire, 24 hour dietary recall, anthropometric measures and agrobiodiversity survey. Table 3.1 outlines what data collection methods were used to meet each of the study's objectives and which participants were involved in these methods.

Table 3.1. Data collection methods and participants involved in meeting each of the study's objectives

Objectives		Data collection methods employed	Participants involved
1	Review, design and pilot a conceptual framework and suite of appropriate measurement tools to accurately measure agrobiodiversity, dietary diversity and nutrition in an Eastern Sub-Saharan Africa context.	Literature reviews	None
		Quadrat sampling and point intercept method	None
		Pilot household questionnaire	Female respondent (pilot study)
		24 hour recall	Female respondent (pilot study)
			Oldest child under five (pilot study)
2	Systematically assess the diversity and abundance of both cultivated and wild plants growing on household agricultural land in two villages in rural Tanzania and investigate how this is related to dietary diversity in under five year old and nutritional status in children in these villages.	Point intercept method	None
3	Measure household crop and animal diversity, dietary diversity of respondents and children under five and nutritional status of children living in these villages, determine whether household produce is sold and investigate how these factors are related.	Household questionnaire	Female respondent
		24 hour recall	Female respondent
			Oldest child under five
		Anthropometric measurements of nutritional status	All children
			Female respondent
			Respondents husband
4	Investigate basic socio-demographic factors affecting dietary intake of children under five and nutrition outcomes in children in these villages.	Household questionnaire	Female respondent
		Observation	None
5	Investigate the socio-demographic determinants of dietary diversity and nutritional status and explore the relationships between land cover, dietary diversity and nutritional status in children under five years at a national level, in Tanzania.	Statistical analyses on secondary data	None
6	Integrate outcomes from this multi-scale investigation of the relationships between agrobiodiversity, dietary diversity and nutritional status, to draw conclusions that inform understandings of food security in sub-Saharan Africa.	Synthesis and discussion of thesis's findings	Based on data collected for objective 1-4 and secondary data for objective 5

3.6 Household questionnaire

Much of the data for this research was collected using a questionnaire which consisted of a mixture of closed and open ended questions generating both quantitative and qualitative data. The majority of questions collected quantitative data. Qualitative data was coded into categories to be used in the data analysis. The questionnaire was made up of three main section: Demographic and livelihood information; Dietary questions; Food sources. A detailed description of the dietary recall, nutritional status and agrobiodiversity methods follow. Protocols for these methods are included in Appendix C.

3.6.1 Dietary recall methods

The dietary diversity data was captured through a three pass 24 hour dietary recall (see Appendix C for the protocol followed). The dietary recall was designed to capture the diversity of what the respondent, and her oldest child under the age of five years, ate the previous day. It asked about all foods, drinks and snacks the respondent has eaten for the 24 hour period from when they got up the day before the interview to when they got up the day of the interview. This was then repeated for items consumed by her oldest child under the age of five. As the diet recall was designed to capture diversity of the diets it did not collect the amount of food consumed. The 24 hour recall was conducted in three passes (Johnson et al., 1996):

1. A list of all foods, drinks and snacks consumed.
2. Details of all the foods, drinks and snacks consumed including cooking methods, ingredients in recipes and additions.
3. A review of all the foods, drinks and snacks consumed and final check the recall is complete.

Foods were subsequently broken down into nine food groups (1. Cereals, roots and tubers, 2. Vitamin A rich vegetables, tubers and fruit, 3. Other vegetables, 4. Other fruits, 5. Flesh meats, organ meats, fish and insects, 6. Eggs, 7. Legumes, nuts and seeds, 8. Milk and milk products, 9. Oils, fats and sweets), as recommended by the FAO dietary diversity workshop that was held in Rome, Italy in October 2004 (FAO/WHO/IFPRI, 2004). The dietary diversity score for each individual was therefore calculated out of nine. The number of different individual food items were also tallied to give a food variety score.

Dietary diversity is a quick and simple measure that is commonly used in a low income country setting. Dietary diversity has been shown to be significantly associated with both measures of food security (Bukusuba et al., 2010, Leroy et al., 2008, Thorne-Lyman et al., 2010) and nutrient adequacy (Arimond, 2004, Ogle et al., 2001, Moursi et al., 2008). The Food and Nutrition Technical Assistance project (FANTA) has indicated household dietary diversity to be an indicator of food security (Swindale and Bilinsky, 2006) which links food security and nutrition together and should help provide a comprehensive view of food access and intake. A 24 hour recall was chosen to collect this data as it is the most common method used to collect dietary diversity data in low income countries, as shown in chapter 2. Additionally, a food frequency style questionnaire for previous day consumption of the nine food groups was tested during the pilot phase of the study and was not as well understood by the participants as the 24 hour recall.

3.6.2 Anthropometric measurements of nutritional status

Anthropometry was used to measure nutritional status of participants and their families. Heights and weights of all children in the family unit (defined as the respondent, her husband or partner and their children) were measured to calculate their height for age, weight for age and BMI for age z-scores using the 2006 WHO Child Growth Standards. MUAC (Mid Upper Arm Circumference) was measured in all children under the age of 15 as an additional measure of nutritional status. Height, weight and BMI z-scores and MUAC are used to reflect nutritional status of the children. Stunting and underweight were defined as height for age and weight for age z-scores below minus two standard deviations from the WHO international reference median values (de Onis et al., 1997).

Specific protocols (Appendix C) were followed to measure the height and weight of the respondent and her husband and all children in the family unit who lived in the household. For infants under the age of two years length was measured instead of height (de Onis et al., 1997). A considerable effort was made to get anthropometric measures for those individuals who were in the village, at school or work, but were not present at the interview. Researchers returned to the household at a more convenient time, family members came to other participating households to be measured and the researchers visited two local schools in Minyenye to get as complete anthropometric records as possible.

SECA Digital weighing scales (SECA GMBH & Co Germany, Model 881, Max Weight 150 kg, Precision 100g) were used to measure weight. Weight was measured without shoes or heavy jackets but otherwise participants remained clothed. A portable wooden infant/child/adult length board (Shorr Productions, Perspective Enterprises, Portage, Missouri) was used to measure height and length. MUAC was measured using non-stretch MUAC measuring tapes provided by UNICEF. The lead researcher (PhD student) and the translator worked together to take these measures.

The pros and cons of the different methods that can be used to measure nutritional status (Table 1.1) were considered and anthropometry was identified as the most appropriate approach to measuring nutritional status in this setting. MUAC is a simple, cheap, acceptable method for detecting malnutrition (Myatt et al., 2006). Height for age, weight for age and BMI for age z-scores are standard anthropometric measures which take into consideration the child's age and gender and are widely recognized as the best indicators of nutritional status in children (de Onis et al., 1997). All these methods are simple, non-invasive measures that are commonly used in nutrition research in low income countries. They will be easily understood and provide a simple and objective measure of undernutrition.

3.6.3 Agrobiodiversity

Agrobiodiversity is defined as the biological diversity of plants, animals and micro-organisms on lands used for agricultural purposes (Brookfield and Stocking, 1999, Cromwell et al., 1999). The primary focus of this thesis is on plant agrobiodiversity. Animal agrobiodiversity is addressed as a secondary analysis and micro-organism agrobiodiversity is not assessed by this project.

3.6.3.1 Systematic measurement of plant agrobiodiversity

The research team aimed to collect agrobiodiversity data on as many of the household farms as possible. In Mbwei, where the households had many parcels of land, some of them very far away from the house, it was not possible to collect data on every farm. The lead researcher collected details on all household farms from the respondent and then selected representative farms for the biodiversity research assistant to visit. This information included estimates of farm sizes, whether they were far from the household (defined as more than 30 minutes walk), garden locations and crop types grown. If more than one farm had the same characteristics the closer farm was selected. The selected farms were then agreed with the household member who volunteered to show the research assistant the farms.

The diversity of all plants, both intentional crops and other plants, growing on the household's farms at the time of data collection were measured using the point intercept method (U.S. Department of Agriculture, 1999). The method used in this project was based on the method outlined in the 'Sampling vegetation attributes' interagency technical reference put out by the US Bureau of Land Management (U.S. Department of Agriculture, 1999).

The methods was designed to measure all plants growing on the farms including crops, wild plants, grasses and trees. Firstly, a string baseline was laid along the top of the farm. String transect lines were laid down the farm every 20 metres along the baseline. A meter long metal pin was inserted into the ground every 10 meters down the transect, starting at a random starting point at either 1, 2, 3, 4 or 5 meters in from the baseline. Family, genus and species of all plants present at these intercepts were recorded and number of individuals tallied. The agrobiodiversity protocol is included in Appendix C (See Appendix E for the data collection sheet).

After the first day of data collection the relative abundance of each species and the total number of species observed from data collected every 20 metres down the transect was compared to data collected every 5 metres. It was found that the abundance of individual species was very similar between these two different intervals. Data collected every 5 meters identified approximately twice the number of species compared to data collected every 20 meters. The missed species, however, were only 2% or less of the overall species encountered. Based on this information it was decided that collecting species data every 10 meters would provide sufficient detail.

In Mbwei, additional data were collected on transects laid every 10 metres along the baseline, due to the smaller size of the farms. Collecting data on transects laid every 20 metres in Minyenye captured enough data to represent the biodiversity of the farm, due to their large size. But in Mbwei the farms were much smaller and laying transect lines every 20 metres may not have captured enough data to reflect the biodiversity of their farms. Biodiversity in vegetable gardens was measured in Mbwei only. Because the vegetable gardens were so much smaller than the farms transects were laid every 5 metres with species data collected every 1 metre.

These data were used to calculate Shannon diversity indices for the household farms. The Shannon index is a species diversity index (Akrofi, 2010) and provides an indication of agrobiodiversity at the household level. The Shannon diversity index takes into account the number of different plant species and the abundance of these species (Pla, 2004). Shannon indices were calculated using the number of different species found and the frequency they were encountered in the household farms. It is a commonly used measure in biodiversity research and has previously been used to compare agrobiodiversity to dietary diversity (Akrofi, 2010, Dewey, 1981). These calculations are described in detail in chapter 5.

There is no one recognised way to measure agrobiodiversity but many different techniques were reviewed and considered for this project. The point intercept method was chosen because it provides systematic, precise and repeatable data on plant agrobiodiversity suitable for household farms in rural Tanzania. The point intercept method records individual plant species, total cover and species composition by cover ((U.S. Department of Agriculture, 1999). The method is particularly well suited for vegetation less than 1.5 meters in height (U.S. Department of Agriculture, 1999). This method is more repeatable and produces more precise measurements than cover estimates acquired through quadrat sampling (U.S. Department of Agriculture, 1999). The method is also more efficient than line intercept methods. The point intercept method is a good method for determining cover of dominant species but is not as well suited to picking up the minor species present (U.S. Department of Agriculture, 1999).

Farm size was calculated in ArcGIS from the GPS coordinates collected at farm borders. Farm size is only available for farms that were visited by the biodiversity research assistants when they were collecting the agrobiodiversity measures. Notes were made by the biodiversity research assistants on the condition of the farm, how well the farms were maintained, whether some crops had already been harvested that year and markers of land degradation. Markers of land degradation were: 'presence of species associated with poor soil'; 'erosion'; 'low soil fertility'; 'fertile soil eroded by rainfall'; 'steep or very steep slope'; 'farm not well maintained/poor condition'; 'rocks and/or stones on the farm'. These qualitative data were coded into categories to be used in the analysis.

3.6.3.2 Plant and animal diversity scores

In addition to the systematic measurement of plant agrobiodiversity outlined above, information on the plant and animal foods consumed throughout the previous year (January to December) were collected through the food sources section of the household questionnaire.

This section collected information on all foods consumed by the household and where these foods had come from; grown or reared by the household, bought by the household, found or hunted in the wild or gifted to the household. For plant foods that were grown, information on when the crops were available for consumption by the household and whether the household sold any of the crops was recorded. For animal foods, whether the household sold animals or animal products was also captured. The data collected through the food sources section allows analysis of foods consumed year round and provides the animal agrobiodiversity data for the project. The results from this section are presented as crop diversity, vegetable diversity and animal diversity scores in order to differentiate this information from the plant agrobiodiversity data. These scores represent the number of different types of plants/vegetables/animals intentionally grown or reared for household consumption in the previous calendar year.

3.7 Sampling strategy

A target of 60 households in each village was set in order to measure 100 children under the age of five years old. This would give enough power to detect a difference of 0.5 in mean weight for age z-scores or height for age z-scores among the communities in a two village design (power=0.85, alpha=0.05, between village variance = 0.04, within village variance = 1.0). These calculations were based on the 2010 Tanzania DHS data.

Households were selected randomly using the following procedure in each village. In Minyenye, Singida household lists were collated for this project by the Village Executive Officer (VEO) and the five sub-village leaders who have a good knowledge of the people living in each sub village. The lists included the name of the sub-village, the name of the head of household and the number of children under five years living in the household. Only households with at least one child under five were included in the list. The average number of children under five per household was 1.57. To meet the target of 100 children under five, 65 households would need to be interviewed. A 10% refusal/drop out rate was allowed and 72 households were randomised using the random number generator function in Microsoft excel (=RANDBETWEEN(bottom,top).

In Mbwei, Lushoto, household lists were collated by the Ward Executive Officer (WEO) who was acting as the VEO for Mbwei, the Chairman and the Assistant Chairman for the village. The list consisted of the seven sub-villages and the names of all the head of household in these sub-villages. Whether the household had under five year olds was not included in the Mbwei list. More household were randomised in order to reach the target 100 children under five years of age. Initially 70 households were randomised but when this number was not sufficient a subsequent additional 25 households were randomised. The percentage of the total number of households in each village that were interviewed is presented in Table 3.2.

Table 3.2. Total number of households and total number of households interviewed by sub-village

	Total number of households	Total number of households with >=1 under five year old	Number of households interviewed	Percentage of total households interviewed*
Minyenye	**-**	**206**	**64**	**31.1**
Bwali	-	41	16	39.0
Mwangozo	-	29	5	17.2
Amani	-	19	5	26.3
Jamida	-	38	16	42.1
Kujitegemea	-	79	22	27.8
Mbwei	**880**	**-**	**58**	**6.6**
Nekrasi	117	-	7	6.0
Kwemeaganga	96	-	6	6.3
Mntindii	113	-	6	5.3
Zagati	109	-	10	9.2
Vugiri	156	-	10	6.4
Pongwe	138	-	8	5.8
Mbunguni	151	-	11	7.3

*For Minyenye this is the percentage of households with at least 1 under five year old, for Mbwei it is a percentage of all households

3.8 Inclusion criteria

Households were included in the survey if they had a woman with a child under the age of five years living in the house. As the preferred option the female head of household would be interviewed. The female head of household was defined as the female in the household who was responsible for the preparation of food for that household. If this female did not have a child under five, was unavailable to be interviewed or did not want to be interviewed then any other female who lives in the household that had a child under five years was asked. If no eligible females were willing to be interviewed then the research team moved onto the next household. If an eligible woman lived in the household but was not home or unavailable when we called we visited three additional times before excluding them from the study. This happened in one households in Mbwei and none in Minyenye.

Women were chosen as participants as the project focused on both diet and agriculture. Women are primarily responsible for food preparation and farming (Hyder et al., 2005) in rural sub-Saharan Africa and would therefore be the most appropriate household member to answer the projects questions. Respondents were asked questions about the family unit. The family unit was defined as the respondent, her husband or partner, referred to as her husband for simplicity, and their children. This definition included step-children or grandchildren that the respondent was raising.

Children under five years of age were the main focus of this study as these first five years are when children are most at risk of malnutrition and not reaching their growth potential. Victora et al (2010) showed rapid growth faltering in height for age in children from 54 different low and middle income countries until 24 months of age. Declines in weight for age z-scores were seen throughout the first five years of life. Inadequate growth in the first 1000 days after conception impacts on the physical, cognitive and socio-emotional well-being of people throughout all lifecycles into adulthood and old age (Hoddinott et al., 2013).

Nutritional status was measured in all children in the household rather than just in under five year olds for two main reasons. Firstly it is possible that the environment these children have grown up in are stable over time and malnutrition seen in the older children could be a result of factors captured in this study. Secondly, weight and BMI for age is affected by recent health and diet and it is expected that measuring these outcomes in older children will provide additional information on the nutritional status of those living in these communities. Demographic data were collected on the respondents husband to give social and financial context to the children's lives and heights and weights were collected in order to control for parental weight in the data analyses.

3.9 Research process

3.9.1 Piloting of methods

The questionnaire and agrobiodiversity methods were piloted during Phase 1 of the research process in Shebomeza village, Muheza district, Tanga region in northern Tanzania. The pilot study took place between the 9th, 10th and 11th of April 2011. Household questionnaires were conducted with six participants (two women and four men) who represented different wealth groups as defined by a field assistant from the village. Different agrobiodiversity survey approaches (including point intercept methods and quadrat sampling) were trialled in the farms of the households. An additional two farms were visited and only agrobiodiversity measures were taken. For these households one male and one female household member were questioned on the utility of crops as part of the agrobiodiversity measurements.

The piloting of method highlighted a number of issues with the original design of data collection methods , including repetition, concepts not translating well, missing interesting information due to the structure of questions and specifically, that the agrobiodiversity data collected was unsystematic and therefore unrepresentative. The pilot activities also provided ideas for how the methods could be improved. Questionnaire questions were modified to improve participant understanding and the dietary diversity score sheet changed to a basic 24 hour dietary recall as detailed above in section 3.5.2. A questionnaire designed to measure food security was removed and more direct questions about the household's ability to feed itself were included. The food sources section was expanded to capture more detail about where specific foods that individuals within households were eating came from. Agrobiodiversity methods were changed from quadrat sampling (Zarin et al., 1999) to the point intercept method. These were better suited to the farms in rural Tanzania.

3.9.2 Ethical approval and permissions

Ethical approval was obtained from the University of Leeds through the Faculty of Medicine and Health (Reference number: HSLTLM/11/031). The application for this approval included the following provisions. Informed verbal consent was obtained from the respondent and the children's free and voluntary assent to participate was sought. The research assistant was trained in how to measure height, weight and MUAC to ensure measures taken on children were done correctly and in the presence of one of the children's parents or older siblings. All data was anonymised and stored securely.

National level permission to conduct the research was obtained from the Commission for Science and Technology (COSTECH) in Tanzania. Letters of permission were also obtained at the regional, district, ward and village level following meetings with the appropriate individuals. The next level of permissions needed was advised at each level and varied between the two sites. A summary of the permissions granted and a copy of the COSTECH permit is included in Appendix A.

3.9.3 Research assistants and translation

A total of three research assistants were employed during this research; A translator and two different biodiversity research assistants, one in Minyenye, Singida and one in Mbwei, Lushoto. In addition, a local contact who knew the potential participants and where they lived was hired in each sub-village.

Both the Minyenye and the Mbwei biodiversity research assistants were experts in the measurement of biodiversity and had experience using similar methods to the point intercept method. They were hired through the project's contacts with Sokoine University of Agriculture. They were assisted by the local contact and sometimes the farmer. A student volunteer from the UK helped collect this data in Mbwei.

The questionnaire used for data collection was written in English and translated to Swahili (the national language which was widely spoken in the research areas) by the project's translator before data collection began. This was then back translated into English by the Minyenye biodiversity research assistant and the lead researcher discussed any loss of meaning that occurred in translation with the translator. Modifications to the Swahili version of the questionnaire were made as necessary before it was administered. The same process was used for the information sheet and consent form.

The translator was trained on how to conduct a 24 hour recall, how to carry out the anthropometric measurements and how to use the research questionnaire by the lead researcher in the days leading up to data collection.

3.9.4 Recruitment of participants and consent process

The local contact in each sub-village escorted the research team up to the households, briefly introduced the team and project to the head of the household and asked if the team could speak with the mother of the under five year olds. The translator would then briefly introduce the research team and the project before reading out the detailed information sheet. The information sheet was then offered to the participants for them to keep. Once the participants had had the opportunity to ask questions the translator asked for consent for the various aspects of the research:

- Opportunity to ask questions?
- Do you agree to take part in this research?
- Can we record some of the interview using this tape recorder?
- Can we measure your height and weight?
- Can we measure the height, weight and mid upper arm circumference of your children?
- Can we measure the location of your house and farm using this global positioning system?

- Can we take pictures of your health records?

Verbal consent was obtained from the mother (the primary research participant). The aspects of the research the participant gave consent for was recorded on a tick list that was retained by the researcher (An English version of the Swahili information sheet and consent form is included in Appendix B).

3.10 Data checking and entry

Questionnaires were checked by the PhD student at the time of data collection in order for clarification and additions to be made while the participants were still available. Agrobiodiversity data was checked and data was clarified with the biodiversity research assistant at the end of the day when possible or soon after. Both biodiversity research assistants were available after data collection for clarification and corrections of species data when necessary. The majority of the data was entered by the PhD student with some being entered by Masters students and a nutrition research volunteer under close supervision of the PhD student.

3.11 Data analysis

3.11.1 Basic descriptive statistics

For chapters 4, 5 and 6, basic descriptive statistics were performed in Stata version 12. Means with 95% Confidence Intervals and percentages are presented at the beginning of the results chapters. In order to detect differences between the villages and between sub-groups of interest (eg. gender) Mann-Whitney tests, for differences in continuous variables, and Chi-squared tests, for differences in proportions in categorical variables were used. Qualitative data were coded into categories in order to be used in the analyses.

3.11.2 Linear regression

Linear regression was used to estimate relationships among variables of interest. The terminology 'independent variable' was used to indicate the effecting or exposure variable and the term 'dependent variable' was used to indicate the affected or outcome variable. For example dietary diversity would be the independent variable and height for age z-scores would be the dependent variable.

Regression results are presented for both villages combined, controlling for village, in the study of the relationship between dietary diversity, complementary feeding and sanitation and nutritional status (chapter 4). This is because the larger sample size is beneficial in detecting relationships between dietary diversity and nutritional status. As the landscape and farming practices varied substantially between the two villages results of plant and animal agrobiodiversity (chapters 5 and 6) are presented for the two villages separately. This was so factors specific to the two villages could be investigated without their effects being lost in combined models. Including the village in the multiple regression as a covariate in chapter 4 addressed the effect of clustering at the village level. Analysing the data by village in chapter 5 and 6 eliminating this potential issue for these analyses.

Both unadjusted models, with just the independent and the dependent variable in the model, and adjusted models are presented. The adjusted models include other variables that could be confounding the relationship between the independent variable and the dependent variable. For each model a list of potential confounders were determined using a Directed Acyclic Graph (DAG). These potential confounders were identified through reviewing the literature and local knowledge. DAGs map causal associations between variables which allows easy identification of variables that may be related to both the independent and the dependant variable. This helps to ensure that appropriate confounders are selected for multivariable regression (Glymour, 2006). The DAG used for the regression between agrobiodiversity and dietary diversity and agrobiodiversity and nutritional status is presented in Figure 3.16.

Once potential confounders had been identified each confounder was added to the unadjusted model one by one to assess if they affected the regression coefficients for the independent variable of interest. If the potential confounder modified the regression coefficient substantially (criteria varied from approximately >0.02 to >0.05 depending on the size of the regression coefficients) then they were included in the adjusted model.

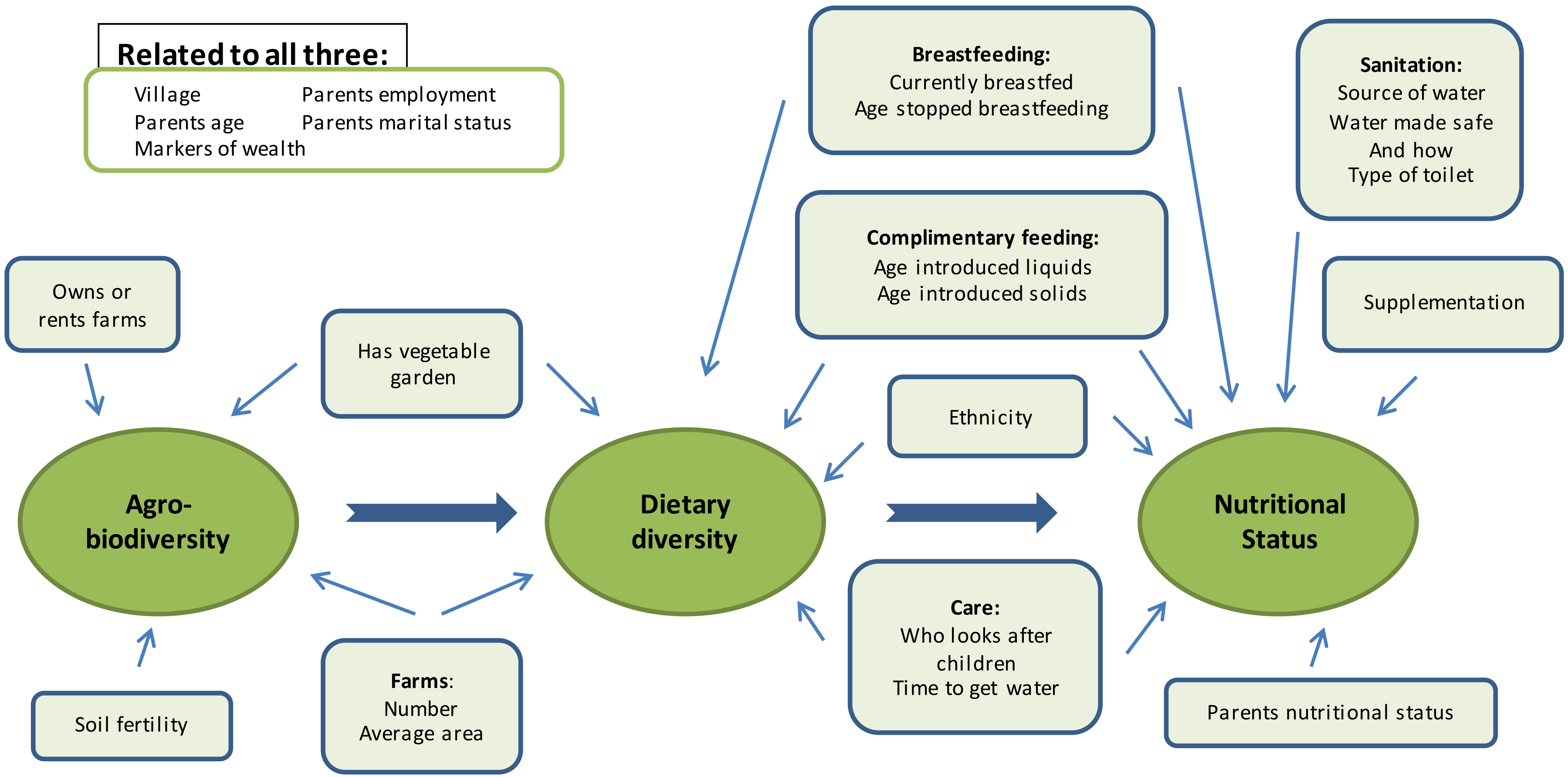


Figure 3.16. Directed Acyclic Graph (DAG) used in determining potential confounders in the regression models

In order to determine if the regression models met the assumptions of linear regression a number of tests were undertaken (UCLA: Statistical Consulting Group, 2014). To test if the residuals were normally distributed Kernel density estimate plots were compared with normal distribution curves. For the assumption of linearity in the unadjusted models scatterplots of the continuous independent and dependant variables were checked to make sure there were a random scatter of points. For the multivariable regression standardised residuals were plotted against each of the continuous predictor variables in the regression model. Again, these were checked that they were a random scatter of points. To test the assumptions of homoscedasticity the residuals were plotted against the fitted values and the scatter plot was checked for randomness. Additionally, the null hypothesis that the residuals are homogenous was tested using the Whites test and the Breusch-Pagan test. Multi-collinearity was tested by checking the variance inflation factors were in the acceptable range. The regression models presented in chapters 4 to 6 met the regression assumptions for linearity, normality of residuals, homoscedasticity and multi-collinearity.

3.11.3 Multiple imputation by chained equations (MICE)

For the adjusted regression multiple imputations by chained equations were used within Stata to estimate missing data in covariates. Leaving out individuals with missing data from analyses can lead to bias and the resulting decrease in sample size leads to loss of power (Sterne et al., 2009). Multiple imputation has been devised to try to deal with missing data. It aims to account for the uncertainty in the missing data by creating different possible data sets based on the available data and combines the results from each of these data sets (Sterne et al., 2009). The command creates multiple copies of the data set and replaces missing values with imputed values. Variability in the imputed variables is created to allow for uncertainty in predicting the missing values. The model is then fitted to each of the imputed datasets. The estimated associations will differ because of the variation in the imputed variables, these are averaged to give an overall estimated association. Rubin's rule (Rubin, 1987) is used to calculate standard errors, this takes into account this variability (Sterne et al., 2009). For all the MICE regression analyses missing variables were assumed to be missing at random (MAR). Values were missing mainly because participants and their husbands were unable to remember their date of births and because the husbands were unavailable to be measured. Ten imputed datasets were used and 100 iterations were carried out. The variables used in the imputation models are reported in the data analysis sections in chapters 4 and 6.

For all results chapters any regression results discussed in the results section but not presented in a table will include the regression coefficients and their 95% Confidence intervals within the text. When results are discussed and no regression results are included they will be presented in the subsequent table. Also, significant regression coefficients, in both the text and the tables, are presented in bold.

The next chapter is the first of the four results chapters of this thesis and focuses on the main results of the primary data collection described in this chapter; the relationship between dietary diversity and nutritional status in Minyenye, Singida and Mbwei, Lushoto.

Chapter 4:

Investigating the associations between dietary diversity and nutritional status in Minyenye and Mbwei, rural Tanzania.

4.1 Chapter summary

This chapter is the first of four results chapters; the first three are based on the primary data collected in rural Tanzania. This chapter explores the relationship between dietary diversity and nutritional status in two Tanzanian villages: Minyenye in Singida district and Mbwei in Lushoto district. This chapter fulfils part of objective 3 (Measure household crop and animal diversity, dietary diversity of respondents and children under five and nutritional status of children living in these villages, determine whether household produce is sold and investigate how these factors are related) and 4 (Investigate basic socio-demographic factors affecting dietary intake of children under five and nutrition outcomes in children in these villages) of this thesis. The chapter objectives are:

Objective 4A: To present descriptive data on the demographic, social, dietary diversity and nutritional status variables in this population to set the context for the analyses.

Objective 4B: To investigate whether dietary diversity and food variety are associated with nutritional status in under five year olds.

Objective 4C: To investigate whether complementary feeding and sanitation are associated with nutritional status in these villages.

The major findings of this chapter include that dietary diversity and food variety scores are not significantly associated with any of the nutritional status variables. No significant differences were seen between the two villages in dietary diversity but those in Mbwei had lower food variety and height and weight for age z-scores than those in Minyenye. Children who had liquids, specifically multiple flour porridge with additions and millet juice or solids introduced to their diets had poorer nutritional status as did children from households not boiling drinking water and households with open pit latrines.

This chapter adds to the literature on the relationship between dietary diversity and nutritional status, providing additional evidence on representative samples from two different villages in Tanzania which conflicts with the majority of evidence in this area so far. It also provides additional data on specific complementary feeding and sanitation factors that are associated with nutritional status in these communities which adds to the body of literature on the determinants of nutritional status in low income countries.

4.2 Introduction

Those living in sub-Saharan Africa have high rates of malnutrition; 26% of the world's undernourished people live in the region (UNFAO, 2010b). In Tanzania specifically, 44.4% of children under the age of five are stunted and 16.7% are underweight (Gollogly, 2009). Childhood malnutrition has been linked with a range of negative consequences. Malnourished children tend to achieve lower academic attainment (Alderman et al., 2006, Victora et al., 2008, Adair et al., 2013), grow into smaller adults (Rivera et al., 1995, Alderman et al., 2006, Victora et al., 2008, Adair et al., 2013), may be at increased risk for chronic disease later in life (Adair et al., 2013) and have a lower capacity for work (Haas et al., 1996) than their well-nourished counterparts. In addition, severe malnutrition in childhood has been linked with overall increased rates of mortality due to infection (Chen et al., 1980).

Many researchers and development organisations have attempted to improve nutritional status in low income countries through various dietary interventions (Bhutta et al., 2013) such as food supplementation (Rivera et al., 1995, Super et al., 1990), agricultural interventions (Berti, 2004) and context specific, tailored nutrition programmes (Berti et al., 2010). Despite success in many of these research projects these lessons have not been translated into population wide decreases in stunting and underweight rates. This is partly because malnutrition is caused by a multitude of interacting factors (Bhutta et al., 2008) making it a difficult issue to tackle.

Dietary diversification has been proposed as a holistic and sustainable nutrition intervention that may have multiple health benefits in low income countries (Gibson et al., 2003). The term dietary diversity refers to the number of different food groups or individual foods consumed over a defined reference period (Ruel, 2003). A summary score of dietary diversity has been proposed as a marker for diet quality as it is relatively easy to collect (Arimond, 2004). Versions of this summary score have been shown to be significantly associated with both measures of food security (Bukusuba et al., 2010, Leroy et al., 2008, Thorne-Lyman et al., 2010) and nutrient adequacy (Arimond, 2004, Ogle et al., 2001, Moursi et al., 2008, Daniels et al., 2007, Hatloy et al., 1998, Kennedy et al., 2007, Torheim et al., 2004, Ponce et al., 2006).

Research has also demonstrated links between increased dietary diversity and improved nutritional status in children (Arimond, 2004, Corbett et al., 1992, Steyn et al., 2006, Garg and Chadha, 2009, Nti and Lartey, 2008) and adults (Savy et al., 2005, Savy et al., 2006). Other studies, however, have shown mixed results (Eckhardt et al., 2005, Sawadogo et al., 2006) or no association (Hillbruner and Egan, 2008, Lin et al., 2007). The evidence for this association is not as strong in Eastern Africa with five of the eleven studies identified in chapter 2 showing no association between dietary diversity and nutritional status. This study will add to the existing literature, providing additional evidence on these associations in Eastern Africa, by presenting the relationship between dietary diversity and nutritional status in these two villages in rural Tanzania.

4.3 Methods

This section covers how dietary diversity and height for age, weight for age and BMI for age z-scores were calculated and the statistical analysis methods used in this chapter. Additional methodological details are presented in chapter 3. A description of the questionnaire and how the anthropometric data was collected is also included in that chapter. Results are presented for the family unit which is defined as the respondent, her husband or partner and her children.

4.3.1 Data sources

4.3.1.1 Dietary diversity and food variety

Dietary diversity scores (the number of different food groups consumed over the previous 24 hours) and food variety scores (the total number of different foods consumed within that timeframe) were calculated for both the respondent and her oldest child under five. The oldest child under five was chosen as the project was specifically interested in under five year olds but younger children were more likely to be breastfed, limiting the other foods they consumed. The dietary diversity scores were derived through the questionnaire from two 24 hour recalls provided by the respondent; one for herself and one for her child. The diet recall asked the respondent about all foods and drinks consumed for a 24 hour period from waking the day before to waking on the day of the interview (see section 3.6.1, page 61 and appendix

C). The design of the recall prompted for details of cooking methods, foods added during cooking, snacks and drinks consumed between meals and food consumed outside the home. These prompts attempted to ensure that all the different foods eaten were captured in the recalls.

Foods were subsequently coded by the researcher and categorised into nine food groups ('Cereals, roots and tubers'; 'vitamin A rich vegetables, tubers and fruit'; 'other vegetables'; 'other fruits'; 'flesh meats, organ meats, fish and insects'; 'eggs'; 'legumes, nuts and seeds'; 'milk and milk products'; 'oils, fats and sweets'), as recommended by the FAO (2004) dietary diversity workshop (FAO/WHO/IFPRI, 2004). This gave each individual a dietary diversity score out of nine for the 24 hour period. The number of different individual food items were also calculated to give a food variety score (Hatloy et al., 1998). This is a tally of all foods consumed in the 24 hour period. For example, if the individual consumed *ugali* (a very common, usually maize based, staple served as a stiff porridge) with spinach, tomatoes and onions as their main meal this would contribute four points towards their food variety score.

4.3.1.2 Food sources

In order to further investigate how households obtain their food and the effect this has on their diet and nutritional status the questionnaire also included questions about the sources of the household's food. The sources were: grown by the household; bought; obtained from the wild and gifted, as defined by the respondent. This data collection technique was designed by the author and aimed to capture a level of detail about household food sources not usually seen in nutrition research. It was an in-depth and time consuming method which was reduced after the first ten interviews in order to capture the necessary information in the shortest possible time.

Which months during the last calendar year each individual food type had been available from each of these sources was ascertained. The respondent was asked for a list of all the food consumed by the household and then questioned about the source of each individual food type and the months it was available. This information was used to calculate a dietary diversity score out of six for each month of the year in order to illustrate the annual variation in dietary diversity. The score was based on the following six categories: 'Cereals, roots and tubers'; 'vitamin A rich vegetables; tubers and fruit'; 'other vegetables'; 'other fruits'; 'legumes, nuts and seeds' and 'oils, fats and sweets'. This differs from the nine item score in that it does not include the animal based categories: 'flesh meats, organ meats, fish and insects'; 'eggs' and 'milk and milk products'. In order to reduce the time taken for this section monthly availability information was not collected on animal source food as participants were unable to say which months meat and animal products were available for consumption. The score was calculated separately for grown food only and again for grown, wild and gifted food.

Data on how long children were breastfed, when complementary liquids and foods were introduced and what kind of liquids and foods were first introduced into the infant's diets was captured through the questionnaire for all children in the family unit under the age of five.

4.3.1.4 Nutritional status

Heights and weights were collected for all individuals in the family unit that lived in the household and were present at the time of interview. If eligible individuals were not present at the time of the interview the researchers attempted to meet these individuals at a later time or day in order to take these measurements. This information, combined with the age and sex of the children collected through the questionnaire, was used to calculate age adjusted z-scores for height, weight and BMI using an excel add-on (WHO, 2010a). These z-scores have been developed by WHO and are based on a pooled sample of breastfed infants from Brazil, Ghana, India, Norway, Oman and the USA. It is considered an international standard suitable for use in all countries (WHO, 2010a). Photographs of the health records of all family unit children were taken if the family agreed and were able to provide them. These health records provided the date of birth of the children and this was used instead of reported date of births when they were available.

Means of height, weight and BMI z-scores were calculated and presented for all children. Individuals with z-scores below negative five or above five were excluded from the analysis. The proportion of children who were stunted and underweight were calculated. Stunting and underweight were defined as below minus two standard deviations from median height for age and weight for age of the reference population (UNICEF, 2014).

4.3.2 Data analysis

4.3.2.1 Descriptive statistics

Basic descriptive statistics of crude associations were performed in Stata version 12 (chapter objective 4A). Means (95% Confidence Intervals) of continuous variables and percentages within groups for categorical variables are presented for the descriptive results. Mann-Whitney tests were used to test differences in means and Chi-squared tests were used to detect differences in proportions between the subgroups of interest, e.g. village and gender.

4.3.2.2 Linear regression analysis

Linear regression (95% Confidence Intervals) was used to estimate the relationship between dietary diversity scores and food variety scores and the nutritional status variables (chapter objective 4B). Both unadjusted and adjusted models are presented. Adjusted models include potential confounders which were identified using a directed acyclic graph (DAG) as described in chapter 3, page 73 (Figure 3.16).

The following variables were controlled for in the adjusted model investigating the relationship between dietary diversity/food variety and nutritional status: village; parent's age; parents highest level of education; parent's height, weight or BMI; parental ethnicity; whether the household has a mobile phone; household takes action to make water safe and whether the parents had an alternative source of income.

Linear regression was used to determine whether complementary feeding and sanitation were associated with nutritional status in under five year olds (chapter objective 4C). Both unadjusted and adjusted regression models are presented for the relationship between complementary feeding and nutritional status. These multivariable regression models were adjusted for: village; parent's age; parents ethnicity; highest level of education; parent's height; weight or BMI; whether the household has a mobile phone; household takes action to make water safe; whether the parents have an alternative source of income.

Unadjusted and adjusted models are presented for the relationships between sanitation and nutritional status. These models were adjusted for village; parent's age; husband's frequency of employment. No potential confounders were identified for the relationships between parental ethnicity, height and weight and the nutritional status variables in the children. Unadjusted models only are therefore presented for these associations.

4.3.2.3 Missing data

Multiple imputations using chained equations (MICE) were used to estimate parameters under the assumption that any missing data were MAR (see section 3.11.3, page 74). MICE were used in the adjusted model investigating associations between dietary diversity/food variety and nutritional status. The missing values were imputed based on the complete variables in the model: village; respondent's weight; whether the household has a mobile phone; respondent's highest level of education; whether the respondent earns extra income; household takes action to make water safe. Imputations were based on under five year olds only.

MICE were used in the adjusted model investigating associations between complementary feeding and nutritional status. Imputations were based on under five year olds only. The missing values were imputed based on the complete variables in the model: village; respondent's weight; whether the household has a mobile phone; respondent's highest level of education; whether the respondent earns extra income; household takes action to make water safe. This analysis was repeated excluding children who were still being breastfed in case this influenced the results.

MICE were again used for the multivariable regression analyses of sanitation and nutritional status. Imputations were done separately for those under five and for all children. The missing values were imputed based on the complete variables in the model and other complete employment variables: village; whether the household has a mobile phone; respondent's highest level of education; whether the respondent works in agriculture; whether the respondent has an additional small business; whether the respondent earns extra income.

4.4 Results

No households in Minyenye and two households in Mbwei declined to take part in the project. One household in Mbwei was excluded as the potential respondent was absent on all three occasions that the researchers visited. Sixty-four households were interviewed in Minyenye. Heights and weights were measured in 295 children (of whom 106 were under the age of five), 64 women and 43 men. Additionally 252 children under the age of 15 had their mid upper arm circumference (MUAC) measured. Fifty-eight households were interviewed in Mbwei; 170 children of whom 104 were under the age of five, 58 women and 35 men were measured. 180 MUAC was measured in 180 children under 15 years old. The proportion of under five year olds that were male and female, under three years and under one year old is presented in table 4.1.

Table 4.1. Number of households, children and under five year olds measured in each village

		Minyenye	Mbwei
Number of households		64	58
Number of children		295	170
Number of under fives		106	104
Percentage of under five years	Male	47.2	41.4
	Female	52.8	58.7
	Under three years	58.5	56.7
	Under one year	17.0	22.1

4.4.1 Wider social and farming context

Detailed information about the climate, agriculture and socio demographics about the two regions are included in section 3.4.1 and 3.4.2. Based on observations made in Minyenye during data collection, the village appeared similar to the surrounding district in the lands characteristics, the farming context and socially. The area was flat and dry, appeared relatively poor and the main economic activity in the village was agriculture. Mbwei appeared to differ from the surrounding district in a number of key aspects. The majority of the land was relatively dry with small shrubs and sparse trees with farms that struggled to grow the planted crops, with the exception of cassava. There was a band of land within the village which followed the river that reflected the crop growth typical of Lushoto district. The way land was farmed could potentially impact on the health and wellbeing of those living in Mbwei. Small pockets of land large distances apart meant more work and energy expenditure for the amount of food harvested. Further information on the land characteristics, habitat and farm types of the two areas and how this relates to agrobiodiversity and farming in the two areas is presented in section 5.4.1, 5.4.2.1 and 5.4.3.1

4.4.2 Demographic and household characteristics of sample

The two villages were similar in many demographic and household factors (Table 4.2). However husbands were significantly older, by approximately eight years, in Mbwei compared to Minyenye and children were significantly younger. Respondents in Mbwei were more likely to be married. The majority (97%) of participants' highest level of education was primary school. 70% of participants over ten were self-employed with approximately 25% defining themselves as unemployed and 3% running an additional small business.

Table 4.2. Demographic information for the family unit for included households in Minyenye and Mbwei and both villages combined

	All	Minyenye	Mbwei	P-value for difference*
Total number of individuals (N)	773	420	353	
Age (mean(95% CI))				
Respondents	31.5 (29.4, 33.5)	30.2 (28.0, 32.4)	34.4 (29.9, 39.0)	0.058
Husband	40.6 (37.3, 43.9)	37.3 (33.5, 41.1)	45.6 (40.1, 51.1)	0.011
Children	7.6 (7.1, 8.1)	8.0 (7.4, 8.7)	7.0 (6.2, 7.8)	0.052
Mean number of children/household	4.1	4.5	3.6	
Respondent's ethnicity (%)				<0.001
Nyantulu	50	95.3	0	
Pare	33.6	0	70.7	
Sambaa	9.8	0	20.7	
Other	4.9	3.1	6.9	
Missing	1.6	1.6	1.7	
Married/engaged (%)^^	62.1	57.7	67.4	0.011
Attended school(%)^	85	86.1	83.7	0.43
Highest schooling (%)^^^				0.449
Primary	96.9	95.8	98.3	
Middle/secondary	3.1	4.2	1.7	
Employment(%)^^				0.633
Unemployed	24.4	26.6	21.9	
Employed	3.7	3.2	4.4	
Self employed	69.1	68	70.5	
Self employed farming and small business	2.5	2.3	2.7	
Doesn't know	0.3	0	0.6	

* Mann-Whitney tests used for difference in means, chi squared used for difference in proportions between the two villages
Total number of respondents is 122 (64 in Minyenye, 58 in Mbwei). Age of respondents is based on 54 individuals (38 in Minyenye, 16 in Mbwei). Age of husbands is based on 33 individuals (20 in Minyenye, 13 in Mbwei). Age of children is based on 499 individuals (288 in Minyenye, 211 in Mbwei).
^only those over 5 years (N=554, 309 and 245 for all, Minyenye and Mbwei)
^^only those over 10 years(N=405/406, 222 and 184/183 for all, Minyenye and Mbwei)
^^^only those who are no longer attending school (N=261, 144 and 117 for all, Minyenye and Mbwei)

Approximately half of the households had a radio and half had a mobile phone, while no households had electricity or a landline (Table 4.3). On average, it took 18 minutes longer to get water in Mbwei than Minyenye (58 vs. 40 minutes; P = 0.003). The majority of Mbwei households got their drinking water from a river (90%) (Figure 4.2), while 56% and 33% of those in Minyenye got their water from a borehole/dug well and through a piped water pump respectively (Figure 4.1). However, people in Mbwei were significantly more likely to take action to make water safe, with 66% of households boiling their drinking water compared to 31% in Minyenye, possibly due to these differences in water sources.

Table 4.3. Characteristics of households in Minyenye and Mbwei and in both villages combined

	All	Minyenye	Mbwei	P-value for difference*
N	122	64	58	
Radio in household (%)	50.0	45.3	55.2	0.277
Mobile phone in household (%)	55.7	57.8	53.5	0.628
Raised animals	77.9	85.9	69.0	0.024
Owned animals	27.9	4.7	53.5	<0.001
Time to get water minutes (mean(95% CI))	48.7 (42.5, 54.9)	39.9 (31.9, 47.8)	58.4 (49.2, 67.6)	0.003
Water source (%)				<0.001
piped water	17.2	32.8	0.0	
spring	4.9	0.0	10.3	
river	48.4	10.9	89.7	
borehole or dug well	29.5	56.3	0.0	
Take action to make water safe (%)				0.001
Boil	47.5	31.3	65.5	
Other eg. Strain, let settle	4.9	7.8	1.7	
Nothing	47.5	60.9	32.8	
Type of toilet (%)				0.056
closed pit latrine	18.0	9.4	27.6	
open pit latrine	80.3	89.1	70.7	
other	1.6	1.6	1.7	

* Mann-Whitney tests used for difference in means, chi squared used for difference in proportions between the two villages

Figure 4.1. Water sources in Minyenye; a water pump, a borehole, holes dug in an almost dry area of a riverbed and a river. The rivers are used as water sources for both animals and people

Figure 4.2. Water source in Mbwei; the river and a water spring. The spring water is diverted into channels for water collection and irrigation

4.4.3 Dietary diversity and food variety

On average, people consumed approximately five out of the nine food groups (Table 4.4). No significant differences in dietary diversity scores were seen between the villages, by gender or between mother and child. Respondents and their oldest child under five consumed on average 7.5 food items in the previous 24 hours. Those in Mbwei consumed significantly more food items (8.5) compared to those in Minyenye (6.5). This was seen in respondents and their oldest child under five. When the children were analysed separately by gender the difference between the two villages was only significant for the male children. In both villages combined, no significant differences in food item variety were seen between mother and children or between female and male children. These results did not differ when respondents and children who reported the past 24 hours as 'not typical' were excluded.

Table 4.4. Mean dietary diversity and food variety scores for respondents and their oldest child under five in Minyenye, Mbwei and both villages combined

		All		Minyenye		Mbwei	P-value for
	N	Mean (95% CI)	N	Mean (95% CI)	N	Mean (95% CI)	difference*
Dietary diversity scores							
All	244	4.8 (4.6, 5.0)	128	4.8 (4.6, 5.0)	116	4.8 (4.6, 5.1)	0.652
Respondent	122	4.9 (4.7, 5.1)	64	4.9 (4.6, 5.2)	58	4.9 (4.6, 5.3)	0.859
Oldest child<5yrs^	122	4.7 (4.5, 5.0)	64	4.7 (4.3, 5.0)	58	4.8 (4.4, 5.1)	0.665
Female children	67	4.8 (4.5, 5.1)	34	4.9 (2.0, 7.0)	33	4.7 (1.0, 7.0)	0.461
Male children	55	4.6 (4.1, 5.0)	30	4.4 (0.0, 7.0)	25	4.8 (1.0, 7.0)	0.255
Food variety scores							
All	244	7.5 (7.1, 7.8)	128	6.5 (6.1, 7.0)	116	8.5 (8.0, 9.1)	<0.001
Respondent	122	7.6 (7.1, 8.1)	64	6.6 (59, 7.2)	58	8.7 (8.0, 9.4)	<0.001
Oldest child<5yrs	122	7.4 (6.8, 7.9)	64	6.5 (5.8, 7.2)	58	8.3 (7.6, 9.1)	<0.001
Female children	67	7.4 (6.7, 8.1)	34	6.8 (2.0, 16.0)	33	8.0 (2.0, 13.0)	0.061
Male children	55	7.4 (6.5, 8.2)	30	6.1 (1.0, 12.0)	25	8.8 (2.0, 14.0)	0.001

* Mann-Whitney tests used for difference in means between the two villages
^19 children had breast milk (included in food variety score but not in dietary diversity score)

Table 4.4 shows that overall, dietary diversity scores were very similar between the two villages. Figure 4.3 shows how the villages compare in their intakes of the food groups that make up the dietary diversity score. Mbwei respondents and their oldest children under five years were significantly more likely to consume 'oils and sweets', 'beans, nuts and seeds' and 'milk and dairy products' the day before the interview. While participants in Minyenye were significantly more likely to consume 'vitamin A rich vegetables' and 'other vegetables' than those in Mbwei.

There were a number of differences in the specific foods eaten between the two villages. For example, data from the respondents on the foods eaten over the last calendar year shows that cassava root was consumed by households more frequently in Mbwei (98%) than in Minyenye (55%). *Mlenda*, a wild green leafy vegetable, was consumed in all Minyenye households but only in 16% of households in Mbwei. Milk was more commonly consumed in Mbwei (83%) compared with in Minyenye (55%).

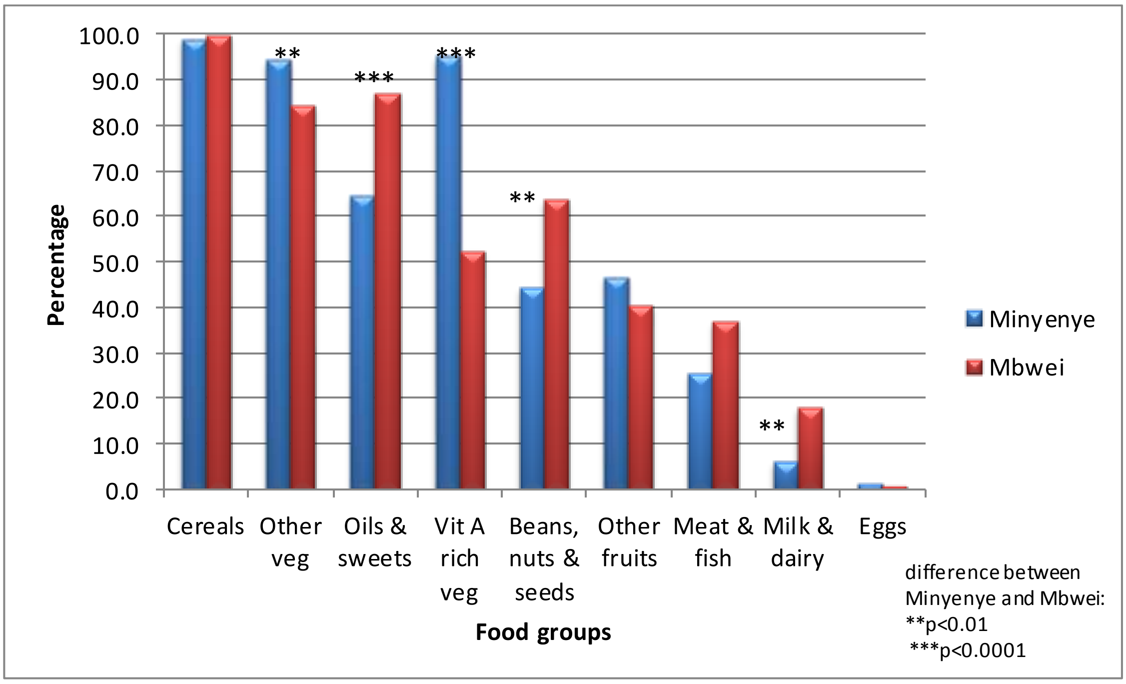


Figure 4.3. Percentage of participants (respondents and children combined) in Minyenye and Mbwei consuming the nine food groups that make up the dietary diversity score on the day before the interview

Figure 4.4 shows the number of different kinds of plant grown by the household, for each month, over the previous year, as reported by the respondent. Figure 4.5 shows plant food grown by the household, gifted to the household or found wild. For both of the graphs the diversity of food available peaks around June and July with the lowest variety of food available between November and February. When considering only grown food Mbwei has a significantly higher diversity of food available in May and June as compared to Minyenye. When wild and gifted food is added in this significant difference disappears and Minyenye then has significantly more variety of food available to them in January, February, April and November compared to Mbwei.

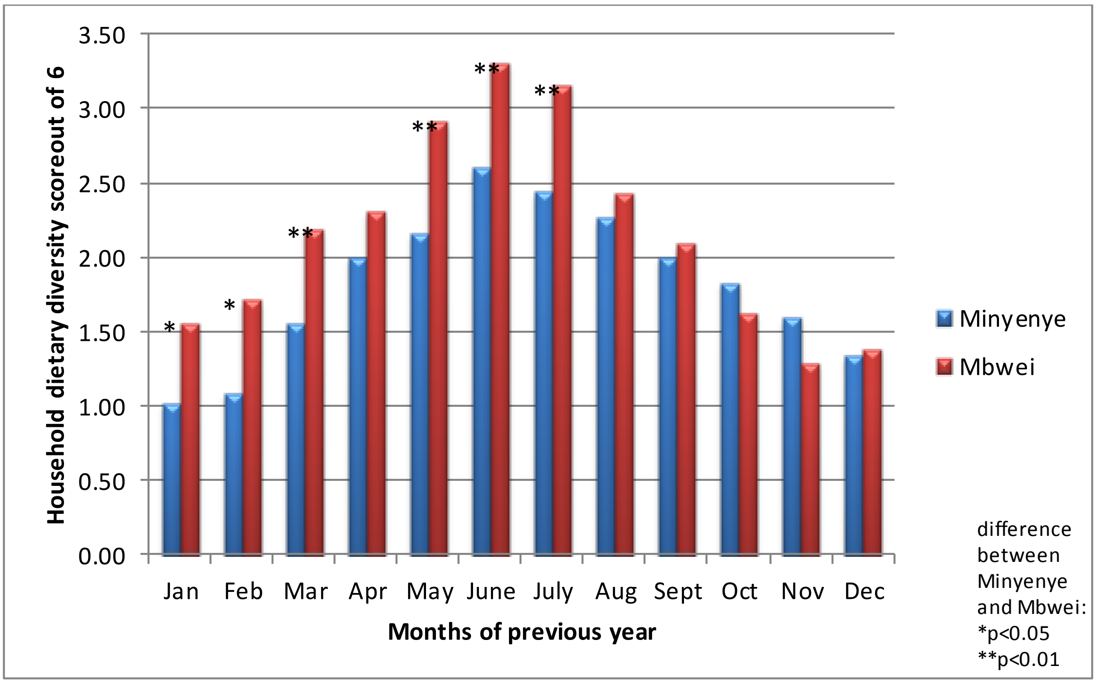


Figure 4.4. Mean household dietary diversity score for the previous calendar year in Minyenye and Mbwei. Score is out of six and based on grown, plant foods only^

^Dietary diversity score includes the following six categories: 'Cereals', 'vitamin A rich vegetables or fruit', 'other vegetables', 'other fruit', 'beans, nuts and seeds' and 'oils and sweets'.

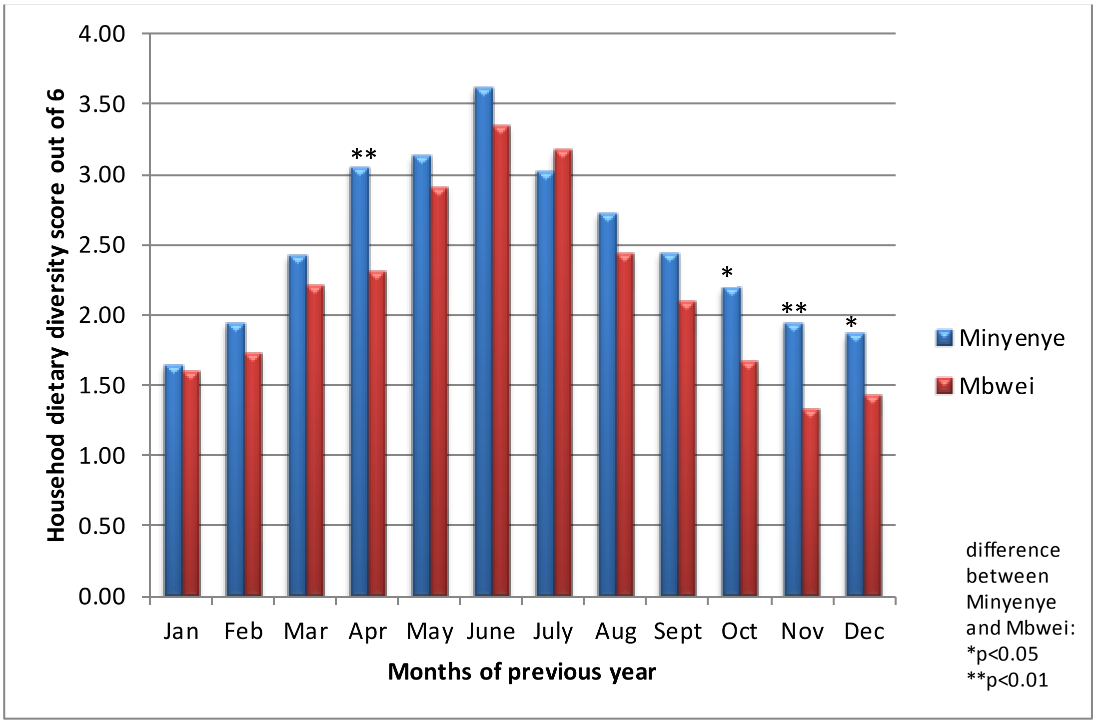


Figure 4.5. Mean household dietary diversity score for the previous calendar year in Minyenye and Mbwei. Score is out of six and based on grown, wild or gifted plant foods only^

^Dietary diversity score includes the following six categories: 'Cereals', 'vitamin A rich vegetables or fruit', 'other vegetables', 'other fruit', 'beans, nuts and seeds' and 'oils and sweets'.

4.4.4 Nutritional status of children

On average, height was 2.05 z-scores and weight was 1.57 z-scores below the reference population median (WHO Child Growth Standards) in children under the age of five (Table 4.5). Mean BMI for age z-scores for these children was 0.14 below the population median. MUAC was approximately 15cm in children under five years of age. Mbwei had significantly lower height and weight for age z-scores with a corresponding higher rate of stunting and underweight in children under five compared to Minyenye. There were no significant differences between the two villages in BMI z-scores or MUAC for children under five.

A similar trend was seen in all children, with Mbwei children having a significantly lower average height z-score and a lower (non-significant) average weight z-score. Mbwei had a significantly higher average BMI z-score than Minyenye in all children. MUAC was on average 16cm in all children under the age of 15 years with Mbwei children having a significantly lower MUAC than children in Minyenye. There were no significant differences between females and males in average z-scores or MUAC.

Table 4.5. Nutritional status of all children and specifically children under the age of five in Minyenye, Mbwei and both villages combined

	All	Minyenye	Mbwei	P-value for difference*
Children under 5 years	204	103	101	
Height z-scores (mean (95% CI))	-2.05 (-2.23, -1.88)	-1.76 (-1.99, -1.54)	-2.36 (-2.61, -2.10)	0.001
Weight z-scores (mean (95% CI))	-1.57 (-1.72, -1.42)	-1.38 (-1.58, -1.18)	-1.76 (-1.98, -1.54)	0.012
BMI z-scores (mean (95% CI))	-0.14 (-0.28, -0.01)	-0.23 (-0.42, -0.04)	-0.06 (-0.24, 0.13)	0.200
Stunted (%)	53.0	40.6	66.0	0.002
Underweight (%)	31.5	23.0	40.0	0.034
MUAC(cm)^ (mean (95% CI))	14.9 (14.7, 15.0)	15.0 (14.8, 15.2)	14.7 (14.5, 15.0)	0.166
All children	432	255	180	
Height z-scores (mean (95% CI))	-1.85 (-1.96, -1.74)	-1.61 (-1.73, -1.49)	-2.22 (-2.40, -2.03)	<0.001
Weight z-scores (mean (95% CI))	-1.74 (-1.84, -1.64)	-1.67 (-1.79, -1.55)	-1.84 (-2.02, -1.67)	0.086
BMI z-scores (mean (95% CI))	-0.66 (-0.75, -0.56)	-0.83 (-0.96, -0.71)	-0.39 (-0.54, -0.24)	<0.001
Stunted (%)	43.0	30.7	62.0	<0.001
Underweight (%)	38.3	34.7	43.7	0.105
MUAC(cm)^ (mean (95% CI))	16.0 (15.8, 16.2)	16.2 (15.9, 16.4)	15.8 (15.5, 16.0)	0.039

*T tests used for difference for normally distributed means, Mann-Whitney tests used for non-normally distributed means, chi squared used for difference in proportions between the two villages

^MUAC only collected in children up to 15 years of age

4.4.5 Breastfeeding and complementary feeding of children

Almost 100% of children under the age of five years had been breastfed (Table 4.6). These children were breastfed until approximately 23 months in Minyenye and, significantly longer (27 months) in Mbwei. Despite children being breastfed longer, liquids were introduced significantly earlier in Mbwei; at an average of 4.5 months compared to 5.3 months in Minyenye. The opposite trend was seen for solids; they were introduce d at 10.5 months in Mbwei and 8.3 months in Minyenye.

Children in Minyenye were more likely to have been weaned onto a porridge made from multiple grains with or without additions such as oil, beans or fish while children in Mbwei were more likely to have been weaned onto a single flour porridge without additions. Millet juice was used as a weaning liquid in Minyenye only. *Ugali* was more likely to be introduced in Minyenye and other staples such as cassava and potato were more likely to be introduced in Mbwei. Vitamin A rich vegetables and other vegetables and fruit were used more frequently as weaning foods in Minyenye compared to in Mbwei.

Table 4.6. Breastfeeding and complementary feeding of children under five in Minyenye, Mbwei and both villages combined

	All	Minyenye	Mbwei	P-value for difference*
Breastfeeding (N)	208	106	102	
Breastfed(%)	99.5	100.0	99.0	0.307
Age breastfed until (months, mean(95% CI))	25.1 (24.1, 26.1)	23.3 (22.3, 24.2)	27.2 (25.5, 29.0)	<0.001
Complementary feeding: Liquids (N)	201	104	97	
Age introduced liquids (months, mean(95% CI))	4.9 (4.6, 5.2)	5.3 (5.0, 5.6)	4.5 (4.0, 5.1)	0.002
Introduced as first liquids(%):				
Single flour porridge(incl. with sugar/salt)	49.8	27.9	73.2	<0.001
Multiple flour porridge eg. Maize, millet (incl. with sugar/salt)	6.5	12.5	0.0	<0.001
Single flour porridge with additions eg. Beans, oil.	13.9	8.7	19.6	0.025
Multiple flour porridge with additions eg. Beans, oil.	21.9	40.4	2.1	<0.001
Cow's milk	14.9	11.5	18.6	0.163
Millet juice	11.9	23.1	0.0	<0.001
Other liquids	14.4	19.2	11.3	0.122
Complementary feeding: Solids (N)	181	96	85	
Age introduced Solids (months, mean(95% CI))	9.3 (8.7, 10.0)	8.3 (7.7, 8.9)	10.5 (9.2, 11.7)	0.001
Introduced as first solids(%):				
Ugali	91.2	97.9	83.5	0.001
Other staples eg. rice, potatoes, cassava, yams	25.4	11.5	41.2	<0.001
Vitamin A rich vegetables	13.3	25	0.0	<0.001
Other fruit and vegetables	17.7	24.0	10.6	0.019
Beans, meat, fish, eggs	15.5	19.8	10.6	0.087
Other solids eg. biscuits	7.7	8.3	7.1	0.749

*Mann-Whitney tests used for difference in means, chi squared used for difference in proportions

4.4.6 Dietary diversity and food variety in relation to nutritional status

The dietary diversity score was not significantly associated with any of the nutritional status variables in either the unadjusted or the adjusted regression models (Table 4.7). Additionally the food variety score was not significantly associated with height, weight or BMI z-scores or MUAC in the adjusted model. The borderline statistically significant negative association seen between the food variety score and height for age z-scores disappears in the adjusted model. Similar results were seen when children who were still being breastfed were excluded from the analysis. The dietary diversity and food variety scores of the respondents were not significantly associated with BMI (results not shown).

Some of the food group components that make up the dietary diversity score are significantly associated with the nutritional status variables. In unadjusted models children who consumed vitamin A rich fruit or vegetables the previous day had higher height z-scores by **0.48** (Regression coefficient (95% confidence intervals):**0.48 (0.02, 0.94)**). Children eating eggs the previous day had higher weight **(1.31 (0.01, 2.62))** and BMI **(1.38 (0.09, 2.66))** z-scores. Children who consumed meat the day before had **0.46** lower height z-scores **(-0.46 (-0.91, -0.01))**. Similarly children consuming milk the previous day had MUACs approximately 0.8cm lower than those not consuming milk **(-0.76 (-1.45, -0.08))**.

When all the individual foods in the dietary diversity score are added to the same model the only two associations that remain significant are egg consumption and BMI z-scores **(1.45 (0.12, 2.79))** and cow milk consumption and MUAC **(-0.76 (-1.48, -0.04))**. No significant associations are found after adjustment for potential confounders.

Table 4.7. Unadjusted and adjusted linear regression results for dietary diversity and nutritional status in children under five for both villages combined

	Height z-scores	**Weight z-scores**	**BMI z-scores**	**MUAC**
	Regression coefficient (95% CI)	Regression coefficient (95% CI)	Regression coefficient (95% CI)	Regression coefficient (95% CI)
Dietary diversity score				
Unadjusted model^	-0.09 (-0.24, 0.06)	-0.12(-0.24, 0.01)	-0.07(-0.19, 0.06)	0.01(-0.14, 0.15)
Adjusted model^^	-0.08(-0.23, 0.07)	-0.011(-0.24, 0.03)	-0.05 (-0.18, 0.08)	0.05 (-0.10, 0.20)
Food variety score				
Unadjusted model^	**-0.08(-0.15, -0.01)**	-0.06(-0.12, 0.00)	0.01(-0.05, 0.07)	-0.01(-0.08, 0.06)
Adjusted model^^	-0.05(-0.13, 0.03)	-0.04 (-0.11, 0.04)	0.00 (-0.07, 0.07)	0.04(-0.05, 0.11)

^N for unadjusted model was 112 for height, weight and BMI z-scores and 115 for MUAC.
^^adjusted for village, parents age, highest level of education, height, weight or BMI, whether the household has a mobile phone, household takes action to make water safe, whether the parents have an alternative source of income. N for adjusted model was 112 for height, weight and BMI z-scores and 115 for MUAC. Of these variables the following had missing values (number of missing values in brackets after each variable): respondent's age (23); husband's age (57); husband's highest level of education (9); respondent's height (2); husband's height (77); husband's weight (77); respondent's BMI (2); husband's BMI (77); parental ethnicity (9) and whether the husband earns extra income (8) out of a total of 210 individuals.

4.4.7 Complementary feeding, demographics, sanitation and nutritional status

The factor that was most strongly associated with the nutritional status variables was complementary feeding variables. In unadjusted regression models, for each month extra the child was breastfed their weight z-score was 0.01 lower (Regression coefficient (95% confidence intervals): **(-0.01 (-0.03, -0.00)**) and MUAC was 0.04 higher **(0.04 (0.03, 0.05))**. Children who had already had liquids introduced to their diet at the time of interview had lower height **(-1.57 (-2.49, -0.64))**, weight **(-1.75 (-2.54, -0.96))** and BMI z-scores **(-0.75 (-1.47, -0.24))** and higher MUAC **(1.36 (0.47, 2.24))** compared to those who had not had liquids introduced. The age liquids were introduced is significantly associated with MUAC **(0.16 (0.09, 0.23))**. For every additional month of age the child was when they had liquids introduced MUAC increased by 0.16cm.

Children receiving multiple flour porridge as their first foods with or without additions had higher heights (with additions: **0.67 (0.25, 1.08)**, without additions: **0.73 (0.02, 1.43))**. However, children receiving single flour porridge with additions had lower heights **(-0.65 (-1.14, -0.16))**. Children receiving multiple flour with additions had lower BMI z-scores **(-0.52 (-0.84, -0.20))**. Those consuming cow's milk as one of the first liquids introduced to the diet had significantly lower height z-scores **(-0.52 (-1.02, -0.02))**. While those consuming other liquids had significantly higher BMI z-scores **(0.65 (0.28, 1.02))**. Children who had received solids at the time of interview had lower height **(-0.72 (-1.24, -0.20))**, weight **(-1.05 (-1.48, -0.62))** and BMI **(-0.68 (-1.07, -0.28))** z-scores but higher MUAC **(1.24 (0.78, 1.69))**. The older the children were when solids were introduced the lower their height **(-0.04 (-0.08, -0.01))** and weight **(-0.05 (-0.08, -0.02))** z-scores were and the higher their MUAC was **(0.07 (0.04, 0.10))**.

Associations between these complementary feeding variables and nutritional status are adjusted for potential confounders and presented in Table 4.8. Children who were breastfed for longer had lower weight z-scores but higher MUAC. The older the child was when liquids were introduced the lower their height and the higher their MUAC were. For each additional month of age the child was when liquids were introduced height was 0.07 z-scores lower and MUAC was 0.17cm larger. Children who received multiple flour porridge with additions as a first complementary food had lower BMI z-scores and MUAC and children receiving single flour porridge had higher MUAC. Children receiving millet juice had lower height and weight z-scores. Children receiving other liquids such as water, fruit juice, tea or soda as the initial complementary foods had lower BMI z-scores.

In the adjusted model those children who had already had solids introduced into their diets had lower height, weight and BMI z-scores and higher MUAC. For every additional month of age at which solids were introduced height decreased by 0.03 and weight decreased by 0.04

while MUAC increased by 0.07cm. As with the unadjusted regression no specific solids were significantly associated with any of the nutritional status variables.

Table 4.8. Adjusted* linear regression results for complementary feeding and nutritional status in children under five for both villages combined

	Height z-scores Regression coefficient (95% CI)	**Weight z-scores** Regression coefficient (95% CI)	**BMI z-scores** Regression coefficient (95% CI)	**MUAC** Regression coefficient (95% CI)
Age breastfed until (months)	-0.01 (-0.02, 0.01)	**-0.02 (-0.03, -0.00)**	-0.01 (-0.02, 0.00)	**0.04 (0.02, 0.05)**
Liquids introduced (Y/N)	**-1.35 (-2.21, -0.48)**	**-1.80 (-2.55, -1.05)**	**-0.89 (-1.60, -0.18)**	**1.17 (0.30, 2.04)**
Age introduced liquids (months)	**-0.07 (-0.15, -0.00)**	-0.05 (-0.11, 0.02)	0.02 (-0.04, 0.08)	**0.17 (0.10, 0.24)**
Single flour porridge (incl. with sugar/salt) (Y/N)	0.35 (-0.07, 0.77)	0.09 (-0.27, 0.45)	-0.19 (-0.53, 0.15)	**0.66 (0.25, 1.06)**
Multiple flour porridge e.g. Maize, millet (incl. with sugar/salt) (Y/N)	0.01 (-0.75, 0.76)	0.11 (-0.53, 0.75)	0.04 (-0.55, 0.64)	-0.03 (-0.77, 0.71)
Single flour porridge + additions e.g. Beans, fish (Y/N)	-0.28 (-0.80, 0.24)	-0.06 (-0.51, 0.38)	0.27 (-0.14, 0.69)	0.08 (-0.44, 0.60)
Multiple flour porridge + additions e.g. Beans (Y/N)	0.43 (-0.04, 0.90)	0.10 (-0.32, 0.52)	**-0.43 (-0.81, -0.05)**	**-0.49 (-0.96, -0.02)**
Cow's milk (Y/N)	-0.36 (-0.89, 0.13)	-0.14 (-0.57, 0.29)	0.03 (-0.37, 0.44)	-0.05 (-0.54, 0.44)
Millet juice (Y/N)	**-0.86 (-1.39, -0.33)**	**-0.54 (-1.01, -0.07)**	0.16 (-0.28, 0.61)	-0.17 (-0.72, 0.39)
Other liquids (water, fruit juice, tea, soda) (Y/N)	-0.20 (-0.66, 0.27)	0.08 (-0.32, 0.48)	**0.55 (0.16, 0.93)**	-0.04 (-0.52, 0.44)
Solids introduced (Y/N)	**-0.72 (-1.21, -0.22)**	**-1.10 (-1.51, -0.69)**	**-0.73 (-1.12, -0.33)**	**1.11 (0.65, 1.57)**
Age introduced solids (months)	**-0.03 (-0.06, -0.00)**	**-0.04 (-0.07, -0.01)**	-0.03 (-0.05, 0.00)	**0.07 (0.04, 0.10)**
Ugali (Y/N)	-0.06 (-0.69, 0.57)	0.06 (-0.47, 0.59)	0.09 (-0.42, 0.59)	0.59 (-0.04, 1.23)
Other staples (rice, potatoes, cassava, yams) (Y/N)	0.38 (-0.04, 0.79)	0.18 (-0.17, 0.52)	-0.21 (-0.53, 0.12)	-0.10 (-0.51, 0.32)
Vitamin A rich vegetables (Y/N)	-0.38 (-0.93, 0.17)	-0.17 (-0.63, 0.29)	0.18 (-0.25, 0.62)	-0.22 (-0.77, 0.33)
Other fruit and vegetables (Y/N)	-0.06 (-0.52, 0.41)	-0.00 (-0.39, 0.38)	-0.08 (-0.45, 0.29)	0.05 (-0.41, 0.52)
Beans, meat, fish, eggs (Y/N)	-0.05 (-0.54, 0.43)	0.03 (-0.38, 0.43)	-0.05 (-0.43, 0.33)	-0.18 (-0.66, 0.30)
Other solids (biscuits, *mandazi*) (Y/N)	-0.18 (-0.81, 0.45)	-0.14 (-0.67, 0.38)	0.04 (-0.46, 0.54)	-0.61 (-1.23, 0.02)

*Adjusted for village, parents age, parents ethnicity, highest level of education, height, weight or BMI, whether the household has a mobile phone, household takes action to make water safe, whether the parents have an alternative source of income. N was 193 for height, 195 for weight, 196 for BMI z-scores and 199 for MUAC. . Of these variables the following had missing values (number of missing values in brackets after each variable): respondent's age (23); husband's age (57); husband's highest level of education (9); respondent's height (2); husband's height (77); husband's weight (77); respondent's BMI (2); husband's BMI (77); parental ethnicity (9) and whether the husband earns extra income (8) out of a total of 210 individuals.

In unadjusted regression analysis for each additional cm in the respondent's height their under five child's height increased by **0.05cm (95% CI: 0.03, 0.08**). This figure was **0.08cm (0.04, 0.11)** for the husband's height. Similarly, for each additional kg of respondent's weight their under five year old's weight was **0.04kg (0.02, 0.06)** higher. For each additional point of respondent BMI the under five year old's BMI was **0.06kg/m2 (0.02, 0.10)** and their MUAC was **0.07cm (0.01, 0.13)** higher. For each additional point of the husband's BMI their under five year old's MUAC was **0.07cm (0.01, 0.13)** bigger.

Parents ethnicity was significantly associated with under five year old's height **(-0.23 (-0.40, -0.07)** and BMI z-scores **(0.15 (0.03, 0.27)** but not weight (-0.07 (-0.21, 0.07)) or MUAC (0.02 (-0.13, 0.18)). Height for age z-scores were highest when both parents were Nyantulu (-1.72) and similar if both parents were Pare (-2.32), Sambaa (-2.29), or mixed/other (-2.39). BMI for age z-scores were highest for under five year olds with mixed or other parental ethnicity (0.21), followed by those with Pare parents (-0.14), with Nyantulu (-0.30) and Sambaa (-0.33) parents having children with similar BMI z-scores.

Households taking action to make water safe for drinking, for example boiling, had under five year olds with **0.18 (0.03, 0.33)** higher weight z-scores in the unadjusted model. This association was no longer significant when adjusted for confounders (village, respondent's and her husband's age and husband's frequency of employment) (0.16 (-0.01, 0.34). The source of drinking water was significantly associated with under five year old's height z-scores in the unadjusted model only **(-0.15, (-0.27, -0.17)**. Height z-scores were -2.27 for households getting water from rivers or lakes, -1.88 in households using piped water, -1.84 where a borehole was the source of water and -1.59 for households using dug wells.

In the adjusted model whether the household did something to make water safe was significantly associated with weight z-scores; those households boiling water had under five year olds with weight z-scores 0.28 higher than those using other methods and 0.56 higher than those doing nothing (regression coefficients (95%CI): **-0.28 (-0.54, -0.02)** . Compared to in houses with open pit latrines, under five year olds in houses with closed pit latrines had **0.37(0.04, 0.70)** higher MUAC and **0.19 (0.01, 0.36)** higher weight for age z-scores. Source of drinking water, taking action to make water safe, time to get water and type of toilet were not significantly associated with other measures of nutritional status in either the unadjusted or the adjusted models (of the variables in the model the following had missing values in under five year olds (number of missing values in brackets after each variable): respondent's age (23); husband's age (57); husband's frequency of employment (9) out of a total of 210 individuals. These number were: respondent's age (59); husband's age (128); husband's frequency of employment (24) out of a total of 532 individuals for all children.)

Seventy-one percent of all respondents (77% in Minyenye and 66% in Mbwei) felt their family did not get enough food and 83% (88% in Minyenye and 78% in Mbwei) felt they did not get enough variety of food.

4.5 Discussion

4.5.1 Nutritional status of children

Growth rates of the children in this study were poor. On average under five year olds were stunted, as defined as two standard deviations (SD) below the median of the international WHO Child Growth Standards in height for age z-scores. The rates of stunting seen in this study were higher than rates seen in the Tanzanian 2010 demographic and health survey (STAT compiler, 2014) (chapter 7, Table 7.4) but broadly similar to those seen in other Tanzanian articles (Beasley et al., 2000, de Onis et al., 2012).

Both villages, but especially Mbwei, had high rates of low weight for age z-scores. Low height for age, or stunting, reflects a failure to reach the expected linear growth for the child's age (de Onis et al., 1997). This occurs over a longer time period than low weight for age or underweight which reflects a lower than average weight for a given age and is influenced by short term factors such as diarrhoea (Rowland et al., 1988). The high rates of both stunting and underweight seen in this study indicates long term adverse conditions where the children have not reached their height potential combined with current adverse conditions where they are not as heavy as would be expected for their already reduced heights. MUAC reflects short term nutritional status. The WHO standards for the definition of severe acute malnutrition is a MUAC of below 11.5cm (Gollogly, 2009). The mean and 95% Confidence Intervals of MUAC showed it to be at acceptable levels in both villages.

4.5.2 Dietary diversity and nutritional status

Participants in this study had average dietary diversity, five out of nine food groups, but low food variety, a total of 7.5 different food items. In much of the literature in this area dietary diversity (Arimond, 2004, Corbett et al., 1992, Steyn et al., 2006, Garg and Chadha, 2009, Nti and Lartey, 2008, Savy et al., 2005) and food variety (Hatloy et al., 2000, Sawadogo et al., 2006, Saibul et al., 2009, Onyango et al., 1998) are significantly, positively associated with nutritional status, something that was not found in this study. In the adjusted regression models no significant associations were seen between dietary diversity or food variety and height, weight or BMI z-scores or MUAC. This result does not support the pathway from dietary diversity to nutritional status illustrated in figures 3.2 a) and b).

There are a number of possible reasons for this. Firstly, there are many factors which have an impact on nutritional status. Infectious diseases in the first five years of life has a significant impact on children's nutritional status (Victora et al., 1990). Many individuals enter into a cycle of malnutrition and infection each exacerbating the other leaving the individual more malnourished and more at risk of infection (Chen et al., 1980). Foods introduced into a child's diet when they are being breastfed have an important impact on their nutritional status (Onyango et al., 1998, Obatolu, 2003). Additionally, vaccinations (Dancer et al., 2008), access to clean drinking water and living with poor sanitation (Fink et al., 2011, Kikafunda et al., 1998) are associated with stunting in children under the age of five. Nutritional status in children has also been liked to their parents' literacy (Fernandez et al., 2002) and maternal education (Kabubo-Mariara et al., 2009, Abuya et al., 2012). These other factors may be enough to offset or mask the effect of dietary diversity on nutritional status in this study. Duration of breastfeeding, introduction of complementary foods and sanitation were assessed in the current study and will be discussed further in the next section. Additionally, dietary diversity varied little across households in the villages, 95% of the study population had dietary diversity between 4.6 and 5.0. There may not be enough variation in dietary diversity to detect an effect on nutritional status.

Secondly, some methodological factors may have affected results. Dietary diversity was assessed cross-sectionally at the same time the nutritional status measures were taken. This assumes that dietary diversity is static and a cross sectional measure can represent dietary diversity of the past. This may be too great an assumption; the study design limits the likelihood an association between dietary diversity and nutritional status would be detected, even if it did exist in this population. However, a number of other studies have found significant associations between dietary diversity (Arimond, 2004, Garg and Chadha, 2009, Savy et al., 2005, Sawadogo et al., 2006, Hatloy et al., 2000) and food variety (Onyango et al., 1998, Hatloy et al., 2000, Saibul et al., 2009, Sawadogo et al., 2006) and nutritional status outcomes measured cross-sectionally.

Lastly, the data was collected in June and July, times of relative food plenty. In the previous year food diversity dropped from approximately 3.5/6 in June to 1.5/6 in November, December and January when looking at foods available to the household through foods grown, found wild and gifted to the household. Perhaps if dietary diversity was measured at a time of food shortage an association between dietary diversity and nutritional status would have been seen.

4.5.3 Complementary feeding, demographics, sanitation and nutritional status

Some complementary feeding, demographic and sanitation factors are associated with nutritional status in these villages. Children under five in Mbwei were more likely to be stunted than children in Minyenye. There were a number of differences between the two villages that may explain why those in Mbwei had poorer nutritional status. Ethnicity was significantly associated with height and weight so the biophysical characteristics of different tribes living in the two villages may explain some of the difference seen between the villages. Habicht et al (1974) found that the effect of ethnicity on the growth of young children in a range of low and high income countries was small compared to environmental factors. While Ebomoyi et al (1991) found ethnicity to be significantly associated with birth weight in Nigeria and a Tanzanian study showed fathers ethnicity to be significantly associated with perinatal mortality (Habib et al., 2008). Proos called for local reference growth data for different ethnic groups and regions to be developed (Proos, 1993). Ethnicity, in this study could have impacted on the nutritional status results but it is difficult to remove its effects from the effect of the village as the majority of people from Minyenye were Nyantulu and the majority of those from Mbwei were Pare.

World Vision has been working in Singida district since 2004 and Minyenye village has been a target for their education and nutrition programs (World Vision Tanzania, 2009). One of their main achievements outlined in their 'Essential nutrition package Mtinko and Kinampanda annual report 2011' is the improvements made to the porridge used in complementary feeding (World Vision Tanzania, 2011). This is reflected in the results of this project with Minyenye being more likely to use a multiple grain porridge and to make additions of oil, beans and fish to their porridge. Although respondents in Minyenye were more likely to report better weaning practices such as introducing multiple grain porridge, porridge with high nutrient additions, vitamin A rich vegetables and fruits and vegetables, this did not have a significant impact on children's nutritional status, in this study.

On the contrary, the practice of introducing multiple flour porridge with additions and millet juice, which was carried out almost exclusively in Minyenye, was negatively associated with the nutritional status outcomes. Respondents in Mbwei introduced liquids to breastfed infants significantly earlier than those in Minyenye. These liquids were typically porridge made with water, as was the porridge and millet juice in Minyenye. This may introduce a risk of infection to the children earlier which could impact on their nutritional status negatively (Motarjemi et al., 1993). Gross et al (2000) found Vietnamese children who had early introduction of complementary foods (typically rice water and rice porridge) to have a higher rate of infection and poorer anthropometric outcomes than children that continued to be exclusively or predominantly breastfed at ages 1-12 months. Children in Mbwei did not receive solids until later than their Minyenye counterparts leaving them at risk of infection from unclean drinking water without sustenance from solid food for longer. This may contribute to the lower height and weight z-scores in Mbwei.

There is an established association between infection and nutritional status in under five year olds (Stephensen, 1999). Although this study did not collect data on markers of infection there are a number of reasons why Mbwei might be expected to have a higher rate of infection which may have contributed to the higher rates of stunting in this village. Firstly the majority of participants in Mbwei collected their drinking water from rivers which were also used as watering holes for livestock. Many infectious organisms are transmitted via the faecal-oral route through contamination of drinking water (Fayer et al., 2000). Different sources of water were not, however, associated with nutritional status. Some of the increased risk of infection may be offset by the higher proportion of people boiling water in Mbwei as wheth er the household took action to make water safe to drink was associated with weight i n under five year olds. Open pit latrines, which were the most common type of toilet in both villages, was associated with poorer nutritional status. Poorer sanitation has previously been linked to poorer health outcomes in low income countries (Fink et al., 2011, Esrey, 1996). Making water safe to drink and the type of toilet the household had, along with the difference in complementary feeding, may still have impacted on rates of infection and nutritional status in these two villages.

There were no significant differences seen in dietary diversity between the two villages. Perhaps using a summary score of dietary diversity means we lose important dietary information. It may be the information that makes up these scores that is most valuable. When looking at the components of the dietary diversity score a higher proportion of those in Minyenye consumed ‘vitamin rich fruit and vegetables’ and ‘other vegetables’ and a lower proportion consumed ‘oils and sweets’, ‘beans, nuts, seeds’, and ‘milk and dairy products’. A significant positive relationship between ‘vitamin A rich fruit and vegetables’ and height and a negative relationship between milk consumption and MUAC were found in unadjusted models. When other dietary diversity components were taken into account only egg consumption and milk consumption showed significant associations and when potential confounders were adjusted for these associations disappeared. Only two children consumed eggs the previous day so it is not appropriate to generalise this result to the wider population. However, the difference in vitamin A rich food and milk intake between the two villages may have contributed to their different rates of stunting.

Vitamin A deficiency has been shown to be causally associated with poor growth (Tarwotjo et al., 1992). A possible mechanism for this association is the protective effect vitamin A has against infection (Sommer et al., 1984). Milk consumption has not been shown to be associated with malnutrition, in fact animal products are often recommended to improve nutritional status in low income countries (Gibson et al., 2003). Kikafunda et al. (1998) found children in Uganda who had never consumed cow's milk to have a significantly higher rate of underweight that those who had consumed milk. Grillenberger et al (2006) showed in Kenya that growth was improved by providing a milk supplement to school children. However a number of respondents mentioned during the course of data collection that milk is often watered down with drinking water in these areas. This practice could introduce a risk of infection.

Other dietary components and practices may also help account for this difference in nutritional status. The majority of participants in Minyenye consumed *Mlenda* (*Corchonus tritocularies Tillaceae*), a wild green leafy vegetable that grew freely in the area. It was a very important part of their diet with many participants consuming only *ugali* and *mlenda* as their main meal. *Mlenda* is eaten fresh but is also dried and ground to be used throughout the year. *Mlenda* is high in iron and calcium (Kinabo et al., 2006) and having this food available year round is expected to be an important contributor to the food security of people living in Minyenye. This is illustrated in the difference between Figure 4.4 and 4.5 which shows that Mbwei has more household dietary diversity than Minyenye in May and June, this difference disappears when wild food is included in Figure 4.5. Minyenye has a higher diversity of food available in January, February, April and November when wild food is taken into consideration, highlighting how important wild food can be to dietary intake. The importance of wild food to those living in rural sub-Saharan Africa has been extensively discussed in the literature (Harris and Mohammed, 2003, Nordeide et al., 1996, Johns et al., 1996, Vainio-Mattila, 2000, Bharucha and Pretty, 2010) and has been shown to be an important source of energy and micro-nutrients (Nordeide et al., 1996), especially at times of food scarcity (Harris and Mohammed, 2003).

Households in Mbwei were more likely to grow and eat cassava compared to Minyenye. Cassava typically provides enough calories but inadequate protein, iron, zinc and vitamin A (Stephenson et al., 2010). Gregios et al (2010) found the proportion of the diet made up of cassava was inversely correlated with vitamin A, zinc and iron intake. Cassava, however, is an important crop for food security as it can be stored in the ground, it grows in poor conditions with limited input and is unusually tolerant (El-Sharkawy, 2007). It can help maintain energy intake during the hungry season and provide an in ground food store in case of crop failure (Prudencio and Al-Hassan, 1994). Both the higher growth and higher consumption of cassava in Mbwei may indicate poorer food security in this area.

Minyenye had significantly lower rates of stunting than Mbwei but their under five year olds were still 41% stunted, rates higher than outlined in the millennium targets for 2015 (United Nations, 2014). Reasons for this high rate of stunting found in both villages, in addition to infection and the types of foods introduced to breastfed children discussed above, includ e the high level of poverty and low food security found in rural Tanzania (Hadley et al., 2007). The households participating in this study were poor with none of the houses having electricity and only half reporting owning a radio. Approximately three quarters of the participants reported not getting enough food as well as not getting enough variety of food. All these factors are likely to contribute to the poor nutritional status seen in these villages. These factors relating to poverty and acting through diet and infection, were illustrated by the social/economic/care/health factors section of the conceptual framework (Figure 3.2 a) and b)). In comparison to agrobiodiversity, these factors have a large impact on child nutritional status.

4.5.4 Limitations and strengths

This study has a number of limitations that need to be acknowledged, in addition to the cross sectional nature of the study and the seasonal effects discussed above. As with all studies that rely on a translator there will be inaccuracies in the information translated and interesting detail in the participants responses may have been lost. The cross-cultural dynamic of the study may have affected the honesty of the responses from the participants (Twyman et al., 1999). The researcher was white and from a high income country and it is possible that some of the respondents exaggerated the difficulties they faced in the hope that they would receive aid from the research project. It is also possible that the participants underplayed the difficulty of their circumstances if they felt embarrassed in front of the research team. The cross-cultural dynamic could have affected the answers the participants gave, the way this was translated and how this has been interpreted by the researcher in a number of different ways (Twyman et al., 1999). This needs to be taken into consideration when interpreting the results of the study. The household questionnaire collected mainly quantitative data, collecting more qualitative data may have provided additional insights into the determinants of nutritional status in these communities.

Additionally the interview often took place within hearing distance of other family and community members and this may have affected how the participants answered the questions. The interview was detailed and took between 1 and 1.5 hours to complete. The researcher expects the quality of the responses to have decreased over the course of the interview.

Information collected on complementary feeding would have been affected by recall bias as it was collected on all children under the age of five years. Anthropometric measures were taken outside the family home, almost exclusively on mud ground. There were no truly flat surfaces to take the height and weight measures which may have decreased the accuracy of the results. Similarly some of the young children were upset, making taking accurate anthropometric measures more difficult. The researchers did their best to minimise the effect of the above limitations on the data collected but expect them still to have had an effect. The effect of clustering at the village level was taken into consideration for the sample size calculation; the study is powered to detect differences between the two villages. This calculation did not however allow for clustering at the household level. As approximately 55% of the households in Minyenye and 65% of Mbwei households had more than one under five year old, this may have decreased the studies power to detect differences in nutritional status between the two villages.

Using a set of indicators to represent household wealth, such as the DHS wealth index (Rutstein et al., 2004) is a useful approach in a low income country setting. However, wealth was not addressed directly by this study as it was outside the scope of the study's objectives. Using individual variables as proxies for wealth was therefore considered sufficient to act as potential confounders in regression analyses. Factors potentially associated with wealth were added to data analyses to try and control for wealth in these villages. The only variable that impacted on the regression coefficients, indicating it was a confounding variable, was whether the household owned a mobile phone. This variable was therefore used as a proxy for wealth in a number of the data analyses.

The limitation of this approach is that mobile phone ownership may be confounding the relationships for reasons other than its relationship to household wealth. For example, improved communication may be having a positive impact on nutritional status. The other limitation is that, if it is representing wealth, it is just one aspect of wealth when a wealth index summarises many aspects of wealth making it a more accurate estimate.

This study comprehensively collected paired data on dietary diversity and nutritional status on a randomly selected sample within the two villages. This data and information on other potential determinants of nutritional status in these villages was collected specifically for this project and data collection methods were tailored to collect the data needed to meet project objectives.

4.6 Conclusions

Malnutrition was high in these communities but typical for Tanzania. This is likely to be due to high levels of poverty, low food security, poor access to clean water and poor complementary feeding leading to high rates of infection among other inter-related factors. This study identified factors that may have been responsible for the higher rates of stunting in Mbwei. These included differences in ethnicity between the two villages, the early introduction of liquids and late introduction of solids in Mbwei, Mbwei's poorer access to clean drinking water and greater time taken to collect water. With the exception of ethnicity, all of these factors raise the risk of infection in children which, along with food intake, has been identified as the major determinant of nutritional status in under five year olds in low income countries.

Participants in Minyenye and Mbwei had average dietary diversity but low food variety. There was no relationship found between dietary diversity or food variety and nutritional status in these communities and no difference in dietary diversity or food variety between the two villages. It should be acknowledged that these results may have been influenced by design, methodological and seasonal limitations of the study. However, other dietary factors may have contributed to the difference in height and weight between Minyenye and Mbwei. Specifically, the higher intake of vitamin A rich fruit and vegetables and lower intake of potentially contaminated milk in Minyenye may have played a part. Additionally, the high proportion of households consuming wild green leafy vegetables in Minyenye may have buffered food intake at times of food shortage while the higher proportion of households in Mbwei eating cassava may indicate worse food security in this village.

The high rates of stunting in children under five years old shows that there is still a great need for interventions to improve nutritional status these villages, and most likely others like them. The multiple determinants of nutritional status discussed in this chapter highlight the difficulty of intervening in order to improve nutrition and health outcomes. This chapter provides evidence to support broad nutrition interventions which address the wide range of factors, such as sanitation and complementary feeding, shown to be related to nutritional status.

Chapter 5:
Investigating the associations between plant agrobiodiversity and both dietary diversity and nutritional status in Minyenye and Mbwei, rural Tanzania.

5.1 Chapter summary

The previous chapter outlined the relationship between dietary diversity and nutritional status as well as the associations between other demographic, social and dietary factors and nutritional status. This chapter aims to investigate the relationship between plant agrobiodiversity and both dietary diversity and nutritional status in households reliant on subsistence farming in rural Tanzania. It reports on plant agrobiodiversity measured cross-sectionally in the household farms as well as the number of crops and vegetables grown over the previous calendar year. These second sets of measures of plant agrobiodiversity will be referred to as the crop and vegetable diversity scores. Whether selling different types of crops is associated with dietary diversity and nutritional status is also reported in this chapter.

This chapter meets objective 2 (Systematically assess the diversity and abundance of both cultivated and wild plants growing on household agricultural land in two villages in rural Tanzania and investigate how this is related to dietary diversity in under five year old and nutritional status in children in these villages) and contributes to meeting objective 3 (Measure household crop and animal diversity, dietary diversity of respondents and children under five and nutritional status of children living in these villages, determine whether household produce is sold and investigate how these factors are related) and objective 4 (Investigate basic socio-demographic factors affecting dietary intake of children under five and nutrition outcomes in children in these villages) of this thesis. The objectives of this chapter are to:

Objective 5A: Present descriptive data on habitat, species present, farm characteristics, cross-sectional plant agrobiodiversity and crop and vegetable diversity scores in the two villages.

Objective 5B: Investigate whether plant agrobiodiversity and crop/vegetable diversity scores are associated with dietary diversity and nutritional status in children.

Objective 5C: Investigate whether selling staple crops, vegetables, fruit and other produce is associated with dietary diversity and nutritional status in children.

Agrobiodiversity is not associated with dietary diversity or food variety in Minyenye or Mbwei. Households with higher annual crop or vegetable diversity scores, however, had individuals with more diversity in their diets. Associations between agrobiodiversity and crop diversity scores and nutritional status are mixed in Minyenye but negative in Mbwei. Individuals from households selling produce they grew had higher dietary diversity in both villages. Households selling produce had the same or better nutritional status in Mbwei but results in Minyenye were mixed.

Only one study (Dewey, 1981) has linked these factors together within a study, tracing associations between food production, consumption and growth. This study therefore provides important data on the association between agrobiodiversity, dietary diversity and nutritional status and shows that these associations are not to be assumed. This study informs future interventions intending to use improvements in plant agrobiodiversity as a tool to improve health and encourages researchers and development agencies to explore some of the barriers to the pathway from diversity in crops grown to diversity in diets to health outcomes.

5.2 Introduction

Agrobiodiversity has been defined as the biological diversity on lands used for agricultural purposes (Brookfield and Stocking, 1999). It includes all aspects of biological diversity which affect agriculture and food; the diversity of plants, animals and micro-organisms at species and ecosystem levels (Cromwell et al., 1999). This chapter focuses on plant agrobiodiversity. There has been discussion in the literature about the importance of improving agrobiodiversity to improve food security, diet and nutrition (Thrupp, 2000, Frison et al., 2011). An increase in the types of crops grown also opens up the potential for these crops to be sold, supplementing the households income and potentially improving nutritional status through this pathway (Shack et al., 1990). Crops may also be specifically grown for sale with none of the grown crops being eaten within the household.

Agrobiodiversity has been highlighted as essential in the sustainable delivery of a more secure food supply (Frison et al., 2011, Thrupp, 2000). According to Frison et al (2011) the more diverse farming systems and crops are, the more resilient farming systems are to shocks and changes in the climate. Thrupp (2000) outlines the problems associated with agrobiodiversity loss. These are most relevant for plant agrobiodiversity: disruption of ecosystem services including water retention, nutrient cycling and decomposition which leads to decreases in productivity; erosion of genetic resources of crops and livestock leading to increased risk and decreased food security; erosion of insect diversity leading to decreased pollination and increased susceptibility; erosion of soil diversity leading to fertility loss and decreases in productivity; loss of habitat diversity including wild foods and loss of indigenous methods and biodiversity knowledge.

Ecosystem services provided by biodiversity are considered in detail by Altieri (1999) who discusses how the disruption in these ecosystem services are linked to reductions in food production. Tilman et al (1996) provided experimental evidence supporting the diversity-sustainability theory that the sustainability of soil fertility is reliant on plant biodiversity. They found that ecosystem productivity increased and nitrogen loss decreased with higher plant diversity.

Two distinct types of plant-based biodiversity are present in the majority of agricultural systems. The first is the biodiversity of the crops planted by the farmer. The second is the wild plants as well as the soil flora and fauna, pollinators, decomposers, herbivores and carnivores associated with this planned biodiversity (Altieri, 1999). How these two different kinds of biodiversity interact and impact on ecosystem function is outlined in Figure 5.1.

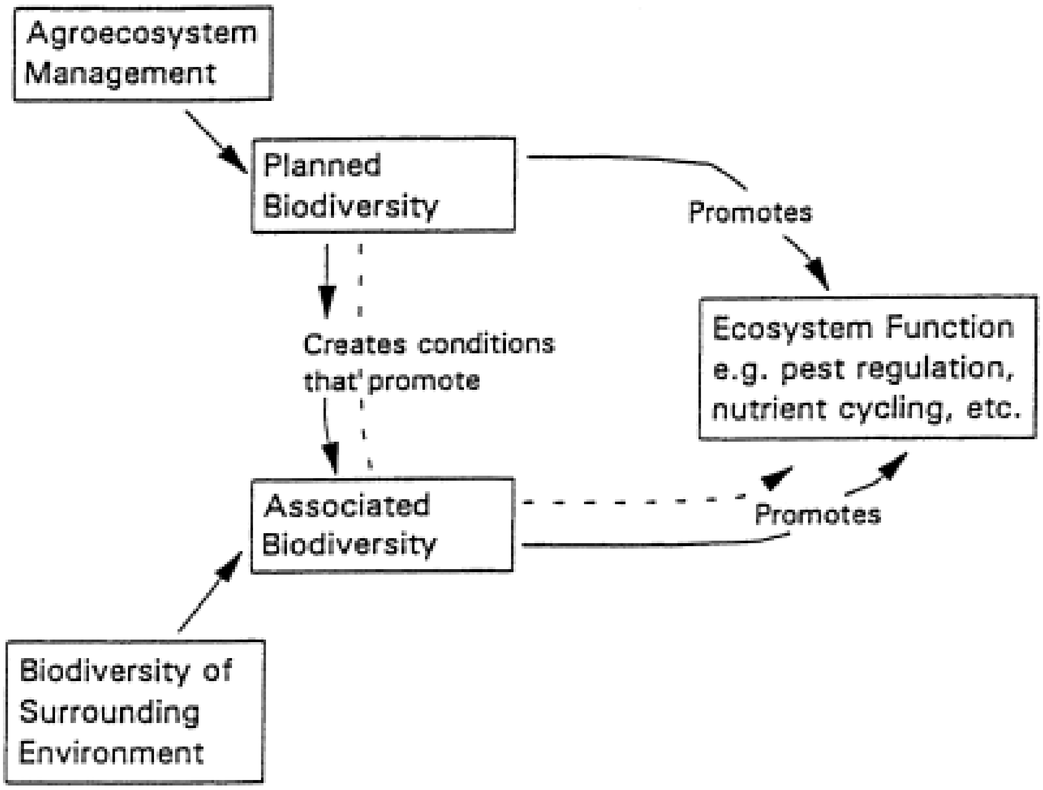


Figure 5.1. The relationship between planned biodiversity and associated biodiversity and how they promote ecosystem function (presented by (Altieri, 1999), modified from Vandeermeer and Perfecto, 1995)

Alongside conservation rationales, one of the most important reasons cited for improving agrobiodiversity is to improve food security (Thrupp, 2000) and dietary diversity (Frison et al., 2006) with the hope that this will lead to improvements in nutritional status and health in malnourished populations. For these reasons, it has become an important focus of discussions around delivering a sustainable food supply (Wahlqvist and Specht, 1998, Chivian, 2002, Frison et al., 2006, Gotor, 2010). To date there has been very little empirical research into how plant agrobiodiversity is related to consumption and health.

Some evidence points to a relationship between agrobiodiversity, dietary diversity and nutritional status. Increased agricultural diversity has been linked with a greater production of essential nutrients (Marten and Abdoellah, 1988). Dewey found farmers cultivating more diverse farms to have higher dietary diversity and nutritional status than those farming cash crops (Dewey, 1981). Ekesa et al (2008) found agrobiodiversity to be positively correlated with dietary diversity in a cross-sectional survey in Kenya. However, agrobiodiversity was estimated using number of crops grown rather than accepted measures of biodiversity and the project did not go as far as to link these factors to nutritional status.

Other studies have failed to find associations between agrobiodiversity and nutritional status. Shack et al. found no association between number of food crops grown in home gardens and nutritional status in Papua New Guinea (Shack et al., 1990). Kidala et al. (2000) found communities that received a nutrition education intervention leading to the establishment of household and school gardens had higher green leafy vegetable intakes but lower serum retinol concentrations compared to control areas receiving no intervention. The authors concluded that these results were confounded by *helminths* infection. A long term study in Senegal found no improvements in nutritional intake after the establishment of home vegetable gardens, despite a positive impact on women's income (Brun et al., 1989).

The assumption that increased agrobiodiversity leads to increased dietary diversity and improved nutritional status appears logical but perhaps does not acknowledge the complexity of the pathway from food production through consumption to nutrient utilization in people living in low income countries. However, the potential that increased agrobiodiversity can improve the diets and health of subsistence farmers while making an important contribution to biodiversity conservation (Chivian, 2002) is an important research area to be investigated. To contribute further understanding of these relationships this chapter will explore the associations between agrobiodiversity, dietary diversity and nutritional status variables in Minyenye and Mbwei in rural Tanzania.

5.3 Methods

This study aimed to systematically assess the diversity and abundance of cultivated and wild plants on the households agricultural land. In order to meet this objective a systematic measurement of plant biodiversity was chosen as a proxy indicator of agrobiodiversity. The diversity of crops grown by the household over the last calendar year, as reported by the respondent, supplements this data. This is referred to as the crop diversity score. Vegetable diversity scores, referring to the number of different types of vegetables grown over the previous calendar year, are also reported. Data collection methods have been described in detail in chapter 3. Specific data sources, plant biodiversity index calculations and statistical analysis methods are described below.

5.3.1 Data sources

5.3.1.1 Agrobiodiversity

The number of farms the household had, where they were and which were going to be measured were established. The biodiversity research assistant left the interview with a family member, often the husband, to measure the agrobiodiversity on the chosen farms. The diversity of plant species were collected as an indicator of agrobiodiversity using the point intercept method (Coulloudon et al., 1999). Details of how data was collected is presented in chapter 3, section 3.5.4.1. The agrobiodiversity protocol and the data collection sheets are included in appendix C and E.

5.3.1.2 Questionnaire

Additional quantitative data were collected using the questionnaire, including the number of crops the household grew in the last calendar year. This information was used to calculate the crop and vegetable diversity scores. These scores represent the number of different types of crops and vegetables intentionally grown for household consumption in the previous calendar year. Whether they sold any staple crops, vegetables, fruit or other produce (oil, beans, honey or sugarcane) was also collected. Data on potential confounding variables, such as husband's type of employment, was also collected through the questionnaire (See Appendix D for a copy of the questionnaire).

5.3.2 Data calculations

5.3.2.1 Agrobiodiversity index

The Shannon diversity index was used to provide a measure of the number of different plant species and the abundance of these species (Pla, 2004). The higher the index number the more diverse the area. Shannon indices were calculated using plant species data from farms collected using the point intersect method described in chapter 3 and provide an indication of plant agrobiodiversity at the household level.

The following Shannon diversity index formula was used:

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

H= the Shannon diversity index

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

S=number of species encountered

The Shannon index calculations were carried out in excel. The excel spreadsheet contained the list of all the plant species encountered on all the farms measured for a household and the number of times they were encountered through the data collection method. *Pi* was calculated by dividing the total number of times the individual species was encountered by the number any species was encountered. For each species this was multiplied by the natural log of *pi* and these numbers were added together to give the Shannon indices per household. This plant agrobiodiversity index was calculated separately for 1) all plant species and 2) food plant species (species either intentionally grown for food or that could be used for food). Due to the different methods used, diversity indices for farms and vegetable gardens were calculated separately.

5.3.3 Data analysis

5.3.3.1 Descriptive statistics

Qualitative data on indicators of land degradation, recorded by the biodiversity research assistant, and changes in crop production, collected through the questionnaire, were coded into categories to be used in the analysis. Basic descriptive statistics including the number of farms, abundance data and average plant agrobiodiversity indices (the Shannon indices) were calculated for all plants and food plants for each village (chapter objective 5A). Mann Whitney and Chi-squared tests were used to detect significant differences between the villages in plant agrobiodiversity indices and farm characteristics.

5.3.3.2 Linear regression analysis

Linear regression was used to answer the main aim of this study; to estimate the relationship between plant agrobiodiversity, dietary diversity and nutritional status (chapter objective 5B). Relationships between selling staples, vegetables, fruit and other produce and dietary diversity and nutritional status was investigated using linear regression (chapter objective 5C). The relationship between farm characteristics and dietary diversity and nutritional status was also investigated using linear regression in order to provide more information on the context of the agrobiodiversity measures.

Data collected on transects laid every 20 metres was used to calculate Shannon indices for both villages to make like for like comparisons. However, for the regression analysis, when villages were analysed separately, data collected on transects every 10 metres was used for Mbwei as this more detailed level of data collection was more appropriate for Mbwei's smaller farms.

Both unadjusted and adjusted regression models are presented. For adjusted regression models potential confounders were identified using the Directed Acyclic Graph (Glymour, 2006) (Figure 3.15) and confounders were selected as described in chapter 3 (page 73). Variables included in the dietary diversity/food variety regression models included: husband's type of employment; husband's frequency of employment; number of farms; average farm size. The village the participant lived in was the only variable identified through the DAG which substantially altered the regression coefficients in the agrobiodiversity nutritional status regression models. As the regression coefficients varied substantially between the two villages presenting regression results separately for Minyenye and Mbwei was felt to be more informative than using multivariable regression.

5.3.3.3 Missing data

Multiple imputations using chained equations were used for the multivariable regression analyses for the associations between selling crops and dietary diversity. Imputations were done separately by village for respondents and those under five. The missing values were imputed based on the complete variables in the model: whether the household has a mobile phone; respondent's highest level of education; whether the respondent works in agriculture; whether the respondent earns extra income; number of farms and number of vegetable gardens the household has.

Multiple imputations using chained equations were also used for the multivariable regression analyses for the associations between selling crops and nutritional status. Imputations were done separately by village for children under five and all children. The missing values were imputed based on the complete variables in the model: whether the household has a mobile phone; respondent's highest level of education; whether the respondent works in agriculture; whether the respondent earns extra income and whether the husband has an additional small business.

5.4 Results

5.4.1 Habitat and farm characteristics

A total of 163 farms were sampled, representing 96% of farms in Minyenye and 44% of farms in Mbwei (Table 5.1). All farms near the house and three quarters of farms far from the house had plant agrobiodiversity data collected in Minyenye. Three quarters of farms close to the house and approximately 20% of those far from the house had data collected on them in Mbwei. The farms where agrobiodiversity data were not collected were estimated to be larger than the other farms, this difference was most pronounced in Minyenye. In farms where agrobiodiversity data were collected, Minyenye respondents reported a higher number of crop types grown, especially staple crops as compared to the farms where agrobiodiversity data were not collected. In Mbwei, the reported number of crop types did not vary between farms where agrobiodiversity data were collected and where this data were not collected. This indicates the farms where data were collected were representative of all household farms in terms of crop types grown. The distribution of the households and their farms is displayed in Figures 5.2 and 5.3.

The farm types were very different in Minyenye compared to Mbwei. In Minyenye the majority of participants had one medium to large farm very close to their household and sometimes an additional farm further away from their house. In Mbwei it was typical for the household to have a number of smaller farms, often quite far away from the household, in the valley, in the mountains and sometimes in both areas.

Table 5.1. Farm characteristics of farms where agrobiodiversity data were and were not collected in Minyenye and Mbwei

	Minyenye		Mbwei	
	ABD data collected	**No ABD data**	**ABD data collected**	**No ABD data**
Number of farms	95	4	68	88
Percentage of total farms	96.0	4.0	43.6	56.4
Farms near the house (%)	100.0	0.0	75.0	25.0
Farms away from the house (%)	75.0	25.0	21.1	78.9
Estimated size of farm (acres, mean (95% CI))	1.8 (1.6, 2.1)	3.0 (0.0, 7.4)	1.1 (0.8, 1.3)	1.5 (1.1, 1.9)
Reported number of crop types grown (mean (95% CI))	2.4 (1.4, 3.3)	1.0 (1.0, 1.0)	2.8 (2.5, 3.0)	2.9 (2.7, 3.1)
Reported number of staple crops types grown* (mean (95% CI))	1.4 (0.6, 2.1)	0.3 (0.0, 1.8)	1.6 (1.4, 1.7)	1.5 (1.4, 1.7)
Reported number of fruit/vegetables types grown** (mean (95% CI))	0.2 (0.0, 0.5)	0.0 (0.0, 0.0)	1.1 (0.9, 1.3)	1.3 (1.1, 1.4)

ABD: agrobiodiversity data

*included maize, cassava, millet, finger millet and sorghum

**included tomatoes, beans, onions, pumpkin leaves, cabbage, potatoes, yams, pumpkin, sweet potato, green pepper, banana, papaya

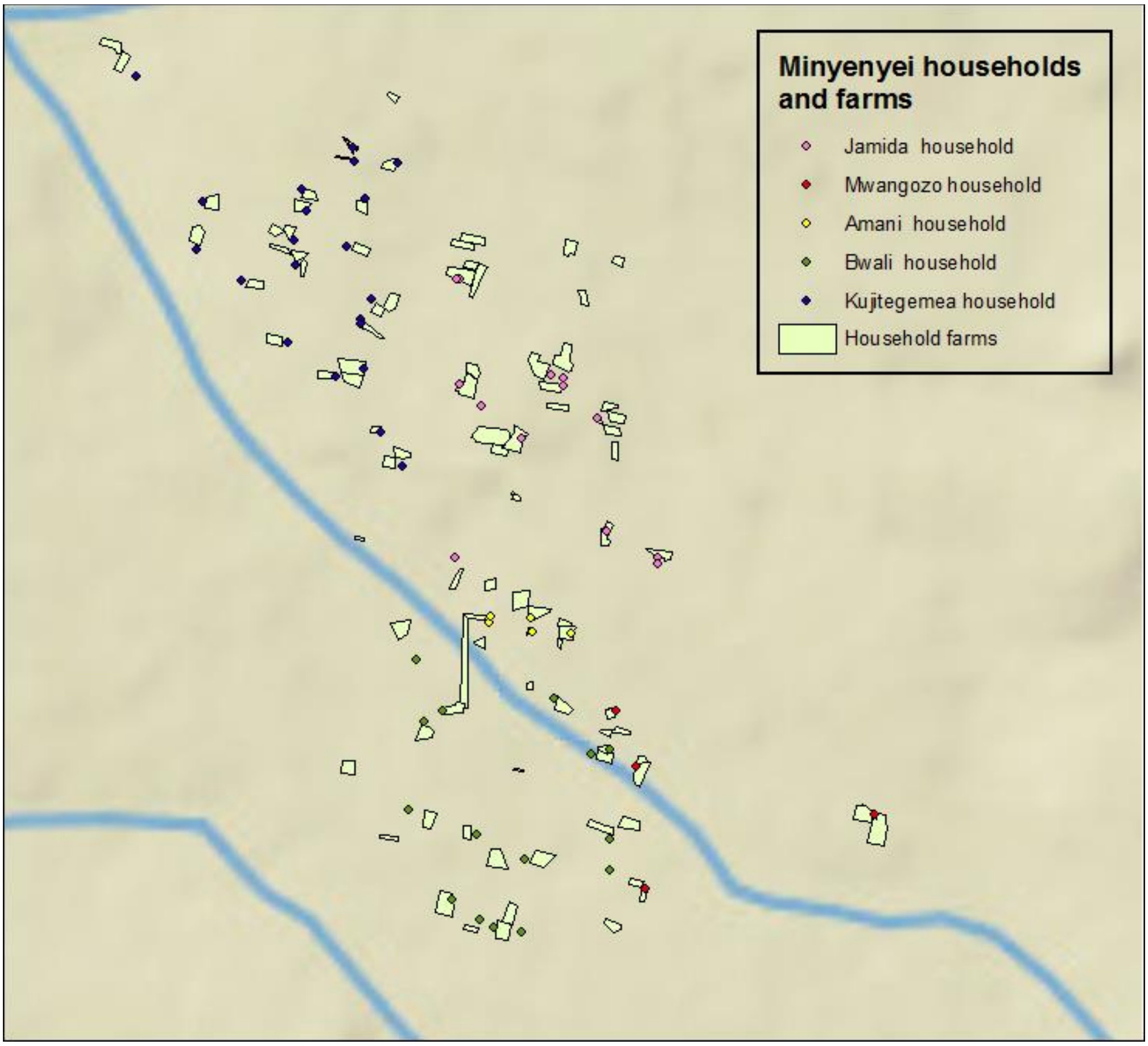


Figure 5.2. Households and all measured household farms in the five sub-villages of Minyenye

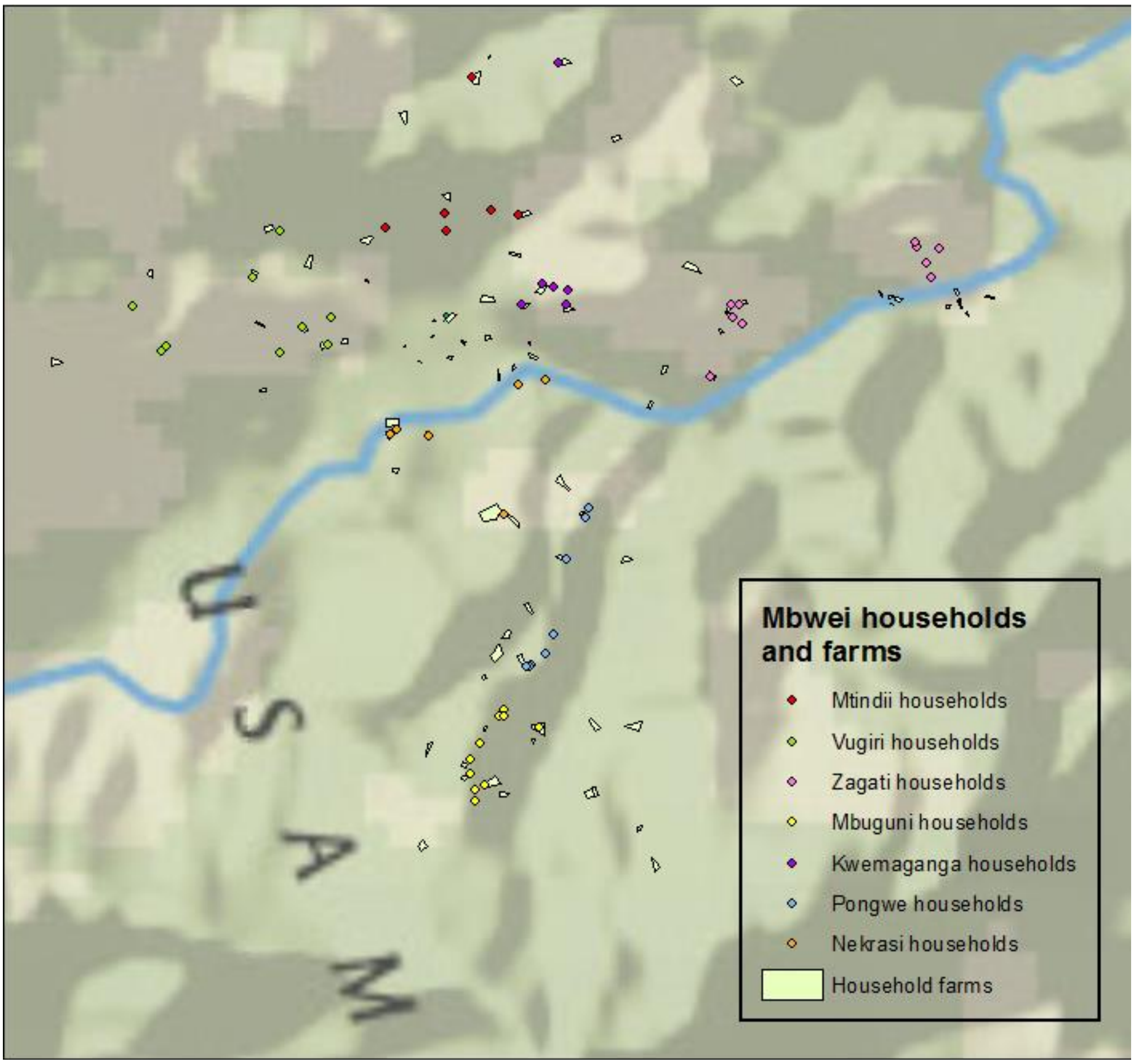


Figure 5.3. Households and all measured household farms in the seven sub-villages of Mbwei.

In Mbwei, in 51% of households, indicators of land degradati on or characteristics that were likely to be associated with land degradation were observed on at least one of the household farms. These included farm 'not well maintained/poor condition' in 9% , 'erosion' in 7% and 'low soil fertility' in 7% of the households. This figure was only 16% in Minyenye. The slope of at least one of the household farms was described as steep or very steep in 40% of the households in Mbwei.

Household farms in Minyenye were significantly more diverse than in Mbwei with an average plant agrobiodiversity Index of 2.5 compared to 1.1 in Mbwei (Table 5.2). This difference was even more marked when looking at the agrobiodiversity of food plants (2.3 compared to 0.6). This is the opposite of what would be expected based on the site selection; Minyenye was intended to be the low diversity village and Mbwei was the high diversity village. Mbwei, however, had significantly higher crop and vegetable diversity scores (7.9 and 4.3) compared to Minyenye (6.0 and 2.1). Mbwei had significantly more farms far from their houses (more than 30 minutes walk) contributing to a significantly higher number of total farms per household. However, Minyenye, on average, had significantly bigger farms (mean (95% CI):1.5 (01.3, 1.6) acres) than those in Mbwei (0.4 (0.3, 0.5) acres). The mean (95% CI) total amount of land used for farming in Minyenye was 2.2 (1.8, 2.6) acres. Unfortunately, due to the number of farms not visited in Mbwei, the equivalent statistic was not able to be calculated for Mbwei. Figures 5.2 and 5.3 illustrate the difference in farm size of the measured farms.

A significantly higher proportion of households had vegetable gardens in Mbwei compared to Minyenye. Those households in Mbwei with vegetable gardens, approximately 35% of participating households, had an mean (95% CI) plant agrobiodiversity index of 1.3 (1.2, 1.5) and 1.3 (1.1, 1.5) for all plants and food plants respectively within the vegetable gardens.

Table 5.2. Plant agrobiodiversity indices, percentage selling grown food, farm types and farming issues for Minyenye and Mbwei

	Minyenye	Mbwei	P-value for difference*
Plant agrobiodiversity by household (mean (95% CI))			
All plants agrobiodiversity index	2.5 (2.5, 2.6)	1.1 (1.0, 1.3)	<0.001
Food plants agrobiodiversity index	2.3 (2.2, 2.3)	0.6 (0.5, 0.8)	<0.001
Crop diversity score	6.0 (5.2, 6.8)	7.9 (6.7, 9.2)	0.031
Vegetable diversity score	2.1 (1.7, 2.5)	4.3 (3.4, 5.1)	<0.001
Household sold foods they grew (%)			
Sold staples	26.6	43.1	0.055
Sold vegetables	12.5	44.8	<0.001
Sold fruit	10.9	20.7	0.138
Sold other	42.2	12.1	<0.001
Farm types			
Grow food on their own land (%)	89.1	91.4	0.826
Vegetable gardens (%)	18.8	34.5	0.049
Farms per household (mean(95% CI))	1.4 (1.2, 1.5)	2.9 (2.5, 3.2)	<0.001
Nearby farms per household (mean(95% CI))	1.1 (1.0, 1.2)	0.9 (0.7, 1.2)	0.045
Far away farms per household (mean(95% CI))	0.2 (0.1, 0.3)	1.9 (1.6, 2.3)	<0.001
Total area of farms (acres, mean(95% CI))	2.2 (1.8, 2.6)	-	
Average area of farms (acres, mean(95% CI))	1.5 (1.3, 1.6)	0.4 (0.3, 0.5)	<0.001
Farming issues (%)			
Grew food not eaten or sold	3.2	75.9	<0.001
Food not eaten/sold: not enough rain	50.0	72.7	0.485
Food not eaten/sold: wrong kind of rain	50.0	0.0	0.050
Food not eaten/sold: too much sun	0.0	15.9	0.054
Food not eaten/sold: land not fertile	0.0	11.4	0.621

*Mann Whitney tests used for difference in means, chi squared used for difference in proportions between the two villages

The majority of households in both settlements grow Maize (over 85%) and a high proportion of households in Minyenye grow sorghum (86%) and in Mbwei grow cassava root (90%) (Figure 5.4). Many Mbwei households grow pumpkin, beans and pumpkin or potato leaves to eat and approximately 40% of households in this village grow sweet potatoes, tomatoes, *mchicha* (spinach) and potatoes. Common vegetables grown in Minyenye included pumpkins and cassava leaves. Between approximately 15% and 30% of those in Mbwei grow guava, avocado, banana and papaya while the main fruit grown in Minyenye, in 25% of households, was guava. Forty-four percent and 52% of households grow groundnuts and sunflowers in Minyenye while households in Mbwei were more likely to grow sugarcane (45%).

In the last year, 2011, 71% (72% in Minyenye and 69% in Mbwei) said that there were no changes in what they grew and harvested as compared to the last five years. Twenty percent of respondents in Minyenye said they harvested less crops and 3% said they harvested more crops. While in Mbwei 26% said they harvested less and 4% said they harvested more crops. Seventy-six percent of those in Mbwei compared to only 3% of those in Minyenye said they grew food that was not eaten or sold. The majority of participants said this was because there was not enough rain (72%), too much sun (15%) or that the land was not fertile (11%).

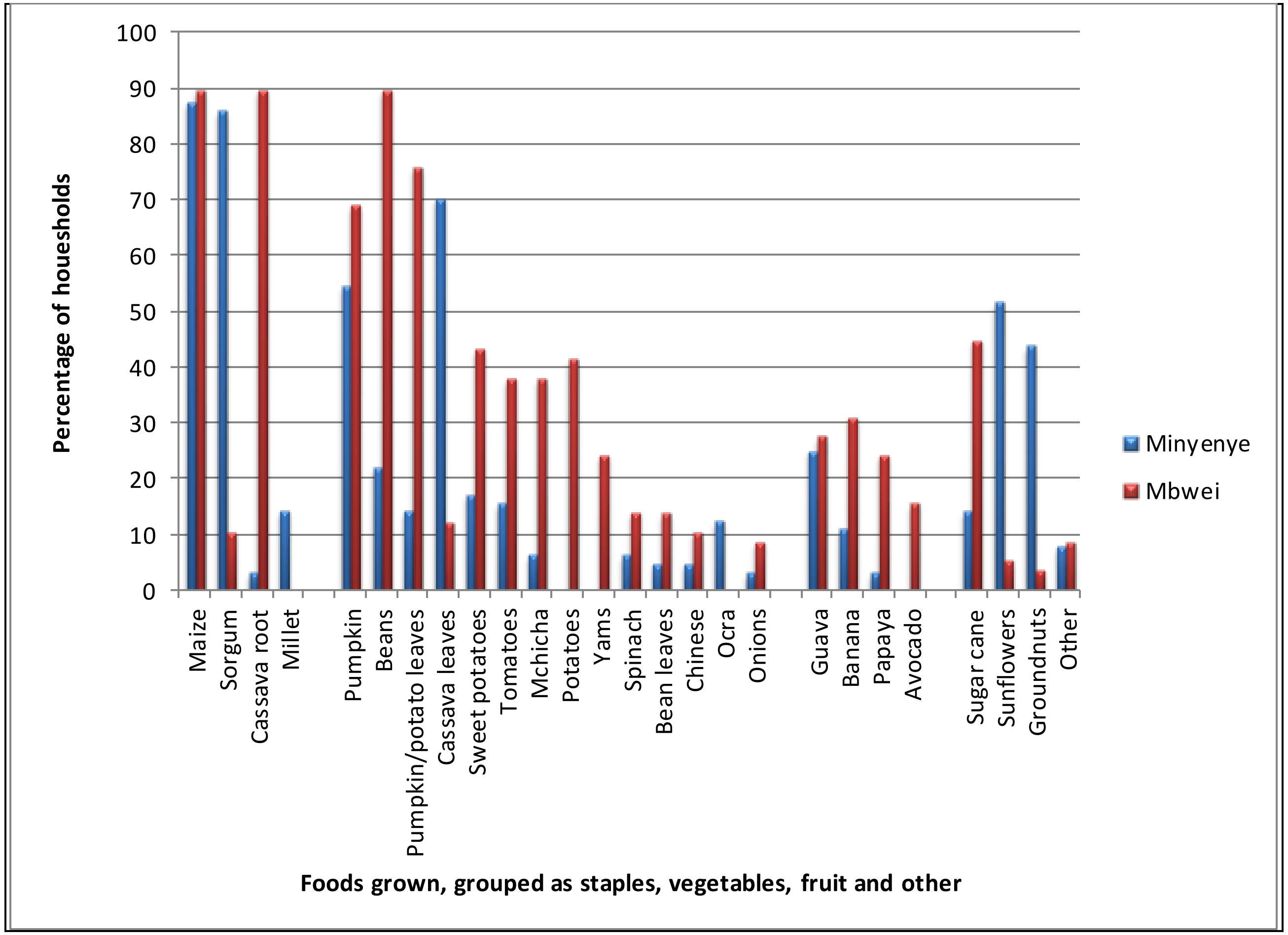


Figure 5.4. Percentage of households growing different crop types in Minyenye and Mbwei over the previous calendar year

5.4.2 Minyenye village, Singida district

5.4.2.1 Habitat, species present, farm characteristics and plant agrobiodiversity

Minyenye, the 'low biodiversity' village, is situated in the central plains of Tanzania. Although Singida region is approximately 1200 to 1500m above sea level it is not a steep area. The landscape has gentle hills and the majority of the farms were relatively flat. The earth in this area is a rich red colour and the area is dry and susceptible to drought (Tanzanian NBS and Singida Regional Commissioner's Office, 2005). The majority of the land is dirt with brush and trees (Figure 5.5) but there are areas, where the river runs in the rainy season that has grass (Figure 5.6). It was common for farms in Minyenye to be covered in different types of grasses in amongst the staple crops. It was not uncommon for Minyenye farms to be overgrown (Figure 5.7). In 16% of households the biodiversity research assistant noted indicators of land degradation on one or more of the household farms. These characteristics most commonly included perceived low quality soil in this village.

Figure 5.5. A typical area in Minyenye of dry red dirt with a few larger trees

Figure 5.6. The dry riverbed running through the valley in Minyenye, some grass is available for grazing in this area at this time of year

Figure 5.7. A typical farm in Minyenye

Figure 5.8. A typical vegetable garden in Minyenye

The majority of households in Minyenye had between 5 and 15 species per acre growing on their farms (Figure 5.9). Approximately 10% of households have more than 20 species per acre. Around 28% of households grow between 0 and 5 species per acre and over 55% of households grow between 5 and 10 food species per acre. 84% of households grow less than 10 species per acre of farmland. On average households in Minyenye had 9 food species and 12 species in total per acre of farmland.

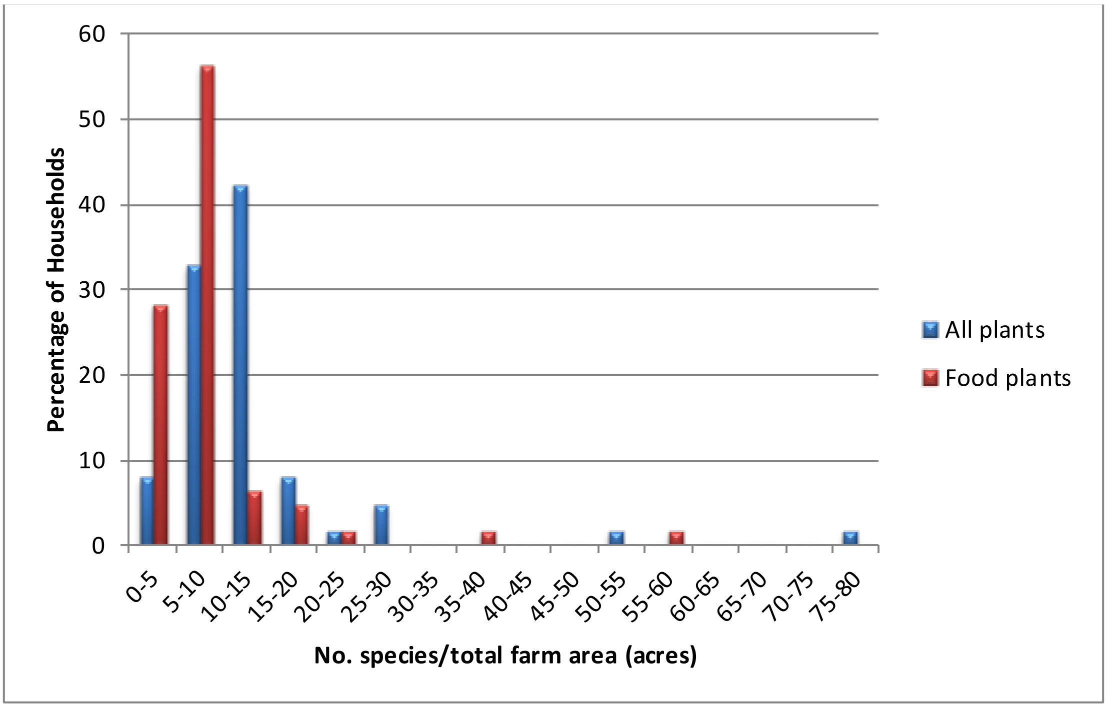


Figure 5.9. Number of species; all plants and food plants grown per acre of household farm in Minyenye

Table 5.3 shows all the species present on the Minyenye household farms where agrobiodiversity data was captured. It shows the total count for each species made for the agrobiodiversity index calculations and percentage abundance. Fifty-nine different food species and 29 different non-food species were found on the household farms in Minyenye. The most common food species found were Sorghum (*Sorghum Bicolor Gramineae),* followed by *Gafinda* (*Commelina African Commelinaceae*) and Maize (*Zea Maize Gramineae*) at 6%, 5% and 4% of the total species found. Finger millet (*Eleusine Africana Gramineae*) only made up 1% of the total species found and Cassava was not encountered. *Fagio* (*Elerngia Cordifolia Compositae*) and *Ighimbi* (*Eleusine Jaegeri Gramineae*) were the two most common non-food species encountered at 12% and 5% of all species.

Table 5.3. Abundance of species present on household farms in Minyenye split by food species and non food species

Species genus name	Family name	Common (local) name	Number of individuals*	Abundance (%)**
Food species* **				
Sorghum bicolor	Gramineae	Sorghum (Mtama)	162	5.8
Commelina african	Commelinaceae	(Gafinda)	131	4.7
Zea maize	Gramineae	Maize (Mahindi)	108	3.9
Corchorus trilocularis	Tiliaceae	(Mlenda)	105	3.8
Helianthus annuus	Compositae	Sunflower (Alizeti)	101	3.6
Eleusine indica	Gramineae	(Busai)	91	3.3
Cleome hirta	Capparidaceae	(Mnyisira)	86	3.1
Clotalaria cylindro stachys	Papilionaceae	(Mukuku)	61	2.2
Bidens pilosa	Compositae	(Mpangwe)	57	2.1
Setaria verticilata	Gramineae	(Kinasa nguo)	56	2.0
Hibiscus diversifolius	Malvaceae	(Inkongwa)	55	2.0
Ceratotheca sesamoides	Pedaliaceae	(Mbata)	50	1.8
Combretum collinum	Combretaceae	(Mlahaa)	49	1.8
Cynodon nlemfuensis	Gramineae	(Tahai)	49	1.8
Sonchus luxurians	Compositae	(Mchunga)	49	1.8
Cajanus Cajan	Papilionaceae	(Kunde)	45	1.6
Combretum zeyheri	Combretaceae	(Mhanyati)	45	1.6
Amaranthus hybridus	Amaranthaceae	(Mchicha)	40	1.4
Cucumis pepo	Cucurbitaceae	Pumpkin (Boga)	38	1.4
Panicum miliaceum	Gramineae	Millet (Uwele)	35	1.3
Oxygonum sinuatum	Polygonaceae	(Mbigili)	34	1.2

Dichrostachys cinerea	Mimosaceae	(Mtunduru)	32	1.2
Cucumis dipsaceus	Cucurbitaceae		31	1.1
Citrullus lanatus	Cucurbitaceae	(Tikiti)	30	1.1
Eleusine africana	Gramineae	Finger millet (Ulezi)	25	0.9
Trichodesma zeylenicum	Boragnaceae	(Majani washa)	24	0.9
Triumfetta rhomboidea	Tiliaceae	(Mululi)	22	0.8
Dactyloctenium aegyptium	Gramineae	(Talanje)	20	0.7
Solanum lycopersicum	Solanaceae	(Nyanya)	18	0.6
Dalbergia nitidula	Papilionoideae		17	0.6
Azanza garckeana	Malvaceae	(Mtogo)	15	0.5
Solanum incanum	Solanaceae	(Ntula)	13	0.5
Solanum villosum	Solanaceae		11	0.4
Physalis peruviana	Solanaceae	(Vitunda)	10	0.4
Vigna subterranea	Fabaceae		9	0.3
Abelmoschus esculentus	Malvaceae	Ocra	8	0.3
Ipomea batatas	Convolvulaceae	Sweet potato	8	0.3
Markhamia obtusifolia	Bignoniaceae		8	0.3
Combretum molle	Combretaceae		6	0.2
Solanum incanum	Solanaceae		6	0.2
Hibiscus sabdariffa	Malvaceae	(Choya)	5	0.2
Solanum villosum	Solanaceae		5	0.2
Balanites aegyptiaca	Zygophyllaceae		4	0.1
Caylusea abyssinica	Redeceae	(Ngwiba)	4	0.1
Syzygium cumini	Myrtaceae		4	0.1
Albizia harveyi	Mimocaceae		3	0.1
Amaranthus spinosus	Amaranthaceae	(Mchicha pari)	3	0.1

Manihot glaviozii	Euphorbiaceae		3	0.1
Ampelocissus africana	Vitaceae		2	0.1
Cordia monoica	Boraginaceae		2	0.1
Emilia coccinea	Compositae		2	0.1
Manihot esculenta	Euphorbiaceae		2	0.1
Mucuna pruriens	Phytolaccaceae		2	0.1
Vangueria infausta	Rubiaceae		2	0.1
Bauhinia fassoglensis	Convolvulaceae		1	0.0
Commiphora africana	Burseraceae		1	0.0
Erythrina abyssinica	Fabaceae		1	0.0
Grewia bicolor	Tiliaceae		1	0.0
Salvadora persica	Salvadoraceae		1	0.0
Non food species				
Elerngia cordifolia	Compositae	(Fagio)	342	12.3
Eleusine jaegeri	Gramineae	(Ighimbi)	132	4.8
Digitaria scalarum	Gramineae		97	3.5
Leucas martinicensis	Lamiaceae		97	3.5
Dolithia uniflorus	Papilionaceae	(Simbilili)	89	3.2
Polemonium viscosum	Compositae		29	1.0
Ipomea biloba	Convolvulaceae	(Ikhombe)	25	0.9
Borreria stricta	Labiate		19	0.7
Corchorus kirkii	Malvaceae	(Ikhandaghii)	19	0.7
Perotis hildebrandtii	Gramineae	(Ginkhokwe)	18	0.6
Astro Ipomoea hyoscyamine	Convolvulaceae	(Irang'anga)	12	0.4
Hippocratea parviflora	Labiate	(Mdima mpahi)	11	0.4
Indigofera spicata	Papilionaceae		10	0.4

panicum trichocladium	Gramineae	(Iraangimba)	7	0.3
Tridax procumbens	Asteraceae		7	0.3
Cynodon dactylon	Gramineae		6	0.2
Leonotis leonurus	Labiate		6	0.2
Acacia drepanolobium	Mimosaceae		5	0.2
Rothia hirsuta	Leguminosae		5	0.2
Senecio vulgaris	Compositae		5	0.2
Striga asiatica	Orabansiaceae		5	0.2
Albizia amara	Mimosaceae		4	0.1
Eucalyptus maideni	Myrtaceae		4	0.1
Hypochoeris glabra	Asteraceae		4	0.1
Turea amoena	Meliaceae		3	0.1
Lonchocarpus bussei	Papilionaceae		2	0.1
Albizia gummifera (Gmel) C.A Smith	Mimosoidea		1	0.0
Markhamia lutea	Bignoniaceae		1	0.0
Senna senguena	Papilionaceae		1	0.0

* Number of individuals is the number of times the specific species was encountered along the transects for all the farms in Minyenye

**Number of times this specific species was encountered as a percentage of the total number of encountered plants

***Identified as plant species by the biodiversity research assistant, books (Pendaeli, 2010, Dharani, 2002, Peters et al., 1992)) and reputable internet sites ((FAO, 2014a, JSTOR, 2014, World Agroforestry Centre, 2014).

5.4.2.2 Plant agrobiodiversity and dietary diversity /food variety

Plant agrobiodiversity is not associated with dietary diversity or food variety in Minyenye. No significant associations were seen between all plant or food plant agrobiodiversity indices and the nine food group dietary diversity score or the individual food variety scores of respondents or children under five years in regression models (Table 5.4).

In Minyenye, the more crop types grown in the previous year the higher the respondent's dietary diversity scores were in the unadjusted but not the adjusted model. The higher the crop diversity score the higher the respondent's and their oldest child under five's food variety score was in both the unadjusted model and when the model was adjusted for husband's type of employment; husband's frequency of employment; number of farms; average farm size. For example, for each additional crop the household grew in the previous calendar year the number of foods the child ate in the previous 24 hours increased by **0.31** items (95% CI: **0.12, 0.50**) in the adjusted model.

The more different types of vegetable grown the higher the respondent and their oldest child under five's food variety was in the unadjusted model. This association remained significant with the under five year olds in the adjusted model.

None of the farm characteristics listed in Table 5.2 were significantly associated with dietary diversity or food variety in Minyenye.

Table 5.4. Associations between plant agrobiodiversity and crop and vegetable diversity scores and dietary diversity/food variety in children under five and respondents in Minyenye

	Dietary diversity score		Food variety score	
	Child <5 years	**Respondent**	**Child<5 years**	**Respondent**
Unadjusted model^				
All plants agrobiodiversity	-0.82 (-2.24, 0.60)	-0.36 (-1.54, 0.82)	0.39 (-2.29, 3.06)	0.42 (-2.13, 2.96)
Food plants agrobiodiversity	-0.36 (-1.65, 0.93)	-0.09 (-1.16, 0.97)	0.37 (-2.03, 2.78)	0.49 (-1.80, 2.78)
Crop diversity score	0.09 (-0.02, 0.21)	**0.12 (0.03, 0.21)**	**0.35 (0.14, 0.55)**	**0.32 (0.12, 0.51)**
Vegetable diversity score	0.09 (-0.15, 0.33)	0.18 (-0.01, 0.36)	**0.57 (0.16, 0.99)**	**0.54 (0.15, 0.93)**
Adjusted model^^				
All plants agrobiodiversity	-0.86 (-2.18, 0.46)	-0.65 (-1.87, 0.57)	0.02 (-2.60, 2.65)	-0.34 (-2.97, 2.29)
Food plants agrobiodiversity	-0.38 (-1.60, 0.84)	-0.33 (-1.45, 0.78)	0.21 (-2.19, 2.60)	0.02 (-2.37, 2.41)
Crop diversity score	0.08 (-0.02, 0.18)	0.09 (-0.01, 0.18)	**0.31 (0.12, 0.50)**	**0.24 (0.05, 0.44)**
Vegetable diversity score	0.06 (-0.16, 0.27)	0.11 (-0.08, 0.30)	**0.46 (0.05, 0.87)**	0.35 (-0.05, 0.75)

^Unadjusted model. N was 61 for children under five and 64 for respondents.
^^Adjusted for husband's type of employment; husband's frequency of employment; number of farms; average farm size. N was 55 for children under five and 58 for respondents.

5.4.2.3 Plant agrobiodiversity and nutritional status

Plant agrobiodiversity and crop diversity scores show mixed associations with nutritional status in Minyenye. Higher agrobiodiversity indices for all plants and for food plants were significantly associated with higher height z-scores in all children (Table 5.5). The more different types of crops and vegetables grown by the household the lower the MUAC of children under the age of five years.

For each additional farm far from the house a household has under five year old BMI z-scores decreases by 0.50 (regression coefficient (95% confidence intervals): **-0.50 (-0.93, -0.07))**. Those households reporting crops that could not be eaten or sold had children with weight z-scores 0.81 lower than those households not reporting this **(-0.81 (-1.59, -0.04))**. There were no other significant associations seen between farm characteristics and nutritional status in children in Minyenye.

Table 5.5. Associations between plant agrobiodiversity and crop and vegetable diversity scores and nutritional status in children under five and all children in Minyenye

	Height z-scores	**Weight z-scores**	**BMI z-scores**	**MUAC**
	Regression coefficient (95% CI)	Regression coefficient (95% CI)	Regression coefficient (95% CI)	Regression coefficient (95% CI)
Children <5 years^				
All plants agrobiodiversity	0.64 (-0.27, 1.55)	0.05 (-076, 0.87)	-0.57 (-1.36, 0.21)	-0.17 (-1.06, 0.71)
Food plants agrobiodiversity	0.70 (-0.11, 1.50)	0.08 (-0.64, 0.80)	-0.61 (-1.31, 0.09)	-0.09 (-0.88, 0.70)
Crop diversity scores	-0.00 (-0.08, 0.07)	-0.04 (-0.10, 0.02)	-0.05 (-0.11, 0.02)	**-0.07 (-0.14, -0.00)**
Vegetable diversity scores	0.01 (-0.13, 0.16)	-0.04 (-0.16, 0.09)	-0.06 (-0.18, 0.06)	**-0.14 (-0.27, -0.00)**
All Children^^				
All plants agrobiodiversity	**0.75 (0.26, 1.23)**	0.22 (-0.26, 0.70)	-0.23 (-0.73, 0.28)	-0.31 (-1.32, 0.70)
Food plants agrobiodiversity	**0.66 (0.24, 1.08)**	0.23 (-0.19, 0.64)	-0.21 (-0.65, 0.23)	-0.16 (-1.04, 0.71)
Crop diversity scores	-0.01 (-0.05, 0.03)	-0.01 (-0.05, 0.03)	0.01 (-0.03, 0.04)	-0.04 (-0.12, 0.04)
Vegetable diversity scores	-0.04 (-0.12, 0.03)	-0.04 (-0.11, 0.04)	0.01 (-0.07, 0.08)	-0.13 (-0.29, 0.02)

Unadjusted model only is presented as no potential confounders were identified.

^Unadjusted model. N was 101 for height, 100 for weight, 102 for BMI z-scores and 103 for MUAC in children under five.

^^Unadjusted model. N was 251 for height, 251 for weight, 255 for BMI z-scores and 252 for MUAC in all children.

5.4.2.4 Selling produce and dietary diversity

Individuals from households selling staples, vegetables and other produce had higher dietary diversity in Minyenye. Focusing on the results for the adjusted models shows households who sold other produce such as oil, beans, honey or sugarcane had children and respondents with higher dietary diversity and children with higher food variety (Table 5.6). Households selling staples and vegetables had children under five years of age with higher food variety.

Table 5.6. Associations between households selling foods they grew and the respondent's and children's dietary diversity and food variety scores in Minyenye

	Dietary diversity score		Food variety score	
	Child <5 years*	**Respondent****	**Child<5 years***	**Respondent****
Unadjusted models^				
Sold staples	**0.89 (0.07, 1.71)**	**0.71 (0.05, 1.37)**	**2.23 (0.76, 3.70)**	**1.72 (0.31, 3.12)**
Sold Vegetables	0.86 (-0.37, 2.10)	0.55 (-0.35, 1.45)	**3.28 (1.11, 5.46)**	1.79 (-0.13, 3.70)
Sold Fruit	-0.01 (-1.18, 1.17)	**1.09 (0.16, 2.01)**	1.00 (-1.16, 3.17)	**2.10 (0.08, 4.11)**
Sold Other	**1.16 (0.46, 1.85)**	**0.89 (0.33, 1.46)**	**1.87 (0.55, 3.19)**	**1.78 (0.55, 3.02)**
Adjusted models^^				
Sold staples	0.76 (-0.22, 1.74)	0.66 (-0.11, 1.44)	**1.91 (0.16, 3.66)**	1.42 (-0.28, 3.11)
Sold Vegetables	0.69 (-1.03, 2.41)	0.07 (-1.16, 1.30)	**3.36 (0.41, 6.30)**	1.09 (-1.53, 3.71)
Sold Fruit	-0.19 (-1.80, 1.42)	1.06 (-0.11, 2.23)	0.82 (-2.12, 3.77)	2.08 (-0.53, 4.68)
Sold Other	**1.28 (0.39, 2.17)**	**0.83 (0.09, 1.57)**	**1.75 (0.05, 3.44)**	1.46 (-0.18, 3.11)

^Unadjusted model; N was 61 for children under five and 64 for respondents.

^^Adjusted for respondent's and husband's age, whether the household has a mobile phone; respondent and husband's highest level of schooling; respondent's and husband's type of employment (farming/other); husband has extra small business; respondent's and husband's frequency of employment; Respondent or husband earns extra income; number of farms; number of vegetable gardens; average farm size. N for children under five was 61 and N for respondents was 64.

*The following variables had missing values (number of missing values in brackets after each variable): husband's age (17); husband's highest level of education (7); whether the husband works in agriculture (6); whether the husband has an additional small business (6); respondent (1) and husband's frequency of employment (7) and whether the husband earns extra income (6) out of a total of 106 individuals.

**The following variables had missing values: husband's age (12); husband's highest level of education (6); whether the husband works in agriculture (5); whether the husband has an additional small business (5); respondent (1) and husband's frequency of employment (6) and whether the husband earns extra income (5) out of a total of 64 individuals.

5.4.2.5 Selling produce and nutritional status

Selling produce showed mixed associations with nutritional status in Minyenye. The majority of the associations between whether a household sold produce and children's nutritional status were not significant (Table 5.7). Focusing on the adjusted models; households that sold vegetables and fruit had children with **0.42** and **0.49** higher height z-scores. Those selling other produce such as oil, beans, honey or sugarcane had children with lower height for age and weight for age z-scores.

Table 5.7. Associations between household selling foods they grew and under five year old's and all children's nutritional status in Minyenye

	Height z-scores	Weight z-scores	BMI z-scores	MUAC
	Regression coefficient (95% CI)	Regression coefficient (95% CI)	Regression coefficient (95% CI)	Regression coefficient (95% CI)
Under five year olds*				
Unadjusted^				
Sold staples	0.14 (-0.38, 0.66)	-0.29 (-0.74, 0.17)	**-0.48 (-0.93, -0.04)**	-0.16 (-0.66, 0.34)
Sold Vegetables	0.42 (-0.25, 1.09)	0.28 (-0.32, 0.87)	-0.05 (-0.63, 0.54)	**-0.64 (-1.27, -0.00)**
Sold Fruit	0.08 (-0.65, 0.80)	0.19 (-0.44, 0.83)	0.16 (-0.47, 0.79)	-0.27 (-0.96, 0.43)
Sold Other	-0.19 (-0.64, 0.27)	-0.25 (-0.65, 0.15)	-0.15 (-0.54, 0.24)	-0.05 (-0.48, 0.39)
Adjusted^^				
Sold staples	0.03 (-0.54, 0.61)	-0.40 (-0.91, 0.10)	-0.53 (-1.01, -0.05)	-0.18 (-0.74, 0.38)
Sold Vegetables	0.59 (-0.16, 1.34)	0.33 (-0.34, 1.00)	-0.13 (-0.77, 0.52)	-0.68 (-1.41, 0.04)
Sold Fruit	-0.08 (-0.87, 0.71)	0.14 (-0.56, 0.84)	0.21 (-0.46, 0.88)	-0.33 (-1.10, 0.45)
Sold Other	-0.34 (-0.85, 0.16)	-0.36 (-0.81, 0.09)	-0.17 (-0.60, 0.25)	-0.02 (-0.52, 0.47)
All children**				
Unadjusted^^^				
Sold staples	0.08 (-0.19, 0.36)	-0.09 (-0.36, 0.18)	-0.16 (-0.44, 0.12)	-0.11 (-0.67, 0.45)
Sold Vegetables	0.24 (-0.13, 0.60)	0.25 (-0.11, 0.61)	0.11 (-0.26, 0.48)	-0.24 (-0.99, 0.51)
Sold Fruit	**0.50 (0.11, 0.88)**	**0.44 (0.06, 0.81)**	0.10 (-0.30, 0.50)	0.32 (-0.47, 1.10)
Sold Other	**-0.47 (-0.71, -0.23)**	**-0.37 (-0.60, -0.13)**	-0.06 (-0.31, 0.20)	-0.30 (-0.80, 0.19)
Adjusted^^^^				
Sold staples	0.08 (-0.21, 0.38)	-0.09 (-0.37, 0.20)	-0.12 (-0.43, 0.18)	-0.21 (-0.80, 0.37)
Sold Vegetables	**0.42 (0.01, 0.83)**	0.27 (-0.13, 0.67)	-0.00 (-0.43, 0.42)	-0.43 (-1.24, 0.39)
Sold Fruit	**0.49 (0.08, 0.90)**	0.37 (-0.03, 0.77)	0.09 (-0.34, 0.53)	-0.09 (-0.90, 0.71)
Sold Other	**-0.50 (-0.77, -0.23)**	**-0.40 (-0.66, -0.14)**	-0.09 (-0.38, 0.19)	-0.27 (-0.79, 0.26)

^Unadjusted model. N was 101 for height, 100 for weight, 102 for BMI z-scores and 103 for MUAC in children under five.
^^Adjusted model. ^^ and ^^^^ were adjusted for respondent's and husband's age, mobile phone in the household, respondent's and husband's highest level of school, husband employed in farming or other and plus small business, frequency of respondent and husband employment, respondent and husband earns extra income. N was 101 for height, 100 for weight, 102 for BMI z-scores and 103 for MUAC in children under five.
^^^Unadjusted model. N was 251 for height, 251 for weight, 255 for BMI z-scores and 252 for MUAC in all children.
^^^^Adjusted model. N was 251 for height, 251 for weight, 255 for BMI z-scores and 252 for MUAC in children under five.

*The following variables had missing values: husband's age (17); husband's highest level of education (7); whether the husband works in agriculture (6); whether the husband has an additional small business (6); respondent (1) and husband's frequency of employment (7) and whether the husband earns extra income (6) out of a total of 106 individuals.

**The following variables had missing values: husband's age (51); husband's highest level of education (26); whether the husband works in agriculture (18); whether the husband has an additional small business (18); respondent (3) and husband's frequency of employment (21) and whether the husband earns extra income (18) out of a total of 296 individual

5.4.3 Mbwei village, Lushoto district

5.4.3.1 Habitat, species present, farm characteristics and plant agrobiodiversity

Mbwei, the 'high biodiversity' village, is situated in the West Usambara mountains at approximately 2300m above sea level. Much of the surrounding area is forest but the area of Mbwei and the area immediately surrounding the village is open with scrubby vegetation. The area was quite dry at the time of data collection. In Mbwei, in 51% of households, characteristics that were likely to be associated with land degradation, such as presence of specific species associated with poor soil or farm on a very steep slope were observed on at least one of the household farms. The slope of at least one of household farms was described as steep or very steep in 40% of the households in Mbwei. Figure 5.10 and 5.11 show typical farms in Mbwei and 5.12 shows a typical vegetable garden.

Figure 5.10. A typical farm in Mbwei

Figure 5.11. A typical farm in Mbwei

Figure 5.12 A typical vegetable garden in Mbwei

Approximately 50% of households in Mbwei have between 5 and 15 species per acre growing on their household farms (Figure 5.13). Approximately 15% have between 15 and 20 species and approximately 25% of households have more than 20 species per acre. Over 30% of households grow between 0 and 5 food species per acre and another 30% grow between 5 and 10 species per acre. A similar distribution to what was seen in Minyenye. 64% of households grew less than 10 species per acre of farmland. On average households in Mbwei had 10 food species and 17 species in total per acre of farmland a similar number of food species to Minyenye but more non food species.

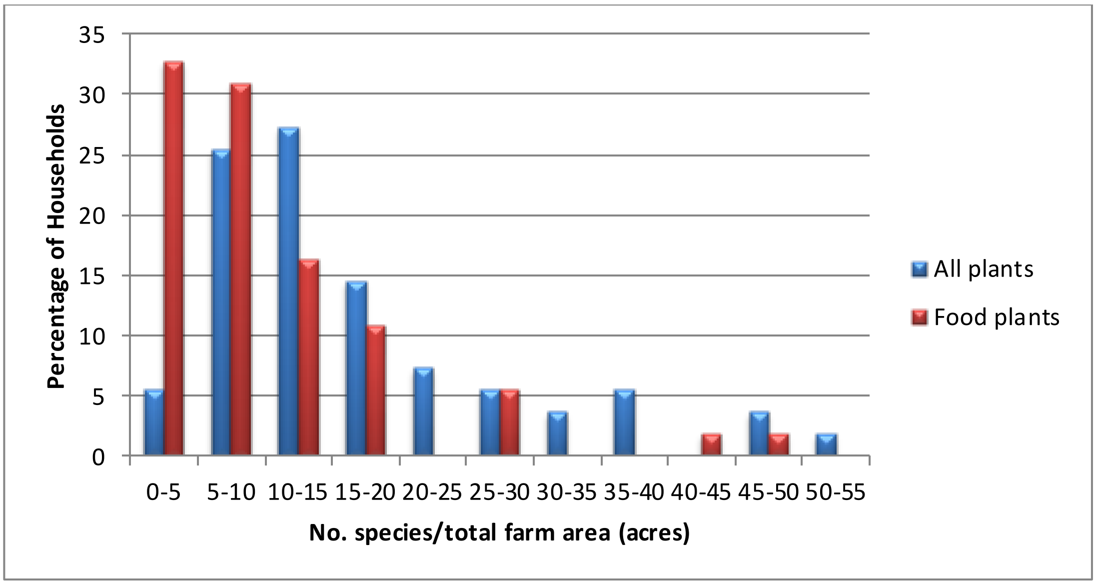


Figure 5.13. Number of species; all plants and food plants grown per acre of household farm in Mbwei

A total of 45 species were found on the Mbwei household farms that were measured, 22 food species and 23 non food species (Table 5.8), much less than was found in Minyenye. The most common three food species present on Mbwei farms were Cassava (*Manihot Aspera Crantz Euphorbiaceae*), *Mpangwe (Bidens Pilosa Compositae*), and Maize (*Zea Maize Gramineae)* at 25%, 13% and 8%. Finger millet and Sorghum were not encountered. *Enneapogon Cenchroides Gramineae* (12%) and *Albizia Gummifera (Gmel) C.A Smith Mimosoidea* (4%) were the two most common non food species found on Mbwei household farms.

Table 5.8. Abundance of species present on household farms in Mbwei split by whether they are food species or non food species

Species genus name	Family name	Common (local) name	Number of individuals*	Abundance (%)**
Food species* **				
Manihot aspera Crantz.	Euphorbiaceae	Cassava	146	24.9
Bidens pilosa	Compositae	(Mpangwe)	77	13.1
Zea maize	Gramineae	Maize (Mahindi)	49	8.3
Phaseolus vulgaris	Fabaceae	Beans	20	3.4
Saccharum officinarum L.	Gramineae	Sugarcane	19	3.2
Musa sapientum L	Musaceae	Banana	16	2.7
Amaranthus hybridus L.	Amaranthaceae	Spinach (Mchicha)	11	1.9
Cucurbita moschata	Cucurbitaceae	Pumpkin	10	1.7
Ipomea batatas	Convolvulaceae	Sweet potato	7	1.2
Xanthosoma violaceum Schott	Araceae	Yam	6	1.0
Lycopersium esculentum Mill.	Solanaceae	Tomato	5	0.9
Solanum tuberosum L.	Solanaceae	Potato	5	0.9
Sonchus luxurians	Compositae	(Mchunga)	4	0.7
Telfairia pedata (sims)Hook.	Cucurbitaceae		3	0.5
Cajanus Cajan	Papilionaceae	Pigeon pea (Kunde)	2	0.3
Combretum molle	Combretaceae		2	0.3
Lablab purpureus (L) Sweet	Papilionaceae		2	0.3
Vangueria madagascariensis Gmail.	Rubiaceae		2	0.3
Aphloia theiformis (Vahl) Benne	Flacourtiaceae		1	0.2
Helianthus annuus	Compositae	Sunflower (Alizeti)	1	0.2
Mangifera indica L.	Anacardiaceae	Mango	1	0.2
Persea Americana Mill.	Lauraceae	Avocado	1	0.2
Non food species				

Enneapogon cenchroides	Gramineae	72	12.3
Albizia gummifera (Gmel) C.A Smith	Mimosoidea	22	3.7
Aristida adscensionis	Gramineae	16	2.7
Grevillea robusta A.	Proteaceae	16	2.7
Chloris virgata	Gramineae	15	2.6
Acacia microphylla	Mimosoidea	10	1.7
Croton megalocarpus Hutch.	Euphorbiaceae	8	1.4
Catha edulis	Celastraceae	6	1.0
Ricinus communis	Euphobiaceae	5	0.9
Vernonia galamensis	Compositae	4	0.7
Dissotis sp	Melastomataceae	3	0.5
Panicum sp	Gramineae	3	0.5
Turraea robusta Gürke	Meliaceae	3	0.5
Clerodendrum rotundifolium	Verbenaceae	2	0.3
Eragrostis aspera	Gramineae	2	0.3
Eucalyptus camaldulensis	Myrtaceae	2	0.3
Markhamia lutea	Bignoniaceae	2	0.3
Anise Pappus buchwald H.wild	Compositae	1	0.2
Dombeya shupangae K.schum	Sterculiaceae	1	0.2
Euclea divinorum Hiern	Ebenaceae	1	0.2
Olea chrysophylla Lam	Oleaceae	1	0.2
Psiadia punctulata (Dc) vatke	Asteraceae	1	0.2
Tithonia diversifolia (hemsl)A.Gray	Compositae	1	0.2

* Number of individuals is the number of times the specific species was encountered along the transects for all the farms in Minyenye

**Number of times this specific species was encountered as a percentage of the total number of encountered plants

***Identified as plant species by the biodiversity research assistant, books (Pendaeli, 2010, Dharani, 2002, Peters et al., 1992)) and reputable internet sites ((FAO, 2014a, JSTOR, 2014, World Agroforestry Centre, 2014).

5.4.3.2 Plant agrobiodiversity and dietary diversity

Crop and vegetable diversity scores, but not plant agrobiodiversity indices were associated with dietary diversity in Mbwei. As in Minyenye, no significant associations were seen between either all plant or food plant agrobiodiversity indices and any of the dietary diversity or food variety measures in Mbwei (Table 5.9). No significant associations were seen between vegetable garden agrobiodiversity indices and dietary diversity or food variety in Mbwei.

The higher the crop diversity score the higher the children's and respondent's dietary diversity and food variety scores were in the unadjusted model. When the model was adjusted for husband's type of employment; husband's frequency of employment; number of farms; average farm size, these associations were only significant for the respondent's dietary diversity and food variety scores. Similar results were seen for the vegetable diversity score; the more vegetables grown the higher the dietary diversity and food variety of both children under five and the respondents were in the unadjusted model. In the adjusted model the higher the vegetable diversity score the higher the under five year old's dietary diversity score and the respondent's dietary diversity and food variety scores. These results are similar to those found in Minyenye.

As in Minyenye, none of the farm characteristics listed in Table 5.2 were significantly associated with dietary diversity or food variety.

Table 5.9. Associations between plant agrobiodiversity and crop and vegetable diversity scores and dietary diversity/food variety and children under five and respondents in Mbwei

	Dietary diversity score		Food variety score	
	Child <5 years	**Respondent**	**Child<5 years**	**Respondent**
Unadjusted model^				
All plants agrobiodiversity	0.23 (-0.59, 1.05)	0.43 (-0.29, 1.14)	-0.49 (-2.20, 1.23)	-0.15 (-1.63, 1.34)
Food plants agrobiodiversity	0.44 (-0.33, 1.21)	0.38 (-0.30, 1.06)	0.60 (-1.01, 2.22)	0.29 (-1.11, 1.70)
Crop diversity score	**0.09 (0.01, 0.17)**	**0.11 (0.04, 0.18)**	**0.20 (0.04, 0.36)**	**0.26 (0.13, 0.39)**
Vegetable diversity score	**0.14 (0.02, 0.27)**	**0.16 (0.06, 0.27)**	**0.31 (0.05, 0.57)**	**0.35 (0.14, 0.57)**
Adjusted model^^				
All plants agrobiodiversity	0.14 (-0.73, 1.00)	0.45 (-0.32, 1.21)	-0.66 (-2.40, 1.09)	-0.11 (-1.63, 1.41)
Food plants agrobiodiversity	0.41 (-0.40, 1.22)	0.41 (-0.31, 1.14)	0.34 (-0.31, 2.00)	0.16 (-1.28, 1.61)
Crop diversity score	0.09 (-0.00, 0.17)	**0.13 (0.05, 0.20)**	0.18 (-0.00, 0.35)	**0.28 (0.13, 0.42)**
Vegetable diversity score	**0.14 (0.00, 0.28)**	**0.19 (0.07, 0.30)**	0.28 (-0.00, 0.57)	**0.38 (0.15, 0.61)**

^Unadjusted model. N was 52 for children under five and 55 for respondents.

^^Adjusted for husband's type of employment; husband's frequency of employment; number of farms; average farm size. N was 51 for children under five and 54 for respondents.

5.4.3.3 Plant agrobiodiversity and nutritional status

Higher plant agrobiodiversity was linked with poorer nutritional status in Mbwei. Higher food plant agrobiodiversity indices were associated with lower BMI z-score in under five year olds and all children (Table 5.10). For each unit increase in agrobiodiversity indices, BMI z-scores decreased by 0.37 and 0.46 units respectively. This is in contrast to the higher height seen with increased agrobiodiversity in Minyenye. No other significant associations were seen between agrobiodiversity indices or crop/vegetable diversity scores and nutritional status variables in Mbwei.

For vegetable gardens in Mbwei the higher all plant diversity indices were the lower children's height z-scores in all children (Regression coefficient (95% confidence intervals): **-0.86 z-scores (-1.57, -0.15))** and children under five **(-0.95 (-1.85, -0.04)**. Higher food plant diversity was associated with lower height in all children only **(-0.83 (-1.52, -0.14))**. The more diverse the vegetable gardens, the lower the children's height z-scores. No significant associations with the other nutritional status variables were found.

The larger the average size of the farms the lower height z-scores were in all children **(-0.78 (-1.54, -0.02))**. For each acre increase in average farm size height z-scores decreased by 0.78 units. Children in household reporting that they grew crops that they could not eat or sell had significantly lower BMI z-scores compared to children in other households **(-0.51 (-0.87, -0.15))**. Reasons given for not being able to harvest all crops mainly included 'not enough rain' 'too much sun' and 'land not being fertile'. BMI z-scores were found to be significantly related to reasons given for crops not being eaten of sold. Children in households reporting the reason for crops not being eaten or sold was that the land was not fertile had significantly lower BMI z-scores than those citing other reasons **(-0.65 (-1.20, -0.10))**. Under five year olds in households citing not enough rain as the reason for this had significantly higher BMI z-scores **(0.69 (0.23, 1.15))**.

Table 5.10. Association between plant agrobiodiversity and crop and vegetable diversity scores and nutritional status in children under five and all children in Mbwei

	Height z-scores	Weight z-scores	BMI z-scores	MUAC
	Regression coefficient (95% CI)	Regression coefficient (95% CI)	Regression coefficient (95% CI)	Regression coefficient (95% CI)
Children <5 years^				
All plants agrobiodiversity	0.40 (-0.12, 0.91)	0.08 (-0.36, 0.51)	-0.27 (-0.63, 0.09)	0.07 (-0.42, 0.56)
Food plants agrobiodiversity	0.33 (-0.15, 0.80)	0.06 (-0.36, 0.47)	**-0.37 (-0.71, -0.04)**	-0.02 (-0.48, 0.44)
Crop diversity score	-0.04 (-0.09, 0.13)	-0.02 (-0.07, 0.02)	0.01 (-0.03, 0.05)	-0.02 (-0.07, 0.03)
Vegetable diversity score	-0.05 (-0.13, 0.03)	-0.03 (-0.10, 0.05)	0.02 (-0.04, 0.08)	-0.03 (-0.11, 0.06)
All Children^^				
All plants agrobiodiversity	0.09 (-0.28, 0.46)	-0.08 (-0.43, 0.26)	-0.28 (-0.58, 0.02)	0.27 (-0.30, 0.85)
Food plants agrobiodiversity	0.20 (-0.16, 0.55)	-0.09 (-0.43, 0.25)	**-0.46 (-0.75, -0.18)**	0.25 (-0.29, 0.79)
Crop diversity score	-0.02 (-0.05, 0.02)	-0.01 (-0.05, 0.02)	0.00 (-0.03, 0.03)	0.05 (-0.01, 0.10)
Vegetable diversity score	-0.01 (-0.06, 0.05)	-0.00 (-0.05, 0.05)	0.00 (-0.04, 0.05)	-0.09 (-0.00, 0.18)

Unadjusted model only is presented as no potential confounders were identified.

^Unadjusted model. N was 92 for height, 95 for weight, 94 for BMI z-scores and 96 for MUAC in children under five.
^^Unadjusted model. N was 154 for height, 158 for weight, 160 for BMI z-scores and 169 for MUAC in all children.

5.4.3.4 Selling produce and dietary diversity

As in Minyenye, selling produce was associated with better dietary diversity in Mbwei. Households selling vegetables had respondents and under five year olds with higher food variety scores in both the unadjusted and adjusted models (Table 5.11).

Table 5.11. Associations between households selling foods they grew and the respondent's and children's dietary diversity and food variety scores in Mbwei

	Dietary diversity score		Food variety score	
	Child <5 years*	**Respondent****	**Child<5 years***	**Respondent****
Unadjusted models^				
Sold staples	0.25 (-0.54, 1.04)	0.19 (-0.52, 0.90)	1.50 (-0.11, 3.12)	**1.75 (0.38, 3.12)**
Sold Vegetables	**0.98 (0.23, 1.73)**	**0.82 (0.15, 1.49)**	**2.51 (0.98, 4.04)**	**2.38 (1.09, 3.67)**
Sold Fruit	0.61 (-0.35, 1.58)	0.82 (-0.02, 1.66)	**2.09 (0.10, 4.08)**	**2.76 (1.16, 4.37)**
Sold Other	-0.03 (-1.29, 1.23)	0.89 (-0.16, 1.94)	0.30 (-2.36, 2.95)	**2.59 (0.51, 4.67)**
Adjusted models^^				
Sold staples	0.15 (-0.77, 1.06)	-0.09 (-0.93, 0.74)	1.32 (-0.51, 3.15)	1.11 (-0.43, 2.66)
Sold Vegetables	0.94 (-0.05, 1.93)	0.88 (-0.01, 1.74)	**2.43 (0.42, 4.44)**	**2.61 (1.08, 2.66)**
Sold Fruit	0.35 (-0.92, 1.62)	0.49 (-0.67, 1.64)	1.14 (-1.48, 3.76)	1.71 (-0.41, 3.82)
Sold Other	-0.01 (-1.64, 1.63)	0.54 (-0.86, 1.94)	-0.49 (-3.84, 2.87)	1.51 (-1.08, 4.12)

^Unadjusted model; N was 55 for children under five and 58 for respondents.

^^ Adjusted for respondent's and husband's age, whether the household has a mobile phone; respondent and husband's highest level of schooling; respondent's and husband's type of employment (farming/other); husband has extra small business; respondent's and husband's frequency of employment; Respondent or husband earns extra income; number of farms; number of vegetable gardens; average farm size. N for children under five was 55 and N for respondents was 58.

*The following variables had missing values: respondent's age (23); husband's age (40); husband's highest level of education (2); whether the husband works in agriculture (2); whether the husband has an additional small business (2); husband's frequency of employment (2); whether the husband earns extra income (2) and average farm size (5) out of a total of 104 individuals.

**The following variables had missing values: respondent's age (11); husband's age (20); husband's highest level of education (1); whether the husband works in agriculture (1); whether the husband has an additional small business (1); respondent (0) and husband's frequency of employment (1); whether the husband earns extra income (1) and average farm size (3) out of a total of 58 individuals.

5.4.3.5 Selling produce and nutritional status

As in Minyenye, the majority of associations between whether households sold produce and nutritional status were non-significant (Table 5.12). In adjusted models, households selling fruit however, had children with 1.13cm higher MUAC.

Table 5.12. Associations between households selling foods they grew and under five year old's and all children's nutritional status in Mbwei

	Height z-scores	Weight z-scores	BMI z-scores	MUAC
	Regression coefficient (95% CI)	Regression coefficient (95% CI)	Regression coefficient (95% CI)	Regression coefficient (95% CI)
Under five year olds*				
Unadjusted^				
Sold staples	-0.07 (-0.59, 0.45)	0.06 (-0.39, 0.51)	0.24 (-0.13, 0.62)	0.01 (-0.50, 0.52)
Sold Vegetables	**-0.61 (-1.11, -0.11)**	-0.42 (-0.86, 0.02)	-0.02 (-0.39, 0.35)	-0.34 (-0.84, 0.16)
Sold Fruit	-0.12 (-0.74, 0.50)	0.06 (-0.48, 0.60)	0.26 (-0.19, 0.70)	0.01 (-0.60, 0.62)
Sold Other	-0.35 (-1.15, 0.46)	-0.27 (-0.95, 0.42)	0.03 (-0.56, 0.62)	**-0.77 (-1.53, -0.00)**
Adjusted^^				
Sold staples	-0.08 (-0.68, 0.52)	0.05 (-0.46, 0.55)	0.24 (-0.17, 0.64)	0.11 (-0.45, 0.67)
Sold Vegetables	-0.60 (-1.22, 0.02)	-0.17 (-0.70, 0.36)	0.24 (-0.18, 0.65)	-0.07 (-0.64, 0.51)
Sold Fruit	-0.10 (-0.87, 0.67)	0.24 (-0.40, 0.88)	0.40 (-0.11, 0.92)	0.43 (-0.26, 1.13)
Sold Other	-0.04 (-1.13, 1.04)	0.02 (-0.89, 0.93)	0.10 (-0.59, 0.79)	-0.30 (-1.23, 0.64)
All children**				
Unadjusted^^^				
Sold staples	0.01 (-0.36, 0.38)	0.03 (-0.32, 0.38)	0.10 (-0.21, 0.40)	0.30 (-0.27, 0.88)
Sold Vegetables	-0.25 (-0.62, 0.12)	-0.23 (-0.58, 0.11)	-0.04 (-0.34, 0.26)	0.25 (-0.32, 0.82)
Sold Fruit	-0.07 (-0.49, 0.35)	-0.03 (-0.43, 0.36)	-0.00 (-0.35, 0.34)	**0.83 (0.18, 1.49)**
Sold Other	-0.03 (-0.54, 0.48)	-0.15 (-0.62, 0.32)	-0.21 (-0.62, 0.21)	0.32 (-0.51, 1.14)
Adjusted^^^^				
Sold staples	0.03 (-0.42, 0.47)	0.04 (-0.36, 0.45)	0.12 (-0.21, 0.44)	0.49 (-0.16, 1.14)
Sold Vegetables	-0.23 (-0.66, 0.19)	-0.09 (-0.49, 0.30)	0.11 (-0.21, 0.43)	0.27 (-0.37, 0.91)
Sold Fruit	-0.13 (-0.68, 0.41)	0.01 (-0.49, 0.51)	0.06 (-0.36, 0.47)	**1.13 (0.34, 1.92)**
Sold Other	-0.04 (-0.71, 0.62)	-0.20 (-0.80, 0.40)	-0.25 (-0.76, 0.27)	0.28 (-0.75, 1.30)

^Unadjusted model. N was 97 for height, 100 for weight, 99 for BMI z-scores and 101 for MUAC in children under five.
^^Adjusted model. ^^ and ^^^^ were adjusted for mobile phone in the household, respondent's and husband's highest level of school, husband employed in farming or other and plus small business, frequency of respondent and husband employment, respondent and husband earns extra income. N was 97 for height, 100 for weight, 99 for BMI z-scores and 101 for MUAC in children under five
^^^Unadjusted model. N was 163 for height, 167 for weight, 169 for BMI z-scores and 1680 for MUAC in all children.
^^^^Adjusted model. N was 163 for height, 167 for weight, 169 for BMI z-scores and 180 for MUAC in children under five

*The following variables had missing values (number of missing values in brackets after each variable): respondent's age (23); husband's age (40); husband's highest level of education (2); whether the husband works in agriculture (2); whether the husband has an additional small business (2); husband's frequency of employment (2) and whether the husband earns extra income (2) out of a total of 104 individuals.

**The following variables had missing values: respondent's age (59); husband's age (77); husband's highest level of education (3); whether the husband works in agriculture (3); whether the husband has an additional small business (3); husband's frequency of employment (3) and whether the husband earns extra income (3) out of a total of 236 individuals.

5.5 Discussion

5.5.1 Plant agrobiodiversity and dietary diversity/food variety

No significant associations were seen between the plant agrobiodiversity measures and dietary diversity and food variety scores in either village. There are a number of factors that could contribute to the lack of association seen. Firstly, seasonal variation; the agrobiodiversity was only measured at one time point. The availability of foods that have already been harvested may be related to dietary diversity when agrobiodiversity is not. This will be discussed in the section on annual plant diversity. Secondly the agrobiodiversity measure does not account for crop failure. Intentional crops may be planted but have been unable to be harvested and therefore unable to contribute to the households diets. Crop failure was common in Mbwei; 76% of households said that they had crops that they were unable to either eat or sell, but not in Minyenye. Thirdly, planted crops may also not be eaten by household members as they are sold. In Minyenye, 13% of households sold some of the vegetables they grew, 11% sold fruit and 42% sold other produce like oil or sugar cane. In Mbwei 45% of households sold vegetables, 21% sold fruit and 12% sold other produce. And finally, the agrobiodiversity in the household farms may not have impacted on the diversity of the diets of the respondent and her oldest child under the age of five due to the distribution of food within the household (Engle and Nieves, 1993, Gittelsohn et al., 1997).

More generally, there are many factors which could be influencing diets in these communities. For instance food intake is determined partly by cultural norms (Gittelsohn et al., 1997) and, to a lesser extent in low income countries, individual food preferences. Socioeconomic status and the money available to buy food supplementary to grown food will also affect the foods eaten (Shack et al., 1990). Knowledge about what are healthy and age appropriate foods for under five year olds may impact on food choice and dietary diversity (Caulfield et al., 1999). In the context of these factors, growing a more diverse set of crops at a household level may not improve the diversity of foods eaten in the household.

5.5.2 Plant agrobiodiversity and nutritional status

Associations between plant agrobiodiversity and crop diversity scores and nutritional status are mixed in Minyenye but negative in Mbwei. In Minyenye, biodiversity indices were positively associated with height in children i.e. households with farms with higher plant agrobiodiversity had children who were less chronically malnourished. As the plant agrobiodiversity indices were not associated with the diet variables measured in this study it may be that higher biodiversity is associated with nutritional status through another pathway or it may be that dietary diversity measured at one time point is not a good enough measure of diet to capture these associations; A possibility that was raised in chapter 4.

In Mbwei, higher plant agrobiodiversity was associated with poorer height and BMI in children. Additionally, diversity in vegetables gardens in Mbwei was negatively related to children's height z-scores. These results do not support the main pathway from agrobiodiversity to individual dietary diversity to child nutritional status illustrated in the conceptual framework (figure 3.2 a) and b). Based on discussions in the literature, finding negative relationships between biodiversity and nutritional status in this study was surprising. On the contrary, there has been much discussion about biodiversity and its potential benefits on diet and health in the literature (Wahlqvist and Specht, 1998, Chivian, 2002, Frison et al., 2004, Frison et al., 2006, Gotor, 2010).

However, despite these discussion papers there have been few studies actually investigating these relationships. There have been a number of interventions designed to improve dietary diversity and nutritional status through agriculture. A review by Berti et al. identified 30 such projects (Berti, 2004) and Masset et al identified 23 (Masset et al., 2012). Few of these focused explicitly on techniques to increase the diversity of crops grown but many focused on additions of or improvements in vegetable gardens. In the first review anthropometry outcomes improved in three out of the four vegetable garden interventions collecting these outcomes (Berti, 2004). In the review by Masset et al (Masset et al., 2012) eight interventions presented prevalence of stunting, wasting and underweight post intervention and only three of these found improvements in these markers of nutritional status.

There have been a few studies, while not actually measuring agrobiodiversity, which suggest that improved agrobiodiversity would be associated with improved dietary intake. Mixed cropping fields and home gardens were identified as major sources of essential minerals and vitamins in communities studied in Java. The production of these nutrients were greater in farms and gardens with greater diversity of crops (Marten and Abdoellah, 1988). The study linked crops grown to supplied nutrients but did not go so far as to assess actual consumption and resulting health. A novel ecological tool, nutritional functional diversity, was developed by Remans et al. to reflect the nutrients available from all edible species available on household farms (Remans et al., 2011a). The study found that this metric was related to dietary diversity and iron and vitamin A levels in the blood in three villages in sub-Saharan Africa at the village but not household level.

In terms of research explicitly investigating agrobiodiversity, Akrofi et al (2010) had similar findings to the current study. They found no significant correlation between the Shannon indices in the home gardens and the household dietary diversity scores. Dewey (1981) had mixed findings were households with more than five crops in the family farm had greater dietary diversity in the Socios but there was no difference seen in the other village studied. Interestingly, there was no association between agrobiodiversity and nutritional status in the Socios but in the nearby village crop diversity was significantly correlated with height for age. Unfortunately the details of how agrobiodiversity was measured were not presente d; this may have been a systematic measure of the diversity of crops growing on the household farms, as in this study, or it could be a count of crops grown by the household reported by a household member. Shack et al (1990) found the number of food crops grown in the households vegetable garden, as observed by a researcher, to be significantly associated with mother BMI but not children's nutritional status. Despite the logical pathway from agrobiodiversity through dietary diversity to nutritional status, strong evidence for this pathway occurring in rural areas of low income countries is still lacking.

5.5.3 Crop and vegetable diversity scores, dietary diversity and nutritional status

Crop diversity scores were associated with measures of dietary diversity. Plant agrobiodiversity was not positively associated with dietary diversity but the crop and vegetable diversity scores were related to dietary diversity and food variety in both villages. Annual plant diversity was negatively associated with MUAC in under five year olds in Minyenye but no associations with nutritional status were found in Mbwei.

Studies attempting to link agrobiodiversity to dietary diversity usually use a simple count, captured at one time point, of the number of crops the household is growing or has grown over the course of the year (Ekesa et al., 2008, Shack et al., 1990, Walingo and Ekesa, 2013, Bhagowalia et al., 2012). Both Ekesa et al. (2008) and Walingo and Ekesa (2013) found agrobiodiversity, defined as the variety of animals kept and plants grown for food over an unspecified time period, to be positively correlated to dietary diversity in a cross-sectional survey in Kenya (Ekesa et al., 2008). Unfortunately neither of these studies reported statistical significance associated with these correlations. Bhagowalia et al (2012) found the number of crops grown by a household to be significantly associated with household dietary diversity over the previous 30 days.

When agrobiodiversity is defined by the number of crops grown by the household over the previous year it is often found to be significantly associated with dietary diversity, as was found in this study. As this method captures the number of crops grown over the entire year as opposed to those grown only at data collection, perhaps this is a more appropriate method for measuring agrobiodiversity. There are both benefits and disadvantages to this approach. It is quicker and easier to capture but it relies on memory and honesty rather than observation of the crops grown.

5.5.4 Vegetable gardens, dietary diversity and nutritional status

Having a vegetable garden is not associated with improved dietary diversity or nutritional status. In this study farm diversity indices did not include diversity from vegetable gardens. These were more common in Mbwei so it can be expected that vegetable gardens contribute to the diversity of foods available to households in about a third of the households in Mbwei and a fifth of Minyenye households. Households with vegetable gardens had higher crop diversity scores than those households without vegetable gardens but there were no significant differences in any of the dietary diversity or nutritional status variables between households with vegetable gardens and those without.

No significant associations were seen between the biodiversity indices measured in the vegetable gardens of Mbwei and dietary diversity or food variety but it should be noted that the sample size for these analyses were likely to be too small to detect any associations that may exist. Diversity in vegetables gardens in Mbwei was, however, negatively related to children's height z-scores. The more diverse the vegetable gardens were, the lower the heights. This is comparable to the overall results showing no or negative associations between agrobiodiversity of household farms and nutritional status. The reasons for this will be explored in the section comparing Minyenye and Mbwei.

Research using vegetable gardens to improve agricultural diversity with the intention of improving diet and nutritional status have shown mixed results. Some have had positive results; Cabalda et al. showed that having a fruit or vegetable garden was positively associated with dietary diversity in children under five in the Philippines although not with household food security (Cabalda et al., 2011). In Bangladesh, children in households with more developed vegetable gardens which were producing vegetables year round consumed more vitamin A rich vegetables than those with the traditional, limited vegetable gardens (Talukder et al., 2000). English et al. found a decrease in diarrhoeal and respiratory infections in Vietnam in a controlled multi-intervention nutrition trial which improvement of vegetable gardens was one of the components of the intervention (English et al., 1997).

However others have failed to find an association between number of crops grown in vegetable gardens and nutritional status (Shack et al., 1990) or have shown no improvement in nutritional intake (Brun et al., 1989) or biochemical markers of nutritional status (Kidala et al., 2000) on the establishment of household vegetable gardens in Senegal and Tanzania respectively.

5.5.5 Comparison of Minyenye and Mbwei

It may be possible to get some insights into the results of this study by examining some of the differences between the two villages. The land cover in the area surrounding the DHS Enumeration Area (EA) centre point as defined by the Globcover 2009 project (Bontemps et al., 2011) was used to select Minyenye as a low biodiversity village and Mbwei as a high biodiversity village.

The agrobiodiversity measurements of the household farms revealed a very different picture to what would be expected from the surrounding land cover. Minyenye showed slightly greater diversity than Mbwei for overall plant agrobiodiversity (2.5 vs. 2.3). When the agrobiodiversity index was broken down into just plants that can be used for food this difference was even more pronounced (1.1 vs. 0.6).

To try and understand the discrepancy between the surrounding land cover and the agrobiodiversity of the household farms, the habitat observed in the villages and the characteristics of the farms in the two villages were examined. On average households in Mbwei had more farms than households in Minyenye but Minyenye households tended to have larger farms than those in Mbwei. Minyenye is likely to have more land available for growing food on.

The soil quality of the farms is likely to also play a part in this difference in diversity. Approximately 50% of households had markers of land degradation on one or more of their farms in Mbwei compared to only 16% in Minyenye. This is reflected in the fact that respondents in Mbwei were much more likely to report not being able to eat or sell crops that they grew, mainly due to the rain, sun and fertility of the land.

It is likely that the poorer quality of the land in Mbwei is partly due to the topography of the area. Mbwei is situated in the West Usambara mountains and the seven sub villages that make up Mbwei were situated on hill-tops or in valleys with 40% of their farms on steep slopes. It was noted in Mbwei that the farmers mentioned that rains had carried off fertile soil from their lands on two occasions. This issue has been identified in the literature as an important agricultural problem in the Usambara mountains (Ezaza, 1988, Stahl, 1993). Steep topography is linked to poor soil fertility which causes decreased food production (Ezaza, 1988).

Farmers in Mbwei raised less animals than those in Minyenye, which means they would have less natural fertiliser available to improve the quality of the soil on their farms, especially considering the greater distance between the farms in Mbwei. The poorer quality of the land may help to explain the lower biodiversity seen on Mbwei's household farms. As low biodiversity has also been linked with poor soil fertility (Tilman et al., 1996) these factors combined may be having a negative impact of food production in Mbwei. The higher quality of the farms in Minyenye could also help explain the positive association seen between agrobiodiversity and height in Minyenye when no or negative associations were seen in Mbwei. Barriers such as crop failure could be preventing the crops grown from being consumed by the household. This may be a significant finding as such a high proportion of households in Mbwei (76%) reported growing food that they could neither eat or sell and these households had children with lower BMI z-scores. Additionally, respondents in Mbwei attributing poor harvests to the fertility of their land had children with lower BMIs.

Minyenye had a far greater number of species encountered on their household farms (88 species) compared to Mbwei (45 species). The variety of food species was also far greater, 59 compared to 22 in Mbwei. Another important difference between the two villages is the growth of staple crops. Sorghum, maize and finger millet made up 6%, 4% and 1% of all the plants found on household farms in Minyenye. In Mbwei, cassava made up 25%, maize made up 8% and finger millet and sorghum were not encountered. Minyenye's greater number of and variety of staples grown could have a beneficial effect on their food security and could contribute to the better nutritional status seen in this village. Additionally, the nutrient content of the staple crops grown in Minyenye are higher than the main crop grown in Mbwei, cassava (Gegios et al., 2010).

Interestingly, when one considers the crop diversity scores and the proportion of households growing specific crops it appears that Mbwei does, in fact, grow a greater variety of food compared to Minyenye. This was particularly pronounced when looking at the vegetables grown by the two villages in Figure 5.4. The plant and vegetable diversity scores include foods grown on vegetable gardens, these numbers may have been higher in Mbwei partly because vegetable gardens were more common in Mbwei. This result may also reflect a higher number of crops grown throughout the year which is not reflected by the agrobiodiversity indices as these were taken at one time point.

The negative association between agrobiodiversity and nutritional status in Mbwei in both the farms and in the vegetable gardens may be partly explained by energy expenditure through work and time taken from care of the children. Kumar and Hotchkiss (1988) found that the more time children spent in agricultural work such as grazing animals and working on farms the poorer the nutritional status of their preschool age siblings.

Mbwei has children with poorer nutritional status, more farms far from the house, higher crop failure and a negative association seen between agrobiodiversity and nutritional status. Perhaps, in the context of increased workload and increased time away from caring for the children, for presumably less food, a relationship does not exist between agrobiodiversity and nutritional status. Whereas in Minyenye, farms are nearer the house and crop failure is less common suggesting a better workload to food production ratio compared to Mbwei. In this context, the higher agrobiodiversity translates into better nutritional status.

It is also possible that families that are more at risk are more likely to grow more different types of crop to minimise the risk to their families if a crop fails (Altieri, 2009). As this was a cross sectional study there is no way to tell the direction of the observed effect.

It may be that there are too many other factors contributing to undernutrition in these villages for a difference in agrobiodiversity measured at one time point, to be more strongly associated with nutritional status. From agricultural factors such as the quantity of food grown and the annual variation in the diversity and amount of food grown to diet and health factors as outlined in chapter 4 such as infection (Chen et al., 1980, Alvarado et al., 2005), complementary feeding (Onyango et al., 1998, Obatolu, 2003) and maternal education (Kabubo-Mariara et al., 2009, Abuya et al., 2012). The pathway from the diversity of crops grown in the household farms through dietary diversity to nutritional status, shown in the conceptual framework (figure 3.2 a) and b)), may be too long with too many confounding factors to be seen in a cross-sectional sample.

5.5.6 Selling produce, dietary diversity and nutritional status

Whether households sold vegetables, fruit or other produce was positively associated with dietary diversity and food variety. There are two likely reasons for this. Firstly, the sale of produce generated an increased income which had a positive effect on the households diets or, secondly, being able to sell crops indicates that there was enough, of that particular crop, to feed the household members.

Previous research has shown that an increased income is positively associated with nutritional status (Shack et al., 1990, Yang et al., 2012). This study found mixed relationships between selling produce and nutritional status; selling fruit and vegetables appears to have a positive effect while selling other produce such as oil, beans, honey or sugarcane was negatively associated with nutritional status. This difference can be explained through the division of labour down gender lines. Subsistence foods such as vegetables and fruit are thought of as 'women's crops' while cash crops fall into men's domain (Due and Gladwin, 1991, Berinyuy and Fontem, 2011). These results suggest that the money raised by selling fruit and vegetables is used to buy food while the income from cash crops is not. Fruit that was most commonly sold was avocado, banana and guava. These fruits are easy to grow and pick, not requiring much additional time and effort and providing not only a good source of nutrients for the household members but additional money for the household. Consuming and selling fruit has been identified as a coping strategy in times of food shortage in Kenya (Thorlakson et al., 2012).

5.5.7 Limitations and strengths

The true association between agrobiodiversity and dietary diversity may have been masked by some of the study's methodological limitations. There are a number of potential issues in the way the agrobiodiversity measures were collected in this project. Firstly the biodiversity data were collected by two different research assistants for the two different villages. Although both research assistants followed the same data collection protocol there may still be differences in the way this data were collected leading to differences in the resulting biodiversity measurements.

The timing of the data collection would also have impacted on the agrobiodiversity results. Data collection took place in June in Minyenye and July in Mbwei. Mbwei falls in the bimodal part of Tanzania (Kabanda and Jury, 1999) and it was expected that it would have two harvests and that data collection would take place before the main harvest. This was unfortunately not the case in many households and a high proportion of participants reported only one harvest. The Village Executive Officer indicated that Mbwei was in a micro-climate within Lushoto and did not experience the same weather patterns as the surrounding area. The weather tended to be hotter and drier than what was typical in Lushoto. The result of this was that Mbwei did not represent the high diversity area as planned and the agrobiodiversity measures were taken post harvest for a number of households, reducing the diversity indices for this village.

Due to the greater total number of farms and greater number of farms far from the household a smaller proportion of total farms were measured in Mbwei compared to in Minyenye. So, while in Minyenye the biodiversity of almost all of the farms used by the household were measured, in Mbwei only a selection of farms were measured and those far from the household were under-represented. This may introduce error into the biodiversity measurements, but the reported size and types of crops grown on the measured farms did not differ markedly from the farms where no data were collected. This should minimise the bias introduced by this limitation.

Despite these limitations this project has brought together detailed data on plant agrobiodiversity, dietary diversity and nutritional status, something which is rare within one project. Plant agrobiodiversity is measured systematically and biodiversity indices have been calculated. This is the first study to compare biodiversity indices on households farms to nutrition outcomes. This study has also collected detailed supplementary data which provides important insights into the context of this work. The results have highlighted some of the complexities of relating factors with multiple determinants to each other and has produced some interesting insights into how agricultural, dietary and health factors are related.

5.6 Conclusions

This project aimed to investigate the relationship between agrobiodiversity, dietary diversity and nutritional status in villages in rural Tanzania. Chapter 4 illustrated a lack of association between dietary diversity and nutritional status in these villages. This chapter has found no significant associations between agrobiodiversity and dietary diversity and a limited number of associations between agrobiodiversity and nutritional status variables. Due to the push for improving agrobiodiversity to improve dietary diversity and health, this is an important finding.

A simple count of the foods that a household grows was significantly associated with dietary diversity and food variety while a more systematic measure of biodiversity in the household farms was not. This has implications for nutrition focused research both in terms of measurement of agrobiodiversity indices and in terms of targets for dietary improvement. If researchers or development organisations are interested in improving diets in a subsistence farming setting asking the household members what they grow over the course of a calendar year may give a better representation of food availability compared to employing time consuming cross-sectional agrobiodiversity measures. Project targets could focus on adding a certain number of crops to the households annual planting cycles, simplifying monitoring and evaluation procedures.

The results of this study also provide a word of caution for those attempting to increase agrobiodiversity on the assumption that this will lead to improvements in diet and nutritional status. In a number of cases in this study measures of biodiversity and numbers of crops grown were negatively associated with nutritional status. Households with greater diversity in their household farms and vegetable gardens as well as households which sold staples, vegetables or other food had children with poorer nutritional status. The results from this study illustrates some of the complexities of the relationships between factors along the pathway from food production through consumption to nutrient utilization in low income countries.

Chapter 6:
Investigating the associations between animal diversity and both dietary diversity and nutritional status in Minyenye and Mbwei, rural Tanzania

6.1 Chapter summary

This is the last results chapter for the primary data collection. The previous chapter focused on the relationships between plant agrobiodiversity and both dietary diversity and nutritional status. This chapter will build on this work by investigating the relationships between these health outcomes and animal diversity. The previous chapter reported plant agrobiodiversity as measured in the household farms and as the number of crops grown over the previous calendar year. This chapter reports animal agrobiodiversity using the number of animals raised over the previous year. This will be referred to as the animal diversity score to maintain consistency with the terminology used chapter 5. This chapter also reports how eating meat and animal products and selling animals and animal products are associated with dietary diversity and nutritional status.

This chapter helps meet objective 3 (Measure household crop and animal diversity, dietary diversity of respondents and children under five and nutritional status of children living in these villages, determine whether household produce is sold and investigate how these factors are related) and objective 4 (Investigate basic socio-demographic factors affecting dietary intake of children under five and nutrition outcomes in children in these villages) of this thesis. The objectives of this chapter are:

Objective 6A: To assess animal diversity and present descriptive data on animal product consumption and animal rearing practices in the two villages.

Objective 6B: To examine whether eating animals and animal products and animal diversity are associated with dietary diversity in respondents and under five year olds and nutritional status in children.

Objective 6C: To examine whether selling animals and animal products is associated with dietary diversity in respondents and under five year olds and nutritional status in children.

The results presented in this chapter have shown that households eating more animal products have members with higher dietary diversity in Minyenye and Mbwei. Higher animal diversity scores are associated with higher dietary diversity in Minyenye only. Households eating more animal products and households with higher animal diversity scores have poorer nutritional status in Minyenye only. Selling animals and animal products is not associated with dietary diversity in either village. However, Minyenye households selling animals and animal products have children with poorer nutritional status.

These results contradict much of the literature on the consumption of animal products in low income countries (Krebs et al., 2011). These results have shown that eating and raising animals is not necessarily beneficial to diet and nutritional status of subsistence farmers living in environments such as rural Tanzania. This is an important finding that should encourage caution in those working to improve nutritional status through animal rearing focused interventions.

6.2 Introduction

Meat and animal products have the potential to make an important contribution to dietary diversity and nutritional status and increasing animal protein in the diets of those living in rural sub-Saharan Africa has long been heralded as a potential avenue for improving undernutrition in these communities (Gibson et al., 2003, Bwibo and Neumann, 2003).

There is evidence in the literature that meat supplementation or higher intakes of animal products are linked to better dietary quality and improvements in micronutrient status but there is limited evidence of the impact on growth. Despite finding a significant inverse association between meat consumption and stunting in populations in Guatemala, Democratic Republic of Congo, Zambia, and Pakistan (Krebs et al., 2011), a year long trial using 30 to 45g of meat per day failed to decrease the rates of stunting in this population (Krebs et al., 2012). Gibson et al. ((Gibson et al., 2003) developed a dietary diversification intervention which included increasing the consumption of animal source food, mainly fish, and showed significant improvements in energy, protein calcium, zinc, haem iron and vitamin B12 intake and improvements in MUAC z-scores and arm muscle area. There were no improvements in height or weight after 12 months. Providing a daily snack containing meat to Kenyan school children for 21 months showed significantly improved cognitive function over a milk or energy supplement and the control group in a randomised trial (Whaley et al., 2003). Dietary quality

(Murphy et al., 2003), plasma vitamin B-12 (Siekmann et al., 2003), mid upper-arm muscle area and mid-upper-arm fat area (Neumann et al., 2013) were increased in the meat and milk groups. But there were no changes in height (Grillenberger et al., 2003).

Cross-sectional data provides some evidence of the link between animal product consumption and growth in communities not involved in development programs or interventions. Marquis et al (Marquis et al., 1997) found linear growth to be positively associated with intake of animal products but only in children with low intakes of complementary foods. Consumption of animal foods was significantly correlated with weight and height z-scores in Mexican children 18 to 30 months of age (Allen et al., 1992).

Literature on the effects of animal agrobiodiversity and animal rearing more generally on diet and nutritional status is lacking. Two of the papers reporting a positive associations between agrobiodiversity and dietary diversity used a score which combined plant and animal agrobiodiversity (Correlation of 0.697 (Ekesa et al., 2008) and coefficient of determination=0.496 (Walingo and Ekesa, 2013) (significances not reported)). Leroy and Frongillo (2007) conducted a review on the effects of promoting animal production in order to combat undernutrition in which the majority of studies found improved dietary intake with animal production. The authors suggest this is not necessarily through the consumption of animals raised but, more likely, through increased income (See Figure 6.1 taken from Leroy and Frongillo (2007)). All the projects that measured nutritional status integrated different food production interventions and nutrition education and showed improvements in the prevalence of iron deficiency, serum retinol and ferritin and child growth. As these were multi-component interventions it is not possible to determine how much of this effect was due to improvements in animal production.

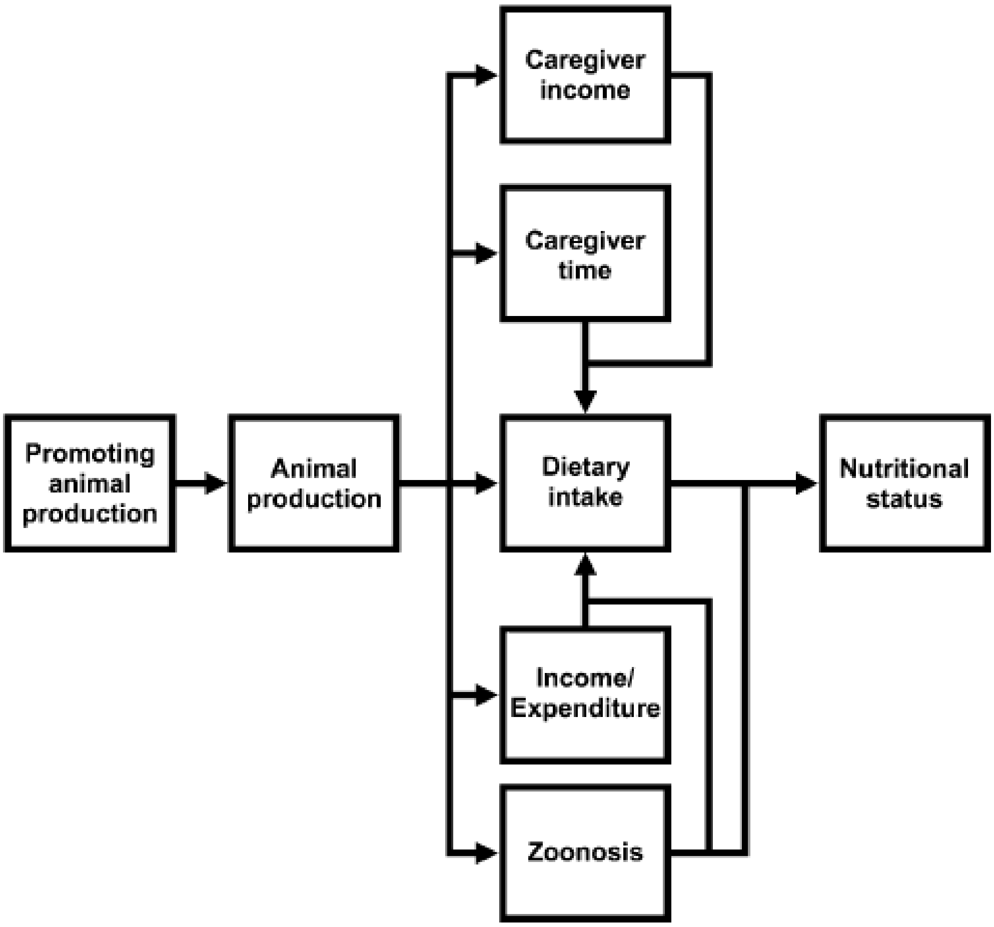


Figure 6.1. Pathway between livestock production and nutritional status (Leroy and Frongillo, 2007)

There is some evidence to suggest that increasing the intake of animal products in low income countries can improve measures of health (Gibson et al., 2003, Whaley et al., 2003, Murphy et al., 2003, Siekmann et al., 2003, Neumann et al., 2013), especially in the context of multi-component interventions (Gibson et al., 2003, Leroy and Frongillo, 2007). However, due to the complex set of determinants of diet and nutritional status in these communities, it is important to investigate whether animal diversity and consumption of meat and animal products is linked in communities receiving no food production intervention. This chapter will outline the associations between meat and animal product intake and animal diversity and both dietary diversity and nutritional status. Along with providing additional evidence of the affect of animal product intake in low income environments this chapter provides complementary data for the last chapter on plant agrobiodiversity, dietary diversity and nutritional status.

6.3 Methods

6.3.1 Data collection

The food sources section of the household questionnaire was used to collect the animal food sources and animal diversity data for this chapter (see chapter 3 for full details of methods). Details on how dietary diversity and nutritional status was measured and transformed for analysis were described in chapter 3 and 4. The specific information collected on animal diversity, animal rearing, animal and animal product consumption and the statistical analysis methods used in this chapter are described below.

The respondent was asked if members of the household had consumed chickens, eggs, cows, milk, sheep, goats, pigs, ducks or fish in the past calendar year. For positive responses the respondents were asked if the meat or animal products came from animals raised in the household or if they were bought, gifted to the household or obtained from the wild. For animals that were raised by the household additional questions about the number of animals the household raised and whether the animals, meat or animal products were sold by the household were also asked. The number of different types of animals that were raised by the household – the animal diversity score, was used to reflect animal agrobiodiversity.

6.3.2 Data analysis

6.3.2.1 Descriptive statistics

Descriptive data of crude associations are presented as means (95% Confidence Intervals) of continuous variables and percentages within groups for categorical variables (chapter objective 6A).

6.3.2.2 Linear regression analysis

Linear regression was used to estimate the relationship between the number and type of animals raised and eaten by the household and dietary diversity/food variety and nutriti onal status (chapter objective 6B). Again, a DAG was used to identify potential confounders to these relationships (Glymour, 2006) (See description on page 73, chapter 3 and Figure 3.16). These variables were added into the model one by one to assess if they affected the regression coefficients for the independent variable of interest. When the potential confounder modified the regression coefficient substantially they were included in the model. Variables included in the regression models investigating the relationships between animal consumption and rearing and dietary diversity or food variety were: household mobile phone; respondent and husband's highest level of education; whether husband is employed as a farmer or other employment; respondent and husband's frequency of employment and number of farms the household uses for growing food.

In the multivariable regression analyses investigating the relationships with nutritional status these potentially confounding variables were included: respondent and husband's highest level of education; whether husband is employed as a farmer or other employment and respondent's frequency of employment.

Unadjusted and multivariable regression were used to assess the relationship between selling animals, meat and animal products and dietary diversity and nutritional status (chapter objective 6C). Analyses for dietary diversity were adjusted for: household mobile phone; respondent and husband's highest level of education; whether respondent and husband are employed as a farmer or other employment; respondent has small business on top of farming; respondent earns extra income; number of farms the household uses for growing food; average size of household farms. Analyses for nutritional status were adjusted for: household mobile phone; respondent and husband's highest level of education; respondent and husband's frequency of employment; average size of household farms.

6.4 Results

6.4.1 Animal product consumption and animal diversity in the two villages

In Minyenye, the average animal diversity score was 1.42 (95% CI: 1.21, 1.63), this is the number of types of animals raised by the household. Of 64 households in Minyenye, the majority raised chickens, approximately 40% raised cows and less than 10% raised sheep, goats, pigs or ducks (Figure 6.4). On average those households raising sheep, goats or pigs (only 6 households) raised approximately 11 of these animals, the 43 households raising cows raised, on average, about 7 cows and those 53 households raising chickens raised about 10 chickens per household.

Figure 6.2. Animals kept in a pen in a households yard and being taken to get water in Minyenye

In Mbwei, the mean animal diversity score was 1.12 (95% CI: 0.85, 1.40). Approximately 55% of the 58 households raised chickens, 35% raised cows and 15% raised ducks. No households in either village kept fish. Only one household in Mbwei reported raising sheep and goats and they raised 5 of these animals in total. Thirty-five households raised cows and each household, on average raised 2.5 cows. Of those 45 households raising chickens each household raised on average 5 chickens.

Figure 6.3. A single cow being kept by a household in Mbwei

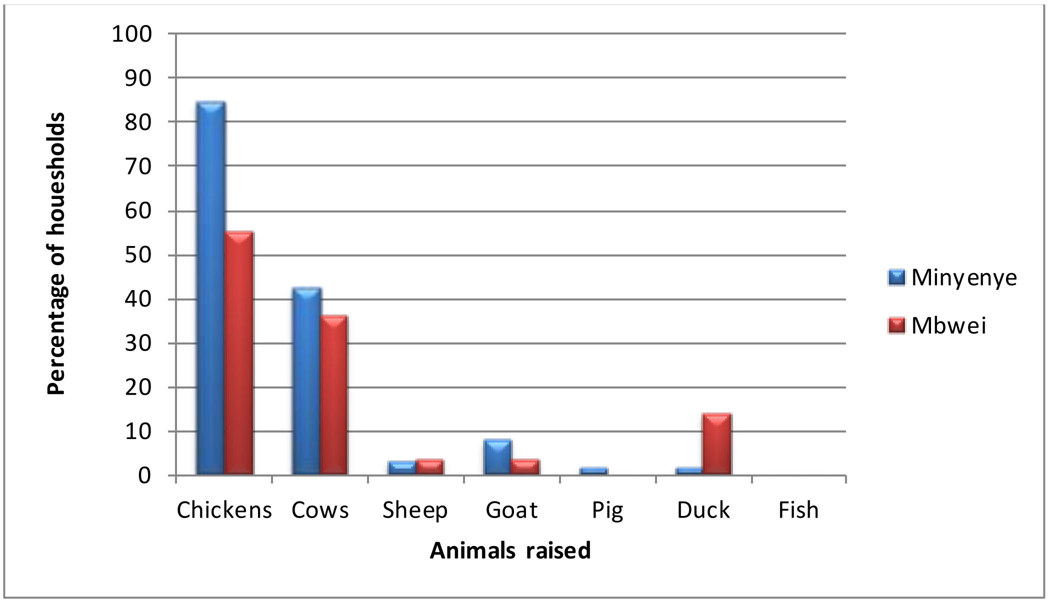


Figure 6.4. Percentage of households raising specific animals in the Minyenye and Mbwei

100% of households ate animals in the past year and 87.5% (95% CI: 79.2, 95.8) raised animals. 4.03 (95% CI: 3.74, 4.32) different types of animals were eaten by the household in the previous calendar year. Of those households raising animals 62.0% (95% CI: 48.1, 75.9) of households sold animals or meat in the past calendar year.

A high proportion of households in Minyenye ate chicken (83%) and eggs (69%), with most of these foods coming from animals they raised in the household (Table 6.1). Approximately 85% of households ate beef with almost all of those households buying this meat. Just over half the households drank milk, with 80% of this milk coming from cows they raised in the household. All households ate fish in the last calendar year, approximately three quarters of the households ate meat from goats, 40% ate meat from sheep, 13% meat from pigs and 5% duck meat. The majority of this meat was bought by the household rather than raised and a small proportion was gifted to the household. Sixteen percent of households ate no chicken, 8% ate no meat from goats, sheep or pig and 20% ate no milk or eggs in the last calendar year. No households in Minyenye consumed any animals or animal products from wild sources (data not shown).

Forty-eight percent of all the Minyenye households sold meat and 29% sold eggs or milk. Of those households raising chickens 60% also sold them and approximately 40% sold eggs for additional income. Only one household sold a cow for income and five households sold milk from cows they raised. Three households sold goat, one sold pig while none of the households raising sheep or ducks sold these animals for additional income.

In the previous calendar year in Mbwei, 4.40 (95% CI: 3.87, 4.92) types of animals were eaten by the household. In the past calendar year 94.8% (95% CI: 89.0, 100) of households ate animals and 69.0%(95% CI: 56.7, 81.2) raised animals. Of those households raising animals 21.9% (95% CI: 6.7, 37.0) of households sold some of the animals or meat.

Compared to Minyenye, a lower proportion of households in Mbwei raised animals. Sixty-three percent raised chickens and 16% raised goats, sheep. A high proportion of households ate both chicken and eggs in the last calendar year. Approximately three quarters of households ate meat from cows and all of this meat was bought by the households. Eighty percent of households consumed milk, approximately 40% got milk from cows they raised in the household and approximately 70% bought milk. Approximately 70% of households consumed sheep and goat meat in the previous calendar year with the majority of this meat being bought. Just over half the households consumed duck meat with a quarter of households raising the ducks themselves and three quarters buying this meat. About 90% of households ate fish with all households buying this fish. Twenty one percent of households ate no chicken, 24% ate no meat from goats, sheep and 14% ate no milk or eggs in the last calendar year. No households in Mbwei ate meat from pigs. As in Minyenye, no households in Mbwei consumed any animals or animal products from wild sources (data not shown).

A much lower proportion of Mbwei households, as compared to Minyenye, sold animals or animal products. Twelve percent of Mbwei households reported selling some meat and 18% sold eggs or milk. Of those households raising specific animals six households sold chicken, eggs and milk and one household sold sheep and goat. Seven households who raised ducks sold some of the animals or meat.

Table 6.1. Number of households in Minyenye and Mbwei eating, raising, buying, being given and selling animals and animal products in the last calendar year

		Of those who ate:			Of those that raised:
	Ate (N)	Raised (N)	Bought (N)	Gift (N)	Sold (N)
Minyenye (N=64)					
Chickens	53	50	3	0	30
Eggs	44	42	3	0	16
Cows	54	2	53	0	1
Milk	35	28	6	3	5
Sheep	25	2	22	1	0
Goat	49	5	42	2	3
Pig	8	1	6	1	1
Duck	3	1	2	0	0
Fish	64	0	63	1	0
Mbwei (N=58)					
Chickens	46	30	18	0	6
Eggs	36	24	13	0	6
Cows	43	0	43	0	0
Milk	48	21	35	0	6
Sheep	42	2	40	0	1
Goat	40	2	38	0	1
Pig	0	0	0	0	0
Duck	33	8	24	1	7
Fish	51	0	51	0	0

*Respondents could respond with more than one source

6.4.2 Minyenye

6.4.2.1 Animal diversity and dietary diversity

Eating animals and animal products and animal diversity is positively associated with dietary diversity in Minyenye. The more types of animals the households had consumed in the past calendar year and the higher the animal diversity score the higher the food variety scores of the respondents and their oldest child under the age of five (Table 6.2). The more different types of animals eaten (in the unadjusted model only) and animal diversity (in both the unadjusted and the adjusted models) the higher the respondent's dietary diversity scores. For example, for each additional type of animal raised by the household the respondent's dietary diversity increased by 0.42.

Table 6.2. Associations between the number of different animals eaten by the household and animal diversity scores and dietary diversity and food variety in respondents and under five year olds in Minyenye

	Dietary diversity score		**Food variety score**	
	Child <5 years	**Respondent**	**Child<5 years**	**Respondent**
	Regression coefficient (95% CI)	Regression coefficient (95% CI)	Regression coefficient (95% CI)	Regression coefficient (95% CI)
No. animals/animal products eaten				
Unadjusted^	0.19 (-0.02, 0.40)	**0.23 (0.07, 0.40)**	**0.67 (0.31, 1.03)**	**0.62 (0.27, 0.96)**
Adjusted^^	0.15 (-0.07, 0.37)	0.20 (-0.01, 0.40)	**0.68 (0.27, 1.08)**	**0.57 (0.13, 1.01)**
Animal diversity scores				
Unadjusted^	0.01 (-0.45, 0.43)	**0.37 (0.03, 0.72)**	0.70 (-0.09, 1.49)	**1.14 (0.43, 1.85)**
Adjusted^^	0.08 (-0.37, 0.52)	**0.42 (0.03, 0.81)**	**1.00 (0.17, 1.83)**	**1.31 (0.50, 2.13)**

^Unadjusted model. N was 61 for children under five and 64 for respondents.

^^Adjusted for household mobile phone, respondent and husband's highest level of education, whether husband is employed as a farmer or other employment, respondent and husband's frequency of employment, number of farms the household uses for growing food. N was 54 for children under five and 57 for respondents.

6.4.2.2 Animal diversity and nutritional status

Eating animals and animal products and animal diversity is negatively associated with nutritional status in Minyenye. In the adjusted models the more different types of animals eaten by the household the lower the BMI z-scores of all children and those children under the age of five (Table 6.3). The higher the animal diversity score, the lower the BMI z-scores in all children only. Additionally, in children under five only, the higher the animal diversity score the lower the children's MUAC in both unadjusted and adjusted models. No other significant associations were seen between the number of animals eaten and the animal diversity score and nutritional status in children.

Table 6.3. Association between the number of animals eaten by the household and animal diversity scores and nutritional status in all children and children under five in Minyenye

	Height z-scores	Weight z-scores	BMI z-scores	MUAC
	Regression coefficient (95% CI)	Regression coefficient (95% CI)	Regression coefficient (95% CI)	Regression coefficient (95% CI)
Children <5				
No. animals eaten				
Unadjusted^	0.05 (-0.08, 0.18)	-0.03 (-0.15, 0.09)	-0.10 (-0.21, 0.02)	-0.10 (-0.22, 0.03)
Adjusted^^	0.05 (-0.11, 0.21)	-0.07 (-0.21, 0.06)	**-0.15 (-0.28, -0.02)**	-0.14 (-0.29, 0.01)
Animal diversity scores				
Unadjusted^	0.07 (-0.20, 0.34)	-0.05 (-0.28, 0.19)	-0.14 (-0.37, 0.08)	**-0.27 (-0.52, -0.02)**
Adjusted^^	0.04 (-0.29, 0.36)	-0.13 (-0.40, 0.13)	-0.23 (-0.48, 0.03)	**-0.35 (-0.65, -0.06)**
All children				
No. animals eaten				
Unadjusted^	0.02 (-0.06, 0.09)	-0.02 (-0.09, 0.05)	-0.01 (-0.09, 0.06)	-0.03 (-0.18, 0.11)
Adjusted^^	0.04 (-0.04, 0.13)	-0.05 (-0.13, 0.03)	**-0.09 (-0.17, -0.01)**	-0.07 (-0.24, 0.09)
Animal diversity scores				
Unadjusted^	0.01 (-0.14, 0.15)	-0.08 (-0.22, 0.06)	-0.08 (-0.22, 0.07)	-0.06 (-0.35, 0.23)
Adjusted^^	0.03 (-0.14, 0.19)	-0.13 (-0.28, 0.02)	**-0.17 (-0.32, -0.02)**	-0.06 (-0.38, 0.27)

^Unadjusted model. N was 101 for height, 100 for weight, 102 for BMI z-scores and 103 for MUAC in children under five. N was 251 for height, 251 for weight, 255 for BMI z-scores and 252 for MUAC in all children.

^^Adjusted for respondent and husband's highest level of education, whether husband is employed as a farmer or other employment, respondent's frequency of employment. N was 93 for height, 93 for weight, 95 for BMI z-scores and 95 for MUAC in children under five. N was 230 for height, 231 for weight, 235 for BMI z-scores and 232 for MUAC in all children.

6.4.2.3 Selling animal products and dietary diversity

Selling animal products is not associated with dietary diversity in Minyenye. No significant associations were seen between whether a household sold milk or eggs and the dietary diversity and food variety scores of the respondents or their oldest children under five (Table 6.4).

Selling animals or meat was positively associated with respondent's food variety scores. In the unadjusted model those households who sold animals or meat from animals had respondents and children with higher food variety scores and respondents with higher dietary diversity scores. When the models were adjusted for potential confounders the association between whether animals were sold and the respondent's food variety score was the only coefficient that remained significant. Respondents from households selling animals or meat had food variety scores approximately two points higher than those in households not selling animals or meat.

Table 6.4. Association between whether animals and animal products are sold and dietary diversity and food variety in respondents and under five year olds in Minyenye

	Dietary diversity score		Food variety score	
	Child <5 years	**Respondent**	**Child<5 years**	**Respondent**
Sold milk and/or eggs				
Unadjusted^	-0.43 (-1.43, 0.57)	0.31 (-0.45, 1.07)	-0.66 (-2.48, 1.16)	0.04 (-1.62, 1.70)
Adjusted^^	-0.40 (-1.31, 0.52)	0.31 (-0.48, 1.09)	-0.97 (-2.73, 0.78)	-0.02 (-1.89, 1.86)
Sold animals/meat				
Unadjusted^	0.86 (-0.03, 1.75)	**0.78 (0.09, 1.46)**	**2.06 (0.47, 3.65)**	**2.44 (1.09, 3.80)**
Adjusted^^	0.18 (-0.76, 1.11)	0.72 (-0.11, 1.55)	0.91 (-0.95, 2.76)	**2.19 (0.55, 3.83)**

^Unadjusted model. N was 43 for children under five and 46 for respondents for sold milk and/or eggs. N was 47 for children under five and 50 for respondents for sold animals/meat.

^^Adjusted for household mobile phone, respondent and husband's highest level of education, whether respondent and husband are employed as a farmer or other employment, respondent has small business on top of farming, respondent earns extra income, number of farms the household uses for growing food, average size of household farms. N was 40 for children under five and 43 for respondents for sold milk and/or eggs. N was 44 for children under five and 47 for respondents for sold animals/meat.

6.4.2.4 Selling animal products and nutritional status

Selling animals and animal products is negatively associated with nutritional status in Minyenye. Households selling milk and/or eggs had under five year olds with significantly lower height z-scores compared to those in households not selling milk and/or eggs (Table 6.5). Looking at all children shows that households selling milk and/or eggs have children with lower height and weight z-scores in both unadjusted and adjusted models.

Households selling animals or meat from animals they raised had under fives and all children with significantly lower BMI z-scores than those not selling animals or meat. In the adjusted model these households had children with significantly lower weight z-scores and MUAC.

Table 6.5. Association between whether animals and animal products are sold and nutritional status in all children and children under five in Minyenye

	Height z-scores	**Weight z-scores**	**BMI z-scores**	**MUAC**
	Regression coefficient (95% CI)	Regression coefficient (95% CI)	Regression coefficient (95% CI)	Regression coefficient (95% CI)
Under 5				
Sold milk and/or eggs				
Unadjusted^	**-0.74 (-1.35, -0.14)**	-0.45 (-0.98, 0.08)	0.19 (-0.34, 0.72)	-0.07 (-0.62, 0.48)
Adjusted^^	**-0.75 (-1.46, -0.03)**	-0.45 (-1.05, 0.16)	0.18 (-0.40, 0.76)	-0.19 (-0.83, 0.46)
Sold animals/meat				
Unadjusted^	0.12 (-0.45, 0.68)	-0.25 (-0.70, 0.19)	**-0.44 (-0.88, -0.01)**	-0.42 (-0.95, 0.10)
Adjusted^^	-0.00 (-0.72, 0.72)	-0.43 (-0.98, 0.11)	**-0.56 (-1.08, -0.04)**	-0.62 (-1.26, 0.01)
All Children				
Sold milk and/or eggs				
Unadjusted^	**-0.32 (-0.65, -0.00)**	**-0.35 (-0.65, -0.05)**	-0.19 (-0.48, 0.11)	0.24 (-0.35, 0.83)
Adjusted^^	**-0.39 (-0.74, -0.04)**	**-0.33 (-0.65, -0.01)**	-0.14 (-0.46, 0.17)	0.06 (-0.59, 0.70)
Sold animals/meat				
Unadjusted^	0.04 (-0.25, 0.33)	-0.21 (-0.47, 0.05)	**-0.35 (-0.62, -0.09)**	-0.50 (-1.05, 0.05)
Adjusted^^	0.03 (-0.33, 0.38)	**-0.32 (-0.64, -0.00)**	**-0.45 (-0.76, -0.13)**	**-0.92 (-1.57, -0.26)**

^Unadjusted model. N was 68 for height, 67 for weight, 69 for BMI z-scores and 70 for MUAC in children under five and was 175 for height, 175 for weight, 179 for BMI z-scores and 176 for MUAC in all children for sold milk and/or eggs. N was 76 for height, 76 for weight, 78 for BMI z-scores and 78 for MUAC in children under five and was 207 for height, 208 for weight, 212 for BMI z-scores and 207 for MUAC in all children for sold animals/meat.

^^Adjusted for household mobile phone, respondent and husband's highest level of education, respondent and husband's frequency of employment, average size of household farms. N was 64 for height, 64 for weight, 66 for BMI z-scores and 66 for MUAC in children under five and was 163 for height, 164 for weight, 168 for BMI z-scores and 165 for MUAC in all children for sold milk and/or eggs. N was 73 for height, 73 for weight, 75 for BMI z-scores and 75 for MUAC in children under five and was 198 for height, 199 for weight, 203 for BMI z-scores and 199 for MUAC in all children for sold animals/meat.

6.4.3 Mbwei

6.4.3.1 Animal diversity and dietary diversity

Eating animals and animal products but not animal diversity scores were positively associated with dietary diversity in Mbwei. The more animals eaten by the household in the past calendar year the higher the respondent's and the under five year old's dietary diversity and food variety in the previous 24 hours in both the unadjusted and the adjusted analyses (Table 6.6), as was the case for food variety in Minyenye. The higher the animal diversity score the higher the respondent's and her oldest child under five's food variety score in the unadjusted model only. This association was seen in both the unadjusted and the adjusted models in Minyenye.

Table 6.6. Association between the number of different animals eaten by the household and animal diversity scores and dietary diversity and food variety in respondents and under five year olds in Mbwei

	Dietary diversity score		Food variety score	
	Child <5 years	**Respondent**	**Child<5 years**	**Respondent**
	Regression coefficient (95% CI)	Regression coefficient (95% CI)	Regression coefficient (95% CI)	Regression coefficient (95% CI)
No. animals/animal products eaten				
Unadjusted^	**0.18 (0.04, 0.32)**	**0.22 (0.09, 0.34)**	**0.57 (0.29, 0.85)**	**0.54 (0.30, 0.78)**
Adjusted^^	**0.22 (0.08, 0.37)**	**0.23 (0.09, 0.36)**	**0.58 (0.29, 0.88)**	**0.51 (0.26, 0.76)**
Animal diversity scores				
Unadjusted^	0.34 (-0.02, 0.70)	0.31 (-0.02, 0.64)	**1.09 (0.36, 1.81)**	**0.85 (0.20, 1.50)**
Adjusted^^	0.37 (-0.08, 0.82)	0.35 (-0.06, 0.76)	0.89 (-0.05, 1.84)	0.62 (-0.18, 1.42)

^Unadjusted model. N was 55 for children under five and 58 for respondents.

^^Adjusted for household mobile phone, respondent and husband's highest level of education, whether husband is employed as a farmer or other employment, respondent and husband's frequency of employment, number of farms the household uses for growing food. N was 54 for children under five and 57 for respondents.

6.4.3.2 Animal diversity and nutritional status

Eating animals and animal products and animal diversity scores were not associated with nutritional status in Mbwei. No significant associations were seen between the number of animals eaten by the household or the animal diversity scores for the last calendar year and the nutritional status variables of the children (Table 6.7). This differs from the results seen in Minyenye where eating animals and animal diversity was negatively associated with nutritional status.

Table 6.7. Association between the number of animals eaten by the household and animal diversity scores and nutritional status in all children and children under five in Mbwei

	Height z-scores	Weight z-scores	BMI z-scores	MUAC
	Regression coefficient (95% CI)	Regression coefficient (95% CI)	Regression coefficient (95% CI)	Regression coefficient (95% CI)
Children <5				
No. animals eaten				
Unadjusted^	-0.07 (-0.17, 0.03)	-0.01 (-0.10, 0.07)	0.02 (-0.05, 0.10)	-0.04 (-0.14, 0.06)
Adjusted^^	-0.07 (-0.18, 0.04)	0.00 (-0.09, 0.09)	0.04 (-0.04, 0.11)	-0.04 (-0.14, 0.07)
Animal diversity scores				
Unadjusted^	-0.10 (-0.33, 0.13)	-0.02 (-0.23, 0.18)	0.04 (-0.13, 0.21)	-0.06 (-0.29, 0.17)
Adjusted^^	-0.04 (-0.31, 0.22)	0.08 (-0.14, 0.31)	0.12 (-0.06, 0.30)	0.03 (-0.22, 0.29)
All children				
No. animals eaten				
Unadjusted^	-0.01 (-0.09, 0.06)	0.01 (-0.06, 0.07)	0.00 (-0.05, 0.06)	0.03 (-0.08, 0.14)
Adjusted^^	-0.01 (-0.09, 0.06)	0.01 (-0.06, 0.08)	0.01 (-0.05, 0.07)	0.04 (-0.08, 0.15)
Animal diversity scores				
Unadjusted^	-0.06 (-0.24, 0.11)	0.01 (-0.16, 0.17)	0.07 (-0.08, 0.21)	0.04 (-0.24, 0.31)
Adjusted^^	-0.01 (-0.21, 0.18)	0.10 (-0.08, 0.27)	0.14 (-0.01, 0.29)	0.09 (-0.21, 0.38)

^Unadjusted model. N was 197 for height, 100 for weight, 99 for BMI z-scores and 101 for MUAC in children under five. N was 163 for height, 167 for weight, 169 for BMI z-scores and 180 for MUAC in all children.

^^Adjusted for respondent and husband's highest level of education, whether husband is employed as a farmer or other employment, respondent's frequency of employment. N was 95 for height, 98 for weight, 97 for BMI z-scores and 99 for MUAC in children under five. N was 161 for height, 165 for weight, 167 for BMI z-scores and 178 for MUAC in all children.

6.4.2.3 Selling animal products and dietary diversity

Selling animals and animal products is not associated with dietary diversity in Mbwei. No significant associations were seen between whether households sold milk, eggs or meat and respondent's and children's dietary diversity and food variety scores (Table 6.8). Similar non-significant associations were seen in Minyenye in the majority of associations between selling animal produce and measures of diversity in the diet.

Table 6.8. Association between whether animals and animal products are sold and dietary diversity and food variety in respondents and under five year olds in Mbwei

	Dietary diversity score		Food variety score	
	Child <5 years	Respondent	Child<5 years	Respondent
Sold milk and/or eggs				
Unadjusted^	0.44 (-0.67, 1.56)	-0.11 (-1.15, 0.93)	0.35 (-1.93, 2.62)	0.47 (-1.34, 2.27)
Adjusted^^	0.53 (-1.18, 2.24)	0.50 (-0.98, 1.97)	0.20 (-3.11, 3.51)	0.70 (-1.84, 3.24)
Sold animals/meat				
Unadjusted^	0.10 (-1.15, 1.35)	0.15 (-0.84, 1.14)	0.88 (-1.54, 3.30)	1.66 (0.01, 3.31)
Adjusted^^	0.22 (-1.24, 1.68)	0.28 (-0.71, 1.26)	0.67 (-2.39, 3.73)	1.36 (-0.29, 3.00)

^Unadjusted model. N was 31 for children under five and 34 for respondents for sold milk and/or eggs. N was 30 for children under five and 32 for respondents for sold animals/meat.

^^Adjusted for household mobile phone, respondent and husband's highest level of education, whether respondent and husband are employed as a farmer or other employment, respondent has small business on top of farming, respondent earns extra income, number of farms the household uses for growing food, average size of household farms. N was 29 for children under five and 32 for respondents for sold milk and/or eggs. N was 29 for children under five and 31 for respondents for sold animals/meat.

6.4.3.4 Selling animal products and nutritional status

Selling animals and animal products shows mixed associations with nutritional status in Mbwei. Those households selling milk and/or eggs had under five year olds with weight z-scores approximately 0.8 z-scores lower than those not selling milk and/or eggs in the adjusted model (Table 6.9). This is similar to the negative associations seen between selling animal produce and nutritional status in Minyenye. Households selling animals or meat in Mbwei, however, had children with approximately 1cm larger MUAC in both unadjusted and adjusted models.

Table 6.9. Association between whether animals and animal products are sold and nutritional status in all children and children under five in Mbwei

	Height z-scores	**Weight z-scores**	**BMI z-scores**	**MUAC**
	Regression coefficient (95% CI)	Regression coefficient (95% CI)	Regression coefficient (95% CI)	Regression coefficient (95% CI)
Under five year olds				
Sold milk and/or eggs				
Unadjusted^	-0.60 (-1.38, 0.19)	-0.57 (-1.25, 0.12)	-0.20 (-0.76, 0.35)	-0.27 (-1.06, 0.51)
Adjusted^^	-0.73 (-1.65, 0.19)	**-0.82 (-1.62, -0.03)**	-0.34 (-0.98, 0.29)	-0.30 (-1.17, 0.56)
Sold animals/meat				
Unadjusted^	-0.46 (-1.26, 0.34)	-0.23 (-1.00, 0.54)	0.24 (-0.44, 0.92)	0.30 (-0.56, 1.16)
Adjusted^^	-0.56 (-1.55, 0.43)	-0.36 (-1.29, 0.58)	0.24 (-0.57, 1.04)	0.29 (-0.68, 1.25)
All children				
Sold milk and/or eggs				
Unadjusted^	-0.27 (-0.81, 0.26)	-0.27 (-0.77, 0.23)	-0.16 (-0.58, 0.26)	-0.18 (-1.05, 0.70)
Adjusted^^	-0.51 (-1.13, 0.11)	-0.53 (-1.11, 0.05)	-0.23 (-0.73, 0.26)	-0.33 (-1.36, 0.71)
Sold animals/meat				
Unadjusted^	-0.11 (-0.61, 0.39)	-0.03 (-0.55, 0.49)	0.01 (-0.45, 0.47)	**1.04 (0.07, 2.00)**
Adjusted^^	-0.23 (-0.82, 0.36)	-0.08 (-0.69, 0.53)	0.10 (-0.44, 0.64)	**1.14 (0.02, 2.26)**

^Unadjusted model. N was 58 for height, 60 for weight, 59 for BMI z-scores and 60 for MUAC in children under five and was 105 for height, 108 for weight, 107 for BMI z-scores and 112 for MUAC in all children for sold milk and/or eggs. N was 55 for height, 57 for weight, 56 for BMI z-scores and 57 for MUAC in children under five and was 96 for height, 99 for weight, 98 for BMI z-scores and 103 for MUAC in all children for sold animals/meat.

^^Adjusted for household mobile phone, respondent and husband's highest level of education, respondent and husband's frequency of employment, average size of household farms. N was 55 for height, 57 for weight, 56 for BMI z-scores and 57 for MUAC in children under five and was 98 for height, 101 for weight, 100 for BMI z-scores and 103 for MUAC in all children for sold milk and/or eggs. N was 53 for height, 55 for weight, 54 for BMI z-scores and 55 for MUAC in children under five and was 92 for height, 95 for weight, 94 for BMI z-scores and 97 for MUAC in all children for sold animals/meat.

6.5 Discussion

6.5.1 Animal diversity, dietary diversity and nutritional status

Animal diversity and consumption of animals and animal products is linked with higher dietary diversity but not nutritional status. The majority of households in Minyenye and Mbwei both raised animals and consumed some meat and animal products in the last calendar year. The more different types of animals eaten by the households the higher the food variety score of the respondents and the under five year olds were. This did not however convert into better nutritional status. If anything, the opposite was true; in Minyenye either no association or a negative association with nutritional status was seen; the greater the number of animals eaten, the poorer the children's BMI z-scores were. In Mbwei, there were no significant associations seen with any of the nutritional status variables.

A similar pattern was seen with the animal diversity score and dietary diversity and nutritional status in Minyenye. Animal diversity was positively associated with dietary diversity scores in the respondents and food variety scores in both the respondents and the children. However, either no associations were seen with nutritional status or negative associations were seen. In Mbwei, there were no associations seen between the animal diversity score and either the dietary diversity/food variety scores or nutritional status variables. These results indicate that there is no benefit to nutritional status of households raising animals in these communities. These results contradict much of the research in this area (Marquis et al., 1997, Allen et al., 1992, Ekesa et al., 2008, Walingo and Ekesa, 2013).

The negative association seen between meat consumption and BMI z-scores seen in Minyenye may be due to an increased risk of infection introduced by the meat, for example from hookworm (Pasricha et al., 2008), Salmonella or Campylobacter (Pouillot et al., 2012). The negative association seen between animal diversity and nutritional status seen in Minyenye may simply be because those buying meat are better off financially which is associated with better nutritional status (Shack et al., 1990) or it may actually have something to do with raising these animals.

There are a number of differences between these two villages that could help explain the different associations seen. Due to the dry nature of the land in Minyenye, at the time of survey, there was not very much grass available for animals to eat and it was often the children's responsibility to take the animals to graze elsewhere. This may have impacted on the children's energy expenditure and requirements. Kumar and Hotchkiss found that how much children were involved in collection, grazing and agricultural activities was negatively related to their nutritional status in Nepal (Kumar and Hotchkiss, 1988). Despite Mbwei households being more likely to own animals (53% in Mbwei compared to 5% in Minyenye), Minyenye households were more likely to raise animals (86% in Minyenye compare to 69% in Mbwei). Households in Minyenye who were raising animals kept a higher number of those animals compared to Mbwei. Time and energy spent and resource use for animal rearing is therefore higher in Minyenye.

Interestingly, despite these two villages being quite different (Table 4.2, chapter 4 and Table 6.1, chapter 6) associations between animal diversity and eating animal products and meat and dietary diversity and nutritional status are similar in this study. There is evidence in the literature that supplementing children's diets with animal products in a low income country context leads to better diet quality (Murphy et al., 2003), micronutrient status (Siekmann et al., 2003) and cognition (Whaley et al., 2003, Murphy et al., 2003, Siekmann et al., 2003, Neumann et al., 2013). However, this study illustrates that in communities with no outside intervention, households eating meat and animal products do not necessarily have children with better nutritional status. This, along with the results from chapter 5, provide evidence against the pathway illustrated in figure 3.2 a) and b): increases in agrobiodiversity do not necessarily lead to improved nutritional status through increased dietary diversity.

6.5.2 Animal rearing for reasons other than consumption

In attempting to understand why this might be it is important to consider the reasons why people were raising animals. It has been documented (Fafchamps et al., 1998, Dovie et al., 2006) that it is common for animals to be kept, not to be slaughtered for food, but to sell when the household needs money. Animals act as insurance against times of extreme food insecurity or can be sold to cover the cost of school fees (Mazzeo, 2011). Animals raised also fulfil the important task of providing fertiliser for household farms (Powell and Williams, 1994). Often a household would raise animals that they did not own, and therefore could not slaughter for food, in order to get fertiliser for their farms. In these villages it was common for households to raise chickens, not to provide eggs for consumption, but to eat or sell the chickens the eggs would develop into.

6.5.3 Barriers to animal diversity positively impacting nutritional status

Poultry diseases are common in these areas, reducing the number of animals available to eat and sell. It is also common for animals in these villages, especially chickens, to roam in and out of houses and to live in the yards outside the house (personal observation). According to

Upton (2000) it is difficult to control the spread of infectious diseases among such widely dispersed system of poultry production. These practices can lead to zoonosis (Angulo et al., 2000, Butzler, 2004), which impacts negatively on children's nutritional status through infection (Stephensen, 1999).

The impact on caregivers time, although not assessed by this study, should also be considered. It is possible that the amount of time it takes the female head of household to care for these animals takes time away from food preparation and childcare (Guèye, 2005, Kumar and Hotchkiss, 1988).

6.5.4 Selling animals and animal products

There is published evidence that raising animals improves the household income (Nielsen et al., 2003) which, in turn, has been shown to be linked positively to children's nutritional status (Shack et al., 1990, Yang et al., 2012). The results of this study do not support this hypothesis. In Minyenye, either no association or positive associations were seen between animals, meat, eggs or milk being sold and dietary diversity and food variety and either no association or negative associations were seen with nutritional status variables. Eggs/milk being sold was negatively related to height z-scores and animals or meat being sold was negatively associated with weight, BMI and MUAC. In Mbwei, all associations between animals and their products being sold and dietary diversity and food variety were non-significant. Milk and/or eggs being sold was negatively associated with weight in the under five year olds and meat or animals being sold was positively associated with MUAC in children. That selling animals and their products was not positively associated with nutritional status variables would suggest that if households were making extra money by raising and selling animals, this was not getting fed back into buying household food.

6.5.5 Limitations and strengths

A number of the limitations outlined in chapter 4, such as translation, study dynamics and the research environment are also relevant to the results in this chapter. Translation errors may have affected the accuracy of the studies results recorded. Cross cultural dynamics and having family members present at the interview could have affected the honesty of the responses from the participants. Additionally, results are cross-sectional and based on respondent's memory of household consumption and animal rearing practices over the previous calendar year. This recall bias may have affected the accuracy of the results given by the participant. However, the respondent was well placed to answer questions about both diet and farming practices due to her central role in food production and preparation. The questionnaire collected very thorough information on the animal foods consumed and the animals raised by the household. Data was translated at the time of data collection and recorded by the researcher. This allowed information to be checked on collection to minimise missing data.

6.6 Conclusions

This chapter presents detailed, household level information on animal consumption and animal diversity of households and whether this animal produce was sold. It tests associations between these practices and both dietary diversity and nutritional status in order to inform understanding on how animal food production practices are related to diet and nutritional status in these rural villages.

The key results of this chapter are that, despite having higher dietary diversity, households eating more animal products and households with higher animal diversity scores had poorer nutritional status in Minyenye. Mbwei households eating more animal products have members with higher dietary diversity but no associations were seen with nutritional status. Additionally, no associations were seen with animal diversity and dietary diversity or nutritional status. Selling animals and animal products is not associated with dietary diversity in either village but households in Minyenye selling animals and animal products have children with poorer nutritional status. These results go against much of the literature published in this area, which generally encourages the consumption of animal products in low income countries in order to improve nutritional status.

The mixed associations between raising animals and nutritional status raise questions about how successful interventions which solely encourage households to raise animal s in order to improve nutritional status are likely to be in low income countries. Rural households reporting eating and raising animals were worse off nutritionally than those not eating and raising animals in both villages despite having different animal rearing, dietary and social practices.

Additionally, exploring the reasons why supplying animal foods to communities has a different effect on diet and health than local improvements in animal production could provide some interesting lessons on effective interventions. Reasons for raising animals, the uses these animals are put to and animal rearing practices need to be more fully investigated before interventions designed to increase animal rearing in rural areas are implemented.

Meat and animal products are rich sources of protein and essential micronutrients. As such, they have potential to improve nutritional status in populations that are malnourished. The projects, perhaps surprising, results again highlight the complexity of the determinants of diet and nutritional status in these contexts. Viewing this project's results in the context of the wider literature, which has shown animal rearing interventions to be more successful as part of a multi component projects, should encourage researchers and development organisations into more thorough approaches to combating malnutrition. The results presented in this chapter suggest caution and in-depth research into local contexts and practices before outside intervention by researchers and development organisations attempting to improve nutritional status through encouraging the rearing of livestock.

Chapter 7:
Investigating the relationships between land cover, dietary diversity and nutritional status in a national sample in Tanzania

7.1 Chapter summary

The previous three results chapters have presented the results and analyses of primary data collected at local village scales. This chapter broadens analysis to investigate the factors of interest at the national level. Due to data availability at the national level there are a number of differences in the methodology and resulting data as compared to chapter 5. This earlier chapter focused on agrobiodiversity as measured at the level of household farms, this chapter has taken a broader view and links land cover to individual diet and nutrition variables. This chapter meets objective 5 of the thesis (Investigate the socio-demographic determinants of dietary diversity and nutritional status and explore the relationships between land cover, dietary diversity and nutritional status in children under five years at a national level, in Tanzania). The chapter objectives are:

Objective 7A: To investigate whether demographic, social, agricultural and dietary factors are associated with dietary diversity and nutritional status in under five year olds in Tanzania.

Objective 7B: To investigate whether dietary diversity is associated with nutritional status in under five year olds in Tanzania.

Objective 7C: To investigate whether dietary diversity and nutritional status in under five year olds vary spatially in Tanzania.

Objective 7D: To investigate whether land cover is related to dietary diversity and nutritional status in under five year olds in Tanzania.

The results in this chapter show that those children with higher dietary diversity had lower height for age. The later children had complementary foods introduced to their diet the lower their height for age. Children from households using piped, tank, rain or bottled water for drinking or taking action to make water safe to drink had higher height for age. Those recently experiencing diarrhoea had poorer nutritional status. The more agricultural land cover surrounding the DHS EA centre point the higher the respondent and child dietary diversity scores were but the lower the children's height. More agricultural and forest land cover was associated with a higher weight for height.

These results contribute knowledge about the determinants of nutritional status in Tanzania. In contradiction to much of the literature carried out in low income countries, dietary diversity was negatively related to nutritional status. To date there has been little research linking land cover to diet and nutritional status, this research provides some important data to fill this gap.

7.2 Introduction

Chapters 4 to 6 have suggested and discussed some potential determinants of nutritional status in low income countries that were identified by work carried out in two villages in Tanzania. To broaden the usefulness of this work this chapter will conduct similar analyses using data that is less detailed but from a much larger, nationally representative study conducted in Tanzania in 2010; the Demographic and Health Survey (DHS). In order to explore the relationship between diet, nutritional status and agrobiodiversity at this level, land cover maps are used as a proxy for agrobiodiversity. Relationships between land cover as well as social, demographic, agricultural and dietary factors and children's nutritional status will be explored.

Satellite data comes from environmental sensors that have been placed in orbit to observe the earths surface (Brown, 2009). Data from this remote sensing technique has been used to determine land cover. Land cover has been defined as the observed (bio)physical cover on the earth's surface by Di Gregorio and Jansen (1998). There are a number of reasons why land cover might be related to diet and health. One of these reasons is that land cover and biodiversity are related. There is a strong precedence for using satellite data to estimate biodiversity of plant populations (Skidmore et al., 2003, Walker et al., 1992, Tucker and Sellers, 1986) and to estimate vegetation or land cover in order to locate animal habitats (Austin et al., 1996, Homer et al., 1993, Miller and Conroy, 1990).

Few studies, however, have used satellite data to link land use or land cover to diet and human health (Xu et al., 2008, Brown, 2009, Johnson et al., 2013, Powell et al., 2011). There are many ways in which changes in land use can impact on human health including risk of flash flooding, risk of malaria and changes to food production (Xu et al., 2008). Brown (2009) outlines how remote sensing can be used to identify conditions which may lead to famine in particular spatial, temporal and social contexts. Relevant conditions identified through remote sensing include climate, specifically rainfall, and plant growth which, Brown states, can be used to estimate agricultural production.

A study published in 2013 (Johnson et al., 2013) used Normalized Difference Vegetation Indices (NDVI) and Vegetation Continuous Fields (VCF) based on Moderate Resolution Imaging Spectroradiometer (MODIS) satellite data collected for Malawi and linked percentage forest cover to dietary diversity, intake of vitamin A rich foods, incidence of diarrhoea and rates of stunting. They found that children living in areas with more forest cover consumed more vitamin A rich foods and were less likely to have diarrhoea. Powell et al (Powell et al., 2011) calculated tree cover from Landsat eTM+ and Probationary System of Earth Observation (SPOT) satellite data to investigate forest cover and dietary intake in the East Usambara mountains. While the relationship between dietary diversity and tree cover were not directly examined in this study they did find that households with greater tree cover nearby were more likely to consume forest foods and individuals using forest foods had higher dietary diversity.

Linking large scale measures of vegetation or land cover to health outcomes is a relatively new area of inquiry. This chapter will add to this area by providing data on the association between land cover, dietary diversity and nutritional status at a national level in Tanzania. This chapter will also provide additional data on how dietary diversity and nutritional status are related in Tanzania and on other social and demographic factors associated with nutritional status to add to the data from the primary data collection. This national level data will strengthen or contend the hypotheses discussed in the previous chapters. How the primary data collection and this national level analysis come together will be discussed further in chapter 8.

7.3 Methods

7.3.1 Data sources

7.3.1.1 Demographic and Health Survey data

The ‘Measure DHS’ project (Demographic and Health Surveys) has been collecting nationally representative data on maternal and child health, gender, and nutrition across the world since 1984 (Measure DHS, 2014). The project is funded by the US Agency for International Development (USAID). DHS is a source of good quality data on a wide range of demographic and health factors in Tanzania (The DHS Program, 2014a). The DHS survey carried out in Tanzania in 2010 (DHS VI) was used for these analyses. GPS co-ordinates were captured at the centre point of each of the 475 clusters included in this survey. Clusters were based on Enumeration Areas (EA) defined by the 2002 population and housing census. These are the units of randomisation for the DHS and household data collection takes place within the selected EA, an average of 15 households per EA. Seventy-six percent of clusters were rural and 24% were classed as urban. 19% of the clusters were on Zanzibar or Pemba and 5% were in Dar es Salaam.

This research project was registered with 'Measure DHS'. The 'Individual recode dataset', for the respondent and child data, and 'Household recode dataset', for household level data were downloaded (The DHS Program, 2014c) as Stata files. Variables relevant to this project were selected from these datasets and combined into one Stata file using the household ID to merge the variables from the two different datasets together. Average dietary diversity, nutrition, demographic and social variables at DHS EA level were linked to the GPS co-ordinates through the EA number present in each original dataset.

The outcomes of interest are nutritional status and dietary diversity. Nutritional status measures that were used are BMI of the respondents and height for age and weight for height z-scores in the respondent's youngest child.

In the DHS, dietary diversity was calculated from a 24 hour recall for the respondents and their youngest child. The dietary diversity data available through the DHS is presented as a 'yes', 'no' or 'don't know' for each food category. This was recoded into a dietary diversity score based on the food groups used in chapters 4 to 6 ('Cereals, roots and tubers'; 'vitamin A rich vegetables, tubers and fruit'; 'other vegetables'; 'other fruits'; 'flesh meats, organ meats, fish and insects'; 'eggs'; 'legumes, nuts and seeds'; 'milk and milk products'; 'oils, fats and sweets'), as recommended by the FAO (2004) dietary diversity workshop (FAO/WHO/IFPRI, 2004). Unfortunately, in the DHS questionnaire other vegetables and other fruit were asked in one question so the dietary diversity score used for this chapter is out of eight food categories instead of nine.

The DHS collected information on basic demographics and background, reproduction, pregnancy, breastfeeding, health, marriage, husband's background, women's work and residence throughout Tanzania. Potentially confounding variables were identified from these categories using the DAG described in chapter 3 (page 73, Figure 3.16). Whether these variables confounded the relationships between land cover and dietary diversity and nutritional status was checked by adding them to the model one by one and seeing if they modified the regression coefficient substantially (criteria varied from approximately >0.02 to >0.05 depending on the size of the regression coefficients). They were included in the multivariable model if they confounded the relationships. Questions on the number of meals per day, number of days in the last seven days meat and fish were eaten and some food preparation data were also collected. DHS VI has specific questions on agriculture directed at the women respondents that were used in the analysis. These included whether they had land usable for agriculture and how much land.

7.3.1.2 Land cover

The Land Cover Classification System (LCCS) was developed by the United Nations Food and Agriculture Organisation (UNFAO). It is an attempt to develop an internationally agreed reference base for land cover. It is a hierarchical system based on a set of independent diagnostic criteria eg. life form, cover, height and density (Di Gregorio and Jansen, 1998). It is a flexible system with two main phases. The first phase distinguishes eight major land cover types:

- Cultivated and Managed Terrestrial Areas
- Natural and Semi-Natural Terrestrial Vegetation
- Cultivated Aquatic or Regularly Flooded Areas
- Natural and Semi-Natural Aquatic or Regularly Flooded Vegetation
- Artificial Surfaces and Associated Areas
- Bare Areas
- Artificial Water bodies, Snow and Ice, and
- Natural Water bodies, Snow and Ice.

In the second phase classes are created using pre-defined classifiers which are specific to each of the above land cover types. The result is a system that allows comparisons of land cover over different smaller areas and projects but is flexible enough to accurately categorise different areas. For example, within the ‘Cultivated and Managed Terrestrial Areas’ land cover type sits the following classes: ‘Post-flooding or irrigated croplands (or aquatic)’, ‘Rainfed croplands’, ‘Mosaic cropland (50-70%) / vegetation (20-50%)’ and ‘Mosaic vegetation (50-70%) / cropland (20-50%)’. The LCCS was used to define land cover for land cover maps of Tanzania produced by GlobCover 2009.

7.3.1.3 GlobCover 2009 data

A global land cover map was produced in 2010 by the European Space Agency (ESA) and the Université catholique de Louvain based on data collected from January to December of 2009. The map is based on MERIS (Medium Resolution Imaging Spectrometer Instrument) fine resolution surface reflectance mosaics (Bontemps et al., 2011). MERIS is a wide field of view pushbroom imaging spectrometer on ENVISAT, an ESA environmental satellite. It measures 15 spectral bands of solar radiation that is reflected by the earth (Rast et al., 1999). The map is in geographic coordinates in a Plate-Carrée projection (WGS84 ellipsoid) (Bontemps et al., 2011).

The land cover map goes through a number of pre-processing (geometric corrections, cloud screening, atmospheric corrections, bidirectional reflectance distribution function correction and time compositing) and classification stages (spectro-temporal classification, labelling, validation). The final land cover map has a 300m resolution and counts 22 GlobCover categories within the 8 land cover classes defined with the United Nations LCCS, listed above (Bontemps et al., 2011).

GlobCover 2009 data was downloaded from the ESA GlobCover Portal (European Space Agency, 2010). The data was unzipped and added to the base map of Africa in ArcGIS version 10. The land cover categories for GlobCover2009 are presented in Figure 7.1. Those land cover categories that were assigned to the three categories used in this study: Agricultural, Forest and Other land cover are presented in Box 7.1-7.3. These categories are very similar to those used in site selection (Box 3.1 and 3.2) but are stricter on what constitutes biodiverse forest. The decision on what land cover categories were assigned to agricultural, forest and other land cover were based on the LCCS categories. The agricultural land cover is identical to the croplands used for site selection and it covers all the categories of the LCCS 'Cultivated Terrestrial Areas and Managed Lands'. The forest land cover category includes 6 out of the 8 categories of the LCCS 'Natural and Semi-natural Terrestrial Vegetation: Woody-Trees' and all three of the LCCS 'Natural and Semi-natural Aquatic Vegetation'. The other land cover category includes 2 categories from LCCS 'Natural and Semi-natural Terrestrial Vegetation: Woody-Trees' and all those in the Shrub and Herbaceous sub-section of LCCS 'Natural and Semi-natural Terrestrial Vegetation' as well as those in LCCS 'Artificial Surfaces', 'Bare Areas' and 'Inland Water bodies, snow and ice'.

Box 7.1. Land cover types classified as agricultural land cover

When assessing the land cover in the surrounding 5km of the DHS EA centre points in ArcGIS the following codes were used to represent 'agricultural' land cover:

1) Post-flooding or irrigated croplands (none present in Tanzania)

2) Rainfed croplands

3) Mosaic Cropland (50-70%) / Vegetation (grassland, shrubland, forest) (20-50%)

4) Mosaic Vegetation (grassland, shrubland, forest) (50-70%) / Cropland (20-50%)

Box 7.2. Land cover types classified as forest land cover

Whether biodiverse land falls within 5km of the DHS centrepoint is also of interest in this chapter. The land cover classes used to represent the more biodiverse 'forest' areas are:

1) Closed to open (>15%) broadleaved evergreen and/or semi-deciduous forest (>5m)

2) Closed (>40%) broadleaved deciduous forest (>5m)

3)Open (15-40%) needleleaved deciduous or evergreen forest (>5m);

4) Mosaic Forest/Shrubland (50-70%) / Grassland (20-50%)

5) Mosaic Grassland (50-70%) / Forest/Shrubland (20-50%)

6) Closed (>40%) broadleaved forest regularly flooded - Fresh water

7) Closed (>40%) broadleaved forest or shrubland permanently flooded – Saline or brackish water (none present in Tanzania)

8) Closed to open (>15%) vegetation (grassland, shrubland, woody vegetation) on regularly flooded or waterlogged soil - Fresh, brackish or saline water.

Box 7.3. Land cover types classified as other land cover

The land cover categories that fall into the 'other' category, considered to be not biodiverse, include:

1) Open (15-40%) broadleaved deciduous forest (>5m);

2) Closed to open (>15%) mixed broadleaved and needleleaved forest (>5m);

3) Closed to open (>15%) shrubland (<5m)

4)Closed to open (>15%) grassland

5) Sparse (>15%) vegetation (woody vegetation shrubs, grassland)

6) Artificial surfaces and associated areas (urban areas >50%)

7) Bare areas

8) Water bodies

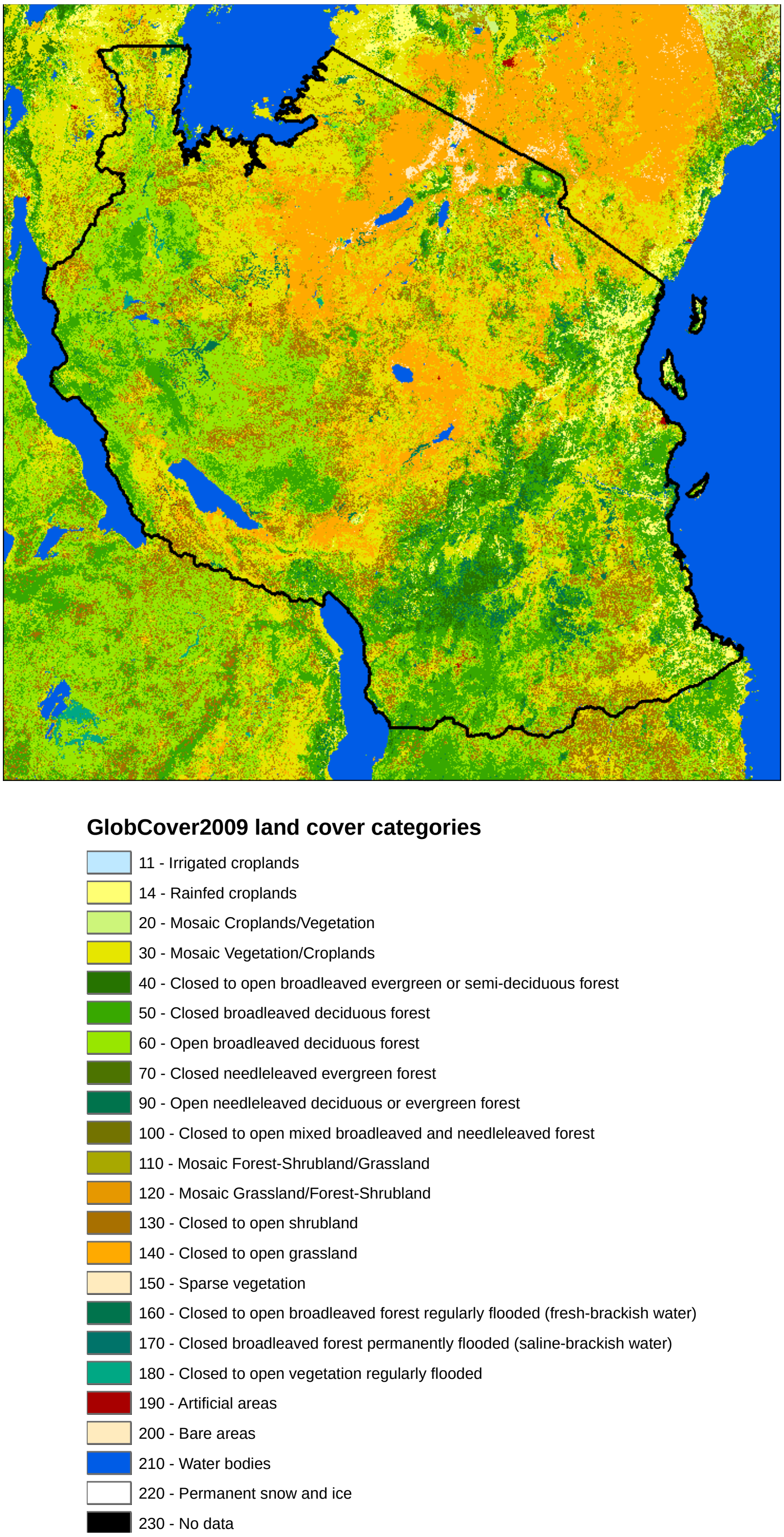


Figure 7.1. GlobCover2009 land cover map of Tanzania

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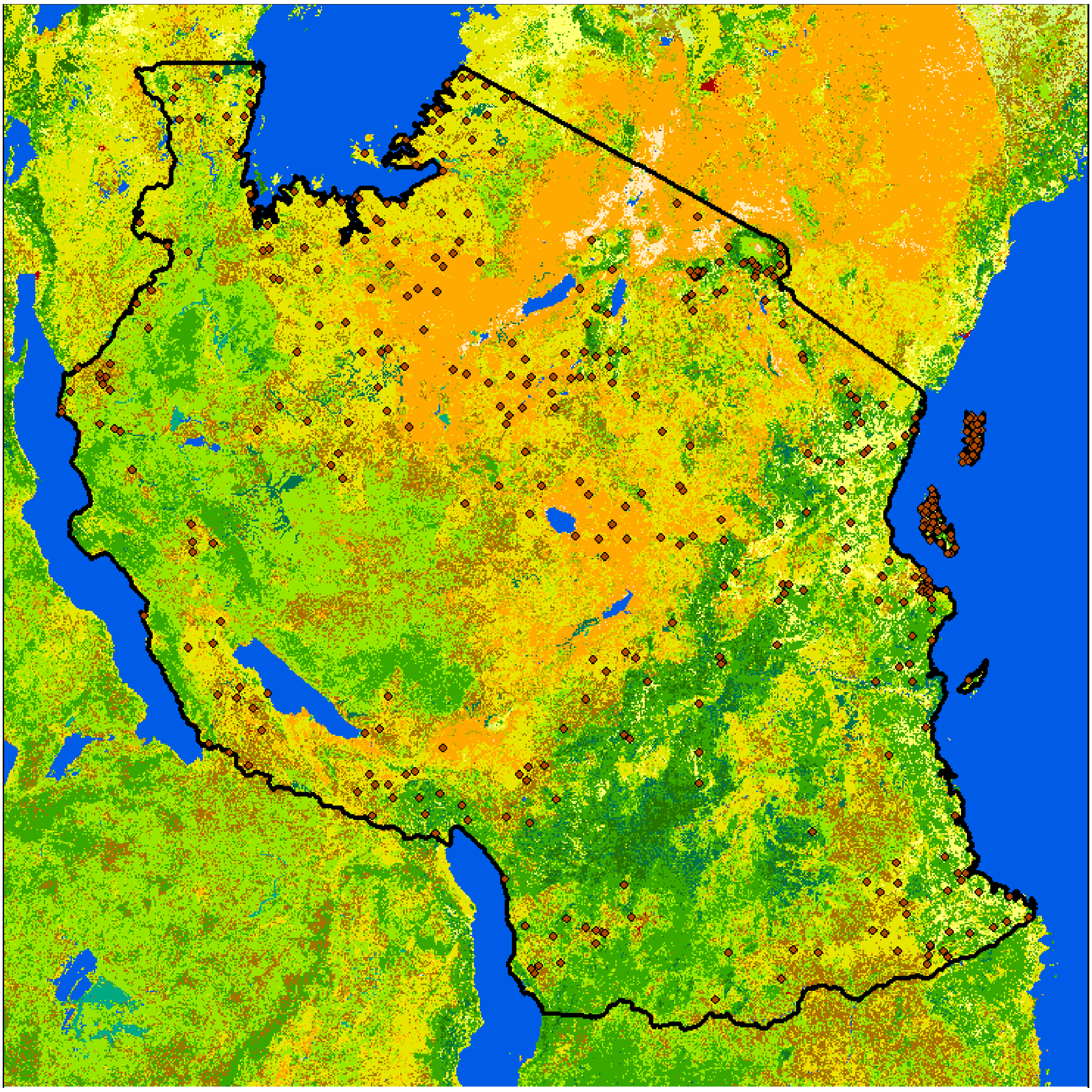

Figure 7.2. Globcover 2009 map of Tanzania with DHS EA centre points

7.3.2 Data analysis

7.3.2.1 Descriptive statistics

Figure 7.2 shows the land cover map with the location of the DHS EA used in the analysis. DHS EA are not distributed evenly throughout the country but are designed to collect representative data on the population at national and regional levels.

Basic descriptive statistics from the DHS data were calculated using Stata (version 12). Means (95% confidence intervals) and percentages (95% confidence Intervals) are presented for these descriptive results. BMI cut-offs of <20, 25-30 and >30 were used to determine whether the respondent was categorised as underweight, overweight or obese. A cut-off of -2 was used to define whether a child was stunted (height for weight z-scores) or wasted (weight for height z-scores).

7.3.2.2 Linear regression analysis

Linear regression was used to investigate the relationships between demographic, social, agricultural and dietary factors and dietary diversity and nutritional status variables (chapter objective 7A). Factors potentially associated with nutritional status were identified through the literature and the results presented in chapters 4-6. The DHS is a rich dataset with many similar variables likely to be reflecting the same underlying construct. Multi-collinearity negatively effects the integrity of the regression model (UCLA: Statistical Consulting Group, 2014). In order to avoid this factors were grouped into categories (wealth; marital status; education; literacy; employment; urban/rural; sanitation; breastfeeding; complementary feeding; health; supplementation) and redundant variables within these categories were disregarded. This meant that there were only between 1 and 3 variables per category in the models (see Table 7.1). Univariate and multivariable regression with all relevant variables included in the model are presented.

Table 7.1. The 17 covariates in 10 categories identified as being potential determinants of nutritional status

Area	**Employment**
• Urban or rural	• Respondent's occupation
• Distance to nearest health facility	• Husband's occupation
Demographics	**Wealth**
• Current marital status	• Wealth index
Education	**Drinking water/sanitation**
• Education (years)	• Source of drinking water
• Husband's education (years)	• Something done to make water safe to drink
Literacy	**Vaccinations and medication**
• Literacy	• Received vitamin A in last 6 months
Health	**Breastfeeding and complementary feeding**
• Children < 5 slept under bednet last night	• Given foods/liquids other than breastmilk in first 3 days
• Had diarrhoea recently	• Age when first fed with other food
	• Currently being breastfed

As this chapter is specifically focused on the relationship between dietary diversity and nutritional status separate regression analyses were conducted to investigate these relationships (chapter objective 7B). Variables that could potentially confound the relationship between dietary diversity and height for age and weight for height z-scores in the youngest child were identified using a DAG, as described in chapter 3 (page 73, figure 3.16). Then, for the multivariable regression, as in chapter 4-6, variables were added to the model one by one to determine whether they influenced the regression coefficients for dietary diversity. When the potential confounders modified the coefficient substantially they were included in the model. Variables included were: respondent's education in single years; frequency of watching television; currently breastfed; age when first fed with other food; wealth index; respondent employed all year or seasonally; respondent works for family, other, self.

Cluster analyses were carried out in Satscan version 9.1.1 in order to investigate whether dietary diversity and nutritional status vary spatially (chapter objective 7C). This program uses the GPS co-ordinates collected at DHS EA level to identify clusters of both high and low levels of the dietary diversity and nutritional status variables. Satscan clusters can be described as areas where the value of the characteristic of interest is unusual as compared to the area surrounding it. Clusters of the continuous variables dietary diversity, height for age and weight for age z-scores in children and dietary diversity and BMI in the respondents were analysed using a continuous normal model. This model, designed for continuous data, uses a likelihood function based on a normal distribution (Kulldorff, 2005). For the binary variables of whether the children were stunted or wasted a Bernoulli Model was used. The Bernoulli Model codes individuals as cases or controls, in this instance a case would be a child that was stunted and a control would be a child that was not stunted. For the analysis Satscan draws all possible windows, of variable sizes, centred on the DHS EA midpoints calculating a scan statistic for the normal models and prevalence for the Bernoulli models and these statistics are compared between within the window and outside the window. Those windows that have the scan statistic which is least likely due to chance is the most likely spatial cluster. P-values are assigned to the clusters (Kulldorff, 2005). The cluster output of the most likely clusters were then mapped by GPS co-ordinates using ArcGIS version 10 and the results which show where the clusters of high and low values are situated are presented as maps of Tanzania.

7.3.2.3 Land cover analyses

To investigate whether land cover is related to dietary diversity and nutritional status (chapter objective 7D) two analyses were carried out using data derived from the GlobCover 2009 land cover map using ArcGIS version 10. The dietary diversity and nutrition data averaged at DHS EA level was linked with this land cover data through the DHS EA GPS co-ordinates. These analyses were carried out to determine whether surrounding land cover was associated with diet and nutrition outcomes in the DHS survey.

The first analysis aimed to present the percentage agricultural, forest and other land cover types surrounding the DHS EA in high and low Satscan clusters in order to determine whether land cover was different around areas with high dietary diversity or good nutritional status as compared to areas with poor dietary diversity and nutritional status. The proportion of the total area that was defined as agriculture, forest and other was calculated in buffer zones 5km from the DHS EA centre point. Figure 7.3. illustrates the buffer zones around the DHS centre points and shows the different areas each land cover type occupies. The light green area represents the 5km buffer around the DHS centre points (original categories are retained). ArcGIS was used to sum these areas by each of the 22 different land cover types. All the land cover types defined in this project as agricultural, forest were then added together in order to calculate the total proportion of the buffer they occupy. The same was done for all land cover types defined as other. For example, in the image on the right the majority of the land cover is "Rainfed croplands"(yellow) with some "closed to open (>15%) grassland" (orange) and "closed to open (>15%) shrubland (<5m)" (brown). A high proportion of the 5km buffer will be calculated to be rainfed croplands which is classed by this project as agricultural land cover.

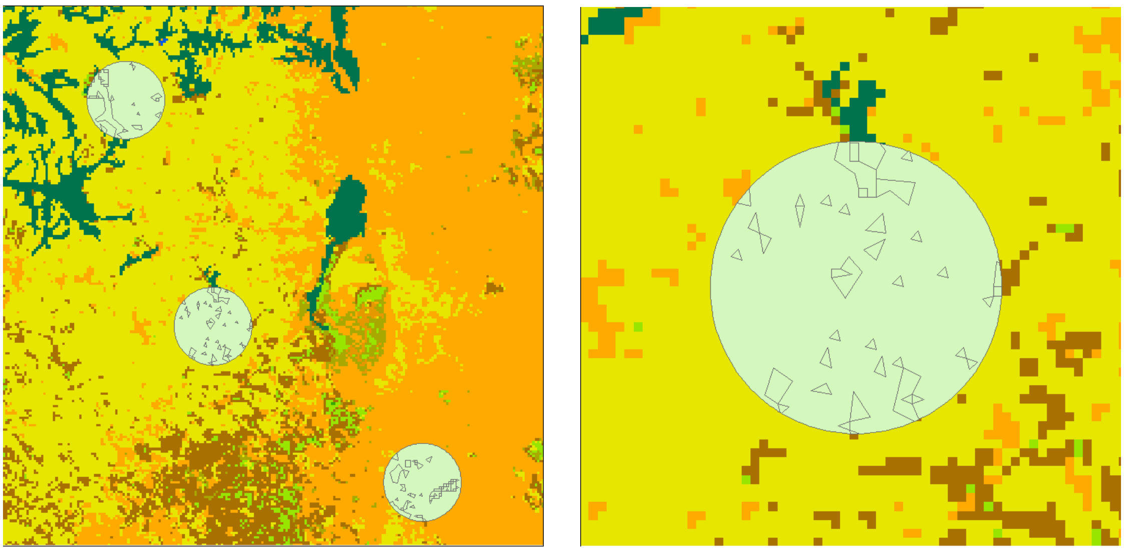

Figure 7.3. Globcover2009 map with the 5km buffer zones around the DHS EA centre point marked in green; the image on the right is a close up look at the central cluster from the image on the left (different colours represent different land cover types)

This information was then linked to the Satscan clusters described above. The land cover surrounding the high and low clusters of dietary diversity and nutritional status variables were summed and the average proportion of the surrounding land cover that fell into the agriculture, forest and other categories is presented. For example, the proportion of agricultural land cover in the surrounding 5km of the DHS centre points identified in the Satscan cluster of high dietary diversity and the proportion of agricultural land cover in the area surrounding those DHS in the low dietary diversity Satscan cluster were calculated and can be compared in the results table. This was repeated for the following variables with significantly high and low Satscan clusters; child dietary diversity, height for age z-scores, weight for height z-scores and mothers BMI.

In the second analysis, regression was used to determine whether land cover is significantly associated with average dietary diversity and nutritional status variables. The percentage of agricultural, forest and other land cover in the 5km surrounding the DHS centre points were used as the independent variables in the regression models. Average dietary diversity and nutritional status variables for each DHS EA were the dependent variables. Both unadjusted models and models adjusted for whether the DHS EA was defined as urban or rural were run.

7.4 Results

7.4.1 Demographic characteristics of participants in the Tanzanian 2010 DHS

A total of 10139 female respondents took part in the DHS survey. Of the respondents that had children under the age of five, they had an average of 1.9 children each (Table 7.2). Over 60% of these respondents were married with approximately 30% having never married and about 10% being widowed, divorced or separated. The respondents and their husbands had, on average, 6 years of education. Approximately 70% of respondents fell in to the highest level of literacy; 'can read whole sentences' while almost 30% couldn't read at all. Fifty percent of respondents and 60% of their husbands worked in agriculture. Twenty-four percent of respondents and less than 1% of their husbands reported not working.

Table 7.2. Respondent's characteristics information in the Tanzanian 2010 DHS

Total number of respondents	10139
Number of children under five per respondent (mean (95% CI))*	1.8 (1.8, 1.9)
Marital status (% (95% CI))	
Married/living together	62. (61.7, 63.5)
Never married	26.7 (25.9, 27.5)
Widowed/divorced/separated	10.7 (10.1, 11.3)
Education (mean (95% CI))	
Average number of years of education	5.9 (5.8, 5.9)
Husband's average number of years of education	6.1 (6.0, 6.2)
Literacy (% (95% CI))	
Cannot read at all	27.4 (26.6, 28.3)
Able to read only parts of sentence	5.4 (5.0, 5.8)
Able to read whole sentence	67.1 (66.2, 68.0)
Respondent's employment (% (95% CI))	
Working in agriculture	48.8 (47.9, 49.8)
Working in other area	26.8 (26.0, 27.7)
Not working	24.3 (23.5, 25.1)
Husband's employment (% (95% CI))	
Working in agriculture	58.6 (57.5, 59.6)
Working in other area	41.1 (40.0, 42.2)
Not working	0.4 (0.2, 0.5)

*excluding those with no children under five

Table 7.3 shows the households characteristics from the DHS survey. Two thirds of households had a radio in the household and over half had mobile phones and a bicycle. Under 20% had electricity. Around a quarter of the households got their water from a public or neighbours tap/standpipe and another quarter from an open well. Twenty percent got their water from a borehole, river, dam, lake, pond, stream, canal or spring. Almost 15% used piped water. Over 60% of households took no action to make their drinking water safe. Almost 30% of households boiled their drinking water to make it safe. On average it took household members approximately 30 minutes to collect their drinking water. Over 50% of households used an open pit latrine toilet while 17% used a closed or improved pit latrine and another 17% had no facility available to them. 12% used a flush toilet.

Table 7.3. Household characteristics in the Tanzanian 2010 DHS

Characteristics and ownership (% (95% CI))	
Radio in household	66.0 (65.0, 66.9)
Mobile phone in household	57.3 (56.4, 58.2)
Bicycle in household	51.1 (50.1, 52.1)
Household has electricity	19.1 (18.4, 19.9)
Television in household	17.1 (16.4, 17.9)
Refrigerator in household	9.5 (9.0, 10.0)
Motorcycle/scooter in household	4.9 (4.5, 5.3)
Car/truck in household	2.8 (2.5, 3.1)
Water source (% (95% CI))	
Public/neighbours tap/standpipe	27.7 (26.9, 28.6)
Open well	23.1 (22.2, 23.9)
Borehole/river/lake/spring etc	21.6 (20.8, 22.4)
Piped water	13.6 (12.9, 14.2)
Protected well	11.3 (10.7, 11.9)
Tank	1.7 (1.5, 2.0)
Rainwater	0.7 (0.6, 0.9)
Bottled	0.3 (0.2, 0.4)
Take action to make water safe (% (95% CI))*	
Nothing	61.8 (60.9, 62.7)
Boil	29.2 (28.4, 30.1)
Other e.g. Strain, let settle	9.0 (8.4, 9.5)
Time to get water minutes (mean (95% CI))	27.6 (26.9, 28.3)
Type of toilet (%)	
Open pit latrine	54.4 (53.4, 55.3)
Closed or improved pit latrine	16.5 (15.8, 17.2)
No facility	16.6 (15.9, 17.3)
Flush	12.4 (11.7, 13.0)
Other	0.2 (0.1, 0.3)

Respondents had an average BMI of approximately 23kg/m^2: 27% were underweight, 51% were normal weight, 16% were overweight and 6% were obese (Table 7.4). The height for age z-scores for the respondent's youngest child was -1.5 with 38% of these children being classed as stunted. The average weight for height z-scores was -0.1; 7% of the children were wasted.

Table 7.4. Respondent's and their youngest child's nutritional status

Respondents(N)	10041
BMI (kg/m^2, mean (95% CI))	22.7 (22.6, 22.8)
Underweight (% (95% CI))	26.9 (26.0, 27.7)
Normal weight (% (95% CI))	51.1 (50.2, 52.1)
Overweight (% (95% CI))	15.7 (15.0, 16.3)
Obese (% (95% CI))	6.3 (5.9, 6.8)
Children under 5 (N)	4730
Height for age z-scores (mean (95% CI))	-1.5 (-1.5, -1.4)
Weight for height z-scores (mean (95% CI))	-0.1 (-0.1, -0.0)
Stunted (% (95% CI))	36.4 (35.1, 37.7)
Wasted (% (95% CI))	7.4 (6.7, 8.1)

7.4.2 Demographic and social factors, dietary diversity and nutritional status.

The mean (95% CI) dietary diversity score for respondents and their youngest child was 3.03 (3.00, 3.07) and 2.56 (2.50, 2.61) out of 8 categories. Focusing on the adjusted regression model which was created including all variables in table 7.5 (respondent's education, husband's education, respondent's occupation, husband's occupation, current marital status, wealth index, literacy, urban/rural, time to get to water source, currently breastfed, age when first fed with other food, given foods/liquids other than breastmilk in first 3 days) the respondent's education remains significantly positively associated with both the child's and the respondent's dietary diversity score. For example, for each additional year the respondent was in education the child's dietary diversity scores increased by 0.06. The respondent's and their husband's occupation remains associated with the respondent's dietary diversity only. Diversity is highest for professional, technical, administrative and service occupations but interestingly, agricultural occupation is now positively associated with the respondent's dietary diversity. A higher wealth index is associated with higher dietary diversity in both the child and the respondent. Living rurally was associated with a lower dietary diversity in the respondents only.

On average (95% CI) the youngest child was breastfed until they were 19.3 (19.0, 19.5) months old. 29.8% of children were given food or drink other than breastmilk in their first three days of life. On average (95% CI) children were 3.8 (3.7, 3.8) months when they were first fed foods or drinks other than breastmilk. Children that are currently being breastfed have lower dietary diversity and children who were older when complementary feeding began have higher dietary diversity.

Table 7.5. Association between household and demographic variables and dietary diversity in the respondent and their youngest child

	Youngest child dietary diversity score		**Respondent dietary diversity score**	
	Unadjusted	**Adjusted^**	**Unadjusted**	**Adjusted^**
	Regression coefficient (95% CI)	Regression coefficient (95% CI)	Regression coefficient (95% CI)	Regression coefficient (95% CI)
Demographics				
Education (years)	**0.08 (0.07, 0.10)**	**0.06 (0.03, 0.09)**	**0.08 (0.07, 0.09)**	**0.04 (0.01, 0.06)**
Husband's education (years)	**0.07 (0.05, 0.08)**	0.01 (-0.01, 0.03)	**0.07 (0.06, 0.08)**	0.01 (-0.00, 0.02)
Respondent's occupation				
Not working	-0.05 (-0.20, 0.10)	0.28 (-0.23, 0.79)	-0.02 (-0.13, 0.09)	0.26 (-0.71, 0.19)
Professional, technical, managerial or clerical	**1.14 (0.72, 1.57)**	-	**0.83 (0.53, 1.13)**	-0.31 (-0.90, 0.28)
Agricultural	**-0.31 (-0.43, -0.20)**	0.23 (-0.28, 0.74)	**-0.40 (-0.48, -0.32)**	-0.06 (-0.51, 0.39)
Household or domestic	0.32 (-0.27, 0.91)	0.06 (-0.70, 0.82)	0.38 (-0.03, 0.80)	-
Services	**0.44 (0.07, 0.82)**	0.15 (-0.45, 0.75)	**0.63 (0.37, 0.90)**	-0.06 (-0.58, 0.46)
Manual	**0.36 (0.20, 0.51)**	0.36 (-0.15, 0.86)	**0.48 (0.37, 0.59)**	0.02 (-0.42, 0.48)
Husband's occupation				
Not working	0.16 (-1.10, 1.41)	0.49 (-0.80, 1.77)	-0.03 (-0.98, 0.92)	0.35 (-0.68, 1.38)
Professional, technical, managerial or clerical	**0.57 (0.31, 0.83)**	0.38 (-0.34, 1.09)	**0.68 (0.49, 0.86)**	**0.79 (0.24, 1.35)**
Agricultural	**-0.31 (-0.43, -0.19)**	0.32 (-0.36, 1.00)	**-0.42 (-0.50, -0.34)**	**0.56 (0.03, 1.09)**
Household or domestic	0.44 (-0.34, 1.23)	-	-0.03 (-0.58, 0.52)	-
Services	**0.72 (0.50, 0.95)**	0.64 (-0.07, 1.34)	**0.55 (0.39, 0.71)**	**0.77 (0.23, 1.32)**
Manual	-0.02 (-0.16, 0.11)	0.14 (-0.55, 0.82)	**0.16 (0.07, 0.26)**	0.45 (-0.07, 0.98)

Table continued on page 211.

	Youngest child dietary diversity score		Respondent dietary diversity score	
	Unadjusted	**Adjusted^**	**Unadjusted**	**Adjusted^**
	Regression coefficient (95% CI)	Regression coefficient (95% CI)	Regression coefficient (95% CI)	Regression coefficient (95% CI)
Current marital status				
Never married	-0.02 (-0.27, 0.23)	-	0.15 (-0.02, 0.33)	-
Married/living together	-0.12 (-0.29, 0.04)	0.02 (-0.18, 0.21)	-0.04 (-0.16, 0.08)	-0.03 (-0.18, 0.12)
Widowed, divorced or separated	**0.21 (0.00, 0.42)**	-	-0.04 (-0.19, 0.11)	-
Wealth index (5 point scale)	**0.23 (0.19, 0.27)**	**0.13 (0.08, 0.19)**	**0.27 (0.24, 0.30)**	**0.16 (0.12, 0.20)**
Respondent's literacy				
Cannot read at all	**-0.39 (-0.51, -0.27)**	-1.21 (-3.89, 1.47)	**-0.45 (-0.53, -0.37)**	0.29 (-1.90, 2.48)
Able to read only parts of sentence	-0.08 (-0.32, 0.16)	-1.22 (-3.91, 1.48)	-0.17 (-0.34, 0.00)	0.29 (-1.91, 2.48)
Able to read whole sentence	**0.39 (0.27, 0.50)**	-1.30 (-3.99, 1.40)	**0.47 (0.39, 0.55)**	0.33 (-1.87, 2.52)
Lived rurally (Y/N)	**-0.52 (-0.66, -0.38)**	-0.10 (-0.28, 0.07)	**-0.70 (-0.80, -0.60)**	**-0.28 (-0.41, -0.15)**
Time to get to water source (hours)	-0.08 (-0.16, 0.01)	-0.00 (-0.09, 0.08)	**-0.18 (-0.24, -0.11)**	-0.04 (-0.11, 0.02)
Breastfeeding and complementary feeding				
Currently breastfed (Y/N)	**-1.00 (-1.14, -0.86)**	**-0.49 (-0.63, -0.36)**		
Age when first fed with other food (months)	**0.17 (0.14, 0.19)**	**0.16 (0.13, 0.19)**		
Given foods/liquids other than breastmilk in first 3 days (Y/N)	0.01 (-0.11, 0.14)	0.06 (-0.06, 0.18)		

^ Model adjusted for all other independent variables in the table. N is 2567 for the youngest child and 2563 for the respondent.

Variable with missing regression results in the adjusted model were excluded due to collinearity.

When the 17 covariates from the 10 categories identified as being important potential determinants of nutritional status (shown in Table 7.1) were added to the model simultaneously a number of significant associations were seen with height for age z-scores of the youngest child (Table 7.6). The wealthier the household the higher the child's height for age. For each additional point on the five point scale height for age improved by 0.14. Children in households where the respondent either did not work or worked in a manual job had higher height for age. There was no effect of her husband's occupation. The more literate the respondent was the higher the children's weight for height z-scores.

Children from households doing something to make water safe to drink had 0.16 higher height for age z-scores. Children from households using water that was piped in, was tank, rain or bottled water had higher height for age z-scores, as did those from households using well water. Children who had received vitamin A in the last 6 months had 0.31 lower height for age z-scores. Children who had diarrhoea recently had lower height for age by 0.14 and lower weight for height by 0.13 z-scores.

Those children currently being breastfed had higher height for age, by 0.52 z-scores, but lower weight for height z-scores, by 0.09 z-scores, compared to children not currently being breastfed. The older the child was when they were first fed foods or liquids other than breastmilk the lower their height for age z-scores were. Those first given food/liquids between 0 and 3 months of age had an mean height for age of -1.34, between 3 and 6 months; -1.57, between 6 and 12 months; -1.73 and more than 12 months; -1.93.

Table 7.6. Association between household and demographic variables and nutritional status in the youngest child

	Height for age z-scores		Weight for height z-scores	
	Unadjusted	**Adjusted^**	**Unadjusted**	**Adjusted^**
	Regression coefficient (95% CI)	Regression coefficient (95% CI)	Regression coefficient (95% CI)	Regression coefficient (95% CI)
Demographics				
Education (years)	**0.05 (0.04, 0.06)**	0.01 (-0.01, 0.04)	0.00 (-0.01, 0.01)	-0.01 (-0.04, 0.01)
Husband's education (years)	**0.04 (0.03, 0.05)**	0.01 (-0.00, 0.02)	0.01 (-0.00, 0.02)	0.01 (-0.00, 0.03)
Respondent's literacy				
Cannot read at all	**-0.17 (-0.26, -0.08)**	2.06 (-0.72, 4.83)	-0.07 (-0.15, 0.01)	2.47 (-0.09, 5.02)
Able to read only parts of sentence	-0.09 (-0.27, 0.08)	1.90 (-0.88, 4.68)	0.08 (-0.08, 0.24)	**2.63 (0.07, 5.19)**
Able to read whole sentence	**0.18 (0.09, 0.27)**	1.96 (-0.82, 4.74)	0.05 (-0.03, 0.12)	**2.60 (0.04, 5.16)**
Respondent's occupation				
Not working	**0.51 (0.40, 0.62)**	**0.53 (0.11, 0.96)**	**-0.32 (-0.42, -0.22)**	-0.06 (-0.45, 0.34)
Professional, technical, managerial or clerical	**0.39 (0.10, 0.68)**	0.31 (-0.24 ,0.86)	0.11 (-0.15, 0.37)	0.26 (-0.25, 0.77)
Agricultural	**-0.54 (-0.62, -0.45)**	0.23 (-0.19, 0.65)	**0.16 (0.8, 0.23)**	0.22 (-0.17, 0.61)
Household or domestic	-0.10 (-0.46, 0.26)	-	**-0.39 (-0.71, -0.07)**	-
Services	**0.38 (0.10, 0.65)**	0.35 (-0.16, 0.85)	0.14 (-0.10, 0.39)	0.28 (-0.19, 0.74)
Manual	**0.31 (0.20, 0.41)**	**0.44 (0.01, 0.86)**	0.03 (-0.06, 0.13)	0.14 (-0.25 ,0.53)
Husband's occupation				
Not working	0.28 (-0.59, 1.15)	-	-0.43 (-1.20, 0.34)	-
Professional, technical, managerial or clerical	**0.35 (0.16, 0.54)**	-0.10 (-0.96, 0.76)	0.08 (-0.10, 0.25)	0.19 (-0.60, 0.98)
Agricultural	**-0.47 (-0.56, -0.39)**	-0.25 (-1.09, 0.59)	**0.10 (0.02, 0.18)**	0.30 (-0.47, 1.07)
Household or domestic	**0.78 (0.22, 1.34)**	0.41 (-0.61, 1.42)	**-0.82 (-1.32, -0.33)**	-0.52 (-1.46, 0.41)
Services	**0.42 (0.25, 0.58)**	0.01 (-0.84, 0.86)	**-0.19 (-0.34, -0.04)**	0.10 (-0.68, 0.89)
Manual	**0.33 (0.23, 0.42)**	-0.10 (-0.94, 0.75)	-0.05 (-0.14, 0.04)	0.23 (-0.55, 1.00)

Table continued on page 214.

	Height for age z-scores		Weight for height z-scores	
	Unadjusted	**Adjusted^**	**Unadjusted**	**Adjusted^**
	Regression coefficient (95% CI)	Regression coefficient (95% CI)	Regression coefficient (95% CI)	Regression coefficient (95% CI)
Current marital status				
Never married	0.00 (-0.18, 0.19)	-	0.09 (-0.08, 0.25)	-
Married/living together	0.11 (-0.01, 0.23)	-0.02 (-0.17, 0.13)	-0.00 (-0.11, 0.10)	0.10 (-0.04, 0.24)
Widowed, divorced or separated	**-0.16 (-0.30, -0.02)**	-	-0.05 (-0.18, 0.08)	-
Wealth index (5 point scale)	**0.18 (0.15, 0.21)**	**0.14 (0.10, 0.19)**	0.01 (-0.02, 0.04)	0.02 (-0.02, 0.07)
Lived rurally (Y/N)	**-0.53 (-0.63, -0.43)**	-0.00 (-0.14, 0.14)	-0.02 (-0.11, 0.07)	-0.12 (-0.24 ,0.01)
Breastfeeding and complementary feeding				
Currently being breastfed (Y/N)	**0.64 (0.56, 0.73)**	**0.52 (0.43, 0.61)**	-0.04 (-0.11, 0.03)	**-0.09 (-0.17, -0.01)**
Age when first fed with other food (months)	**-0.05 (-0.07, -0.03)**	**-0.03 (-0.05, -0.01)**	**0.02 (0.00, 0.04)**	0.01 (-0.01, 0.03)
Given foods/liquids other than breastmilk in first 3 days(Y/N)	-0.07 (-0.17, 0.02)	-0.03 (-0.13, 0.07)	-0.03 (-0.11, 0.06)	0.02 (-0.07, 0.11)
Health				
Received vitamin A in last 6 months (Y/N)	**-0.23 (-0.30, -0.16)**	**-0.31 (-0.41, -0.22)**	**-0.08 (-0.15, -0.02)**	0.00 (-0.09 ,0.09)
Some/all children < 5 slept under bednet last night(Y/N)	-0.05 (-0.15, 0.04)	-0.04 (-0.14, 0.07)	**0.10 (0.01, 0.19)**	0.07 (-0.03, 0.17)
Distance to nearest health facility (km)	**-0.02 (-0.03, -0.01)**	0.00 (-0.01, 0.01)	**0.01 (0.00, 0.02)**	0.01 (-0.00, 0.02)
Something done to make water safe to drink (Y/N)	**0.26 (0.17, 0.35)**	**0.16 (0.06, 0.25)**	**0.11 (0.03, 0.19)**	0.08 (-0.01, 0.17)
Source of drinking water				
Borehole, river, lake, spring	**-0.29 (-0.38, -0.19)**	-	-0.04 (-0.13, 0.04)	-
Open or protected well	**-0.12 (-0.20, -0.03)**	**0.17 (0.06, 0.29)**	**0.09 (0.01, 0.17)**	0.04 (-0.06, 0.15)
Piped, tank, rainwater or bottled	**0.34 (0.26, 0.43)**	**0.15 (0.02, 0.27)**	-0.06 (-0.13, 0.02)	0.03 (-0.09, 0.14)
Had diarrhoea recently (Y/N)	-0.05 (-0.11, 0.01)	**-0.14 (-0.26, -0.03)**	**-0.08 (-0.13, -0.03)**	**-0.13 (-0.24, -0.02)**

^ Model adjusted for all other independent variables in the table . N is 3953.

Variable with missing regression results in the adjusted model were excluded due to collinearity.

7.4.3 Agricultural and dietary factors, dietary diversity and nutritional status.

In regression models adjusted for whether the DHS EA was rural or urban, the more meals per day, more days eating meat and days eating fish at the household level, the higher the respondent's and their youngest child's dietary diversity (Table 7.7). For each additional meal per day the child's and respondent's dietary diversity increased by 0.36. For each additional day in the last seven days eating meat and fish the child dietary diversity scores increased by between 0.16 and 0.03 respectively. Children and respondents in households reporting having problems meeting food needs often or always had lower dietary diversity than those from households who never, seldom or sometimes have problems meeting food needs. Children and respondents in households preparing *ugali* with maize flour or using oil for cooking in the last 7 days had higher dietary diversity.

Table 7.7. Association between agricultural and dietary variables and dietary diversity in the respondent and their youngest child

	Dietary diversity score	
	Youngest child	**Respondent**
	Regression coefficient (95% CI)	Regression coefficient (95% CI)
Own land usable for agriculture (y/n)	0.04 (-0.08, 0.17)	0.05 (-0.04, 0.13)
Amount of agricultural land (Hectares)	0.01 (-0.01, 0.02)	0.01 (-0.00, 0.02)
Meals per day (N)	**0.36 (0.25, 0.46)**	**0.36 (0.28, 0.43)**
Days eating meat (N)*	**0.16 (0.11, 0.21)**	**0.20 (0.17, 0.24)**
Days eating fish (N)*	**0.03 (0.00, 0.05)**	0.01 (-0.01, 0.02)
Problem meeting food needs**	**-0.35 (-0.49, -0.21)**	**-0.23 (-0.32, -0.13)**
Prepared *ugali* with maize flour (y/n)*	**0.33 (0.19, 0.47)**	**0.45 (0.36, 0.55)**
Used oil for cooking (y/n)*	**0.55 (0.41, 0.68)**	**0.49 (0.40, 0.58)**

Models adjusted for living rurally. N is 3334.

*in the past 7 days

**Problem meeting food needs: never, seldom or sometimes compared to often or always.

In models adjusted for whether the DHS EA was rural or urban, households owning land usable for agriculture had children with significantly lower height for age z-scores and significantly higher weight for height z-scores (Table 7.8). The more hectares of agricultural land a household had the higher the weight for height of the children.

In order to understand these associations additional analyses were conducted to compare wealth indices between those working in agriculture and those not working in agriculture. It was found that a higher percentage of both respondents and their husbands who worked in agriculture fell into the poorest wealth category (24.9% and 26.0%) compared to those not working in agriculture (6.7% and 6.7%). The difference in wealth indices between agricultural and non-agricultural workers was significant for both the respondents and their husbands (chi squared tests, p<0.001).

Children in households having more meals per day had higher height for age z-scores. The more days in the last week the household ate meat the higher the child's height for age and weight for height. The more days the household ate fish in the last seven days the higher the child's height for weight but the lower their weight for height. Children from households who often or always have problems meeting food needs had lower weight for height z-scores than those from households who never, seldom or sometimes have problems meeting food needs. Children from households who prepared *ugali* with maize flour had higher weight for height and those from households using oil for cooking in the last seven days had higher height for age and lower weight for height.

Table 7.8. Association between agricultural and dietary variables and nutritional status variables in the youngest child

	Height for age z-scores	**Weight for height z-scores**
	Regression coefficient (95% CI)	Regression coefficient (95% CI)
Own land usable for agriculture (y/n)	**-0.18 (-0.28, -0.08)**	**0.21 (0.12, 0.30)**
Amount of agricultural land (Hectares)	-0.00 (-0.01, 0.01)	**0.02 (0.01, 0.03)**
Distance to nearest market (km)	**-0.00 (-0.00, -0.00)**	**0.00 (0.00, 0.00)**
Meals per day (N)	**0.14 (0.06, 0.22)**	0.04 (-0.03, 0.12)
Days eating meat (N)*	**0.04 (0.01, 0.08)**	**0.03 (0.00, 0.06)**
Days eating fish (N)*	**0.04 (0.02, 0.05)**	**-0.03 (-0.05, -0.01)**
Problem meeting food needs**	-0.03 (-0.13, 0.07)	**-0.10 (-0.19, -0.00)**
Prepared *ugali* with maize flour(y/n)*	0.02 (-0.09, 0.12)	**0.22 (0.12, 0.31)**
Used oil for cooking(y/n)*	**0.23 (0.14, 0.32)**	**-0.36 (-0.44, -0.28)**

Models adjusted for living rurally. N is 3999.

*in the past 7 days

**Problem meeting food needs: never, seldom or sometimes compared to often or always.

7.4.4 Dietary diversity and nutritional status

Dietary diversity was significantly negatively associated with both height for age and weight for height z-scores in the youngest children in the unadjusted models (Table 7.9). When models were adjusted for: respondent's education in single years; frequency of watching television;

currently breastfed; age when first fed with other food; wealth index; respondent employed all year or seasonally; respondent works for family, other, self; the association between dietary diversity and height for age remained significantly negative **(-0.11 (-0.15, -0.07)**. For each additional category of dietary diversity consumed the previous day children's height for age decreased by 0.11 z-scores.

When the individual components of the dietary diversity score (whether the child ate cereals, vitamin A rich fruit or vegetables, other fruit or vegetables, meat/fish, eggs, legumes, milk or oil/sweets the day before the interview) were added all together to the adjusted model instead of the composite score, whether the child ate legumes, meat, vitamin A rich fruit or vegetables or cereals were negatively associated with height for age. Oil and sweets were positively associated with height for age. Legumes were positively associated with weight for height.

Table 7.9. Association between dietary diversity scores and its components and nutritional status variables in the youngest children

	Height for age z-scores	**Weight for height z-scores**
	Regression coefficient (95% CI)	Regression coefficient (95% CI)
Dietary diversity scores		
Unadjusted^	**-0.15 (-0.18, -0.11)**	**-0.04 (-0.07, -0.01)**
Adjusted^^	**-0.11 (-0.15, -0.07)**	0.02 (-0.02, 0.06)
Dietary diversity score components (adjusted only) ^^^		
cereals	**-0.38 (-0.63, -0.14)**	-0.02 (-0.27, 0.23)
vitamin A rich fruit or vegetables	**-0.27 (-0.40, -0.15)**	0.02 (-0.10, 0.15)
other fruit or vegetables	-0.05 (-0.21, 0.12)	-0.10 (-0.26, 0.07)
meat/fish	**-0.19 (-0.32, -0.07)**	0.07 (-0.06, 0.20)
eggs	0.11 (-0.14, 0.36)	-0.06 (-0.31, 0.19)
legumes	**-0.22 (-0.35, -0.09)**	**0.14 (0.01, 0.27)**
milk	0.10 (-0.04, 0.23)	0.06 (-0.07, 0.20)
oil/sweets	**0.16 (0.02, 0.29)**	-0.04 (-0.17, 0.10)

^Unadjusted model N is 3335.
^^Adjusted for respondent's education in single years, frequency of watching television, currently breastfed, age when first fed with other food, wealth index, respondent employed all year or seasonally, respondent works for family, other, self and whether they live rurally. N is 2698.

^^^Adjusted for all the other dietary diversity score components, respondent's education in single years, frequency of watching television, currently breastfed, age when first fed with other food, wealth index, respondent employed all year or seasonally, respondent works for family, other, self and whether they live rurally. N is 2698.

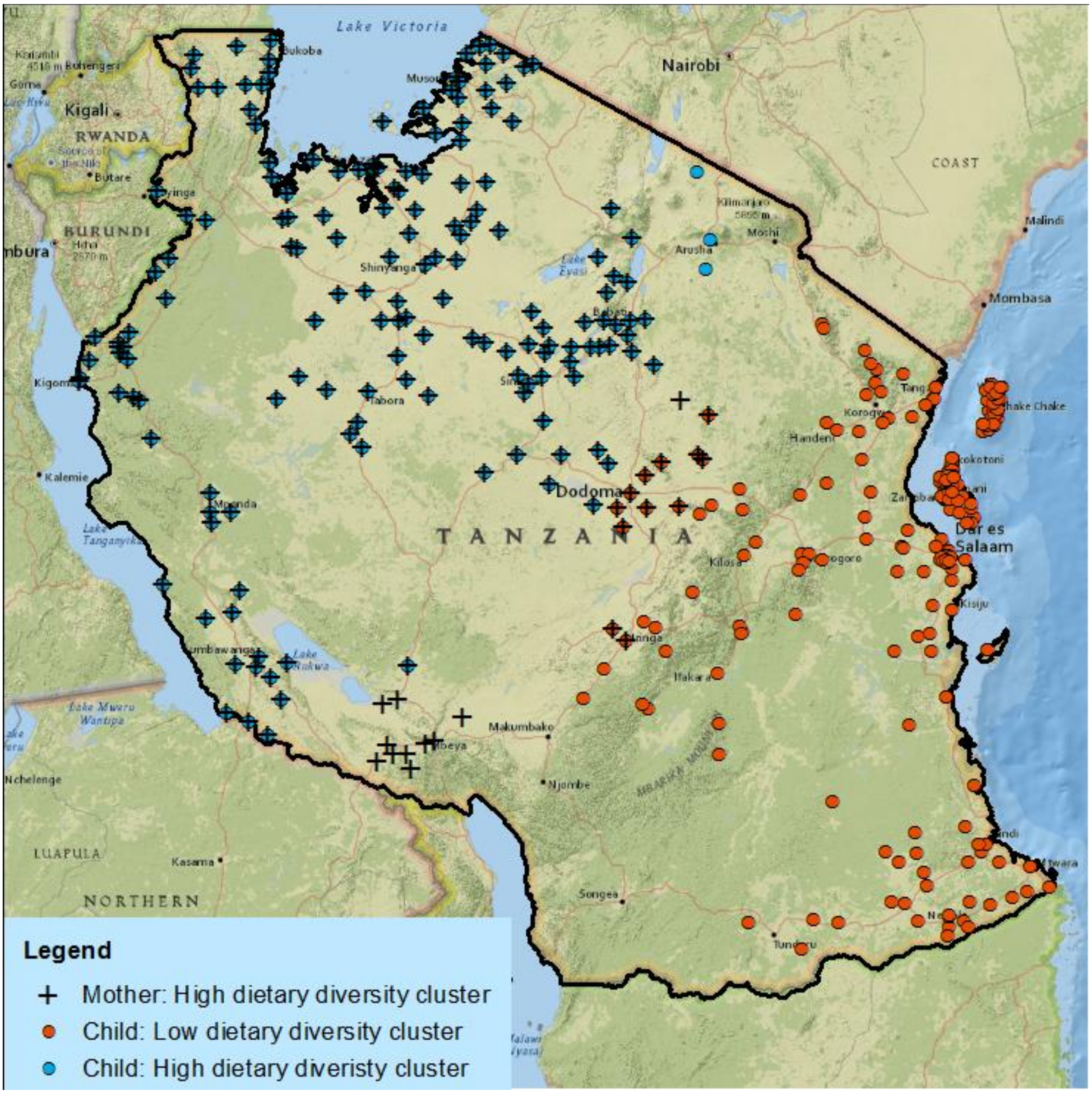

Figure 7.4. Clusters of high and low dietary diversity in the youngest child and high dietary diversity in the mother

7.4.5 Spatial variation of dietary diversity and nutritional status

Figures 7.4 to 7.8 show the significant clusters of high and low dietary diversity, height for age, weight for height in the youngest child and dietary diversity and BMI in the mother (there was no significant cluster of low dietary diversity for the mother). There is a large cluster of high child dietary diversity in the North West half of the country. This cluster includes DHS EA near lake Victoria and other lakes in the North and stretches down to Singida region. This corresponds with a cluster of high dietary diversity in the respondent. Low dietary diversity is seen in the east of Tanzania including the capital, Dar es Salaam and Zanzibar.

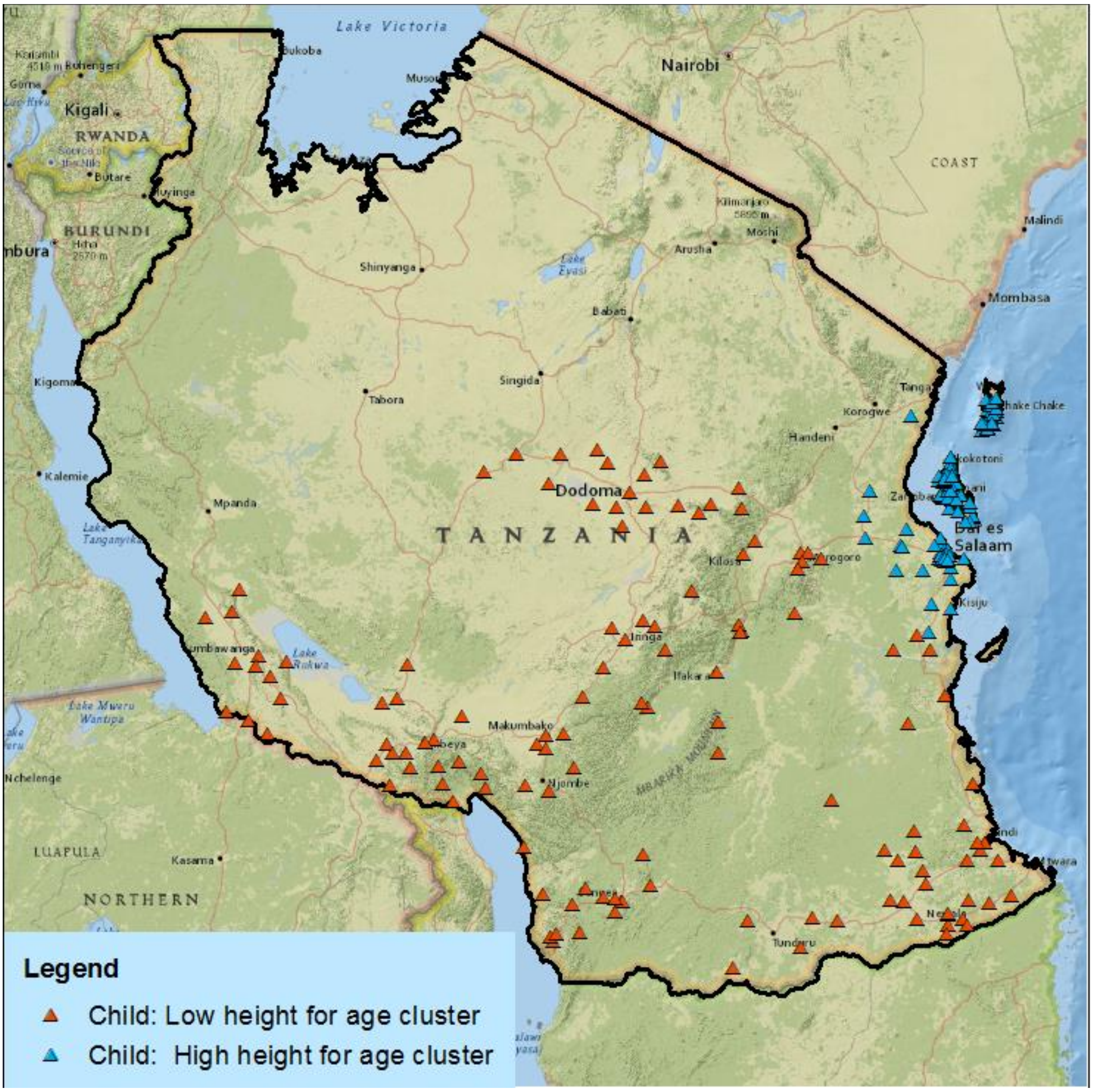

Figure 7.5. Clusters of high and low height for age in the youngest child

The area of low dietary diversity (the east of Tanzania including the capital, Dar es Salaam and Zanzibar) is where a cluster of high height for age and low weight for age in the youngest children is seen as well as a cluster of high BMI in the respondents. Interestingly the cluster of low respondent BMI corresponds with the cluster of high dietary diversity in the respondents. These cluster analyses have shown Dar es Salaam, Zanzibar and Pemba to have low child dietary diversity, low weight for height and high height for age and high respondent BMI.

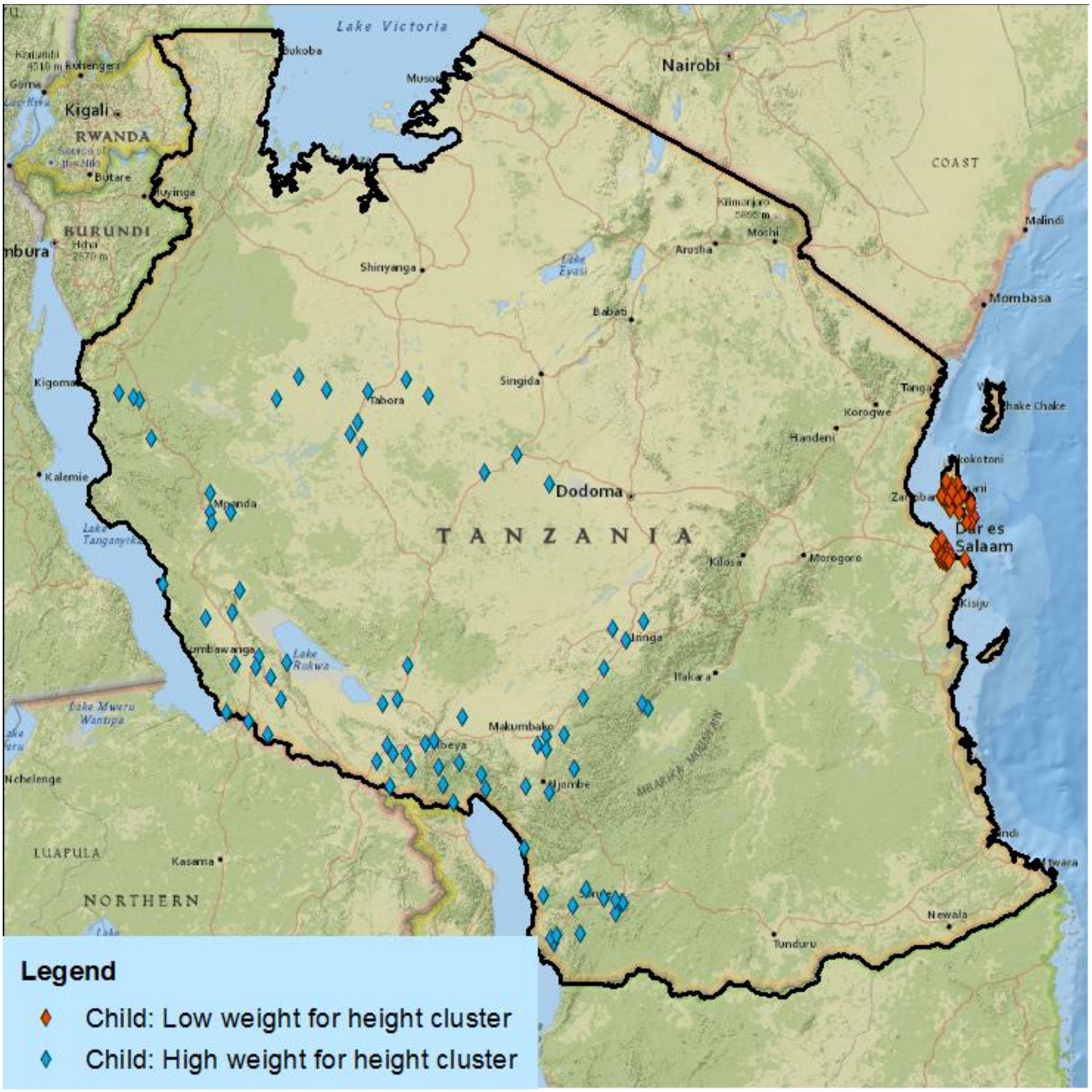

Figure 7.6. Clusters of high and low weight for height in the youngest child

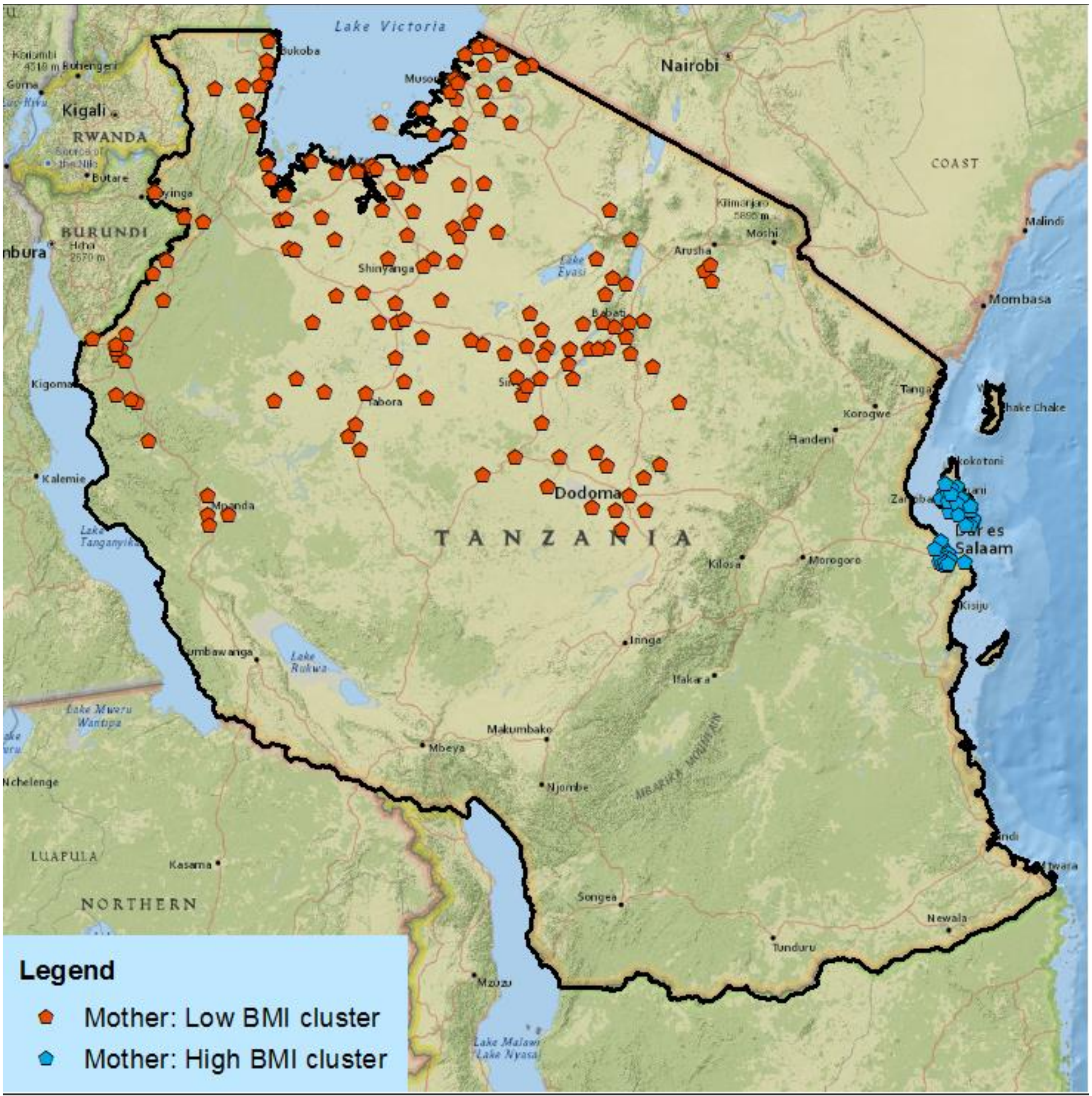

Figure 7.7. Clusters of high and low BMI in the mother

7.4.6 Land cover, dietary diversity and nutritional status.

Agricultural, but not forest, land cover is associated with higher dietary diversity. The land cover surrounding the DHS EA of high child dietary diversity was approximately 50% agricultural while the land cover surrounding the cluster of low dietary diversity was only 30% agricultural (Table 7.10). The high dietary diversity clusters were surrounded with only 3% forest land cover compared to approximately 25% around the low dietary diversity clusters. The land cover surrounding the cluster of high respondent dietary diversity was very similar to the land cover seen around the high child dietary diversity cluster.

More agricultural and forest land cover is associated with lower height. The cluster of high child height for age was surrounded by approximately 20% agricultural land cover compared to 40% around the low height for age cluster. The high height for age cluster was surrounded by only 16% forest and 63% other land cover types. The low height for age cluster was surrounded by 32% forest and only 28% other land cover.

More agricultural land cover was associated with better weight for height. High children's weight for height clusters had approximately 50% agriculture, 18% forest and 30% other land cover in the 5km surrounding the DHS EA centre point and low weight for height clusters had 23% agriculture, 16% forest and 61% other land cover in their 5km buffer zone.

More agricultural land cover was associated with poorer respondent BMI. The majority of the land surrounding the high respondent BMI clusters was classed as other (70%), 21% was agricultural and only 9% was forest. Forty-nine percent of the land surrounding the low BMI cluster was classed as other, 48% as agricultural and 3% as forest land cover.

Table 7.10. Percentage of land cover falling into agriculture, forest and other land cover categories in the 5km surrounding the significantly high and low DHS EA centre points

	Agriculture %^	Forest %^^	Other %^^^
Children's dietary diversity			
High cluster (N=167)	51.2	3.0	45.8
Low cluster (N=224)	28.5	24.4	47.1
Children's height for age			
High cluster (N=115)	21.3	15.5	63.2
Low cluster (N=132)	39.9	31.7	28.4
Children's weight for height			
High cluster (N=80)	52.3	17.5	30.2
Low cluster (N=139)	23.3	16.2	60.5
Respondent's dietary diversity			
High cluster (N=187)	52.7	2.6	44.7
Respondent's BMI			
High cluster (N=62)	21.3	9.3	69.5
Low cluster (N=153)	48.4	2.5	49.0

Reported N is number of DHS EA in each Satscan cluster

^Rainfed croplands; Mosaic Cropland (50-70%) / Vegetation (grassland, shrubland, forest) (20-50%); Mosaic Vegetation (grassland, shrubland, forest) (50-70%) / Cropland (20-50%).

^^Closed to open (>15%) broadleaved evergreen and/or semi-deciduous forest (>5m); Closed (>40%) broadleaved deciduous forest (>5m); Open (15-40%) needleleaved deciduous or evergreen forest (>5m); Mosaic Forest/Shrubland (50-70%) / Grassland (20-50%); Mosaic Grassland (50-70%) / Forest/Shrubland (20-50%); Closed (>40%) broadleaved forest regularly flooded - Fresh water; Closed to open (>15%) vegetation (grassland, shrubland, woody vegetation) on regularly flooded or waterlogged soil - Fresh, brackish or saline water.

^^^ Open (15-40%) broadleaved deciduous forest (>5m); Closed to open (>15%) mixed broadleaved and needleleaved forest (>5m); Closed to open (>15%) shrubland (<5m); Closed to open (>15%) grassland; Sparse (>15%) vegetation (woody vegetation, shrubs, grassland); Artificial surfaces and associated areas (urban areas >50%); Bare areas; Water bodies.

The percentage of agricultural land cover in the 5 km surrounding the DHS centre point is positively associated with dietary diversity in the youngest child and the respondent; the more agricultural land cover the higher the dietary diversity (Table 7.11). There was no association between the amount of forest land cover in the surrounding area and dietary diversity. The higher the percentage of other land cover types, such as sparse vegetation, grassland and bare areas, the lower the dietary diversity in both the youngest child and the respondent.

The more agricultural land cover, the lower the youngest child's height for age and the higher the proportion of other land cover the higher the children's height. The higher the proportion of both agricultural and forest land cover (and the lower the other land cover) the higher the children's weight for height z-scores. In the respondent, having a higher proportion of agricultural land cover in the 5km surrounding the DHS EA centre points was associated with having a lower BMI and a higher proportion of forest land cover was associated with a higher

BMI. The percentage of other land cover was positively associated with respondent BMI in the unadjusted model only, when the model was adjusted for whether the DHS EA was classed as rural or as urban, this significant association disappeared.

Table 7.11. Association between dietary diversity and nutritional status and percentage land cover of agriculture, forest or other land cover types in the 5km surrounding the DHS centre points

	Youngest child			Respondent	
	Dietary diversity	Height for age z-scores	Weight for height z-scores	Dietary diversity	BMI
	Regression coefficient (95% CI)	Regression coefficient (95% CI)	Regression coefficient (95% CI)	Regression coefficient (95% CI)	Regression coefficient (95% CI)
Percentage agricultural land cover (5km buffer)^					
Unadjusted	**0.04 (0.02, 0.05)**	**-0.05 (-0.08, -0.03)**	**0.04 (0.01, 0.06)**	**0.04 (0.02, 0.06)**	**-0.20 (-0.28, -0.13)**
Adjusted*	**0.03 (0.02, 0.05)**	**-0.04 (-0.06, -0.01)**	**0.04 (0.02, 0.06)**	**0.03 (0.02, 0.05)**	**-0.11 (-0.18, -0.05)**
Percentage forest land cover (5km buffer)^^					
Unadjusted	-0.01 (-0.03, 0.01)	-0.01 (-0.04, 0.02)	**0.04 (0.02, 0.06)**	-0.01 (-0.03, 0.01)	**0.08 (0.01, 0.15)**
Adjusted*	-0.01 (-0.03, 0.00)	0.00 (-0.02, 0.03)	**0.04 (0.02, 0.06)**	-0.01 (-0.03, 0.01)	**0.12 (0.06, 0.18)**
Percentage other land cover (5km buffer)^^^					
Unadjusted	**-0.02 (-0.04, -0.01)**	**0.07 (0.05, 0.09)**	**-0.07 (-0.08, -0.05)**	**-0.03 (-0.04, -0.01)**	**0.15 (0.09, 0.20)**
Adjusted*	**-0.02 (-0.03, -0.01)**	**0.04 (0.02, 0.06)**	**-0.07 (-0.09, -0.05)**	**-0.02 (-0.03, -0.01)**	0.02 (-0.02, 0.06)

N for unadjusted and adjusted models are: 837 for agricultural land cover, 1084 for forest land cover and 1341 for other land cover.

*Adjusted for whether the cluster was urban or rural.

^Rainfed croplands; Mosaic Cropland (50-70%) / Vegetation (grassland, shrubland, forest) (20-50%); Mosaic Vegetation (grassland, shrubland, forest) (50-70%) / Cropland (20-50%).

^^Closed to open (>15%) broadleaved evergreen and/or semi-deciduous forest (>5m); Closed (>40%) broadleaved deciduous forest (>5m); Open (15-40%) needleleaved deciduous or evergreen forest (>5m); Mosaic Forest/Shrubland (50-70%) / Grassland (20-50%); Mosaic Grassland (50-70%) / Forest/Shrubland (20-50%); Closed (>40%) broadleaved forest regularly flooded - Fresh water; Closed to open (>15%) vegetation (grassland, shrubland, woody vegetation) on regularly flooded or waterlogged soil - Fresh, brackish or saline water.

^^^ Open (15-40%) broadleaved deciduous forest (>5m); Closed to open (>15%) mixed broadleaved and needleleaved forest (>5m); Closed to open (>15%) shrubland (<5m); Closed to open (>15%) grassland; Sparse (>15%) vegetation (woody vegetation, shrubs, grassland); Artificial surfaces and associated areas (urban areas >50%); Bare areas; Water bodies.

7.5 Discussion

7.5.1 Demographic and social factors, dietary diversity and nutritional status

Wealth, education and occupation all affected the diversity of the diets of mothe r and child as would be expected from the literature (Fouere et al., 2000, Torheim et al., 2004, Nyangweso et al., 2007). Children who were breastfed for longer, a WHO recommended practice (WHO, 2003), had higher dietary diversity. Children who were older when they were first given complementary foods or liquids had higher dietary diversity. As complementary foods were introduced at four months, on average instead of the recommended six months (WHO, 2003) these practices may reflect a better understanding of nutrition guidelines for both complementary feeding and improving nutrition through dietary diversity.

The respondent's and their husband's employment and the households wealth index were associated with children's nutritional status. A number of factors associated with infection were also significantly related with height for age and weight for height. Children who had access to water from a tank or tap as opposed to water from a borehole or river and children from households who treated their drinking water all had better markers of nutritional status. This shows that those children who had a decreased exposure to infection had better nutritional status. This finding is supported by the finding that children who had diarrhoea recently had poorer height for age and weight for height than those not experiencing diarrhoea recently. These findings are supported by other findings in the literature regarding the association between infection and nutritional status (Chen et al., 1980, Stephensen, 1999).

Children who were still being breastfed had better nutritional status than those who either had never been breastfed or had stopped being breastfed. Interestingly the older the child was when complementary foods were given the lower the height for age of the child. The majority of the children had complementary foods introduced early (mean (95% CI: 3.78 months (3.73, 3.84)). The highest height for age was seen in the group of infants that were first given complementary foods in the first three months of life, despite the WHO recommendations to exclusively breastfeed until six months of age (WHO, 2002). Whether the child was given foods or liquids other than breastmilk in the first three days of life was not associated with height for age or weight for height. The results presented in chapter 4 showed that the age liquids and solids were introduced as well as the types of foods children are weaned onto were associated with nutritional status. The data available in the DHS does not allow for these relationships to be interrogated.

7.5.2 Agricultural and dietary factors, dietary diversity and nutritional status.

Having agricultural land was associated with poorer long term nutritional status and improved short term nutritional status in regression models adjusted for living rurally; Individuals in households with land that is deemed usable for agriculture have poorer height for age z-scores. However, these children, and children in households with more agricultural land had higher weight for height. Lack of land ownership is used as a marker of poverty (Murthy et al., 2008) and land ownership is expected to be associated with better nutritional status (Swaminathan et al., 2012). This finding may be due to energy expended through farming and time away from childcare (Kumar and Hotchkiss, 1988) as discussed in chapter 5. It may also be linked to income as those working outside of agriculture had significantly higher wealth indices than those working in agriculture.

The more meals eaten per day and the more days eating meat and fish the higher the dietary diversity and the higher the children's height for age. Although this finding was not replicated in the primary data collection there is evidence of the association between animal product consumption and nutritional status in low income countries (Allen et al., 1992, Marquis et al., 1997, Krebs et al., 2011). The more days eating meat the higher the weight for height in the children while the more days the household ate fish the lower their weight for height. The consumption of small fish in small quantities (Thilsted et al., 1997) is common in Eastern Africa (Kawarazuka and Béné, 2011) and it may be that fish is not consumed in great enough quantities to impact on weight, which is more changeable and strongly influenced by infection. The consumption of animal products in this population appears to be positively associated with nutritional status in the long term but has mixed association with nutritional status in the short term.

In households using oil for cooking, individuals had both higher dietary diversity and better nutritional status. This may be a reflection of additional calories from the oil, that cooking with oil allows the household to cook more nutritious foods such as green leafy vegetables or it could simply be a reflection of the socio-economic status of the household. A randomised controlled trial on stunted children (3-9 years old) in Gambia found no effect on height or weight of an oil supplement given in the form of a biscuit (1600KJ) for 12 months (Krähenbühl et al., 1998). Bajaj et al (2005) found that an oil supplement displaced breastmilk in the diet of 6-10 month old infants in India, decreasing overall energy intake. Although oil intake is often included in dietary diversity scores the effect of oil intake on nutritional status, outside of complementary feeding, has not been reported. Further research is needed to assess the impact of habitual oil intake on nutritional status in low income countries.

7.5.3 Dietary diversity and nutritional status

Dietary diversity was negatively associated with height for age, the opposite association than would be expected based on the literature (Arimond, 2004, Steyn et al., 2006) and shown in the project's conceptual framework (figure 3.2 a) and b)). This provide extra evidence that the association between dietary diversity and nutritional status is not as strong in Eastern Africa as in other low income countries. The specific foods that were negatively associated with height were cereals, vitamin A rich fruit or vegetables, legumes and meat, the latter three groups are considered to be essential additions to the staple diet in a low income country context. Although this regression model was adjusted for potential confounders captured by the DHS survey it is likely that there are a number of other factors influencing the relationship between dietary diversity and height in the survey that have not been captured, for example total energy intake, ethnicity (Habicht et al., 1974) and soil fertility (Byiringiro and Reardon, 1996). As was seen in the data collected in Minyenye and Mbwei, the results from the DHS data showed no significant relationship between the dietary diversity in the youngest children and their weight for height.

When the multiple determinants of nutritional status are acknowledged and other studies that have controlled for potential confounders are singled out, mixed results have been shown in the literature. Some have found no significant association between dietary diversity and weight for height z-scores in all populations studied (Hillbruner and Egan, 2008) or in some sub-groups of the studied population. Higher dietary diversity was associated with lower rates of stunting in urban but not rural populations (Hatloy et al., 2000), with height for age in boys but not girls (Eckhardt et al., 2005) and height for age in 11-23 month olds but there was no association seen for those 24-35 months or in any age group in weight for height (Sawadogo et al., 2006). However, Arimond (2004) found dietary diversity to be significantly positively associated with height for age when potential confounders were controlled for in seven out of the eleven countries studied through the DHS surveys (not including Tanzania). Positive associations between dietary diversity and height for age and weight for height was found in Indian infants aged 9-12 months (Garg and Chadha, 2009). Rates of stunting were associated with dietary diversity in Moroccan children (Aboussaleh and Ahami, 2009).

These mixed results in the literature as well as the results presented both in chapter 4 and the current chapter suggest that the relationship between dietary diversity and nutritional status in children in low income countries varies from context to context and should not be assumed. This is not to say that dietary diversity does not benefit health and is not important in and of itself but it does not appear appropriate for dietary diversity to be used as a marker of anthropometric nutritional status.

7.5.4 Spatial variation of dietary diversity and nutritional status

The Satscan, spatial analysis results did not find small pockets of dietary diversity or nutritional status variables which varied significantly from these variables in other DHS EA. The clusters were generally quite large and generally indicated that dietary diversity and nutritional status differs from West to East or from inland to coastal areas. There are a number of possible reasons for this variation. Dietary diversity was higher in the West or inland half of Tanzania. The clusters of low dietary diversity, high height for age and low weight for height in children were centred around Dar es Salaam and Zanzibar. Although it would be reasonable to expect the results to be influenced by the large population living in Dar es Salaam, this analysis did not show any significant effect of living in an urban environment. The results may also reflect different access to fish along the coastal areas or different cultural practices.

The inland cluster of high child dietary diversity and weight for height but low height for age compared to the coastal cluster of low dietary diversity and weight for height and high height for age generally corresponds to different agro-ecological zones (FAO, 2014b). There is limited evidence in the literature of the relationship between agro-ecological zones and diet and nutrition outcomes but it is well established that soil fertility varies between the different agro-ecological zones (Smaling and Braun, 1996) and that soil fertility is linked to food production (Arshad and Martin, 2002). This difference in soil fertility as well as the difference in other climatic factors between the agro-ecological zones may explain part of the difference seen in dietary diversity and nutritional status across Tanzania.

These analyses used all of the DHS data, both urban and rural, while the primary data collection focused on rural areas only. The inclusion of the urban data at a national level broadened the relevance of the work to cover Tanzania as a whole. Regression analyses were controlled for whether the area was rural or urban but if this analysis was focused on the rural areas only it is possible that different results would have been seen. For example, dietary diversity and nutritional status may have been positively associated as a more diverse diet in a rural setting is more likely to be beneficial while a more diverse diet in an urban setting may mean diets that are not necessarily associated with better health such as those that are processed or high in sugar (Popkin, 1998). Also, land cover may have shown different associations with dietary diversity and nutritional status as people relate to the land differently in rural compared to urban environments.

7.5.5 Land cover, dietary diversity and nutritional status

The results of these analyses show that agricultural land cover is positively associated with average dietary diversity. The more cropland land cover in the surrounding area, the higher the dietary diversity. When cropland is viewed as a proxy for agrobiodiversity this results provides support for the pathway from agrobiodiversity to dietary diversity illustrated in the conceptual framework (figure 3.2 a) and b)). These categories do not differentiate between subsistence farming which you would expect to be associated with greater agricultural diversity and large mono-crop farms. This result may reflect higher dietary diversity in subsistence farming areas or in areas with large cash crop farming. In either case, without being able to address the food security pillars of access or utilization, these results indicate a higher diversity in peoples diets with greater food availability.

This association did not, however, consistently carry through to the nutritional status variables. More agricultural land cover was associated with poorer average height for age in the child and lower respondent BMI. It was also associated with higher weight for height in the child. The fact that this agricultural land cover is positively associated with the short term measures of dietary diversity and weight for height at a group level but not with the long term nutrition measures of height for age is interesting. This mirrors the association that those households with agricultural land had better short term but poorer long term nutritional status. The reasons for this may be connected to the energy expenditure associated with farming impacting on the chronic measures of nutritional status as well as the time spent farming impacting on time for care of children, as discussed earlier (Kumar and Hotchkiss, 1988).

The results of these analyses show that more biodiverse land cover categorised as 'forest' land cover is not associated with average dietary diversity. However, more forest land cover was associated with a higher weight for height z-score in the youngest child and higher respondent BMI. In contrast to the dietary diversity results of this study, a similar study by Johnson et al (Johnson et al., 2013) found that communities experiencing loss in forest cover over the previous ten years had lower dietary diversity than children living in areas with no change in forest cover. Also, higher overall percentages of forest cover were associated with the consumption of more vitamin A rich foods and lower rates of diarrhoea. A study measuring tree cover and dietary diversity in the East-Usambara mountains in Tanzania found households with greater nearby tree cover were more likely to consume forest foods which in turn was linked to higher dietary diversity (Powell et al., 2011).

The current study found no association between forest cover and dietary diversity but did find a positive association between amount of forest cover and average weight for height in the children and BMI in respondents. This may reflect better access to nutritious foods available in the forest (Johns and Maundu, 2006), as was shown in Johnson et al (2013) and Powell et al (2011). However, neither this study nor Johnson et al (2013) found positive associations between forest cover and height for age.

7.5.6 Limitations and strengths

The findings from this chapter should be interpreted in the context of the limitations of the analyses. All analyses are based on the demographic and health survey data which will be subject to all the biases associated with survey data. For example, questions on complementary feeding of children may be biased as they rely on memory of past behaviour and the honesty of the responses given may be effected by the presence of the research team. Additionally, it is a cross-sectional survey so the direction of causality between the variables found to be significantly associated is not know, it can only be said that the variables are associated. This is a large study which uses a number of different research assistants to collect data, inconsistencies between data collected in different areas in Tanzania are possible.

For the DHS data used in the spatial and land cover analyses the data was aggregated at the DHS EA level and attached to the DHS EA centre point. DHS EA vary in geographic size as they are based on population rather than distance. The 5km buffer zones around the DHS EA centre points used in the land cover analysis may be less appropriate for some of the geographically larger clusters than the smaller clusters. As the borders of the DHS EA areas were not available there was no way to get around this limitation. The land cover data itself also has its own limitations. The land cover map was validated using land cover experts from around the world. The validation report states the accuracy of the map to be 67.5% and states that globally there was 5% missing data of inland surfaces that were filled in using the 2005 map (Bontemps et al., 2011).

Individual data has been summarised at the DHS cluster level for comparison with land cover data. Interpretations about the implications of these associations at a DHS cluster level for individuals must be made with caution (Morgenstern, 1995). This ecological study uses groups, the DHS clusters, as the unit of analysis and it is the group exposure and how this relates to the groups average outcome that is examined. Individuals within DHS clusters with high levels of surrounding agricultural or forest land cover may not, themselves be exposed to factors associated with these land covers. Using these group associations to make conclusions about these associations at the individual level would be misleading, referred to as committing the ecological fallacy.

The DHS is a large nationally representative sample in which data collection has been developed and tested over many years to ensure the data collected is as accurate as possible. It collects very detailed data ideal for analyses investigating nutritional status. This data has been spatially linked to land cover data that has been pre-processed and classified by specialists in their fields and validated by local experts.

7.6 Conclusions

A number of factors such as wealth, education, occupation, breastfeeding and the timing of the introduction of complementary foods were associated with dietary diversity in this large, nationally representative survey. Wealth, occupation, currently being breastfed, timing of complementary foods, source of drinking water, taking action to make water safe to drink and having recently experienced diarrhoea were associated with height for age in children. Contrary to previous findings, dietary diversity itself was not significantly associated with nutritional status.

The results from this chapter indicate that a higher intake of animal products corresponds to a higher dietary diversity and a better nutritional status in children. Other factors such as having more meals and oil being used in cooking were also positively associated with nutritional status.

Households with agricultural land had better markers of short term nutritional status and worse markers of long term nutritional status. This raises some interesting questions about some of the potential consequences of farming such as increased energy expenditure and impact on caregivers time which warrant further investigation.

Both dietary diversity and nutritional status vary spatially and are associated with the surrounding land cover, especially the amount of agricultural land cover. This has implications for the distribution of intervention and support across the country. Perhaps communities in areas with low amounts of agricultural land in the vicinity would require more interventions focusing on dietary diversification while communities in areas with high amounts of agricultural land would need more long term nutritional support to counteract their higher rates of stunting. Proximity to biodiverse forested areas was not associated with dietary diversity but was associated with acute measures of malnutrition. This provides some evidence in support of the benefits of access to forests in subsistence farming environments.

Chapter 8:
Overall discussion

8.1 Chapter summary

Detailed results from the primary data collection were presented in chapters 4 to 6 and results using national data from Tanzania were presented in chapter 7. This chapter aims to pull together the findings from these two different approaches. The main lessons learnt will be synthesised and discussed to arrive at the final conclusions reached by the study, which will be presented in chapter 9. This chapter will also discuss the limitations and strengths of the two approaches, some methodological insights for future research, the contribution of this research and suggestions for future research. The combination of detailed data collection from data collection in the two villages and nationally representative data complements each other and provides interesting insights in to the determinants of nutritional status and the relationship between agrobiodiversity and dietary diversity and nutritional status.

8.2 Key messages

- This project is one of only two projects investigating the relationship between agrobiodiversity, dietary diversity and nutritional status, the last being conducted in Mexico and published in 1981 (Dewey).
- Dietary diversity was not associated with nutritional status at local village scales and was negatively associated with height for age in the national DHS analysis.
- Agrobiodiversity and land cover showed mixed associations with nutritional status.
- The results of the primary data collection generally show positive associations between eating and rearing animals and dietary diversity but negative or no associations with nutritional status.
- Selling crops was positively associated with dietary diversity but showed a mixed association with nutritional status at the local village scale.

- The results suggest that the effectiveness of agricultural interventions aimed at improving nutrition through improvements in agrobiodiversity can only be evaluated in light of the multiple determinants of nutritional status.
- Standard definitions and methods for measuring agrobiodiversity would benefit future research in this area.

8.3 Dietary diversity and nutritional status

The results of the primary data collection points to the complexity of the determinants of nutritional status in sub-Saharan Africa. It has been well established in the literature that dietary diversity and nutritional status are related (Arimond, 2004, Marriott et al., 2012, Rah et al., 2010). It is biologically plausible that a diversity of different foods including foods high in energy, protein and different micronutrients would contribute to the health and growth of children (Daniels et al., 2007, Onyango, 2003). This combined with the wealth of literature in this area means that it was reasonable to hypothesise that dietary diversity and nutritional status would be related in this study.

Neither dietary diversity nor food variety were significantly associated with nutritional status in Minyenye or Mbwei. Additionally, dietary diversity and height for age was negatively associated in the national DHS analysis. It seems likely that this is due to the multitude of other factors that impact on nutritionals status. Education, occupation and wealth were associated with dietary diversity and nutritional status in the DHS analysis. As discussed, one of the main determinants of nutritional status is infection ((Chen et al., 1980, Stephensen, 1999). Although rates of infection were not measured in the primary data collection there were a number of risk factors for infection present in both villages. These include poor access to clean water, poor sanitation, early introduction of potentially unsafe complementary foods, unprocessed milk consumption, no refrigeration for meat, free roaming animals within the house and yard, and no facilities for hand washing after using the toilet. The DHS analysis showed a number of factors associated with nutritional status that may reflect infection, specifically access to tap water and treating drinking water. It found that children with recent diarrhoea had poorer nutritional status. Data at both the local scale and the national scale points to infection being a cause of malnutrition in Tanzania.

It is also reasonable to hypothesise that the age complementary foods are introduced to an infant's diet as well as the type of foods that are introduced have an effect on their growth. Firstly for the nutrients these foods provide to the infant and secondly for the potential exposure to infection. The results of the primary data collection support this theory. Children who had already had liquids and/or solids introduced to their diets had poorer nutritional status in Minyenye and Mbwei. The type of foods first added to the diet also had an impact; children who were given multiple flour porridges with additions such as beans, oi l or fish or millet juice had poorer nutritional status. These additions may act as vehicles for exposure to infection (Motarjemi et al., 1993). In the DHS results, children who were younger when complementary feeding began had higher height for age suggesting earlier introduction of complementary feeding is beneficial. At a national level the potential negative impact of introduced infection appears to be outweighed by the extra nutrients provided to the diet by these complementary foods.

There were other dietary factors identified by this study that may have impacted on the nutritional status of the children in the villages. There was quite a significant difference in the intake of vitamin A rich fruit and vegetables between the two villages. Ninety-five percent of participants consumed vitamin A rich fruit or vegetables in the day before the interview in Minyenye while only 53% of those did in Mbwei. In the majority of households in Minyenye this was a wild plant, *Mlenda,* which was readily available and also dried and used throughout the year. This may have had a positive effect on the micronutrient intake and potentially health of individuals in this village as compared to Mbwei where consumption of *Mlenda* was not common.

Mlenda highlights an important aspect of diet in Tanzania; the use of wild foods. These results showed that wild food contributed to dietary diversity in Minyenye year round, shifting the average dietary diversity score in the period of lowest diversity from approximately 1 to 1.5. The fact that wild foods consumed in this area tend to be green leafy vegetables high in micronutrients means that this could have a significant impact on the health of those in this area, filling an important gap at times of food shortage.

Another marked difference in consumption between the two villages was cassava. As discussed in chapter 4 cassava acts as an important food source in times of food scarcity. It is not as nutritious as other staples (Stephenson et al., 2010) but it is resilient, can grow in poor conditions and can be stored in the ground (El-Sharkawy, 2007). This means it can be used as an important tool against crop failure and food insecurity (Prudencio and Al-Hassan, 1994). It can be grown and left until times of food shortage when it can bridge the shortfall in energy intake.

Dietary diversity is likely to have many health benefits in low income countries, such as increased intake of vitamins. However, more diverse diets do not necessarily lead to better growth, the main outcome for this project. Diversifying diets in low income countries has the potential to improve markers of health such as risk of anaemia (Gibson et al., 2003).

Diversifying crops grown may have additional benefits to food security through resilience to drought and crop failure and improved distribution of food throughout the year. The results of this project combined with the findings of other projects (Ekesa et al., 2011, Hatloy et al., 2000, Eckhardt et al., 2005) illustrate that the relationship between dietary diversity and nutritional status vary depending on the area and characteristics of the population of interest. It cannot be assumed that increasing the diversity of the diet will improve growth or nutrition outcomes in all settings.

A high proportion of children in Minyenye and Mbwei (53%) as well as nationally (36%) are stunted. There were a number of factors that are linked to nutritional status occurring in the two villages and nationally. Other, more significant determinants of nutritional status, such as infection, may have masked any relationship between dietary diversity and nutritional status that was present. Additionally, the variation in dietary diversity in these two villages was very low (mean (95%CI): 4.8 (4.6, 5.0)). Dietary diversity and nutritional status were measured at the same timepoint in both these studies. The combination of the low variety in dietary diversity and the cross sectional nature of the studies may have prevented any association between dietary diversity and nutritional status being seen in these studies in Tanzania.

8.4 Plant agrobiodiversity, dietary diversity and nutritional status

This study aimed to investigate the relationship between agrobiodiversity and dietary diversity and nutrition in these two villages in rural Tanzania and it addresses the main pathway from agrobiodiversity to dietary diversity to nutritional status in the conceptual framework (Figure 3.2a) and b)). The results suggest that there either is not an association between agrobiodiversity and dietary diversity or nutritional status or these associations are being masked by the other determinants of dietary diversity and nutritional status. The results of this study illuminated the complexity of the pathway from foods grown in the household farms though diet to the children's nutritional status.

As there were no significant associations between dietary diversity and nutritional status it is not that surprising that there were no significant associations between plant agrobiodiversity and nutritional status. However, it was surprising that there were significant negative associations between plant agrobiodiversity and nutritional status. Crop and vegetable diversity indices, which showed the diversity of crops planted over the previous year, were significantly positively associated with dietary diversity and food variety in both Minyenye and Mbwei. However, as with the plant agrobiodiversity indices these were negatively associated with nutritional status in Minyenye. Additionally, the DHS and land cover analyses found that more agricultural land cover in the surrounding area was associated with higher dietary diversity and weight but poorer height in children. Higher proportions of high diversity forest land cover was not associated with dietary diversity but was associated with higher weight in the youngest child.

It is also possible that there are no associations between plant agrobiodiversity or high diversity land cover and dietary diversity or nutritional status due to their multiple determinants, that the variety of crops grown or the diversity of the surrounding land cover is too distant to the growth of children on a hypothetical causal pathway. There are many steps, decisions and biological processes between what is grown in a household farm and the growth of a child. Figure 8.1 takes the study's conceptual framework (figure 3.2a) and b)) and adds the decisions and agricultural, biological and socio-demographic factors that may confound the relationships between agrobiodiversity, dietary diversity and nutritional status. The figure firstly acknowledges the political, social, economic, care and health factors that are operating in this environment that are likely to be effecting agrobiodiversity, dietary diversity and nutritional status and potentially confounding the relationships of interest. Measuring the majority of these factors was beyond the scope of this project.

The figure illustrates factors that could potentially be interfering with the relationship between agrobiodiversity and dietary diversity. The cross sectional measurement of plant agrobiodiversity does not take into account seasonal variation in agrobiodiversity and crop failure, both of which would impact on the food available in the household farms. Once the crops leave the farm they could either go to the household for consumption by the family or they may be sold. The effect of selling crops was explored by the primary data collection but is not captured within the measure of plant agrobiodiversity. Finally, if the crops are consumed within the household, how these are distributed would also have an impact on the mother and young children's dietary diversity (Gittelsohn and Vastine, 2003). These factors may help account for the lack of association seen between plant agrobiodiversity indices and dietary diversity in the primary data collection.

The figure also illustrates factors that were not captured in this study that may have affected the relationship between dietary diversity and child nutritional status. The amount of food available from the household farms is an important factor that was not measured by this study. Annual variation in dietary diversity is another factor that needs to be considered and has been discussed throughout this thesis. Any anti-nutrients and illness that would reduce the absorption of micronutrients from the diet would limit the effectiveness of eating a diversified diet (Molla et al., 1982, Stephensen, 1999, Gibson et al., 2006). All these factors have the potential to impair higher dietary diversity impacting positively on nutritional status.

Figure 8.1 also shows the potential pathway from agrobiodiversity to dietary diversity through household income, which is supported by the results of the primary data collection which showed that selling crops was positively associate with dietary diversity. Increased income from selling crops did not, however, translate into improved nutritional status in these households. Finally, this framework illustrates the specific socio-demographic factors measured in the primary data collection that were found to be significantly associated with child nutritional status. This framework illustrates the complexity of the pathway from foods grown by the household through foods eaten by the household to health outcomes in the household members and helps explain the lack of associations seen between plant agrobiodiversity, dietary diversity and nutritional status in the primary data collection.

As outlined in the literature review (Table 2.3 and 2.4) six other cross sectional studies investigated the relationships between agrobiodiversity and dietary diversity and two the relationships between agrobiodiversity and nutritional status. The two studies using a systematic measure of agrobiodiversity and reporting statistical significance of the associations in household farms or vegetable gardens found no significant association between agrobiodiversity and dietary diversity (Remans et al., 2011a, Akrofi et al., 2010). The one study using a crop diversity score as reported by a household member and reporting statistical significance found a positive association with dietary diversity (Bhagowalia et al., 2012). In the two studies investigating the relationship between agrobiodiversity or crop diversity scores and nutritional status, one found no association (Shack et al., 1990) and the other found a significant association in one of the villages but not the other (Dewey, 1981). As a whole, these results are very similar to those found in the current study; mixed associations with no strong message. It is possible that the study design of these previous studies, as well as the current study has limited the ability of the studies to detect these associations. In all the studies the exposure and outcomes are measured at the same time and agrobiodiversity is measured at only one time point, missing out on any seasonal effects. Future studies with stronger study designs such as longitudinal studies or randomised controlled trials may reveal a clearer picture of these associations.

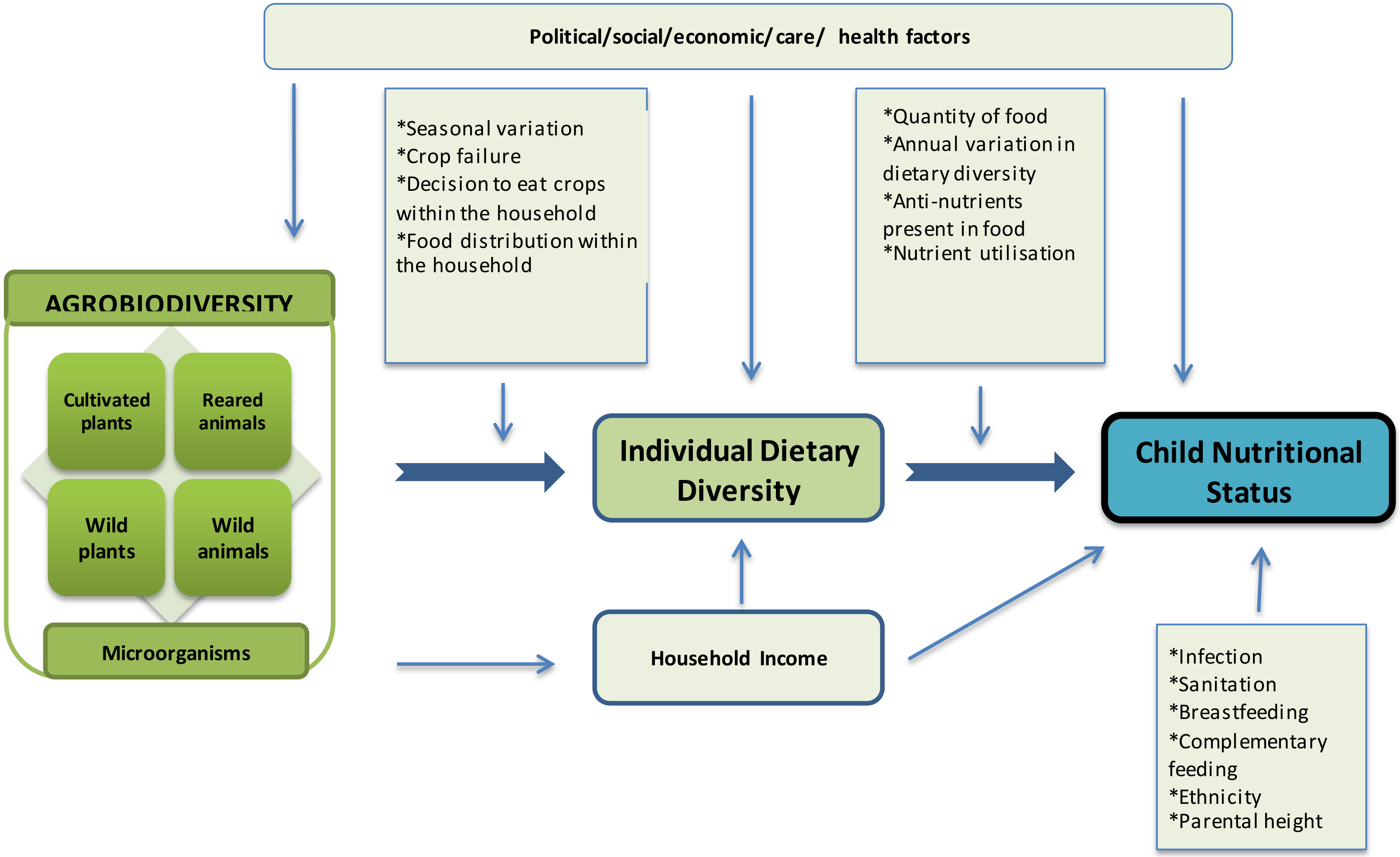

Figure 8.1. Conceptual framework of factors impacting on the relationship between agrobiodiversity, dietary diversity and nutritional status

Many interventions attempting to increase agrobiodiversity in order to have an effect on dietary diversity focus on creating or improving vegetable gardens (Cabalda et al., 2011, Talukder et al., 2000, Talukder A, 2010). The results of the primary data collection provide some interesting insights into the relationship between vegetable gardens, dietary diversity and nutritional status. Households with vegetable gardens grew a higher number of crops throughout the year than those households without but there were no significant difference in any of the dietary diversity or nutritional status variables between these households. Agrobiodiversity indices measured in Mbwei's vegetables gardens were not associated with dietary diversity but they were negatively associated with children's height; the higher the diversity, the lower the height. These results are not encouraging of vegetable garden based interventions and, as with many of the projects results, suggests simply encouraging the use of vegetable gardens in subsistence farmers may not lead to the improvements in diet and health that are expected.

Another interesting insight the primary data collection affords us is on the effect of land degradation on food production. Mbwei had poorer quality farms and were more likely to report not being able to eat the crops they had planted. These households had children with poorer nutritional status. This study adds evidence of the effect on nutritional status to the body of evidence on the association between soil quality and food production (Ezaza, 1988, Doran and Zeiss, 2000).

It is also important to consider the relationships between plant agrobiodiversity and food security. More diverse agricultural fields are more resilient against changes in the climate Frison et al (2011). Growing a variety of crops suited to different conditions is therefore less risky than growing one or two main crops. Due to this increased resilience, higher agrobiodiversity reduces the risk of food insecurity (Frison et al., 2011, Thrupp, 2000).

In areas where agricultural projects aiming to improve diet and nutritional outcomes are being set up, thorough investigations of social and dietary factors likely to impact on nutritional status, such as wealth, education, nutrition knowledge, sanitation and complementary feeding practices present in these areas should occur. Interventions focused on improving agrobiodiversity are likely to be more effective as part of a broad, long term, multi-component intervention. Increasing agrobiodiversity while simultaneously reducing crop failure, ensuring food produced by the household is available year round, ensuring enough of the produced food reaches the household and the vulnerable members within the household, ensuring food is prepared with minimal impact of anti-nutrients in the diet and given to individuals who have decreased risk of infection due to improved sanitation practices will smooth the pathway between agrobiodiversity and nutritional status, allowing improvements in agrobiodiversity to improve health as intended.

8.5 Animal agrobiodiversity and animal product consumption

The results of this study generally show positive associations between eating and rearing animals and dietary diversity and food variety. But they show negative associations between animal diversity and animal consumption and nutritional status in Minyenye children with no associations seen in Mbwei. These similar results were seen in both the villages, which are geographically and socially quite different from each other.

In the DHS analysis it was found that the more days eating meat and fish the higher the dietary diversity and the higher the children's height for age. Although this finding was not replicated in the primary data collection there is evidence of the association between animal product consumption and nutritional status in low income countries (Allen et al., 1992, Marquis et al., 1997, Krebs et al., 2011). Comparing the results from the primary data collection, the DHS analysis and the literature, again, demonstrates the complexity between food produced by the household and the health of the household members.

Given these complex results it is important to consider what motivates people to raise animals. Many people keep animals so they can be sold at times of need, for example to cover the costs of school fees or to buy food in times of food shortage. Keeping certain animals provides an important source of fertiliser to be used on household farms. Households raising animals for these reasons would not benefit from the consumption of meat and animal products.

The difference between just supplying children with extra meat or dairy in order to improve nutritional status in children and encouraging households to produce more animals for meat and animal products needs to be fully explored. The available literature shows that although increased intake of animal products often improves health outcomes, (Gibson et al., 2003, Whaley et al., 2003, Murphy et al., 2003, Siekmann et al., 2003, Neumann et al., 2013), the evidence is less clear on the effect of increased animal production (Leroy and Frongillo, 2007). The further up the path from food production to nutritional status a project attempts to intervene the more barriers the intervention will face in attempting to meet its aims. These barriers need to be addressed and a good understanding of these complexities are needed or projects that could have positive effects on health are likely to fail.

Researchers need to consider the reasons farmers make the decisions they do, for example whether animals raised for food or to provide fertiliser (Powell and Williams, 1994). The primary data collection found that many households raised animals they did not own, the main benefit for this was using the manure for fertilisers for their farms. Another example is whether animals are raised to feed their family or to be able to sell them in order to send one of their children to school (Mazzeo, 2011). Without an understanding of why individuals in sub-Saharan Africa follow certain agricultural practices researchers will be unable to provide the support needed to make improvements that can lead to improvements in diet and health in these in these environments.

8.6 Selling household produce

Selling crops was positively associated with dietary diversity but, showed mixed associations with nutritional status. A similar effect was seen with selling animals, meat, eggs or milk. It is expected that the generation of additional income through the sale of household produce would have a positive effect on diet and growth. As with the other findings in this study this points to the complexity of the determinants of nutritional status. It is possible that money generated from the sale of produce is not being used to buy additional food for the household or perhaps that food is being sold rather than being consumed in the household. Neither scenario would be beneficial for the nutritional status of young children.

8.7 Limitations

In the primary data collection, data was collected at just one time point, at a time of year that the villages were experiencing relatively high amounts of food availability. If data was collected at more time points throughout the year and at times of food shortages the results may have been different (Poskitt EME). Additionally, both the primary data collection and the DHS analysis were cross-sectional studies and dietary diversity and nutritional status were measured at the same time. Height for age reflects long term nutritional trends so would not be influenced by current diet. Weight for age and weight for height are influenced by shorter term factors (Rowland et al., 1988). The reason why dietary diversity and these measures of nutritional status might be expected to be associated when measured cross-sectionally is because diet is very stable in these communities. The assumption that dietary diversity is the same the year of data collection as it was the preceding five years is not unreasonable and has been shown to be the case in a number of other studies (Arimond, 2004, Garg and Chadha, 2009, Savy et al., 2005, Sawadogo et al., 2006, Onyango et al., 1998, Saibul et al., 2009, Hatloy et al., 2000).

Questionnaire data from the primary data collection was collected using a translator and will be subject to errors in translation between Swahili and English. The dynamics between the researcher who is white and comes from a high income country and the respondents may have impacted on the honesty of the participants responses. It has previously been documented (Twyman et al., 1999) that participants may alter their responses either to make their situation better or worse than it actually is; either to avoid judgement by the researcher or in order to be more eligible for aid. There were other family and community members present for many of the interviews which may have impacted on the honesty of the results given. Some of the data, for example the complementary feeding and food sources data, relied on the respondent's memory and would be subject to recall bias. The accuracy of anthropometric measurements may have been affected as there were no flat surfaces available in the villages to measure height and weight.

There are also a number of limitations associated with the collection of the agrobiodiversity data which are discussed in detail in chapter 5. Two different biodiversity experts collected the agrobiodiversity data in the two different villages. Data collection was planned to take place before harvest in each village. In many households in Mbwei, and some households in Minyenye, data collection occurred after their main harvest which decreases the agrobiodiversity indices for these households. The fact that agrobiodiversity was only measured at one timepoint was another limitation of this study. Ideally agrobiodiversity would be measured at a number of different times in the year to counteract any seasonal effects. Farm size differed between the two villages necessitating more frequent data collection methods in Mbwei compared to Minyenye. As the farms were much further away in Mbwei it was not possible to collect data on every farm and those farms that were an hour or more away were not visited for practical reasons.

Based on the site selection process it was expected that Minyenye would have lower plant agrobiodiversity than Mbwei. Due to hotter and dryer weather in Mbwei than is typical for the surrounding area this was not the case. This should not impact on the accuracy of the results but gives less contrast between the two villages than expected.

As with all survey methods, the demographic and health survey data is likely to be affected by bias. Some of the data, for example on complementary feeding, relies on the memory of the respondent and the accuracy of the responses may have been effected by recall bias. As with the primary data collection, the honesty of the responses may have been effected by the presence of the research team. The DHS survey is cross sectional so, as in the primary data collection, no causation can be applied to the results of the analyses. The DHS data is summarised for the DHS EA centre point and linked to the land cover data surrounding the centre point. As the DHS EA vary in geographical size this technique may introduced error in to the analyses conducted; It is possible that a surveyed household could be outside of the 5km buffer and their surrounding land cover would not be included in the analysis.

8.8 Strengths

For the primary data collection households were selected within the villages using randomised household lists so the results of the analyses are representative of the villages. The primary data collection was multi-disciplinary, employing mixed methods which were tailored to the study objectives. The data collection methodology was very thorough, collecting detailed data on the areas of interest. All measures; agrobiodiversity, dietary diversity and nutritional status were measured on the same households allowing the regression to be carried out at the household level. The interviewer spoke to the female head of household, through a translator, so issues could be explored and points could be clarified on data collection. In the same way all data collected was checked as the data collection took place ensuring little missing data.

The project employed a biodiversity expert in each village to ensure the accurate collection of species data on the household farms. Local contacts were hired for each sub-village to find the selected participants and introduce them to the research team and to help with data collection issues to ensure the smooth running of the study.

The national analysis was based on the DHS survey data which is a large, nationally representative data set with detailed information on demographic, social and dietary data. Nutritional status measures were taken following strict protocols. This data was collected in 2010 and temporally matches the land cover data which was collected in 2009 quite closely. This land cover data has been validated using land cover experts from around the world. The validation report states the accuracy of the map to be 67.5% and states that globally there was 5% missing data of inland surfaces that were filled in using the 2005 map (Bontemps et al., 2011).

8.9 Implications and contributions of this study

There are very few projects investigating the relationship between agrobiodiversity, dietary diversity and nutritional status. One other project looks at the relationship between all three factors (Dewey, 1981) and four papers investigate the relationship between agrobiodiversity or the number of crops grown and dietary diversity (Walingo and Ekesa, 2013, Bhagowalia et al., 2012, Akrofi, 2010, Ekesa et al., 2008). One other published study reported the relationship between agrobiodiversity and nutritional status (Shack et al., 1990). This project looks directly at these relationships, at both a local level in two villages in rural Tanzania, and less directly at a national level, using land cover as a proxy for diversity.

Many discussion papers point to agrobiodiversity as a way to increase the diversity of peoples diets in the hope of improving health. The project provides evidence against the theory that increasing agrobiodiversity will increase dietary diversity and mixed evidence about the relationship between agrobiodiversity and nutritional status. It also shows that dietary diversity is not related to nutritional status in these local settings or at the national level. The main implication of these findings are that future nutrition interventions need to address the multiple determinants of nutritional status in order to test whether improvements in agrobiodiversity can lead to improvements in diet and nutritional status.

8.10 Future research and methodological and study design insights

Important questions around whether improvements in agrobiodiversity can lead to improvements in diet and health remain unanswered. In this study, results on the relationship between agrobiodiversity and nutritional status differ between the two different villages indicating the relationship is context specific within rural Tanzania. The DHS study also showed mixed results with agricultural but not forest land cover being positively associated with dietary diversity, both agricultural and forest land cover being positively associated with weight for height and agricultural land being negatively associated with height for age.

The conceptual framework proposed in chapter 3 is largely not supported by the results of either the primary data collection or the national analysis. More research is required to investigate the barriers between agrobiodiversity and dietary diversity as well as why, in some areas such as those studied in this project, dietary diversity is not related to nutritional status. More detailed investigation into how higher agrobiodiversity effects household income and how selling household produce can benefit child nutritional status is needed.

Collecting detailed biodiversity data in the household farms resulted in data that was not associated with dietary diversity and food variety while asking the respondents what they have grown in the past year resulted in a simple count of crops that was associated with food variety. This raises the question; is this simple count a more useful measure than collecting time consuming detailed data on all the different plants that are growing in the household farms at the time of data collection? This measure would be quicker, easier and cheaper to collect and it would represent foods grown over the whole year which is potentially more useful that a measure taken at a limited number of cross-sectional time points. There would be disadvantages to this approach though, it would rely on the recall of the respondent, it requires more interview time and it is not as objective a measure as the systematic collection of agrobiodiversity data in the household farms.

For studies investigating the relationships between plant agrobiodiversity and dietary diversity and health it is important to measure what is grown in household farms and vegetable gardens and not to just rely on the recall of the household members as these two methods provide different information. To improve on the reliability of the plant agrobiodiversity data collected in this study, data should be collected at more than one timepoint throughout the year. These data collection times should match the growing seasons for the area to be confident all crops grown in the household farms and gardens are captured.

Capturing dietary diversity at these different times will increase the understandings of annual variation in dietary diversity and how this relates to the current and previous agrobiodiversity. Capturing both agrobiodiversity and dietary diversity longitudinally and linking these measures to either nutritional status at the end of the data collection or growth over this time period would allow for causal inferences to be made. If it was established that higher agrobiodiversity was associated with higher dietary diversity and nutritional status longitudinally then RCT intervention trials to improve agrobiodiversity in order to improve dietary diversity and nutritional status would be appropriate.

However, for monitoring and evaluating agricultural interventions in resource limited research environments, the simpler crop and vegetable diversity scores could be useful. If it is established that increasing the number of different types of crops grown throughout the year is a desired outcome then asking how many different crops types are grown annually, before and after any given intervention, would provide evidence towards determining whether an intervention had been effective in improving agrobiodiversity.

Due to the multiple determinants of nutritional status in rural sub-Saharan Africa single interventions focused on agrobiodiversity may miss important findings if the results are confounded by, for example, infection. An example of this occurred in an food based vitamin A intervention to improve dietary practices and serum retinol in Tanzania. The intervention area had higher incidence of *helminths* infection and the authors concluded that this was a reason for not seeing any improvements in serum retinol in the intervention group (Kidala et al., 2000). The most successful interventions have been broad, multi-component interventions (Berti, 2004, Leroy and Frongillo, 2007, Remans et al., 2011b). The Millennium villages project found improvements in food security, dietary diversity and stunting with a long term, intersectorial project with agricultural, health, education and infrastructure components (Remans et al., 2011b). More research is needed to continue to unpick the associations seen between agrobiodiversity, dietary diversity and nutritional status in the varied contexts in rural sub-Saharan Africa. Longitudinal research is needed to better understand these associations and comprehensive multi-component interventions are needed in order to determine whether increasing agrobiodiversity improves dietary diversity and nutritional status.

Chapter 9:
Overall conclusion

9.1 How the study fulfils the aim and objectives

This project has fulfilled its aim to **investigate the relationship between agrobiodiversity, dietary diversity and nutritional status in Tanzania**. Before carrying out the primary data collection the methodology and data collection tools were designed and piloted in a village in the Usambara mountains in Tanzania (Objective 1). Methodology was tailored to assess the diversity and abundance of cultivated and wild plants growing on household farms in the two villages in Tanzania (Objective 2). On carrying out the primary data collection, dietary diversity and nutritional status were measured in household members living in these two villages (Objective 3). Other demographic, social and local environmental data were collected to explore the effect these factors had on both dietary diversity and nutritional status. These data were compiled and statistical analyses were used to investigate how these different factors were related and which were related to nutritional status (Objective 4).

In the second phase of this study data from the Demographic and Health Survey carried out in 2010 in Tanzania and land cover data from the Globcover 2009 map were analysed to investigate the relationships between land cover, social and demographic data, dietary diversity and nutritional status (Objective 5).

The results from the primary data collection and the DHS and land cover analyses are collated and discussed in chapter 8 in order to draw conclusions that can inform understanding of food security and the determinants of nutritional status in Tanzania (Objective 6).

9.2 Dietary diversity is not associated with nutritional status in cross-sectional data

No association was found between dietary diversity and nutritional status in Minyenye or Mbwei. When these analyses were repeated on a national level using the Tanzanian DHS data it was found that children with higher dietary diversity actually had lower height for age. Despite the many papers published on data from low income countries showing positive associations between dietary diversity and nutritional status this study found no or opposite associations. It is not appropriate to suggest that there is not an association between dietary diversity and nutritional status from the evidence presented in this thesis but it does illustrate that the association between dietary diversity and nutritional status is not universal and should not be assumed.

9.3 Agrobiodiversity is not associated with dietary diversity in cross-sectional data

No significant associations were found between the agrobiodiversity found in household farms and dietary diversity or food variety in either village. There was however an association between crop and vegetable diversity scores and dietary diversity.

Looking at both agricultural land cover and forest land cover separately in the DHS analysis is a different approach to looking at agrobiodiversity of household farms. This approach, however, provides some interesting insights. Agricultural land cover is linked with higher dietary diversity. Interestingly the more diverse forest land cover is not associated with increased dietary diversity which supports the lack of association seen between the household diversity indices and dietary diversity in the primary data collection.

9.4 Agrobiodiversity has mixed associations with nutritional status

Different associations between agrobiodiversity and nutritional status were seen between the two villages. In Minyenye, agrobiodiversity was positively associated with height in children while in Mbwei it was negatively associated with BMI z-scores. Factors such as farm size, distance to the farms, soil fertility and crop failure, as well as the non-agricultural determinants of nutritional status vary between these two villages and are likely to be the reasons behind these differences. The results of land cover and nutritional status were mixed and revealed no clear picture overall.

9.5 Simply increasing agrobiodiversity will not necessarily improve dietary diversity and nutritional status

Both the DHS analysis and the primary data collection results suggest the often cited association between agrobiodiversity, dietary diversity and nutritional status should not be taken for granted. Areas with access to greater biodiversity, both in the surrounding area and on the households farms will not necessarily be better off nutritionally than those with less diversity. These results have shown that there are many different demographic and social factors that are associated with nutritional status and suggest that, in the context of high rates of poverty and infection, improvements in agrobiodiversity in isolation will not necessarily have the desired positive impact on diet and nutritional status in low income countries.

9.6 Streamline monitoring agrobiodiversity through diversity scores

Asking the female head of household about the variety of foods the household has eaten over the past year and whether these foods were produced within the household gave a simple measure of the crops grown and animals raised by the household. These measures were significantly associated with the dietary diversity of the respondent and her youngest child where measures of agrobiodiversity were not.

Measuring agrobiodiversity in the household farms was a time consuming process which required a research assistant with expertise in biodiversity and knowledge of local species. The data represented the diversity at the time point of data collection but did not give any indication of the other foods grown throughout the year. Although a simple count of food grown by a household annually does not represent agrobiodiversity it is an easier, less resource intensive method which gives data which is associated with dietary diversity. This suggests that this simple count may be more useful to evaluate projects which are, for example, aiming to increase the number of crops grown in order to increase dietary diversity.

9.7 Animal production and consumption will not necessarily improve dietary diversity and nutritional status

The results from the primary data collection found that eating meat and animal products were generally positively associated with dietary diversity but negatively associated with nutritional status. Also, households raising animals for consumption of their meat or products had worse nutritional status in most cases than those not raising animals. Chapter 6 outlines a number of hypotheses of why this might be but the major conclusion from this work is that it cannot be assumed that encouraging subsistence farmers to raise animals will have a positive effect on the health of family members. Again, it must be acknowledged that the effects raising animals has and the uses animals are put to are more complex than may be expected. These results, along with the results from the plant agrobiodiversity work suggest local understanding and collaboration and detailed scoping and monitoring are essential in projects aiming to improve nutritional status through modifications in food production practices in subsistence farmers.

Looking at the national results from the DHS survey indicates that consuming meat and fish has a positive effect on children's height. Relying on data averaged at a national level means differences between regions and villages are lost. This again highlights the importance of local understanding. Although increased consumption of animal products has the potential to improve nutritional status these interventions need to be very carefully implemented and monitored.

9.8 Selling produce will not necessarily improve dietary diversity and nutritional status

Selling crops was positively associated with dietary diversity. This was not found in the majority of cases for selling animals or their products. Selling crops and products from animals raised in the household showed mixed associations with nutritional status. Again this provides caution to those development agencies and nutrition projects operating on the assumption that households raising additional income from selling food products that they produce will have a positive impact on the health of the family members. There are a number of reasons why households will chose to sell crops and animal products and the context these households are living in need to be well understood before any particular intervention is encouraged.

9.9 Agricultural interventions designed to improve nutritional status need to be piloted, context specific and regularly monitored

In order to improve the effectiveness of agricultural interventions aiming to impact on nutrition outcomes in low income countries it is important for their environmental, political, social and cultural context is taken into consideration at all stages of the project. More people need to be fed nutritious diets with less land and resources than in the past and funding for nutrition research in low income countries is limited. Programs cannot be instituted without evidence of effectiveness. Factors determining the dietary intake of individuals are complex and context specific. Researchers cannot assume that interventions will have the effect they are intending or that effect alone.

For these reasons thorough background research, piloting of methodology, locally led research or at least community involvement is essential. Projects also need to be regularly and effectively monitored in order to determine the effect the project is having on the participants and their communities.

9.10 Interventions need to be broad to successfully address malnutrition

This project has provided much evidence and discussion on the multiple determinants of nutritional status. The fact that many of these determinants are still to be addressed in Minyenye and Mbwei could have limited the association seen between agrobiodiversity, dietary diversity and nutritional status. Following on from this hypothesis it is important for interventions designed to improve diet and nutritional status to address as many of these determinants as possible in order to truly test the effectiveness of the intervention of interest. It is likely that many interventions have failed to show an effect due to confounding from, for example, infection and consequently potentially effective interventions may have been disregarded. That agrobiodiversity, dietary diversity and nutritional status were not associated in this cross-sectional study provides evidence of the complexity of these relationships. Agricultural interventions designed to improve nutritional status need to be broad in scope, addressing food security, diet, risk of infection among other factors relevant to the local context. They will likely need to be multi-component interventions investing much time and resources in order to have a positive effect on the health of the target group.

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Appendix A: Ethical approval

Permissions obtained to carry out the primary data collection for Minyenye, Singida and Mbwei, Lushoto

Level	Minyenye, Singida	Mbwei, Lushoto
National	COSTECH, Dar es Salaam	COSTECH, Dar es Salaam
Regional		Regional Administrative Secretary, Tanga Regional Medical Director, Tanga
District	District Executive Director, Singida	District Medical Director, Lushoto District Executive Director, Lushoto District Commissioner, Lushoto Agricultural Extension Officer, Lushoto
Ward	Ward Executive Officer, Mtinko	Ward Executive Officer, Malimbwe
Village	Village Executive Officer, Minyenye	Acting Village Executive Officer of Mbwei, Malimbwe

TANZANIA COMMISSION FOR SCIENCE AND TECHNOLOGY (COSTECH)

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Ali Hassan Mwinyi Road
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Dar es Salaam
Tanzania

RESEARCH PERMIT

No. 2012–216-NA-2012-93 **08th May 2012**

1. Name : **Christine L. Cleghorn**

2. Nationality : **New Zealander**

3 Title : **The Relationship between Agrobiodiversity, Dietary Diversity and Nutrition in Rural Tanzania**

4 Research shall be confined to the following region(s): **Dodoma, Pwani, Singida and Tanga**

5 Permit validity: **08th May 2012 – 7th May 2013**

6. Local Contact/collaborator: **Prof. Joyce Kinabo, Department of Food Science and Technology, P.O. Box 3006, Sokoine University of Agriculture, Morogoro**

7. Researcher is required to submit progress report on quarterly basis and submit all Publications made after research.

M.Mushi

DIRECTOR GENERAL

Appendix B: Information sheet and consent form

Information Sheet

Agrobiodiversity, dietary diversity and nutritional status in Sub-Saharan Africa.

*Cristina Cleghorn is conducting this research project in order as part of her university degree. She is studying at and is being funded by the University of Leeds in the United Kingdom.

*You are being invited to take part in this research project. Before you decide it is important for you to understand why the research is being done and what it will involve.

*The researchers hope to provide information that will help people in rural Tanzania develop strategies to make sure they have enough food to eat.

*The purpose of this project is to look at how the food people grow effects what people eat in rural Tanzania.

*Participants have been randomly chosen from a list of people living in this village. We are hoping to interview about 60 people here in the next 2 weeks.

* To be a participant in this research means:

-To be interviewed by us for approximately 40 minutes on what you and you children eat, where this food comes from and some other basic information about your household.

-To have your height and weight measured.

-To have your children's height, weight and upper arms measured.

-To have 2 of our researchers walk around your household farm writing down the type and amount of plants growing there.

-To have the location of your house and farms measured.

*Whilst there are no immediate benefits for the people participating in the project it is hoped that this work will be useful to farmers in Tanzania in the future.

*Personal information that we collect will not be shared with anyone outside of the research team. Information will be summarised and anonymised for before being disseminated to Nutrition and Agriculture experts and/or used for publication. No personal information will be published.

*It is up to you to decide whether or not to take part in this research. If you decide to take part you can still withdraw at any time during the interview or measurements.

*Do you have any questions? Would you like more information on anything?

*Take the time you need to decide whether or not you wish to take part.

Consent Form

Agrobiodiversity, dietary diversity and nutritional status in Sub-Saharan Africa.

Selection of respondent within household:

Is there a female in this household who has children under the age of 5 living here and is responsible for the preparation of food in this household?

Would it be possible to speak with her? Yes? No?

If no, is there another female who lives in this household that has children under the age of 5 living here?

Would it be possible to speak with her? Yes? No?

If yes → Go to Information Sheet

If no → Go to next household

…………………………………………………………………………………………………

Name: ………………………………...............….

ID Number: ……………………………………

Circle Participants response: Yes or No

Opportunity to ask questions?	Yes?	No?
Do you agree to take part in this research?	Yes?	No?
Can we record some of the interview using this tape recorder?	Yes?	No?
Can we measure your height and weight?	Yes?	No?
Can we measure the height, weight and mid upper arm circumference of your children?	Yes?	No?
Can we measure the location of your house and farm using this global positioning system?	Yes?	No?
Can we take pictures of your health records?	Yes?	No?

Appendix C: Data collection protocols

24 hour recall protocol

For the respondent and her oldest child under five:

1. This is designed to capture the diversity of what the individual is eating.
2. It will ask about all foods, drinks and snacks the respondent has eaten for the 24 hour period from when they got up yesterday to when they got up today.
3. We are not collecting the amount of food the respondent has had, just the different types.
4. We will be doing a 24 hour recall for the respondent and the respondent's oldest child under 5 years of age.
5. The 24 hour recall will be conducted in 3 passes:
    a) A list of all foods, drinks and snacks consumed
    b) Details of all the foods, drinks and snacks consumed
    c) A review of all the foods, drinks and snacks consumed
6. Start by telling the participant that this recall covers all foods, drinks and snacks they had yesterday.
7. First pass:
    a) List all the foods and drinks consumed between the time they got up yesterday morning and the time they got up this morning.
    b) This should be a quick list with no details asked for. Any details they give however should be translated and I will write them down.
    c) Don't ask about specific meals. Instead ask: "What was the next thing that you ate or drank yesterday?"
    d) Don't show surprise or judgement in your responses.
8. Second pass:
    a) Go through the quick list you have collected and probe for more detail about the foods and drinks they have consumed.
    b) Ask "about what time did you eat/drink .....?"
    c) Then "where did you eat/drink ....?"
    d) The details of the actual food we want to collect are:
        i. Cooking method.
        ii. Additions to the food/drink before consumption. Prompt for vegetables eaten eg. Did you have any vegetables with this food?
        iii. For recipes we want to know all the different foods that went into the dish.
        iv. Brand names if packaged food/drinks were eaten.

v. If they had salt on their food, ask if it was iodised.

9. Final pass:
    a) This is a final check to see that you haven't missed any foods or drinks or any details about these foods and drinks. It is also to check that I have everything down correctly.
    b) Read through all the information that I have written down and ask the respondent if it is correct.
    c) Look for gaps in time and prompt the respondent eg. "did you eat anything between the porridge you had at 9am and the rice you had at 6pm?"

Anthropometry protocol

---

1. I need to measure the height and weight of the respondent, her husband/partner and the respondent's children. And the mid upper arm circumference of the respondent's children.
2. I will need you to help with these measures. The family may feel more comfortable with you taking the measures and this may be the easier option considering you can communicate with them.
3. There is no script for this section but you will have to facilitate the measurements and help do the actual measurements.
4. You will need to ask the child if it is ok to take their height and weight in a way that is appropriate to the child's age.
5. You will also have to ask if it is ok for us to look at the health records (after the anthropometry measures) We would have already asked consent to take photos of these.
6. **Weight:**
    a) Adults and children over 2 years: standing on the scales.
        i. Place the scale on a flat surface in a well-lit area.
    b) Children under 2 years being held by their mother using the tear function on the scales.
        i. The mother stands on the scale first, without the child. After the mother's weight appears on the display, tell her to remain standing on the scale.
        ii. Write down the mothers weight.
        iii. Push the tare button.
        iv. Pass the child to be weighed to the adult on the scale. Record the child's weight indicated by the scale.
7. **Height:**
    a) Adults and children over 2 years: Stadiometer, standing up.
        i. 2 people need to help take these measures.

ii. Heels need to be against the back of the board. Heels must not be raised off the ground.
iii. Chin needs to be level. The earholes should be in the same horizontal plane as the lower border of the eye sockets.
iv. Participant needs to be standing comfortably but straight.
v. Tell the participant to reach up as much as he/she can , take a deep breath and relax her/his shoulders.
vi. Make sure the wooden slide that is brought down gently onto their head is flat against the back of the board.
vii. Same person should take the measures to reduce measurement error.

b) Children under 2 years: length measurement with the stadiometer laid down on the ground.
   i. 2 people need to help take these measures. It would also be helpful if the mother could help calm the child and keep her/him still.
   ii. Head should be against the fixed board.
   iii. The ear/eye plane should be in line as for the standing height.
   iv. The measuring tape should be closest to us for ease of reading.
   v. The body should be as straight as possible. Ankles should be gently pulled to straighten child.
   vi. Feet should be turned up vertically.
   vii. Push the movable wooden slide into the heels to read the length measurement.

8. MUAC:

a. MUAC measuring tape.
   i. To be taken on the left arm of the child while the arm is hanging down the side of the body and relaxed.
   ii. With the left arm bent, use a string to find the midpoint of the arm between the shoulder and the tip of the elbow. Mark the midpoint with a pen if this is acceptable to the child.
   iii. Slide the tape around the midpoint of the arm and take the reading on the tape.
   iv. Use enough tension to hold the tape against the skin but not so much that the skin is pinched.

Agrobiodiversity protocol

Point intercept method:

1. Transect lines will be laid every 20 meters along the baseline.
2. The transect lines will run down the farm if the land is hilly.
3. Records will be made every 10 meters along the transect starting at a random starting point at either 1, 2, 3, 4 or 5 meters in from the baseline(to be randomly selected using tokens).
4. A metal pin 1meter in length and 2 mm in diameter will be inserted into the earth at the 10 meter points. All vegetation touching this metal pin will be recorded.

Information to be recorded:

1. Family, genus and species names will be recorded for each plant. This can be coded for ease of recording. If the pin hits only bare earth, this will be recorded as well.
2. Transect number, transect length and number of points along the transect need to be recorded in the margins of the data recording sheet. Use { to indicate what lines of information are for each transect.
3. The number of times the pin hits specific species and bare ground is recorded using a tally.
4. The photo numbers of the photos taken should be recorded in the notes section of the data collection form.
5. Take general photos of the farm from baseline down the farm. These photos should cover the whole farm.
6. Also take photos of specific plants that need to be identified later or specific points if necessary.
7. In addition to data collected on the data collection form some information needs to be collected in a notebook:
    a. Make sure the household ID is clearly recorded on each page.
    b. Record a description of the farm, what the landscape is like, how well it is kept, the main crops growing, whether crops have been recently harvested, any crop damage etc. Record anything that you find interesting.
    c. Draw a sketch of the farm (A4 size) that shows the shape of the farm and where the transects are laid. GPS points along the edges need to be recorded on the sketch so the size of the farm can be calculated.
    d. GPS co-ordinates at both ends of each transect line should also be recorded.
    e. Record the latitude, longitude and elevation for each GPS point.
    f. Add any trees to the sketch and write the family, genus and species of all the trees on the farm.
    g. Mark where photos were taken.

Agrobiodiversity equipment:

1. Data entry sheets.
2. Notebook for the written description of the farm and the sketch with the GPS co-ordinates.
3. Transect string.
4. 1m x 2mm metal pin.
5. Camera (2 AA batteries plus 2 spares).
6. GPS (2 AA batteries plus 2 spares).
7. Randomisation tokens.
8. Stakes for either end of the transect.

Appendix D: Household Questionnaire

Date:
Time:
Interviewer:

Household ID:
Respondent ID:
Location:

Observations

House materials: *Floor* *Roof* *Exterior walls*	Interview:
Children:	Other of interest:

Household ID: Respondent ID:

Demographic and livelihood information

1. How many people live in your household? ………………………………………

A. Family schedule

All family members						If >=5yrs			If >=10yrs				
Family member ID	**Family member name**	**Present?**	**Relationship to respondent**	**Gender**	**Date of Birth**	**Education**			**Marital status**	**Employment**			
	1. Please give me the names of your family members living in this household.	2. Is this family member present in the village?	3. How is (NAME) related to you?	4. Is (NAME) male or female?	5. What is (NAME)'s Date (or year) of birth?	6. Has (NAME) ever attended school? *If yes go to Q7 If no go to Q9*	7. Is (NAME) still attending school?	8. What is the highest level of school (NAME) has attended?	9. What is (NAME)'s marital status?	10. Is (NAME) employed? *If yes go to Q11 If no go to Q12*	11. Does (NAME) work throughout the year, seasonally or just once in a while?	12. Does (NAME) do any other income generating activities? *(prompt)*	13. Does (NAME) have any other sources of income? *(prompt)*
(Respondent)			*5 b) Respondents ethnicity:*	M F		Y N	Y N						
Who looks after your children when you are working/doing these activities?													
(Husband/partner)			*5 b) Husband/ partners ethnicity:*	M F		Y N	Y N						
Others…				M F		Y N	Y N						
				M F		Y N	Y N						
				M F		Y N	Y N						

Household ID: Respondent ID:

Family member ID	Family member name	Present?	Relationship to respondent	Gender	Date of Birth	Education			Marital status	Employment			
				M F		Y N	Y N						
				M F		Y N	Y N						
				M F		Y N	Y N						
				M F		Y N	Y N						
				M F		Y N	Y N						
				M F		Y N	Y N						
				M F		Y N	Y N						
				M F		Y N	Y N						
				M F		Y N	Y N						
				M F		Y N	Y N						
				M F		Y N	Y N						

Note: Others in household except nuclear family just enter name, relationship to respondent, gender and age

Household ID: Respondent ID:

B. Household characteristics *From now on I am going to be asking questions referring to you, your husband/partner and your children.*

1. What is the main source of drinking water for members your family members? *(don't read out options)*

piped water	☐	tanker truck	☐
tube well or borehole	☐	cart with small tank	☐
dug well	☐	river or lake	☐
water from spring	☐	bottled water	☐
rain water	☐	other(specify) …………………………………	☐

2. Where is the water source located? *(don't read out options)*

in own dwelling	☐	*Go to Q4*
in own yard/plot	☐	*Go to Q4*
elsewhere	☐	*Go to Q3*

3. How long does it take to get there, get water and come back? ……………………………………… minutes

4. Do you do anything to the water to make it safer to drink? yes *Go to Q5* No *Go to Q6* don't know *Go to Q6*

5. What do you usually do to make it safer to drink? *(don't read out options)*

boil	☐	solar disinfection	☐
add bleach/chloride	☐	let it stand and settle	☐
strain through a cloth	☐	don't know	☐
use water filter	☐	other (specify) …………………………………	☐

6. What kind of toilet facility do family members in your household usually use? *(don't read out options)*

flush or pour flush toilet	☐	bucket toilet	☐
pit latrine – open	☐	hanging toilet	☐
pit latrine - closed	☐	no toilet/bush/field	☐
composting toilet	☐	other (specify)…………………	☐

7. Do you share this toilet facility with other households? yes no don't know

Household ID: Respondent ID:

Does your household have:

8.	Electricity?	yes	no	don't know
9.	A radio?	yes	no	don't know
10.	A television?	yes	no	don't know
11.	A mobile phone?	yes	no	don't know
12.	A non-mobile telephone?	yes	no	don't know
13.	A refrigerator?	yes	no	don't know

C. Livelihoods *These questions refer to you, your husband/partner and your children.*

1.	Do you, your husband/partner or your children own any agricultural land?	yes *Go to Q2*	no *Go to Q3*	don't know *Go to Q3*
2.	How many hectares/acres of agricultural land do you own all together?	....		acres/hectares
3.	Do you, your husband/partner or your children grow food?	Yes *Go to Q4*	No *Go to next sec.*	don't know *Go to next sec.*

4. Do you, your husband/partner and your children grow food mainly on your own land, on family land, on rented land or on someone else's land?

- On your own land ☐
- On family land ☐
- On rented land ☐
- On someone elses land ☐

5. Where is this land?

....

....

....

....

Follow-up prompts:
Do you just have x farms?
Are these all the places you grow food?
Do you have a vegetable garden?

Household ID: Respondent ID:

Diet

A. 24 hour recall of foods eaten by the respondent I am going to ask you about food and drink you consumed yesterday, from when you woke up in the morning to when you woke up this morning. What was the first thing you had to eat or drink when you woke up yesterday?

Time of day	Name of item or dish and ingredients	Cooking method	Notes

Prompt: Did you eat anything (meal or snack) outside of the home yesterday? Yes No ***IF YES: food included above? No? ask details.***

1.	Was yesterday a special or feast day where you ate unusual foods?	yes	no	don't know
2.	Were you feeling unwell yesterday?	yes	no	don't know
3.	Was yesterday a typical day for your food and drink intake?	yes	no	don't know

Household ID: Respondent ID:

B. 24 hour recall of foods eaten by the respondents oldest child under 5 years (Household Member ID:..........................)

Now I am going to ask you about food and drink .... consumed yesterday, from when he/she woke up in the morning to when he/she woke up this morning. What was the first thing they had to eat or drink when they woke up yesterday?

Time of day	Name of item or dish and ingredients	Cooking method	Notes

Prompt: Did (NAME) eat anything (meal or snack) outside of the home yesterday? Yes No ***IF YES: food included above? No? ask details.***

1. Was yesterday a special or feast day where (NAME) ate unusual foods? yes no don't know
2. Was (NAME) feeling unwell yesterday? yes no don't know
3. Was yesterday a typical day for (NAME'S) food and drink intake? yes no don't know

Household ID: Respondent ID:

C. Diet questions *In the following question 'family' refers to you, your husband/partner and your children.*

1. What do you think a healthy diet is? ……………………………………………………………………………………

………

2. Do you feel that your family has enough food to eat? yes *Go to Q3b* no *Go to Q3a* don't know *Go to Q3b*

3. a) What is stopping your family from having enough to eat?
b) What factors influence what your family eats?

4. Do you feel that your family has enough different types of food to eat? yes *Go to Q5b* no *Go to Q5a* don't know *Go to Q5b*

5. a) What is stopping your family from having enough different types of food to eat?
b) What factors influence what different types of food your family eats?

D. Supplementation questions

1a). Do you take any supplements? yes *Go to Q1b* no *Go to Q2* don't know *Go to Q2*

b). What supplements do you take? ……………………………………………………………………………………

Household ID: Respondent ID:

2a). Do your children take any supplements? yes *Go to Q2b* no *Go to sec.E* don't know *Go to sec. E*

b). Which children and what supplements do they take?

Childrens names	Supplements

E. Breastfeeding questions *These questions refer to your children under the age of 5.*

		Last birth: Name: …………	Second to last birth: Name: …………	Third to last birth: Name: …………
1.	Did you ever breastfeed (Name)?	Y N	Y N	Y N
2.	How old was (Name) when you stopped breastfeeding, or are you still breastfeeding (Name)?	…………	…………	…………
3a).	At what age did you introduce liquids (including water)?	…………	…………	…………
b).	What liquids did you introduce?	…………	…………	…………
4a).	At what age did you introduce solids?	…………	…………	…………
b).	What solids did you introduce?	…………	…………	…………

9

Household ID: Respondent ID:

Food Sources

A. Food Sources table: Please think about the last year and tell me the foods that you, your husband/partner and children have eaten.

Food	Eaten?	Food eaten was? *(tick)* *(if other, give details)*			GROWN					BOUGHT	WILD	Notes
		Grown *Go to column 6*	Bought *Go to column 11*	Wild *Go to column 13*	How much of this food did you harvest in the last year? (in bags/kgs/plants/local measures)	1 or 2 harvests	What months did you have this crop available to eat?	Did you sell any of this crop?	If yes, how much? (in bags/kgs/plants/local measures)	What months did you buy this food?	What months did you collect this food?	
Maize												
Mtama												
Ulezi												
Uwele												
Rice												
Sweet potatoes												
Yams												
Cassava root												
Cassava leaves												
Beans												

Household ID: Respondent ID:

Bean leaves												
Spinach												
Avocado												
Bananas												
Groundnuts												

Wild foods:

Jan Feb Mar Apr May June July Aug Sept Oct Nov Dec

Household ID: Respondent ID:

Would you consider this normal compared to the last 5 years? No? Why? ....

....

....

Animals	Eaten ? *(tick)*	Food eaten was? *(tick)* *(if other, give details)*			RAISED					Notes
		Raised	Bought	Wild	How many of these animals do you have in your household?	Do you own them?	How many have been killed for food in the last year?	Did you sell any of the meat/milk/eggs?	If yes, how much?	
Chicken										
Eggs										
Cows										
Milk										
Sheep										
Goats										
Pigs										
Ducks										
Fish										

Household ID: Respondent ID:

Did you raise any:

Goats	Yes (add to table above)	No
Sheep	Yes (add to table above)	No
Cows	Yes (add to table above)	No
Chickens	Yes (add to table above)	No

Would you consider this normal compared to the last 5 years? No? Why? ....

....

....

B. Food Sources questions

1.	Did you grow any crops to sell in the past year?	yes *(add to table)*	No	don't know
2.	Is this new in the last 5 years?	yes	no	don't know

3. From this information it seems like you don't have much food available to you in .... (months). What does your family do for food during this time?

4.	In the past year, did any of the crops you grew go uneaten or unsold?	yes *Go to Q6*	No *Go to next sec.*	don't know *Go to next sec.*

5. Why?

Household ID: Respondent ID:

Nutritional status of family members: Respondent, husband/partner and respondent's children

Name	*Household member ID*	*Weight*	*Height*	*MUAC*	*Notes*
	01 *(Respondent)*			XXX	
	02 *(Respondent's husband/partner)*			XXX	

Photographs taken of health records? *yes* *no*

Photo #	What the photo is of:	Photo #	What the photo is of:

Appendix E: Agrobiodiversity data collection sheet

Date:
Time:
Research Assistants:

Household ID:
Household member ID:
Location:
HH GOS co-ordinates:

Agrobiodiversity measures: "Agrobiodiversity, dietary diversity and Nutritional Status"

Transect number	Transect length	Photo number	Species	Number of plants	Notes

Date:
Time:
Research Assistants:

Household ID:
Household member ID:
Location:
HH GOS co-ordinates:

1. How many hectares/acres is the farm? …………………………………… acres/hectares

2. Description of farm:

3. Photo numbers of farm:

Date:
Time:
Research Assistants:

Household ID:
Household member ID:
Location:
HH GOS co-ordinates:

4.	Sketch (including GPS co-ordinates at corners and key points)
5.	Key for sketch: