Biodiversity and human nutrition in a landscape mosaic of farms and forests in the East Usambara Mountains, Tanzania

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Abstract

This dissertation sought to add to knowledge of the links between human and ecosystem health by examining relationships between biodiversity and human nutrition in the East Usambara Mountains, Tanzania. Grounded in a theoretical framework drawing from systems approaches to human and EcoHealth this dissertation explores these relationships using qualitative, quantitative and landscape level approaches, with attention to mediators of these relationships. Dietary diversity has been suggested to be an important pathway through which biodiversity contributes to human nutrition and has been separately linked to agricultural diversity and nutrient intake and adequacy; however, there are very few studies that have demonstrated these links in the same population.

This research included data for N=274 children, their mothers and households in 6 villages. Dietary diversity was measured 6 ways: food variety score (FVS) and two dietary diversity score (DDS_6 and DDS_{14}) of food group diversity (based on 6 and 14 groups respectively), each determined from a 7 day qualitative food use questionnaire and from one 24 hour recall (1 day). Nutrient intake was determined from repeat 24 hour recalls from which an MAR (mean adequacy ratio) was calculated. Growth was assessed using WHO protocols. Biodiversity and landscape level variables were assessed by questionnaire and GIS.

Most of the dietary diversity scores showed significant positive correlations to energy intake, in concurrence with local knowledge which emphasizes the importance of dietary diversity for maintenance of appetite. The 1 day FVS, DDS_6 and DDS_{14} were positively correlated with nutrient intake and adequacy (MAR); the correlation between MAR and 1 day DDS_6 remained significant after controlling for energy. Conversely, 7 day diversity was positively associated with crop diversity, forest food use and forest cover.

Although only 3% of food items consumed were wild foods obtained from forest, 15% of items consumed were from wild species, mostly obtained on farm (another way on-farm biodiversity contributed to nutrition). Wild foods from the farm and forest were found to be more important for the intake of micronutrients such as vitamin A, vitamin

C, and iron in the season of food insecurity (the wet season). Individuals using foods from forest and other non-farm land consumed more dense and more nutrient dense diets. Wild and forest foods may also be important for community level (inter, rather than intra-individual) dietary diversity.

Biodiversity from agricultural land was found to contribute to human diet and nutrition: 41% of foods consumed were obtained on farm, including 62% of wild foods. In addition to quantity of vegetables consumed, percent of food obtained on farm and crop diversity (number of crops cultivated in past 12 months) were positively associated with of dietary adequacy (MAR), while percent of food purchased was negatively associated.

Mediators of the relationships between biodiversity, dietary diversity and nutrition included: dietary patterns, education / local knowledge, and forest access (both physical and legal).

Our research suggests that biodiversity from across the landscape mosaic (including farms and forests) plays an important role in the local food system and nutritional resilience of local people in the face of social, economic and environmental change. In order to achieve positive change we must re-examine our intervention approaches and ensure that nutrition is a cross-cutting issue, a priority not only for health professionals, but for those working in agriculture and forestry as well.

Résumé

Ce présent travail cherche à consolider le rapport santé humaine et écosystémique en examinant la relation entre la biodiversité et la nutrition humaine dans les montagnes Usambara de l’Est dans le nord-est de la Tanzanie. Fondée sur un cadre théorique, cette thèse étudie le rapport Écosanté en utilisant des approches qualitatives, quantitatives et paysagères, tout en considérant les médiateurs de ces relations. La diversité alimentaire a été suggérée comme moyen à travers lequel la

biodiversité maintient la nutrition humaine. Ce moyen est bel et bien associé à la diversité agricole, aux apports en nutriments et à la suffisance.

La présente étude comporte des données recueillies auprès de 274 enfants et de leurs mères provenant de six villages ruraux. La diversité alimentaire a été mesurée suivant quatre procédés différents: le score de la diversité nutritionnelle (FVS) et le score de la diversité alimentaire de la diversité du groupe en aliments (basée respectivement sur 6 et 14 groupes), calculés à partir d'un questionnaire qualitatif portant sur l'usage des aliments (7 jour), et à partir d'un rappel de 24 heures (1 jour). L'apport en nutriments a été évalué à l'aide d'une répétition de rappels de 24 heures et à partir desquels le pourcentage moyen de suffisance en nutriments est calculé (MAR). La croissance est évaluée en utilisant les protocoles standards de l'OMS. La biodiversité et les variables éco-systémiques sont évalués à partir d'un questionnaire et du SIG.

La plupart des scores de la diversité alimentaire ont montré des corrélations positives et significatives par rapport aux apports énergétiques, en accord avec le savoir local et qui renforce l'importance de la diversité alimentaire pour l'entretien de l'appétit. Un jour de FVS, DDS_6, et du DDS_{14} sont positivement corrélés avec les apports en nutriments et la suffisance (MAR); la corrélation entre MAR et un jour de DDS_6 reste significative après contrôle pour l'énergie. Inversement, les sept jours diversité étaient positivement associés à la diversité agricole, l'usage alimentaire forestier et le couvert forestier.

Bien que 3% des aliments consommés proviennent de la forêt, 15% de ces aliments est considéré comme sauvage, habituellement obtenues de la ferme. Les aliments sauvages ont une importance en terme d'apport en micronutriments tels que: vitamine A, C, et en fer ainsi que dans la saison de l'insécurité alimentaire. Les individus consommant des produits de provenance forestière et sauvage présentent des régimes concentrés en nutriments et une suffisance alimentaire élevée. Ces aliments sauvages peuvent être aussi d'une grande importance pour ce qui est de la diversité alimentaire communautaire.

La biodiversité des terrains agricoles a été également montrée en faveur de la nutrition humaine: 41% des aliments consommés ont été obtenus des fermes, inclus 62% d'aliments de provenance sauvage. De plus, la quantité des légumes consommés, le pourcentage de la nourriture obtenue des fermes, et la diversité agricole ont été positivement associés à la suffisance alimentaire (MAR), tandis que le pourcentage des aliments achetés y était négativement associé. Les rapports relationnels entre la biodiversité, la diversité alimentaire et nutritionnelle incluent: les modèles alimentaires, l'éducation / savoir local, et l’accès à la forêt (à la fois physique et légal).

Ce travail suggère que l’ensemble de la biodiversité d’un paysage (inclus les fermes et les forêts) joue un rôle important dans le système alimentaire local et dans la résilience nutritionnelle des communautés locales pour faire face aux changements sociaux, économiques et environnementaux. Afin de réaliser des changements positifs, nous devons réexaminer nos approches d'intervention et nous assurer que la nutrition est une question transversale, une priorité non seulement pour les professionnels de santé, mais pour ceux qui travaillent dans l'agriculture et la conservation.

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Contribution of Co-authors

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The research team, data collection and data entry were overseen on a daily basis by Bronwen Powell. All dietary and nutrition data presented herein was entered by Bronwen Powell and analyzed by Bronwen Powell. Other data were checked and cleaned by Bronwen Powell. All statistical analysis was performed by Bronwen Powell, primarily with guidance from Katherine Gray-Donald and Alison Benbow. Analysis was also done by Bronwen Powell. GIS and LandStat analysis were conducted by Jaclyn Hall and the maps in Chapter 6 were created by her.

The dissertation was written in its entirety by Bronwen Powell. Co-authors of respective chapters provided feed-back on study design, data collection and analysis and methods and the manuscripts at various stages of their development. Their suggestions and advice significantly shaped the direction and final form of each manuscript. Guidance on the preparation of the overall dissertation came primarily from the dissertation supervisor and committee at McGill: Timothy Johns, Katherine Gray-Donald and Harriet Kuhnlein.

Statement of Originality

The research presented herein provides a novel case study using a systems approach and the EcoHealth approach in nutrition; approaches that have previously been used primarily for investigation of infectious disease. The systems approach, participation of local communities in setting of research priorities and inclusion of substantial qualitative work have allowed for a more thorough exploration of dietary, social, cultural and environmental mediators of the relationships between biodiversity and human nutrition than has been provided by any previous research.

This research is one of the first studies to examine dietary diversity as a pathway between biodiversity and nutrition. Many previous studies have sought to link dietary diversity to either biodiversity or nutrition but few have examined these relationships simultaneously.

This is one of the first studies to our knowledge: to examine the relationships between biodiversity and human nutrition at the landscape level; to examine the relative contribution of different land use types to dietary and nutrient intake; and, to include landscape characteristics such as forest cover.

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List of Abbreviations

ANOVA – Analysis of Varience

CIFOR – Center for International Forestry Research

DDS – Dietary Diversity Score

FAO – Food and Agriculture Organization of the United Nations

FVS – Food Vareit Score

g - grams

GIS – Geographic Information System

GPS – Global Possitioning System

HAZ – Height for Age Z Score

ICRAF - The World Agroforestry Center

IDRC – International Development Research Center

km - kilometer

kcal – kilocalorie (4.184 kilojoules)

kg - kilogram

MAR – Mean Adequacy Ratio

m - meter

m - miligram

µg - microgram

NSS – Not statitically significant

RAE – Retinol Activity Equivalents

SD – Standard Deviation

TFCG – Tanzania Forest Conservation Group

TSh – Tanzanian Shillings

USD – US Dollar

USDA – United States Department of Agriculture

WHO – World Health Organization

Chapter 1
Introduction, Literature Review and Objectives

The synergies between human and ecosystem health are fundamental to development and sustainability. Human actions have direct and indirect consequences for environmental health: empowered, healthy, food and livelihood-secure people are better able to make rational, long-term resource management decisions that will have a positive impact on environmental health and sustainability (Chweya and Eyzaguirre 1999, Mikkelson et al. 2007, Millennium Ecosystem Assessment 2005). Conversely, environmental health is essential for human well-being. The Millennium Ecosystem Assessment (2005) identified 'ecosystem services' through which biodiversity and ecosystems contribute to maintenance and improvement of human health. Ecosystems services include provisioning (food, water, timber, fuel, medicine), regulating (climate, disease transmission), supporting (nutrient cycles, crop pollination, waste management), and cultural (spiritual and recreational benefits). Although food production is one of the most salient, virtually all ecosystem services contribute to food systems and nutrition in some manner. Fuelwood is essential for cooking food in many rural areas in developing countries; climate regulation assures regular rainfall; reduced disease transmission helps to sever the cyclical relationship between nutrition and infection. Biodiversity and forest cover are two key elements of ecosystems that are needed to ensure ecosystem services.

This dissertation seeks to contribute to the body of work linking human and ecosystem health by examining the contributions biodiversity makes to human nutrition in the East Usambara Mountains, Tanzania. The dissertation provides novel insight by using a systems and landscape level approach to examine these relationships and by focusing on mediators of these relationships. Most previous work linking biodiversity to human nutrition has, understandably, focused on cultivated diversity and agricultural landscapes. The contributions of forests to human health are rarely framed in terms of contribution to nutrition, which is often presented as of secondary importance. This dissertation seeks to take a holistic look at biodiversity from the entire landscape mosaic, including the forests and farms therein, as well as the social and cultural aspects of the biocultural system.

1.1 Human Health and Ecosystem Health

The links between human and environmental health are now well accepted (CBD 2006, Millennium Ecosystem Assessment 2005); the concepts of biocultural diversity (Maffi 2001, Maffi 2005) and social-ecological systems (Berkes and Folke 1998, Folke 2006) highlight the broad links between environmental health and biodiversity, and human cultural diversity and human well-being. Social-ecological systems approaches view humans and their social and cultural characteristics as an essential part of the ecosystem (Berkes and Folke 1998, Folke 2006). Arising from the co-evolution of biological processes and human cultural systems, biocultural diversity is defined as 'diversity of life' including biological, cultural, and linguistic diversity (Maffi 2001, Maffi 2005).

Herein the important interrelationships between ecosystem health and biodiversity, and human health are reviewed, including, for example, links between forests and climate regulation or disease transmission. Food security and nutrition are one of the most important components of human health; 50% of child mortality is directly or indirectly due to malnutrition (UN-SCN 2004). Biodiversity contributes to nutrition through the consumption of wild foods from forests and farms, the diversity of agricultural crops consumed as foods and by supporting agricultural production. These links are reviewed in detail, followed by a brief exploration of economic, geographic, social, cultural and environmental mediators of the relationships.

Links between human health and agricultural health, as well as environmental pollution and contamination are obvious. Forests are linked to human health, in ways additional to the local and global climate regulation they provide (Arnold 2008, Arnold et al. 2011, Sunderland 2011). The impact of forest clearance, transitions in land use and changes in subsistence strategies on infectious disease transmission has been documented (Butler 2008, Dounias and Froment 2006, Dounias et al. 2007, Froment et al. 1993, Koppert et al. 1993, Wilcox and Ellis 2006). For example, Dounias and Froment (2006) suggest that forest-based hunter-gatherer communities avoided parasites and infectious diseases by frequently moving their camps, and that parasite density was a stronger determinate of move timing than food resources depletion. A recent paper showed that a 4.3% change in forest cover (deforestation) was associated with a 48% increase in malaria incidence in Brazil (Olson et al. 2010). The importance of biodiversity for traditional pharmacopeias is frequently highlighted (Anyonge et al. 2006, Cunningham et al. 2008, Karjalainen et al. 2010, Muriuki 2006). The socio-cultural importance of forests for human well-being has been explored (Dounias and Colfer 2008) and recently the links between forests and mental and psychological well-being have been delineated (Karjalainen et al. 2010).

At the landscape level, human-modified land within forested landscape mosaics often provides a greater number of useful plant, but not animal, species than primary forests, a function of intentional human modification and management (Anderson 2006). In the Brazilian Amazon primary forests were found to sustainably provide more wild meat per kilometre squared than secondary forest (Parry et al. 2009), whereas, density of useful plant species was lower in mature forests than secondary forests in the Bolivian Amazon (Toledo and Salick 2006). In the Peruvian Amazon, Gavin (2004) found that fallow provided fewer useful species than secondary forest, but that the total monetary value of the items obtained from fallow was higher.

The last century has seen unprecedented and irreparable human impact on forested ecosystems. In the last half-century, over ½ of the world's tropical forests have been lost, over 9 million km^2 (Pimm et al. 2001). Although currently human activity is leading to an annual loss of 0.13% of the world's forests (FAO 2011), historically not all human impact was negative. Indeed, it is increasingly accepted that many, if not all, of the world's forests have been heavily shaped by past human use (Anderson 2006, Denevan 1992, Hamilton 1989, Heckenberger et al. 2007, Heckenberger et al. 2003, van Gemerden et al. 2003, White and Oates 1999). Human modifications have been on a scale and time frame large enough that it is unlikely that ecosystems (both wild and agricultural) and the species in them have evolved independent of human modification (Altieri et al. 1987, Anderson 2006). Rather than pristine wildernesses forests are now described by many authors as ‘cultural or working forests’ and ‘cultural landscapes’ dependent on human intervention (Anderson 2006, Heckenberger et al. 2003). Although there is no consensus as to whether these historical disturbances had a positive or negative impact on biodiversity (van Gemerden et al. 2003, White and Oates 1999), many careful and deliberate traditional management strategies have been demonstrated to maintain and enhance not only populations of useful species, but also the structure and diversity of the ecosystem where they are found (Anderson 2006, Castle 2006, Reid 2005, Shebitz 2005, Shebitz et al. 2009). The act of harvesting edible roots of the prairie turnip significantly increases seedling recruitment (thereby maintaining populations) and decreases grass dominance (Castle 2006), and, in New Zealand, the rate of decline in Sooty Shearwater (*Puffinus griseus*) abundance was found to be lower at sites where the Maori maintained traditional harvesting (Moller et al. 2009).

1.2 Food Systems, Food security and Nutrition

Food and food security have been designated as a human right (Article 25, The Universal Declaration of Human Rights, The United Nations). In 1996 experts at the World Food Summit defined food security as “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 a healthy and active life”, where ‘food preferences’ is most commonly interpreted to mean foods that are socially and culturally acceptable and consistent with religious and ethical values (Pinstrup-Andersen 2009). This definition highlights the social and cultural aspects of food security. In this definition the use of ‘nutritious food’ highlights the fact that food security should equate with nutritional security in terms of micronutrients, as well as with energy. Unfortunately researchers from some fields (e.g. agriculture or economics) interested in food security have often been guilty of what has been called ‘nutritional reductionism’ or ‘the calorific obsession’

(Ellen 1982, Vayda and McCay 1975). Since the 1996 World Food Summit, immense efforts have been made to overcome world hunger and food insecurity but, only minimal progress towards these goals has been achieved, especially in Africa (FAO 2010b, UN-SCN 2004).

Improving nutrition is central to global development objectives and the Millennium Development Goals (MDGs). Food security is the central tenet of the first MDG: Eradicate extreme poverty and hunger (half the proportion of people who suffer from hunger). But beyond hunger, nutrition also plays a role in achieving MDGs 2 (Universal Primary Education), 3 (Gender equality), 6 (HIV, malaria and disease eradication) and especially 4 (child mortality) and 5 (maternal mortality) (UN-SCN 2004). Malnutrition: i) impairs cognitive development, ability to learn and school attendance; ii) increases the risk of maternal mortality; iii) is directly and indirectly associated with more than 50% of child mortality; iv) decreases immunity; v) weakens resistance to infectious diseases, and, vi) leads to inter-generational transmission of poverty (UN-SCN 2004). Women of child-bearing age and young children are often the most nutritionally vulnerable members of a community (Gibson 2005).

That many of the above impacts of malnutrition are related to micronutrient deficiency, rather than to hunger or protein-energy malnutrition, has led to an increasing focus in international nutrition on the former (Allen 2003, Allen and Gillespie 2001, Underwood and Smitasiri 1999). The links between nutrition and infection are also gaining attention (Koski and Scott 2001, Semba and Bloem 2008), not surprisingly given the evidence linking child growth (and stunting – a measure of growth failure that compares a child's height and age against standard WHO growth curves), biochemical micronutrient status and other outcome measures of nutrition to infection (Allen 1994, Dewey and Mayers 2011, Stephensen 1999). Of significance are inter-relationships between vitamin A and infection (including diarrhoea, and intestinal parasites), iron and infection (particularly malaria), zinc and immunity and the impact of intestinal parasites and schistosomiasis on the status of multiple micronutrients (Scott and Koski 2000, Semba and Bloem 2008).

Global rates of obesity are increasing, even in least developed regions of the world. More worryingly, a ’double burden of disease’ - when communities which have not yet overcome infectious diseases and micronutrient deficiency additionally confront obesity and chronic, nutrition-related diseases (such as cardiovascular diseases and type II diabetes mellitus) - is increasingly common around the globe (Doak et al. 2004, Doak et al. 2000, Popkin 2004). There are widespread reports of over- and undernutrition coexisting in the same households (for example, obese mothers with stunted children) (Doak et al. 2004, Doak et al. 2000, Garrett and Ruel 2005). This nutrition paradox is largely caused by a nutrition transition characterized by a dietary shift away from traditional foods towards increased consumption of processed and other foods that are high in fat, refined sugar, salt and energy (Popkin 2001, Popkin 2004, Popkin and Gordon-Larsen 2004). The resulting diet, high in energy but low in micronutrients (increasingly linked to stunting), helps to explain how over- and underutrition can be found within the same household.

Local or traditional food systems include culturally important and locally-available foods (including from hunting and gathering and small scale agriculture), the technologies needed to obtain, process and prepare those foods, as well as the associated social and cultural characteristics, beliefs and practices (including the associated traditional knowledge) (Kuhnlein and Receveur 1996). When intact, many traditional food systems have ensured adequate dietary intake for generations; for many people in developing countries, traditional food systems remain the foundation of their food and nutrition security (Kuhnlein 2009).

Traditional food systems are dependent on the environment in which they are situated. Food systems are also shaped by the social and cultural contexts in which they exist. The social and cultural characteristics of food, including meanings, symbolism and social structures and contexts in which foods are consumed, contribute to the emotional, mental and spiritual aspects of health, healing, protection from disease, and broader concepts of well-being (Etkin 2009, Kuhnlein 2009, Kuhnlein and Receveur 1996). For example, the cultural and symbolic characteristics of foods play a central role in cultural and personal identity, an important but often over-looked aspect of well-being (Khare 1980, Kuhnlein and Receveur 1996).

1.3 Nutrition and Biodiversity

Within landscape mosaics biodiversity needed to ensure food security and nutrition is found across a wide range of land use types (farm, forest, fallow, etc.). Understanding the importance of foods from different land use types for the diets of local populations is important for conservation, as efforts to link forest conservation to the well-being and livelihood of local people continue and intensify (Sayer et al. 2007). In the widest sense, biodiversity is the source of all food humans consume; links between biodiversity and nutrition are thus one of the most direct links between environmental and human health. Both agricultural biodiversity (domesticated species diversity), and wild (non-domesticated) biodiversity make important contributions to food security and nutrition.

1.3.1 Forests and Nutrition

Forests cover around 30% of the earth's land surface and are a major feature in the environment upon which many rural traditional food systems are based, and are thus an essential part of their integrity. The most widely accepted definition of forests is : "Forests are lands of more than 0.5 hectares, with a tree canopy cover of more than 10 percent, which are not primarily under agricultural or urban land use." and that "The trees should be able to reach a minimum height of 5 meters (m) at maturity *in situ*." (FAO 1998, FRA 2000). The Clean Development Mechanisms of the Kyoto Protocol (i.e., the Marrakech Accords) modified the FAO definition slightly to allow each country to define the minimum crown cover (10-30%), minimum area (0.05-1ha) and the minimum height of trees (2-5m) (Neeff et al. 2006). However significant ambiguity, debate and disagreement remain (Putz and Redford 2010, Sasaki and Putz 2009, Verchot et al. 2007). As Putz and Redman (2010) note: "Vegetation classification systems ... can ... fail to capture the fluidity of 'forest' and other ecosystem types both in nature and as social constructs." Both historically and in many communities around the world today, the word "forest" is defined more by political factors than vegetation structure (Putz and Redford 2010). This is also the case in the East Usambara Mountains where local people also use the word forest (*msitu*) to refer to protected areas (Rantala 2010). Given that forests, especially tropical forests, contain some of the highest levels of biodiversity globally (Myers et al. 2000), they are of central importance to the contributions that wild biodiversity makes to supporting human food security and nutrition (Johns and Maundu 2006, Millennium Ecosystem Assessment 2005, Vinceti et al. 2008). Broadly, forests contribute to nutrition by ensuring agricultural productivity through ecosystems services including: maintenance of soil and water cycles (e.g. erosion control), climate and rainfall regulation, nutrient and waste cycle regulations, (Arnold 2008, Arnold et al. 2011, Millennium Ecosystem Assessment 2005, Sunderland 2011). In many forested areas trees provide fuel, an essential component of the local food system. Limited access fuelwood causes many families to alter what they eat, often leading to decreased consumption of legumes and associated protein and micronutrients. Shrinking access to fuelwood near the home often means women have less time for other activities that ensure the food security and health of their families. Improperly cooked food can lead to illness which worsens nutritional status (Arnold et al. 2011, Brouwer et al. 1996, Brouwer et al. 1997, Wan et al. 2011).

While it is widely agreed that no communities are now wholly dependent on wild gathered forest food (all cultivate, barter or trade to some degree), forest biodiversity makes important contributions to nutrition by providing both, a safety net in times of food insecurity and, micronutrients, which are often less available from other food sources (Colfer et al. 2006, Vinceti et al. 2008). Forests have been linked to food security through the importance of agroforestry products for nutrition and income (Hoskins 1990, Jamnadass et al. 2011, Styger et al. 1999), especially in times of food insecurity (Falconer 1990). Forest foods and other products are often more important to the poorest members of society, some of whom sell wild NTFPs (Non-Timber Forest

Products, e.g. forest foods, firewood, etc.) to earn income needed to ensure their food security in times of crisis (Arnold 2008, Fisher 2004, McSweeney 2004).

Forest foods most often include fruit, vegetables, mushrooms, insects, fish and meat (Vinceti et al. 2008). Because fruits, vegetables and animal source foods are important sources of micronutrients, even in small amounts, they make an important contribution to local diets. These types of foods, compared to starchy staples and snack foods obtained through agriculture or purchasing, have higher density of most micronutrients relative to energy, carbohydrates and sugars. These characteristics mean that forest and other wild foods could play an important role in mediating the nutrition transition.

Although often in conflict with conservation priorities, in many forested regions the consumption of bush meat accounts for a large portion of total animal sources food intake and, presumably therefore, protein and micronutrient intake (Fa et al. 2003, Nasi et al. 2008, Pailler et al. 2009, van Vliet and Nasi 2008). In a paper using data from Madagascar, Golden and colleagues (2011) estimate that the loss of wild meat from the diet of children would result in a 29% increase in the numbers of children suffering from anemia. While populations of many species plummet under even moderate hunting pressure, some smaller species have been found to be quite resilient (Arnold 2008, Nielsen 2006).

The relative importance of different types of food resources (wild, domestic, market) and land use types (forest, fallow, farm) for human subsistence, livelihood and adaptation are long-standing questions in anthropology and human ecology. Rappaport’s (1968) application of ecosystems theory to examine the different of importance and procurement strategies of energy and protein in Papua New Guinea stimulated interest in the use of energetics and the Optimal Foraging Theory to examine human substance decisions, strategies and adaptation (Ellen 1982, Smith 1979). Keegan (1986) applied the Optimal Foraging Theory to subsistence decisions of the Machiguenga, a horticultural society in the Peruvian Amazon, and showed that gardens produce more energy per hour of time input than other subsistence strategies, and that protein per hour production for forest and fishing activities is dependent on fishing methods, season and amount of time a forest patch has been under use. Keegan confirmed that, as shown in hunter-gatherer communities, Machiguenga subsistence decisions are not based purely on energy. Johnson and Behrens (1982) broadened the approach further by including nine nutrients in their model predicting which Machiguenga subsistence strategies would be most efficient to produce a balanced diet. Their model indicated that while gardening produced far more energy per unit of time, because micronutrients (vitamin A, riboflavin and niacin) were the limiting nutrients in the diet, the most efficient way to achieve a balanced diet would be to spend 86% of time hunting and gathering and 14% of time gardening. Johnson and Behrens (1982) proposed that the discrepancies between their model and the Machiguenga reality, in which over 50% of food procurement time was spent gardening, could be explained by the fact that their model included only nine of many nutrients, that gardens provided security (providing large amounts of energy), and that increased reliance on wild resources would lead to overexploitation.

1.3.2 Wild Foods and Nutrition

Herein, 'wild foods' refer to uncultivated foods (plant and animal) obtained from any land use type (farm, forest, river); whereas 'forest foods' are a sub-category of wild food referring exclusively to those obtained from the forest. A separate but associated body of literature examines wild food use and the contributions of wild foods (especially wild plant foods and wild vegetables) to diet and nutrition (Fleuret 1979b, Grivetti and Ogle 2000, Herzog et al. 1994, Ogle et al. 2001). This body of literature covers wild foods from any land use type, and often (but not always) the land use type or ecosystem from which the wild foods were obtained is not specified. A growing body of work documents extensive habitual wild food (especially wild vegetable) use around the globe (Batal and Hunter 2007, Booth et al. 1993, Etkin 1994, Fleuret 1979b, Harris and Mohammed 2003, High and Shackleton 2000, Humphry et al. 1993, Ladio and Lozada 2004, Maroyi 2011, Moreno-Black and Somnasang 2000, Msuya et al. 2011, Mwajumwa et al. 1991, Pieroni et al. 2002, Pieroni et al. 2005, Price 1997, TardÍo et al. 2006, Vainio-Mattila 2000, Vázquez-García et al. 2004, Zinyama et al. 1990). In Sub-Saharan Africa it has been estimated that in many areas close to 100% (in Kenya and Tanzania the estimate was 94%) of rural households are dependent on local wild plants for their daily needs (Millennium Ecosystem Assessment 2005). A study in rural Côte d'Ivoire found that over 50% of the fruit consumed in the course of one year were wild (Herzog et al. 1994). In coast areas, the implementation of protected areas has been shown to support the availability of fish and thus local communities' food security (Aswani and Furusawa 2007, Gjertsen 2005).

Although documentation of the nutrient composition of wild foods has increased significantly (Batal and Hunter 2007, Lyimo et al. 2003, Msuya et al. 2008, Nordeide et al. 1996, Toledo and Burlingame 2006), data on the nutrient composition of wild foods remain insufficient to compare wild and non-wild fruits or vegetables effectively (and impossible for animal source foods). Moreover, nutrient content of fruits and vegetables can be extremely variable within a given species, depending on variety, climate, ecology, harvest and storage factors (Englberger et al. 2003, Msuya et al. 2008).

Wild plants are unfortunately often overlooked in nutrition and agriculture, in part due to the paucity of data (Chweya and Eyzaguirre 1999, Grivetti and Ogle 2000). This is especially worrying in light of the fact that wild foods are most important to the most vulnerable members of society, i.e. those of lower socio-economic status and women (Daniggelis 2003, Harris and Mohammed 2003, Johnson and Grivetti 2002, Ogle et al. 2001), although associations between gender, socio-economic status and wild food use do not hold true in all contexts (Bharucha and Pretty 2010, Booth et al. 1993). In their study in rural Thailand, Johnson and Grivetti (2002) found that poor households gather wild foods almost twice as often as wealthier ones. The collection and sale of wild food plants is one of the few means by which poor people can generate income for purchasing food or agricultural inputs in many parts of the world (Arnold 2008, Chweya and Eyzaguirre 1999, Harris and Mohammed 2003). Women are almost always responsible for collection and preparation of wild foods (Chweya and Eyzaguirre 1999, Daniggelis 2003, Howard 2003). Because of this women harbour the traditional knowledge needed for collection, management and conservation of wild food plants (Howard 2003, Johnson and Grivetti 2002, Shrestha and Dhillion 2006); Daniggelis (2003) notes that in Nepal it was the poor women who first notice changes in species composition and diversity of wild food plants on communal lands. Moreover, Moreno-Black and Somnasang (2000) reported higher wild food usage in the most food scarce season in Thailand (where the most food scarce season is the dry season, when wild foods are less available), and in Niger local people report greater reliance on wild foods in drought (Humphry et al. 1993).

Many studies have looked at the contributions of traditional foods (which are often wild) to diet and nutrient intake of indigenous peoples (Kuhnlein 2009). Of work focusing specifically on wild foods, to our knowledge only one has previously reported the contribution of wild foods (wild vegetables) to the intake of different nutrients (Ogle et al. 2001, Ogle et al. 2003). The study, conducted in the Mekong Delta and forested Central Highlands of Vietnam, found that wild vegetables made the greatest contribution to carotene (providing 19% in the Central Highlands), vitamin C (13% in the Central Highlands) and iron (14% in the Central Highlands) intake, with lesser contributions to energy and macronutrient intake.

1.3.3 Agrobiodiversity and Nutrition

Agricultural ecosystems cover 33-38% of the earth's land surface (Zimmerer 2010), thus the biodiversity found in agricultural landscapes makes up a significant portion of the total global biodiversity (CBD 2007). Agricultural systems, as part of mosaics of land use around protected areas, are increasingly the focus of landscape level approaches to conservation and livelihood improvement (Sunderland 2011, Zimmerer 2010).

It is important to differentiate between agrodiversity, agrobiodiversity and agricultural diversity, terms which are often used exchangeable. Agrodiversity, the broadest of these terms, is used most often in reference to diversity within and between agricultural ecosystems (agroecosystems) and their management (Brookfield 2002). Agrobiodiversity is somewhat more specific. Hardon (2000) notes that definitions of agrobiodiversity vary; the Convention on Biological Diversity (CBD) defines agrobiodiversity as all living organisms associated with agriculture, crops and livestock and the ecosystem of which they are a part, while IPGRI's (now Bioversity International) definition is more limited, including only cultivated crops. Some authors use the term agricultural diversity to differentiate the diversity of cultivated crops (diversity of crops, varieties and genetic diversity) from the CBD definition of agrobiodiversity (the system used herein). Others use the terms agricultural biodiversity and agrobiodiversity interchangeably (Brookfield 2002).

Both agrobiodiversity (agrodiversity) and agricultural diversity contribute to human nutrition. Agrobiodiversity contributes to human nutrition through ecosystem services, improved agricultural resilience, and importantly, through wild foods procured from agroecosystems. For example, a study of rice-based aquatic agroecosystems highlights that biodiversity within the agroecosystem provided nutritionally beneficial wild foods (vegetables, fish and crustaceans) and provided ecosystem services such as pest control and nutrient cycling (Halwart 2006). Other environmental services provided by agrobiodiversity include: pollination, integrated / biological pest management, and new genetic material for cultivated crops from wild relatives (Chweya and Eyzaguirre 1999, Frison et al. 2011, Grivetti and Ogle 2000, Millennium Ecosystem Assessment 2005, Sunderland 2011).

Agricultural diversity is an important source of agricultural development and innovation (Toledo and Burlingame 2006); however, the contribution agricultural diversity makes to human dietary diversity, food security and nutrition is perhaps the most salient contribution that biodiversity makes to human health. Evidence in support of the links between agricultural diversity and human nutrition comes from diverse sources. The connections, especially in relation to dietary diversity, have been extensively reviewed (CBD 2006, Frison et al. 2011, Frison et al. 2006, Johns and Eyzaguirre 2006, Johns and Sthapit 2004) and strong empirical evidence of these links continues to emerge (Ekesa et al. 2008). In Kenya and Tanzania agricultural diversity (crop diversity) has been linked to dietary diversity [1 day DDS (Dietary Diversity Score) and DVS (FVS – Food Variety Score))] (Herforth 2010a). One study focused on assessing the link between dietary diversity and nutritional adequacy found that agricultural diversity (number of crop species cultivated) made a significant contribution, along with dietary diversity, to dietary adequacy (MAR – Mean Adequacy Ratio) for nine nutrients (Torheim et al. 2004). In Ethiopia, Harden-Baars (2000) suggests that through the maintenance of genetic diversity of the local grain crop Enset, farmers can achieve food security. Agricultural diversity is of such importance to well-being that the number of landraces a farmer maintains is a symbol of social status (Harden-Baars 2000). Farmers around the world report that agrobiodiversity and agricultural diversity provide them with security in the face of environmental, climate, economic and social change: "The main reasons for maintaining high biodiversity by farmers are mostly to ensure food security and to meet various qualitative preferences and household requirements" (Sthapit and Subedi 2000).

Home gardens are an important reservoir for agricultural diversity and in many settings and are particularly important for nutrition (especially micronutrient intake) (Coomes and Ban 2004, Eyzaguirre and Linares 2010, Galluzzi et al. 2010, Tontisirin et al. 2002). A study in Nepal found that the diversity rather than the size of home gardens was positively related to nutritional status. Another study in Puerto Rico found a strong association between child nutritional status and the presence of a home garden (Immink et al. 1991 in Jones) (Jones et al. 2005). Home garden interventions have been shown to be some of the most effective food-based interventions from improving micronutrient intake and nutrition (Berti et al. 2004, Tontisirin et al. 2002).

Many wild foods are procured from agricultural land, even within landscape mosaics that contain significant forested areas (Arnold 2008, Bharucha and Pretty 2010, Fleuret 1979b, Grivetti and Ogle 2000, Powell et al. 2010, Price 1997). Conventional agricultural paradigms view many of these important foods as weeds and pests (Shemdoe et al. 2009). In many settings a significant portion of wild meat is also obtained on agricultural land (Arnold et al. 2011, Nasi et al. 2008). Even larger game is opportunistically hunted when it invades farmlands; the line between hunting to protect crops versus hunting to provide meat is often blurred (Ibarra et al. 2011, Powell et al. 2010). A study in South Africa has shown that of the income households made from their small-scale farms, 31% of that income was from wild plants (High and Shackleton 2000). In Thailand 35% of wild vegetables were obtained from fields, 26% grew in the village and only 17% grew in the forest (Price 1997). Additionally, wild food plants are often wild and weedy relatives of crops and act to preserve the genetic diversity of many important cultivated species. In fact, many rural farming communities do not clearly differentiate between cultivated and wild species (Bharucha and Pretty 2010); most species exist on a continuum of management intensity. Many communities have developed advanced management practices to ensure their supply of 'wild' foods (Grivetti and Ogle 2000, Johnson and Grivetti 2002, Shrestha and Dhillion 2006). In Thailand, Johnson and Grivetti (2002) found home gardens to contain 5 to 10 formerly wild species that local women had begun to cultivate when they became scarce locally.

Historic ideas about cultural evolution assume that progressive changes in subsistence strategies led to changes in reliance on 'wild resources'; however, a recent review of wild foods in agricultural systems highlights that the labels of 'hunter-gather' versus 'agricultural' create a false dichotomy suggesting that wild foods are of limited importance in agricultural livelihoods (Bharucha and Pretty 2010). "It would seem that the crucial role of hunting and the gathering of wild vegetable foods in societies normally regarded as subsisting by swidden agriculture has not always been appreciated or received the attention it deserves" (Ellen 1978). The reliance of local people on wild plants as a source of food and income many be a key motivator to encourage the preservation and maintenance of the biodiversity within agroecosystems.

1.3.4 Traditional Foods

Traditional foods include those from the wild and traditional agricultural systems, as well as traded items which have been used historically or have social or cultural importance (Kuhnlein and Receveur 1996). In many rural areas, current food systems are very similar to historic ones and can be considered 'traditional'. Traditional food diversity can include the diversity of wild and cultivated foods discussed above, and similarly makes important contributions to food security and nutrition. Many studies have looked at different contributions of traditional versus market foods to diet and nutrient intake of indigenous peoples, especially in North America (Kuhnlein 2009). For example, a paper on the diet of Inuit people on Baffin Island found that for women aged 20-40 years, traditional foods (mostly wild sea and land mammals, birds and fish) contributed approximately 29% of energy, 62% of protein, 57% of vitamin A, 81% of iron, 67% of zinc and 11% of calcium intake (Kuhnlein et al. 1996). In the Peruvian Amazon, traditional food diversity was positively correlated with micronutrient intake (Roche et al. 2007). Traditional vegetables specifically have also been much researched, with their importance in the diets of people in developing countries highlighted (e.g. (Campbell 1985, Chweya and Eyzaguirre 1999, Fleuret 1979b, Nordeide et al. 1996, Orech et al. 2007, Uiso and Johns 1996).

Traditional foods are particularly bound by social and cultural factors, contributing to biocultural diversity. Yucatan natives were found to maintain their culinary traditions after leaving their home region to find wage labour in neighbouring areas of Mexico by making special trips home to gather seeds and cuttings which they transport to their new home in order to maintain their culinary heritage and cultural identity, while at the same time improving the quality of their diets and preserving and enriching agricultural diversity (Greenberg 2003). Johns (1996) suggests that humans have used a diversity of cultural means, including plant domestication, to modify plant biodiversity to meet their evolving dietary and medicinal needs; Nabhan (2004) lays out some of the many ways in which food plants, humans and cultural practices have co-evolved (e.g. faba beans and malaria resistance); and Etkin (1982) emphasizes that the line between food and medicine is bounded by cultural norms, and in many societies there is little differentiation between the two.

Food is a central part of individual, social and cultural identity. Eating or not eating certain foods is a part of cultural expression and participation, an important strategy for maintaining a sense of belonging to a given group, and a marker of ethnic identity (Kuhnlein and Receveur 1996): "Food makes the eater: it is therefore natural that the eater should try to make himself by eating", or in anthropologist Levi-Strauss's words "A society's cookery is the language into which it translates its structure" (Fischler 1988)(p. 282). Cultural ideas, legends and myths create meanings and dictate prescriptions and taboos about how, when, where and why foods are eaten (Khare 1980). Kuhnlein and Receveur (1996) give the example that "Certain textures, for instance, are considered appropriate as food for infants and the elderly. The color blue is important for certain traditional Hopi food, and preparation technologies favour the development of the blue color in blue corn bread (*piki*) and other meal items". Shell-Duncan and McDade (2005) provide another salient example in their work describing how different foods are thought to be good for girls and boys by the Rendille of northern Kenya, illustrating how cultural beliefs and practices can mean that economic development alone will not suffice in changing nutritional status. Nutritional, health and cultural qualities of traditional foods are "an underutilized vehicle for promoting positive behaviours" (Johns and Sthapit 2004). The above example from Johnson and Grivetti (2002) is evidence that local people are willing and able to make the necessary behaviour changes to ensure the conservation of their traditional foods and the ecosystems from whence they come.

1.4 Dietary Diversity

Dietary diversity is increasingly appreciated as a key component of healthy diets (Ruel 2003). On a theoretical basis dietary diversity is an important aspect of a healthy diet because, by varying items in the diet, the likelihood of consuming adequate amounts of all food components essential to health increases, and the likelihood that excessive intake of any one potential toxin decreases (Gibson et al. 2000, Johns and Sthapit 2004).

The strongest evidence linking dietary diversity to health is based on the fact that dietary diversity increases overall consumption. This is supported by research on 'sensory-specific satiety', whereby satiety is modified by the number of different sensory options present (Brondel et al. 2009, Rolls 1986). For example, if only salty or sweet options are present people eat less than when both are present. This body of research shows that diversity of meal items increases consumption in both humans and animals (DiBattista and Sitzer 1994, Rolls et al. 1981).

Given the links between dietary diversity and overall intake (and therefore energy intake) it is not surprising that dietary diversity has been linked to higher micronutrient intake and adequacy, as well as higher nutritional status of both children and adults (Arimond and Ruel 2004, Arimond et al. 2010, Daniels et al. 2007, Foote et al. 2004, Hatløy et al. 1998, Kennedy et al. 2007, Onyango et al. 1998, Roberts et al. 2005, Ruel 2003b, Spigelski 2004, Steyn et al. 2005, Torheim et al. 2004).

Since dietary diversity was first proposed as an indicator of diet quality over 30 years ago (Duyff et al. 1975, Kant 1996, Randall et al. 1985), over 200 papers have been published the topic. In addition to evidence linking dietary diversity and improved nutrient intake, adequacy and anthropometric status, dietary diversity has also been linked to: higher nutrient density (Ferguson et al. 1993, Moursi et al. 2008); improved food security (Hoddinott and Yisehac 2002); lower likelihood of dual burden of malnutrition (over and undernutrition in the same household) (Bouzitou et al. 2005, Saibul et al. 2009); reduced risk of chronic diseases (Azadbakht et al. 2005, Fernandez et al. 1996, Franceschi et al. 1995, Slattery et al. 1997) and overall mortality (Kant et al. 1993, Kant et al. 1995).

1.5 Mediators of Human and Ecosystem Health

1.5.1 Equality, Wealth and Poverty

In their review of poverty and malnutrition Peña and Bacallao (2002) argue that nutrition is one of the central mediators of the links between poverty and health, and that without attention to nutrition, development will not necessarily lead to improved health. 'Poverty' is a term which should be used with caution as development discourse has often acted to produce power imbalances, focusing on weaknesses rather than strengths of those 'in need of development' (Escobar 1995).

Vulnerability, equality and wealth are also important mediators of reliance on environment and wild resources, with significant implications for conservation. Many studies have demonstrated that those with lower socio-economic status are more reliant on forest resources for income and livelihood (Arnold 2008, Colfer et al. 2006, Vinceti et al. 2008), although relationships are not always consistent (Ambrose-Oji 2003, Bharucha and Pretty 2010). In Malawi asset-poor households were found to be more reliant of forest activities than better-off ones (Fisher 2004). In the Marsabit forest in Kenya households which sold forest products had lower mean incomes than those that did not and in those that did not (Adano and Witsenburg 2005). Conversely, in Cameroon, households from lower wealth categories earned lower total, and a lower percentage of, their income from NTFPs compared to households in higher wealth categories (Ambrose-Oji 2003). Arnold (2008) reports cases from Vietnam, Western Africa and the Amazon where forest foods and bush meat are eaten by wealthy households but are sold by poorer households in order to buy food staples.

Fisher and Christopher (2007) demonstrate significant overlap between levels of biodiversity and poverty globally, and Mikkelson et al. (2007) demonstrate spatial links between income inequality and biodiversity loss. It is important to not infer causation from such data; a recent study from Uganda showed that although those living adjacent to Kibale National Park tended to be poorer, there was no indication that the park was the cause of their poverty. In fact, being adjacent to the park had a protective effect against farm loss and sale of land attributed to emergency or debt (Naughton-Treves et al. 2011).

Globally, many indigenous groups have historically been oppressed. Today, many are still alienated from their lands, socially and culturally disadvantaged and politically marginalized; international recognition of indigenous groups (through the United

Nations for example) and their human rights has helped to empower and protect many of these minority groups (Niezen 2003, Tooley 2008). In Sub-Saharan Africa virtually all ethnic groups could claim indiengeniety, but those who have sought international identification as ‘Indigenous’ have been mainly pastoral and hunter-gather groups, disadvantaged by colonial policy and with less visible claims to land. Agricultural groups, although no less ‘indigenous’, have stronger ties to their traditional lands and have thus had less to gain from engaging in international discourse on indignity (as others have done in order to secure land-tenure and autonomy in politically completed national spheres) (Hodgson 2009, Igoe 2006, Lynch 2011, Pelican 2009).

1.5.2 Gender

Gender is an important source of inequality that mediates health, nutrition and reliance on environment and natural resources. Physiological needs of women in their child-bearing years increase their nutrient requirements (Gibson 2005). Moreover, in times of food shortage women will often skip meals and reduce their portion sizes in order to maintain food availability for their children. Unequal distribution of food resources often means that women and girls get smaller portions of foods, especially micronutrient-rich foods, than do boys and men. In northern Kenya, Shell-Duncan and McDade (2005) found that girls were 2.4 times more likely to be iron deficient than boys. Ethnographic work revealed that ‘hard foods’ (meat, blood, beans) were believed to be important for boys, while ‘soft foods’ (rice, maize, porridge, tea) were believed to be beneficial for girls’ health.

Gender mediates economic equality (poverty and development) in a number of ways other than health and nutrition. Kabeer (2003) notes that, although other factors can lead to larger disparities, gender is the most pervasive form of inequality around the world: “Gender inequality intersects with economic deprivation to produce more intensified forms of poverty for women than men”. Girls are less likely to attend school and stay in school for fewer years than boys. In many countries girls are still required to leave school if they become pregnant and a recent study from Tanzania reports that inadequate support and facilities for girls during menstruation (lack of clean toilets, lack of feminine hygiene products, or the ability to purchase them) is another barrier to girls education (Sommer 2010).

Health is a strong motivator for women; the health of their families is perhaps a greater priority for women than men, as they bear the burden of care of ill family members (Wan et al. 2011). Perhaps because of this, increased income in the hands of women has greater impact on food expenditure and overall family well-being than it does in the hands of men (Blumberg 1988, Engle 1993, Hoddinott and Haddad 1991, Kabeer 2003, Katz 1994). In Guatemala, increases in women's income from the introduction of non-traditional export crops (broccoli and snow peas) had twice the impact on food expenditure than increases in men's income (Katz 1994), and, children from homes where women earned a larger percentage of the family income had better nutritional status (Engle 1993).

Gender is a key mediator of forest use and reliance on natural resources. The importance of wild foods to women has been mentioned above and recent reviews by Wan et al. (2011) and Colfer et al. (2008) cover inter-relationships between reliance on forest products and women's health.

1.5.3 Market Integration and Economy

Most assessments of the impacts of conservation on livelihoods focus on economic factors; diet, food security and nutrition are often overlooked. The assumption that increased income is necessarily linked to improved diet and nutrition must be questioned (de Walt 1993, Dewey 1989, Kennedy 1989); for example, income in the hands of women has been shown to have a different impact on household health and nutrition than income controlled by men (Blumberg 1988, Engle 1993, Hoddinott and Haddad 1991, Kabeer 2003, Katz 1994). There is also a growing body of research showing that while commercialization of agricultural systems may improve income, it does not always lead to increased food consumption, and is sometimes even associated with declines in nutritional status (de Walt 1993, Dewey 1981, Dewey 1989, Kennedy

1989, Kennedy and Cogill 1987, Kennedy 1993, Shack et al. 1990, VonBraun 1988). De Walt (1993) suggests that the impacts of commercialization on nutrition are mediated by the type of crop, control of income, maintenance of subsistence production, land tenure, and greater market factors. In India, households participating in a milk cooperative drank less milk than those not participating (Alderman 1987 in (Herforth 2010a). In northern Tanzania (Mt. Meru), cash cropping was found to not have a negative impact on nutrition because the cash crop, coffee, was grown intercropped with bananas and, intercropping had a positive impact on nutrient adequacy ratios (Lev 1981). Market integration has also been linked to increased consumption of processed foods and the likelihood of a nutrition transition (Kuhnlein and Receveur 1996, Popkin 2004).

The commercialization of non-timber forest products (NTFPs) has been linked to decreased availability of subsistence species for local consumption and may not have any benefit for biodiversity and forest conservation (Ambrose-Oji 2003, Belcher et al. 2005, Powell et al. 2010). As noted above, when they can, poor people often choose to sell forest foods and bush meat rather than keep them for family consumption (Arnold 2008). Recently, increased integration into the market economy via payment for environmental services (PES) programs has been shown to decrease dietary diversity, deteriorate food sovereignty and potentially accelerate a nutrition transition in Chinantla Mexico (Ibarra et al. 2011). Moreover, out-migration in rural Mexico has altered land-use patterns and forest governance institutions with potential negative, rather than positive, impacts on local biodiversity (Robson and Berkes 2011a, Robson and Berkes 2011b).

Improved road access has been linked to reduced poverty (Gibson and Rozelle 2003, Kristjanson et al. 2005, Okwi et al. 2007, Warr 2010). For example in Laos Warr (2010) attributed 13% of the decline in rural poverty to improved road access. This reduced poverty is linked to: increased agricultural income from increased access to markets and reduced transportation costs (Jacoby 2000); increased income from non-farm enterprise and off farm employment (Gibson and Olivia 2010); increased school enrollment (Khandker et al. 2009); and decreased maternal and child mortality rates due in part to improved health care access (Blaney 1994, Ombok et al. 2010). Conversely, it is well established that increased road access can have major negative impacts on forests and biodiversity. Multiple papers have demonstrated that both paved and unpaved roads are key drivers of the deforestation process (Chomitz 2007, Kirby et al. 2006, Perz et al. 2008, Pfaff et al. 2007). Road access has also been shown to have a negative impact on wildlife populations due to road avoidance, road kill, and increased access for hunters and poachers, in addition to habitat loss (Benítez-López et al. 2010, Laurance et al. 2006, Nasi et al. 2008, Newmark et al. 1996, Poulsen et al. 2009, Wilkie et al. 2000). The impact of road access on diet and nutrition has rarely been examined. One study in Cameroon found that increased income from road access was not been matched by an equivalent consumption increase (Gachassin et al. 2010). Even if the increased income affiliated with increased road access is used to purchase food, because of this may be accompanied by a nutrition transition and factors mentioned above, the improved market integration provided by roads may not lead to improved diets and nutrition.

1.5.4 Governance

Many authors reviewing the links between forest health and human health note that the loss of forests and forest biodiversity threatens local people's food security and nutrition. While deforestation and climate change can result in significant loss of forests, local people can equally lose access to forests and other uncultivated lands through the creation of protected areas and reserves which restrict their access and define the terms by which they can use natural resources (West et al. 2006, Wilkie et al. 2006). West and colleagues (2005) discuss the social and political implications that parks and protected areas have had for local people and draw into question the notion that conservation and people are mutually exclusive.

1.5.5 The African Context

The legacies of colonization persist in Africa; colonial policy and practice has left enduring cultural tensions and prejudices (far beyond the scope of this dissertation).

Mudimbe (1988) notes that even the most Afrocentric perspectives are imbued with Western epistemology.

Over recent decades, Africa has seen the least improvement in food security and nutrition outcomes compared to any other region of the globe (UN-SCN 2004). Improvement has been marred by conflict, corruption, HIV, and climate uncertainty, to name but a few of the recognized contributing factors.

Sub-Saharan Africa, bears more than its share of the burden (in terms of loss of life and hardship) resulting from global climate change (Parry et al. 2009) and is also less equipped to cope (Patz et al. 2005). Drought and associated malnutrition are particularly salient impacts of climate change in Africa, where climate is among the most frequently cited drivers of food insecurity (Gregory et al. 2005).

Habitual African diets, based heavily on starchy staples such as maize, cassava, banana and millet, are notorious for their low percentage of energy from protein and fat and for their lack of animal source foods, qualities that are affiliated with low content and bioavailability of many micronutrients (Murphy and Allen 2003, Siekmann et al. 2003, Stephenson et al. 2010). Despite the continued poor nutrition situation in Africa, increasing evidence suggests that a nutrition transition has begun (Maletnlema 2002, Raschke and Cheema 2008).

About 17% of global forest exists in Africa; 23% of Africa's land area is covered with forest, which, in 2010 was disappearing at an annual rate of 0.5% (FAO 2011). The forests of Africa are home to a substantial portion of the world's biodiversity and some of the world's highest levels of endemism (Myers et al. 2000). The highest rates of deforestation in the world exist in Central America, East and West Africa, all of which are losing about 1% of their forests per annum (FAO 2011). However, rates of deforestation in Africa (and around the world) are slowing and the percent of forest designated for conservation is increasing, especially in East Africa (FAO 2011). With 38% of its land area covered in forest, Tanzania has one of the highest proportions of land covered by forest in East Africa. It also has one of the highest rates of forest loss in East Africa and the world, with over 1% of forests lost per year. It is one of the few countries where forest loss is accelerating (FAO 2011).

1.6 Research Objectives

1.6.1 General Objectives

Many types of diversity are now proposed as adaptive, including biodiversity, agricultural diversity, linguistic diversity and cultural diversity (Boyd and Richerson 1983, D'Andrade 1987, Frison et al. 2006, Hajjar et al. 2008, Jackson et al. 2007, Johns and Sthapit 2004, Keesing 1974, Millennium Ecosystem Assessment 2005, Sunderland 2011). Some of the adaptive function of these many types of diversity is drawn from their potential to support resilience and synergistic interactions between components of (factors in) biocultural systems. The broadest objectives of this work seek insight into the adaptive nature of both biodiversity and cultural diversity for local people's ability to efficiently and sustainably use local natural resources (biodiversity) to: overcome food insecurity and malnutrition (especially micronutrient malnutrition); mitigate the progression and impact of a nutrition and epidemiological transitions; and, for the maintenance of the local food system in the face of accelerating climatic, environmental, economic and social-cultural change.

While the relationships between biodiversity and nutrition have been the topic of a number of previous research projects, (e.g. yet to be published work by Bioversity International, (Herforth 2010a, Johns and Sthapit 2004), this research specifically focuses on the mediators of these relationships. In order to ensure identification, inclusion and examination of the many potential social, cultural, economic and environmental mediators this research applies a systems (and EcoHealth) approach and includes extensive descriptive and ethnographic data and diverse scales of inquiry (individual through to landscape level factors).

Additional general objectives include the pursuit of a better understanding of the utility of systems (EcoHealth) approaches for human nutrition (especially in relation to environmental health) by providing a case study and through careful reflexive examinations of the requirements of transdisciplinarity. Informing policy and practice are a central focus and objective throughout, including how to achieve behaviour change in interventions, as well as providing evidence in support of integration among governmental ministries and disciplinary efforts for health, development and conservation.

1.6.2 Specific Objectives

Specifically this research seeks to understand if and how dietary diversity acts as a pathway from biodiversity to human nutrition, as well as the cases when and reasons why it may not. Specific objectives in order to achieve this include:

- Test the utility of dietary diversity as a measure of nutrition
- Examine local perspectives on the importance of dietary diversity and what is needed to maintain it
- Document how seasonal change affects dietary diversity
- Explore of the relationships between dietary diversity and measures of biodiversity (forest food use, forest cover and crop diversity)

Specific mediators of the relationship between biodiversity and human nutrition highlighted in this research included:

- Dietary patterns and social cultural aspects of the local food system
- Socio-economic factors such as gender and wealth
- Knowledge systems and education (in and out of school)
- Characteristics of the landscape mosaic, especially forest access (in terms of physical and legal access)
- Road access

The dissertation seeks to explore the different contributions to human nutrition of biodiversity from different land use types, across land use types, and to compare reliance on foods from purchased sources, the farm and wild and forest foods. The importance of wild and forest foods is examined at different scales (individual and community level) so as to examine the contribution of wild biodiversity to both inter and intra-individual variation. The impact of landscape level factors (such as forest cover and road access) on the use of foods from different sources, are tested so as to better understand how biodiversity from across the landscape mosaic contributes to human diet and nutrition. Additionally the contribution of biodiversity to nutrition is compared between the season of food plenty and season of food scarcity. By examining the contribution of biodiversity from different components of and across the entire landscape mosaic this research seeks to inform biodiversity and forest conservation research and practice by providing insight into the implications of landscape level approaches to conservation for human diet, nutrition and health.

This case study also has the potential to act as a baseline for future longitudinal research, examining, for example, the impact of changes in forest and road access on nutrition and the relationships between biodiversity and nutrition.

Preface to Chapter 2 (Methodology)

The Methodology Section, Chapter 2, has three sections. It begins with an examination of the methodological approach and theoretical grounding. While not typical in much human and environmental science research, this theoretical framework is an important aspect of the novelty of this dissertation, which has sought to straddle epidemiological paradigms of natural science, social science and local communities. The effort to reflexively examine theoretical grounding has helped this dissertation to achieve greater transdisciplinarity, which has contributed improved perspective on methodological limitations and overall ability to draw broad conclusions about the links between biodiversity and human nutrition.

The second section of the methodology chapter describes the research site, including the geography, political history, people, livelihood and environment of the East Usambara Mountains. The third section provides a detailed description of the ethical procedures, qualitative and quantitative methodologies used in the overall research project, including those which are not central to any of the manuscripts included in the dissertation.

Chapter 2
Methodology and Field Site

2.1 Methodological Approach

2.1.1 A Systems Approach and Theoretical Framework

> "Systems are groups of interacting, interdependent parts linked together by exchanges of energy, matter and information. Complex systems are characterized by strong (usually non-liner) interactions between the parts, complex feedback loops that make it difficult to distinguish between cause and effect, and significant time and space lags, discontinuities, thresholds, and limits. These characteristics all result in scientists' inability to simply add up or aggregate small-scale behaviour to arrive at large-scale results. Ecological and economic systems both independently exhibit these characteristics of complex systems. Taken together, linked ecological and economic systems are devilishly complex" (Constanza et al., 1993), in (Cunningham et al. 2002)

Systems, of various types and definitions (ecological, social, etc.) are a starting point for the theoretical framework of a diverse set of research approaches and theories from Ecology and the Ecosystems Approach to Human Health (EcoHealth), to Human Ecology and Ecological Anthropology. From Systems Theory come concepts such as adaptation, resilience, vulnerability and synergy (Folke 2006, Holling 1973, Walker and Salt 2006). These concepts have influenced thinking and approaches in many disciplines but should be used with caution as meanings can differ from one discipline to another. Historical Ecosystem Theory was criticized for being over-simplified and for assuming a closed-system and static-state; however, Ecosystems Theory has advanced significantly (Abel and Stepp 2003). The criticism that systems approaches are heavily bounded by cultural pre-conceptions or epistemology (Schoon 2005), remains.

This research is set within an array of frameworks that share systems theory as a common foundation, including: systems approaches to human health; the EcoHealth approach; landscape level approaches to conservation and the trade-offs between conservation and livelihoods; and, anthropological traditions of human ecology and ecological anthropology. These frameworks have much in common, including an emphasis on the role of humans in ecological systems and a focus on the ways in which humans affect nature and nature affects humans. They also share an emphasis on participatory, transdisciplinary approaches with attention to social-cultural mediators of the relationships between humans and their environments.

2.1.2 Systems Approaches to Health and the EcoHealth Approach

Systems approaches are increasingly common in human health research. In nutrition, food systems approaches are seen by many as the only sustainable solution to global malnutrition (Gibson and Hotz 2001, Pinstrup-Andersen 2007, Underwood and Smitasiri 1999). Gohlke and Portier (2007) argue that a continued focus on the individual in current medical research paradigms will impair development of an understanding of how social, ecological, and physical aspects of the environment interact to result in disease, and, that a systems approach is needed.

The Ecosystems Approach to Human Health (EcoHealth approach) has gained popularity, and is increasingly the predominant paradigm in systems approaches to human health (de Plaen and Kilelu 2004, Wilcox et al. 2004, Wilcox and Kueffer 2008). Although Lebel (2003) identifies the origins of attention to the links between environment and human health as the field of sustainable development, many researchers ascribing to the framework are clearly rooted in biological, environmental and ecological science (Wilcox and Kueffer 2008). The three pillars of the EcoHealth approach are transdisciplinary, participation and equality (Lebel 2003, Lebel 2004). While most academics come to EcoHealth from the natural sciences, in insisting on the use of participatory and qualitative methodologies, the approach creates exposure to alternative epistemologies. For these reasons, EcoHealth and other transdisciplinary approaches have done much to enhance awareness of the importance of socio-cultural factors in human-environment interactions. Unfortunately the EcoHealth approach has yet to spread widely to the field of nutrition; very few works utilize it (Kerr et al. 2008, Vázquez-García et al. 2004).

2.1.3 Landscape Level Approaches to Conservation

With the integration of landscape ecology and conservation, has come enhanced focus on landscape level approaches and processes for biodiversity conservation (Pfund 2010, Sayer et al. 2007). There is increased attention to agricultural landscape mosaics surrounding, and on the margins of, forests and other protected areas (not surprisingly since protected areas cover only around 10% of the earth's land surface, whereas agricultural land covers 33-38%) (Widgren 2011, Zimmerer 2010). "Given the fragmented nature of most tropical ecosystems, agricultural landscapes should be an essential component of any conservation strategy" (Perfecto and Vandermeer 2008). Cunningham et al. (2002) refer to these mosaics as 'matrices'.

The increased attention to human dominated landscapes in conservation has increased emphasis on how human-environment interactions change across multiple land use types within landscape mosaics (Cunningham et al. 2002, Pfund 2010, Sayer et al. 2007). While early 'Conservation and Development' efforts had limited success, landscape level approaches treat people as part of the ecosystem and seek to understand the synergies and trade-offs between livelihoods and conservation (Sayer et al. 2007).

2.1.4 Anthropological Theory

> "Every somatic human action which results in an environmental change (however small) is preceded by, and undertaken in relation to, a process of interpretation and specification which is culturally coded and socially situated" Roy Ellen (1982)

Drawing on anthropological theory has enhanced the integration of social and cultural perspectives in this research. Work from nutritional anthropology examines the role of food in culture and culture in food (e.g. (Fischler 1988, Keesing 1974, Khare 1980), although other work has been less useful (Messer 1984).

Human ecology and ecological anthropology (as well as environmental anthropology) offer the 'other side of the coin' to ecosystem approaches to human health. Both are interested in how humans affect and are affected by the environment. However, there are substantial epistemological differences; anthropological approaches see humans as cultural beings, full of agency and complicated by politics and power, and able to interpret their environment, whereas ecosystems approaches to human health sees humans first and foremost as biological entities. Many formulations of the ecological problematic “ignore the theoretical significance of human *interpretation* of the environment, treat it as irrelevant or assign it to some unexamined (perhaps unexaminable) ‘black box’ which mysteriously mediated between humans and their environments” (Ellen 1982). Ecological anthropologists, such as Roy Rappaport and Roy Ellen, experienced significant criticism from their contemporaries for many of the same reasons that early ecological theory was criticized (Abel and Stepp 2003, Ellen 1978, Ellen 1982), but their work has been instrumental in informing the research herein. One influence of ecological anthropology in this dissertation is the exploration and critique of the optimal foraging theory herein. Importantly, use of an ecological anthropology and systems approach has led to the acceptance that, for relationships between humans and their environments, causality is multi-scaled and continuously self-organizing (Abel and Stepp 2003). Human systems are vastly complex, nested, and hierarchical with interactions between multiple spatial and temporal scales; simple models, using single dependent variables are often overthrown by events from smaller or larger scales. While anthropologists have historically had a hard time fitting human culture and nature into the narrow, reductionist models of traditional scientific paradigms, human ecosystem research specifically attends the complexity of biocultural systems (Abel and Stepp 2003).

The work herein on ethno-science, knowledge and classification, as mediators of how humans interact with their environments and make decisions about food and diet, has drawn on works by Keesing, Levi-Strauss, and cognitive anthropologists such as Goodenough (Keesing 1974). Theories that view culture and cultural diversity as adaptive have also been influential for the work in this dissertation (Boyd and Richerson 1983, Maffi 2001, Romney et al. 1996). “It seems likely that the range of diversity in individual versions of the 'common' culture is not simply a social imperfection, but an adaptive necessity: a crucial resource that can be drawn on and selected from in cultural change" (Keesing 1974: 88). Traditional knowledge and diversity thereof, as a key component of cultural diversity, is thus portrayed as an evolving and essential resource, enabling local populations to adapt in times of rapid change. In this work, knowledge and culture make up one component of diversity within a complex biocultural system.

2.2 Study site: East Usambara Mountains, Tanzania

For a research project seeking to examine the links between human nutrition and biodiversity, including biodiversity from both farm and forest, it was important to choose a field site where malnutrition was still common and where local people had access to high levels of biodiversity. The East Usambara Mountains were chosen for a number of reasons:

- The area is known for its agricultural productivity and high agricultural diversity
- The area is known for its biodiversity and has greater forest cover than many other areas of East Africa
- The area had on-going forestry research which enabled collaborations leading to broader understandings at the landscape level (Chapter 6)
- The area is known to be one of the less developed parts of East Africa with moderate to high rates of malnutrition
- The area is known for its cultural diversity, providing an interesting context in which to examine social and cultural mediators of the relationships between biodiversity and human nutrition

2.2.1 Geography

The East Usambara Mountains, in north-eastern Tanzania, rise from 200 to over 1200m, with the first foot hills about 40km west of the Indian Ocean coast and the port city of Tanga. They are separated from the more populated and deforested West Usambaras by Lwengera Valley. The East Usambara Mountains lie within Tanga Region of

Tanzania, mostly in Muheza district with the northern-western edge within Korogwe district (Figure 2.1). Two ecologically different zones are identified by both local people and researchers: the uplands >600m and the lowlands <600m (Feierman 1974, Hall et al. 2009, Tanzania 2008).

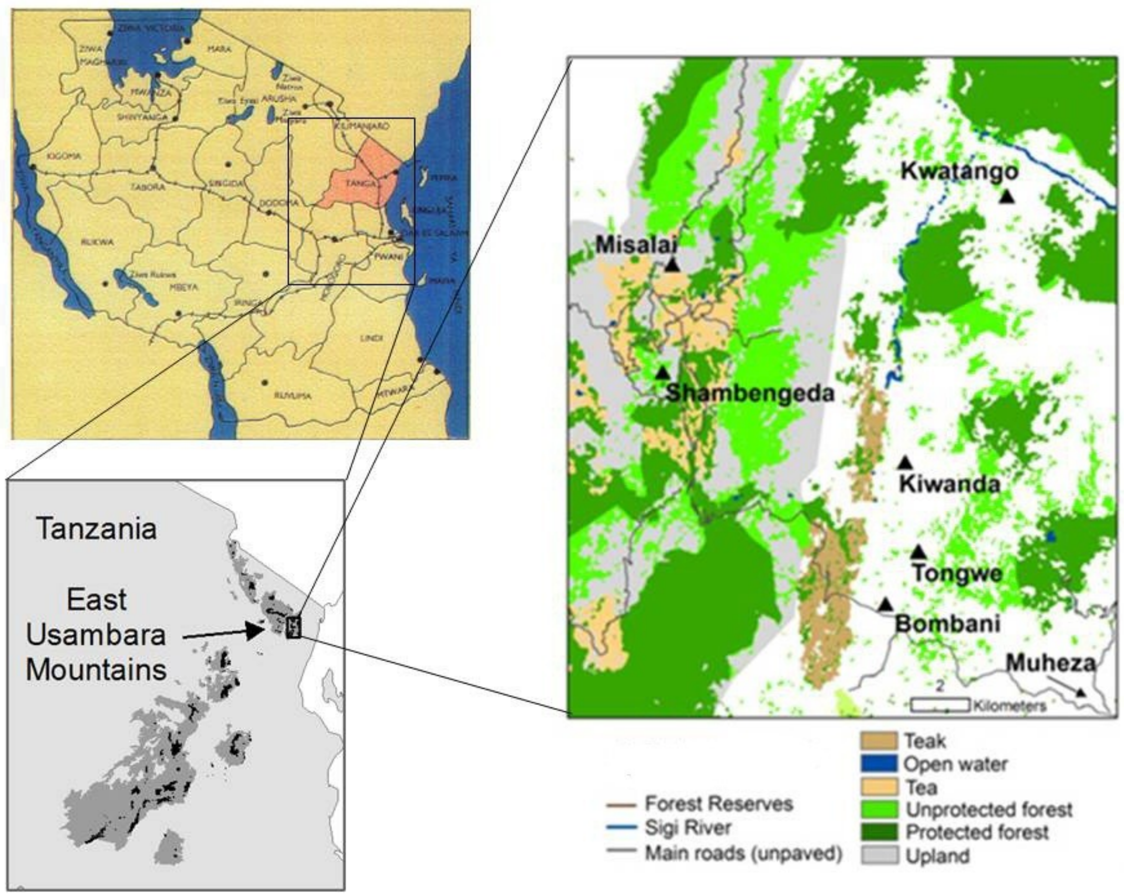

Figure 2.1 Map of Tanzania with Tanga District highlighted in pink, map of the Eastern Arc Mountain Range with the East Usambaras marked, Map of the East Usambara Mountains with the 6 research villages marked (▲) Land cover map generated by Jaclyn Hall)

2.2.2 Politics and History

The country Tanzania gets its name from the languages of the Usambara Mountains. The city Tanga, which was an important stop along Arabic trade routes (along with Mogadishu, Lamu, Mombasa and Zanzibar) (Palace Museum 2009) and the principle port during the German colonial era, got its name from the word '*tanga*', which means ‘farm’ in the languages of the Shambaa, Bondei and Zigua tribes. The territory inland from the city was named Tanganyika from the term ‘*nykia*’, which refers to the dry bush habitat that spreads across the flat lowlands between the Usambaras and the coast. During the colonial era Tanga Region was politically and economically important due to the railroad, the active port in Tanga and agricultural production (especially sisal in the lowlands and tea in the highlands). With the collapse of the sisal industry, the region experienced an economic downturn and is now considered an underdeveloped part of Tanzania (Feierman 1974, Tanzania 2008, Yeager 1989).

2.2.3 People and Livelihoods

People have inhabited the East Usambara Mountains for at least the last 2000 years (Schmidt 1989). As in other parts of Africa, the human impact on the forests of the East Usambaras likely extends well beyond the extensive deforestation of the last 50-100 years (Hall 2009, Hamilton 1989).

Although considered the traditional home of the Wasambaa (Shambaa) tribe, the East Usambaras have long been culturally diverse, being also home to the Zigua, Bondei, and Digo ethnic groups (Willis 1992). Currently 54% of population is Shambaa, 20% Bondei, and 10% Zigua; 40% of households have one or more members who were not born in Muheza district (data from survey population). The ethnic groups of the area have historically inter-married, a tradition which continued as the area experienced significant in-migration of people looking for employment in the tea and timber industries. Ethnic intermixing in the area was further enhanced by socialistic (and anti-tribal) values promoted by the Tanzanian government under Nyerere (1964-1985) (Yeager 1989). These same socialist policies emphasized gender equality and have helped to create a policy environment in which women are more empowered than women in many other countries in Africa (Ellis et al. 2007). Yet, despite government policies, such as mandatory quota of women in village governments, there remains a large distance to go before traditional practices and social norms cease to disempower women in the local context (Feierman 1974, Rantala et al. 2011).

Tanga region has a population density of 64.3 people per square kilometre and Muheza district has a density of 59.8 people per square kilometre, with significant variation between villages (from 21 people per square kilometre in remote Kwatango village to over 200 people per square kilometre in the uplands of the East Usambaras) (Tanzania 2002, Tanzania 2008). About half of the population is Muslim and half Christian. Most people are literate, with less than 30% having not completed primary school (data from this study population). Local livelihoods are based primarily on subsistence agriculture, supplemented with cash crops, wage labour in the tea and timber industries, small business and livestock (Kessy 1998, Porter 2006). About 45% of households have one or more members who participate in some form of wage labour (data from survey population).

Historical accounts substantiate that traditional agriculture was based largely on banana cultivation (Farler 1879, Johnston 1879). The fact that unique species of banana have been discovered in the Usambara Mountains provides further evidence of the long history of banana cultivation in the area (Schumann 1904). Today maize and cassava are also important staple crops (Fleuret and Fleuret 1980); beans and other legumes, rice, yams, sweet potatoes, okra and leafy vegetables are also cultivated mainly for home consumption. In the lowlands, oranges, teak and black pepper, are common cash crops. Teak, sugarcane, spices (especially cardamom and cloves) and oranges are common cash crops in the uplands.

2.2.4 Diet, Nutrition and Health

Tanzania has one of the highest maternal mortality ratios (MMR, also called maternal mortality rate) in the world. In Muheza district the MMR is lower than the national average but higher than the rest of Tanga region at 633 deaths per 100,000 live births (2002) (Tanzania 2008). In 2002, the infant mortality rate was 96/1000 and the child (under 5 years) mortality rate was 158/1000 (Tanzania 2008). The most common causes of mortality reported in Muheza in 1998 were malaria, pneumonia and HIV, and in 2006, of those tested for HIV, 6.1% were positive (Tanzania 2008).

Rates of stunting [a measure of growth failure: height-for-age (HAZ) z-score < -2 standard deviations (S.D.)] in Tanzania are among the highest in the world (42%) (Figure 2.2) (de Onis and Blössner 2003, UN-SCN 2004). Rates of stunting in Tanga region (44.4%), are some of the highest in Tanzania (Tanzania 2010). Globally, stunting occurs mostly before the age of 24 months with catch up growth possible but not the norm (de Onis and Blössner 2003) (Figure 2.3). Trends in Tanzania show increasing rates of stunting from <6 months to the 18-24 month old group, the group in which rates are highest (55% stunted). The rates of stunting then decrease after 24 months of age (to 38.9% stunted by 60 months) (Tanzania 2010). The national rate of stunting is higher in boys than girls (Tanzania 2010).

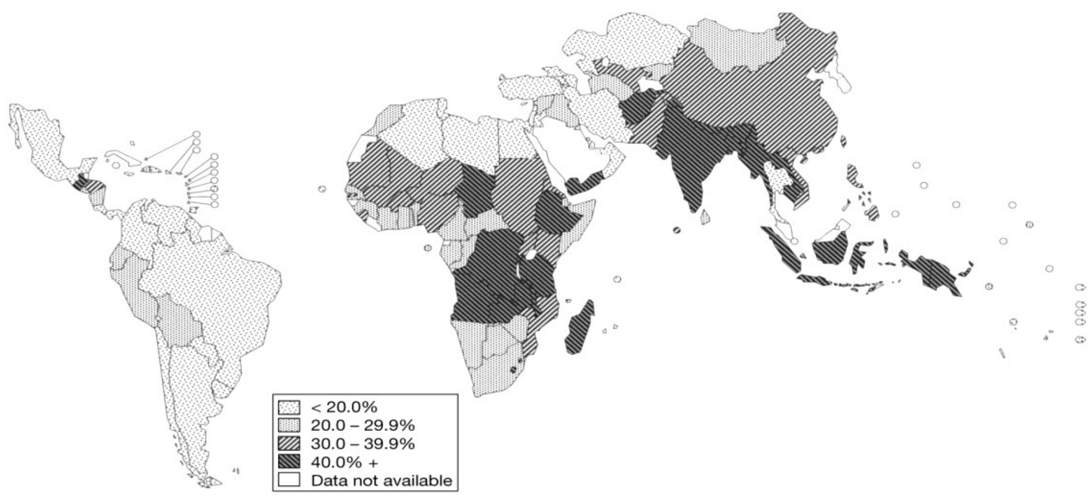

Figure 2.2 Global map of rates of stunting (HAZ < -2 S.D.), from (de Onis and Blössner 2003).

The FAO reported that in 2007 34% of Tanzanians were undernourished (FAO 2010b). In Tanga region that number is lower, only 25% are reported to be undernourished (Tanzania 2010). Micronutrient deficiency remains a problem in the country. Vitamin A supplementation has declined over the last decade (in 2010 60.3% received supplementation nationally, 56% in Tanga region) (Tanzania 2010, UN-SCN 2004). Iron, zinc and calcium are other micronutrients have been reported to be a problem in the country (Mulokozi et al. 2003, Tanzania 2010). A study in Muheza District (villages of Misongeni, Ubembe and Kilometa Saba) in 1994 found 60% of children between 7-12 years old to be stunted (Height-for-Age Z score ≤-2), 35% wasted (Weight-for-Height Z score≤-2), and 49% of children to be anaemic (Hb≤110g/L), with high rates of parasite infection (Beasley *et al.* 2000). More recently (2007) a government survey found that across Tanga region the rate of stunting in preschool children was 49.9% (HAZ<-2 S.D.) and the rate of wasting was 5.5% (WHZ<-2S.D.), both higher than the national average (Tanzania 2010).

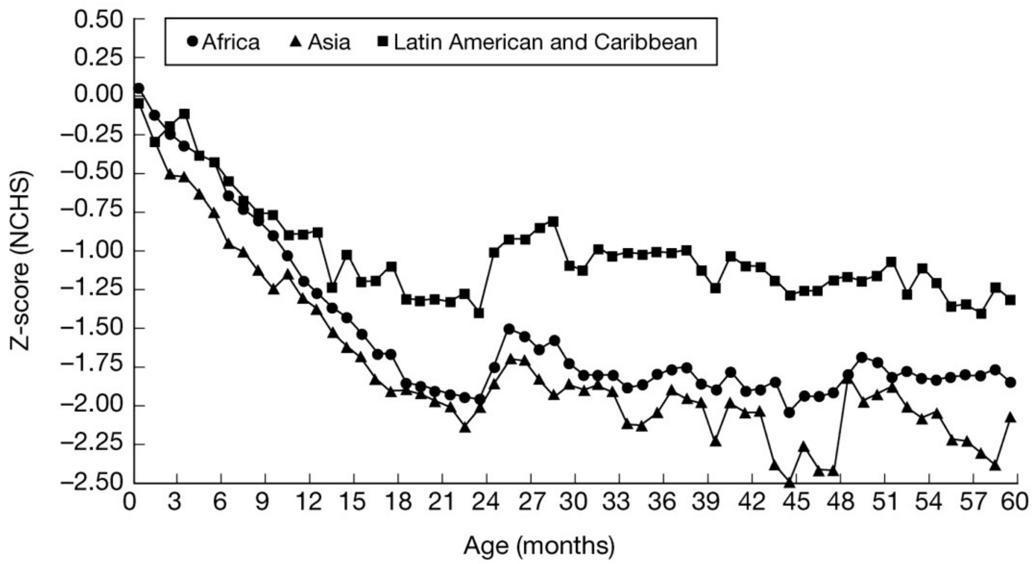

Figure 2.3 Variation in rates of stunting by age (de Onis and Blössner 2003)

In 2007 the average expenditure on food was 450TSh (approximately $0.50 USD) per person per day in Tanga (Tanzania 2010). Local diets are based on maize, cassava, beans and dry fish. Meals are usually made up of a staple (most commonly *ugali,* made of maize flour cooked into a hard porridge), and a side dish (such as *dagaa,* a small, dry, freshwater fish (primarily from Lake Victoria), or legumes or vegetables). In Kenya, a similar diet, based on maize and beans, was suggested to usually supply enough energy, protein and iron but to often be deficient in vitamin A, C, and calcium (Mwajumwa et al. 1991).

Wild or uncultivated foods such as wild meat (wild bush pig) and wild vegetables have traditionally been important in the diets of the Wasambaa (Feierman 1974, Fleuret

1979b). Today, people in the area use a high diversity of traditional vegetables and a higher ratio of wild to cultivated vegetables compared to other parts of Tanzania (other areas included in study: Arumeru, Singida, Kongwa) (Keding et al. 2007, Vainio-Mattila 2000, Weinberger and Swai 2006).

2.2.5 Environment

Part of the Eastern Arc Mountains, the East Usambaras are renowned for their high concentration of endemic species (Burgess et al. 2007, Lovett 1998) and have been identified as one of the world's most threatened forest ecosystems and as a 'biodiversity hot-spot' (Brooks et al. 2002, Hall 2009, Myers et al. 2000, Newmark 1998). The area contains moist tropical montane forest above ~600m and some of the last remaining but ecologically important lowland montane forest in East Africa, with deforestation prevalent throughout the area's remaining unprotected forests (Figures 2.4) (Dewi and Ekadinata 2010, Hall et al. 2009).

Forest in the East Usambaras exists in a landscape mosaic which includes agroforests, farms and villages (Figure 2.6). Forests are under varying degrees of protection, although most lie within government nature reserves or catchment forests. The East Usambaras encompass some of the oldest protected areas in East Africa; these have historically excluded local people from management and decision making and placed major restrictions on use by local people. Recently there have been significant efforts to decentralize forest management in Tanzania, including in the East Usambaras, where both joint forest management and community-based forest management have been initiated (Rantala 2010, Vihemäki 2005). Despite these efforts aimed "to promote and facilitate active participation of people in sustainable planning, management, use and conservation of forests" (Vihemäki 2005) access to forests under various types of protection for food (and other resources) remains limited (limited deadwood collection has long been allowed in even the most highly protected areas) (Rantala 2010, Vihemäki 2009). Over 90% of people in Muheza district use fuelwood for cooking (Tanzania 2008).

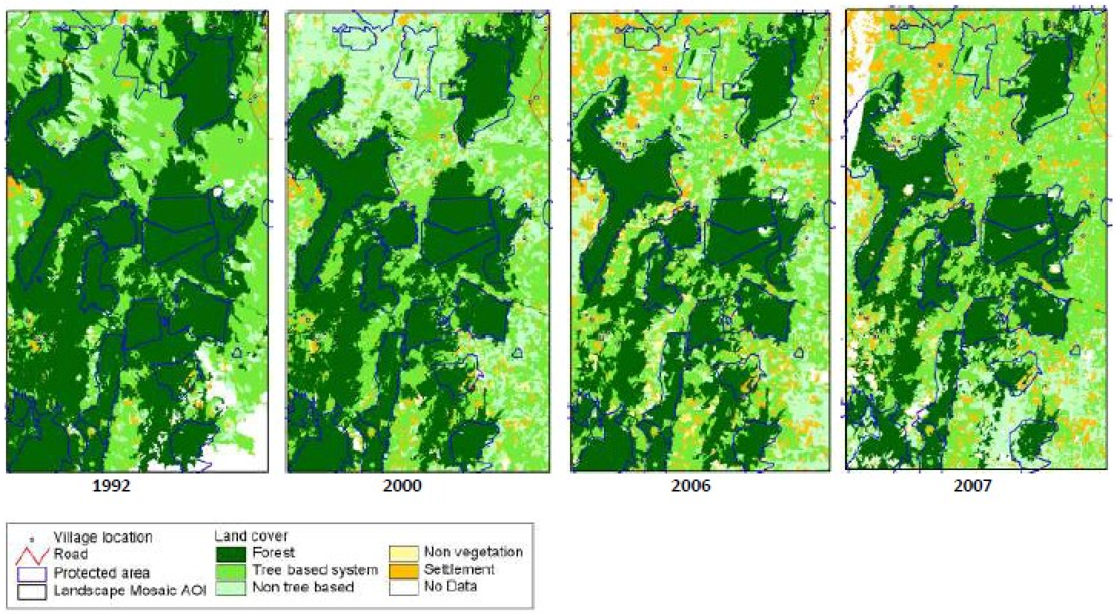

Figure 32. Time series of land cover map of East Usambara site.

Figure 2.4 Change in forest cover in the East Usambara Mountains between 1992 and 2007 (Dewi and Ekadinata 2010).

2.2.6 Seasonality

As in most parts of sub-Saharan Africa, there are two wet seasons and two dry seasons in the East Usambara Mountains. Some years there is an additional period of rain in July and August, linked to the costal monsoon rainy season (Figure 2.5). The area typically receives an average of 1500mm of rain annually. In the East Usambaras the main harvest comes from crops planted in the long rainy season (*mvua ya mwaka*) with a smaller harvest sometimes obtained after the short rain (*mvule*). Fields are prepared before the rains begin (March), and seeds are planted in the first few days of rain. Many crops reach maturity about 3 months after planting. Typical dates for the start of planting in Kiwanda village are March 15-30th in *mwaka* and October 1-15th in *mvule* (Porter 2006). As has been reported elsewhere in Tanzania, food shortage (mostly a shortage of maize for *ugali*) increases and is greatest in the months preceding the harvest from *mwaka* in July (Wandel and Holmboe-Ottesen 1992). The harvest from *mwaka* increases the amount of home produced foods as well as cash availability as some of the harvest is often sold. Although there is a often a smaller harvest in

December and January from crops planted in *mvua*, this is also the time of year when school fees are due (and school uniforms and supplies purchased). Certain cash crops such as black pepper and bananas are harvested a multiple points throughout the year, but the money from these are often saved and used for school fees and other expenses rather than for the purchase of food (and their harvest is limited in the period before the *mwaka* harvest). Elsewhere in Tanzania the decreasing availability of maize in the pre-harvest period has been linked to a 3% decrease in body weight in women (Wandel and Holmboe-Ottesen 1992). In other areas of Africa, dietary diversity (DDS, 1 day) has been shown to be higher in the season of food plenty compared to the food scarce season (Savy et al. 2006); thus, according to Swindale and Bilinsky (2005) if dietary diversity will be assessed at only one point in a year, it should be during a food shortage period. In this research dietary and nutrient intake were assessed in the pre-harvest wet season (*mwaka*) between March and May 2009 and then again at the end of the post-harvest dry season before the start of *mvule*, September – October 2009.

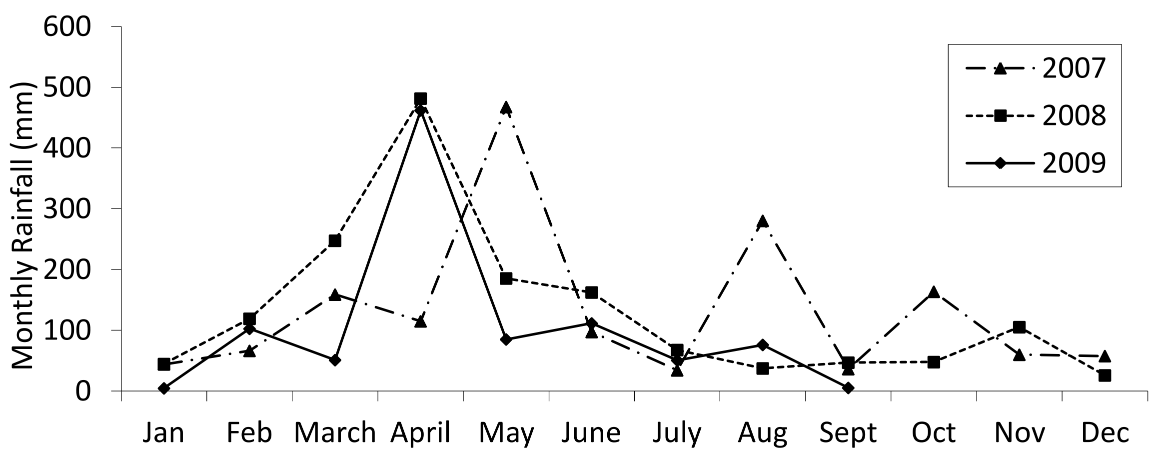

Figure 2.5 Seasonal variation in rainfall in the East Usambara Mountains over 3 years

2.2.7 Villages

Six rural villages in Muheza district were selected using a stratified sampling method based on road access and two elevation categories – 2 upland (>500m) and 4 lowland (<500 m) (Figure 2.1, Table 2.1). All 6 villages contain multiple hamlets or clusters of houses made mostly of poles and mud, baked mud brick and occasionally cement, with thatched or tin rooves (Figure 2.7). In the lowlands, Bombani village, which is 13.5km from the district administrative and commercial centre, Muheza town, and at a junction of the main road leading into the uplands and a smaller one to the lowlands, has regular public transit and significant opportunity for wage labour (especially in the timber industry in the near-by Lunguza teak plantation). Tongwe village is spread-out along a secondary road from Bombani. Much of Tongwe enjoys fairly easy access to market and wage labour, but only one or two public transit vehicles leave the village per day, fewer in the rainy season. Some 8km further along this road, Kiwanda is significantly more isolated, with only one public transit vehicle leaving the village most days. Households are spread across a large area and have limited access to wage labour and markets. A full day's walk from Kiwanda, down Sigi River valley, lies Kwatango village. Kwatango has a very low population density (21 people per square kilometre) (Tanzania 2002) and is only sometimes accessible by a different road coming from the plains to the east (at the time of research this road was in extremely poor condition and frequently impassable during the rains). Public transit leaves Kwatango once or twice a week in good weather; most produce is taken to market on foot (either 6-8km on foot to Misozwe and then by public transit, or on foot the entire ~20km into Muheza town).

Misalai and Shambangeda, on the Amani plateau (between 800 and 1100m elevation), were surveyed as the two upland villages. Although over 15km up the mountain from Bombani, they benefit from a road which is maintained by the government to ensure access to tea estates and the Amani research station. Public transit leaves twice a day, in virtually all weather, as well as vehicles carrying crops to markets. Both villages have high population density (between 200 and 400 people per square kilometre when calculated using only village owned land and not including surrounding forests and tea estates) (Tanzania 2002). Hamlets are squeezed between tea estates and government protected forests (Figure 2.8). Many inhabitants in both villages engage in wage labour on the tea estates for their only source of income, or in addition to agricultural activities.

Table 2.1 Villages and their characteristics

Village	Sub-villages	Population (2002)	Population Density	Road Access	Elevation
Bombani	Bombani Kati, Kwemkuyu, Kosta, Kwasekibaia, Majengo, Timba, Uhamiaji	1870	Medium-high	Very Good	Lowland
Tongwe	Bagamoyo, Hoima, Kinondo, Kwelusolo, Masiwa, Masimba, Pongwe, Zimbiri	1863	Medium	Moderate	Lowland
Kiwanda	Wenyeji, Mission, Kwevumo, Kwemanansi, Mangubli, Misajini, Mlembule, Mngeza A&B	1876	Low	Poor	Lowland
Kwatango	Kilindini, Gombero, Vumba	788	Very Low	Very Poor	Lowland
Shambangeda	Shambangeda A, Shambangeda B, Gonja, Marvera	1067	High	Good	Upland
Misalai	Barabarani, Kiwandani, Kigoma, Misalai Misalai, Mlalo, Tononoka	2237	High	Good	Upland

Figure 2.6 Photograph of mixed farm and forest landscape mosaic in Kiwanda village

Figure 2.7 Photograph of Masiwa subvillage, Tongwe village (left) and, looking down from Mlembule subvillage to another hamlet, Kiwanda village (right)

Figure 2.8 Looking across the tea estates at the mountain where Misalai village is found

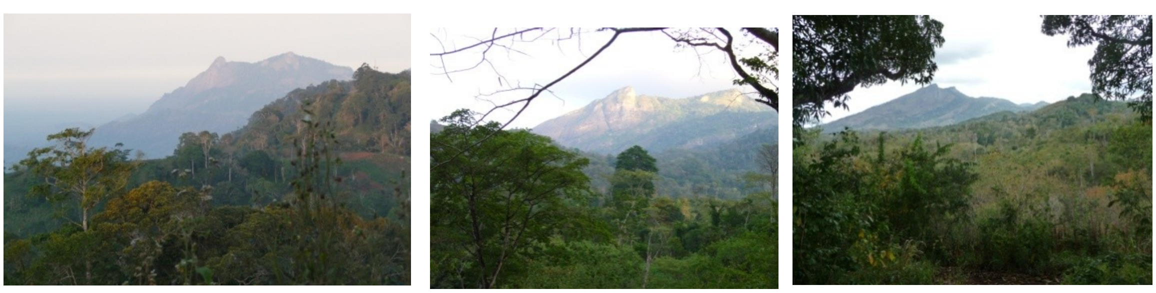

Figure 2.9 Mlinga peak viewed from Amani Research Station, Kiwanda Mission, Kwatango Gombero (from left to right)

2.3 Community Participation and Ethics

2.3.1 Ethics Review

The project was approved by the McGill University, Faculty of Agriculture and Environmental Science Research Ethics Board (Ethics Approval No. 904-1207) after the researcher completed the Tri-Council on-line ethics training. According to the *"Tri council Policy Statement: Ethical Conduct for Research Involving Humans"* this research was classified as 'minimal risk' (Tri-council 1998).

2.3.2 Local and National Government Approval

During field work the researcher was affiliated with the World Vegetable Center, Regional Center for Africa in Arusha (as a visiting student, supervised by Dr. Mel Oluoch) and Bioversity International (as a Research Fellow, supervised by Patrick Maundu), as well as advised by Dr. John Msuya of Sokoine University in Morogoro. Parts of this research project were carried out in collaboration with the CIFOR-ICRAF Landscape Mosaics Project (LM project). This research project was approved at the national level through COSTECH (Tanzania Commission for Science and Technology, http://www.costech.or.tz/ Permit No. 2008-283-NA-2008-57) and a residence permit was obtained for the duration of the research. Local (district) government officials in Muheza supported the research; The Director of the District Department of Agriculture and Livestock in Muheza supported the research and facilitated the use of the office transportation and the help of extensionists.

2.3.3 Community Approval and Participation

Community level approval and participation was sought from village governments. The village government is one of the strongest levels of government in Tanzania, respected and participated in by most, made strong by Nyerere's socialist policies (1964-1985) (Yeager 1989). Hierarchal levels of government existed in the East Usambara Mountains well before colonial structures were introduced, in the form of a kingdom governed by Shambaa and Kilindini kings and their appointed subordinates. However, even under historical governance arrangements, villagers had a certain amount of control over local matters and many decisions were made in a democratic manner (Feierman 1974, Winas 1962, Winas 2004). Today local people are highly engaged in village level politics; there are virtually no marginalized groups or individuals who express dissent from the current governance system. Because of this, it is believed that the consent and participation of village governments truly represents community consent and participation.

Before research begun, the village government leaders of Kiwanda village were approached, the project was explained and they were given time to discuss the project with the communities. Kiwanda village agreed to participate and a meeting to set research priorities was held. Because of research priorities identified by the village leaders in Kiwanda, two additional villages where brought on-board through a similar process (no additional research priorities were identified in subsequent village consultations in Tongwe and Bombani villages). Village level consent was obtained and research agreements were signed by these 3 villages. Shortly after qualitative research had begun, collaboration with the ICRAF-CIFRO Landscape Mosaics project (the LM project) was developed and the 3 villages from that project were added (Kwatango, Misalai and Shambangeda). As these villages already had extensive participatory research agreements in place with the LM project, research was conducted under the existing agreements.

Sims and Kuhnlein (2003) note that currently the onus often falls to researchers to initiate community participation, as indigenous and local people may not even be aware that they can play an active role in the research process. Communities involved in this research seemed relatively naïve to participatory research. Care was taken to ensure that communities' expectations were met and that nothing was promised beyond the capacity of the researcher or project. During introduction of the project the choice to participate was presented as a right of the communities, not just a nicety. Community leaders were asked to discuss the decision among themselves and with community members; it is hoped that this approach set a precedent for any future research in the area.

Although the dietary assessment methods precluded the use of local enumerators with limited education, 2 to 5 local guides were employed in each village during the surveys. In each of the original 3 villages, village leaders were asked to identify research priorities and ways that they thought this project might help them. Two priorities were identified: they wanted the results returned to the communities, and, they felt the road needed repair and maintenance. Upon the completion of each publication resulting from this research a summary will be prepared in Kiwahili and sent to the village governments of each of the 6 villages (1 summary was returned to the communities in 2011 via ICRAF and TFCG staff, the rest are in preparation, Appendix 1). Additionally, attempts will be made to ensure that people whose words or photographs appear in publication also receive copies of those publications. While construction or repair of the road was not within the capacity of this project, the impact of road access on diet, nutrition, agriculture, resource use and their interrelationships was added to the list or key research questions and research priorities (see Chapter 1, section 1.6.2). In order to explore this question, villages were chosen using stratification based on road access (Bombani having the best, followed by Tongwe, Kiwanda and then Kwatango in the lowlands). A closer examination of road access will be explored in a paper that will not be included in the dissertation (Powell et al. forthcoming-b).

2.3.4 Prior Informed Consent

Community level approval was not used as a substitute or used to influence individual prior free and informed consent which was obtained in accordance with the *"Tri council Policy Statement: Ethical Conduct for Research Involving Humans". A*fter the participant had been read the research statement in Kiswahili (a copy of which was left with every informant), and had been asked if they had any questions, comments of concerns (which were recorded), individual consent was obtained verbally (by one research team member and confirmed by the principle researcher). Consent for the participation of children was obtained verbally from one of their parents. All informants whose names appear in this dissertation expressly asked that they and their words and stories be identified by name. During interviews they were asked to identify any sections to which they did not want their names attached.

2.4 Qualitative Data Collection

2.4.1 Ethnographic Data Collection

Qualitative work took place from October 2008 to November 2009 using ethnographic data collection techniques including: open-ended, semi-structured one-on-one interviews, unstructured discussion, focus group discussions and participant observation (Bernard 2002). One line of investigation in the qualitative work looked at local ideas about knowledge, local classifications of types of knowledge and local people's ideas about how to assess knowledge in their community.

The main body of qualitative worked was done in 15 case study households. Households were selected as case studies out of the larger group of households included in the dietary study. Selection was based on review of dietary intake questionnaires with the aim of selecting households with both high and low dietary diversity (with diversity within each group, including: more and less education, male and female headed households, etc.). The household's life stories were collected and their perceptions of their diet quality and reliance on natural resources were recorded (following an interview schedule). This work sought to understand which factors mediate people's ability to make use of their local resources and biodiversity to improve the diet and nutrition. All interviews and discussions with the 15 case study households were recorded, transcribed and then translated into English. Although many informants spoke Kisambaa, all were fluent in Kiswahili, the *lingua franca* in this culturally diverse area that has a long history of trade and migration. Kiswahili was used for all interviews because the primary researcher spoke and understood the language to a functional level. Despite this, a translator was always present. Standard qualitative analysis of interview transcriptions was conducted following Bernard (2002) and was supported with field notes and observations from extensive participation in local daily life (participant observation).

2.5 Quantitative and Semi-quantitative Data Collection

2.5.1 Study Design, Sampling and Retention

2.5.1.1 Study Design and Sample Size Calculations

The study used a cross-sectional design (accounting for seasonal variation in diet and nutrient intake through assessment in wet (food insecure) and dry (food secure) seasons). Preliminary sample size calculations were made based on dietary diversity as the primary outcome variable, following Hulley (Appendix 6A) (2000) and the required sample size was found to be less than 100 per group: α=0.05, β=0.2, Estimated Expected Effect = 0.9 (15% of a mean of 6), and a Standard Effect Size = 0.45 (0.9/1.98 dietary diversity mean ±S.D. = 6± 1.98) (Gibson et al. 2003, Onyango et al. 1998). Based on mean adequacy ratio (MAR) as the primary outcome variable the required sample size was found to be less than 50 per group: α=0.05, β=0.2, Estimated Expected Effect = 0.1125 (15% of a mean of 0.75), and a Standard Effect Size = 0.70 (0.1125/0.16 dietary diversity mean ±S.D. = 0.74± 0.16) (Oldewage-Theron and Kruger 2009). Using MAR data from Steyn et al. (2005) and assuming a 10% difference between groups sample size calculations suggest a need for N=150 per group. However, the multiple outcome variables, limited data relevant to the population of the study, and even less information on the size of differences to be expected between groups, made sample size calculation impractical for this research. A total sample size between N=250 and 300 was targeted based on the advice of experts and logistical limitations. One reason it was necessary to include multiple villages in the study was that villages in Tanzania have between 500 and 2000 inhabitants, and only about 100 eligible households for this study (with a child between 2 and 5 years of age).

2.5.1.2 Sampling and Retention

Approximately 45 households from each of 6 villages were selected (Table 2.2). 'Household' was defined as any group of people cooking together or 'eating out of the same pot'. The Kiswahili word *kaya* was used, which refers to any group of people functioning as one economic unit (with the primary focus of economic activities being that of procuring and consuming food together). Households with a child between the ages of 2 and 5 were selected from a list of households with children under 5 provided by village governments using systematic sampling (taking every n^{th} item on a list). Villages had between 750 and 2250 inhabitants, and the 45 households represented a sample frame of every 2^{nd} to 5^{th} household, depending on the population size of the village (in cases where every 3^{rd}, 4^{th} or 5^{th} household was selected, exclusion criteria required additional households to be chosen (again with systematic sampling) to achieve the final sample size in each village). Over 50% of eligible households in most villages were sampled. Some households on the list of eligible households used for sampling did not actually have a child of the correct age. If the child was >1 and <6 they were included in the survey (with later implications for the ability to determine height-for-age using WHO software). If the household had moved away or did not have any child, another household was selected. Of the households selected from the list 24% were unavailable or not suitable for inclusion in the survey and were therefore excluded.

A total sample size of N=274 was achieved (based on 24 hour recall data for children in the wet season); however, within each variable data were often missing for a few households (Table 2.2). Each household was visited at 3 stages: 1.) Preliminary data collection [Jan-March 2009]: Basic household demographics, location, *et cetera*.; 2.) The wet season survey [March-May 2009]: 2 visits to collect health and nutrition information, 1 visit to collect agriculture, wealth and livelihood information and a visit to conduct a knowledge questionnaire with the male and female heads of the household. In this period anthropometric data were also collected for mothers and children; 3.) The dry season survey [Sept-Oct 2009]: 1 visit to collect nutrition data (N=129, 3 villages only), 1 follow up questionnaire, any agricultural and knowledge questionnaires missed or incomplete in the wet season. In this period the location of each household was marked using GPS. Between the wet season survey in March-May 2009 and the dry season survey in September-October 2009, 11 households were lost (8% loss) (had moved or were ill or travelling in the second survey period).

Table 2.2 Sample sizes and retention by village

Variable / Questionnaire	MSL	SMB	TGW	BMB	KTG	KND	Total
Total households sampled in wet season	**42**	**45**	**48**	**46**	**47**	**46**	**274**
Original Number Selected from government list	48	60	64	60	69	60	361
Percent excluded*	14%	25%	25%	23%	32%**	23%	24%
Percent lost in dry season	-	-	4%	7%	-	13%	8%
Wealth Ranking	41	45	48	46	47	48	273
Agriculture Practices Information	43	45	47	46	47	46	274
Forest Use Information	44	45	48	46	47	46	276
Food security (collected in the dry season)	43	44	46	44	46	44	267
Wet season: Mothers 24 hour recall (1st day)	41	45	48	46	47	46	273
Wet season: Mothers 7-day food use (2nd day)	40	43	48	46	47	46	270
Dry season: Mothers 24 hour recall and food use	-	-	46	43	-	40	129
Wet season: Children 24 hour recall (1st day)	42	45	48	46	47	46	274
Wet season: Children 7-day food use (2nd day)	39	43	48	46	47	46	269
Dry season: Children 24 hour recall and food use	-	-	46	43	-	40	129
Growth / Stunting (HAZ) (only children <60 mo)	35	34	42	34	40	35	220

* Exclusion (not included in the survey) due to not being found/ located, had moved away (divorce, out-migration for work) or were not suitable for inclusion in the study (did not actually have a child of the correct age due to mistakes made on the list provided by the village governments).

** High exclusion rate due to the fact that households were very spread out and it was more difficult to find houses (longer travel times and fewer people to give directions)

- These villages not surveyed during the dry season

2.5.2 Food Availability and Identification

In preparation for the dietary assessment a list of food items potentially available in the area was prepared from the literature and previous experience in the region (Feierman 1974, Fleuret 1979b, Fleuret and Fleuret 1980, Hamilton and Benstedt-Smith 1989, Harkonen et al. 2003, Keding et al. 2007, Kessy 1998, Ruffo et al. 2002, Vainio-Mattila 2000, Weinberger and Swai 2006, Woodcock 2002).

A series of focus groups were held between November 2008 and February 2009 to validate the availability of items on the food list and local names used, and to identify any missing items. For each item, information on local names, list of local varieties', habitat / land use type, frequency of its use, seasonal availability, season of flowering and fruiting, harvesting or hunting, important cultural beliefs and, knowledge about the food was recorded. Two focus groups were held in each of the 6 villages (except Misalai); one with men and one with women. The focus groups lasted up to 6 hours (with a lunch break) and involved approximately 10 participants, identified by local governments as the most knowledgeable about food and agriculture in the communities and from different areas of the villages.

Botanical collections for identification of wild plant species were made throughout the research project (Forman and Bridson 2000, Martin 2004). Specimens were identified by Simon Mathenge, a Kenyan botanist and deposited in the East African Herbarium. At the end of the project all food items were reviewed to ensure as many as possible had been identified. Agricultural, exotic, introduced and other wide-spread or common plant species were identified using photographs and local vernacular names (Kiswahili) (with assistance from Patrick Maundu and Mel Oluoch). Mushroom, bird, animal and fish species were identified by their local vernacular (Kiswahili) names using secondary resources (Harkonen et al. 2003, Harkonen and Vainio-Mattila 1998, Moreau 1940, Woodcock 1995), as well as grey material and support from local experts (e.g. FishBase.org, Patrick Maundu and Victor Mkongewa).

2.5.3 Survey Logistics and Training

2.5.3.1 Translation and Piloting

All quantitative data collection tools were translated and back translated to ensure accuracy of translation and to standardize language used. They were all pre-tested prior to use (although significant changes were made to the knowledge questionnaire that were not subsequently tested). Although most of the assessment tools employed are commonly used, none had been validated for the study population. Validation was beyond the capacity of this project.

2.5.3.2 Enumerators and Training

Four enumerators were hired with the help of The World Vegetable Center and the Tanzania Forest Conservation Group (TFCG). They were all young men between 20 and 35 years old, of various ethnicities (Maasai, Hehe, Chagga, etc.). They all held university degrees in Agriculture or Conservation and they all had previous experience collecting data for large research projects.

Before the initiation of the wet season survey the enumerators and translator participated in a week-long training course, hosted by the World Vegetable Center in Arusha. During training, each research tool was reviewed and practiced to ensure familiarity with research goals and harmonization of techniques. The team was also familiarized with the local situation in the East Usambaras and sensitized to local issues (including gender and ethnicity). One member who joined the team for the dry season survey was trained for 3 days by shadowing 3 other team members in the field.

2.5.3.3 Local Guides

Local guides were hired in each village. They were responsible for informing their communities about the research project and its goals, ensuring the survey households for each day were available (present and ready to be interviewed) and, helping the enumerators find each household (which were sometimes quite some distance apart). About 50% of the local guides hired were women. It is hoped that the participation of local guides enhanced communities' willingness to participate and openness with the research team. Their participation also enhanced the guides' familiarity with research in general and therefore capacity to engage with future research in a participatory manner.

2.5.3.4 Remuneration

Policies on remuneration varied between different funding organizations, ethics and review boards and other stake-holders of the project. Cash remuneration was avoided (as stated in the ethics review application, McGill FAES REB). In Tanzania and the East Usambaras there is a strong and universal expectation of remuneration for any form of participation in foreign research or development projects (even when the projects are entirely participatory or community initiated). In the case of this study, because each survey household gave up numerous hours of time on multiple occasions it was felt that they should receive remuneration equivalent about a half a day's pay for manual labour. Universally usefully household items were considered including: soap, salt and sugar. Sugar was chosen, as salt was not costly enough and soap was not universally used. Each household received ½kg of sugar, at the end of the survey period, so as not to influence the dietary intake during the survey period (at the local cost of about 750TSh, 1-5 days worth, depending on the household). The sugar was given to the women who had participated in the dietary survey. The women seemed happy, satisfied and appreciative of this small gift.

2.5.4 Anthropometric Measurements

The heights and weights of mothers and children were measured, according to standard United Nations (1989) protocol at various central locations in each village. Height was measured using a portable plastic SECA™ Stadiometer and weight was measured on a portable solar Tanita™ scale. The scale was calibrated to zero before each subject and was standardized at each location using a 6L plastic water container that remained sealed for the duration of the study and weighed 5.9±0.1kg. The age of the mother was recorded to the closest month, from memory, and the age of the child was determined from Maternal and Child Health record cards. Measurements were taken in the wet (least food secure season) between March and May 2009. All measurements were taken by the same researcher (except for 3 cases where the child was so afraid of the foreign researcher that a measurement could only be taken by a Tanzanian team member, all of whom had basic training). No repeat measures were taken so the researcher's Technical Error of Measurement (TEM) is unknown. All measurements were taken between 9am and 6pm but time of day was not recorded as suggested by Gibson (2005).

Height-for-age Z scores (HAZ) were calculated using the WHO Anthro software and child growth standards (WHO 2006). Children with a z-score <-2 SD were classified as stunted. Original sampling included children older than 60 months (N=~50); therefore, because WHO growth charts and Anthro software only go up to 60 months, the HAZ scores for N=220 children were obtained.

2.5.5 Dietary Assessment

2.5.5.1 Overview

There are 4 principle means of assessing nutritional status: histories (including dietary intake), anthropometric, clinical, and biochemical (Gibson 2005). Nutrient intake was chosen as the primary indicator of nutrition for this study for a number of reasons. Clinical indicators are either unreliable or require highly trained medical staff who were not available (Wedner et al. 2004). Anthropometrics and biochemical indicators are generally considered to be more accurate than dietary intake but, they are both highly influenced by infection; the area of study has high rates of multiple infectious diseases including malaria and helminths (Beasley et al. 2000, Semba and Bloem 2008). Although infection is an extremely important component of nutrition and health in East Africa, this study was already very broad and therefore a nutritional indicator less likely to be influenced by infection was chosen.

Dietary and nutrient intake assessment can have many sources of error. These reduce precision and thereby decrease the ability to find links between intake and other factors. A few of the major sources of error include:

- Human recall / Memory
- Parents not being aware of child's intake
- Serving size estimation (especially from a shared plate)
- Food nutrient composition
- Large day-to-day variation

Mothers and young children were chosen because they are the most nutritionally sensitive members of a household due to both higher requirements and inadequate intake (Gibson 2005). Children over the age of 2 were chosen to remove the complication of assessing breast milk intake. The survey employed a qualitative 7 day food use questionnaire and 24 hour recalls to assess dietary intake and nutrient intake (Gibson 2005).

2.5.5.2 The 24 hour recalls

In the wet season two 24 hour recalls were collected for each mother and child on non-consecutive days of the week (Appendix 2). In the dry season only one 24 hour recall was collected. The 24 hour recalls were collected by trained and experienced enumerators and used a multi-pass technique to improve recall. Inability to provide accurate recall has been demonstrated in young children (under 8-10 years), therefore children's intake was collected from the mother (Livingstone and Robson 2000, Serdula et al. 2001). However, many studies have noted that because children are not always with their mothers, mothers often omit items from their child's intake (Ferguson et al. 1994). This is especially true in East Africa where children are commonly left in the care of friends and relatives (Gewa et al. 2007) and where food items such as fruit are not considered 'food' and thus commonly omitted from recalls (Ferguson et al. 1994, Fleuret 1979a). Mothers were encouraged to consult with their children if unsure during interview and enumerators probed multiple times about specific food types (fruit, snacks, candy). Each 24 hour recall was reviewed within a day of completion by the lead researcher with specific attention to completeness (e.g. missing fruits, snacks, etc.). Missing information was identified on around 5% of recalls and the mother was revisited; however, for logistical reasons (long distances between villages and households) it was sometimes impossible to obtain missing information.

Local serving size aids used included: large and small spoons, large and small cups, a bowl, a plate / dish and a common plastic bag (for measuring leafy vegetables) (Figure 2.10-2.11). The serving size aids were used to help women estimate servings of liquids, sauces, salt, sugar, oil, flour, other cooking ingredients, and prepared cooked dishes. Size of fruits, vegetables and tubers were recorded in centimetres of length or diameter, and a few foods were reported directly in weight (if a specific weight had been purchased and all of it was cooked (e.g. beans)).

Figure 2.10 Plastic plates and bowls used as serving size aids (left - *ugali* and *tembele*, right - *bada* and *dagaa*)

Figure 2.11 Zaina Housseni preparing a meal using large plate and large cup used as local serving size aids

Some store bought beverages were reported in millilitres. Serving sizes of stiff porridge staples (*ugali* and *bada*) were either measured in cups / bowls or in centimetres from the base of the plate on which the serving was pilled. Each measure was standardized for each type of food item (e.g. a bowl of: water=438g, maize flour=282g, ugali=490g, cooked rice=337g) and weight of fruit, vegetables and tubers of different sizes was determined (averaged over at least 3 measurements, more if large variation was seen). Despite relatively high rates of literacy in the area (men and women) and the use of local serving size aids, limited functional numeracy and inexperience with qualifying measurements may have reduced accuracy of serving size estimation by local women. Additional error in serving size estimation likely occurred due to most meals being consumed from a shared plate or bowl (Dop et al. 1994, Hudson 1995, Shankar et al. 2001).

2.5.5.3 Nutrient Composition Data

The computer programme CANDAT (Godin 2007), London, Ontario) was used to calculate nutrient intake from food intake. For local food items (consumed in 4 or more recalls and for which no code already existed in CANDAT, or for which the nutrient values for the existing code varied greatly from local values), a new food code was created. Data on the nutrient composition for local foods were obtained from Tanzania Food Composition Tables (Lukmanji et al. 2008)(which mostly contain very general data, similar to averages from USDA Nutrient Data Base), the FAO Food Composition Tables (Wu Leung 1968), USDA Nutrient Data Base and an extensive literature search for the most recent and most accurate data. When no data were available for a given species, data from a similar food / species were used. All leafy greens were given a new food code. The data for beta-carotene, iron and zinc for all leafy greens were obtained from Msuya et al. (2008) because this publication provided geographically specific (from the East Usambara Mountains), recent and accurate data for all of the most commonly consumed leafy greens.

Although recipes were collected for each recall, they were standardized for entry into CANDAT. The recipe function in CANDAT was used to determine the overall composition of prepared dishes. All foods were analyzed in raw form; no attempt was made to adjust for bioavailability or loss due to cooking. This may have led to an over-estimation of intake of nutrients which suffer high losses in cooking such as vitamin C.

2.5.5.4 Nutrient Intake

Dietary intake data were entered into the program CANDAT (Godin 2007) London, Ontario) (WorldFood2 from the FAO was also considered, however technical support for WorldFood was limited compared to CANDAT). Intake was entered in grams except for purchased beverages recorded in millilitres on the recalls. Standardized recipes did not include salt and fat /oil, which were entered individually for each recipe and recall so as not to lose the variation between individuals. Edible portion (percent refuse) was determined from USDA Nutrient Data Base information on refuse for different food items (only for items with >5-10% lost to refuse). CANDAT was used to generate data on nutrient intake by day, average nutrient intake across 2 days, nutrient intake from different sources (purchased, farm/ home, forest, etc. using the meal coding option in CANDAT), grams and nutrient intake from different foods and food groups. Nutrients examined included: energy (kilocalories (kcal)), protein, fat, carbohydrate, fibre (TDF – total dietary fibre), thiamine, riboflavin, niacin, vitamin B_6, vitamin B_{12}, folate (DFE – dietary folate equivalents), vitamin C, vitamin A (RAE – retinol activity equivalents), vitamin D, calcium, iron, zinc and magnesium.

The relative variation between individuals was examined, rather than actual intake for individuals or populations. Day-to-day variation adjustments are needed when intake data from two 24 hour recalls are used to determine actual intake and the proportion of a group at risk of deficient intake. The most commonly used approach for the adjustments was developed at Iowa State University with the Institute of Medicine (Dodd et al. 2006, Institute of Medicine 2000, Murphy et al. 2002). These adjustments were not performed for this study because only relative intake was examined; no effort was made to estimate the proportion of the population at risk of inadequacy.

2.5.5.5 MAR (Overall Diet Quality)

To provide a measure of overall dietary quality (in terms of nutrient intake) a mean adequacy ratio (MAR) was calculated. The MAR is widely considered a good indicator of overall diet quality. Based on nutrient intake rather than food intake and dietary patterns, it is often the standard against which other measures of diet quality are tested (Dubois et al. 2000, Kant 1996).

The MAR is the mean of a set of nutrient adequacy ratios (NARs), calculated in this manner:

$$\text{MAR} = \Sigma\ \text{NAR (cut off at 1, or 100\%)} / \text{number of nutrients}$$

The NAR of each nutrient is the ratio of an individual's intake relative to the recommended intake for their age, gender and physiological group (pregnant / breastfeeding), with a value between 1 and 0, cut off at 1 (100%) so that high intake of one nutrient could not compensate for inadequate intake of another. The FAO/WHO recommended nutrient intakes (RNIs) used to calculate the NARs are presented in Table 2.3 (Nantel and Tontisirin 2001). In this research 11 nutrients were included: protein, thiamine, riboflavin, niacin, vitamin B_{12}, vitamin A, vitamin C, calcium, iron, zinc and magnesium. The MAR had a normal distribution.

The use of a MAR has the benefit of countering the tendency to focus on individual nutrients and foods; such focus does not represent the reality of foods and nutrients consumed in combination. It also helps to overcome complications associated with multicollinearity between intakes of many nutrients (Dubois et al. 2000, Kant 1996). The MAR is limited in that it is always highly correlated with energy intake, and is based on each individual's meeting the RNI for each nutrient when the RNIs are the amount required by 97.5% of a population to meet their requirement, as opposed to the mean requirement of a population.

Table 2.3 Recommended Nutrient Intakes (RNIs) used to calculate NARs (Nantel and Tontisirin 2001)

	Children		Mothers							
				Breastfeeding				Pregnant		
Amount per day	1-3 yrs	4-8 yrs		1-3 mo	4-6 mo	7-12 mo	12+ mo	1-3 mo	4-6 mo	7-9 mo
Protein (g)	13	19	x	x	x	x	x	x	x	x
Thiamine (mg)	0.5	0.6	1.1	1.5	1.5	1.5	1.1	1.4	1.4	1.4
Riboflavin (mg)	0.5	0.6	1	1.6	1.6	1.6	1	1.4	1.4	1.4
Niacin (NE)	6	8	14	17	17	17	14	18	18	18
B_{12} (µg)	0.9	1.2	2.4	2.8	2.8	2.8	2.4	2.6	2.6	2.6
Vitamin C (mg)	30	30	45	55	55	55	45	55	55	55
Vitamin A (RAE)	400	450	500	850	850	850	500	800	800	800
Calcium (mg)	500	600	1000	1000	1000	1000	1000	1200	1200	1200
Iron (mg)	11.6	12.6	58.8	30	30	30	58.8	22.6	22.6	22.6
Magnesium (mg)	60	76	220	220	220	220	220	220	220	220
Zinc (mg)	8.3	9.6	9.8	19	17.5	14.4	9.8	11	14	17.5

2.5.5.6 Nutrient Density

Nutrient density of the diet is one way to examine diet quality without the confounding effect of energy (intake of most nutrients is highly correlated with energy intake). Moreover, nutrient density in the diet is needed to ensure micronutrient adequacy without leading to diets with excess energy, associated with nutrition transitions. Although nutrient density has been measured multiple ways, one of the most common is in grams or milligrams of nutrient per 100kcal of energy (Drewnowski 2005, Moursi et al. 2008). In the work herein the nutrient density (nutrient / 100 kcal of energy) of individuals' diets was calculated for 12 different nutrients: fat, protein, thiamine, riboflavin, niacin, vitamin B_{12}, vitamin A, vitamin C, calcium, iron, zinc and magnesium. A rough, overall nutrient density score was then calculated by quintile ranking each individual (from 1 to 5) for each nutrient and summing their score across 12 nutrients (for a maximum value of 60). Unlike the MAR which was cut-off at 100% of the RNI, high intake of some nutrients can hide low intake of other nutrients in the nutrient density score. The overall nutrient density score had a normal distribution.

2.5.5.7 Grams of Intake and Food Groups

Grams of intake for each food item and food group were calculated from data exported from CANDAT. Because CANDAT does not export data on grams of a food, grams were calculated as the sum of grams of carbohydrate, protein, fat, water and ash.

Food was grouped based on both local and nutritional principles. Food groups included: staples (*chakula*), legumes (*jamia za maharage*), fruit (*matunda*), vegetables (*mboga*, which included mushrooms + items considered flavouring agents locally but vegetables nutritionally such as tomatoes, onions, carrots, green peppers), fish (*samaki*, the local definition of which includes crabs, Crayfish and shark), animal source foods (*nyama*, which can also include birds + not included in the local definition – eggs and milk), and other food (including drinks, snacks, spices, etc.).

2.5.5.8 The 7-day Food Use Questionnaire

A qualitative 7-day food use questionnaire recorded all foods used in the past 7 days (technically not a food frequency questionnaire as the frequency – number of days or number of meals each food was consumed – was not recorded) (Gibson 2005) (Appendix 2). This questionnaire was used to identify use of wild foods from the farm and forest, dietary diversity, and source of food items in the diet and use of different food groups, as discussed below.

2.5.6 Dietary Diversity

2.5.6.1 Food Variety Score (FVS) - 7 day

The Food Variety Score (FVS) was defined as the number of unique foods consumed in a given period (here 7 days), determined from the qualitative 7 day food use questionnaire. The FVS herein includes any food item for which the respondent indicated “yes” when the item was read from a list of just over 250 items (e.g. boiled banana, okra, pumpkin leaves, tomatoes, kidney beans, eggs, chicken, Crayfish, guava, wild raspberries, lemon, bread, coconut milk, black pepper). There were no restrictions on the items included (in terms of serving size or percent of individuals using them). Of the 202 items used by 1 or more individual, only 3 were used by more than 97.5% (salt, sugar, tea); 5 were used by more than 95% (salt, sugar, tea, maize (*ugali*), *dagaa* – a type of small dried fish). However, 70 (34.7%) items were used by 2.5% of individuals or fewer, 100 (49.5%) items were used by less than 5% of individuals and 120 (59.4%) items were used by less than 10%. Table 2.4 reports the descriptive statistics for the different dietary diversity scores.

2.5.6.2 Dietary diversity score (DDS_6) – 7 day

The Dietary Diversity Score (DDS_6) 7 day was calculated from the same qualitative questionnaire as FVS and was defined as the number of food groups from which the individual had consumed one or more items in the last 7 days. The score was based on 6 groups: starchy staples / carbohydrates, vegetables, fruit, legumes, fish and other animal source foods. Additional categories were considered but, as almost all individuals consumed one or more items of fat and oil and one or more 'other foods' (snacks, spices, beverages) and almost no individuals consumed eggs, these groups would not have added much additional information. Fish was included as a food group separate from other animal source foods because of the widespread use of small dried freshwater fish (*dagaa*). This score was adapted from DDS scores used previously following the acknowledgement that: "prior to using [a dietary diversity score] in the field, it will be necessary to adapt it to the local context" (Kennedy et al. 2011).

2.5.6.3 DDS_{14} – 7 day

The DDS_{14} 7 day was calculated from the same qualitative questionnaire as FVS and DDS_6 and was defined as the number of food groups from which the individual had consumed one or more items in the last 7 days. The score was based on the Individual Dietary Diversity Score (IDDS) recommended by "Guidelines for measuring household and individual dietary diversity" prepared by the FAO and the Food and Nutrition Technical Assistance (FANTA) Project (FAO and FANTA 2007), and used 14 food groups.

These 14 food groups included: grain, white tubers, vitamin A rich tubers, leafy vegetables, other vegetables, vitamin A rich fruits, other fruits, legumes, fish, egg, meat, organ meat, milk and oil. This score, as a DDS score using a large number of food groups, was chosen to complement the above score using a limited number of food groups in order to ensure robustness of findings.

Table 2.4 Descriptive statistics for the dietary diversity scores for children

Score		Definition	N =	Distribution	Min-Max	Mean± S.D.
1 day	FVS	Number of unique foods	269	Normal	3-16	9.4±1.8
	DDS_6	Number of food groups (out of 6)	269	categorical	1-5	3.2±0.8
	DDS_{14}	Number of food groups (out of 14)	269	Normal	2-9	5.9±1.3
7 day	FVS	Number of unique foods (out of 250)	274	near normal, long + tail	15-80	39.3±11.7
	DDS_6	Number of food groups (out of 6)	274	categorical	4-6	5.5±0.6
	DDS_{14}	Number of food groups (out of 14)	274	Normal	7-13	10.4±1.3

2.5.6.4 FVS - 1 day

A FVS was also calculated from the 24 hour recalls and consisted of the number of unique items entered into CANDAT. The score did not count items that were repeated (salt, sugar, etc.) and represents the 1st of 2 days of recall (representing a period of one day). Because it was not a list based score there was no maximum number of items that could be achieved, unlike the 7 day FVS. The score is simplified relative to the actual items consumed as 'banana cooked with coconut milk' (a recipe that included banana, coconut milk, onion and tomatoes) counted as only one item.

2.5.6.5 DDS_6 – 1 day

A DDS_6 was also calculated from the 24 hour recalls (again for the 1st of 2 days of recall). The same food groups were used as in the DDS_6 score calculated from the 7 day food use questionnaire. While one mother achieved the maximum score of 6 on the DDS_6 in one day, no children did (Table 2.4).

2.5.6.6 DDS_{14} – 1 day

A DDS_{14} was also calculated from the 24 hour recalls (again for the 1st of 2 days of recall). The same food groups were used as in the DDS_{14} score calculated from the 7 day food use questionnaire. The maximum DDS_{14} score achieved by any child in 1 day was 9 out of 14 (Table 2.4).

2.5.7 Source of Foods

The source of each food item consumed was recorded on both the 7 day food use questionnaires and the 24 hour recalls. Sources of food recorded included: purchased foods (store, market, vendor, and local restaurant); farm (garden was combined with farm because its use and definition were inconsistent across informants, this category also included fallow which people consider to be part of their farm); gift (including foods consumed at a friend's house or funeral); and foods from forest or uncultivated land (river, forest, bush). The percent of food items from each source was calculated from the 7 day food use questionnaire. The percent of intake of each nutrient from each source was calculated from the 24 hour recalls. The contribution of wild foods, from any source, was also examined.

2.5.7.1 Wild Foods

Foods were defined as 'wild' if they were not cultivated. This was complicated by the fact that some species had both wild and cultivated varieties (e.g. *mnavu* (*Solanum nigrum*) and *mchicha* (*Amaranthus* spp.)); for these cases, foods were classified as 'wild' if they were collected from the wild a substantial amount of the time. Qualitative data and local perceptions supported which foods were identified as wild. A total of 92 species of wild (or spontaneous growing) foods were reported on the 7 day food use questionnaire; use of these 92 species, relative to how many other food items were used, determined the percent of the diet from wild foods.

Calculations of percent of nutrient intake from wild foods from the 24 hour recall data compared each individual's total intake of each nutrient to their intake from wild species. Classification of food items as wild, on 24 hour recalls, was similarly complicated by the fact that food items reported on a 24 hour recall that were purchased or from the farm could have been either cultivated or wild (e.g. *mchicha, Amaranthus* spp.). Of the foods recorded in CANDAT, the food codes / items which were classified as wild for the calculation of contribution of wild foods to nutrient intake included: passion fruit, including *dodoki* (#1630), guava (#1578), *perakai* (#1579), ground cherry (#1577), raspberry (#1747), palm fruit (#8880032), fresh fish (#8800020), *mchunga* (#8800021), *kibwando* (#8800023), *kisamvu cha mpira* (#8800026), *mbwembwe* (#8800031), *mnavu* (#8880016). These classifications, which were based on local people's classifications (passion fruit, guava and raspberry are not planted) adapted to try to adjust for items which are both cultivated and wild. These classifications were conservative; for example, the exclusion of *mchicha* from the calculation not only missed any contribution of wild varieties of *mchicha* but of any wild vegetables entered as *mchicha (mnavu*, which is sometime cultivated was classified as wild to try to make up for this but it is used much less frequently). The estimation of contribution of wild foods was further underestimated because wild foods were rare. Any food reported on less than 4 recalls was not given its own food code in CANDAT because nutrient composition information was not available for many wild foods and attempts to estimate nutrition composition error prone and time consuming. Instead was entered using a similar, more common food. The clearest example of this is wild mammals and birds, which were entered as cow or chicken.

2.5.7.2 Wild foods from the Forest

'Forest' foods were defined as any food item reported as obtained from the forest or other non-farm / uncultivated land use type (bush, river, etc.). "Forest" foods were thus a subcategory of 'wild' foods. Food items often were 'forest' foods for one individual and not for another (for example birds trapped in the forest versus on the farm or fruit from a tree growing in the forest versus in a field margin). Almost 30% of wild species were never obtained in the forest. The percent of each food item obtained from each source was calculated and the 'primary source' of each food item was determined as the most common source of each food item. Of wild species, 45 were obtained in the forest on at least 10% of the occasions that they were consumed. The forest was the primary source of 26 items.

The contribution of foods from the forest to overall intakes of food items was calculated for each informant from the 7-day food use questionnaire, and, the mean contribution was determined. The percent of nutrient intake from the forest foods out of an individual's total intake of each nutrient was calculated from the nutrients intake data from the 24 hour recalls. The source of each food item was marked in CANDAT using the meal code function (e.g. instead of 'dinner', meal code 5 marked foods from the forest or bush). CANDAT was able to export data on the intake of each nutrient from each code. The mean contribution of each source to each nutrient was then determined.

2.5.8 Agricultural Data

An extensive set of data on agricultural practices was collected using a questionnaire conducted with the head of the household (male or female, identified by the household members). Data collected included: agricultural diversity (crop diversity); hours spent in the farm; number, size, quality and distance of fields; land tenure and how the land was obtained; source and trade of seeds and planting material; agricultural practices (crop rotation, fallow, use of natural and chemical fertilizer, pesticide, etc.); livestock and other agricultural assets; sources of information; and, important crops. Crop diversity (number of crop species cultivated in past 12 months) was used as a proxy of agricultural diversity for each household. The affiliation of this research project with a well-known agricultural institution and introduction to communities and facilitation from local District Ministry of Livestock and Agriculture likely encouraged local people to make an effort to accurately respond to these questions. Unlike issues surrounding forest use, other than the fact that many of the enumerators were recent graduates of an agriculture program, there are no known factors that may have created significant bias in the answers to questions on agricultural practice.

2.5.9 Forest Use Data

Questionnaires conducted with the head of each household covered forest use by the entire household. The questionnaire included information on frequency of trips to the forest, reasons for visiting the forest, and non-food NTFP use (mostly building material, fodder and firewood).

2.5.10 Forest Cover and Biophysical Variables

The location of each household was recorded using a hand held GPS60CSX (Garmin™). Geographic Information Systems (ArcGIS9.2) was used to analyze aspects of the landscape in proximity to each household, including the area of forest cover and surface area of open water resources. Forest cover was determined using a Landsat eTM+ gap filled image (30m resolution, Row 166, path 064, Feb. 23, 2006) and a SPOT satellite image (10m resolution, Feb. 17, 2007). Classification of the image was performed using a supervised maximum likelihood algorithm using ERDAS imagine software in 2008 by Jaclyn Hall in association with the ICRAF Landscapes Mosaics project. An index of photosynthetic activity was created using the Landsat red and near infrared spectral data. This Normalized Difference Vegetation Index (NDVI) is significantly related to phosynthetically active leaf area across different land covers and it is used herein as a proxy for healthy leaf area (Carlson and Pripley 1997, Jensen 1996). Total forest area, total area of open water, and average leaf area index was determined for circular areas around each household within radii of 200m to 2km.

2.5.11 Wealth Assessment

Wealth or socio-economic status (SES) is well known to be a common mediator of biodiversity use, dietary diversity and nutritional status, and was thus an important variable in this research. Wealth was assessed 3 ways:

1. Self-assessed Rank (average, low, very low)
2. Participatory, Community-based Rank (from low =1 to high= 5)
3. Asset Ranking (out of 13 assets)

Questionnaires conducted with the head of each household collected data on assets and an asset ranking scale was developed based on binary variables. From a wider set of variables, 13 variables were chosen so as to achieve a wide spread in the percent of households with / without each marker of wealth. Variables included in the asset based ranking covered household structure, household assets (soap, bicycle, livestock), access to investment inputs (paid labour on the farm, credit, fallow land, purchased land) but did not include income, livelihood, land owned, travel, education, or other assets (e.g. telephone). Self ranking proved to be difficult, due to highly personal motivations for over or under reporting one's own wealth, and was therefore discarded. Participatory community-based ranking (a common participatory technique) was conducted with a group of 10-20 community leaders (including village government members, health practitioners, teachers and religious leaders) in each community (Protocol in Appendix 3). Participants were asked to reach consensus on the wealth rank of each of the households in the study (based on their own set of criteria that they reported to include, among others: livelihood, housing, health and diet, education, clothing, travel). This measure of wealth was chosen over asset based ranking because it was more holistic and better able to incorporate more diverse and nuanced factors than asset based ranking. The comparison of these methods (not covered in this dissertation) will add to the growing understanding of participatory methods and wealth assessment in Tanzania and elsewhere.

2.6 Data Analysis

Data were entered in Microsoft Excel and then checked (every 10^{th} questionnaire, if more than ~ 1 mistake / 5 questionnaires were identified, every 2^{nd} or 3^{rd} questionnaire was checked in the set - most questionnaires were 4 or more pages). Data were cleaned (checked for outliers, descriptive statistics, etc.), and preliminary calculations were done (dietary diversity, percent of diet from a given source, etc.). Data were transferred to SPSS Student Pack 17 where descriptive statistics, bivariate and multivariate statistics were preformed (e.g. correlations, partial correlations, chi squared tests, t-tests, Mann-Whitney U tests, ANOVA, multivariate and logistic regression).

Preface to Chapter 3 (Manuscript 1)

As noted in the introduction (Chapter 1), dietary diversity is viewed as an important pathway between biodiversity and human nutrition; demonstration of this underlies one of the main objectives of this dissertation. Those working to link dietary diversity to nutritional intake and adequacy tend to use simple measures of dietary diversity and short study periods with the aim of easing data collection. On the other hand, in an effort to account for all the pathways through which biodiversity enters the human diet, those seeking to link dietary diversity to biodiversity and agricultural diversity advocate for broader diversity scores and longer study periods. Recent work linking higher agricultural diversity (crop diversity) to increases in dietary diversity in Kenya used a 7 day food item based dietary diversity score (Ekesa et al. 2008). Torhiem et al. (2004) showed that FVS, but not DDS, is associated with higher crop diversity (although only when SES was not included in the model) and Kennedy et al. (2005) created an extended dietary diversity score which included crop variety diversity as well as food item diversity. Herforth's (2010a) work, which linked crop diversity to 1 day food item (DVS, akin to FVS herein) and food group (DDS) based scores in Kenya and Tanzania, is an exception.

This first manuscript examines the links between 1 day and 7 day dietary diversity and stunting, measures of nutrient intake and adequacy in the East Usambara Mountains. Later chapters will examine relationships between measures of biodiversity (wild food use, forest use and aspects of the landscape) and dietary diversity as well as nutrient intake, adequacy and density (and other markers of diet quality such as use of animal source foods). This manuscript was co-authored with Katherine Gray-Donald, Anna Herforth, Mel Oluoch, John Msuya and Timothy Johns. It will be submitted to the journal Public Health Nutrition for peer review.

Chapter 3 (Manuscript 1)

Dietary patterns and methodological issues affecting the relationship between dietary diversity and nutrition: The case of *ugali* and *dagaa*

Bronwen Powell, Katherine Gray-Donald, Anna Herforth, Mel Oluoch, John Msuya and Timothy Johns

3.1 Abstract

Dietary diversity is a promising tool for nutrition assessment but there are inconsistencies in its relationships with measures of nutrition. Our goal was to understand the links between dietary diversity and nutrition in children aged 2 to 5 years (N=274) in rural Tanzania. Nutrient intake was assessed using repeat 24 hour recalls from which overall nutrient adequacy (mean adequacy ratio, MAR) was calculated. Dietary diversity was measured 6 ways: food variety score (FVS) (number of unique food items consumed), a dietary diversity score (number of food groups consumed) based on 6 food groups(DDS_6) and based on 14 food groups (DDS_{14}) each from a 7 day qualitative food use questionnaire and from one day of 24 hour recall.

All dietary diversity scores except the 7 day DDS_6 showed positive correlations to energy intake. The 7 day scores were correlated with intake of only a few nutrients each. None of the 7 day scores were correlated with MAR; however, the all the 1 day scores were. After controlling for energy intake, the 1 day DDS_6 remained correlated with MAR. The 7 day DDS_6 score was related to growth, but not after controlling for confounding factors.

The 12 most commonly consumed foods contributed to 60 - 85% of total energy, protein, zinc, calcium and thiamine consumed. Our results indicate that under conditions where a few food items contribute to a large proportion of nutrient intake, and, where less commonly consumed foods are not more nutrient dense than the most commonly consumed foods, it is more difficult to detect relationships between dietary diversity and nutrition.

3.2 Introduction

Since early use of the concept of dietary diversity (Duyff et al. 1975, Kant 1996, Randall et al. 1985), over 200 papers have been published describing the relationship of either food (FVS) or group (DDS) diversity with various measures of nutrition and health. Dietary diversity has been linked to: nutrient intake, adequacy and density; other dietary quality indexes; other health outcomes and mortality; as well as socio-economic and environmental factors. Strong theoretical cases for dietary diversity as an important aspect of a healthy diet have been built on the principle that by varying items in the diet the likelihood of consuming adequate amounts of all food components essential to health is increased, and, the likelihood of excessive intake of any potential toxin is decreased (Gibson et al. 2000, Johns and Sthapit 2004). The holistic nature of this approach, its simplicity and its ease of use are particularly appealing relative to incomplete understanding of: food composition; requirements, absorption, utilization, storage and metabolism of essential nutrients; their relationships to health and disease; as well as continuously emerging evidence of new food elements linked to health.

Limitations of conventional methods of dietary assessment are particularly apparent when it comes to the errors and variation in nutrient content of foods used to determine nutrient intake from food intake. McBurney et al. (2004) found a large number of errors in published nutrient composition data for *Moringa oleifera* and other African wild food plants (also: McBurney 2010, for errors in cowpea leaf data). Englberger and colleague reported high variation in carotenoid content between banana varieties in the Pacific (Englberger et al. 2003, Englberger et al. 2006). Large geographical variation has also been reported for single species or variety; Barikmo et al. (2007) reported coefficients of variation frequently over 100% for content of iron, zinc, thiamine and niacin in grains (rice, sorghum, millet) from various regions of Mali and Msuya et al. (2008) reported 10 fold differences in beta-carotene, iron and zinc content in leafy greens from different regions of Tanzania.

The Food Variety Score (FVS) is the most common measure of diversity of food items in the diet (consumed in a given period), and the Dietary Diversity Score (DDS) commonly refers to the number of different food groups consumed within a given period, although other terms and scores are also common (Ruel 2003a, Ruel 2003b). We use 'dietary diversity' to refer to both FVS and DDS, as well as other scores of dietary diversity in general. While findings on the relationships between dietary diversity scores and intake or adequacy of individual nutrients are inconsistent (Ferguson et al. 1993, Hatløy et al. 1998, Roche et al. 2007), many studies have linked children's dietary diversity to nutrient intake or adequacy across many nutrients or to a score of overall adequacy (such as the mean adequacy ratio, MAR) (Hatløy et al. 1998, Kennedy et al. 2007, Onyango et al. 1998, Steyn et al. 2005). The universality of the links between dietary diversity and overall nutrient intake (or at least energy intake, and thus intake of most nutrients) is supported in part by the concept of sensory-specific satiety (Brondel et al. 2009, Rolls 1986); research shows that diversity of meal items is linked with decreased satiety and increased consumption in both humans and animals (DiBattista and Sitzer 1994, Rolls et al. 1981). Many (but not all) studies report relationships between energy intake and dietary diversity (Ferguson et al. 1993, Hatløy et al. 2000, Onyango et al. 1998, Saibul et al. 2009); however, recent work has shown relationships between nutrient adequacy and intake and dietary diversity to persist (if somewhat diminished) after controlling for energy intake (Daniels et al. 2007, Kennedy et al. 2007). Moursi et al. (2008) recently showed a positive relationship between dietary diversity and overall nutrient density of the diet. But, not all studies agree (Campbell et al. 1982, Ferguson et al. 1993, Hatløy et al. 2000, Knol et al. 2004).

Dietary diversity, especially food group diversity (DDS) scores have also been linked to children's growth and stunting in some locations or groups studied (Arimond and Ruel 2004, de Gwynn and Sanjur 1974, Eckhardt et al. 2005, Hatløy et al. 2000, Rah et al. 2010, Sawadogo et al. 2006), but not others (Arimond and Ruel 2004, Eckhardt et al. 2005, Hatløy et al. 2000, Saibul et al. 2009).

Contributing to inconsistencies, methodologies have yet to be standardized, although significant progress has been made recently by FAO and FANTA (Kennedy et al. 2011, Kennedy and Nantel 2006). Measurement varies greatly including: tool used (24 hour recall, Food Frequency Questionnaire (FFQ), weighed record); period of study (from 1 day to months), and, types of items included (e.g. traditional foods only, only foods used by more than 10% of the population, only foods with a serving size over a certain cut-off, only healthy foods, etc.) (Ruel 2003a, Ruel 2003b). Mean FVS scores range from 5.5 in 0-9 year olds in South Africa (Steyn et al. 2005) to 20.5 in 1-6 year olds in Mali (Hatløy et al. 1998) and between 7 (many studies), 13 (Bouzitou et al. 2005) and 21 (Arimond et al. 2010) groups have been used in the calculation of DDS.

The evidence in support of dietary diversity has been further complicated by debate over whether diversity of food items (dietary diversity or FVS) or diversity of food groups (DDS) is the most appropriate measure. Since Ruel's (Ruel 2003a, Ruel 2003b) influential review of measurement issues, a number of papers have expressly aimed to improve the measurement and utility of dietary diversity (e.g. Martin-Prevel et al. 2010). Daniels et al.'s (2007) work suggested that portion requirement restrictions improves dietary diversity scores; conversely Kennedy et al. (Kennedy et al. 2005) explored how to incorporate data on intra-specific diversity (diversity of different varieties of crops) into a score of dietary diversity. Others have examined the length of time period needed to assess dietary diversity (Falciglia et al. 2009, Falciglia et al. 2004, Savy et al. 2007).

The growing evidence base and the ease of collecting dietary diversity data has led to its increasing popularity amongst researchers and international health and development practitioners alike. Seeking to inform current methodological debate, this paper presents data from rural north-eastern Tanzania comparing 6 different scores of dietary diversity to growth (HAZ), nutrient intake, nutrient adequacy and density in children between the ages of 2 and 5 years old. Dietary patterns (in this case extensive reliance on a maize staple - *ugali*, and a side dish prepared from a small dried fish – *dagaa*) are examined in an exploration of potential reasons for inconsistencies in the relationship between dietary diversity and other measures of nutrition. The paper concludes with an inspection of how dietary patterns and methodological issues may modify relationships in the context of this study and with an examination of the relevancy of different measures of dietary diversity.

3.3 Methodology

3.3.1 Study Site

The East Usambara Mountains, in north-eastern Tanzania are covered by a biodiverse mosaic of small-scale farms and forests (Hall et al. 2010, Myers et al. 2000). Local livelihoods are based primarily on subsistence agriculture, supplemented with cash cropping, wage labour, small business and cattle keeping (Kessy 1998).

Like many rural African diets, high in starchy staples and low in animal source foods (Murphy and Allen 2003, Siekmann et al. 2003, Stephenson et al. 2010), local diets in the East Usambaras are based mainly on maize, cassava, beans and dry fish. Meals are usually made up of a starchy staple (most commonly *ugali,* maize flour cooked into a hard porridge), and a side dish (such as *dagaa,* a small dry freshwater fish, primarily from Lake Victoria). A similar diet in Kenya has been suggested to provide enough energy, protein and iron but insufficient vitamin A, C, and calcium (Mwajumwa et al. 1991). In 1994 a study from the area found 60% of children between 7-12 years old to be stunted (Height-for-Age Z score ≤-2) and 49% of children to be anaemic (Hb≤110g/L), with high rates of parasite infection (Beasley et al. 2000). The area is known for the high diversity of traditional vegetables used by local people and the importance of wild vegetables in local diets (Fleuret 1979b, Keding et al. 2007, Vainio-Mattila 2000, Weinberger and Swai 2006).

3.3.2 Sampling

Research was conducted in six rural villages in Muheza district (which covers most of the East Usambaras). The villages were selected using stratified sampling based on road access, distance to the urban centre (Muheza town) and elevation (2 upland

(>500m) and 4 lowland (<500 m)). Within each village approximately 45 households with a child between the ages of approximately 2 and 5 years were selected using systematic sampling from a list of households with children under 5 provided by village governments (~50% of eligible households per village were sampled by selecting every 2nd or 3rd household from the list). A total sample size of 274 households was obtained for dietary intake. The youngest child between the age of 2 and 5 was selected within each household but some households only had a child between 5 and 6 years. Stunting data were only available for children under 5 years N=250.

3.3.3 Anthropometric Measures

Height and weight were measured according to standard United Nations (1989) protocols at centralized locations in each village. Height was measured using a portable plastic SECA™ Stadiometer and weight was measured on a portable solar Tanita™ scale. The scale was calibrated to zero between subjects and was standardized at each location using a full 6L water container. Age was determined from Maternal and Child Health record cards. Stunting (a measure of growth failure) or Height-for-age Z score (HAZ) was calculated using the WHO Anthro software and child growth standards (WHO 2006). Children with a z-score <-2 SD were classified as stunted.

3.3.4 Nutrient Intake

Dietary intake information for children was collected from their mother or primary caregiver during the rainy season (March to May 2009). Multi-pass technique 24 hour recalls were collected on 2 non-consecutive days within a one week period, in Kiswahili by trained enumerators. Each 24 hour recall was checked for accuracy and completeness by the primary researcher (BP) in the field. Local serving size aids were standardized to grams for each common food. The 24 hour recalls were entered in to CANDAT (Godin 2007, London, Ontario), which was used to generate nutrient intake data (averaged across 2 days of intake). Novel food codes for local foods were created with the most up-to-date nutrient composition data compiled from Tanzania and FAO food composition tables and published literature (Lukmanji et al. 2008, Wu Leung 1968). No adjustments were made for loss due to cooking or bioavailability. In addition to energy, intake of protein, fat, calcium, iron, zinc, magnesium, vitamin C, vitamin A (RAE), thiamine, riboflavin, niacin, and B_{12} were examined. Nutrient density per 100 kcal for each nutrient was calculated, as well as a mean adequacy ratio (MAR). The MAR was the mean of the nutrient adequacy ratios (NARs) calculated for protein and the 10 micronutrients as the proportion of the child's intake divided by the recommendations (RNIs) used by the WHO/FAO (Nantel and Tontisirin 2001) and cut off at 1 (100%) so that high intake of one nutrient could not compensate for inadequate intake of another (Dubois et al. 2000, Kant 1996). Many other previous studies examining the relationships between dietary diversity and diet quality have used an MAR (Hatløy et al. 1998, Oldewage-Theron and Kruger 2009, Steyn et al. 2005, Torheim et al. 2004).

3.3.5 Dietary Diversity

FVS (7 day): The Food Variety Score (FVS) was defined as the number of unique foods consumed in a given period (here 7 days) determined from a 7 day qualitative food use questionnaire. The 7 day FVS included any food item for which the mother indicated "yes, the child had consumed the food" when the item was read from a list of just over 250 items (e.g. boiled banana, okra, pumpkin leaves, tomatoes, kidney beans, eggs, chicken, Crayfish, guava, wild raspberries, lemon, bread, coconut milk, black pepper). There were no restrictions on the items included (in terms of serving size or percent of individuals using them). Of the 202 items used by 1 or more individuals, only 3 were used by more than 97.5% (salt, sugar, tea) and 5 were used by more than 95% (salt, sugar, tea, maize (*ugali*), and *dagaa*). However, 70 (34.7%) items were used by 2.5% of individuals or fewer (descriptive statistics are presented in Table 3.1).

DDS_6 (7 day): The Dietary Diversity Score (DDS_6) was calculated from the same qualitative questionnaire as the number of food groups from which the child had

consumed one or more items in the last 7 days. The DDS_6 score was based on 6 groups: starchy staples / carbohydrates, vegetables, fruit, legumes, fish and other animal source foods. Additional categories were considered but as almost all individuals consumed one or more items of fat and oil and 'other food' groups (such as spices or snacks) and almost no individuals consumed eggs, these groups would not have added additional information to the score. Fish was included as a food group separate from other animal source foods because of the widespread use of *dagaa*. This score was adapted from DDS scores used previously following the acknowledgement that: "prior to using [a dietary diversity score] in the field, it will be necessary to adapt it to the local context" (Kennedy et al. 2011).

DDS_{14} (7 day): The DDS_{14} 7 day was calculated from the same qualitative questionnaire as FVS and DDS_6 and was defined as the number of food groups from which the individual had consumed one or more items in the last 7 days. The score was based on the Individual Dietary Diversity Score (IDDS) recommended by "Guidelines for measuring household and individual dietary diversity" prepared by the FAO and the Food and Nutrition Technical Assistance (FANTA) Project (FAO and FANTA 2007), and used 14 food groups. These 14 food groups included: grain, white tubers, vitamin A rich tubers, leafy vegetables, other vegetables, vitamin A rich fruits, other fruits, legumes, fish, egg, meat, organ meat, milk and oil. This score, as a DDS score using a large number of food groups, was chosen to complement the above score using a limited number of food groups in order to ensure robustness of findings.

FVS (1 day): A FVS was also calculated from the 1st day of 24 hour recall and consisted of the number of unique items entered into CANDAT. The score did not count items that were repeated. Because it was not a list based score there was no maximum number of items that could be achieved, unlike the 7 day FVS score.

DDS_6 (1 day): Food group diversity was also calculated from the 24 hour recalls (again for the 1st of 2 days of recall). The same food groups were used as in the DDS_6 score calculated from the 7 day food use questionnaire (Table 3.1).

DDS_{14} (1 day): A DDS_{14} was also calculated from the 24 hour recalls (again for the 1st of 2 days of recall). The same food groups were used as in the DDS_{14} score calculated from the 7 day food use questionnaire. The maximum DDS_{14} score achieved by any child in 1 day was 9 out of 14 (Table 3.1).

3.3.6 Statistics

Dietary diversity scores were compared to nutrient intake using Spearman's correlations because the nutrient intake distributions were not normal. Partial correlations were used to control for energy intake while comparing dietary diversity scores to nutrient intake. Multivariate regression was used to examine variables predicting variation in MAR after accounting for wealth, energy intake and child's age and sex. Stunted children were compared to non-stunted children using paired t-tests and logistic regression was used to identify determinants of stunting.

3.4 Results

3. 4.1 Dietary Diversity and Nutrient Intake and Adequacy

Descriptive statistics for the 4 dietary diversity scores are presented in Table 3.1. For the 7 day DDS_6, almost 60% of children scored a full score of 6, 33.5% scored 5 and only 6.7% scored 4. There were 3 children who had not consumed any fruit in the last 7 days, but 46 (17%) children had not consumed any legumes and almost 30% of children had not consumed any animal source foods. The scores for the 1 day DDS_6 and DDS_{14} were more spread out (Tables 3.1 and 3.2).

The 7 days FVS was weakly associated with energy intake (average from 2 days of recall) ($r=0.19$; $p< 0.01$), whereas the 1 day FVS score was more highly correlated with energy intake (r= 0.421; p<0.001) (Table 3.3). Both the 1 day and the 7 day DDS_{14} scores were positively correlated with energy intake. The 1 day but not the 7 day DDS_6 score was correlated with energy intake. The higher correlations from the measures derived from the 24 hr recalls and compared to the nutrient intake from the 24 hr recalls is not unexpected as they were derived from the same measurement tool.

Table 3.1 Descriptive statistics for the dietary diversity scores for children

Score		Definition	N =	Distribution	Min-Max	Mean± S.D.
1 day	FVS	Number of unique foods	269	normal	3-16	9.4±1.8
	DDS_6	Number of food groups (out of 6)	269	categorical	1-5	3.2±0.8
	DDS_{14}	Number of food groups (out of 14)	269	normal	2-9	5.9±1.3
7 day	FVS	Number of unique foods (out of 250)	274	near normal, long + tail	15-80	39.3±11.7
	DDS_6	Number of food groups (out of 6)	274	categorical	4-6	5.5±0.6
	DDS_{14}	Number of food groups (out of 14)	274	normal	7-13	10.4±1.3

Table 3.2 Percent of children consuming different food groups, by DDS_6 (1 day) score

	Total	DDS_6 = 1	DDS_6 = 2	DDS_6 = 3	DDS_6 = 4	DDS_6 = 5	DDS_6 = 6
N= (%)	274	2 (1%)	54 (20%)	123 (45%)	85 (31%)	10 (3%)	0
Starchy staples	100	100	100	100	100	100	X
Fish	76	0	7	71	89	80	X
Fruit	65	0	4	70	94	90	X
Vegetables	43	0	13	36	67	100	X
Legumes	18	0	9	13	26	60	X
Animal Source Food	15	0	6	10	24	70	X

The 7 day FVS score correlated to fat and vitamin C intake but not other nutrients. The 7 day DDS_{14} was correlated only with fat intake. The 7 day DDS_6 correlated with zinc, vitamin C and thiamine. None of the 7 day scores were correlated with MAR. Conversely, all of the 1 day scores (FVS, DDS_6, and DDS_{14}) were positively correlated with the MAR. The 1 day FVS was positively correlated with intake of all nutrients except vitamin A (RAEs) and the 1 day DDS_6 was positively correlated with intake of all nutrients except niacin. The 1 day DDS_{14} was positively correlated with fat, calcium, vitamin C, riboflavin and vitamin B_{12} intake. After controlling for energy intake the 1 day FVS was no longer correlated with most nutrients and the MAR, and, became negatively correlated with others. Likewise, the 1 day DDS_{14} was positively correlated with calcium and vitamin C intake after controlling for energy. Controlling for energy reduced correlations between the 1 day DDS_6 and some nutrients but there was little change in the correlations to MAR ($r=0.212$; $p<0.001$) (Table 3.3).

While quantity of certain food groups was better able to predict variation in MAR than any of the dietary diversity scores, multivariate regression was used to demonstrate that dietary diversity made a unique contribution to variation in MAR in addition to the contribution of quantities consumed. To determine which of the dietary diversity score made the most significant contributions to the variation in MAR the 4 dietary diversity scores were entered into the same (step-wise conditional) multivariate regression model, which included child's age and sex, household wealth and energy intake as fixed independent variables. With conditional stepwise addition the variables included in the final model for MAR included quantity of vegetables, fish, animal source foods, percent of diet purchased and 1 day DDS_6 (Table 3.4).

Table 3.3 Spearman's Correlations (r) between measures of dietary diversity and energy, nutrient intake and Mean Adequacy Ratio (MAR) and partial correlations, controlled for energy, for 1 day measures of dietary diversity and nutrient intake and MAR (N=274)

		7 days Food use questionnaire			1 day 24 hour recall			1 day Controlled for energy		
Nutrient	Intake Mean ±S.D.	FVS	DDS_6	DDS_{14}	FVS	DDS_6	DDS_{14}	FVS	DDS_6	DDS_{14}
Energy	1085±280	0.191**	NSS	0.157**	0.421***	0.164**	0.253***	-	-	-
Protein (g)	32±11	NSS	NSS	NSS	0.193***	0.165**	NSS	NSS	NSS	NSS
Fat (g)	23±11	0.182**	NSS	0.209***	0.465***	0.181**	0.216***	0.252***	NSS	NSS
Calcium (mg)	378±176	NSS	NSS	NSS	0.229***	0.268***	0.190**	NSS	0.192***	0.121*
Iron (mg)	10.3±5.6	NSS	NSS	NSS	0.131*	0.193***	0.114[c]	NSS	NSS	NSS
Zinc[a] (mg)	3.4±1.3	NSS	0.127*	NSS	0.123*	0.150*	NSS	-0.204***	NSS	NSS
Vit A (RAE) (µg)	316±266	NSS	NSS	NSS	NSS	0.168**	NSS	NSS	NSS	NSS
Vitamin C (mg)	98±74	0.140*	0.126*	NSS	0.147*	0.276***	0.236***	NSS	0.173**	0.126*
Thiamine (mg)	0.64±0.26	NSS	0.127*	NSS	0.121*	0.179**	NSS	-0.185**	NSS	NSS
Riboflavin (mg)	0.55±0.22	0.107[b]	NSS	NSS	0.174**	0.205***	0.144*	NSS	0.106[e]	NSS
Niacin (mg)	6.94±2.63	NSS	NSS	NSS	0.144*	NSS	0.113[d]	-0.142*	-0.117[f]	NSS
B_{12} (µg)	0.58±0.52	NSS	NSS	NSS	0.192***	0.128*	0.151*	NSS	NSS	NSS
MAR	0.76±0.12	NSS	NSS	NSS	0.180**	0.242***	0.116**	NSS	0.212***	NSS

NSS = Not Statistically Significant

* p<0.05, ** p<0.01, *** p<0.001

a. ANOVA tests of across tertiles of 7 day DDS_6 and 1 day FVS show a non-linear relationship with zinc (significantly lower zinc intake in middle tertile), b. p=0.081, c. p=0.060, d. p=0.061, e. p=0.080, f. p=0.054

Table 3.4 Multivariate regression model for children's MAR (wet season) (N=274)

Model	B	R^2	R^2 change	Significance of change
Fixed:				
Child's age, sex, household wealth, energy intake		0.199	0.199	-
Entered:				
Vegetable intake (grams)	+	0.454	0.255	p<0.001
Fish Intake (grams)	+	0.608	0.154	p<0.001
Animal Source food intake (grams)	+	0.643	0.035	p<0.001
Percent of food items purchased	-	0.661	0.017	p<0.001
DDS_6 1 day	+	0.677	0.017	p<0.001

3.4.2 Dietary Diversity and Stunting

The mean HAZ for the children was -1.73±1.23 and 39.5% of children were stunted. The 7 day DDS_6 was lower for stunted children (5.40) than normal children (5.59) ($p<0.05$ in a t-test), but the other dietary diversity scores were not related to stunting. Nutrient intakes and MAR were also not related to stunting with the exception of a slightly lower mean zinc intake in the stunted group (3.09mg vs. 3.42mg; $p<0.01$ in a Mann-Whitney U test).

Children using water from a tap were far less likely to be stunted than those from families using water from a well or spring (unprotected) (31% not stunted vs. 58% stunted used well or spring water; $p<0.001$ in a chi squared test). Child's age and gender had no statistically significant relationship to stunting. Household characteristics, including household composition, type of work, and farming practices, were also not related to stunting. In a logistic regression, controlling for wealth, elevation, child's age and sex, source of drinking water is the only variable that made a significant improvement to the model. In forward conditional analysis, no other variables (including DDS_6) made a significant contribution to the model, even when source of drinking water was not included in the analysis.

3.4.3 Nutrient Distribution across Foods

To better understand why there were limited associations between 7 day dietary diversity scores and nutrient intake; and why the associations between 1 day dietary diversity scores and nutrient intake did not remain after controlling for energy intake we examined which foods were contributing to intake of a number of nutrients in relation to how those foods contributed to dietary diversity. The top 20 foods accounted for 74% of total energy intake (Figure 3.1, see Appendix 4 for foods contributing to intake of other nutrients). Oils (vegetable oil, palm oil and homemade coconut milk), and added sugar, were not included in this analysis, and accounted for an additional 14.9% of total energy intake. Many of the most common foods appearing on the 24 hour recalls (and on the 7 day food use questionnaire) also made some of the greatest contributions to intake for many nutrients. The 12 of the most commonly consumed foods on the 24 hour recalls contributed a large portion of the total nutrient intake for a number of nutrients (Table 3.5). For example, the top 6 most commonly consumed foods contributed over 50% of the total intake of energy, protein, thiamine and zinc. The top 12 foods contributed 80% of total thiamine, 77% of protein, 71% of zinc, 68% of energy and 66% of calcium intake, but only contributed 18% of total vitamin A (RAE) intake.

Ugali is a starchy staple made from maize; *bada* is a similar starchy staple made from cassava flour; *mandazi* is fried, sweet, wheat-flour bread; *dagaa* is small, dried, freshwater fish, and, *pelege* is tilapia (usually dried). *Ugali* was not only the most common food item on 24 hour recalls (excluding, tea, salt, sugar and oils), of the 89.3% of the recall days it appeared on, it was consumed twice on 46.7% of them. *Ugali* (*dona* – whole grain and *sembe* – partially de-husked) also accounted for 51.6% of total riboflavin intake and 25.3% of total niacin intake.

The most commonly consumed foods (Table 3.5) account for a smaller overall intake of vitamin A (RAE), vitamin C and iron, in part because these nutrients are obtained primarily from fruits and vegetables which are not among the top 12 most commonly eaten foods (see foods contributing to intake of vitamin A and iron in Appendix 4 and Figure 3.2 for vitamin C). However, the most commonly consumed vegetables account for a large amount of vitamin A (RAE) intake. The 5 most commonly consumed vegetables were amaranth (*Amaranthus* spp.) (12.6% of recalls), *mchunga* (*Launaea cornuta*) (10.2% of recalls), pumpkin leaves (*Cucurbita* spp.) (8.5% of recalls), *kibwando* (*Corchorus* spp.) (5.9% of recalls) and sweet potato leaves (*Ipomoea batatus*) (5.7% of recalls), contributed 9.6%, 19.5%, 7.0%, 9.2% and 4.3% (for a total of just under 50%) of RAE intake respectively.

Table 3.5 Frequency of use and contribution of 12 of the most commonly consumed foods to overall nutrient intake (from all 24 hour recalls N=540), with those making a contribution of >5% of the total or greater highlighted

FOOD	Percent of 24 h recall	Energy (% of total)	Protein (% of total)	Fat (% of total)	Vitamin C (% of total)	RAE (% of total)	Thiamine (% of total)	Calcium (% of total)	Iron (% of total)	Zinc (% of total)
Ugali	89.3%	24.3	18.9	8.4	0	2.6	30.5	2.0	16.8	28.1
Dagaa	62.8%	5.1	28.4	6.2	3.9	5.3	3.6	34.4	3.4	13.0
Mandazi	46.1%	10.1	4.9	13.7	0	0	4.7	0.6	1.8	3.9
Orange	36.5%	2.1	1.4	0.2	26.0	1.7	6.4	5.0	0.5	1.0
Porridge	26.7%	3.6	2.6	1.2	0	0.3	4.6	0.7	2.6	4.1
Banana, cooked	22.6%	4.8	1.1	0.3	5.0	6.4	3.2	0.2	2.5	1.7
Bada	19.8%	4.8	1.4	0.4	6.9	0.1	4.4	1.5	0.9	3.3
Cassava	18.3%	5.5	1.6	0.5	8.0	0.1	5.1	1.6	1.0	3.8
Banana, ripe	16.3%	1.3	0.5	0.2	1.4	0.1	0.7	0.2	0.4	0.7
Pelege	15.9%	1.5	7.8	2.2	1.2	1.7	1.1	14.6	4.8	1.8
Beans	12.4%	2.9	6.5	0.4	0.4	0	8.7	2.3	6.0	7.6
Bread / Skonzi	11.3%	2.1	2.3	1.1	0	0	7.6	2.6	6.2	2.2
TOTAL	Top 6	50	57.3	30	34.9	16.3	53	42.9	27.6	51.8
	Top 8	60.3	60.3	30.9	49.8	16.5	62.5	46	29.5	58.9
	Top 10	63.1	68.6	33.3	52.4	18.3	64.3	60.8	34.7	61.4
	Top 12	68.1*	77.4	34.8	52.8	18.3	80.6	65.7	46.9	71.2

* When calculated from total energy not including the 14.9% from oils and sugar the top 12 foods account for 79.8% of remaining energy intake

Because guava, at 228mg/100g, is a good source of vitamin C, even though it was consumed infrequently (in 3.9% of the recalls) and in moderate quantities (~100g /serving) it was the second largest contributor to overall vitamin C intake (Figure 3.2). Other fruit such as papaya, passion fruit and avocado, also infrequently consumed, were also in the top 20 contributors to overall vitamin C consumption (Figure 3.2). Conversely, for other micronutrients examined (Appendix 4) commonly consumed items contributed much of the overall intake. This difference may explain why 7 day FVS is correlated to vitamin C intake but not other nutrients, as will be discussed further below.

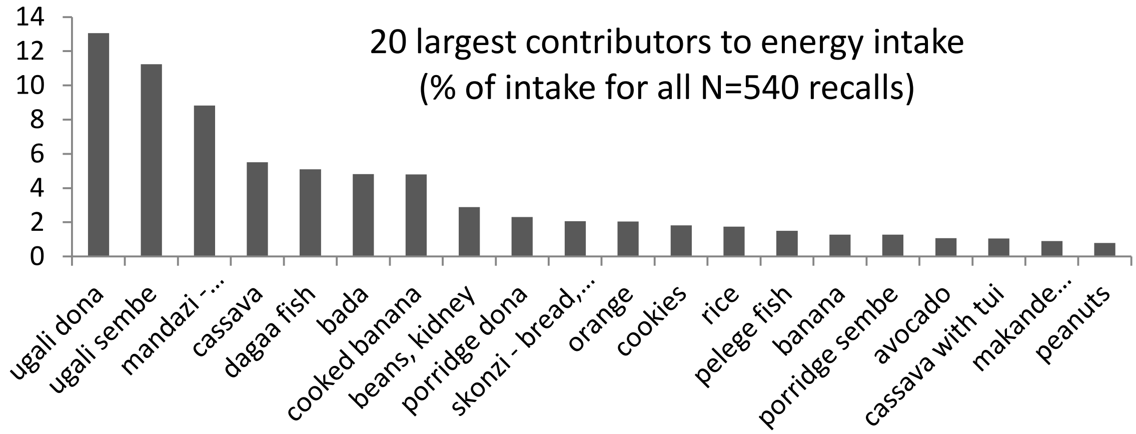

Figure 3.1 Foods contributing to energy intake (kcal)

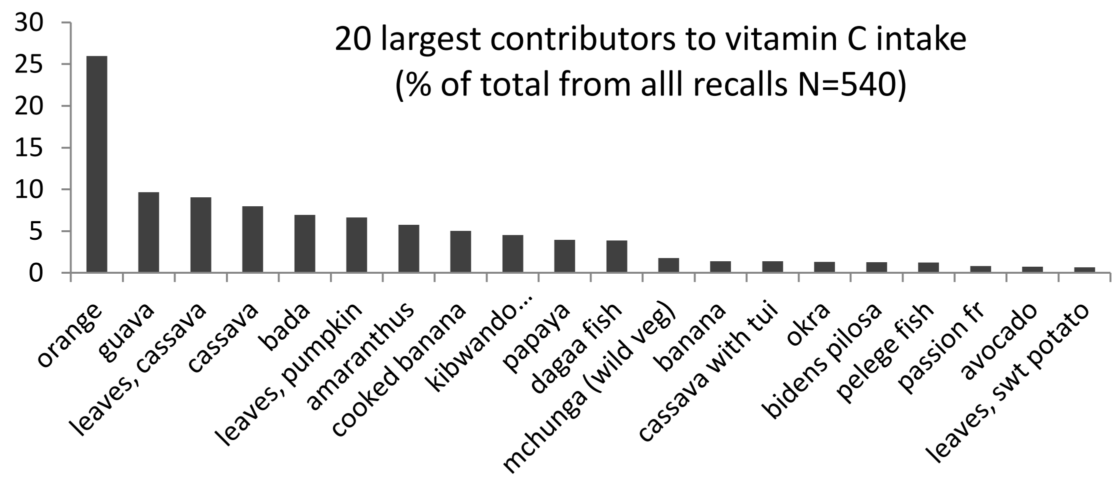

Figure 3.2 Food contributing to vitamin C intake (mg)

3.5 Discussion

3.5.1 Dietary Diversity, Appetite and Energy Intake

Our study showed a relationship between energy and 7 day FVS and DDS_{14}, as well as the 1 day DDS_6, DDS_{14} and 1 day FVS (all scores except the 7 day DDS_6), findings consistent with the literature: virtually all studies report associations between energy and dietary diversity. Only Hatløy et al. (1998) failed to find such relationships. Many recent studies on dietary diversity have also demonstrated a relationship between dietary diversity and nutrient intake or adequacy, after controlling for energy. However, overnutrition and obesity aside (McCrory et al. 1999), for children of the same age range increased intake of energy inevitably means increased intake of micronutrients which, in a setting where undernutrition and stunting remain major nutritional problems is the end goal (if the sample includes a wide age range then it is of course necessary to control for different energy intakes, or age). If dietary diversity ensures that children eat more, and thus that they get more nutrients, it ensures that they have a better chance of achieving their full growth and developmental potential. That dietary diversity helps ensure energy intake is supported by mechanistic evidence from 'sensory specific satiety' which shows that satiety is mediated by the number of different sensory stimuli (i.e. tastes and foods) available (Brondel et al. 2009, DiBattista and Sitzer 1994, Rolls 1986, Rolls et al. 1981). However, with obesity and the nutrition transition an increasing concern, it would be ideal to be able to achieve dietary diversity and adequate nutrient intake without increased risk of excess energy intake (McCrory et al. 1999, McCrory et al. 2000).

3.5.2 Quantity versus Quality (and Diversity)

Certain dietary patterns may lead to a lack of relationship between dietary diversity and nutrient intake. As Arimond and Ruel (2004) note "Depending on local dietary patterns, high diversity scores may be more or less nutritionally meaningful" (p.2528). The most common aspect of dietary patterns suggested to affect the relationship between dietary diversity and nutrient intake is consumption of certain food items in very small, nutritionally irrelevant portions. This has led several authors to explore minimum serving size cut-offs for dietary diversity scores (Daniels et al. 2007, Kennedy et al. 2007, Moursi et al. 2008).

The impact of a few food items contributing a large amount of overall intake of nutrients has not been well explored as a dietary pattern that could mediate the relationship between dietary diversity and nutrient intake. In a study from the Philippines, the authors noted that correlations between DDS and nutrient adequacy were less robust to adjustment for energy intake for some nutrients (thiamine, niacin, absorbed iron) than others and that this was likely due the fact that those nutrients are concentrated in commonly consumed and energy dense foods (Daniels et al. 2007). We feel that this is likely why, in our study, so few of the nutrient intakes remained correlated with 1 day DDS_6, DDS_{14} and FVS after adjusting for energy intake.

Our finding that, unlike for other nutrients, vitamin C intake was correlated with all FVS, DDS_6 and DDS_{14} scores and remained correlated to 1 day DDS_6 and DDS_{14} after adjusting for energy, supports the above argument: unlike other nutrients, few of the top 12 most commonly consumed foods appear in the top 20 foods contributing to vitamin C intake (Figure 3.2). In another example, Roche and colleagues' (2007) study from the Peruvian Amazon found a significant correlation between traditional food variety and vitamin A intake but not vitamin C intake (after controlling for energy). In their study 6 of the top 10 traditional foods contributing to energy intake were also among the top 10 contributing to vitamin C intake but only 3 were among the top 10 contribution to vitamin A intake.

In our study the top 12 foods along with sugar and oils accounted for 83% of the total energy consumed. *Ugali* accounted for 24% of total energy intake and starchy staples accounted for 59% of energy intake. Perhaps, relative to Kennedy et al's (2007) case of Filipino children, where 68% of energy came from staple foods or Stephenson et al.'s (2010) study from Kenya where over 80% of energy was obtained from staples (59% from cassava alone) the diets of the children in our study do not lack side dishes;

however, lack of diversity within side dishes consumed may be of equal importance. *Dagaa* appeared on 62.8% of recalls, whereas the next most common side dish – *pelege* – appeared on only 15.9% and beans on 12.4%, despite the great diversity available in the communities (e.g. over 50 species of vegetables).

The relative nutrient density of commonly eaten foods compared to less commonly eaten foods could be an additional factor mediating the relationship between dietary diversity and nutrient intake. In order for dietary diversity to improve nutrient intake, the most commonly eaten foods should have a lower nutrient density than less commonly consumed foods. If this is the case then the inclusion of additional foods (in substitution for repeated use of commonly eaten ones) should lead to increased nutrient density of the diet and thus increased nutrient intake and adequacy after controlling for energy intake. Torheim et al. (2004) noted that because the different foods within each group were similar in nutrient composition, the positive relationships between within-group diversity for dairy and vegetables to MAR in their study, was likely due to diversity leading to consumption of greater quantities. An examination of relative nutrient density per serving of the top 5 most commonly consumed side dishes (*dagaa*, *pelege*, beans, amaranths and *mchunga*), and the top 5 most commonly consumed leafy vegetables (see above) in our study, showed that none were consistently more or less nutrient dense across multiple nutrients (energy, protein, RAE, thiamine, iron, calcium, zinc) (data not shown). In this context, increasing diversity would not likely alter the nutrient density of the diet, and thus could not improve nutrient intake unrelated to quantity consumed. In other studies there is a progressive increase in the percent of individuals using a given food group as the DDS score increases (what is called a Guttmann scale). This was not the case in our study (Table 3.2), where there was a strong negative relationship between the use of fish (i.e. *dagaa*) and the use of other animal source foods, vegetables and legumes (those who use fish are less likely to use other side dishes) as well as between vegetable and legume use (those who use legumes are less likely to use vegetables) (data not shown).

In cases where a few foods account for much of the dietary intake (of specific nutrients or across nutrients) quantity of food can easily be a stronger determinant of nutrient intake than quality or diversity. This does not preclude the possibility that dietary diversity may still be a marker of diet quality, but rather that it accounts for a small amount of the variation in nutrient intake and adequacy. Our finding that the strongest determinants of variation in the regression model of MAR were quantities of vegetables, fish, and animal source foods provides evidence that, in this context, quantity is a stronger determinant of nutrient intake and adequacy than dietary diversity.

3.5.3 Length of Study Period, Tools and Score Lengths

In this study, the 1 day measures, based on a 24 hour recall, were more strongly correlated with nutrient intake and adequacy than the 7 day measures, based on a food use questionnaire. In this study it is impossible to differentiate the effect of different assessment tools from the impact of study period.

A study of 550 women in Burkina Faso found that the mean DDS (based on 9 groups) increased as the study period increased from 1 to 3 days (Mean DDS 1 day = 3.5, 2 day = 4.2, and 3 days = 4.4) (Savy et al. 2007). The 5% increase in DDS between day 2 and 3, versus the 20% increase between day 1 and 2 suggested that, in their study, DDS had already begun to plateau between day 1 and 2. Another recent study showed that 3 days of dietary diversity assessment is enough to predict dietary diversity over 14 days, although the authors also suggest that dietary diversity can continue to increase for two weeks or more, they found that 1 day of diversity was 22% of that achieved by 14 days, whereas after 7 days 73% of the 14 day diversity was achieved (Falciglia et al. 2009). In our study, it is possible that the lack of relationship between the 7 day scores and MAR and nutrient intakes (the the lack of relationship between the 7 day DDS_6 and energy intake) was at least in part due to the fact that the variation in the scores had begun to plateau well before 7 days.

Only one study has assessed the impact of different assessment tolls on the associations between dietary diversity and nutrient intake and adequacy. Using similar tools to those used in our study (a simple qualitative list-based questionnaires and quantitative 24 hour recall of the same 3-day duration), a study in Burkina Faso showed that, food group diversity assessed using the qualitative method was able to predict MAR almost as well as diversity determined from 24 hour recalls (Martin-Prevel et al. 2010).

Results of a study from Madagascar suggested that reducing the number of groups used to calculate the DDS improves associations with nutrient adequacy (Moursi et al. 2008). Conversely, Arimond and colleagues (2010) found that DDS scores using 6, 9, 13 or 21 food groups were all significantly correlated with nutrient adequacy in women, but that the associations were somewhat stronger for the scores with more groups. We found little difference in the relationships between the DDS_6 and DDS_{14} scores and nutrient intake and adequacy. The both the 1 day DDS_6 and DDS_{14} were positively correlated with energy intake, MAR and the intake of most nutrients (although not exactly the same set of nutrients). Similarly, neither the 7 day DDS_6 nor the DDS_{14} were associated with MAR, although the 7 day DDS_{14} was correlated with energy intake while the DDS_6 was not. Our results suggest that recommendations to adapt DDS scores to local cultural contexts and food systems (as done herein) can be undertaken without risk of significant changes to research outcomes (Hatløy et al. 1998, Kennedy et al. 2011).

3.5.4 Dietary Diversity, Infection and Stunting

Unlike measures of dietary intake, anthropometric measures of nutrition represent a longer term measure of nutritional status and are heavily influenced by infection and other environmental factors. In our study the 7 day DDS_6 was the only diversity score associated with stunting in children (HAZ). This may be because this score was best able to identify children with the most limited habitual diet (i.e. lacked animal source foods or legumes). Alternatively this association could be a result of colinaereity with other determinants of stunting, as is suggested by the fact that the relationship does not remain significant after controlling for confounders in a regression model. Hatløy et al. (2000) attribute lack of a relationship between stunting and dietary diversity in Mali in part to the fact that there are may be factors other than the composition of the diet that can have a stronger influence on anthropometric measures of nutrition. Previous studies in the East Usambaras found very high rates of parasitic infection: <1% of children not infected and 95% of children with 2 or more varieties of parasite (Beasley et al. 2000). The area also has high rates of malaria infection. In this context, it is possible that infection plays an greater role in stunting than dietary intake, as is supported by the finding that source of drinking water was the variable most strongly associated with stunting. The role of infection and clean drinking water for children's growth and nutrition is increasingly recognized (Koski and Scott 2001, Semba and Bloem 2008). Zinc's role in infection may also help to explain why it was the only micronutrient associated with growth (Scott and Koski 2000, Walker and Black 2004). Access to tapped drinking water is related to political history in the area; during the 1970's the national government engaged in rural development projects including provision of clean drinking water, but distribution was uneven.

Most stunting occurs prior to 2 years of age; catch-up growth after 2 years is possible but is not always achieved (de Onis and Blössner 2003, Shrimpton et al. 2001). Lack of a relationship between stunting (HAZ) and child's age in children 2 and 5 years old may indicate that in our study population, most stunting occurred before 2 years of age and was not followed by significant catch-up growth (which would have been indicated by decreasing rates of stunting with increasing age). If most stunting occurred before 2 years of age, it is not surprising that associations between current dietary diversity and stunting were weak. Drinking water may have been one of the few measures of health and environment that was long-term enough to have been relevant to stunting which happened months or years before the study period.

3.5.5 Limitations of both Dietary Diversity and Nutrient Intake Tools

The lack of relationships found in this study could equally be due to error in the measurement of nutrient intake or error in the measurement of dietary diversity. Problems with existing dietary assessment methodologies have been a major driving factor behind the increased interest in dietary diversity. With so many sources of error, 24 hour recalls are a less than ideal "golden standard" against which to compare dietary diversity. Error in nutrient intake data can come from memory lapse, incorrect portion size estimation, incomplete or incorrect nutrient composition information, among others (Gibson 2005). In East African children, other studies have shown that mothers often fail to include fruit, snacks and foods eaten out of the home in dietary recalls (Fleuret 1979a, Gewa et al. 2007). Portion size estimation is also highly susceptible to error as mothers are often not highly numerate and struggle to estimate their child's intake from a shared bowl (Hatløy et al. 1998). The many sources of error in nutrient composition data noted in the introduction are a particular problem in settings such as the East Usambaras, where few of the food consumed have reliable nutrient composition data, let alone data needed to adjust for bioavailability and losses due to cooking. The nutrient intake data from this study are thus expected to have a high degree of error (random error). In this study we used a MAR, as opposed to a MPA (mean probability of adequacy) which has also been used as a score of over overall diet quality against which dietary diversity is tested. The MAR was used because it has been suggested that a probability method is only valid for use to assess population adequacy (and not individual adequacy) (Institute of Medicine 2000). Because both the MAR and the MPA compare an individual's intake to a fixed DRI we do not expect different results if the MPA had been used instead to the MAR.

3.6 Conclusion

One important quality of dietary diversity, often seen but not highlighted in studies, is the fact that it is consistently associated with nutrient adequacies averaged over a number of nutrients (MAR) even when it is not associated with all individual nutrients. Other studies have shown similar findings (Sawadogo et al. 2006), suggesting that dietary diversity may act to improve diet and nutrition in a synergistic manner.

This paper highlights a number of issues relevant to the validation, assessment and use of dietary diversity scores including: number of food groups used in DDS scores, cases when a few foods accounting for a large portion on nutrient intake, comparable nutrient density between common and less commonly consumed foods, and high levels of error in nutrient intake data assessed by 24 hour recall.

Hatløy et al. (1998) noted that breast milk is the only known food which can provided a balanced diet: all other foods must be eaten in combination. The assumption that dietary diversity helps to ensure good nutrition is based on strong theoretical foundations (Gibson and Hotz 2001, Johns and Sthapit 2004); however, despite significant gains in recent years, sound empirical support remains limited. The results of this paper found that that 5 out of 6 dietary diversity scores were positively associated with energy intake and overall food intake. All 3 of the 1 day scores (FVS, DDS_6 and DDS_{14}) were positively correlated with overall dietary adequacy (MAR).These results suggest that single day dietary diversity scores are feasible indicators of diet quality and nutrient intake. Dietary diversity data is also substantially easier to collect and analyze and additionally provides a picture of what foods are consumed in communities and which not; providing information on what foods might be promoted to improve dietary intake.

Preface to Chapter 4 (Manuscript 2)

This manuscript contains a small portion of a larger body of qualitative research done during the research project. It provides important emic (an anthropological term denoting the perspective of the people and culture being studied) perspectives on nutrition and diet, the role of dietary diversity in health and nutrition and the links between nutrition and the environment (specifically agriculture). The inclusion of this qualitative work has played an important role in the overall shape of the research project and dissertation and has greatly enhanced the insight gained from the quantitative research. This qualitative work provided insight into drivers and mediators of relationships between nutrition and biodiversity that would otherwise have been overlooked; it necessitated an examination of the theoretical framework of the entire dissertation, which has provided for unique new perspectives; and, has been a key driver of the examination of epistemology (Chapter 7, Conclusions) yielding novel arguments for what is necessary to achieve a truly transdisciplinary approach to research that is promoted by many systems approaches to human and environmental health.

This manuscript builds on the previous one (Chapter 3); it describes local people’s perspectives on the importance of dietary diversity for human health and nutrition. The importance of dietary diversity for overall dietary intake (and appetite) is a common theme shared by the first two manuscripts. Together they lay the groundwork for the second pair of manuscripts in the dissertation which examine relationships between dietary diversity, other markers of nutrition and biodiversity.

Chapter 4 (Manuscript 2)

The importance of agricultural biodiversity for dietary diversity: Local knowledge from the East Usambara Mountains, Tanzania

Bronwen Powell, Timothy Johns

4.1 Abstract

Diet and nutrition-related behaviour is affected by complex factors including: biology, environment, previous experiences with food, knowledge, and social and cultural determinants and context. The assumption that change in knowledge will lead to change in behaviour is increasingly questioned; achieving behaviour change needed for public health nutrition interventions will require a better understanding of how various factors mediate the relationship between knowledge and behaviour.

This paper applies anthropological theory and approaches in seeking broader understanding of knowledge within the field of nutrition. Ethnographic data from the East Usambara Mountains in north-eastern Tanzania are presented as a case study of local knowledge of food and nutrition. The region has high cultural diversity, yet community members share cohesive ideas about nutrition and health. Concepts including *kujenga mawili* (to build the body), *kuongeza damu* (to enhance / increase blood) and the importance of dietary diversification for appetite, are used to highlight how anthropological approaches can provide important insight into how local nutrition knowledge is formed and acquired. Overlap between local and scientific understandings of these food and nutrition concepts are explored, with a focus on dietary diversity.

4.2 Introduction

> "My grandfather used to advise me that if you want to have a good life, a good life is not to have money, it is about food which ensures that you will not be troubled... If you want a good diet you must have foods for changing your diet."
> **Ramadhani Juma,** successful farmer and small business man, community leader, Tongwe village

4.2.1 Nutrition Interventions and Difficulties with Behaviour Change

The focus of nutrition efforts in developing countries has shifted away from protein-energy malnutrition to micronutrient malnutrition (Allen 2003, Underwood and Smitasiri 1999), and increasingly the double burden of disease created by the nutrition transition (Popkin 2004). In developing countries, recent efforts to reduce micronutrient deficiency have had mixed success (Boy et al. 2009). Compared to supplementation and fortification, disease control and food-based strategies provide safe, holistic, and highly sustainable solutions.

Food-based or dietary modification strategies, including modifications in food production, storage, processing, consumption, and dietary diversification, have the potential to be self-sustaining and even self-perpetuating as beneficial changes are spread from one person or community to the next. Importantly, they are ideal for addressing multiple micronutrient deficiencies simultaneously (Boy et al. 2009, Tontisirin et al. 2002). Moreover, they are well-suited to address complex situations, such as the concurrence of over- and undernutrition within the same communities (and even households) and are often more culturally appropriate. Dietary diversification features increasingly in food-based dietary strategies and is purported to be one of the best solutions for overcoming multiple micronutrient deficiencies simultaneously (Gibson and Hotz 2001, Tontisirin et al. 2002).

Food-based interventions require complex, system wide changes in production and consumption, often achieved through education (Berti et al. 2004, Tontisirin et al. 2002). However, to be effective, interventions must result in behaviour change. There is a growing understanding and recognition of the importance of cultural, social and psychological factors play in mediating dietary behaviour, and their role in nutrition interventions (Baranowski et al. 1999). Contento et al. (2002) note that human dietary behaviour is influenced by: (a) biologically determined behavioural predisposition; (b) experience with food (e.g. physiological and social conditioning); (c) personal factors (including: beliefs, attitudes, knowledge and skills, etc.), and (d) environmental factors (availability, accessibility, cultural practices, etc.). Kuhnlein and Receveur (1996) similarly present a number of ecological and cultural factors that mediate dietary choices. Krumeich et al. (2001) note that health decisions are often shaped by factors, such as social and cultural context, that are beyond the control of the individual and that healthful behaviour change is not simply a matter of convincing people to act in a more rational manner.

The capacity of an education program to affect change in nutrition is dependent on the quality of the education program, the acceptability of the proposed changes, and existing resources, among other things (Hotz and Gibson 2005). Many innovative strategies to address these issues have been developed and are improving interventions. It is increasingly recognized that interventions which include the community in a truly participatory manner (including the inclusion and empowerment of women) are both more effective and more sustainable (Allen and Gillespie 2001, Tontisirin et al. 2002, Underwood and Smitasiri 1999). A study from Kenya showing that girls learn better from peers or perceived experts (Feldman 1983); studies from Senegal and Malawi showing the importance of targeting grandmothers, rather than mothers alone, in nutrition education programs (Aubel et al. 2004, Kerr et al. 2008); and, the successful application of social marketing to nutrition education (Smitasiri and Chotiboriboon 2003), emphasize the potential of innovation in program design (Contento et al. 2002).

As noted above, “new ideas, services, or products can best be introduced if the intended beneficiaries see them as fulfilling their own aspirations and wellbeing” (Allen and Gillespie 2001). Because of this, as nutritionists we should make efforts to carefully and reflexively examine our approaches to knowledge, knowledge transmission and education in order to strengthen the links between knowledge/education and behaviour change. Worsley (2002) noted the "need to pay greater attention to the development of children's and adults' knowledge frameworks (schema building)" and for "more research into the ways people learn and use food-related knowledge".

In order to broaden our understanding of nutrition knowledge, this paper examines anthropological approaches to knowledge and uses local ('traditional') nutrition knowledge from the East Usambara Mountains as a case study to examine how anthropological approaches and theories of knowledge could be applied to improve nutrition interventions and education. The ethnographic data presented focus on one concept from the local knowledge system: dietary diversity – including local people's perceptions about factors that mediate their ability to achieve and maintain a diverse diet. The paper concludes by highlighting where local knowledge and scientific knowledge in nutrition overlap and where there is greater contrast between the two, as well as the implications this might have for nutrition education in Tanzania and beyond.

4.2.2 Anthropological Perspective on Knowledge

As an example of knowledge, Barth (2002) gives "The content of the Baktaman [of Papua New Guinea] ritual". Knowledge is defined by the Oxford dictionary as "facts, information, and skills acquired through experience or education; the theoretical or practical understanding of a subject"; however, the concept of knowledge is used and applied differently from one discipline to another. Anthropology yields some of the most holistic, as well as some of the most diverse interpretations. In his review 'An Anthropology of Knowledge' Barth (2002) noted: "We all live lives full of raw and unexpected events, and we can grasp them only if we can interpret them—cast them in terms of our knowledge". Anthropologists, ardently reflexive, take a humble approach to knowledge: "Keesing (91) has suggested that we know virtually nothing about how to represent the knowledge we possess and act upon as social creatures" (Crick 1982)(p. 288).

An important aspect of the anthropological approach to knowledge is the emphasis on its dynamic nature and focus on transmission (what many call 'learning').

Anthropologists insist that knowledge, including 'traditional knowledge' is fluid and transient and seek to understanding how knowledge changes and the factors that mediate that process (Ellen 2000, Ellen 2010).

Those interested in knowledge propose "knowledge as a major modality of culture" (Barth 2002) and define the concept of culture as "a process of acquainting and displaying knowledge" (Crick 1982). When culture is defined as 'shared knowledge' (D'Andrade 1987, Reyes-Garcia et al. 2004, Romney et al. 1996), the topic of knowledge transmission and change extends to the core questions of anthropology: How is culture generated, shaped and transmitted? Some draw, albeit controversial, parallels between biological evolution and cultural evolution (Cavalli-Sforza 1986, Cavalli-Sforza and Feldman 1981). Knowledge, like culture, can be viewed as adaptive: "It seems likely that the range of diversity in individual versions of the 'common' culture is not simply a social imperfection, but an adaptive necessity: a crucial resource that can be drawn on and selected from in cultural change" (Keesing 1974), p.88). Likewise, Ellen characterizes culture as an adaptive mechanism that is "rapid, focused and flexible....an engine for the production of diversity more complex than anything found in biological systems" (Ellen 2010). These approaches to knowledge would suggest that local or traditional knowledge is highly functional, ensuring individual and community well-being.

The presentation of knowledge as a core part of culture, and culture as evolving and adaptive, highlights another aspect of anthropological approaches to knowledge: intra-cultural (or inter-individual) variation. "When we talk about systems of cultural knowledge, we have to ask whose knowledge this really represents. Informant variability is an important issue here... We cannot eliminate all the differences and call an ironed-out system 'cultural knowledge'" (Crick 1982) (p. 295). 'Consensus' is discussed as a measure of how much similarity there is in the knowledge (and culture) of members of the same group (it is also used to refer to the most commonly given response by members of a group). Consensus is often used to estimate 'culturally correct' answers in order to assess (and quantify) individual competency (Reyes-Garcia et al. 2004). It is, however, common to find situations when there is limited consensus (D'Andrade 1987);

sometimes there are multiple ‘correct’ answers - other times there is no ‘correct’ answer. Anthropologists pay close attention to how knowledge is validated. Barth (2002) points out that each knowledge system has its own criteria for validity. For example, the ritual knowledge of the Baktaman is validated by “having been received from now deceased ancestors under the constraints of secrecy” (Barth 2002).

Within every knowledge system there are different domains, or categories of knowledge. The number and content of these categories of knowledge vary between individuals and cultures. The implications of unreflective categorization of knowledge has been eloquently pointed out by Etkin and others who demonstrate the error made when consumed items are classified as either ‘food’ or ‘medicine’, without allowing for the common occurrence in which an item is both (Etkin 1982, Herforth 2010b, Jeambey et al. 2009). While discussing categories of knowledge, it is worth noting a differentiation made by many nutritionists and psychologists between declarative and procedural knowledge. Declarative knowledge is defined as knowledge of ‘what is’ or awareness of things, and, procedural knowledge is defined as knowledge about how to do things (Worsley 2002). In anthropology the latter is often referred to as ‘enskillment’ by Ingold and others (Marchand 2010). The importance of procedural knowledge to the field of nutrition and nutrition education is increasingly apparent (Worsley 2002).

As noted above, a central focus of anthropological treatment of knowledge is the factors that mediate the validation, generation, evolution and transmission. Knowledge (and culture) gains its adaptive nature because it is a resource; knowledge gives power and those in authority positions have the ability to validate knowledge (Barth 2002). For example the role of power in knowledge generation has been explored in relation to: the promotion and sale of infant formula and breast-milk substitutes to populations in developing countries with limited access to clean drinking water (Maher 1992, Van Esterik 1996); the dairy industry’s involvement in setting of dietary recommendations (and food groups) (Etkin 2009); and, expert consultations around the definitions of concepts such as ‘dietary fibre’ (Lee 2011).

Taking an anthropological approach to nutrition knowledge helps to move away from traditional health behaviour paradigms which traditionally emphasize individual determinates of health behaviour (and can thus lead to positing of responsibility for health and disease entirely on the individual), towards greater attention to the embeddedness of human behaviour in cultural context and social and political structures (Krumeich et al. 2001).

4.2.3 Applying an Anthropological Approaches in Nutrition

An examination of local knowledge within the framework of an anthropological perspective on knowledge has much to offer public health nutrition and nutrition education. There are multiple forms of 'culturally correct' knowledge; understanding this ensures that we seek out and identify differing views and differing forms of local knowledge. This can have potential benefits for nutrition education, if one form of existing local knowledge is more aligned with scientific ideas or health positive behaviour (similar to the positive deviance approach). Acknowledging that knowledge is dynamic and adaptive, and that whether or not new information is integrated into existing knowledge systems depends on a myriad of factors within complex social and cultural contexts, will ensure that nutrition messages and interventions are designed with the aim of having the highest cohesion with existing knowledge systems and being seen as useful to the target audience, leading to sustained behaviour change.

Applying these lessons requires a detailed examination of local nutritional knowledge, or 'ethnonutrition'. If we accept the argument that knowledge can be validated many ways (i.e. that the scientific method by which we validate our knowledge is not the only way of determining 'truth'), and that other ways of knowing are not inferior to our own, then we can create a respectful relationship with the communities in which we work and can gain a better understanding of their knowledge. Below, we present a case study of ethnonutrition from the East Usambara Mountains, followed by an exploration of how the above ideas apply to this case study.

4.3 Methodology

4.3.1 Study site: The East Usambara Mountains, Tanzania

The East Usambara Mountains provide an interesting setting for the study of local knowledge in Tanzania. The East Usambara Mountains lie 40 kilometres inland from the port city of Tanga. Human population density in the region is now 61.3 people per square kilometre, with an annual growth rate of 2.4% (Tanzania 2002). The mountains are the home of the Shambaa, Bondei and Zigua tribes, but the area is now very culturally diverse due to immigration to the area for wage labour opportunities in the tea and timber industries (Feierman 1974, Willis 1992). The political history of Tanzania has ensured that more than 90% of Tanzanians speak Kiswahili, the national language. In addition to being the *lingua franca*, Kiswahili is increasingly used in the home, especially in culturally diverse areas such as the East Usambara Mountains.

Local livelihoods are based on small-scale farming supplemented with cash crops, wage labour, small business and animal husbandry. Local diets in the East Usambaras are based mainly on maize (most commonly *ugali,* maize flour cooked into a hard porridge), cassava, beans and dry fish (such as *dagaa*). Of all of the food recorded in the area during the research 52% of items were purchased, 41% were obtained on farm, 4% were gifts and 3% were obtained in the forest (Powell et al. 2011). Malnutrition, especially micronutrient deficiencies (e.g. vitamin A and iron), remain a problems in the East Usambaras and in Tanzania in general. The area also has extremely high rates of parasite infection (Beasley et al. 2000). Quantitative research conducted as part of the same project found that 39.5% of 2 to 5 year old children in the study villages were stunted (HAZ< -2SD). Stunting (which is a measure of growth failure) was most associated with source of drinking water. Dietary diversity (7 day FVS and DDS_{14}; 1 day FVS, DDS_6 and DDS_{14}) was correlated with intake energy and 1 day dietary diversity scores (DDS_6, DDS_{14} and FVS) were correlated with intake of a most nutrients tested (Chapter 3).

4.3.2 Data Collection and Analysis

Core ethnographic methodologies of participant observation and key informant interviews were used in data collection (Bernard 2002), supplemented with data obtained from a semi-quantitative questionnaire given to ~N=400 men and women. Qualitative data collection took place between Sept 2008 and Nov 2009, primarily in 15 case study households in six research villages (Kiwanda, Tongwe, Bombani, Kwatango, Shambangeda and Misalai) (see (Powell et al. 2011) for more detailed description). Data collection was framed within a participatory and EcoHealth framework (akin to Ecological Anthropology (see Abel and Stepp 2003, Ellen 1982, Orlove 1980) aimed at understanding local people's perceptions of their diets, the importance of agriculture and wild resources in their diets and the social and cultural variables that mediate their ability to maintain their preferred diet. The EcoHealth framework and a systems approach to nutrition was used to address the research questions in a holistic manner and to ensure that important social and cultural factors were identified (Lebel 2003).

Interviews were conducted in Kiswahili by the primary researcher, with support from a translator. Research was approved by at the local, district and national government levels, and prior free and informed consent was obtained from all participants (or their parents in the case of children). While all households which participated in the larger dietary / nutrition survey were offered a small gift for their time (a full day was spent in each household in total), no additional payment was offered to the 15 case study households that participated in the qualitative work. All informants requested that they be identified by name when their stories and words were published.

Interviews were transcribed and then translated from Kiswahili to English (blinded to in-text English). Analysis was conducted following Bernard (2002), the standard in ethnographic research. We acknowledge the subjective nature of this analysis and the possibility that other themes would be apparent to other researchers, and that the relative importance of themes could seem quite different to others.

4.4 Local Knowledge of Food and Nutrition in the East Usambaras

Much of the nutritional knowledge held by local people in the East Usambara Mountains is relatively cohesive. For example, there seems to be strong consensus on basic food classification, perhaps because such classifications are tied to language and Kiswahili is almost universally spoken. The Kiswahili word for 'food' *chakula* is also used to refer more specifically to carbohydrate staples, indicating their cultural importance. The complement of *chakula* is *mboga*, another word with multiple meanings, referring to any side dish or vegetables (mostly leafy) specifically. *Mchuzi*, meaning sauce, is also used to describe side dishes, especially when they could be of either vegetable or animal origin. Meat has a special place in the diet, and is not the prototypical or most salient side dish, despite, or perhaps because of the social and cultural importance attached to it (also see, (Feierman 1974). This classification scheme, in which *mlo (*diet or meals) is made up of *chakula* and a side dish, is found throughout much of Tanzania and is common across sub-Saharan Africa (Fleuret 1979b, Fleuret and Fleuret 1980, Ohna 2007). Fleuret's (1979a) finding that fruits are not considered a true part of the diet, that they are on the margins of the culturally constructed category of 'food', was also evident in our (more recent) research in the East Usambara Mountains. Feierman (1974) wrote that the Shambaa (the main ethnic group in the area then and today) concept of a 'complete diet' included both a starchy staple (from agricultural land) and sauce, or side dish (often from wild sources). He noted that: Shambaa people saw consumption of a staple alone as 'unpleasant' but the consumption of a sauce with no staple as 'famine'.

Our data provide insight into the perceived roles of foods in health and nutrition. People were asked to name the benefit to health or nutrition provided by different foods, including: mango, *ugali* (local starchy staple made from maize meal), *tikini* (*Asystasia* spp., a wild vegetable), groundnuts, salt, cassava, *mchicha* (*Amaranthus* spp.), cooking bananas, pineapple, African eggplant (*Solanum macrocapon*), *kimguwina* (a wild fruit, *Sorindeia madagascariensis*) and green coconuts. There was a consistent set of responses commonly given to these questions, including: *wanga* (carbohydrate), *nguvu* (strength), *ladha / utamu* (flavour / taste), *joto* (heat [in the body, not the mouth]) and a number of other more scientific nutritional concepts such as *mafuta* (fat), *sukari* (sugar), *protini* (protein), *vitamini* (vitamins), *madini* (minerals) (see below for more detail). Also included were a number of physiological functions such as: *kujenga mwili* (to build the body), *kuongeza damu* (to increase blood), and *kushibisha* (to fill you up).

Wanga means starch or carbohydrate, but it also implies the imparting of energy. The idea that it is required for energy is reflected in the fact that local people also say that mangos give "*wanga wa macho"* (energy for the eyes). W*anga* was the response given by 6.8 % of informants when asked about the health benefit of ground nuts (despite the fact that fat / oil was given as the benefit from groundnuts by 53% of informants).

Nguvu or 'strength' is associated with muscles, ability to lift heavy weights, *et cetera*. It is similar to the concept of *wanga* and energy as is seen by the fact that *nguvu* was given as 76.1% of responses about the benefits of *ugali*, while *wanga* was the next most common responses. Similarly for cassava, *wanga* was the most common response given (69.3%), followed by *nguvu* (13.8%). It seems that the conceptualization is that *wanga* is the physical 'starch' and *nguvu* and the resulting benefit.

Ladha or 'taste / flavour' is reported to be a benefit of many different foods. Although, it seems to be given as a benefit of foods that have no other benefit, taste is seen as having an important contribution to health because of its role in appetite generation. Although there was low consensus on the benefits of African eggplant, *ladha* was the most common benefit reported (31.9% of responses). While fat / oil (50% of responses) was the most commonly given benefit from coconut milk, *ladha* was the second most commonly reported benefit (16.5%), followed by *joto* (11.9%). From this it seems that coconut milk may be perceived as having multiple benefits or that there is significant intra-cultural variation in the knowledge of its benefits.

Joto literally translated to 'hot' or 'heat' refers to heat in the body (it is also a term used for fever). *Joto* was reported as a benefit of ripe coconut (12% of responses) and salt (the 4th most common response at 10.7%). Hot / cold classifications are common in local nutrition and health knowledge systems around the world. A fact that makes it surprising that it was so rare seen in our work in the East Usambara Mountains, as well as sub-Saharan Africa (the concept was rarely encountered in qualitative work, nor is any literature known) (Messer 1981, also see Boster and Weller 1990, Manderson 1987, Pool 1987).

Kuongeza damu translates to 'to increase / add blood' and is, somewhat but not entirely, similar to the medical concept of anaemia (*upungufu wa damu* in Kiswahili). From our data it is not clear if the 'increase in blood' refers to volume or quality. Many fruits and vegetables were seen as making important contributions to *kuongeza damu;* in fact, it was the most common perceived health benefit of leafy vegetables and fruits, followed by 'vision'. For example, *kuongeza damu* was the reported health benefit of *mchicha* (86.7% of responses), *tikini* (55.3%), *kimguwina* (60.6%) and mangos (59.8%). When asked about which food were best for increasing blood, vegetables in general and more specifically *mchicha* and *tembele* (sweet potato leaves, *Ipomoea batatus*), were the most common answer (one or more of the above was given by 79.4% of informants). A few informants emphasized that *mboga za asilia* 'traditional vegetables' were best. Fruit was the second most common answer (given by 35.1% of informants). Other foods listed as good for 'increasing the blood' included honey (33%), beans (25.1%), milk (19.6%), eggs (6.8%) and less commonly other animal source foods.

Kujenga mwili meaning 'to build the body' is similar to, but not completely aligned with, biomedical concepts of growth (it can refer to children's growth, as well as increased weight in adults, different from getting fat, as in increased lean body mass). The most commonly listed foods important for 'building the body' included protein rich foods: milk (51.2% of informants), beans (32.9%), eggs (25.3%), meat (25.3%), fish (11.1%); and a number of starchy staple foods including: *uji* (porridge) (35.7%) as well as *ugali* (18.5%), boiled bananas (8.5%) and rice (6.8%). Finally, leafy vegetables (30.1%) and fruit (12.2%) were also listed as important. Although overall *uji* was listed less often than milk, it was listed first (as the most important food) more often (25.5% of informants) than milk (20.9%). *Uji* is a 'children's food', often given to them instead of boiled tuber or bananas consumed by adults with tea in the mornings and evenings (with potentially detrimental results for nutrition).

Vitamin (vitamin), *protini* (protein) and *virutubisho* (important element / nutrient) were other common concepts listed as health benefits of various foods. Unlike the above concepts, these were probably adopted from Western / scientific knowledge systems (that the English word is used for *vitamin* and *protini* provides linguistic evidence of this). However, it seems that the transmission of these concepts has not been exact; local conceptualization lack consensus and is often not highly consistent with a scientific ones. Both knowledge systems hold that vitamins are present in all food, but in the local knowledge system the distinction between vitamin and the macronutrients (carbohydrate, protein and fat) is unclear and seems to vary between informants. This is possibly due to these concepts having not been readily or completely integrated into the local knowledge system. During the questionnaire, *vitamin* seemed to be given after the respondent unsuccessfully struggled to think of a health or nutrition benefit of a food, and believing that every food has some benefit gave *vitamin* in lieu of "I don't know". The response *vitamin* was given as an answer more frequently when the foreign researcher was present in the interview, suggesting that it was used when local people tried to give an answer aligned with what they perceive to be a scientific knowledge system rather than their own. Only for one food (*ngogwe*, African eggplant) was *vitamin* the most common answer (43.1% or responses); however, African eggplant was the food with the lowest consensus. Probably some of these responses fit within a genuine concrete concept, although people seem to have a very vague conceptualization of what *vitamin* actually represents.

Unlike *vitamin*, *madini* (minerals, as in the same word used for mining) and *virutubisho* (important element) were not given as health benefits of foods when informants were unable to retrieve what they perceived to be a correct answer; one of the few time *madini* was seen was as a reported benefit of salt (26% of responses) (along with bones (35.6%) and taste / flavour (18.7%)).

Although some foods clearly have important cultural functions (Feierman 1974, Powell et al. 2010) and are seen as having higher health and nutritional value than others, many local people hold a belief akin to "every food has its own benefit / value". This concept can be seen in response to questions on the nutrition or health benefit of different foods: "I don't know" was given in response to the questions: what is the health or nutritional value of this food, on average 1.92% of the time; whereas "there is no benefit" was given only 0.9% of the time (a benefit was listed the rest of the time).

Informants were also asked which foods people should eat more of and less of to improve their nutrition. Foods which informants recommended increasing included: beans, leafy vegetables (such as *mchicha*), *ugali*, cooked banana, rice, fish and fruit; foods recommended to decrease included: *bada* (*ugali* made from cassava), cassava, oil / fat (or things cooked in too much fat) and alcohol. To improve nutrition, a few informants alternatively recommended: eating three times a day, *mlo wa kamili* (or 'an exact / complete diet'), and increased diversity in the diet. It is interesting that the cultural importance of and preference for meat is not apparent in these findings and it must be noted that the data from questionnaires cannot highlight all the nuanced details and variations of the local knowledge system of food, nutrition and health.

4.5 Local knowledge on Dietary Diversity in the East Usambaras

Informants seemed very comfortable with the concept of dietary diversity: "using different types of food" or "changing the diet / foods". Although one of the focus topics of qualitative research, it frequently came up spontaneously. This was true even among informants who had had very little contact with the research and thus had not had exposure to our research questions and topics. For example, in group discussions on diet, nutrition and well-being in the communities, in which village leaders were asked to rank the households of the village in terms of diet quality, nutrition and health, dietary diversity came across as an important aspect of how people assessed the diets and health of their colleagues; arguments that a household belonged in a higher or lower group because they had higher or lower dietary diversity were heard in multiple villages.

The high degree of consensus surrounding the concept of dietary diversity between various informants suggested that this concept was a salient part of local nutrition knowledge. There was a very strong consensus that dietary diversity is important because it maintains and enhances appetite.

> "The benefit [of changing your diet] is that food should not bore you so that you don't lose your appetite for eating. Because with one food, many people lose their appetite. That's why human beings need to change food. Children get an appetite if today you have cooked cassava *ugali*, tomorrow let it be cassava *ugali* with good *mlenda* (*Corchorus* spp.). So tomorrow if you change to *ugali* [of maize] and beans it will be better than eating *ugali* and beans [for many days in a row]. [If you do not change] you will discover the children saying that they are not going to eat, they go to play outside yet they are hungry." **Beatrice Akida**, single mother, successful farmer, kindergarten teacher, community leader, Tongwe village

The role of a varied diet in improved appetite applied for various periods of time: from meal to meal, day to day and season to season. The importance of dietary diversity pertained not only to the diet in general, but to specific food groups as well. Moreover it seemed to hold true across all food groups, including carbohydrate staples, side dishes and fruit. The importance of diversity for appetite and adequate intake also applied to varieties of a single crop – an indication that local people perceive dietary diversity as one of the benefits of agricultural diversity and crop diversity.

> "If you eat *dagaa* (small dried freshwater fish) today, tomorrow *dagaa*, yes you eat, but you are tired, you think: 'Now this is how it will be every day? I eat *dagaa*?'....it will become boring / tiresome. You won't get any pleasure [from eating], you won't have any appetite. That is why you need to frequently change.

> You eat *mchicha* (*Amaranthus* spp.) today, tomorrow you eat *kushone ngou* (*Bidens pilosa*), the day after maybe you eat *mchunga* (*Launaea cornuta*), for those who can get it. That is how you get an appetite. But if you eat only one vegetable (or side dish) every day and *ugali* as your staple food every day, if you eat like this, only *ugali* and *mchicha* every day, you won't have any appetite to eat. Other times you see, if a mama cooks the same vegetable all the time... [her family] won't eat enough. Because children will eat only a little bit and leave the rest." **Saidi Kombo**, well educated, very successful farmer and community leader, Misalai village

Appetite was overwhelmingly the first, most important and most salient benefit of dietary diversity discussed by local informants. The importance of having different foods in the diet was also linked to the fact that "every food has its own benefit / value".

> "The benefit [of having many different crops / foods] is for children not to suffer, because everything has got its own importance..... Every food crop has got its own value. We eat fruits because every fruit like pineapple helps the blood (*inasaida damu*)." **Mathias Martin**, young, somewhat educated, farmer, Kwatango village

Talk about *vitamins* or nutrients as a benefit of dietary diversity was uncommon (and only occurred with more educated informants). In virtually all interviews the concept that vitamins are one of the benefits of dietary diversity, was secondary to the concept its importance for appetite. For example when we first discussed dietary diversity **Amina Njiku** said: "You get tired of eating one type of food, you get tired", whereas later on she told us: "There are [health] benefits [of eating different types of foods].... The benefits are for the body to have strength, there are types of vitamins they are needed by the body." Other benefits were always listed as a secondary benefit, after appetite. Many informants did not report dietary diversity as having any benefit beyond its value for enhanced appetite and descriptions of additional benefits were vague.

> "For example if you eat *ugali* for a whole week or a month, you need to change....It takes time for you to develop an appetite for something else.... There's no other reason [for changing]. It's just if today you are bored/ tired of

ugali then you substitute with bananas. **Ramadhan Hassani**, poor but successful farmer, Kwatango village

"The benefit of changing the diet... is to build up health. [For example] when you eat all different types of food it build the health of the body." **Tumaini Miringa**, recently immigrated with her husband who was born locally, a small business man

Among the poorest (most disadvantaged) informants there was less discussion of dietary diversity; these informants also struggled to articulate all aspects of their life, diet, nutrition and health. **Tabea and Dominic John** were not cultivating their farm, since it was perceived as too difficult. They were living almost entirely off of the small earnings Tabea made from the kitchen / restaurant attached to their house and very small amounts of cash from Dominic's occasional business enterprises. When asked why she thought her diet and nutrition were of a lower quality that others, **Tabea** answered "I have no explanation for that".

The diversity of the informants who talked about dietary diversity (below) indicated that the concept of dietary diversity transcends gender, age, social and economic status. This would suggest that this concept is a salient part of local nutrition knowledge, and, more importantly, that there is a high degree of consensus between individuals across different groups.

4.6 Perceived Factors Needed to Support Dietary Diversity

The factors affecting people's ability to vary their diet, to achieve and maintain dietary diversity, were also discussed by local people (described in Kiswahili as "*kubadilisha mlo / vyakula*" or "*kukula aina aina ya vyakula mbalimbali*" among others). Informants tended to blur the line between factors affecting dietary diversity and having (enough) food in general. Clearly food security is important to local people, and, as in the scientific literature (Hoddinott and Yisehac 2002), linked to dietary diversity.

Discussion with local informants highlighted numerous factors affecting local people's ability to achieve and maintain a varied diet. The access to agriculture and having a diversity of crops in the field (or agricultural diversity, Brookfield 2002) to improve dietary diversity was a dominant theme. Wealth and available cash was reported to increase dietary diversity directly, as well as indirectly through agriculture. Outside experience and expertise and a large social network were seen by some as important factors which allowed local people to increase their knowledge and agricultural diversity (crop diversity), and thus their dietary diversity. Certain personality traits (such as determination and motivation) were frequently reported as a determinant of individual and household dietary diversity.

Availability in general was reported as a limitation on dietary diversity; some foods simply are not available in some places. Even if one has enough money, if a food item is not available, it cannot contribute to dietary diversity: "But there are those vegetables which you can't get. Foods [and vegetables] are available in your environment, and that's why you can't eat more and more because they are not there" commented **Saidi Kombo**. Season, one important aspect of availability, was reported to have an effect on diet (linked to harvest of different crops). Food from specific food categories, especially fruits and vegetables are reported to be highly affected by seasonality. The impact of seasonality on dietary diversity due to varying availability of foods from the farm is mitigated by purchasing food when less is available on the farm.

> "[The farm provides us with food / fruit for changing the diet] I have avocado, guavas and pineapples, everything is there [in the farm]. There are many guavas, we just pick them, and the children eat them.... They go with their own seasons. There are seasons you will get many fruits, and then there are many seasons when you will get a few fruits. In that season when fruit are scarce you will buy a few, like pineapple that is normally available in the field, when it is not there, before it is ripe [you must buy it] or oranges and bring them home." **Rehema Amiri**, divorcee, farmer and very successful business owner, Shambangeda

> "[Right now our diversity of vegetables] is low because those leafy vegetables are not there.... it is not possible to fulfill even one day or one week, you find that you are using the same vegetable, you did not get another for changing.... If you don't get another one you just eat the one you have. In the dry season... you get vegetables mostly from travelling vendors. There are those who pass by on the

road here... our colleagues who live near rivers, they irrigate. That is why they harvest vegetables there and sell here by vending and we buy. But during the rainy season vegetables grow in all the fields (wild).... They each have their own season of availability." **Rehema Singoti**, young wife of a prosperous farmer and carpenter, Bombani village

Agricultural diversity (and agriculture in general) was one of the most salient factors to local people that affected diet and dietary diversity. Links between dietary diversity and agricultural diversity came out as a clear theme in 13 out of the 15 case study households we worked in. Whether the importance of these links (compared to other determinants of diet and dietary diversity) was an artefact of interviewer bias or not, these are clearly concepts which 'make sense' to local people. Agriculture and agricultural diversity are seen as an important strategy for overcoming seasonal variation and food insecurity / hunger, as well as maintaining dietary diversity on both a short- and a long-term basis. Agricultural diversity seems to be especially important for ensuring diversity of vegetables and fruit.

"[Having many varieties of banana] helps us because if you eat them each variety has a different taste. Also they ripen differently [at different times].... In this way it allows me to have bananas all the time. Each time a different variety. If one variety fails / dies, there is another variety that continues to grow. Also... the time to cook [some varieties] is short, and this is helpful. You can cook quickly, eat quickly. Other [varieties] are a little bit hard and they need a little bit longer." **Benjamin Njuiku**, educated, retired from a career in government and as a tea factory manager, now a successful farmer, Shambangeda

"[Compared to other households] it could be that [our diet is] sometimes better, because, I don't know, here in the village their [other people] side dish is *dagaa* unless you have your own kitchen garden. I have my kitchen garden with *mchicha* (*Amaranthus* spp.)." **Zaina Housseni,** farmer in Tongwe

The few informants (e.g. **Tabea and Dominic John**) who did not link diet and dietary diversity to agriculture and agricultural diversity were among the most disadvantaged of the people we worked with. Their concerns and efforts were focused on small business enterprises which produced small amounts of cash with which they purchase very basic food items.

Wealth was reported as an important determinant of diet and dietary diversity. According to local people in the East Usambaras, wealth affects dietary diversity both directly (through purchasing power) as well as by modifying agricultural diversity. Within the communities, wealthier people could afford to purchase more different types of seeds and other agricultural inputs, could afford to hire help with agricultural labour, and usually had more access to land. Both wealthy and poor informants identified wealth as a factor limiting some local people's access to food and dietary diversity.

Tumaini and Kibua Daudi and **Anna and Ernest Singano** talked about their lack of land tenure affecting their agricultural and crop diversity, food security and dietary diversity. An important aspect of the impact of agriculture and wealth on dietary diversity that frequently came out in discussion was the play between obtaining food by way of agriculture and purchasing and the fact that lack of money could be made up for by successful agricultural endeavours. Wealth gives a household choice; lack of wealth requires the household to balance more activities.

> "[Even if people are poor, if they change their diet they will have better nutrition], one way for poor people is that they get everything in the farm all those things that are eaten in the town come from the farm so why shouldn't I get them when they are in the farm?" **Mathais Martin,** young, somewhat educated, farmer, Kwatango village

As noted above, local people not only draw connections between wealth and high agricultural diversity supporting high dietary diversity, they also identified a lack of wealth and lack of agricultural diversity as decreasing their ability to maintain their dietary diversity. In many of those cases, livelihood diversity was an important factor acting to support dietary diversity in the absence of wealth or agricultural diversity. Certain livelihood activities, such as livestock keeping, came out consistently as beneficial for dietary diversity. **Ramadhani Juma** was an excellent example; his family had excellent dietary diversity, which he attributed to livelihood diversity. He told us how his black pepper harvest gave him a lump sum of earnings once a year, bananas could be sold, but only for a small amount, how he grew maize and beans for home consumption, and how his dairy cows helped him educate his children (pay for school costs). He took occasional work as a mason, as well as tailoring work at holidays, and his wife had a small business selling fried fish. **Rehema Amiri** a single mother, farmer and very successful business owner in Shambangeda also talked about how her "commitment / dedication and efforts in business and agriculture" helped her to "ensure for different [foods]" and her family's well-being and nutrition. Conversely, a lack of livelihood diversity was observed in case study households with some of the lowest dietary diversity. A number of informants noted that those who worked as labourers on the tea estates were significantly disadvantaged, and had very monotonous diets if they didn't have any other livelihood activity. Also, a number of informants noted that households which focus all their agricultural efforts on cash crops were more likely to encounter difficulties maintaining a good diet.

> "If I plant cassava like this one, I do not need to buy it, even beans. You will find them [those who work for the tea company and don't engage in agriculture] drinking tea alone, or tea and boiled banana. And as for cultivated vegetables, I will harvest leafy vegetables and they will eat only *dagaa*." **Anna Ernest,** poor but determined farmer, renting their home from the tea plantation for which her husband works, Shambangeda

However, in a number of cases, livelihood diversity, or at least certain livelihood activities actually acted to decrease diet quality and dietary diversity. In one (**Tabea and Dominic John**), but not the other (**Rehema Amiri**), of the households we worked in where the mother of the home ran a small restaurant and prepared *manadazi* (African doughnut) the diet diversity was quite low. This livelihood activity may have increased the risk of low dietary diversity, as it is very time demanding for the mother, who may then not have as much time to cook other meals, and has less impetus to cook as the family can fill up on *mandazi*. In another household the head of the household was a well known traditional healer. This household had very high intake of chicken, which are brought by patients for sacrifice during treatment. The meat is given the healer as part of the payment for his services. This ready access to chicken meat acted to decrease the consumption of other side dishes (especially vegetables), and thus the dietary diversity of the family.

Some of the effects of gender were clear: reduced work force limits food security, diet in general and dietary diversity. Livelihood diversity, and the positive benefits resulting from livelihood diversity, requires a household to have a large enough work force, something which is often lacking in female headed households.

> "I was married and I separated. Now, I earn my living by *sukuma miwa* (literary means pushing sugar cane, refers to making and selling sugarcane alcohol)... Other households eat better than mine... because my strength is that of only one person, *kwasabu mkono wangu ni mmoja* (because I have one pair of hands, meaning she is a single parent)." **Mary Mathayo,** very disadvantaged single mother in Kiwanda.

However, the role of gender in determining dietary diversity in the East Usambaras is complex; gender often affects other factors which mediate dietary diversity. For example traditional inheritance laws which disadvantage women were seen as limiting agriculture and agricultural diversity. In one household, because the wife, from the area, had married a man from the West Usambara Mountains, she was barred by her brothers from inheriting or even using her family's land after her father's death. In another family, patrilineal land tenure practices limited which crops the wife could plant on her husband's land (especially because she had sons from another marriage). It is important to note the many, many, success stories we encountered of women overcoming gender-based obstacles; in fact, many of the most successful (in terms of diet, dietary diversity and agriculture) households we worked with were run by women. Unlike in other regions of East Africa and the world, we noted little difference between men's and women's (and boy's and girl's) diets.

Dependency ratio is sometimes used to describe the number of working adults relative to the number of dependent members of the household. A number of households we worked in identified large family size as an obstacle affecting diet and dietary diversity. Interestingly, while a large family size increases the demands on the adults in the household and decreases their ability to overcome obstacles which require monetary input, in some cases it seemed to increase dietary diversity (because it is more difficult to get enough of any one type of food to feed more people).

> "One [of my brothers] got ill while in Tanga and died.... So we have continued to live with his sons, who are here together with mine. That is why my family is a little bit bigger." **Ramadhan Hassani.**... "We have problems because our family is very big..... Food is a problem, also sleeping (they have only one bed).... I'm intelligent, I vary those vegetables [more than other households]... because, as you have seen, my family is large. So, all of those vegetables that you have cooked in the afternoon will be finished, and I you're compelled to cook a different type in the evening" **Halima Ramadhani**... "She has a huge task" **Ramadhan Hassani,** poor but successful farmer, Kwatango village

After agriculture, personality (including personal traits or family habits) was one of the most predominant themes in local people's discussion of what determines dietary diversity and nutrition. Interestingly, personality came out particularly when people with better diets / higher dietary diversity tried to explain why other households might not have the same level of diversity. Many different aspects of personality came out as impacting diet and dietary diversity. Some informants simply said that people "don't like to / don't want to" pursue various activities needed to ensure dietary diversity. "Each person has their own thoughts or ideas or plans" was another very common explanation for differences between people. An individual's determination, drive, dedication, effort and motivation were often cited as aspects of personality which can support improved dietary diversity.

> "You can get many types of vegetables, but it all depends on the effort / determination (*juhudi*) of the mother of the house... to struggle to find them. Because there are many mothers who don't want to go to the bush to look for vegetables - They get money and buy *dagaa*. Others who are determined to look for vegetables, [they think]: 'Wait, I will look for that vegetable' and when they

> goes to the farm, they finds it and brings it home. So it helps for the mother of the house to have determination." ***Saidi Kombo....*** "[I am more able / determined than other women] because I really like leafy vegetables." **Amina,** his wife, Misalai village

Other informants linked a person's choices and habits to their family's traditions / heritage; or to their knowledge or ability.

> "I would say [that the reason we use more different types] is that it is the habit in this family; our father didn't like to eat only one variety of vegetable." **Beatrice Akida,** single mom, successful farmer, kindergarten teacher, Tongwe

> "There is a difference in cooking. We have a saying '*Wali mmoja wapishi mbali mbali*' ('rice starts out the same but cooks have different abilities'). Every person has their own knowledge of how to cook a particular vegetable." **Rehema Singoti,** young wife of a prosperous farmer and carpenter, Bombani

A final aspect of personality is the commitment to culturally held food taboos. While in some settings, cultural taboos are universally held and adhered to, in the East Usambara Mountains many food taboos are highly variable from one family to another (others, like taboos against eating snails and monkey meat, are held by the majority of people).

> "We [eat more different types of vegetables in our household compared to others because] we don't have taboos, we just eat... There are other people who do not eat leafy vegetables, especially there are certain different vegetables." **Mathais Martin**, young, somewhat educated, farmer, Kwatango.

Rarely did people say that others lack dietary diversity because they were in some way disadvantaged, suggesting that local people perceive dietary diversity as something all people in their community (rich and poor) can achieve.

4.7 Discussion and Conclusions

4.7.1 Limitations of the Study and Methods

In our study there were potential biases inherent in the methodology. For example, the interview schedule used could have caused some themes to seem more important than others. The fact that the primary investigator (PI) introduced herself as a nutrition researcher could have introduced researcher bias. To a nutrition researcher, informants may have been more likely to give responses which they perceived to align with the scientific knowledge system. The PI attempted to overcome this by maintaining respectful interactions with local people and conducting careful probing. The fact that the researcher was able to elicit a diverse range of responses from local people, including many that were not close to scientific concepts (and was able to do this when Tanzanian members of the team with university degrees in science often were not able to) suggests that this aspect of researcher bias was at least partly overcome in qualitative work. Finally, the cultural practices of minding one's own business made it difficult for many informants to compare themselves (and their diets) to their peers: "*That is where it becomes hard, because in your neighbour's house, you can't know what they eat*" Rehema Singoti, Bombani.

4.7.2 Lessons for Nutrition Intervention in the East Usambaras and beyond

The qualitative case study approach to nutrition knowledge use herein has achieved a number of findings that could have easily been overlooked by other approaches. One example is the role of personality in determining / mediating diet and dietary diversity.

Different forms of knowledge (different answers to the same question) can represent either; varying levels of knowledge between individuals or variation in knowledge (more than one culturally correct answer) (Crick 1982, D'Andrade 1987, Reyes-Garcia et al. 2004). Different culturally correct answer can be the outcome of differing integration of novel knowledge into existing knowledge systems. In this light, the lack of consensus around vitamins could indicate poor transmission of the knowledge or poor integration into the pre-existing knowledge systems.

4.7.2.1 Personality, Engagement and Participatory Interventions

Personality is but one of the myriad of complex factors that mediate whether or not new information is integrated into existing knowledge systems (Ellen 2010, Marchand 2010, Worsley 2002). Personality and engagement are likely key explanatory factors for the success of participatory approaches in building engagement and enhance efficacy of interventions. Lack of dietary diversity was rarely reported as due to inequality, disadvantage or power; rather local people perceive dietary diversity as something all people in their community can achieve. The absence of dietary diversity is often portrayed as due to lack of personal effort, mindset*, et cetera*. If individuals or households do not make use of the cultural knowledge needed to ensure their dietary diversity, perhaps it is partly due to a lack of integration of nutrition and diversity values into their existing knowledge / value framework (Worsley 2002). Participatory approaches are championed for their ability to create a sense of ownership and engage local people in an intervention or research. Participatory approaches may be best equipped to engage those individuals who are perceived as uninterested or unmotivated, by addressing the larger structural factors leading to their lack of interest and motivation and engaging them to become more active in an effort to improve their dietary diversity and nutrition.

4.7.2.2 Cultural Consensus and Inter-individual Variation in Knowledge

Current local knowledge and the means by which it is developed and acquired in Tanzania have been significantly shaped by political history, not the least of which is the role of universal primary school education, which has had a significant role in introducing new knowledge and creating consensus on concepts in local knowledge in the East Usambara Mountains. The concept of *vitamini*, was likely adopted from scientific knowledge systems (along with the word *vitamin)* at least in part via primary school curriculum. It is used very frequently by scientifically trained health practitioners, in addition to in the classroom (Chapter 7), thereby, enhancing its familiarity, if not the clarity of its meaning. It may be that rather than replacing traditional knowledge with modern scientific information, education actually imparts socialization to a western / scientific way of knowing, increasing the ability to integrate scientific knowledge into existing knowledge systems. It is possible that the lack of discourse around scientific concepts (such as *vitamini*) among the most disadvantaged informants is actually because, in a setting where the majority of people attended at least a couple years of primary school, they are the few who had no primary school education. The role of the primary school curriculum in the East Usambara Mountains and Tanzania as a whole is a major driving force behind the creation of consensus among informants on current local nutrition knowledge is discussed further in Chapter 7.

> **Anna Ernest:** "[Eating only cassava and vegetables is] not enough because a person needs to eat food that contains all the vitamins necessary to the body. There should be three groups: carbohydrates, proteins, oils. So if it's cassava and vegetables…if the body of a human being lacks sufficient carbohydrate, protein and oil, the body won't be healthy, you will fall sick, it will be attacked often because it is lacking many things."
> **Bronwen Powell:** "Where did you learn this?"
> **Anna Ernest:** "I learnt and was taught it in school (laughing). For example, eating leafy vegetables helps your eye sight/vision"

Both the universal use of the Kiswahili language and universal Primary School education are legacies of Tanzania's socialist era (Yeager 1989). It is important for current leaders to build on the strengths of the system they have inherited.

4.7.2.3 The Role of Cultural Classifications in Nutrition Knowledge

This case study highlights the benefits of attention to different cultural classifications; a number of differences between Western cultural classifications and local classifications were seen. Differences between scientific and folk taxonomies (Berlin 1973), have been reported by a number of studies showing cross-cultural and intra-cultural differences in food group classification (Behrens 1986, Kuhnlein and Pelto 1997, Powell 2006). Local classification of what counts as food and the dual meaning of the local terms *chakula* and *mboga*, indicates that great care must be taken by anyone trained in scientific paradigms to ensure that research findings are interpreted appropriately and that intervention messages are designed accordingly.

One important finding in the case study is that the reported health benefits of foods are often not related to nutrition. While local concepts of *vitamini* , *protini* , *wanga*, *madini* and *virutubisho* are at least partially reflect what scientists might classify as 'nutritional benefits', local concepts of *joto, kujenga mwili, kuongeza damu*, and *ladha* are reported benefits of foods which are closer to scientific definitions of 'medical'. This finding provides further support for Etkin's (1982) argument that in many cultures there is little differentiation between food and medicine. Johns' (1996) hypothesis that the chemical properties of plants were important factors in the evolution of their use as foods and medicines, and which ones became identified as foods and which as medicines, is supported by these results. The importance of medicinal properties of traditional leafy vegetables in the Tanzania and East Usambaras has been reported elsewhere (Herforth 2010b, Powell et al. 2010).

Fleuret (1979a) notes fruits are not truly considered 'foods' by the Shambaa (of the Usambara Mountains). The frequent reports by local people that fruit is 'important for increasing blood' is interesting given that fruit is only peripherally included in the cultural construct of 'food'. Fruit's 'medicinal' qualities' and the blurred lines between categories of food and medicine (c.f. (Etkin 1982), could lead to novel approaches to nutrition education and intervention in the Usambara Mountains and throughout East Africa where this classification is common. Clearly neither the western classification of fruit as a food, nor the Western distinction between food and medicine are useful in the East Usambara setting. These facts pose difficulties to nutrition messages such as 'eat more fruits and vegetables', let alone '5 to 10 a day'.

Shell-Duncan and McDade (2005) give another example from East Africa of cultural classification acting as a barrier to adequate nutrition. They describe higher rates of inadequate iron intake among girls than boys in a Rendille community in northern Kenya and link this to cultural classifications of 'soft' foods (including rice, maize porridge, and tea), important for girls, and 'hard' foods (including meat, blood, and beans) important for boys. Differences in cultural classification occur for even the most basic concepts, such as colour. Berlin and Kay (1969) report large intra-cultural variations in colour classification and nomenclature (also see Berlin and Berlin 1975, Kay et al. 1991, Monberg 1971, Snow 1971, Turton 1980, Witkowski and Brown 1982). These variations could have a significant impact on the interpretation, understanding and integration of messages including reference to foods of a given colour (e.g. 'green leafy vegetables'). While anthropologists have long cautioned against blaming the individual for choices which are constrained by social, cultural, political factors, it is equally important not to blame the culture, and to seek ways aspects of cultural knowledge can be used to ensure healthy behaviours (Krumeich et al. 2001).

4.7.2.4 Seeking Convergence for Improved Knowledge Transmission and Integration

Worsley (2002) points out that "...'messages' are often accepted or rejected according to their consonance with prior beliefs". This would suggest that interventions would be more successful if they built on existing local knowledge rather than introducing foreign constructs. *Kuongeza damu* and *kujenga mwili* are two local concepts which, although not aligned with scientific paradigms, have many potentially healthful benefits.

Kuongeza damu (to increase the blood) differs from scientific concepts of anaemia; *upungufu wa damu* the terminology used by medical professionals, is distinct from *damu imepunguza* (the blood has decreased) used by local women in a nearby community in Pemba (Ringsted et al. 2006, Young and Ali 2005) . There, one of the most common local treatments for anaemia is a diet with more foods *kuongeza damu* (to increase the blood) (Ringsted et al. 2006, Young and Ali 2005). In our research foods most commonly reported to 'increasing the blood' were leafy vegetables, fruit, honey, beans, milk , eggs and less commonly other animal source foods, while in Pemba Young and Ali (2005) list eggs, *mchicha*, meat, beans, chicken, and fish. Rather than introducing new and less culturally salient concepts such as *upungufu wa damu,* by building on existing concepts (for example by adding and emphasizing foods high in iron to the list of foods which *kuongeza damu*), nutrition education and interventions could simultaneously validate local knowledge, and improve their efficacy.

Likewise, while the concept of *kujenga mwili* is not completely aligned with biomedical ideas about growth, there seems to be quite a bit of overlap between the two. As above, small additions or adjustments to this local concept, which already includes protein-rich foods as important, could be an efficient nutrition education strategy, specifically the promotion of protein and micronutrient rich foods over starchy, unfortified staples (such as porridge, *uji*), during critical growth periods for children.

Local people's recommendations of foods to increase (beans, leafy vegetables, *ugali*, cooked banana, rice, fish and fruit) and foods to decrease (cassava, oil / fat (or things cooked in too much fat) and alcohol) to improve nutrition and health are clearly not counter to health objectives, as local 'beliefs' have sometimes been portrayed. However, 52% of items consumed in the area during the research project were purchased (Chapters 5 and 6), and the communities clearly faces the risk of a nutrition transition if steps are not taken to ensure that less healthful cultural food preferences (such as for meat and oil) are not amplified by increasing access. The same principles discussed above could have an important role in mitigating the nutrition transition in the East Usambaras and beyond.

4.7.3 'Making senses' of Other Ways of Knowing: Dietary Diversity as a Foundation for Integrating Scientific and Local Knowledge Systems

The gap between scientific and local knowledge systems remains a major obstacle to nutrition interventions with educational or behaviour change components. Compared to *kujenga mwili* and *kuongeza damu* the local conceptualization of dietary diversity and its role in health and nutrition is better aligned with scientific perspectives. Local perspectives include an emphasis on social, cultural and especially environmental determinants of dietary diversity, which are mirrored in the scientific literature that promotes dietary diversity as an important link between biodiversity and nutrition (Johns and Sthapit 2004).

Compared to the local knowledge around the concept of *vitamini* (vitamins), which shows a lack of consensus between individuals, there is a high degree of agreement among a range of informants surrounding the concept of dietary diversity, and its benefits for enhancing appetite. This suggested that the concept of dietary diversity is a salient part of local nutrition knowledge. The scientific literature on dietary diversity shows increasingly strong evidence of the role of dietary diversity in ensuring adequate intake on energy, supported by experimental studies demonstrating what has been termed 'sensory specific satiety', in which humans and animals ate more when presented with more sensory options per meal (Brondel et al. 2009, DiBattista and Sitzer 1994, Rolls 1986, Rolls et al. 1981). Scientific data indicating that dietary diversity is related to nutrient intake, after controlling for energy, are less consistent, and there is not yet consensus on which study period is most appropriate for the assessment of dietary diversity. Local knowledge from the East Usambara Mountains holds that the importance of a varied diet for improved appetite applies across different time periods as well as across and within food groups.

Scientific ideas about dietary diversity, like many indigenous and local health knowledge systems, focus more on health (and how to maintain it) (Turton 1997), compared to many scientific approaches to nutrition which focus on disease and deficiency. Similarly, the local nutritional knowledge examined in this research tended to focus on the health-giving components of diet and food. Scientific research on dietary diversity often takes wholistic perspectives and presents solutions better aligned with local knowledge systems.

The qualitative approach to ethnonutrition taken herein has revealed that local people perceive a strong link between agriculture and agricultural diversity (and by extension environmental health in general) and human diet and nutrition. Certainly the validity of common nutrition knowledge assessment and the knowledge-attitudepractice paradigm have been challenged previously (Worsley 2002). Nutrition research has struggled to accept other ways of knowing as equal to our own. New paradigms, such as anthropological perspectives on knowledge, can modify current approaches towards greater and more efficient behaviour change in nutrition interventions and public health nutrition. Overlaps between scientific and local knowledge systems (such as dietary diversity) offer excellent platform to provide novel health and nutrition information to local communities; such an approach should enable novel information to be more readily integrated into existing local knowledge systems.

Preface to Chapter 5 (Manuscript 3)

The previous chapter (Chapter 4) describes local knowledge of nutrition and local people's perceptions of environmental factors which enable them to maintain their food security, dietary diversity and nutrition. The last two manuscripts will examine these relationships quantitatively. This manuscript describes the contribution that wild foods make to the diets and local food system in the East Usambara Mountains. The first section provides a detailed description of wild foods (and some aspects of their social and cultural importance). It supports later analytical sections in this and the subsequent (Chapter 6) manuscript. A following section compares dietary diversity and reliance on foods from various sources in two seasons. It highlights the greater importance of wild foods during the food insecure season, providing support for the argument that wild foods provided a safety-net in times of insecurity and rapid change. The relative contribution of foods from the farm and from forest, to the provision of various nutrients, is examined. Finally, determinants of wild food use are tested, showing that agricultural engagement (acres farmed and hours spent in the farm) is positively associated with percent of the diet obtained from wild species. The final manuscript of this dissertation (Chapter 6) will examine the role of forests for ensuring access to forest foods on a day-to-day basis.

Manuscript 3 (Chapter 5) was co-authored with Patrick Maundu, Harriet V. Kuhnlein, and Timothy Johns, and has been accepted for publication in the journal Ecology of Food and Nutrition. This manuscript was inspired by the work of Brita Ogle and Patrick Maundu as well as other ethnobotanists from East Africa. It makes a novel contribution to the growing body of literature on the use and importance of wild foods for human nutrition by supporting Ogle et al.'s (2001) finding that wild foods are of greater importance for the intake of micronutrients than for macronutrients and more important for some micronutrients than others.

Chapter 5 (Manuscript 3)

Wild Foods from Farm and Forest in the East Usambara Mountains, Tanzania

Bronwen Powell, Patrick Maundu, Harriet V. Kuhnlein and Timothy Johns

5.1 Abstract

This study explored the role of wild foods in the diets of children and their mothers in two seasons in the East Usambara Mountains (N=274 dyads). We identified 92 wild food species (from any type of land). Dietary diversity (most measures) was not different between seasons, but wild foods accounted a greater percentage of items consumed in the wet (food insecure) than the dry season. Forest foods accounted for less than 3% of food items consumed (either season). Wild foods were used by virtually all informants but contributed only 2% of total energy in the diet. However, they contributed a larger percentage of vitamin A (RAE) (31%), vitamin C (20%) and iron (19.19%). Only agricultural factors (e.g. hours spent in the farm) were significantly associated with greater wild food use. These findings suggest participation in agriculture may be important for the maintenance of wild food use, and, that wild foods can play an important role the nutritional resilience of local people in the face of social, economic and environmental change.

5.2 Introduction

'Wild' foods (defined here as any uncultivated species, plant or animal) are an important part of many local and traditional food systems (Kuhnlein and Receveur 1996), food systems that, for many rural people in developing countries, have formed the foundation of food and nutrition security for generations. Such food systems include culturally-important and locally-available foods from hunting, gathering and small scale agriculture; the technologies needed to obtain, process and prepare them; and, associated social and cultural characteristics, beliefs and practices (including traditional knowledge) (Kuhnlein and Receveur 1996). Local food systems are defined by environmental and social, economic and cultural contexts in which they occur (Kuhnlein 2009). Major features of local environments shape traditional food systems and are an essential part of their integrity. In forested landscape mosaics, such as in many parts of rural Africa, forest and other wild foods have historically played a central role in the food system. Here we define 'forest food' as any food item procured from the forest (with 'forest foods' being a subcategory of 'wild food' which are procured from the forest, as opposed to other land use types). One important, if controversial, type of forest food in many regions is bush meat, which can provided an excellent source of protein and micronutrients (Fa et al. 2003, van Vliet et al. 2010). In a paper using data from Madagascar, Golden and colleagues (2011) estimate that the loss of wild meat from the diet of children would result in a 29% increase in the numbers of children suffering from anemia. Wild plant foods can also make significant contributions to micronutrient intakes (Fleuret 1979b, Grivetti and Ogle 2000, Ogle et al. 2001), and many authors have noted the importance of wild foods for providing a safety-net for local people in times of food insecurity (Colfer et al. 2006, Falconer 1990, Humphry et al. 1993). For example in Niger, 83% of informants reported increased reliance on wild foods during drought (Humphry et al. 1993). In these settings, the ability of local ecosystems to provide food security without the destruction of forest integrity is key to the sustainability of conservation efforts.

In many food systems wild foods are important for dietary diversity and adequate nutrient intake throughout the year (Butler 2008, Colfer 2008, Colfer et al. 2006, Johns and Maundu 2006). This is true, not only for hunter-gatherer societies but, for many agricultural societies as well (Bharucha and Pretty 2010, Johnson and Behrens 1982). Because most wild foods from both the farm and the forest are low in salt and fat and high in fibre and micronutrients they could play an important role in mitigating the nutrition transition which is leading to increased rates of obesity and chronic, diet-related diseases such as type II diabetes and cardiovascular disease in developing countries around the world (Batal and Hunter 2007, Maletnlema 2002, Popkin et al. 2002).

Wild plant food use has been described in diverse communities (for example see (Batal and Hunter 2007, Delang 2006, Etkin 1994, Fleuret 1979b, Grivetti and Ogle 2000, Herzog et al. 1994, Ladio and Lozada 2004, Maroyi 2011, Moreno-Black and Somnasang 2000, Pieroni et al. 2005, Price 1997, Termote et al. 2010, Termote et al. 2011, Vainio-Mattila 2000) and their nutrient composition is increasingly reported (for example see (Lyimo et al. 2003, Msuya et al. 2008, Nordeide et al. 1996). Yet, few studies have expressly examined the contribution wild foods make to actual nutrient intake and dietary diversity (Ogle et al. 2001). We seek to draw connections between biodiversity, from across the landscape mosaic, and nutrition, by exploring the contribution of wild foods from the forest and the farm to dietary diversity and nutrient intake and, by demonstrating increased use of wild foods during the period of seasonal food shortage. The role of forest and wild foods in local food systems provides an important focus through which interventions may simultaneously conserve local biodiversity and improve local people's health and well-being.

5.3 Study Area: the East Usambara Mountains

Located 40km from the Indian Ocean coast in north-eastern Tanzania, the East Usambara Mountains rise to over 1200m and receive over 1500mm of rain annually (data from 2007-2009). Traditionally home to the Wasambaa (Shambaa) tribe, the East Usambaras are known for their historical cultural diversity; home also to the Bondei and Zigua tribes (Feierman 1974, Willis 1992). Human population density in the East Usambaras is 61 people per square kilometre and growing at an annual rate of approximately 2.4% (Tanzania 2002).

Micronutrient undernutrition remains a major problem in Tanzania (UN-SCN 2004), and in the East Usambaras specifically. In 1994 high rates of stunting (Height-for-Age Z score ≤-2) (60%), anaemia (Hb≤110g/L) (49%) and parasitic infection were reported in children between the ages of 7-12 years in Muheza District in the East Usambara Mountains (Beasley et al. 2000).

Today, local livelihoods are based on small-scale farming. Subsistence crops that are cultivated include: bananas, maize, cassava, beans, yams, and rice. Sugarcane, cardamom, cinnamon, cloves, black pepper, teak and oranges are common cash crops. Other common sources of income include wage labour in the tea estates or timber industry, small business, and livestock keeping.

Part of the Eastern Arc Mountains, the East Usambaras contain moist tropical forest within a mosaic of forests, open fields, agroforests, fallows and settled land (Dewi and Ekadinata 2010, Hall et al. 2010). The area has experienced a high rate of deforestation in the past 30 years, threatening the ecological and biological value of the remaining tracks of forests which are internationally recognised for their remarkable species diversity and high level of endemism (Burgess et al. 2007, Myers et al. 2000). The Eastern Usambara Mountains are home to some of the oldest protected areas in East Africa; these have historically been managed in an exclusionist manner, with strict restrictions on use by local people. Despite efforts to decentralize forest management in Tanzania, including in the East Usambaras, use of protected government forests for food (and other resources) remains limited (Vihemäki 2005).

The area is well known for the diversity of wild foods used (Fleuret 1979a, Fleuret 1979b, Ruffo et al. 2002, Vainio-Mattila 2000). Previous research from the area suggests that historically the majority of vegetables consumed were wild species (although many were obtained from agricultural land) and that wild meat had a culturally (and presumably nutritionally) important role in the local diet (Feierman 1974, Fleuret 1979b). Recent research indicates that people in the area use a greater diversity of wild vegetables and a higher ratio of wild to cultivated vegetables than do people in other parts of Tanzania (Keding et al. 2007, Weinberger and Swai 2006). Woodcock (1995) suggested that communities living adjacent to public forests (to which they have legal access) collect a wider range of wild foods and show a preference for forest derived foods than communities adjacent to reserves (where there is no legal access to forest resources).

5.4 Methods

Six villages (Misalai, Shambangeda, Kwatango, Bombani, Tongwe and Kiwanda) were selected based on stratification for elevation, road access and distance to the market centre, Muheza town. Within each village, approximately 45 households were selected using systematic sampling from a list of households with children under 5 years provided by village governments (in this case of systematic sampling, every 2nd or 3rd house was selected, or about 50% of eligible houses per village, total N=274). Dietary intake information was collected for one child (the youngest in the house between 2 and 5 years) and their mother (or primary caregiver, henceforth referred to as mother) during the long rainy season, from March to May 2009, and, at the end of the dry seasons, September to October 2009, in three of the six villages (N=129). Research underwent ethics review at McGill University and the national ethics board in Tanzania (COSTECH) and research agreements were signed with village governments. Prior free and informed consent was obtained verbally from adults and guardians of children, was recorded by an enumerator and confirmed by the lead researcher.

Dietary information was collected using a qualitative 7-day food use questionnaire and two 24-hour recalls on non-consecutive days of the week (multi-pass technique, using local serving size aids) in the wet season and a 7-day food use questionnaire and one 24-hour recall in the dry season. A 7 day Food Variety Score (FVS - number of unique food items consumed) and a 7 day Dietary Diversity Score (DDS_6 - number of food groups (out of 6) consumed) were calculated from the food use questionnaire. A 1 day FVS and DDS_6 were calculated from the 1st 24 hour recalls (Chapter 3). Data from the 24-hour recalls were entered into the computer program CANDAT (Godin 2007) and energy and nutrient intake were determined using nutrient composition data for local foods obtained from: the Tanzania Food Composition Tables, the Food and Agricultural Organization Food Composition Tables, the United States Department of Agriculture Nutrient Database and scientific literature (Lukmanji et al. 2008, Wu Leung 1968). The source of each food item consumed was recorded and the relative contribution of foods from each source to diet (over 7 days) and nutrient intake was calculated. Sources of food recorded included: purchased foods (store, market, vendor, and local restaurant); farm (garden was combined with farm because its use and definition was inconsistent across informants, this category includes fallow which people consider part of their farm); gift (including foods consumed at a friend's house or funeral); and foods from forest or uncultivated land (river, bush, etc.). The contribution of wild foods from any source was also calculated. Wealth was assessed by participatory, community-based ranking, described elsewhere (Chapter 2). Forest use and agricultural data were collected by questionnaire completed with the head of each household. Differences between the wet and the dry seasons were tested using paired t-tests and, associations between percent of the diet from wild species and economic and environmental factors were tested using correlations in SPSS Student Pack 17.

5.5 Results

5.5.1 Wild Foods from the Farm and Forest in the Local Food System

Wild foods were used by virtually all informants (98.3% in the wet season and 93% in the dry season). A total of 92 species of wild (or spontaneous growing / uncultivated) foods were reported in the dietary surveys conducted between March and May, and September and October 2009 (Table 5.1). Table 5.1 highlights: the percent of individuals reporting use in the last 7 days in both seasons, whether the species was available on the farm or from the forest / un-cultivated land (i.e. was reported by one or more individuals); the percent of times that a species was obtained from the farm or forest / uncultivated land; and, the primary source (most commonly reported) for each species (additional species were identified as available in the communities but were not listed here as they were either not in season during the survey periods or were consumed too infrequently). Twenty-six food items were primarily (>50% of times used) obtained from the forest while 45 were obtained from the forest a minimum of 10% of the time they were used (second to last column in Table 5.1). Figure 5.1 and 5.2 show the food groups represented by wild species and foods obtained from the forest at least 10% of the time.

Table 5.1 List of wild food species reported by one or more individuals in either the wet or the dry season, percent of individuals reporting their use by seasons and source

Scientific name*	Identification[1]	Swahili name	English name	% Reporting use – WET Season[2]	% Reporting use – DRY Season[3]	Available on Farm[4]	% Obtained from farm (WET)	Available from Forest[5]	% obtained from Forest[6]	Primary Source[7]
VEGETABLES										
Amaranthus spp.[8]	BP2009-75&77	mchicha / bwache	amaranth	76.3	61.2	yes	67.5	yes	1.4	farm
Launaea cornuta (Hochst. ex Oliv. & Hiern) C.Jeffrey	BP2008-3	mchunga	bitter lettuce	71.0	45.0	yes	97.9	yes	0.5	farm
Bidens pilosa L., possibly also *Bidens schimperi* Sch.Bip. ex Walp.	BP2009-3to6, BP2009-48to50	mbwembwe / kisho wa nguo	black jack	54.4	34.1	yes	98.6	yes	1.4	farm
Corchorus olitorius L. and other *Corchorus* spp.	BP2009-7, BP2009-183	kibwando/ hombo	jute	59.2	10.9	yes	98.8	no	0.0	farm
Manihot glaziovii Müll.Arg.	x	kisamvu cha mpira	tree cassava	34.2	29.5	yes	73.1	yes	22.0	farm
Basella alba L.	BP2009-88to91	ndelema	vine spinach	25.9	14.0	yes	75.2	yes	10.6	farm
Dioscoreophyllum volkensii Engl.	BP2009-101, 112to114	msangani	x	11.4	17.4	yes	64.5	yes	32.3	farm

Solanum americanum L., *Physalis angulata* L.[8]	BP2009-85to87, BP2009-122to125	mnavu	American black nightshade, cutleaf groundcherry	15.4	11.6	yes	77.4	yes	2.4	farm
Manihot esculenta Crantz.[8]	Picture	kisamvu cha mihogo	cassava leaves	17.5	2.3	yes	97.9	yes	2.1	farm
Ipomoea pes-caprae (L.) R.Br., *Ipomoea aquatica* Forssk.	BP2009-29to31	talata	water spinach	9.4	7.0	yes	92.2	yes	3.9	farm
Asystasia gangetica (L.) T. Anders., *A. mysorensis* (Roth) T. Anders. (*A. schimperi* T. Anders.)	BP2009-13, BP2009-135-137, BP2009-161-162, BP2009-192-194	tikini	x	11.8	3.9	yes	98.4	no	0.0	farm
Alternanthera sessilis (L.) R.Br. ex DC.	BP2008-11-13, BP2009-94-96	mkoswee	sessile joyweed	4.4	7.0	yes	100.0	no	0.0	farm
Erythrococca kirkii Prain., *Erythrococca fischeri* Pax.	BP2009-8, 20-22, 102-103, 187-188	mnyembeue	x	7.4	3.1	yes	100.0	no	0.0	farm
Rourea orientalis Baill.	Picture	kisogo	x	4.0	5.8	yes	81.8	yes	18.2	farm
Platostoma africanum P.Beauv.	BP2009-4&5, BP2009-24 - 28	kisugu / kisungu	x	3.7	5.8	yes	80.0	yes	20.0	farm
Lobelia fervens Thunb. and *Lobelia duriprati* T.C.E.Fr.	BP2009-81to83, 118-121	sambae / shambaee	lobelia	2.0	5.4	yes	90.9	no	0.0	farm
Justicia anagalloides T.Anderson	BP2009-32, 132-33, 158-160	zuma	x	4.4	1.6	yes	91.7	yes	8.3	farm
Ormocarpum kirkii S.Moore (or *O. trichocarpum* (Taub.)Engl.)	x	hombo ya munguu	x	4.4	0.8	yes	58.3	yes	33.3	farm
Celosia trigyna L.	BP2009-175 - 177	funga-msnaga	x	1.1	2.3	yes	100.0	no	0.0	farm
Talinum portulacifolium (Forssk.) Asch. ex Schweinf. or *T. triangulare* Willd.	Picture	tonge / tee	x	2.6	0.8	yes	85.7	yes	14.3	farm
Sonchus oleraceus L. and *Sonchus asper* (L.) Hill.	BP2009-195-197	kwake / pwake	sow thistle	2.9	0.0	yes	75.0	yes	25.0	farm

Nasturtium officinale R.Br. *(Rorippa nasturtium-aquaticum* (L.) Hayek)[9]	x	sawade / salade	watercress	0.7	0.8	yes	100.0	no	0.0	farm
unknown	x	kihombo mbunda	x	0.7	0.0	yes	100.0	no	0.0	farm
unknown	x	kikunga	x	0.7	0.0	yes	50.0	yes	50.0	farm
Physalis angulata L.	BP2009-173to175	kimbwabwa / mnavu in some places	cutleaf groundcherry	0.7	0.0	yes	100.0	no	0.0	farm
Emilia coccinea G.Don	BP2009-33to35	limi ya ng'ombe / msunga	x	0.7	0.0	yes	100.0	no	0.0	farm
Aerva lanata (L.) Schultes, *Alternanthera sessilis* R.Br.	BP2009-14to16, BP2009-23, BP2009-186	tebwa	x	0.7	0.0	yes	100.0	no	0.0	farm
Momordica foetida Schumach.	BP2009-2, 76, 91, 214&215	ushwe	x	0.6	0.0	yes	100.0	no	0.0	farm
Portulaca oleracea L.	BP2009-138 - 140	danga-danga / tako la hasani	purslane	0.4	0.0	yes	100.0	no	0.0	farm
unknown	x	kisiwani	x	0.4	0.0	yes	100.0	no	0.0	farm
Trichodesma zeylanicum R.Br.	x	sasamlanda	x	0.4	0.0	yes	100.0	no	0.0	farm
FRUIT										
Psidium guajava L., *P. cattleyanum* Weinw.	Picture	mapera	guava/strawberry guava	42.5	30.2	yes	88.3	yes	3.0	farm
Artocarpus heterophyllus Lam.	Picture	mafenesi	jack fruit	28.5	20.2	yes	87.1	yes	1.3	farm
Elaeis guineensis Jacq.	Picture	mbese	palm oil fruit	9.4	9.3	yes	82.4	yes	3.9	farm
Vitex doniana Sweet[9]	Picture	ngobe / magobe	x	0.0	17.8	x	x	x	x	x
Mangifera indica L.	x	maembe	mango	12.9	2.3	yes	15.7	yes	4.3	purchased
Adansonia digitata L.	x	ubuyu	baobab fruit	0.0	12.4	x	x	x	x	x
Rubus pinnatus Willd. and *Rubus rosifolius*	BP2009-37to39, 57to59	vishaa	wild raspberry	11.0	0.0	yes	78.3	yes	21.7	farm

Physalis peruviana L.	BP2009-45to47	vichupwa	ground cherry	4.4	1.6	yes	100.0	no	0.0	farm
Eriobotrya japonica (Thunb.)Lindl.	Picture	msambia	loquat	4.6	0.8	yes	80.0	yes	4.0	farm
Vangueria infausta var *rotundata* Burch.	BP2009-67	mviru	medlar	1.5	3.5	yes	87.5	yes	12.5	farm
Myrianthus arboreus Beauv. (may be)	x	makonde	x	4.6	0.0	yes	84.0	yes	16.0	farm
Passiflora foetida L.	BP2009-8to10, 104to106	dodoki / matunda nyau	wild passion fruit	1.3	2.3	yes	100.0	no	0.0	farm
Terminalia spp.	x	kungu	x	2.4	0.0	yes	76.9	no	0.0	farm
Syzygium malaccense (L.) Merr. & L.M.Perry	Picture	mfyoksi	water apple	2.4	0.0	yes	46.2	yes	15.4	farm
Syzygium cumini (L.) Skeels	BP2009-208to210	zambaru	java plum	1.3	0.4	yes	42.9	yes	28.6	farm
Sclerocarya birrea (A.Rich.) Hochst. (not very sure)	x	mng'ong'o	Marula tree	1.1	0.4	yes	50.0	no	0.0	farm
Momordica calantha Gilg.	BP2009-216&217	matoyo	x	0.9	0.4	yes	80.0	yes	20.0	farm
Sorindeia madagascariensis DC.	Picture	mkimgwina	x	1.3	0.0	yes	14.3	yes	28.6	forest
Lantana camara L.	BP2009-147-149, 190&191	mvuti	x	0.2	0.8	yes	100.0	no	0.0	farm
unknown	x	vitole		0.4	0.0	no	0.0	yes	100	forest
Saba comorensis (Bojer) Pichon	picture	maungo / ungoungo	white rubber vine	0.2	0.0	no	0.0	yes	100	forest
Ancylobothrys petersiana Pierre	x	vitoria		0.2	0.0	no	0.0	yes	100	forest
MUSHROOMS (Counted as a type of vegetable in dietary calculations)										
unknown	x	nkuuri	x	2.9	0.8	yes	87.5	no	0.0	farm
many	x	mangaa	x	2.2	0.0	yes	83.3	yes	16.7	farm
unknown	x	nyika	x	0.4	0.0	yes	100.0	no	0.0	farm
Auricularia spp.	X	magh'wede	x	0.4	0.0	no	0.0	yes	100	forest
Polyporus spp.	X	ngaha / nyaha	thin bracket fungi	0.4	0.0	yes	100.0	no	0.0	farm
unknown	X	kusaghizi	x	0.4	0.0	yes	100.0	no	0.0	farm

Pleurotus spp (*P. djamor*)	x	mameno / mamama	oyster mushroom	0.4	0.0	no	0.0	yes	100	forest
unknown	x	untondoo	x	0.4	0.0	yes	100.0	no	0.0	farm
Termitomyces aurantiacus	x	magong'ongo	Termitomyces	x	x	yes	x	x	x	x
Termitomyces letestui	x	vitundwi	Termitomyces	x	x	yes	x	x	x	x
HONEY										
x	x	asali	honey	7.7	2.7	no	0.0	yes	21.4	purchased
FISH and other Aquatic Species										
Oreochromis spp., *Tilapia* spp.	x	pelege	tilapia	71.0	67.4	no	0.0	yes	6.7	purchased
many	x	magonyoo	craw fish	13.1	3.9	no	0.0	yes	88.7	forest[7]
Clarias spp.	x	kambale	cat fish	12.1	3.9	no	0.0	yes	69.7	forest[7]
Anguilla spp. and others	x	mkonge (mkunga)	any type of eel	7.4	7.8	no	0.0	yes	5.0	purchased
Labeo victorianus	x	ningu	ningu	10.3	1.6	no	0.0	yes	96.4	forest[7]
many	x	kaa	crabs	7.5	3.9	no	0.0	yes	95.1	forest[7]
unknown	x	hambo	x	5.1	5.4	no	0.0	yes	71.4	forest[7]
Scomberomorus sp. (probably *S. commerson)*	x	nguru	kingfish	4.2	2.3	no	0.0	yes	26.1	purchased
unknown	x	msusa	x	4.0	2.3	no	0.0	yes	36.4	purchased
unknown	x	kamba	may be lobster or crayfish	2.4	0.8	no	0.0	yes	100	forest[7]
unknown	x	mangaa	x	3.1	0.0	no	0.0	yes	100	forest[7]
unknown	x	gombe	x	1.5	0.0	no	0.0	yes	25.0	purchased
BIRDS										
Quelea and other	x	ntaa	weaver, brown	0.4	1.2	no	0.0	yes	100	forest
Pycnonotus spp.	x	chole	bulbul	0.7	0.8	no	0.0	yes	100	forest
Numida meleagris	x	kanga	guinea fowl, helmet	1.1	0.0	no	0.0	yes	100	forest
many sp / genera	x	msozi	mostly sunbirds	0.2	0.8	no	0.0	yes	100	forest
Quelea and other	x	nkuya (kuya)	weaver birds	0.0	0.8	x	x	x	x	x
Ploceus spp.	x	nofi	weaver, yellow	0.6	0.0	no	0.0	yes	100	forest

Colius spp.	x	pasa	mouse bird	0.0	0.4	x	x	x	x	x
Turaco fisheri and others	x	huvi	turaco, likely Fisher's	0.4	0.0	no	0.0	yes	100	forest
Spermestes spp.	x	mtongo	manikins	0.4	0.0	no	0.0	yes	100	forest
Numida guttera	x	kororo	crested guinea fowl	0.4	0.0	no	0.0	yes	100	forest
Turtur spp.	x	pugi	wood dove	0.2	0.0	no	0.0	yes	100	forest
MAMMALS										
Thryonomys spp.	x	ndezi	cane rat	3.5	1.6	yes	10.5	yes	68.4	forest
Colobus abyssinicus	x	mbegha	collobus monkey	0.0	0.8	x	x	x	x	x
Rhynchotragus spp., *Neotragus* spp. or other small antelope	x	paa / digi-digi	dik dik, suni or other small antelope	0.7	0.0	no	0.0	yes	100	forest
Cricetomys gambianus	x	kuhe	giant pouch rat	0.7	0.0	no	0.0	yes	50.0	forest
Cephalophus spp. or *Neotragus* spp.	x	funo	duiker or suni	0.6	0.0	no	0.0	yes	100	forest

*Species are listed in order of most commonly consumed (from the largest to lowest percentage of individuals consuming them – for both seasons).

[1]Identification, when marked x was obtained using the local, vernacular Swahili or Shambaa name compared to the literature: ((Harkonen et al. 2003, Harkonen and Vainio-Mattila 1998, Leonard et al. 2010, Moreau 1940, Woodcock 1995), also Patrick Maundu and Victor Mkongewa)

[2] N=269 for the wet season (for mothers and children combined)

[3] N=129 for the dry season (for mothers and children combined)

[4] Sometimes obtained on the farm (reported by one or more individuals)

[5] Sometimes obtained from the forest / bush / river (reported by one or more individuals)

[6] Food items which were obtained from the forest <10% of the time are highlighted in dark grey.

[7]Most commonly reported source (“forest” includes bush (*pori*), river or other uncultivated land)

[8] Mostly the cultivated varieties are consumed, not included in calculation of percent of diet or nutrients from wild foods

[9] Counted as two different food items on the food-use questionnaire and calculation of contribution of wild foods (also on the questionnaire but not appearing here: mtura)

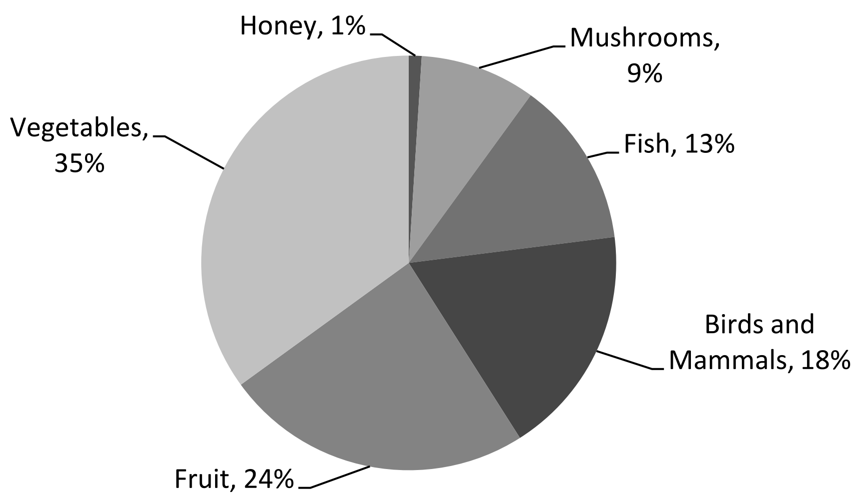

Figure 5.1 Types of wild food species used (as percent out of the 92 total species)

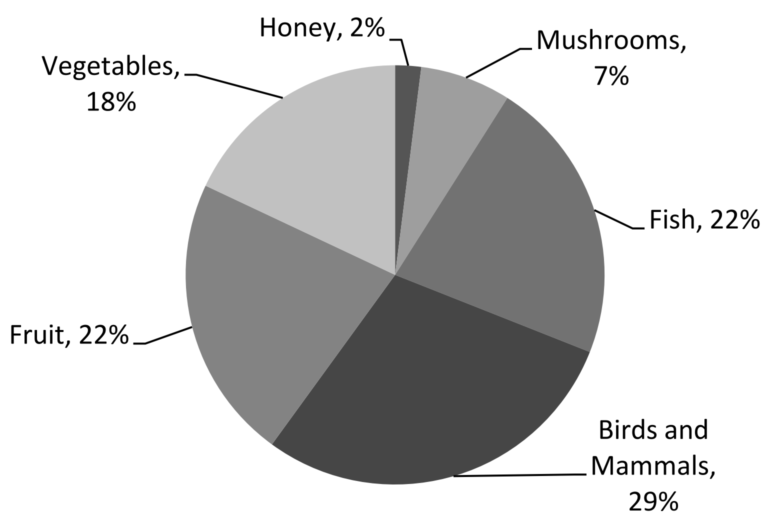

Figure 5.2 Types of foods obtained from forest (of the 45 obtained from the forest at least 10% of the time)

The largest category of wild foods species (from any source) was vegetables. In the wet season 94.1% of mothers and 91.5% of children had consumed one or more wild vegetable species in the past week (mean number of species consumed was 4.1±2.8 for mothers and 4.0±2.8 for children).

Conversely, many forest foods were birds and mammals (Figure 5.2 and Table 5.2), which, although consumed infrequently, can make important contributions to micronutrient intake, even in small quantities (Arnold et al. 2011, Murphy and Allen

2003). Only 6.1% of individuals had consumed any type of wild animal or bird in the last week, compared with 67.8% of individuals who had consumed domestic meat or fowl in the last week (34% had consumed chicken and 32% had consumed beef). Important animal source foods from the forest in the local food system included *kanga* (Guinea fowl, *Numida meleagris*) and *ndezi* (*Thryonomys* spp., cane rat). Although, 3.5% of individuals reported consuming the latter in the last week, in fact, many were ashamed to admit eating this food. Although hunters in the most remote village of our survey (Kwatango) still obtained wild pigs, they report only one per year for the entire village of over 800 people. All species of wild birds and small mammals (2 species of rodent and 2 species of small antelope) consumed were reported to have been obtained from the forest or bush (*pori*) the majority of the time, although small rodents were occasionally captured on farm land as well. Fish (such as *kambale, ningu, kaa* and *magonyoo*) obtained from the river were another commonly consumed type of wild food (Figure 5.3).

Figure 5.3 A boy's fresh catch of *kaa* and *magonyoo* (Tongwe village)

Of the total 38 varieties of fruit consumed (in the wet season) 22 were wild species (or spontaneous / escaped species) (Table 5.1 and Table 5.2). Of these 10 were occasionally obtained in the forest or bush and 4 were primarily obtained from the forest or bush (Figure 5.4). Examples of fruits obtained from the forest included *mkimgwina* (*Sorindeia madagascariensis*), *mviru* (*Vangueria infausta* var *rotundata*) and *ngobe* (*Vitex payos* var *payos*) all of which were highly prized and widely eaten during their short seasons.

Table 5.2 Percent of each food type obtained from all wild species and those specifically from the forests (for mothers and children, wet season only)

	Mother (N=269)	Child (N=269)
	Mean ±SD	Mean ±SD
Percent of **Vegetables*** from ALL WILD SPECIES (%)	48.3±15.5	47.7±16.3
Percent of **Fruit** from ALL WILD SPECIES (%)	20.9±22.3	22.5±22.8
Percent of **Animal & Birds** from ALL WILD SPECIES (%)	3.6±15.8	3.8±15.6
Percent of **Vegetables*** from FOREST (%)	1.0±4.8	1.0±4.8
Percent of **Fruit** from FOREST (%)	1.5±6.8	1.7±8.4
Percent of **Fish** from FOREST / RIVER (%)	11.6±20.1	10.8±19.5
Percent of **Animal & Birds** from FOREST (%)	2.5±12.1	2.8±12.8

* Vegetables here includes leafy and non-leafy vegetables as well as mushrooms

The forest was not an important site for the procurement of vegetables (Table 5.2). Even *msangani* (*Dioscorephyllum volkensii*)*,* often cited as the most important forest vegetable, was obtained from farmland 67.7% of the time (in areas with tree cover). In fact, while 31 of the total 44 varieties of leafy vegetables consumed were wild species, none, primarily and only 18 occasionally, were collected from the forest. However, a number of species were known as 'forest vegetables', including *msagani, ndelema (Basella alba*) and *talata (Ipomoea* spp.), and were highly valued and culturally important. Research revealed a strong cultural preference for bitter taste and slimy texture in side dishes (Figure 5.4). These can be provided by an array of culturally-important vegetables, both cultivated and wild. The most important bitter vegetables included *ngogwe* (African eggplant, *Solanum macrocarpon*), *mnavu* (*Solanum* spp.) and *mchunga* (*Launaea cornuta*); common slimy vegetables included *bamia* (okra, *Abelmoschus esculentus*), *kibwando* (*Corchorus* spp.) and *ndelmea* (Table 5.1). When time and resources permit, both a bitter and a slimy side dish are served simultaneously. Cultivated okra and African eggplants were widely traded and among the few food items sold door-to-door. *Mchunga* (which gets its name from the Kiswahili and Kisambaa word 'bitter'), the quintessential bitter vegetable, consumed by over 70% of individuals in the past week, is a culturally-important wild species obtained primarily from fields and disturbed areas. The knowledge needed for its proper preparation is a key socio-cultural aspect of the traditional Wasambaa food system (Powell et al. 2010). *Kibwando*, consumed by almost 60% of individuals, grows as a weed in fields and disturbed areas. *Ndelema* was sometimes cultivated and other times collected in forests during trips to obtain firewood.

Figure 5.4 Left: *Dodoki* obtained from the road-side (Tongwe village), Right: Preparing *kibwando* (slimy) and *mchunga* (bitter) side dishes for dinner in Kwatango village

5.5.2 Seasonal Differences in Contribution of Wild Food to Diet

The months of April and May were the least food secure time of year, with up to 69% of households reporting inadequate food due to dwindling food stores and limited other sources of cash income. In the East Usambara Mountains, the largest harvest comes from crops planted in the long rainy season (March and April). This harvest begins in July and ends in September (Porter 2006). The *mwaka* harvest produces the majority of staple food produced by a household yearly as well as cash when the harvest is sold. Although cash crops and a smaller second harvest can also be sold for cash at other times of the year, the cash from the sale of these harvests are often used to pay school fees and other expenses rather than to purchase foods. By the end of the cool dry season, when the largest harvest had been brought in and cash crops sold, few (~3%) households reported inadequate supply of food (Figure 5.5).

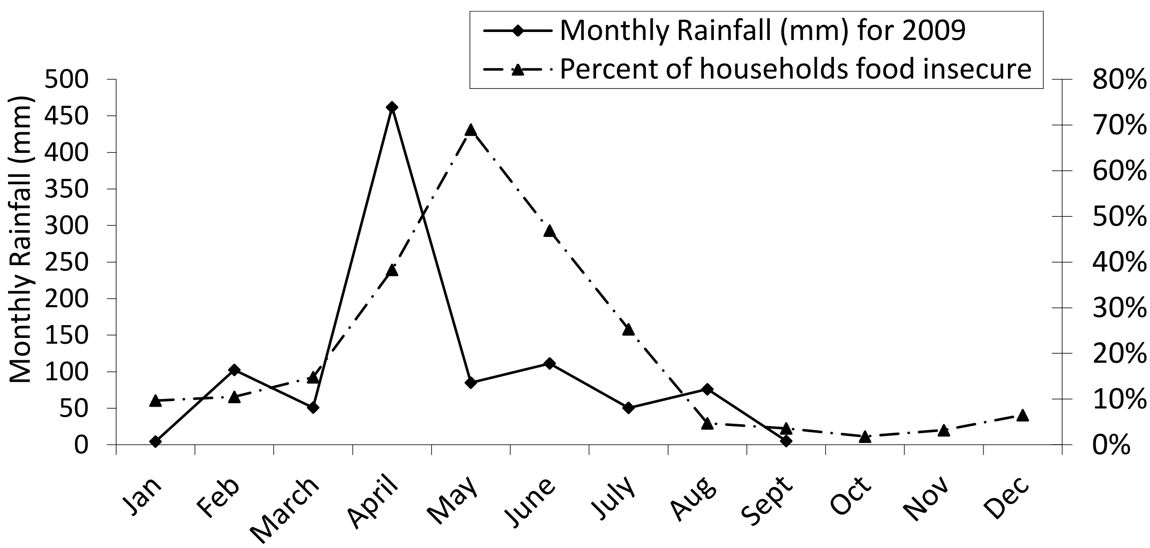

Figure 5.5 Seasonal variations in rainfall and percent of households reporting food insecurity

Paired t-tests showed no difference in mean 7 day FVS and DDS_6, between seasons, for either mothers or children. Children's 1 day FVS score was slightly higher in the dry season but there was no difference in children's 1 day DDS_6 score between seasons. Conversely, significant differences were seen between seasons in the sources of foods (Table 5.3). In the wet season 44.6% of mothers and 45.4% of children consumed one or more foods from the forest or un-cultivated land. In the dry season this is reduced to 31.0% of mothers and remained constant in children. In the wet or the food insecure season, less purchased food was consumed and the percentage of the diet from wild foods from all sources and wild foods from the forest was almost double (wet: 15.4% vs. dry: 8.9% from wild species and wet: 2.6% vs. dry: 1.6% from the forest, average for mothers and children). In both seasons many of the wild species were obtained from the farm; these are removed from fields while weeding or were found in field margins, fallow and agroforests, as noted in Powell et al. (2011). This suggests that in the food insecure season local people shift to greater use of forest and wild resources, while in the dry season, when cash availability is higher, they are able to purchase a greater number of food items. Conversely, part of the reason for lower use of wild foods in the dry season could be due to reduced availability of wild vegetables, which account for a large percentage of wild food species consumed (Powell et al. forthcoming-a).

Table 5.3 Seasonal differences in dietary diversity and types of foods consumed and sources of foods consumed (tested by paired t-test)

	Mothers (N=129)			Children (=129)		
	WET	DRY	P value	WET	DRY	P value
FVS 7 day	38.1±12.0	37.2±12.7	NSS	39.3±11.6	38.1±12.7	NSS
DDS_6 7 day	5.55±0.59	5.60±0.58	NSS	5.53±0.61	5.63±0.56	NSS
FVS 1 day	-	-	-	9.3±1.7	9.8±2.4	<0.05
DDS_6 1 day	-	-	-	3.21±0.81	3.32±0.94	NSS
No. wild foods used	6.0±3.6	3.6±3.2	<0.001	6.0±3.5	3.8±3.1*	<0.001
Wild Species (%)	15.4±5.4	8.7±4.9	<0.001	15.3±5.2	9.1±4.7	<0.001
Purchased (%)	51.4±12.9	57.3±12.6	<0.001	52.4±12.5	57.8±12.1	<0.001
From Farm (%)	41.6±12.2	37.8±12.6	<0.001	40.4±12.0	36.9±12.0	<0.001
From Forest (%)	2.6±0.4	1.4±2.8	<0.001	2.5±3.7	1.8±2.5	<0.001
% using wild foods	98.5	92.2	-	98.1	93.8	-
% using forest foods	44.6	31.0*	-	45.4	45.7*	-

* significant difference between mothers and children in dry season, likely due to consumption of seasonally available wild fruit by children

5.5.3 The Contribution of Wild Foods and Wild Food from the Forest to Nutrition

The contribution of each source (purchase, farm, gift, forest) to mothers' and children's intake of energy, protein, fat, vitamin C, vitamin A (RAE, retinol activity equivalents), thiamine (B_1), riboflavin (B_2), niacin (B_3), folate, calcium, iron and zinc is presented in Table 5.4. The majority of each of nutrients consumed came from foods that were purchased or obtained on the farm.

The contribution of food from the farm to nutrient intake is quite different between nutrients, with as little as 32.4% and 32.7% of fat and protein and, as high as 69.8% of vitamin C, obtained from food from the farm. While wild foods contributed only 2% or total energy in the diet, they provided a greater percentage of vitamin A (RAE) (31.2%), vitamin C (20.2%) and iron (19.2%). Because forest foods were consumed so infrequently, it is not surprising that they contributed less than 1% of most nutrients in the diet (from 0.33% of energy to 1.3% of protein). However, when only the days when forest foods were consumed were considered, they made a significant contribution to most nutrients including: 39.3% of protein, 27.6% of vitamin C, 26.7 % of iron, 25.6% of vitamin A (RAE), 23.2% of calcium (second to last column in Table 4).

5.5.4 Possible Determinants of Wild Food Use

To identify predictors (possible determinants) of wild food use, the percentage of children's diet from wild food (wet season) was tested against economic and environmental factors. Economic factors showed little association with wild food use (the negative correlation between community-based wealth rank and percent of children's diet from wild species (more wealthy have a lower percent of diet from wild food) was not significant ($r= -0.105$; $p=0.086$)). While forest use and access were not associated with wild food use, agriculture factors were (see (Powell et al. 2011) for associations between forest access and use, and forest food use). The percent of children's diet from wild species showed a positive correlation with household crop diversity (number of crops cultivated over the past year) ($r=0.157$; $p<0.01$) and hours spent in the farm over the last 3 days ($r=0.190$; $p<0.01$).

Table 5.4 Contribution of foods from different sources to nutrient intake in mothers and children in the wet season (Mean ± S.D for N=274 mothers and children)

		Percent PURCHASED	Percent from FARM	Percent from GIFT	Percent from FOREST	Percent from days of forest food use ONLY	Percent from WILD SPECIES
Energy	Mothers	48.9±26.9	48.9±27.0	2.0±5.8	0.3±1.3	8.5±6.3	1.5±2.4
	Children	56.4±23.1	40.9±23.2	2.6±5.8	0.4±1.7	10.5±6.7	2.5±3.3
	AVE	**52.7**±25.0	**44.9**±25.1	**2.3**±5.8	**0.3**±1.5	**9.5**±6.5	**2.0**±2.9
Protein (g)	Mothers	60.4±24.8	36.6±24.1	1.8±5.8	1.3±5.6	40.4±22.9	6.7±9.8
	Children	67.8±21.2	28.8±21.1	2.3±6.4	1.4±6.8	38.2±28.2	8.1±11.1
	AVE	**64.1**±23.0	**32.7**±22.6	**2.1**±6.1	**1.3**±6.2	**39.3**±25.6	**7.4**±10.4
Fat (g)	Mothers	61.8±27.3	35.6±27.1	2.3±7.1	0.3±2.0	10.4±12.8	1.8±3.4
	Children	68.2±25.1	29.2±24.5	2.3±8.1	0.3±1.5	8.5±8.1	2.1±3.4
	AVE	**65.0**±26.2	**32.4**±25.8	**2.3**±7.6	**0.3**±1.8	**9.5**±10.4	**2.0**±3.4
Vitamin C (mg)	Mothers	25.2±26.9	74.0±83.0	4.8±13.5	0.9±5.2	27.7±33.0	18.7±27.0
	Children	27.8±25.6	65.6±31.6	6.7±15.6	0.9±5.0	27.5±28.9	21.7±25.7
	AVE	**26.5±26.3**	**69.8±57.3**	**5.7±14.6**	**0.9±5.1**	**27.6±30.9**	**20.2**±26.3
Calcium (mg)	Mothers	57.6±27.7	39.8±25.2	2.4±7.6	0.9±4.3	27.4±23.2	16.4±19.4
	Children	63.8±24.6	33.0±25.4	2.7±7.0	0.8±3.8	23.1±19.6	15.9±19.4
	AVE	**60.7±26.1**	**36.4±25.3**	**2.5±7.3**	**0.8±4.1**	**23.2±21.4**	**16.1**±19.4
RAE (µg)	Mothers	35.5±28.9	60.2±30.7	4.0±11.6	0.8±4.8	27.2±28.7	31.9±87.0
	Children	42.8±40.5	55.3±31.4	3.4±9.8	0.8±4.0	23.9±22.5	30.5±58.7
	AVE	**39.2±34.7**	**57.8±31.1**	**3.7±10.7**	**0.8±4.4**	**25.6±25.6**	**31.2**±72.8
Iron (mg)	Mothers	40.3±30.5	57.0±27.0	3.1±8.5	0.8±4.4	26.7±24.9	18.2±19.7
	Children	46.2±25.0	50.6±26.8	2.8±7.1	0.9±4.4	26.6±23.3	20.1±22.9
	AVE	**43.2±27.8**	**53.8±26.9**	**2.9±7.8**	**0.9±4.4**	**26.7±24.1**	**19.2**±21.3
Zinc (mg)	Mothers	49.1±28.2	48.9±27.8	2.0±6.2	0.5±2.7	16.6±14.8	4.0±5.19
	Children	56.3±24.3	40.9±24.4	2.5±6.7	0.6±2.9	17.3±14.1	5.4±6.6
	AVE	**52.7±26.3**	**44.9±26.1**	**2.3±6.5**	**0.6±2.8**	**17.0±14.4**	**4.7**±5.9
Thiamine (mg)	Mothers	41.2±29.6	57.0±29.6	2.2±6.4	0.3±1.5	9.6±8.2	3.7±5.26
	Children	47.3±26.0	49.1±26.3	3.3±7.4	0.5±2.1	13.2±9.6	5.2±7.1
	AVE	**44.3±27.8**	**53.1±27.9**	**2.8±6.9**	**0.4±1.8**	**11.4±8.9**	**4.5±6.2**
Riboflavin (mg)	Mothers	43.2±24.9	53.9±25.1	2.4±6.35	0.7±3.4	21.9±17.1	11.2±13.8
	Children	49.3±22.8	47.1±23.2	3.0±6.79	0.8±3.6	22.6±16.3	13.9±17.2
	AVE	**46.3±23.8**	**50.5±24.2**	**2.7±6.57**	**0.8±3.5**	**22.2±16.7**	**12.5±15.5**
Niacin (mg)	Mothers	44.5±27.6	52.9±27.4	2.1±6.34	1.0±4.7	33.6±19.8	4.7±8.0
	Children	51.6±23.2	44.5±23.6	2.9±7.04	1.4±6.1	35.1±23.2	6.9±10.1
	AVE	**48.1±25.4**	**48.7±25.5**	**2.5±6.69**	**1.2±5.4**	**34.3±21.5**	**5.8±9.1**
Folate (DFE)	Mothers	42.9±27.0	54.4±26.57	2.9±7.39	0.7±3.6	22.9±18.8	10.4±13.1
	Children	46.8±23.8	49.1±24.73	3.7±8.64	0.9±4.3	25.5±19.5	13.3±16.15
	AVE	**44.8±25.4**	**51.7±25.65**	**3.3±8.02**	**0.8±4.0**	**24.2±19.2**	**11.9±14.6**

5.6 Discussion

5.6.1 Historical Perspective

Fleuret (1979b) noted: that wild leafy greens were the most common side dish in the Usambaras in the 1970s: “an integral and essential element in the diet of the Shambaa people at all seasons of the year”; that the majority of leafy vegetables consumed were wild; and, that exotic vegetables were not replacing the traditional wild ones. She concluded that this was in part due to better affordability, the cultural importance and the preferred taste of traditional vegetables. Much of this appears to be true in the East Usambaran food system today, although data were not comparable between studies. Feierman (1974) wrote in depth about the culinary and cultural importance of wild pigs to the Shambaa people. Today wild pig remains a highly esteemed food; however, they have become extremely scarce (Powell et al. 2010).

5.6.2 Findings in Relation to Other Studies

While many studies describe the importance of wild and forest foods in local food systems, or report intake of wild foods (especially leafy vegetables) or their nutrient composition, few assess the contribution of such foods to nutrient intake, in part due to methodological constraints (Chweya and Eyzaguirre 1999).

Herein we report no difference in 1 day DDS_6, 7 day DDS_6 and 7 day FVS between seasons, but significantly higher 1 day FVS in children in the dry (food plenty) season as compared to the wet (food insecure) season. Only a few other studies describe seasonal differences in dietary diversity; our findings match findings reported by Fergusons et al. (1993) of higher 1 day FVS (number of foods) in the season of food plenty in Malawi and Ghana but not those reported by Savy et al. (2006) of higher 1 day DDS in the food plenty seasons compared to the food scarce season in Burkina Faso. In Burkina Faso the higher 1 day DDS in the food plenty season was linked to higher use of purchased foods [as well as higher use of legumes and vegetables (specifically okra which ripens in the food plenty period)] (Savy et al. 2006). It seems likely that in the East Usambara

Mountains, increased use of wild foods in general and wild foods from the forest is a strategy which allows local people to maintain their dietary diversity during the period of food shortage (to counter balance lower access to purchased foods due to lower agricultural incomes). Wild food use were both higher in the rainy season, when food was scarce, than in the dry season. Although wild foods are considered to be more available in the wet season in the East Usambara Mountains and throughout most parts of East Africa, we conclude that the lower use of wild in the dry season was at least in part due to lower need. Similarly, Weinberger and Swai (2006) reported that diversity of traditional vegetable use was highest (while overall food diversity was lower) amongst the poorest households in their multi-site study in Tanzania (many of the traditional vegetables in their study were wild, and many of the wild foods in our study were 'traditional vegetables'). Although findings of seasonal differences in wild food use vary between studies and regions, most are consistent with our findings: Humphry et al. (1993) noted that 83% of informants in Niger said their reliance on wild foods increased during drought, and Moreno-Black and Somnasang (2000) reported higher wild food usage in Thailand in the food scarce season, when wild foods are less available.

Studies, especially in North America, have compared contributions of traditional versus market foods to diet and nutrient intake of Indigenous peoples (Kuhnlein 2009). For example, in the diet of Inuit women aged 20-40 years on Baffin Island, traditional foods (mostly wild sea and land mammals, birds and fish) contributed approximately 29% of energy, 62% of protein, 57% of vitamin A, 81% of iron, 67% of zinc and 11% of calcium intake (Kuhnlein et al. 1996). However, while most traditional foods reported are wild, different definitions of market / purchased foods and traditional / wild foods make comparison between our findings and this extensive body of research difficult.

A study in the Mekong Delta and forested Central Highlands of Vietnam is, to our knowledge, the only published work which specifically reports the contribution of wild foods to the intake of different nutrients (Ogle et al. 2001, Ogle et al. 2003). The Central Highlands site is more ecologically similar to the East Usambaras, although the contribution of wild foods to nutrient intake was higher in the Mekong Delta. Although our data included all wild foods (the majority of which were vegetables), while those from Vietnam include only vegetables, the results from Vietnam are quite similar to those from the East Usambaras. Wild foods contributed 31% of the RAE in our study, and likewise wild vegetables made the greatest contribution to carotene intake in Vietnam (providing 19% in the Central Highlands). The second and third highest contribution to intake from wild foods was for vitamin C (20%) and iron (19%) in our study; in the Central Highland of Vietnam wild vegetables provided 13% of vitamin C and 14% of iron intake. In both sites the contribution of wild foods to the intake of other nutrients was lower (for example wild foods made limited contribution to zinc and niacin intake).

Anthropological studies following optimal foraging theory paradigms (Keegan 1986, Rappaport 1968) in examining the efficiency of different subsistence strategies for the procurement of energy and protein, have reported that in most horticultural and agricultural societies farming activities provide the large majority of energy, while hunting and fishing provide the majority of protein consumed. For example, the Yassa, Mvae and Bakola of Cameroon obtained 80% of their energy through cultivation and 70-80% of their protein from hunting and fishing in local forests and rivers (Koppert et al. 1993). Johnson and Beherns (1982) expanded this approach to examine micronutrients and suggested that since protein is rarely the limiting nutrient in the diet, hunting and gathering was in fact more important for the provision of micronutrients (especially vitamin A, riboflavin and niacin) than protein for the Machiguenga of South America. Our more recent demonstration, that wild and forest foods make a greater contribution to the intake of many micronutrients than that of energy and protein, supports this hypothesis.

The limited use of forest foods reported here differs from other settings. For example, in Venezuela Melnyk and Bell (1996) cite “a great dependence of Huottuja livelihoods on the forest from which they obtain more food than they would have been able to buy if they invested the same amount of time in wage labor”. However, the types of foods obtained from the forest in the East Usambaras were similar to those reported elsewhere. For example in Thailand, of the food species obtained from the forest, 9% were fruits, 34% were vegetables, 5% were bamboo, 13% were mushrooms and 39% were animal species (Vinceti et al. 2008).

5.7 Conclusion

The results herein highlight the importance of agricultural land and participation for the procurement and use of wild foods. Wild foods from agricultural land make a larger contribution to the diet than wild foods obtained in the forest ('forest foods'). Possible explanations for the limited use and contribution to nutrition of forest foods include: cultural preference for wild foods from agricultural land, limited access due to deforestation, the time needed to travel to the forest to obtain foods, and, present and historical forest governance policies and practices (Arnold et al. 2011, Vihemäki et al. forthcoming, Woodcock 1995). Nevertheless, our data suggest that on days when forest foods are consumed, they contribute between 10 and 34% of the intake of various nutrients.

Because they contribute more to certain micronutrients than to energy intake, the importance of wild foods may be overlooked in studies which examine only energy intake (such as much food security research). In our study population, limiting nutrients (i.e. those most likely to be deficient) in the diet were likely: protein, zinc, calcium and vitamin A (Appendix 5). Wild foods contributed 16% of overall calcium intake and 31% of vitamin A intake. Moreover, our findings show that wild foods were more important in the food scarce season, suggesting that need, rather than availability, is an important driver of wild food use in the wet season. However, we also show greater engagement in agricultural is associated with greater use of wild foods, suggesting that access is also an important factor.

Clearly there is need for attention to the role of wild and forest foods in the diets of local populations across research disciplines and administrative sectors including: forestry and biodiversity conservation, agriculture, public health and nutrition and education. Biodiversity conservation science and practice seek to better integrate local people into ecosystem and biodiversity management. In Tanzania this approach has been embraced, and the country is considered exemplary for its progressive, pro-people, pro-poor forest governance policies. These policies, that are meant to provide local communities with greater access to and control over forest resources needed for their livelihoods, have important implications for the food security and nutrition.

Preface to Chapter 6 (Manuscript 4)

Most previous work linking biodiversity to human nutrition has, understandably, focused on cultivated diversity and agricultural landscapes. The contributions of forests to human health are rarely framed in terms of contribution to nutrition, which are often presented as of secondary importance relative to other ecosystem services. Following on from the last chapter which documents the importance of wild foods in the local East Usambaran diet and their increased role in the diet in the season of food insecurity, this manuscript examines how forest use and forest access (in terms of forest cover) mediate wild food use, dietary diversity and other markers of nutrition. Future work will focus further on agricultural diversity and vegetable consumption for human nutrition in the East Usambara Mountains.

This manuscript was co-authored with Jaclyn Hall and Timothy Johns, and has been published in International Forestry Review. This manuscript grew out of Bronwen Powell and Jaclyn Hall's collaboration with the ICRAF-CIFOR Landscape Mosaics project. This collaboration allowed for an expanded examination of the links between biodiversity and human nutrition beyond that originally planned, to look at individual agricultural diversity and forest use, and allowed examination at a landscape level through the incorporation of landscape level indicators of biodiversity such as tree cover and leaf area. This landscape level approach to the links between biodiversity and human nutrition is one of the novel aspects of this dissertation.

Because this manuscript was written and peer reviewed before other parts of the dissertation there are some small inconsistencies in terminology especially that used for dietary diversity. In previous chapters dietary diversity has been used as a general term referring to diversity at any level or study period whereas Food Variety Score (FVS) referred to the diversity of unique food items and Dietary Diversity Score (DDS_6 and DDS_{14}) referred to the number of food groups consumed over a given period (out of 6 and 14 groups respectively). In this last manuscript, dietary diversity is used to refer to general diversity as well as the number of unique foods consumed (equivalent to the 7 day FVS in the rest of the dissertation). As in previous chapters, in Chapter 6 the term "wild foods" refers to any uncultivated species (plant or animal), determined based on local classifications and the term "forest food" refers to wild foods which are specifically procured from the forest, as opposed to sources (purchase, farm, etc.).

Chapter 6 (Manuscript 4)

Forest Cover, Use and Dietary Intake in the East Usambara Mountains, Tanzania

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6.1 Summary

Food insecurity and malnutrition in local populations both result from and drive deforestation. This paper examines the relationships between diet of local people and measures of forest cover and use in the East Usambara Mountains, Tanzania. Data on dietary diversity and intake were collected for 270 children and their mothers. Area of tree cover within the vicinity of each household was examined in relation to forest use and diet. Individuals using foods from forest and other non-farm land had higher dietary diversity, consumed more animal source foods and had more nutrient dense diets. They also had more tree cover in a close proximity to the home, suggesting a relationship between tree cover and forest food use. Households reporting trips to the forest had lower area of tree cover within close proximity, suggesting that land close to the home with tree cover such as agroforest and fallow is important for obtaining subsistence products. Although historically there has been little motivation for local people to participate in forest conservation in the East Usambaras, the maintenance of tree cover in the landscape around the home, especially on agricultural and village land, may be important in ensuring continued access to the health benefits potentially available in wild and forest foods.

Keywords: East Usambara Mountains, Forest Cover, Wild Food, Dietary Diversity, Nutrition

Couvert forestier, utilisation et alimentation dans les montagnes Usambara de l'Est en Tanzanie

Bronwen Powell, Jaclyn Hall et Timothy Johns

La nourriture non assurée et la malnutrition chez les populations locales résultent toutes deux de la déforestation, tout en la faisant empirer. Cet article examine les relations entre la nutrition des populations locales et la proportion de couvert forestier et son utilisation dans les montagnes Usambara de l'Est en Tanzanie. Des données sur la diverstité nutritionnelle et la consommation ont été recueillies auprès de 270 enfants et de leurs mères. La zone de couvert forestier autour de chaque foyer a été examinée du point de vue de l'utilisation de la forêt et de la nutrition. Les personnes consommant de la nourriture en provenance de la forêt et d'autres terres non-cultivées connaissaient une diversité nutritionnelle plus importante, mangeaient davantage de nourriture de source animale, et leur régime était plus concentré en substances nutritives. Il existait également une plus grande zone de couvert forestier à close proximité de leur foyer, suggérant une relation entre le couvert forestier et l'utilisation de la nourriture forestière. Les foyers effectuant des déplacements vers la forêt avaient une moindre zone de couvert forestier à proximité, suggérant qu'un terre couverte d'arbres proche du foyer, telle que l'agroforêt et la forêt inexploitée est importante pour l'obtention des produits de subsistance. Bien que les populations locales aient une motivation très limitée, historiquement, pour participer à la conservation forestière dans les Usambaras de l'Est, la gestion du couvert forestier dans le paysage encadrant les foyers, particulièrement sur la terre cultivée et celle des villages, pourrait bien être importante pour assurer un accès non interrompu aux bénéfices sanitaires potentiellement obtenus dans les aliments sauvages et forestiers.

Cubierta forestal, usos, y consumo en la dieta en las Montañas Usambara del Este, Tanzania

Bronwen Powell, Jaclyn Hall y Timothy Johns

La inseguridad alimenticia y la malnutrición en las comunidades locales son a la vez causa y resultado de la deforestación. Este artículo examina las relaciones existentes entre la dieta de las comunidades locales y la cantidad de cubierta forestal y su uso en las Montañas Usambara del Este, en Tanzania. Se recolectaron datos sobre la diversidad y el consumo en la dieta de 270 niños y sus madres. Se estudió el área de cubierta forestal en los alrededores de cada vivienda en relación con el uso del bosque y la dieta. Los individuos que hicieron uso de alimentos procedentes del bosque, y otras áreas no cultivadas, mostraron dietas más diversas, consumieron más alimentos de origen animal, y sus dietas contuvieron una densidad de nutrientes más alta. También disponían de una mayor cubierta forestal próxima a su hogares, lo cual sugiere que la cubierta forestal y el uso de alimentos del bosque están relacionados. Los hogares que mencionaron caminatas para llegar al bosque disponían de una menor cubierta forestal en las proximidades, sugiriendo que para la obtención de productos de subsistencia es importante la existencia de áreas cercanas al hogar con cubierta forestal, p. ej. agroforestales o en barbecho. Aunque históricamente las comunidades locales apenas han tenido motivación para participar en la conservación del bosque en las Usambara del Este, el mantenimiento de una cubierta forestal en el paisaje alrededor del hogar,especialmente en terrenos agrícolas y comunales, podría ser importante para asegurar el acceso ininterrumpido a los posibles beneficios que los alimentos silvestres y del bosque ofrecen para la salud.

6.2 Introduction

Human and ecosystem health are integrally linked, in part through the contributions both wild (non-domesticated) and cultivated (domesticated species and crop varieties) biodiversity make to human health by improving food security and nutrition. The role of agricultural biodiversity in improved dietary diversity and human nutrition is increasingly well established (CBD 2006; Johns and Sthapit 2004). Many authors assert the importance of forests and the biodiversity they provide for food security and nutrition (Colfer et al. 2006; Johns and Maundu 2006; Vinceti et al. 2008); however, empirical documentation of these relationships remains scarce. Tree products from forests and agroforests have been suggested to be important in times of food insecurity (Falconer 1990). While the consumption of bush meat is often in conflict with conservation objectives, it is an important part of many local diets (Fa et al. 2003; Nasi et al. 2008; van Vliet and Nasi 2008). Colfer and colleagues (2006) note that there are likely no contemporary communities in the world which wholly depend on wild gathered food, but that for most communities living in or near forests, these foods make important contributions by supplying micronutrients (e.g. vitamins A or iron) often deficient in food from agricultural and purchased sources, and by providing a safety-net in times of food insecurity. In many settings, the poorest members of the community are also the most dependent on forest resources (Colfer et al. 2006; Harris and Mohammed 2003).

Global malnutrition is increasingly attributable to insufficient micronutrients (vitamins and minerals), as opposed to lack of protein and energy. Micronutrient deficiency is associated with growth failure, impaired cognitive development and physical fitness, decreased ability to work, weakened immunity and increased risk of chronic disease (UN-SCN 2004).

Concerns about sustainability of harvesting, even for plant-based forest resources, have in the past often meant that conservation priorities override the importance of forest ecosystems for local nutrition. Over the past two decades, the development of the field of landscape ecology has led the global conservation community to recognize the need to understand the role of humans in landscape level processes, and to approach trade-offs between human and ecosystem health in a more holistic manner (Wiens 2009). Understanding the importance of foods from different land use types (forest, fallow, farm) to the diets of local populations sheds light on the drivers of human actions across landscapes and highlights links between forest conservation, well-being and livelihoods (e.g. (Chomitz 2007). Using a landscape ecology approach, incorporating humans as part of the ecosystem (Pfund 2010; Sayer et al. 2007), this study seeks to understand the synergies and trade-offs between livelihoods and forests in the East Usambaras by addressing the following three questions: What is the contribution of wild food species (both plant and animal) to the local diet? What is the importance of different land use types in the diets of local people? How does forest use and tree cover in the landscape specifically relate to the local diet and consumption of wild foods?

6.3 Methodology

6.3.1 Study site – East Usambara Mountains, Tanzania

In north-eastern Tanzania, the East Usambara Mountains rise from 200m to over 1200m and receive an average of 1500mm of rain annually (data from 2007–2009). Part of the Eastern Arc Mountains, the East Usambaras are renowned for a high concentration of endemic species (Burgess et al. 2007), and have been identified as one of the world's most threatened forest ecosystems (Myers et al. 2000), with deforestation prevalent throughout the area's unprotected forests (Dewi and Ekadinata 2010; Hall et al. 2009). The area contains moist tropical montane forest above ~600m and some of the last remaining but ecologically important lowland montane forest in East Africa (Brooks et al. 2002). Forest in the East Usambaras exists under varying degrees of protection, although most lies within government reserves. The East Usambaras encompass some of the oldest protected areas in East Africa; these have historically excluded local people from management and decision making and placed major restrictions on use by local people. Recently there have been significant efforts to decentralize forest management in Tanzania, including in the East Usambaras, where both joint forest management and community-based forest management have been initiated (Rantala 2010; Vihemäki 2005). Despite these efforts aimed "to promote and facilitate active participation of people in sustainable planning, management, use and conservation of forests" (Vihemäki 2005) access to forests under various types of protection for food (and other resources) remains limited (some deadwood collection has long been allowed in even the most highly protected areas) (Rantala 2010).

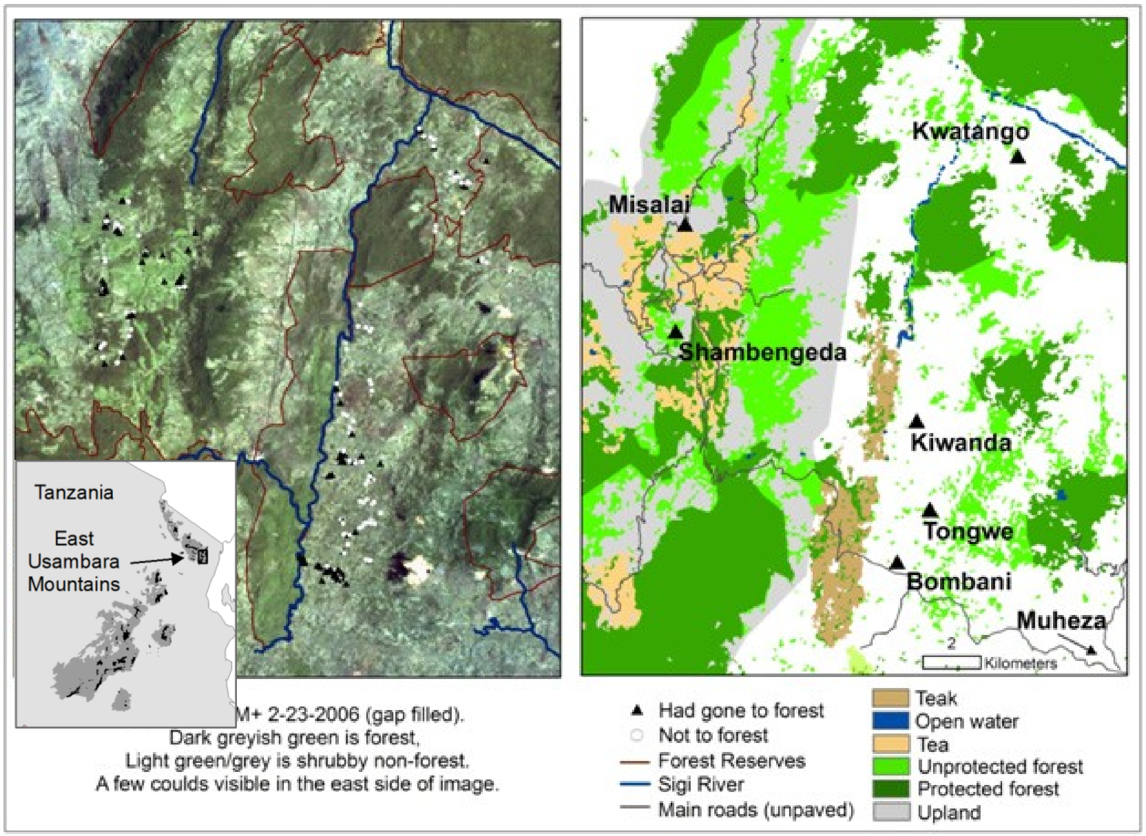

Figure 6.1 Map of the East Usambara Mountains with surveyed households that reported having visited a forest in the previous month (marked with black triangles) and those that did not report a trip to the forest (marked with white dots). Villages marked at location of village office

Although the Usambara Mountains get their name from the Wasambaa (Shambaa) people who make them their home, the East Usambaras have always been culturally diverse; home to the Zigua, Bondei, and Digo ethnic groups as well as (Willis 1992). The ethnic groups of the area have historically inter-married, a tradition which continued as the area experienced significant in-migration of people looking for employment in the tea and timber industries. Ethnic intermixing in the area was further enhanced by nationalistic (and anti-tribal) values promoted by the Tanzanian government under Nyerere (1964–1985) (Yeager 1989). With a population density of 61 people per square kilometre in the East Usambaras, both population density and population growth are higher than most other biodiversity hotspots and the global average (Cincotta et al. 2000; Tanzania 2002). Local livelihoods are based primarily on subsistence agriculture, supplemented with cash crops and wage labour (Kessy 1998). Wild or uncultivated foods have long been important in the diets of the Wasambaa (Feierman 1974; Fleuret 1979). People in the area use a high diversity of traditional vegetables and a higher ratio of wild to cultivated vegetables compared to other parts of Tanzania (including Arumeru, Singida and Kongwa) (Keding et al. 2007; Weinberger and Swai 2006). Malnutrition, especially vitamin A and iron deficiencies, have been found to be a problem in the area (Mulokozi et al. 2003). A study in the East Usambara lowlands[1] in 1994 found 60% of children between 7–12 years old to be stunted (Height-for-Age Z score ≤−2), 35% wasted (Weight-for-Height Z score ≤ -2), and 49% of children to be anaemic (Hb≤110g/L), with high rates of parasite infection (Beasley et al. 2000).

Six rural villages in Muheza district (southern East Usambaras) were selected for this study using stratified sampling based on road access and two elevation categories – upland (>500m) and lowland (<500 m) (Figure 6.1). Villages consists of hamlets or clusters of houses made mostly of poles and mud, mud brick and occasionally cement, with thatched or tin roofs. In the lowlands, Bombani village, 13.5km from the urban centre – Muheza town – and at a junction of the main road leading into the uplands and a smaller one to the lowlands, has regular public transit and significant opportunity for wage labour (especially in the timber industry due to the near-by Lunguza Teak Plantation). Tongwe, and further Kiwanda, villages are spread-out along the secondary road from Bombani. Only one or two public transit vehicles travel this road per day, less in the rainy season, but because Tongwe is close, markets and wage labour are still quite accessible. Kiwanda is significantly more isolated, with households spread across a large area. Down Sigi River valley from Kiwanda lies Kwatango village. Kwatango has a even lower population density (although still high compared to some other tropical forests at 21 people per square kilometre) (Tanzania 2002) and limited accessibility by a different

[1] Villages of Misongeni, Ubembe and Kilometa Saba in Muheza District

road coming from the plains to the east (at the time of research this road was in extremely poor condition and frequently impassable during the rains). Public transit leaves Kwatango once or twice a week in good weather; most produce is taken at least part of the way to market on foot. Misalai and Shambangeda, on the Amani plateau (between 800 and 1100m elevation), were surveyed as the two upland villages. Although over 15km up the mountain from Bombani, they benefit from a road which is maintained by the government to ensure access to tea estates and the Amani Research Station. Public transit leaves twice a day, in virtually all weather, as well as vehicles carrying crops to markets. Both villages have high population density (Tanzania 2002), with hamlets squeezed between tea estates and protected government forests. Many inhabitants in both villages engage in wage labour on the tea estates as their only source of income, or in addition to agricultural activities.

6.3.2 Data Collection

Dietary Assessment: Approximately 45 households from each of 6 villages were selected using systematic sampling from a lists of households with children under 5 provided by village governments (in this case every 2nd or 3rd household was selected, or ~50% of eligible households, total N=270). Dietary intake information was collected for pairs of mothers and children between the ages of 2 and 5 years; the youngest child within the age range in the household was selected with their mother or primary caregiver (henceforth referred to as mothers). Women of childbearing age and young children are the most nutritionally sensitive members of a household both due to higher requirements and inadequate intake (Gibson 2005). The dietary data presented here were collected during the long rainy season from March to May 2009. Dietary data were also collected at the end of the dry season (September to October 2009), in three of the six villages. This paper presents only the data from the wet seasons because it was the period of the year with the highest rates of food insecurity, and highest use of wild and forest foods (Powell et al. forthcoming / Chapter 5), and because it allowed for larger sample sizes. Mothers responded to a qualitative 7 day food use questionnaire for their own and their child's dietary intake (from memory, with mothers consulting older child during interview). Nutrient intake information was collected for each child using two 24 hour recalls on non-consecutive days. A Mean Adequacy Ratio (MAR) for 11 nutrients (protein, thiamine, riboflavin, niacin, B_{12}, vitamin A, vitamin C, calcium, iron, zinc and magnesium) and a score of nutrient density across 12 nutrients (above plus fat) was calculated (Dubois et al. 2000). Despite the error associated with human memory, most dietary information is collected by recall; for preschool children data are collected from a caregiver (Livingstone and Robson 2000). The source of each food item consumed was recorded and the relative contribution of foods from each source (forest, farm, purchased, etc.) to dietary diversity calculated. Dietary diversity is defined here as the number of unique foods consumed in a given period (here 7 days), although it has been measured many different ways (Ruel 2003). Dietary diversity is believed to be a strong marker of diet quality because diversity enhances the likelihood that sufficient quantities of all nutrients are consumed and decreases the likelihood that large quantities of any one potential toxin are consumed (Gibson et al. 2000, Johns and Sthapit 2004). Dietary diversity has been linked to higher nutritional status of children and adults, higher micronutrient intake and adequacy and improved food security (Arimond and Ruel 2004, Ruel 2003, Torheim et al. 2004).

Forest Cover and Biophysical variables: The location of each household was recorded using a hand held GPS 60CSX (Garmin™). Geographic Information Systems (ArcGIS9.2) was used to analyze aspects of the landscape in proximity to each household. Tree cover was determined using a Landsat eTM+ gap filled image (30m resolution, Row 166, path 064, Feb. 23, 2006) and a SPOT satellite image (10m resolution, Feb. 17, 2007). Classification of the image was performed using a supervised maximum likelihood algorithm using ERDAS imagine software in 2008 by Jaclyn Hall in association with the CIFOR-ICRAF Landscapes Mosaics project (Hall 2009). A Normalized Difference Vegetation Index (NDVI) of photosynthetic activity was created using the Landsat red and near infrared spectral data. NDVI is commonly used to represent productivity and is significantly related to the phosynthetically active leaf area across different land covers (Carlson and Pripley 1997, Jensen 1996). NDVI is a measure of growing season productivity, which is different from forest. Total area of tree cover and average NDVI value (Average Leaf Area) for the area in proximity to each household was determined for circular areas around each household with radii of 1.0, 1.5 and 2.0km.

Forest Use and other Household variables: Questionnaires conducted with the head of each household covered education, assets, source of income, participation in wage labour, land use, forest use and agricultural practices of the entire household. Household wealth was assessed using community-based ranking in which a group of community leaders were asked to reach consensus on the wealth rank of each of the households in the study (based on their own set of criteria including: livelihood, housing, health and diet, education, clothing, travel, among others). This measure of wealth was chosen over asset based ranking because it was holistic and better able to incorporate more diverse and nuanced factors than the asset based ranking.

Data Analysis: Survey data were analyzed using SPSS Student Pack 18. Groups were compared using Chi-squared and Independent t-tests. Multivariate analysis compared groups using logistic regression.

6.4 Results

6.4.1 Wild and Forest Foods in the Diet

6.4.1.1 Sources of Food

A total of 202 unique food items were used by all households in the six villages, including 10 staples (including maize, cassava, banana), 38 species of fruit, 53 species of vegetables, 9 mushrooms (identified only by vernacular name), 45 animal sources foods (including fish) and 41 other items (mostly purchased items such as salt, sugar, oil, spices, drinks and snacks). The mean dietary diversity (number of food items consumed within the last 7 days) was 38.4 for mothers and 39.3 for children (with normal distributions and no differences between children and mothers). Sources of food recorded included: purchased foods (store, market, vendor, local restaurant); farm, garden and fallow (combined because use of these terms and their definitions were inconsistent across informants); gift (including foods consumed at a friend's house or a funeral); and foods from forest or non-farm land (river, forest, bush).

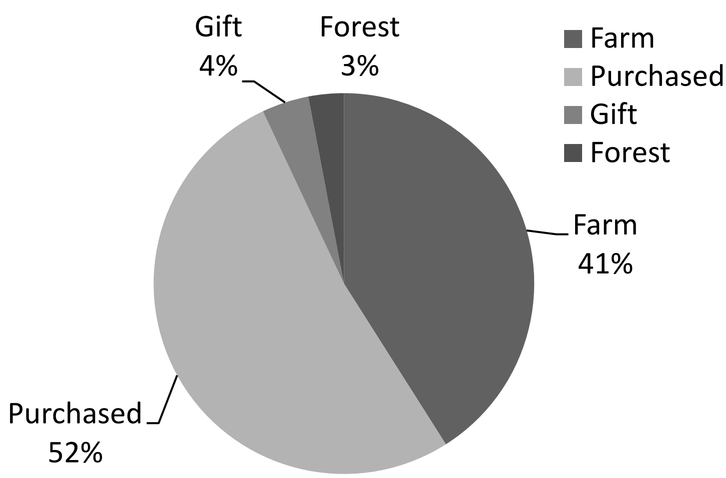

Figure 6.2 Sources of all food items (average of mothers and children)

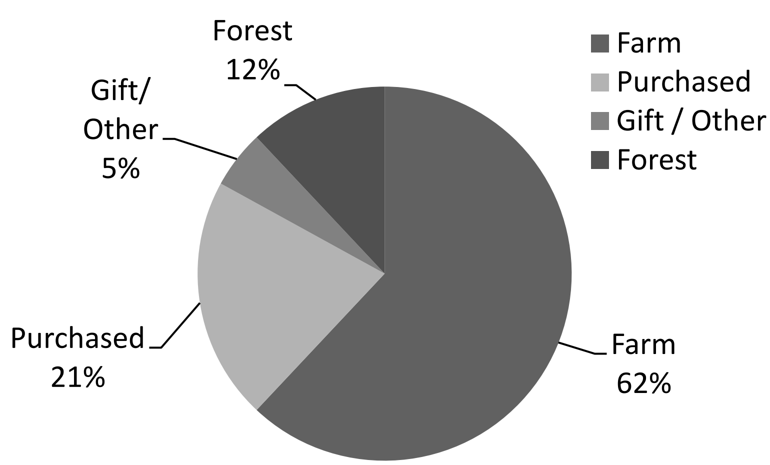

Figure 6.3 Sources of wild food species (average of mothers and children)

An average of 51.9% of food items were purchased, 41.1% were obtained on farm and only 2.6% were obtained from forest (and un-cultivated land) (Figure 6.2). However, wild or uncultivated species (regardless of reported source) accounted for a much higher percentage of the diet (15.4%) than foods that respondents reported were obtained from the forest / non-farm land. Many (61.7%) of these wild species were obtained from areas considered part of farmland, rather than areas considered forest (Table 6.1, Figure 6.3). Of the 53 species of vegetables consumed, 41.5% of them were cultivated (domestic) and 58.5% were wild uncultivated species.

Table 6.1 Dietary diversity, mean percent of food items from forest, purchased, gifts, farm and wild species, and sources of wild species food items for mothers and children

	Mother (N=269)		Child (N=269)	
	Mean ±SD	Min-Max	Mean ±SD	Min-Max
Dietary Diversity (number of items)	38.4 ±11.6	14-81	39.3±11.7	15-80
Percent- Reporting ≥1 items from the FOREST (%)	44.6	-	45.4	-
Percent of Food Items PURCHASED (%)	51.4 ±12.9	25.8-91.7	52.4 ±12.5	25.8-91.7
Percent of Food Items from GIFTS (%)	4.6 ±6.3	0-45.0	4.9 ±6.8	0-50.0
Percent of Food Items from FARM (%)	41.6 ±12.2	5.0-68.3	40.5 ±12.2	5.0-66.7
Percent of Food Items from FOREST (%)	2.6 ±4.0	0-23.9	2.5 ±3.7	0-22.8
Percent Food Items from WILD SPECIES (%)	15.4 ±5.4	-	15.3 ±5.2	-
Percent of WILD SPECIES: PURCHASED (%)	22.1 ±22.5	0-100	20.7 ±21.2	0-100
Percent of WILD SPECIES: from GIFTS (%)	2.5 ±7.8	0-50	3.8 ±10.4	0-80
Percent of WILD SPECIES: from FARM (%)	61.6 ±24.7	0-100	61.9 ±25.2	0-100
Percent of WILD SPECIES: from FOREST (%)	12.5 ±16.8	0-61.5	12.0 ±16.3	0-63.6

Figure 6.4 presents the differences in wild species foods versus foods obtained from forest / non-farm land by food type; while the majority of wild bird (83.3%) and mammal (80%) species consumed are obtained from the forest, most of the wild species of vegetables (70%), mushrooms (62.5%) and fruit (50%) were obtained within farm land (including fallow and agroforests). Data for Figure 6.4 were calculated from the list of all food items consumed, by counting the number of wild species and the number of items that respondents reported as obtained from the forest (>10% of the time).

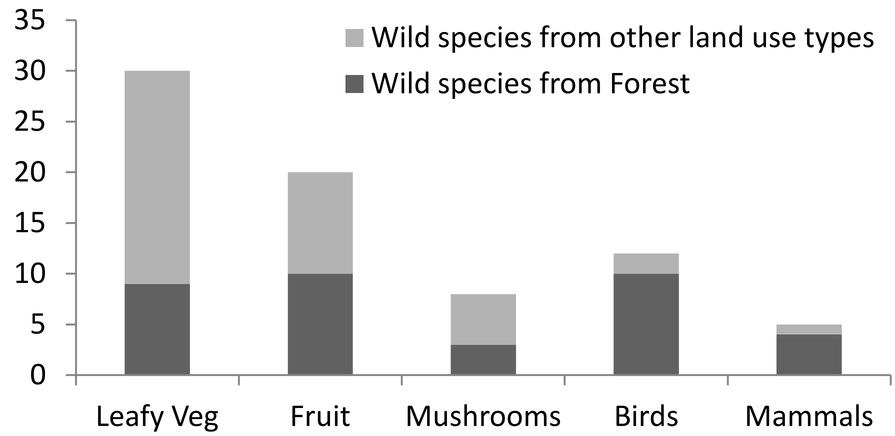

Figure 6.4 Total number of wild species from the forest and other land use types used by all surveyed households, by different food types

6.4.1.2 Percent of Diversity Used

Community level diversity (Table 6.2) was defined as the total number of food items used by the communities as a whole (represented by all individuals included in the survey). The 'primarily source' of each food item was determined as the most common source reported for each food item (used because most food items were obtained from different sources by different households and wild species came from many sources). The percent of diversity used for food from each source was calculated as the mean individual dietary diversity from that source divided by the community level diversity of foods primarily obtained from that source, and is assumed to be approximately equal to the percent of available diversity used.

The higher the percent of diversity used, the more similar individuals were to each other in terms of food items consumed from that source. Table 6.2 shows that the percent of diversity used was 30% for purchased foods and 15% for food from the farm, indicating that individuals used many of the same purchased foods, but were less similar in their use of foods from the farm. Percentage of diversity used was very low for wild species (6.7%) and foods from forests (3.8%) indicating large variation from one individual to the next in terms of species used from these sources (few food items in common).

Table 6.2 Community level diversity, mean individual dietary diversity and percent of (available) diversity used for all foods and different types of foods

Source	Community level diversity	Mean individual dietary diversity	Percent of diversity used
TOTAL (All sources)	202	39	19.3%
Purchased	69	20	29.0%
From Farm	106	16	15.1%
From Forest	26	1	3.8%
Wild Species	91	6	6.7%

6.4.2 Diet, Forest Use and Forest Cover

6.4.2.1 Forest Food Use

Only 44.6% of mothers and 45.6% of children were reported to have consumed one or more foods obtained from the forest in the past 7 days (Table 6.1). Compared to those not reporting use of forest foods, those reporting use of foods from forest / non-farm land had higher tree cover within 1km, 1.5km and 2km radii around their homes. The percent of mothers and children reporting use of foods from the forest was significantly higher in the lower elevations[2]. Table 6.3 displays only results for the 4 lowland villages.

Mothers and children who used foods from the forest had significantly higher dietary diversity, consumed a greater number of animal source food items, obtained a lower percentage of their food by purchasing and a higher percentage of their food from wild species (Table 6.3). Children who consumed forest foods had a higher nutrient density score (Student's t-test p=0.045, 39.0 vs. 36.2 for those not using forest foods), and a higher but statistically insignificant mean nutrient adequacy ratio (MAR) (Student's t-test p=0.114, 0.781, vs. 0.753 for those not using forest foods).

[2] Likely in part due to the ecological differences between the dense humid upland forest and more open the lowland forest types

Those who reported use of forest foods were not different from those reporting no use in terms of wealth[3], wage labour participation, acres owned, age of mother, education, size of household or ethnicity (all elevations and low elevation only).

Table 6.3 Differences in characteristics for mothers and children using and not using foods from the forest for lowland villages

Characteristics	Mothers		Children	
	Using Forest Foods (N=93)	Not using Forest Foods (N=91)	Using Forest Foods (N=92)	Not using Forest Foods (N=92)
Dietary Diversity (Count)	39.5±11.6	36.0±11.3*	40.2±11.5	37.1±11.0^(1)^
No. of Animal Foods Used	6.3±2.7	5.2±2.6*	6.3±2.6	5.3±2.6*
Percent of diet Purchased	44.5±10.1	54.3±12.3**	46.2±9.6	54.8±11.6**
Percent from Animal Foods	15.7±4.4	14.1±4.9*	15.5±4.5	13.8±4.4*
Percent from Wild Species	18.6±6.0	13.3±5.1**	19.0±5.4	13.4±4.8**
Leaf Area 200m (Average)	3.09±0.35	2.82±0.46**	3.07±0.35	2.79±0.47**
Forest Cover 1.0km (ha)	236.7±169.3	158.6±123.1**	233.0±169.1	163.1±126.5*
Forest Cover 1.5km (ha)	793.7±527.3	527.3±304.7**	788.7±515.3	535.3±308.0**
Forest Cover 2.0km (ha)	1785.8±1044.0	1343.4±595.6**	1768.9±1045.1	1365.1±614.0*

* statistically significant in an independent t-test p<0.05

** statistically significant in an independent t-test p<0.001

(1) p=0.061. When both upland and lowland villages are included in the analysis, children reported to have used forest foods had significantly higher dietary diversity than those not using forest foods

However, in addition to elevation, a couple of other potential confounding variables were identified. There was a trend for childrens, but not mothers, reporting use of forest foods to be more likely to come from a male headed household (Chi squared test for low elevation villages mothers p=0.48 and children p=0.057). The percentage of mothers and children who reported using foods from the forest was significantly different among villages [higher in Kiwanda (71%) and Kwatango (81%) than in Misalai (30%) and Shambangeda (39%), Bombani (24%) and Tongwe (25%)]. It is impossible to determine which of the differences between villages are responsible for the observed differences in forest food use; however a number of characteristics of Kiwanda and Kwatango merit consideration, including their greater isolation, lower access to wage labour and lower population densities (Tanzania 2002). In multivariate logistic regression analyses with forest food use by mothers or children as the dependant variables, controlling for village

[3] Using asset based wealth ranking there is a trend for children who had used forest foods to be from less wealthy households (but not mothers)

and elevation, amount of tree cover within 1.5km from the house made a significant addition to the model but gender of the head of household and wealth did not (for mothers using forest foods to those not $R^2 = 0.324$, $p<0.01$ (of change from adding tree cover), N=260; and for children using forest foods to those not $R^2 = 0.297$, $p<0.05$ (of change from adding tree cover), N=254).

6.4.2.2 Trips to the Forest

Of household heads in all 6 villages, 67.4% reported having visited the forest within the last year, 46.4% within the last month and 33.8% within the last week. The average number of trips for respondents who had gone to the forest in the last month was 8.1±8.6 and the last week was 3.0±2.0. Household heads from upland villages reported significantly more trips to the forest than households from lowland villages (past year 75% upland vs. 63% lowland, past month 60% upland vs. 40% lowland, and past week 45% upland vs. 30% lowland).

In the lowland villages, households reporting trips to the forest had lower tree cover within a distance of 1.0, 1.5 and 2.0km from their homes, but greater area of teak plantation. They also had significantly less unprotected forest within a 0.5km radius of their homes (Table 6.4). These relationships can be seen clearly on the map (Figure 6.1). These findings are likely linked to the interpretation of the word forest, as explained below.

Dietary intake was related to reported trips to the forest in a number of unexpected ways. In the lowlands, individuals from households who reported visiting the forest had significantly lower dietary diversity than those that did not report visiting the forest. Individuals from households who visited the forest obtained a lower percentage of their diet from the farm and a higher percentage from purchased sources. Additionally, individuals from households who visited the forest consumed fewer types of animal foods and borrowed food more often than those from households who had not visited the forest. Those from households who reported trips to the forest (across most time periods) also obtained a lower percentage of fruit, fish and animal foods from the forest, consumed fewer wild species and tended to be less likely to use forest foods. This is likely due to the strong relationship between trips to the forest, wage labour and wealth in the lowlands. The 50 year old mature teak plantation is considered forest by local people and was being actively harvested during the study period.

Table 6.4 Differences between households visiting the forest and those not, for tree cover, teak plantation cover, unprotected forest and leaf area for lowland villages only

Land cover Characteristics	Forest in last year		Forest in last month		Forest in last week	
	YES (N=116)	NO (N=68)	YES (N=74)	NO (N=110)	YES (N=56)	NO (N=128)
Leaf Area 200m (Average)	2.88	3.02*	2.73	3.06*	2.70	3.03*
Forest Cover 1.0km (ha)	163.0	256.3**	146.6	231.7**	133.5	225.5**
Forest Cover 1.5km (ha)	550.2	849.3**	512.3	760.6**	470.8	743.9**
Forest Cover 2.0km (ha)	1341.4	1946.7**	1237.6	1785.4**	1144.9	1749.0**
Teak Cover 1.0km (ha)	194.9	38.7**	253.9	58.6**	275.1	76.8**
Teak Cover 1.5km (ha)	614.6	180.2**	782.3	233.2**	832.1	288.6**
Teak Cover 2.0km (ha)	1371.0	443.9**	1665.2	600.0**	1755.5	710.3**
Unprotected Forest 500m (ha)	2.38	4.60**	1.72	4.19**	1.61	3.89**

* statistically significant in an independent Student's t-test $p<0.05$

** statistically significant in an independent Student's t-test $p<0.001$

Individuals from households who had visited the forest in the previous week or month were significantly less wealthy than those who had not (high and low elevation). Chi squared tests showed that those who reported trips to the forest were more likely to engage in wage labour (for high and low elevation, in the last week, month and year $p<0.01$). In the upland, those who engaged in labour on the tea estates were more likely to report trips to the forest (for all study periods). In the lowland, those who engaged in wage labour in the timber industry were more likely to report trips to the forest in the last week and month. Compared to households who did not report trips to the forest (at all elevations), those reporting trips to the forest tended to be less likely to have been born locally (possibly because most immigrants to the area engage in wage labour), to own fewer acres of land and spend fewer hours in the farm; however, there were no differences between ethnic groups nor male and female headed households. In logistic regressions with 'visited the forest in the last year or month' as the dependant variables, controlling for elevation and wage labour in the tea or timber industry, tree cover within 2km from the house and whether the household members had been born locally made significant contributions to the model. With 'visited the forest in the last week' as the dependant variables, wealth and tree cover within 2km were the variables added to the model in forward (stepwise) conditional analysis.

6.5 Discussion

6.5.1 Limitations of the Study

The complexity of the data and the many potential confounding variables meant that this study was only able to identify associations between variables. The collinearity between variables and the cross-sectional study design (rather than longitudinal), prohibit conclusions about causality. While the methodology section notes limitations of dietary assessment methods, alternatives such as anthropometric and biochemical measures of nutrition can be even more problematic in settings where parasitic infection rates are high, such as the East Usambara Mountains (Semba and Bloem 2008). Given the local history of forest policy and governance, reporting may have been biased by hesitancy to disclose illegal forest use / activities. The fact that this study only describes relationships in the wet season, the season with the greatest use of wild and forest foods, could mean that they differ during other times of the year. Further research, especially longitudinal studies examining the impact of changes in forest cover and access over time on the use of forest foods and nutrition would improve the current state of knowledge. Although the relationships described herein remain unsubstantiated their potential implications for policy and practice provide food for thought for conservation researchers and practitioners.

6.5.2 The Importance of Forests and Wild Foods in Contemporary Diets

Although the Shambaa people historically obtained much of their starchy staple food items from agriculture, Feierman (1974) and Fleuret (1979) suggest that much of the leafy vegetables and meat in the traditional diet were obtained from wild sources. Over 30 years later, wild foods, accounting for 15% of the items in the diet, still make a significant contribution.

Of the wild species consumed (from any source) 40% were vegetables, 27% were fruit, 23% were small mammals and birds, and 11% were mushrooms. Of the items obtained from the forest 39% were birds and small mammals, 28% were fruit and 25% were leafy vegetables (figures and total do not include wild fish species / fish from wild sources, e.g. rivers) (Figure 6.4). Because fruits, vegetables and animal source foods are important sources of micronutrients, even in small amounts they make an important contribution to local diets. These types of foods, compared to starchy staples and snack foods obtained through agriculture or purchasing, have higher density of most micronutrients relative to energy, carbohydrates and sugars. Data on the nutrient composition of wild foods are lacking so direct comparison between wild and non-wild fruits or vegetables is difficult (and impossible for animal source foods). Moreover, nutrient content of all fruits and vegetables can be extremely variable depending on variety, climate, ecology, harvest and storage factors. Msuya and colleagues (2008) found high variation in iron, zinc and beta-carotene content of wild vegetables harvested from different regions in Tanzania. In the East Usambaras they found high levels of these 3 nutrients in wild vegetables (compare for example the three most commonly consumed wild vegetables *Launaea cornuta*, *Corchorus olitorius* and *Bidens pilosa* with beta-carotene 6800, 6310, 2320 µg/100g, iron 9.9, 4.2, 12.05 mg/100g and zinc 0.579, 0.196, 0.484 mg/100g values respectively to the three most commonly consumed cultivated vegetables *Amaranthus* spp., sweet potato leaves and pumpkin leaves with beta-carotene 5716, 5870 and 3600 µg/100g, iron 2.3, 0.5, 0.6 mg/100g and zinc 0.6, 0.2, 0.1 mg/100g values respectively).

Rural African diets are notorious for the high percent of energy obtained from staples such as maize and cassava and low intake of animal source foods (Stephenson et al. 2010). The low intake of the latter leads not only to a low intake of protein but also to inadequate intake and low bioavailability of many micronutrients (Murphy and Allen

2003). Consumption of animal source foods (from domesticated animals or sustainably harvested wild mammals, birds or fish) is a preferred strategy for improving micronutrient status and therefore children's growth and cognitive development in developing countries (Murphy and Allen 2003). It is important to note that the wild animal species consumed in this study included two types of small antelope and two types of rodent[4]. Of the 16 reports of wild animal consumption, 10 were for *Thryonomys* spp. (a common small rodent). In another part of the Eastern Arc, the Udzungwa Mountains, populations of all mammals except *Thryonomys* spp. were found to be so depleted that the authors felt that no level of hunting could be sustainable (Nielsen 2006). It seems very likely that in the East Usambaras, faunal resources are similarly depleted and overexploited (possibly with the exception of *Thryonomys* spp.).

In this study population Powell et al. (Chapter 5) report that wild species contribute an average of 2% of daily energy intake, 2% of fat intake, 7.4% of protein intake, 19.2% or iron intake, 20% of vitamin C intake and 31% of vitamin A (in Retinol Activity Equivalents) intake. The finding here that, compared to those who had not, children who had consumed forest foods had higher nutrient adequacy (not statistically significant) and nutrient density across multiple nutrients further supports the contribution of wild and forest foods to nutrition.

6.5.3 Uncultivated Food Species from Cultivated Land

Although the results of this study do not allow for conclusions about the net trade-offs between agricultural intensifications versus maintaining biodiverse agricultural systems[5], they do show that biodiversity within agricultural land makes an important contribution to the local diet by way of the significant amount of uncultivated

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[4] Two households reported *digi digi* or *paa* (said to be the same species, *Rhynchotragus spp.*) and two households reported *funo* (probably a species of Duiker, *Cephalophus spp*.), all from the forest without specification (because hunting in reserved forests is illegal all informants would presumably claim to obtained animals from unprotected forests only). The exact species of antelope is impossible to determine due to error in informant identification, and importantly inaccurate reporting. The other species of rodent was *kuhe* (*Cricetomys gambianus*)

[5] Agricultural shifts towards specialized, intensified systems are often touted as key to development, however improved income does not always translate to improved diet and nutrition, see Kennedy 1989 and Dewey 1989

foods being collected on-farm (62%). Other research has similarly found a large portion of wild species obtained from agricultural land, coining these foods 'the hidden harvest' (Bishop and Scoones 1994).

Wild species from farm land included fruit from trees and shrubs growing in field margins and fallows, mushrooms from recently cleared fields, leafy vegetables from field margins and fallow areas, and many leafy vegetables which would otherwise be considered weeds growing among (and often competing with) newly planted maize and other crops. Micro-climates provided by diversity of land use on farms provide for a diversity of wild plant foods. A recent review of wild foods in agricultural systems by Bharucha and Pretty (2010) highlights the fact that labels of hunter-gather versus agricultural imply a false dichotomy in which wild foods are of limited importance in agricultural livelihoods. Most rural human populations engage in active management of useful wild species; in fact, many farmers do not make clear distinctions between cultivated and uncultivated (Bharucha and Pretty 2010). In the East Usambaras people tolerate (do not clear while weeding) wild leafy vegetables, such as mchunga (*Launaea cornuta*), in their fields and teach their daughters to harvest in a manner that ensures regeneration (Powell et al. 2010). Human activity in forested landscapes tends to increase the density, diversity and/or value of plant, but not animal, species useful to humans (Ambrose-Oji 2003; Gavin 2004; Parry et al. 2009; Toledo and Salick 2006).

The importance of agricultural biodiversity for agriculture and conservation has been established (Sunderland 2011); although further substantiation is needed, the results of this study suggest that the maintenance of farms with biodiverse fallows, field margins and agro- and working forests could benefit human health and nutrition as well, through the provisioning of wild foods. Less than 25% of households in this survey reported having fallow land in the last 12 months (of those the average area was 1.8 acres for 1.5 years). Conservation efforts should focus on the landscape scale approaches; encouraging mosaics of forest, agroforest, fields and fallow within agricultural landscapes surrounding protected areas will likely enhance biodiversity and human health simultaneously (CBD 2006; Dudley et al. 2005; Hall et al. 2010).

6.5.4 Wealth, Time, Proximity of Forests and other Constraints on Use of Forest Species

Wild and forest foods are often suggested to be more important to poorer households (Colfer et al. 2006; Harris and Mohammed 2003), although these relationships are not always consistent (Ambrose-Oji 2003; Bharucha and Pretty 2010). In this study there were no significant quantitative associations between forest food use and wealth (assessed by community-based ranking); however, qualitative evidence suggests that cash availability is a contributing factor in the use of wild and forest foods: "Those leafy vegetables are in the farm and if today I do not have money it will force me to leave home and waste time and go to look for that vegetable so that it can fill that gap." Beatrice Akida (single mother and farmer in Tongwe village).

In many contexts, it is access, rather than availability that limits use of wild and forest foods. One important constraint on access is the free time required to collect wild and forests foods (Kuhnlein and Receveur 1996), mediated by travel time to reach the harvesting site and efficiency of harvesting. Although wild foods are free, they can be inaccessible when daily chores, livelihood efforts and / or wage labour take all of person's time and energy. In Cameroon, Koppert et al. (1993) found that due to women's time-demanding daily tasks, wild or forest foods had to be close to forest camps and in sufficient quantities to be included in the diet. In the East Usambaras wild and forest foods are used by many households when there is not enough available cash to purchase cultivated vegetables, dry fish or legumes. The period just before and during the rains is one of the most agricultural labour intensive (land preparation, planting and early weeding), but is also the period when higher wild food use was recorded. Conversely, despite low labour inputs in the post harvest period at the end of the dry season (when cash is readily available), households reported less use of wild and forest food resources at that time (Powell et al. forthcoming / Chapter 5). Although many species of wild foods, especially wild leafy greens, are less available in the dry season, there are many which persist in shaded field margins and wet areas (as well as many wild fruits which ripen in the dry season). This might suggest that free time and availability of wild and forest foods are not strong factors determining use in the East Usambaras. Of course if a household lacks available cash to purchase foods, but also has constraints on access to wild and forest foods (e.g. is far from the forest or has limited free time), this could preclude any increased use of wild and forest foods, even if the low percent of diversity used for wild and forest foods used suggests that these foods could make greater contributions to the diet. Lack of free time may underpin the finding that female headed households were less likely to use forest foods than male headed households (with a reduced adult work force they may not have the time needed to collect forest foods).

Other research has suggested that wild and forest foods are important as a 'safety-net' in times of hardship (Colfer 2008; Johns and Maundu 2006; Vinceti et al. 2008). In the East Usambara Mountains, this importance seems to be mediated by forest proximity (as households far from forests require more travel time to access forest foods). These findings suggest that maintaining forest cover around villages and homes may be necessary if forest foods are to remain in the diet, with important implications for village and household level land management.

6.5.5 Interpretation of Questions about Forests

In part due to the long and complicated history of forest research and conservation in the East Usambaras, local people have sensitivities to questions about forests and forest use (Vihemäki 2005). Rantala (2010) notes ". . . whenever a tree-dominated area is privately owned, even if it is left to regenerate as forest, it is still called shamba (farm), not msitu (forest). . . . it is common that 'msitu' is only used to refer to a reserved area" such as a government or a village forest reserve. The conservation history in the region has created significant hesitation to admit use of forests; however, this varies from person to person (Vihemäki 2005). The vegetation cover local people refer to as forest (or non-farm land) when women report where a food product has been obtained is likely more closely related to scientific definitions based on vegetation structure or canopy cover. Conversely, questions about 'visiting a forest' conjure ideas about places that are reserved or officially protected, similar to Rantalla's (2010) description. The strong association between wage labour and reported trips to the forest in this study may be related to the fact that wage labour provided legitimate reasons to visit government owned forests. In the lowlands the timber industry provided the majority of wage labour, and in the uplands the tea industry workers often passed through tea estate or reserved forests to reach harvest locations. Had harvesting of the mature teak forest not been underway at the time this study was conducted, results may have been quite different. Vihemäki and colleagues (forthcoming) suggest that historic forest management practices, in which local people had restricted access to forests and no involvement in management and decision making, led to local people's unwillingness to use forest products (forests are seen as a place where illegal activities are undertaken), and that this an important factor in the limited forest food use in the area. Vihemäki and colleagues (forthcoming) describe the current forest management regimes (including joint forest management and community-based forest management of village forests) in the area and the use rights to forest foods associated with each, and note that despite efforts to decentralization forest management local people perceive a major decrease in the importance of the forest as a source of food. Within the framework of these local definitions, two possible conclusions can be drawn from the finding that those who reported visits to the forest had lower area of tree cover and less unprotected forest within a close proximity of their houses. Firstly, the relationship could simply be an artefact of the fact that lowland households who engaged in wage labour lived in areas with less unprotected forest cover nearby; alternatively (or additionally) this finding could suggest that households in areas with greater area of tree cover within the agricultural mosaic obtained subsistence products from treed land which they did not consider forest (such as agroforests, farms and fallows). Households in the uplands, where there was significantly greater tree cover, were more likely to report visiting the forest and yet fewer of them used forest foods. The significantly higher average leaf area and amount of unprotected forest around households not visiting the forest compared to those that did reported visiting the forest lends support to the latter conclusion (see Table 6.4).

6.6 Conclusion

The food-security and nutrition situation in Tanzania remains discouraging. Recent improvements in children's growth rates have not changed the fact that rates of stunting in Tanzania are still among the highest in the world and that micronutrient deficiency remain a major problem (UN-SCN 2004). Globally, Tanzania is one of the lowest ranked countries in terms of percent caloric intake from fats and simple sugars (Millstone and Lang 2003); however a nutrition transition from a traditional diet to a diet high in processed foods, salt, sugar and fat has begun. Because of this, communities may face increased rates of obesity and chronic diseases (such as type II diabetes and hypertension) before overcoming food insecurity and micronutrient deficiency (Maletnlema 2002). Research from the 1970's suggested that at the time a transition had begun (Fleuret and Fleuret 1980), and the high percentage of foods purchased in this study (even in Kwatango, the most remote village) demonstrates that this trend may be becoming ubiquitous. Overcoming micronutrient malnutrition and mitigating the nutritional transition simultaneously will require diets rich in micronutrients but without excess energy, fat, sugar or salt. Many forest and wild foods, especially those of plant origin, meet these criteria and could play an important role, especially if appropriate and timely nutrition education can ensure that they are consumed in place of increasingly accessible processed and fried foods. The contribution of wild and forests foods to dietary diversity may support local people's nutritional resilience in the face of social-cultural, economic and environmental change.

The findings of this study show that in the East Usambaras use of forests for food resources by local people is currently limited, but use of wild species is higher, primarily obtained from the farm. Households with greater tree cover in close proximity are more likely to consume wild and forest foods even while reporting fewer visits to protected forests, underscoring the importance of tree cover and fallow within the agricultural mosaic.

Food plays a central role in cultural and personal identity and fulfils multiple symbolic and cultural functions (Khare 1980; Kuhnlein and Receveur 1996); promoting the cultural importance as well as health and nutritional benefits of forests foods (and the maintenance of the traditional food system) may provide impetus for conservation-positive actions by local communities, people and governments. As population densities in the rural landscapes of Africa continue to increase forest remnants are being reduced and eliminated, as are fallow length and area in the agricultural landscape. Health is one of the strongest motivators for people; the health of their families is a particularly high priority for women, who bear the burden of care of ill family members (Wan et al. 2011). In a setting where participatory strategies for engaging local people in conservation have been only partially successful (Vihemäki 2005), the results of this study linking forest cover, forest food use and nutrition offer potential motivation for local people to maintain forest cover within the landscape mosaic. As paradigms in forest conservation shift, it is important to not lose sight of the importance of forests for human diet and nutrition.

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Preface to Chapter 7

The theoretical framework and methodological approach taken herein have strengths and limitations; these are discussed at the beginning of this final chapter. The contributions of this dissertation to methodological advancement are discussed. The majority of this chapter is dedicated to a discussion of how this dissertation builds on existing evidence demonstrating the ways that biodiversity contributes to human nutrition, in the East Usambara Mountains and beyond. Contributions of wild and forest biodiversity, and, biodiversity from agricultural ecosystems, are delineated. Dietary diversity as a pathway between biodiversity and human nutrition is critically reviewed and evidence of the importance of biodiversity for nutrition from different spatial and temporal scales is synthesized. A few of the mediators of these relationships that are most pertinent to this research are examined. The chapter finishes with some comments on the relevance of this dissertation to policy and practice, provides suggestions for future research and reviews the broad implications for conservation and human health.

Chapter 7
Discussion and Overall Conclusions

Bronwen Powell

7.1 Strengths and Limitations of the Approach

As highlighted in the introduction (Chapter 1), evidence of the links between biodiversity and human nutrition can be drawn from diverse material, settings, scales and approaches. The benefits of biodiversity for dietary intake and nutrition can accrue through: multiple ecosystem services provided by biodiversity and forests (Millennium Ecosystem Assessment 2005); a supporting role in agricultural systems and direct contribution of agricultural diversity to diet and nutrition (Frison et al. 2011, Harden et al. 2000); the consumption of wild foods from farms and forests (Nasi et al. 2008, Ogle et al. 2001); and to social and cultural aspects of local or traditional food systems (Greenberg 2003, Kuhnlein and Receveur 1996).

The search for empirical evidence linking biodiversity and human nutrition is plagued by methodological limitations. Relative to the complexity of biocultural systems and the many mediators of relationships between biodiversity and human nutrition, current methods are lacking. Recent efforts to improve methodologies include: the Biodiversity Indicators Partnership coordinated by the World Conservation Monitoring Centre of the United Nations Environment Programme (UNEP-WCMC); the Expert Consultation on Nutrition Indicators for Biodiversity (FAO 2008, FAO 2010a), efforts by experts at Bioversity International (Fanzo et al. 2011), as well as material covered in Chapter 3. Progress has been made, but there is still a long way to go. The complexity of biocultural systems is the reason many researchers have called for systems approaches, as well as why many projects are able to provide only fragmented empirical demonstration of relationships and are thus dependant on qualitative descriptive evidence. The systems approach and the qualitative data collected in this research have helped bridge the fragmented relationships demonstrated quantitatively herein. This study has been improved through the inclusion of a wide range of evidence, and the inclusion of descriptive data and local perspectives of relationships.

Research examining relationships between biodiversity and human nutrition should continue to be pursued and promoted; longitudinal study-designs allowing for better demonstration of relationships are particularly needed. For the time being, we are obliged to accept that a quantitative understanding of the whole puzzle in any one setting may be beyond the capacity of currently-available methods.

7.1.1 Capacity Building and Other Outputs

Many systems approaches (and especially the EcoHealth Approach) call for full participation of local populations in research. In addition to enhancing awareness and capacity of communities, the participatory approaches make significant contributions to research outcomes. As part of their participation in the identification of research goals and priorities, communities identified road conditions and road access as one of their key problems. Contrary to their expectations, data (not presented herein) showed that in a comparison of the 4 lowland villages, mean use of purchased food was higher and mean overall nutrient adequacy (MAR) and nutrient density was lower in villages with greater road access (tested in a ANOVA comparison between villages) (Powell et al. forthcoming-b). Chapter 6 (Manuscript 4) showed that an average 52% of food items consumed were purchased and Chapter 3 (Manuscript 1) presented data showing that lower percentage of food items purchased contributed to a multi-variety model for improved children's overall nutrient adequacy (MAR). The percent of items in the diet from purchased sources and percent of energy from purchased sources were highly negatively correlated with overall nutrient density score ($r = -0.305$; $p < 0.001$) and overall nutrient adequacy (MAR) ($r = -0.176$; $p < 0.01$) in diets of children in the wet season (Powell et al. forthcoming-b). These findings would have been overlooked if the communities had not been involved from the outset of the research project.

The results of this research have begun to be returned to communities (Appendix 1) and the researcher(s) up-hold the ethical imperative to continue this process. Results that are returned will hopefully empower communities through supporting the realization of adaptive solutions for nutrition which draw on locally-available resources.

This research has also helped to ensure that local agricultural and forestry researchers and practitioners gained greater awareness of issues of diet and nutrition (e.g. through collaboration with TFCG, AVRDC and local ministry of Agriculture and Livestock), furthering efforts to ensure that nutrition is a priority across disciplines and administrative sectors. Finally, this research will contribute to the growing body of research in the East Usambaras and could potentially be used as a base-line for future research tracking longitudinal changes in agricultural practice, deforestation and forest policy / access, and road access and market integration on diet and nutrition.

7.1.2 Methodological Advancements

Chapter 3 (Manuscript 1) showed that some but not all measures of dietary diversity were positively associated with children's intake and adequacy of most nutrients and MAR, but that most of these relationships were primarily due to colinearity with energy intake (relationships became non-significant or negative when energy was controlled for). Chapter 4 (Manuscript 4) provided further support for the importance of dietary diversity for appetite, food intake and thus overall nutrient intake. Both Chapters 3 and 4 provide novel perspectives on the mediators of the relationships between measures of dietary diversity and other measures of diet quality and intake, including the number of food groups used to calculate a DDS and role of dietary patterns (Chapter 3) and environmental, social and cultural factors (Chapter 4).

There is a problematic divergence between dietary diversity scores used in nutrition studies and those used in biodiversity studies. There is a trend in the nutrition literature to promote increasingly narrow dietary diversity scores (for example: DDS over FVS, 1 day study period over longer study periods and scores which impose minimum serving sizes) because they are easier to collect and analyze and are equally strong indicators of diet quality and nutrient adequacy. Conversely, much of the recent work seeking to link dietary diversity and biodiversity has used broader dietary diversity scores (crop variety level diversity rather than species, longer study periods, etc.). For example, the Expert Consultation on Nutrition Indicators for Biodiversity proposed that only dietary diversity data which includes variety level data / specification should be considered as an indicator of biodiversity (FAO 2008, FAO 2010a). Dietary diversity information was collected to the crop variety level during this research but was not included because there were already over 200 unique food items / species consumed within the communities (70 (34.7%) of which were used by 2.5% of individuals or fewer, 100 (49.5%) of which were used by less than 5% of individuals and 120 (59.4%) of which were used by less than 10%). The further division of crops into varieties would have increased the number of items used by very few people and further complicated data analysis and interpretation.

In this research, the 1 day dietary diversity scores were positively associated with nutrient intake and MAR, while the 7 day scores were not associated with MAR. Conversely, the 7 day scores were better associated with measures of biodiversity use. The 7 day FVS was associated with forest food use (Chapter 6, Manuscript 4). Both children's 7 day and the 1 day FVS were positively associated with forest cover (correlations to forest cover within 1km $r=0.136$; $p<0.05$ and $r=0.203$; $p<0.001$ for 7 day and 1 day FVS respectively, all elevations, data not shown elsewhere), and both the 7 day and 1 day DDS_{14} were positively associated with forest cover (correlations to forest cover within 1km $r=0.183$; $p<0.01$ and $r=0.303$; $p<0.001$ for 7 day and 1 day DDS_{14} respectively, all elevations, data not shown elsewhere), while neither the 7 day nor the 1 day DDS_6 scores were associated with forest cover. Crop diversity (agricultural diversity) was positively associated with children's 7 day FVS, DDS_6 and DDS_{14}; the 1 day DDS_{14}, but not the 1 day FVS and DDS_6 (see below).

The explanation for this dissonance may lie in a reconsideration of scale (for example see Zimmerer 2010). Despite the fact that the theoretical literature draws broad connections between biodiversity and nutrition, to date virtually all attempts to provide quantitative evidence of these links have focused on the individual or household level (this research included), in part due to the constraints of current nutrition assessment methodologies. It may be that relationships play out and become relevant only at the community level or across longer study periods. This is supported by the findings in this research that there is much greater heterogeneity between houses in terms of use of wild foods (from all sources as well as specifically from the forest), than for purchased and cultivated foods (Chapter 6, Manuscript 4). Moreover, local knowledge holds that seasonality, agriculture and agricultural diversity help local people to maintain season to season and day to day (as opposed to with-in day) dietary diversity (Chapter 4, Manuscript 2). Although narrower measures of dietary diversity are better associated with nutrient intake and adequacy, broader measures of dietary diversity may make important contributions to human nutrition and health which current nutritional assessment methodologies are less able to detect.

Systems approaches to human health (especially the EcoHealth approach) are well suited to dealing with complexities across variables and scales. Systems approaches have only recently become widely popular and have rarely been applied in the field of nutrition. This research has supported the utility of such approaches in nutrition and has added a case study of the importance of mixed methodologies and participatory methods for dealing with the complexities of health issues which are bounded by the biocultural systems in which they exist.

7.1.3 Bridging Epistemologies for a Truly Transdisciplinary Approach

While systems approaches, especially those which promote mixed methods and participation of local communities, demand transdisciplinarity most researchers are steeped in, and constrained by, disciplinarily distinct epistemologies. A truly transdisciplinary approach requires not just seeking knowledge from diverse literatures and employing diverse methodologies; it requires a critical examination of one's own epistemology and how it differs from other ways of knowing. Even leaders of transdisciplinary approaches, such as EcoHealth, admit they are constrained by their disciplinary backgrounds (Wilcox and Kueffer 2008): significant gaps in epistemology remain between those trained in natural sciences, those trained in social sciences and anthropology, and, the people of the communities under study. For many scientists it is an epistemological leap to accept (let alone value) other ways of knowing (Barth 2002).

Lay, local, indigenous, traditional and other ways of knowing are constructed, transmitted and validated in very different ways than what we consider knowledge in a professional sense. Crick (1982) notes that when studying human nature and culture "... a starting point must be that our own self-knowledge... of necessity the knowledge we formulate about 'the other', is bound to be refracted through the knowledge we have built to define ourselves". The importance of reflexively examining our own perspective of knowledge in an attempt to accept, or at least acknowledge, other ways of knowing, cannot be underestimated.

We must endeavour to accept, value and respect (acknowledge as different but equal) other ways of knowing because failure to do so prevents us from entering into equitable relationships: "it foists our cultural constructs onto others as if they had some inherent superiority" (Crick 1982) (p.290). Continued adherence to scientific paradigms that assign ethical value to one way of knowing, over another, perpetuates hegemony. The assessment of local knowledge against 'scientific truths' perpetuates a dichotomy in which local and indigenous knowledge is qualified or quantified relative to a 'superior' knowledge, dichotomies which maintain colonial cultural supremacies (Brook and McLachlan 2005, TenFingers 2005). Overcoming the epistemological gap between our way of knowing and the ways of knowing in other disciplines and cultures will help ensure interventions achieve their full potential (Worsley 2002).

This research has sought to straddle disciplines and to draw on multiple epistemologies. Careful attention to reflexivity has led to the inclusion of descriptive, ethnographic, quantitative and landscape level evidence in the argument that biodiversity makes important contributions to human nutrition in the East Usambara Mountains. The combination of these different types of evidence has been essential to the construction of a 'bigger-picture' (or systems) understanding of relationships within their biocultural context. Due to the inherent complexities of human and ecological systems, relationships may have been less apparent using any one form of evidence (i.e.

any one methodology). It is hoped that this effort will contribute to a framework upon which future research can draw so as to ensure epistemological reflexivity, acceptance and validation of other ways of knowing, and, transdisciplinary approaches.

7.2 Biodiversity and Human Nutrition

7.3.1 Wild Foods and Forests for Human Nutrition

This research contributes to the growing body of work (reviewed in the introduction) linking forests and forest biodiversity to food security and nutrition. This research showed that people who lived in areas with greater forest cover were more likely to use forest foods and, that individuals who used forest foods had better diet and nutrient intakes as well as higher dietary diversity (Chapter 6). Foods from the forest (and other non-cultivated land) were primarily fruit, vegetables, animals and fish. Forest foods were consumed infrequently, but on the days that they were consumed, they made a significant contribution to most nutrients including: 39% of protein, 34% of niacin, 28% of vitamin C, 27 % of iron, 26% of vitamin A (RAE), 24% of folate and 23% of calcium for the day (mothers and children) (Chapter 5).

Although foods from the forest only account for less than 3 percent of items in the diet, wild foods from any source account for 15% of the items in the diet (Chapter 6, Table 6.1) and while forest foods account for only 0.3% of energy intake, wild foods from any source account for 1.5%. As with forest foods, wild foods (from any source) are more important for some nutrients than others, contributing 31% of vitamin A (RAE), 20% of vitamin C, 19% of iron, 16% of calcium, 13% or riboflavin and 12% of folate in the diets of mothers and children (Chapter 5). These findings support other evidence showing that wild foods make greater contributions to certain micronutrients (including vitamin A, C, calcium and iron) than to energy and macronutrients (Johnson and Behrens 1982, Keegan 1986, Ogle et al. 2001).

Data from Chapter 5 shows that wild foods and wild foods are more important in times of food scarcity, supporting insights from previous work (Colfer et al. 2006, Humphry et al. 1993, Moreno-Black and Somnasang 2000, Vinceti et al. 2008). Similar to Ferguson and colleagues (1993) who showed a higher number of foods consumed over a 3 day period in the season of food plenty compared to food scarce season, this research showed higher 1 day FVS for children in the food secure (dry) season compared to the season with greater food insecurity. However, there was no difference in 7 day FVS and DDS_6 (indicators of dietary diversity which have been most strongly linked to biodiversity) between seasons. Interestingly, the sources of food items used to support dietary diversity were significantly different between seasons, with greater reliance on wild foods in the wet season when food insecurity is highest (Chapter 5). Local people also note the seasonal transition between reliance on wild and agricultural foods to purchased foods for the maintenance of diet and dietary diversity (Chapter 4).

Individuals who had consumed foods from the forest had a higher nutrient density score, a higher, but statistically insignificant, mean nutrient adequacy ratio (MAR), significantly higher 7 day FVS, and obtained a lower percentage of their food by purchasing and a higher percentage of their food from wild species (Chapter 6).

7.2.3 Agricultural Landscapes, Wild Foods, Vegetables and Nutrition

In this research 41% of food items (Chapter 6) and an average of 45% of energy, 32% and 33% of fat and protein were obtained from the farm. The farm was more important for the procurement of micronutrients, providing 70% of vitamin C, 58% of vitamin A (RAE), 54% of iron, 52% of folate, 53% of thiamine, 45% of zinc, and 36% of calcium (Chapter 5), indicating that the foods obtained there have higher nutrient density than those purchased.

Wild foods are an important component of diversity within agroecosystems. Many studies show that wild foods are obtained on the farm more often than from uncultivated land, likely, in part, because they are more accessible there (Bharucha and Pretty 2010, Fleuret 1979b, Ogle et al. 2001, Price 1997). In the research herein, 62% of wild foods were obtained on farm, and agricultural engagement was associated with wild food use, while other environmental and economic factors were not (Chapter 5).

We suggest that this may be in part because access to forest foods was constrained by both distance and time (Chapter 6 shows that households with greater forest cover in the nearby vicinity are more likely to use forest foods) and by legal access and forest governance policies (discussed further below).

A differentiation between agricultural productivity and yield, as opposed to agricultural diversity must be drawn; both have potential to contribute to nutrition but do not necessarily do so in all contexts. For example, many agricultural interventions and the commercialization of agricultural systems have successfully increased yield and income but have not always led to better dietary intake or nutritional status (Berti et al. 2004, de Walt 1993, Dewey 1989, Kennedy 1989, VonBraun 1988). Commercialization often leads to a reduction in diversity within the agroecosystem, diversity which is increasingly acknowledged as essential for the provisioning of adequate nutrition (e.g. diversity of home gardens (Jones et al. 2005)).

The percent of diet obtained on farm was positively correlated with children's dietary adequacy (MAR) (it was not included in the multivariate regression model in Chapter 3 because of high (negative) covariance with percent of diet purchased) (data not shown elsewhere). Crop diversity (number of crop species cultivated in past 12 months) was positively correlated with children's 7 day FVS ($r=0.333$; $p<0.001$), 7 day DDS_6 ($r=0.150$; $p<0.05$), 7 day DDS_{14} ($r=0.290$, $p<0.001$) and 1 day DDS_{14} ($r=0.140$, $p<0.05$), but not with the 1 day FVS and DDS_6. Agricultural diversity (crop diversity) was negatively correlated with percent of the items in the diet purchased ($r=-0.362$; $p<0.001$) and positively correlated with percent of items produced on the farm, as well as positively correlated with children's over all dietary adequacy (MAR, $r=0.182$; $p<0.01$, correlations remains significant after controlling for percent of items purchased) (data not shown elsewhere). A few other papers describe similar relationships between agricultural diversity or home garden diversity and dietary diversity or nutrition (Ekesa et al. 2008, Herforth 2010a, Jones et al. 2005, Torheim et al. 2004). Herforth (2010a) reports that in Kenya and Tanzania crop diversity was associated with the percent of diet that was home-produced but not associated with the percent of the diet that was purchased. It is surprising that more papers have not examined these relationships quantitatively given the multiple qualitative descriptions of these relationships (e.g. Greenberg 2003). Perhaps this is because many researchers simply assume food security, dietary diversity, and nutrient intake to be linked to agricultural diversity? This research also provides qualitative support for these links (Chapter 4). Local people reported agricultural diversity (and agriculture in general) as one of the most important factors affecting their diet and nutrition (mentioned in 13 out of the 15 case study households). Anna Ernest, who lives with her family in a house they rent from the tea estate where her husband works as a manual labourer, noted "[Other people, who harvest tea but do not engage in agriculture], they eat only *dagaa*, but me, because of my salary is meagre I said to myself, if I rely entirely on the salary we will not fulfill our many needs. So I farm".

In our research site agricultural production (yield or quantity produced) is important for nutrition, in addition to agricultural diversity. Two of the strongest predictors of overall nutrient adequacy in children's diets (MAR) were quantity (not diversity) of vegetable intake and quantity of animal source food intake (Chapter 3). This is not surprising in a context with such high dietary monotony (Chapter 3). The importance of vegetables, especially leafy vegetables, traditional vegetables and wild vegetables, has been remarked previously (Chweya and Eyzaguirre 1999), especially in the context of highly monotonous African diets (Stephenson et al. 2010).

The provisioning of sufficient quantity of fruits, vegetables and animal source foods is dependent on access to farms and forests (for example see Chapter5). Local people reported agriculture and agricultural diversity to be especially important for ensuring access to and diversity of vegetables and fruit (Chapter 4). Moreover, the importance of both farm and forest for nutrient adequacy can be seen in the greater nutrient density of items obtained there (Chapter 5).

Finally, the dependence of overall agricultural productivity on biodiversity must be highlighted, providing a further, if in this case theoretical, route through which agrobiodiversity may contribute to nutrition in the East Usambara Mountains.

7.3.3 Dietary Diversity as a Pathway from Biodiversity to Nutrition

Much of the review and theoretical writings on biodiversity and nutrition (Burchi et al. 2011, Frison et al. 2011, Frison et al. 2006, Johns and Sthapit 2004, Sunderland 2011) cite dietary diversity as one of the primary pathways through which biodiversity contributes to human nutrition, but while much work has linked dietary diversity and nutrition and dietary diversity and agricultural diversity, there has been few attempts to 'connect the dots'.

In this research, evidence for dietary diversity as a pathway between biodiversity and nutrition was complicated by methodological issues touched on above. In general, the 1 day, but not the 7 day, indices of dietary diversity were associated with nutrient intake and adequacy (Chapter 3), while the 7 day indices of dietary diversity were better associated with forest cover, forest foods use, and crop diversity (Chapters 3,5,6 and 7). It is interesting to note that for the 7 day FVS, 100 of the food items recorded (49.5% of items) were used by 5% of individuals or fewer, and 120 (59.4%) items were used by 10% of individuals or fewer. While these items contributed to individual's day-to-day variation, due to their infrequent use they did not make a large contribution to variation between individuals. A greater proportion of items used by few individuals were wild and forest foods compared to more common items that were more likely to contribute to 1 day dietary diversity (65.7% of items used by ≤2.5% of people were wild, while 22.7% of items used by >2.5% were wild).

Similarly, research linking dietary diversity with agricultural diversity has used primarily longer, broader indices (Ekesa et al. 2008, FAO 2010a, Kennedy et al. 2005, Torheim et al. 2004), with some exceptions (Herforth 2010a). It may be that shorter and longer study periods for dietary diversity measure different things, with the latter having very little to do with nutrient intake and adequacy. There is, however, evidence against this assumption. In this work local perspectives hold that agriculture and agricultural diversity are important for maintaining dietary diversity across seasons, not just on a short term basis (Chapter 4). And as discussed above (and below) the relationships between dietary diversity, biodiversity and human nutrition may have different importance at different scales of investigation.

It is equally possible that the disconnect between the 7 day measures of dietary diversity and nutrient intake is due to methodological limitations of the assessment of nutrient intake and adequacy. Indeed, it is currently impossible to determine if the reason for the lack of relationship between longer indices of dietary diversity and nutrition intake and adequacy in this research is due to an actual lack of relationship or limitations and differences in the tools used. Given the strong theoretical support and the complexity and diversity of dietary patterns which mediate these relationships (Chapter 3), it is possible to argue that both longer and shorter period indices of dietary diversity enhance diet quality and nutrition. While more research on this topic is very much needed, especially in contexts with different dietary patterns, if we accept the above argument, then it seems that all scores of dietary diversity can act as pathway through which biodiversity contributes to human nutrition.

7.3.4 Beyond the Individual Level – Exploring other Spatial and Temporal Scales

All of the relationships discussed in preceding sections have been at the individual or household level. Biodiversity in agroecosystems contributes directly to individual dietary intake through wild food consumption, agricultural and home garden diversity and traditional foods from all types of land. However, the importance of biodiversity for human nutrition may be more apparent when examined on a broader scale, at the community level or over longer periods. Zimmerer (2010) notes that several scales of analysis are needed to describe the ways agrobiodiversity contributes to food security, and gives the examples of: the role of seed exchange across communities in supporting crop genetic diversity, and the fact that land-use change is often only apparent at the landscape level. One of the most important ways biodiversity contributes to human food security and nutrition is by supporting sustainability and productivity of global and local agricultural systems (Frison et al. 2011, Hajjar et al. 2008, Jackson et al. 2007, Zimmerer 2010). Genetic biodiversity (crop varieties and wild relatives) maintained in gene banks and by local farmers around the world, provides the genetic diversity that has allowed for traditional and modern crop improvement since the evolution of agriculture. Genetic biodiversity also holds the genetic material needed for future innovation and adaptation (Frison et al. 2011, Hajjar et al. 2008, Toledo and Burlingame 2006). Additionally, for local farmers worldwide, agricultural diversity is perhaps most appreciated as insurance against social, economic and environmental uncertainty (Hajjar et al. 2008, Jackson et al. 2007).

Agrobiodiversity (especially non-crop biodiversity) provides essential ecosystem services which contribute to agricultural productivity and sustainability, and thus human diet and nutrition (Hajjar et al. 2008, Jackson et al. 2007). Ecosystem services that are important for agricultural productivity and sustainability include pollination, decomposition, soil and nutrient cycles, water and hydrological cycles and pest control (Hajjar et al. 2008, Jackson et al. 2007, Millennium Ecosystem Assessment 2005). Hajjaret al.'s (2008) review of ecosystem services provided by biodiversity within agricultural ecosystems provides an extensive set of examples and theoretical work which, together, form a convincing argument for the role of biodiversity in maintaining and enhancing pollintation services, pest control and for maintaining a continuous biomass which improves erosion control and carbon sequestration. They note that methodologies do not yet allow for convincing demonstration of the role of biodiversity for soil processes and nutrient cycling, but that some studies suggest that leaf litter diversity supports more diverse decomposition pathways (Hajjar et al. 2008). These principles were behind the CBD Decision VII/23A "Cross-cutting initiative on biodiversity for food and nutrition" (CBD 2006) that emphasized "Biodiversity is essential for food security and nutrition and offers key options for sustainable livelihoods. Environmental integrity is critical for maintaining and building positive options for human well-being".

Evidence that agrobiodiversity makes contributions to nutrition through productive ecosystems services in the East Usambaras can be drawn from the fact that children's overall dietary adequacy (MAR) is correlated with crop diversity (above sections) but MAR and crop diversity are not correlated to the same indices of dietary diversity, suggesting that crop and agricultural diversity contribute to MAR by means other than through dietary diversity.

Local farmer's perspectives highlight the importance of agricultural diversity for food security and dietary diversity across longer time periods and multiple pathways, including income generation: "[Having many varieties of banana] helps us because ... they ripen differently [at different times]....In this way it allows me to have bananas all the time. Each time a different variety. If one variety fails / dies, there is another variety that continues to grow" Benjamin Njuiku. Local farmers clearly value agricultural diversity as an insurance mechanism in the face of environmental, social and economic uncertainty: "[In order to get different foods] we farm, we grow maize, we grow cassava, and we have banana in the farm.... Another reason you plant every type of crop is that it will ensure that the family will overcome hunger, instead of depending on only one crop" Beatrice Akida (see Chapter 4).

Although the highest levels of agricultural diversity are often found in areas with the greatest climatic variation and uncertainty (e.g. the Sahel), little empirical demonstration of the insurance value of agricultural diversity exists (Jackson et al. 2007). But evidence endorsing the insurance provided by agricultural diversity, including for global-scale shocks is increasing. For example, in Indonesia diverse rubber agroforests, less profitable than mono-specific plantations under normal circumstances, provided livelihood security when the prices of rubber decreased in the international market in late 2008 by offering an alternative source of income from secondary products (e.g. fruit) (Feintrenie et al. 2010). As noted above, this research (Chapter 5) found greater use of wild food biodiversity in the season with greatest food insecurity, as has been reported by other research (Humphry et al. 1993). Many authors note that the importance of biodiversity for human nutrition may be more apparent in times of rapid change, insecurity or crisis (Hajjar et al. 2008). Research in settings where farmers are specialists (unlike in the East Usambara Mountains) has suggested that local markets act to pool local agricultural diversity thereby ensuring dietary diversity.

This research has suggested that wild and forest biodiversity may be important for maintaining inter-household variation rather than intra-household variation in dietary diversity and wild food use. If the amount of each resource / food species available in a community is limited (as is expected to be the case with wild foods) then only a limited number of households can consume it. When this is the case, then, having a diversity of similar species (for example wild leafy greens), allows a few households to use one species and a few households to use the next, thereby ensuring that many households have access to a given type of food (in this case to leafy greens) by consuming different species. Chapter 5 showed that individuals consumed an average of 30% of available purchased foods and 15% of available food from the farm, 4% of foods available from forests 7% of available wild species, indicating larger inter-individual variation from one individual to the next in terms of use of wild and forest foods as compared to foods from the farm or purchased source. In a setting where 48% of vegetables consumed were wild, this contribution of biodiversity to local intake must surely be significant. In this study population, those mothers' and children who had consumed traditional vegetables had higher nutrient intake for most micronutrients and higher MAR (children with vegetables MAR=0.799±0.101, children without vegetables MAR=0.685±0.110, $p<0.001$ in a student's t-test; mothers with vegetables MAR=0.703±0.106, mothers without vegetables MAR=0.604±0.127, $p<0.001$ in a student's t-test). For those (mothers and children) who had consumed TVs, the serving size of TVs consumed (in grams) was highly correlated with nutrient intake as well as nutrient density score and MAR. These relationships all remained significant after controlling for energy (kcal) intake. Furthermore, in the dry season (when vegetable consumption is lowest), those who had consumed vegetables had greater tree cover in close proximity to their home (584ha vs. 443ha within a 1.5km radius of the home for mothers who had consumed vegetables vs. those who had not, $p<0.01$ in a Mann-Whitney U test, and 604ha vs. 440ha for children who had and had not consumed vegetables, $p<0.01$) (Powell et al. 2012).

As with agricultural diversity and agrobiodiversity, wild biodiversity and biodiversity found within less-managed ecosystems (forest and bush) also make indirect contributions (through ecosystem services) to human health and nutrition (Chapter 1). In this research one example of this could been seen in the fact that those mothers and children who had consumed vegetables in the dry season survey had greater forest cover in close proximity to their home, suggesting that forest cover helps to ensure access to vegetables by providing appropriate microclimates. In general, forests and forest biodiversity provide important ecosystem services potentially impacting human nutrition including: the provisioning of clean drinking water and mediation of infectious disease transmission (the well-established links between nutrition and infection are reviewed in Chapter 1) (Millennium Ecosystem Assessment 2005). Those promoting attention to biodiversity within agroecosystems in conservation note that landscape heterogeneity (as well as size of, and distance from, natural habitat) is increasingly linked to pollinator maintenance. For example flower-rich field margins, set asides, strip crops, agroforestry crops and permanent hedgerows can provide additional forage (pollen and nectar) and nesting resources for pollinators (Hajjar et al. 2008). Having long struggled with the conservation-livelihood (or conservation-people) trade-off dilemma in conventional forest and biodiversity conservation paradigms, many working in the field have embraced landscape level approaches as the most promising strategy for indentifying win-win options for conservation and development (Chazdon et al. 2009, Cunningham et al. 2002, Hajjar et al. 2008, Sayer et al. 2007). This is especially true given that more than 90% of tropical forests lie beyond the borders of conservation areas (Chazdon et al. 2009).

The research presented herein showed that both physical and legal access to forested areas modified access to wild foods from the forest and thus their consumption: greater forest cover near the home was associated with use of forest foods and greater dietary diversity (Chapter 6 and above).

Landscape level diversity (landscape heterogeneity) is now seen as important for achieving conservation while maintaining local livelihoods, yet the impact of landscape level diversity (or landscape heterogeneity) on local people's livelihoods, diet and nutrition is virtually unknown. Much research has evaluated the differential importance of different land use types for the procurement of wild foods, medicines and other NTFPs (Gavin 2004, Johnson and Behrens 1982, Keegan 1986, Ogle et al. 2001, Price 1997, Rappaport 1968, Toledo and Salick 2006), but the impact of landscape heterogeneity *per se* has not been examined to our knowledge. Observation of the landscape in our East Usambaran field site would suggest that households with greater forest cover were also the households with the most landscape heterogeneity nearby. Further research is needed in the East Usambaras and elsewhere, to test this hypothesis.

7.4 Mediators of the Relationship between Biodiversity and Nutrition

7.4.1 Social and Cultural Aspects of Local Food Systems

The possibility that relationships linking human and ecosystem health can be maintained independent of the mediating role of socio-cultural beliefs, practices and knowledge is doubtful. Both agricultural systems (and other human-managed systems) and natural ecosystems (tropical forests) have evolved under the management of generations of local peoples (Altieri et al. 1987, Anderson 2006, Denevan 1992, Heckenberger et al. 2007, Johns 1996). True understanding of the interrelations among humans, their environments and their foods cannot be achieved outside the cultural context in which these interactions take place (Ellen 1982). Decisions about what one eats are based not only on physiological needs but social and cultural factors as well (Kuhnlein and Receveur 1996). Foods are not just a means of delivering nutrients; they play a central role in cultural and personal identity and fulfill multiple symbolic functions within a given culture (Fischler 1988). Foods define relationships among groups and mark social position, tastes and personality (Khare 1980, Kuhnlein and Receveur 1996).

Nature, biodiversity and natural environments also fulfill cultural functions by providing a sense of place, belonging and identity (Cocks 2006). Ellen (1982) notes that

"…because we see nature in terms of cultural images, and because it is to these that we respond… a proper understanding of indigenous knowledge and cognitive structures is theoretically crucial to the analysis [of the relationship between humans and their environments]." A society's collective understanding of its environment is, like food, largely structured by its myths, sayings, stories and rituals, all of which help to create order and structure. As with food, culture prescribes how, when and why people should view, value and interact with their environments. Conversely, environment provides the context in which cultures evolve and are maintained. If ecosystems are lost then culturally important sites and the functions they serve in preserving cultural meaning are lost.

Over two decades ago Alteri and colleagues (1987) noted that: "Preservation of these traditional agroecosystems cannot be achieved when isolated from the maintenance of the culture of the local people. Therefore, projects should emphasise maintenance of cultural diversity". Although consideration of 'cultural appropriateness', essential to effective education-based nutrition interventions, is now standard practice, the social and cultural properties of food, as a potentially powerful vehicle for maintaining and enhancing health-positive behaviours is still underutilized. "[Building] on the biodiversity and cultural strengths inherent in traditional food systems [will] optimize the chances for vulnerable populations to adapt the changing conditions in a sustainable manner" (Johns and Sthapit 2004).

The magnitude of the research conducted for this dissertation has meant that there has only been room for cursory coverage herein of the many important social and cultural mediators of the relationships between biodiversity and nutrition. Chapter 5 described the social and cultural importance of a number of foods in the local foods system (such as bitter and slimy vegetables) and reconfirmed Feierman's (1974) observation of the cultural importance of meat and agricultural staples (maize, bananas and cassava). Cultural classification of foods is further covered at the beginning of Chapter 4, which notes that the Kiswahili words *chakula* (all food or staple food) and *mboga* (vegetables or any side dish) have multiple meanings. Culturally-bound dietary patterns are described in Chapters 3 and 5 and changes in dietary patterns over time are briefly explored in Chapter 5 and 7. Additionally the social and cultural importance of foods can be seen in their prominence in local knowledge surrounding concepts of health and well-being, including foods which increase the blood (*kuongeza damu*) and build the body (*kujenga mwili)* (Chapter 4). Chapter 4 also reports factors local people felt mediated dietary diversity and food security. For example, an individual's determination, drive, dedication, effort and motivation were cited as factors which modified dietary diversity. Many of the reported factors were social and cultural including: wealth, social networks, gender, tradition and taboo.

Ethnicity was not a significant determinant of nutrition, dietary diversity or biodiversity use when tested quantitatively, nor did it feature prominently in local people's discourse about determinants of nutrition, dietary diversity or biodiversity. It was only mentioned in relation to different food taboos held by different ethnic groups (Chapter 4). This is actually not that surprising given the high level of cultural diversity in the East Usambaras and the long history of ethnic mixing there (Chapter 2).

7.4.2 Wealth and Market Integration

Community-based wealth rank and asset based wealth rank were highly correlated ($r=0.495$; $p<0.001$); community-based asset rank was used because it was more wholistic. Although wealth was included as a fixed variable in multivariate regressions for MAR and stunting (Chapter 3), there were only limited correlations between wealth rank and HAZ ($r=0.146$; $p<0.05$), MAR ($r=0.107$; NSS, $p=0.079$) and energy intake ($r=0.124$; $p<0.05$). Interestingly, wealth was associated with greater intake of animal source foods and greater intake of fruit but was not associated with intake of vegetables or legumes (data not shown elsewhere). Wealth was not associated with the number of wild foods used, the percent of the diet from wild species (Chapter 5), or use of forest foods (but was associated with having visited the forest, likely associated with wage labour) (Chapter 6). Local people noted that lack of wealth doesn't preclude the possibility of achieving a good diet but that cash availability can reduce reliance on wild and agricultural products (Chapter 4).

The diets of children from households engaging in any type of wage labour did not differ in terms of measures of nutrient intake or adequacy but consumed a greater percent of food items purchased and significantly less food items procured on the farm, indicating that with increased market integration there could be greater reliance on purchased foods. As noted above, greater road access also increased percent of the items in the diet purchased. Virtually all of the least healthy food items were purchased including: *mandazi* (and other fired wheat products), fried cassava products, cookies, candy, and soda. As has been seen elsewhere (Chapter 1), greater market integration and road access in these communities may not improve their diets and nutrition. In fact, they may very likely lead to a nutrition transition and associated epidemiological shifts.

7.4.3 Whence the Limited Use of Forest Foods

Methodological differences notwithstanding, the use of forest food species reported in Chapters 5 and 6 seems lower than has been suggested in other regions (Butler 2008, Colfer 2008, Koppert et al. 1993, Melnyk and Bell 1996) and previously in the Usambara Mountains (Feierman 1974, Fleuret 1979b, Woodcock 1995, Woodcock 2002). This limited use of forest foods was unexpected, given high levels of malnutrition in the area and the close proximity of the forest.

Data on local perceptions of the forest are presented in Appendix 7. They showed that food is the least common reason listed as the purpose of the most recent trip to the forest by survey households, listed as the primary reason by only 3.3% of households. Local people report little perceived benefit from the forest, especially for procurement of food "[The forest] is not very important to us, it's doesn't benefit us much... we only consider it important maybe when it comes to firewood." Rehema Amiri, Shambangeda. This evidence suggests that current use of forest food is indeed limited in the study area and that this is related to local perceptions of the value of forests.

Possible reasons for the limited use of forest foods, include: 1. Emphasis on and greater time spent in agricultural land in agricultural communities, 2. Biological characteristics of many wild food species, 3. Cash economy integration, wage labour and reliance on purchased foods, 4. Access (in terms of distance to the forest, time needed to travel to the forest and legal access / tenure over forest foods).

The importance of agriculture to the local ethnic groups has already been touched on. Feirman (Feierman 1974) notes that the Shambaa reality and identity is built around their agricultural livelihood and that forests were seen as places of refuge, magic and rainmaking, associated with spirits and danger (Feierman 1974). Despite living adjacent to forests, many communities have strong cultural and taste preferences for wild vegetables which are obtained from agricultural land, for example *mchunga* and *kibwando* (Chapter 5 and Powell et al. 2010). Woodcock (2002) suggests that only communities with legal access to unprotected forest rank forest vegetables such as *nedelema* and *msangani* as highly preferred vegetables. Moreover, biological characteristics of many of the most commonly used wild food plants (fast-growing, weedy, sun-loving) mean that these species are more abundant in agroecosystems than in the forest. In matrix ranking of the importance of different land use types for the procurement of different resources in the East Usambara Mountains, forests were ranked as most important for poles, medicine, ropes and firewood, but farm land was listed as having equally importance for the procurement of vegetables (Kessy 1998).

Free time to travel to forests to collect food could also constrain the use of forest food species (Koppert et al. 1993, Kuhnlein and Receveur 1996). While this may play a role in the East Usambaras, it is likely not a large determinant. Moreover, there was no difference in use of forest foods between those households engaging in wage labour and those not (Chapter 6).

Finally, the limited use of forests for the procurement of food items is partially driven by local forest governance practices, present and past. More than acting to restrict current legal access to forest foods, it is historical forest governance practices that have more likely acted to modify local people's perceptions about access to forest foods (and ability to enter forests without suspicion of illicit activities) and the role and importance of forests in the local food system. Over the past decades, national governments have been encouraged to decentralize control over forest and natural resources to the lower levels of the government, and ultimately to the villagers themselves so as to achieve greater participation and empowerment of local people. In Tanzania this approach has been embraced, and the country is considered exemplary for its progressive, pro-people, pro-poor forest governance policies, if not for its policies related to other natural areas (Rantala et al. 2011, Vihemäki 2005). The ultimate goal of such policies has been to provide local communities with greater access to and control over forest resources needed for their livelihoods. The limited importance perceived by local people of forests for food procurement echo the impact of historically prescriptive, top-down approaches to conservation of forests, environment and wildlife in East Africa where, as in many other regions, exclusion of people and human activities from protected areas and resources was a central element (Rantala 2010, Vihemäki 2005, West et al. 2006).

Further exploration of how forest governance mediates access to and use of forest products is needed. Forests and biodiversity are increasingly commoditized, in the form of payment for ecosystem services (PES); Tanzania is among the first phase of countries participating in the global adoption of Reduced Emissions through Decreased Deforestation (REDD+) (Burgess et al. 2010). In Mexico, at least one PES scheme has been suggested to have had a negative impact on local people's dietary diversity, food security and food sovereignty (Ibarra et al. 2011). There is also evidence that loss of local agricultural livelihoods leading to out-migration has led to the loss of traditional ecosystem management institutions with negative, rather than positive, implications for biodiversity conservation in Mexico (Robson and Berkes 2011a, Robson and Berkes 2011b). Food security, food sovereignty and nutrition of local populations are too often left out of economic assessments of PES programs (Kissinger 2011), despite strong evidence that increased income does not always insure improvements in diet and nutrition (de Walt 1993, Dewey 1989, Engle 1993, Hoddinott and Haddad 1991, Kennedy 1989). In the face of fundamental transformations of global forest and biodiversity conservation policies, strategies and paradigms, it is imperative that careful attention be paid to the impact these changes have on the food security, food sovereignty and well-being of local populations.

7.4.4 Primary School Education and the Local Knowledge Systems

In Chapter 4 we note that the current local knowledge and the means by which it is developed and acquired in Tanzania have been significantly shaped by universal primary school education policies. Primary school education has acted to introduce new knowledge and create consensus on concepts in local knowledge in the East Usambara Mountains. Chapter 4 presents ethnographic data which suggest that there is strong cultural consensus around local nutritional concepts of 'increasing the blood' (*kuongeza damu*) and 'building the body' (*kujenga mwili*). We note that there is high consensus around the importance of dietary diversity for appetite but much less consensus around its importance for vitamin, mineral or nutrient intake and that the use of terms for vitamins, minerals and nutrients is inconsistent among local people. Varying degrees of consensus on different ethnonutritional concepts likely reflects the accuracy of knowledge transmission and the integration of that concept into overarching cultural knowledge systems.

Sections of the Tanzanian primary school curriculum that cover food and nutrition (Grades 4, 5 and 6 – the grades with the most health and nutrition coverage) are presented in Appendix 6. Some of the concepts covered in the curriculum include: protein, starch, vitamins, minerals, list of different vitamins and deficiency symptoms, kwashiorkor (protein-energy-malnutrition), fruits as a source of vitamins, food safety, importance of breastfeeding, traditional foods and taboos, 'it is not necessary to be rich to have a good diet', as well as eating regularly (many smaller meals, rather than one large one / 3 times per day), and dietary diversity ('Mixing foods is better than eating only one or two types of food' and 'Eat many different types of foods, not only one type of food')**.** The terms *vitamini* (vitamins), *madini* (minerals) and *virutubisho* (nutrients) appear frequently in the curriculum. The concepts of *kuongeza damu* (increase blood) and *kujenga mwili* (to build the body) do not appear at all in the Grades 4-6 science curriculum.

The concepts of *vitamin* and *madini* were likely adopted from scientific knowledge systems (along with the word *vitamin)* at least in part through primary school curriculum, but the lack of consensus surrounding their use suggests poor integration into existing knowledge frameworks. It is unclear whether the concept of dietary diversity existed in local knowledge before formal schooling, but the high consensus surrounding its benefits for appetite suggests that either it was already present or that it has been readily integrated into existing knowledge systems. It is possible that the lack of discourse on dietary diversity among the most disadvantaged informants reported in Chapter 4 was actually due to the fact that they were the few that had no primary school education and thus had not been exposed to the science curriculum which is an important source of current local knowledge shared by other informants.

The significant overlap between many of the ideas about food and nutrition that were expressed by local people, and the content of primary school science curriculum, suggests that schooling is either an important source of nutrition and health knowledge, or that school plays an important role in coalescing cultural consensus on these topics. Indeed other information and knowledge seen in Chapter 4 can be seen in the primary school curriculum including: promotion of leafy vegetables, agricultural diversity, livelihood diversity and on-farm production of fish and small livestock. The primary school curriculum seems to have a significant impact on knowledge of local populations. These findings lend considerable support to the role of school education in public health nutrition. This would suggest that changes in knowledge can be achieved through teacher training and modifications to the curriculum. In particular teachers should be trained to validate and build on existing local nutrition knowledge.

Importantly if primary school curriculums are to contain such apparently influential nutrition information, they must be kept up-to-date. The current primary school science texts used in Tanzania were last published in 2003, yet they still discuss Protein-Energy-Malnutrition and deficiency diseases extensively (for example, if you eat very little protein you can get kwashiorkor) and give only very brief mention to heart disease. With the impending nutrition transition, and associated accelerating rates of obesity, diabetes and heart-disease (despite continued high rates of undernutrition), it would be a shame for public health officials in Tanzania to not act quickly to modify the current curriculum to include appropriate information that addresses these topics.

7.5 Policy and Practice

7.5.1 Behaviour Change

Behaviour change is perhaps one of the most difficult, pervasive and persistent challenges for both biodiversity conservation and public health nutrition. The achievement of effective and sustainable behaviour change is complicated by the complexity of human nature and the complexities of the biocultural systems in which we live. Transdisciplinary and participatory systems approaches are promoted as an important strategy for achieving sustainable behaviour change in both nutrition and conservation.

Social and cultural factors and values are strong mediators of human behavior and are at least in part, responsible for decisions and actions that impact both nutrition and conservation. As noted previously, the extent to which new knowledge can be integrated into existing, culturally-bound, knowledge frameworks is in part responsible for the capacity of new knowledge to mediate behaviour.

While not common, a few experts from both conservation and nutrition have called for increased attention to, and even utilization of, social and cultural values in order to achieve improved outcomes. For example, Shell-Duncan and McDade (2005) suggest that the greater rates of anaemia among girls in a community in northern Kenya could be due to cultural beliefs about the foods that are appropriate for girls and those that are appropriate for boys. Herforth (2010a) shows that knowledge and use of traditional vegetables for their medicinal properties was one of the strongest predictors of their use following an intervention promoting their cultivation and use. Some of the most successful nutrition and health behaviour change interventions have employed innovative methods to address, modify and utilize social and cultural factors to ensure behaviour change. For example, the inclusion of women's mothers-in-law (grandmothers) significantly improved adaptation of positive maternal and child health practices in Senegal and Malawi (Aubel 2012, Aubel et al. 2004, Kerr et al. 2008). Social marketing had great success in the introduction of iron-folic acid supplementation to women in Cambodia and Vietnam, and the introduction of food-based dietary guidelines for enhanced animal source food consumption in Thailand (Kanal et al. 2005, Khan et al. 2005, Smitasiri and Chotiboriboon 2003, Smith 2006).

Social taboos have been suggested to have conservation functions (Colding 2001) and Cocks (2006) notes that "conservation approaches based on cultural and religious values are often more sustainable than legislation or policy"(p195). Infield's (2001) paper "Cultural values: a forgotten strategy for building community support for protected areas in Africa" promotes social and cultural values for the environment as potential motivation for enhanced participation of local people in conservation efforts (and an alternative to financially driven motivations which are often dependant on continued outside support and markets). One successful conservation project engaged community religious leaders in Pakistan to help disseminate important environmental information to local community members (Sheikh 2006, 319).

Food-based strategies have the potential to be self-sustaining (Tontisirin et al. 2002), and even self-perpetuating (as beneficial changes are spread naturally from one person or community to the next) and, importantly, they can address multiple micronutrient deficiencies simultaneously (Tontisirin et al. 2002). Moreover, they are also best suited to address complex situations, such as the concurrence of over and undernutrition within the same communities (and even households) and are often more culturally appropriate.

7.5.3 Cross-cutting Initiatives

The complexity of biocultural systems and the many factors that can impact behaviour change are increasingly acknowledged. Interventions are increasingly diverse and holistic in both public health nutrition and conservation.

In the field of nutrition, experts note that food-based interventions require complex, system wide changes in production and consumption, and that combination of food-based and other efforts towards overall development are more effective than individual interventions (Allen and Gillespie 2001, Berti et al. 2004, Tontisirin et al. 2002, Underwood and Smitasiri 1999). Increasing recognition of the impact of infection on anthropometric indicators (discussed briefly in Chapter 3) is but one example of why integrated approaches, especially those which simultaneously address health and nutrition, are ideal. Proponents of the EcoHealth approach stress that a sectoral approach is not adequate: co-management of human health and the environment is essential (Lebel 2003).

Pinstrup-Andersen (2007) argues that nutrition must be a key focus of agricultural research and policy, that investment in agriculture is necessary to ensure global food-security, and, that integration of efforts (health, development, agriculture) is more likely to be effective than the current separation of sectors. Likewise, Herforth (2010a) notes "Alleviating both undernutrition and overnutrition in sub-Saharan Africa is closely tied to food systems, and solutions cannot come from the health sector alone". Agriculture and nutrition problems are complex enough that solutions from all available sources should be collected and used (Herforth 2010a). That healthy agriculture ecosystems simultaneously are necessary for achieving improved nutrition in rural communities, and play an essential role in biodiversity conservation, has recently been highlighted within the priorities of the Convention on Biological Diversity (CBD 2006). This dissertation provides further validation for the continued promotion of these and other policies.

Early attempts to diversify conservation interventions began with 'Conservation and Development' efforts, which had limited success, perhaps due to the lack of true balancing of objectives (and necessary underlying epistemological shift). Yet the drive to find win-win options for conservation and development has persisted, finding new energy in landscape level approaches (Chazdon et al. 2009, Cunningham et al. 2002, Sayer et al. 2007). Arnold et al. (2011) calls the lack of collaboration between agriculture and forestry a 'yawning gap' and Chazdon (2009) notes that successful conservation efforts will "demand new alliances among conservation biologists, agroecologists, agronomists, farmers, indigenous peoples, rural social movements, foresters, social scientists, and land managers".

The links between conservation, agriculture, education and nutrition have been developed throughout this dissertation. Actors from each of these disciplines influence local people's knowledge systems and day-to-day livelihood decisions. Conversely, local people's decisions and actions are of concern in each of the above disciplines. The role of formal education in shaping local knowledge on nutrition is discussed above. Additionally, when informants in this research project were asked where they got new information about crop varieties, agricultural pests, agricultural chemicals and traditional agricultural practices, 42% indicated "other community members"; however, 11% answered "from an agricultural extensionist" and a few also answered: the agricultural shop, agricultural calendars, teachers and even forest officers. Local experts from many fields are seen as sources of a broad range of information. Although there have been efforts to integrate these sectors (for example the 1998 FAO LiNKS project on Gender, Agrobiodiversity and Local Knowledge Systems for Food Security (Das and Laub 2005)), they have often been short-lived. We must understand how to achieve greater integration of these disciplines and their practitioners - not just researchers, but also those on the ground: primary school teachers, agricultural extensionists and forest officers, as well as the institutions which train these essential and influential staff.

Some have proposed nutrition as a key, cross-cutting issue. The "The World Nutrition Situation" report of the United Nations Standing Committee on Nutrition (UN-SCN 2004) highlighted how nutrition plays a role in 6 of the 8 Millennium Development Goals (Goals1-6, and the work herein suggests a relationship to Goal 7 as well). Arnold et al. (2011) suggests that a mutual desire to improve food security for local populations may be able to reduce the gap between those working in agriculture and forestry. Foods, especially traditional foods that impart social and cultural meaning as well as health benefits, may be a common ground upon which joint strategies for improving health, nutrition, food security, agriculture, and conservation outcomes can be built. As noted above, Johns and Shapit (2004) strongly promote this strategy: "[Building] on the biodiversity and cultural strengths inherent in traditional food systems [will] optimize the chances for vulnerable populations to adapt the changing conditions in a sustainable manner".

7.6 Future Directions

This research described many benefits from systems perspectives, including the EcoHealth Approach and participatory approaches. These approaches ensured that diverse types of evidence were collected and examined, and enhanced our capacity to deal with the complexities of the biocultural system and to address social and cultural factors mediating the relationship between biodiversity and human nutrition. These approaches are still young (Lebel 2004, Wilcox et al. 2004). Their further application will allow better identification of their strengths and weaknesses, while simultaneously improving the research for which they are used. Reflexive examination of their efficacy, including how well they are able to account for social and cultural factors, is needed.

We should continue to pursue an improved understanding of local knowledge systems and to seek broadly for new approaches for achieving behaviour change. This research has identified potential strategies for improved behaviour change, which now need to be applied, in order to test whether improvements can be achieved.

Despite advancements, significant methodological challenges remain in the assessment of relationships between biodiversity and human nutrition (strong methods are lacking for both); much demonstration of these relationships remains descriptive and empirical evidence is inconsistent across cases. Dietary diversity, as a pathway between biodiversity and human nutrition, is a compelling theory (Johns and Sthapit

2004); however, it remains poorly documented. This dissertation represents one of the first attempts to link the three (biodiversity – dietary diversity – nutrition) in the same setting, with only limited success. Further research (and publication of existing data) is very much needed to understand if and how dietary diversity acts as a pathway through which biodiversity contributes to human nutrition.

New methodological approaches for the assessment of biodiversity, as well as the contributions of biodiversity to human diet and nutrition, are very much needed. Research using longitudinal study design holds much promise for demonstration of the impact of change in biodiversity use and access on human nutrition, especially through the impact of changes in agricultural practices, road access and market integration, deforestation, and forest management practices. One specific question of immediate relevance is: how will REDD+ and the commoditization of ecosystem services affect local food security, food sovereignty, food systems and nutrition, over time?

There is also a dearth of information on mediators of the relationships between biodiversity and human nutrition. For example, traditional knowledge has been proposed as an important mediator: those who with more knowledge are better able to make efficient use of biodiversity to improve their nutrition. This dissertation has provided some support for this, for example Chapter 4 highlights local people's knowledge of the relationships between the environment and their diets (much additional information on the role of knowledge as a mediator has had to be left out of this dissertation due to time and space constraints). Another important social-cultural mediator of the relationship between biodiversity and human nutrition, identified throughout the qualitative work in this research, was forest governance policies (Chapter 6). Chapter 6 and 7 suggest that in the East Usambaras, historical, if not current, forest governance policies have affected access to, and use of, forest products. Further research is crucial to better understand how these and other social and cultural factors meditate the relationship between biodiversity and human nutrition, especially as they are likely to explain many of the inconsistent findings in the literature.

This is one of the first studies, to our knowledge, to examine the relationships between biodiversity and human nutrition at the landscape level. We have noted that conservation efforts are increasingly focused on the broader landscape mosaics surrounding tropical forests. Landscape mosaic approaches propose that landscape heterogeneity is important for biodiversity conservation and human livelihoods, yet virtually nothing is known about the impact of landscape heterogeneity on human diet and nutrition. The impact on human diet, nutrition and health is a novel research topic which would likely yield theoretically interesting as well as practical findings for biodiversity conservation. In general there is need for increased use of nutrition as an outcome measure in forestry research. Although, many projects include 'development' and 'livelihoods' outcomes, almost all of the indicators used are based on economics. Economic indicators are rarely as closely related to fundamental well-being as are food security, food sovereignty, diet and nutrition.

Above, we call for enhanced integration of sectoral efforts and for the application of food security and nutrition as a cross-cutting issue in agriculture, forestry, health and development. However, in order to support such shifts, it will be important to understand the current knowledge of local 'experts' (e.g. teachers, forest officers and agricultural extensionists) on the importance, acceptability, suitability, access to, sustainability, of various foods, and foods from different land use types. It is important to examine how, when and where transmission of such knowledge from local experts to local populations, occurs and the sources of knowledge that these local experts rely on for their own learning, as well as the structure of their knowledge systems, and their epistemologies.

7.7 Final Conclusions

Resilience and synergy are common concepts in ecology that have been adopted by many researchers favouring systems approaches. In ecology, resilience is defined as the capacity of an ecosystem to recover from and resist damage after a disturbance or perturbation. If the ecosystem is not sufficiently resilient, or the disturbance is too great, the result can be a profound and permanent shift in the structure and processes of the ecosystem. Resilience, often measured as the time required to return to equilibrium after disturbance, or as the capacity to absorb disturbance and still retain essentially the same function and structure) (Folke 2006, Holling 1973, Walker and Salt 2006), is a concept that has been widely applied to social-ecological systems to explain the importance of biocultural diversity (Berkes and Folke 1998). Synergy occurs when two or more drivers (factors) interact to produce a result, effect, or outcome greater than the sum of the independent impacts of each driver/factor. While synergy is a concept less commonly discussed in social-ecological discourse it is a central concept in ecology.

Both concepts, resilience and synergy, have special relevance in the study of diversity; both are plausible mechanisms of diversity's benefits. Many types of diversity are now proposed as adaptive, including biodiversity, agricultural diversity, linguistic diversity and cultural diversity (Boyd and Richerson 1983, D'Andrade 1987, Frison et al. 2006, Hajjar et al. 2008, Jackson et al. 2007, Johns and Sthapit 2004, Keesing 1974, Millennium Ecosystem Assessment 2005, Sunderland 2011).

So how do the concepts of resilience and synergy apply to nutrition? Is there such a thing as Nutritional Resilience? Grounded in a systems and EcoHealth framework, the overall objectives of this dissertation have included seeking insight into these complex questions. Although methodologies limit the ability to provide concrete answers, evidence herein can support some initial suggestions. The exploration of seasonal differences in Chapter 5, and of community diversity in Chapter 6, both highlight the fact that biodiversity allows local communities greater choice of foods. This work suggests that diversity, and especially diversity from wild and forest foods, is important, as it provides resilience in the food system. The role of diversity for appetite, and the fact that dietary diversity (DDS_6 1 day) made a significant contribution to the multiple regression model of children's dietary adequacy (MAR) (Chapter 3) suggests that diversity in the diet leads to synergistic effects on nutrition. In the above sections I have argued for enhanced focus on and use of cross-cutting efforts and initiatives for nutrition and conservation. De Plaen and Kilelu (2004) note that systems and EcoHealth

“.... approaches are dynamic and enable progress to be made through the synergies of complementary approaches rather than defining and defending disciplinary, sectoral, and intellectual territory”. While one of the theoretical benefits of diverse, cross-cutting interventions is the increased likelihood that the factors most important to achieving change will be addressed (important in poorly understood complex social-cultural systems), another important benefit is that multiple interventions can have synergistic effects and thus achieve greater impact.

The insights into the synergistic, resilience, and adaptive functions of diversity for food systems, food security, diet and nutrition, are particularly timely as populations in Tanzania and around the world face rapid environmental, economic and social-cultural change. As seen in this research, even rural subsistence farmers are entering a nutrition transition (see sections 6.4.1 and 7.1.1) (Fleuret and Fleuret 1980, Maletnlema 2002, Powell et al. forthcoming-b). Around the world, nutrition transitions are associated with increased rates of obesity and chronic diseases, such as diabetes II and hypertension, even in communities that have not yet overcome micronutrient deficiencies (a.k.a ‘hidden hunger’) (Doak et al. 2004, Popkin 2004).

Furthermore, global climate change is leading to profound changes in climate, environment and food systems in Sub-Saharan Africa, where climate is among the most frequently cited drivers of food insecurity (Gregory et al. 2005). Sub-Saharan Africa will bear more than its share of the burden (in terms of loss of life and hardship) of global climate change (Parry et al. 2005) and is also less equipped to cope (Patz et al. 2005). Meanwhile, climate change mitigation and adaptation efforts have initiated what is potentially the largest change in forest governance and local livelihood strategies ever seen globally.

Local populations (and local and national governments) face these changes, on top of the continued struggle to overcome local inequality, food insecurity and micronutrient malnutrition; accelerating globalization and market integration; and, significant global economic uncertainty. This dissertation has sought to highlight the importance of biological and cultural diversity for the maintenance of human dietary diversity and nutrition through uncertainty and change. But, improved understanding of the complex relationships between human and ecosystem health will be essential, specifically how adaptive management of biodiversity, natural resources and food systems at local, national and global scales can contribute to food security and human nutrition. Putting recommendations herein into practice (such as enhanced cross-cutting efforts) will help ensure that local populations in the East Usambara Mountains, Tanzania and around the world are equipped to maintain their food security, food sovereignty and health in the face of the many changes they now face.

Chombo hakiendi ikiwa kila mtu anapiga makasia yake

– Kiswahili proverb

The boat does not get anywhere if each person rows in their own direction/manner
(i.e. To achieve change, people must work together)

Chapter 8

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For all chapters except Chapter 6

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Appendices

Appendix 1: Kiswahili Summaries Returned to Villages

Misitu, matumizi yake na lishe katika Milima ya Usambara Mashariki, nchini Tanzania - BRONWEN POWELL, JACLYN HALL na TIMOTHY JOHNS

Ujumbe muhimu (Main Points for villages to know):

1. Vyakula vinavyokusanywa uhimarisha afya na lishe bora; hasa vyakula vya mimea ya aina mbalimbali kama vile mboga, uyoga na matunda ya miti inayokua mwituni
2. Watu wanapaswa kutumia vyakula vinavyokusanywa kuboresha uakiaji wa virutubisho na kuzuia magonjwa kama vile shinikizo la damu na kisukari
3. Utumiaji wa wanyama pori kama chakula haukubaliki katika Usambara Mashariki (isipokuwa labda katika sehemu ya Kuhe)
4. Vijiji vilivyo na maeneo makubwa ya misitu karibu navyo (yaani kwenye mashamba ya kibinafsi na ya kijamii) vinaweza kupata vyakula kutoka mwituni na rasilimali nyingine kama vile kuni, fito, kamba na kadhalika kwa urahisi zaidi - na hivyo kuweza kuepukisha wakazi wake kusafiri kwenye misitu iliyo mbali
5. Utafiti unaonyesha kwamba wanakijiji lazima wapande na kutunza miti iliyo karibu na nyumba zao kwa sababu inaweza kuwasaidia kupata vyakula vinavyokusanwya mwituni katika mlo wao na kwa jinsi hiyo kuhimarisha lishe yao.

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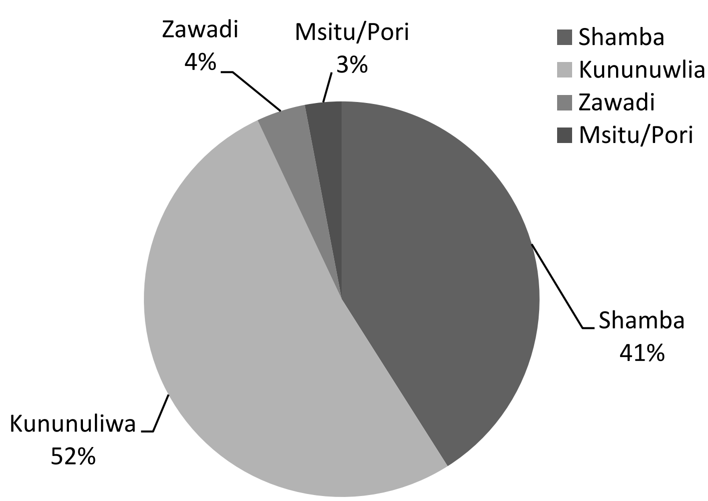
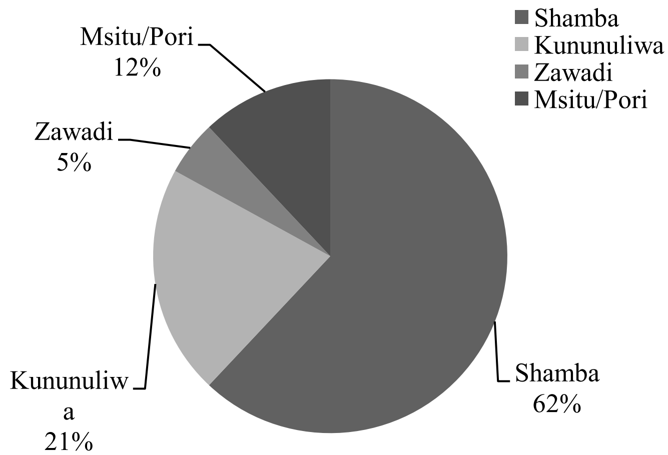
Muhtasari (Abstract): Uhaba wa chakula pamoja na lishe duni katika familia nyingi, kwa kiasi flani umechangiwa na uharibifu wa misitu katika maeneo yanayozunguka jamii nyingi. Vile vile husababisha ukataji huo wa miti. Ripoti hii inachunguza uhusiano baina ya lishe ya wenyeji wa Milima ya Usambara nchini Tanzania kwa upande mmoja, na uhifadhi wa misitu na matumizi yake katika eneo hilo kwa upande mwingine. Takwimu kuhusu lishe na mchanganyiko wa vyakula vya watoto 270 na mama zao zilikusanywa. Uchunguzi ulifanywa kuhusu matumizi ya eneo ya msitu iliyo karibu na nyumba na lishe bora. Watu waliotumia vyakula vinavyokusanywa porini na vingine vilivyokusanywa baada ya kumea bila kupandwa au kupaliliwa kwenye mashamba, wameonekana kutumia vyakula vya aina mbalimbali hasa aina tofauti za wanyama ambapo wamekuwa na milo yenye virutubisho zaidi vya kutosha. Kwa kijumla watu hawa walikuwa na eneo kubwa zaidi ya msitu karibu na makazi yao; jambo ambalo linaonyesha uhusiano baina ya kuwepo msitu na matumizi ya vyakula vilivyokusanywa kutoka porini/msituni. Utafiti unaonyesha pia kaya nyingi ambazo zimekuwa zikienda misituni kwa ajili ya matumizi mbalimbali ya chakula, wana maeneo machache yenye miti katika maeneo yao hali. Hii inaonyesha kuwa kuna umuhimu kuwa na kilimo- msitu karibu ya nyumba kwa ajili ya wao kujipatia chakula cha ziada kitokanacho na mazao ya msitu. Ingawaje historia inaonyesha kuwepo kwa msukumo mdogo kwa wananchi kushiriki katika shughuli za uhifadhi wa misitu katika milima ya usambara, uhifadhi wa misitu katika maeneo mbalimbali hususani katika maeneo ya kilimo pamoja na maeneo mengine ya ardhi za vijiji ni muhimu katika kuhakikisha upatikanaji wa vyakula mbalimbali vya mwituni hali ambayo itapelekea kuwepo kwa uboreshwaji wa afya katika kaya mbalimbali.

JEDWALI 1 *Kubadilisha vyakula; asilimia ya wastani ya vyakula kutoka mwituni, vyakula vilivyonunuliwa, vyakula ambavyo vilipokewa kama zawadi, vyakula ambavyo vilitoka shambani au mwituni, na asili ya aina ya vyakula kutoka mwituni kama ambavyo vilitumiwa na kina mama au watoto*

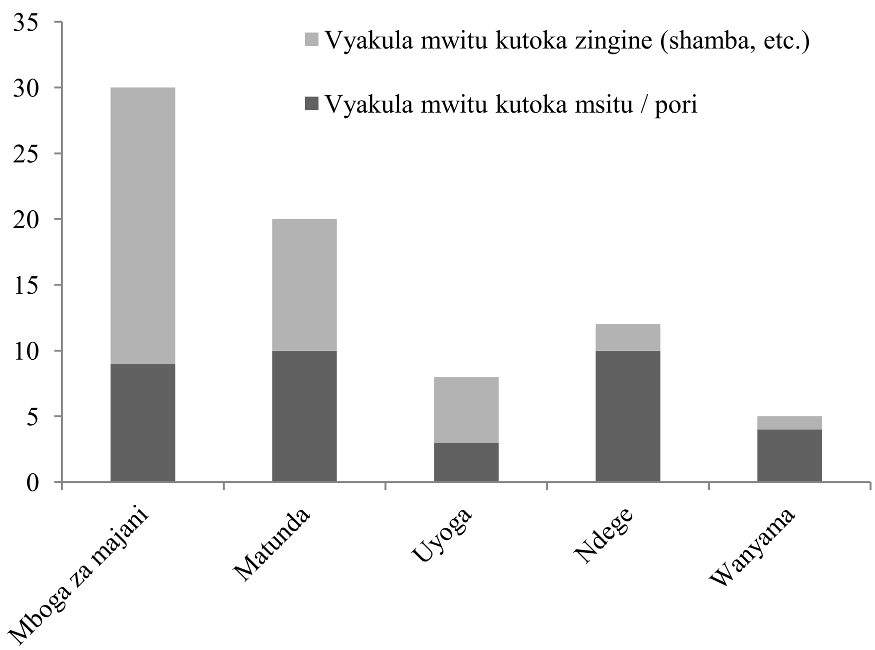
	Mama (N=269)		Mtoto (N=269)	
	Wastani ±SD	Asilimia ya chini – Asilimia ya juu	Wastani ±SD	Asilimia ya chini – Asilimia ya juu
Kubadilisha vyakula	38.4 ±11.6	14-81	39.3±11.7	15-80
Asilimia – Walioripoti ≥1 ya vyakula vilivyokusanywa **MWITUNI** (%)	44.6	-	45.4	-
Asilimia ya vyakula kutoka **SOKONI** (%)	51.4 ±12.9	25.8-91.7	52.4 ±12.5	25.8-91.7
Asilimia ya vyakula vilivyo **ZAWADIWA** (%)	4.6 ±6.3	0-45.0	4.9 ±6.8	0-50.0
Asilimia ya vyakula kutoka **SHAMBANI** (%)	41.6 ±12.2	5.0-68.3	40.5 ±12.2	5.0-66.7
Asilimia ya vyakula kutoka MWITUNI (%)	2.6 ±4.0	0-23.9	2.5 ±3.7	0-22.8
Asilimia ya vyakula vya asili ya MIMEA ISIYOKUZWA MASHAMBANI (%)	15.4 ±5.4	-	15.3 ±5.2	-
Asilimia ya vyakula kutoka MWITUNI **VILIVYONUNULIWA** (%)	22.1 ±22.5	0-100	20.7 ±21.2	0-100
Asilimia ya vyakula kutoka MWITUNI **VILIVYO ZAWADIWA** (%)	2.5 ±7.8	0-50	3.8 ±10.4	0-80
Asilimia ya vyakula kutoka MIMEA ISIYOKUZWA **VILIVYOKUSANYWA SHAMBANI** (%)	61.6 ±24.7	0-100	61.9 ±25.2	0-100
Asilimia ya vyakula kutoka MIMEA ISIYOKUZWA MASHAMBANI **VILIVYOKUSANYWA MWITUNI** (%)	12.5 ±16.8	0-61.5	12.0 ±16.3	0-63.6



KIELELEZO 2 Asili ya vyakula vyote (akina mama na watoto pamoja)



KIELELEZO 3 Asili ya vyakula kutoka mimea isiyokuzwa shambani (akina mama na watoto pamoja)



KIELELEZO 4 *Jumla ya aina ya vyakula vyenye asili ya mwituni vilivyokusanywa porini, na matumizi ya ardhi mbalimbali katika kaya mbalimbali zilizotafitiwa; aina ya vyakula mbalimbali*

Appendix 2: 24 hour recall and 7 day Food Use Questionnaire

24 hour Recall

HH Code Number: ____________________ Date:______________________
Interviewer Name: ___________________ Start time: _________________
Informant Position in HH: _____________ Informant Gender: male / female

MOTHER	Time	Food	Description (including VARIETY)	Source	Amount (HH measures)	Amount (grams)
Quick List						
CHILD						

Additional Questions:

Je, ulichokula jana ni kawaida au tofaouti na siku nyingine? (Kwa kivipi?)
Was yesterday's food intake unusual? (how?)

Je jana ulitumia vitamini yeyote, madini au dawa? (aina, kiasi gani?)
Did you take any vitamins, minerals or medicines yesterday? (kind, amount?)

Je kwa sasa wewe ni mjamzito au unanyonyesha? (Miezi mingapi?)
Are you pregnant or lactating right now? (what month?)

Je umepikia watu wangapi jana?
How many people did you cook for yesterday?

Thank you very much!   Asante Sana!

QUALITY CONTROL:

Questions or Comments of the Interviewee:
____
____
____
____

Start time: ____________   End time: _____________   Length: ________________

Check List

Recorded Information / Probing:	Yes	No
Water		
Raw and Cooked Information Recorded		
Preparation cooking time, etc		
Additions: Milk, Salt, Oil		
Snacks: Candy, Drinks, Nuts, Fruit, Wild Fruit		
Variety and Ripeness		

Food Frequency Questionnaire

HH Code Number: ____________________ Date:______________________
Interviewer Name: ___________________ Start time: _________________
Informant Position in HH: ____________ Informant Gender: male / female

FOOD	**Mother** ***Mama***	**Child** ***Mtoto***	**Varieties** (number and names)	**Source** (duka, bustani, msitu…)

FOOD	**Mother** ***Mama***	**Child** ***Mtoto***	**Varieties** (number and names**)**	**Source** (duka, bustani, msitu…)

Appendix 3: Wealth Ranking Protocol

By: Bronwen Powell, February 2008

OBJECTIVES:

1. To determine the relative wealth of survey households within each village
2. To determine the relative wealth of survey villages relative to their neighbours.

EQUIPMENT:

1. Markers, pens and paper.
2. Heavy-duty paper / cards with the household names (head male and female and sub-village) for each of the household written clearly in marker.

PARTICIPANTS: 10-15 people should participate in this focus group.

- Community leaders and Village government
- Religious leaders, school teachers, traditional and western health care workers, and agriculture extensions and other people who know many people in the village
- It is important that both 'rich' and 'poor' key informants are invited

ACTIVITIES:

<u>Household Wealth Ranking:</u>

STEPS:

a. Discuss Wealth and what it means in the community
b. Discuss and record the main determinants and indicators of household wealth in the community (LIST 5 to 10)
c. Take 5 pieces of paper and write 1 to 5 on each, with 5 = highest and 1 = lowest. Place them in order on a table or the floor and ask the participants to go through each of the 45 household names and chose which pile they belong in (this should be done as a group and discussion points should be recorded)
d. Describe the characteristics of a typical household in the highest group and the lowest group
e. Review determinants and indicators of wealth used during the exercise (RANK the top 3 to 5 that were used) and name the piles.

<u>Village Wealth:</u>

STEPS:

a. Use ABOVE List all of the neighbouring / near-by villages (between 6 and 12)
b. Discuss if determinants and indicators of household wealth are the same or different from those for VILLAGE wealth (LIST 5 to 10)
c. Write the names of the villages on pieces of paper and then rank them on the 1-5 labelled pieces of paper (this should be done as a group and discussion points should be recorded)
d. Review determinants and indicators of wealth used during the exercise (RANK the top 3 to 5 that were used).

Appendix 4: Food Sources of Important Nutrients

Figure A1 Foods contributing to energy intake

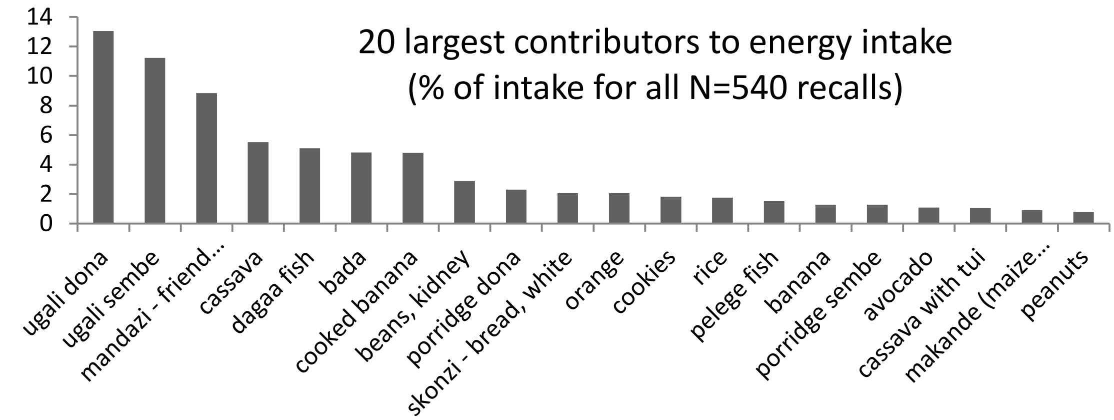


Figure A2 Food contributing to protein intake

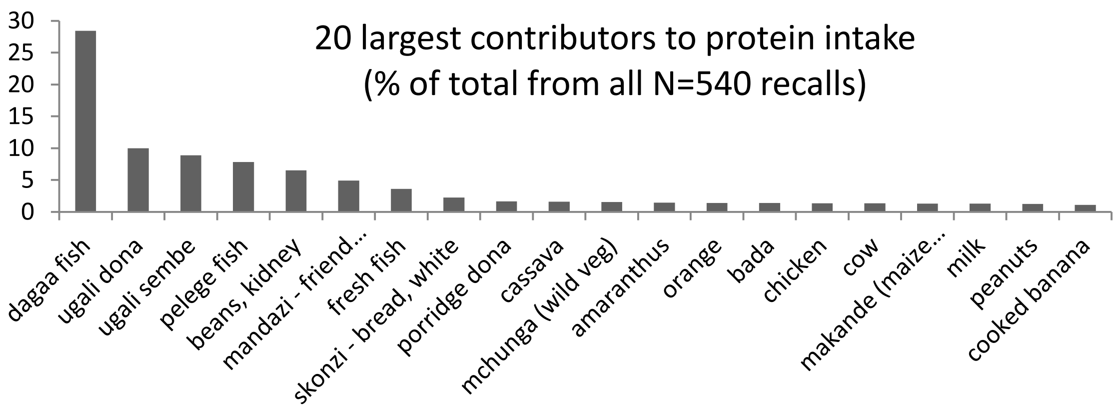


Figure A3 Food contributing to fat intake (not including oils and coconut milk)

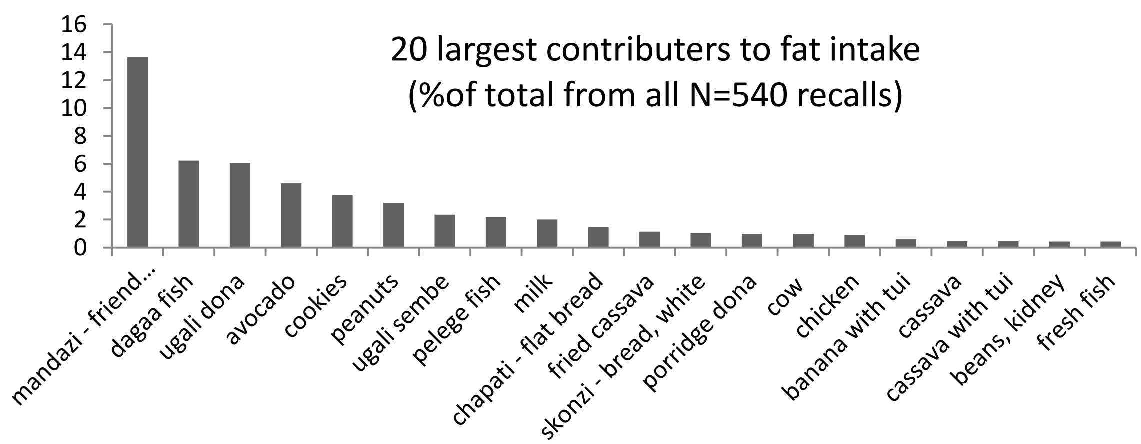


Figure A4 Food contributing to calcium intake

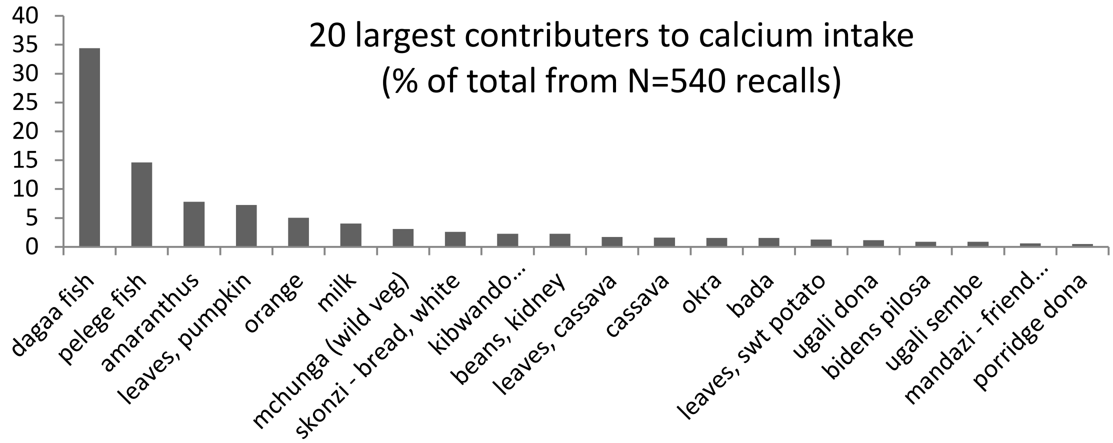


Figure A5 Food contributing to iron intake

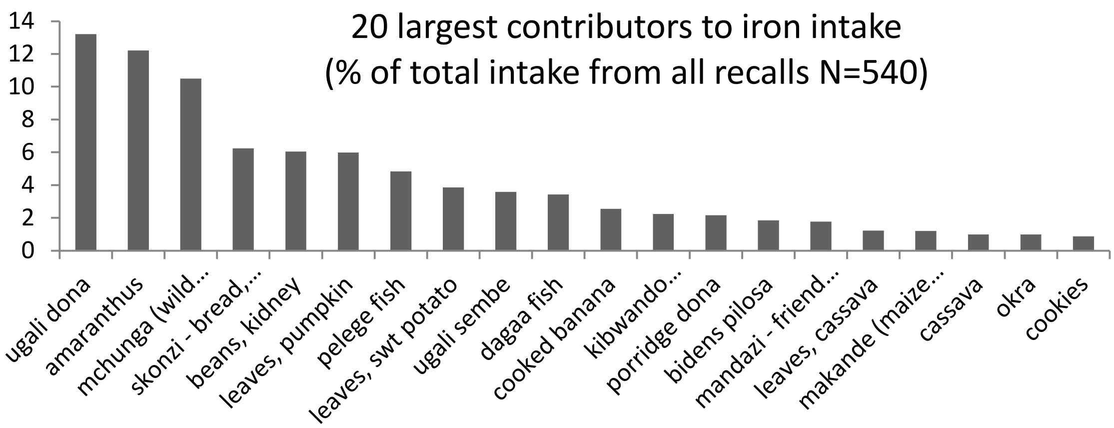


Figure A6 Food contributing to zinc intake

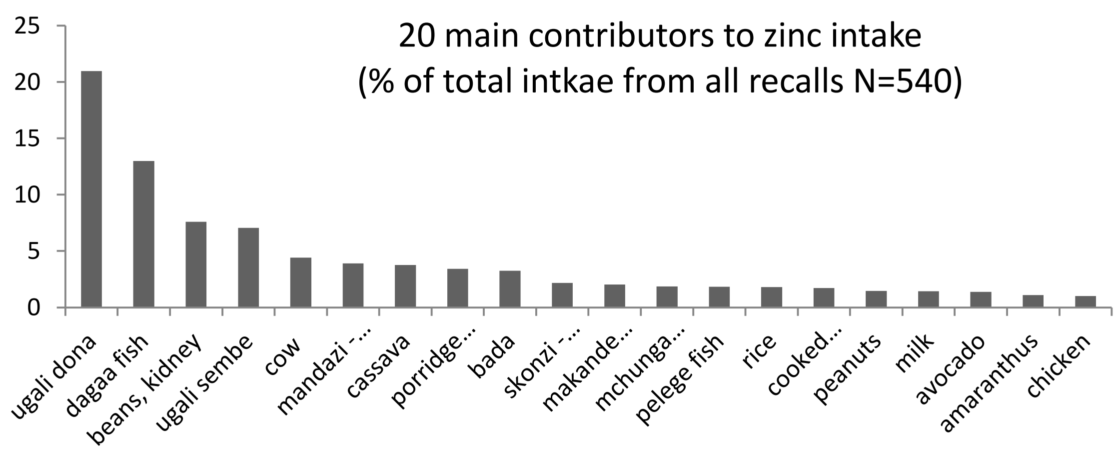


Figure A7 Food contributing to vitamin A (RAE) intake

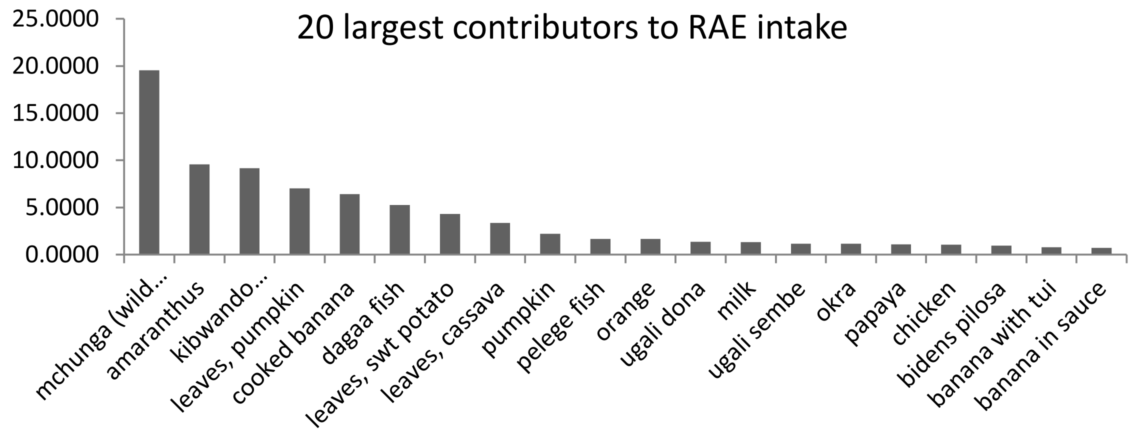


Figure A8 Food contributing to vitamin C intake

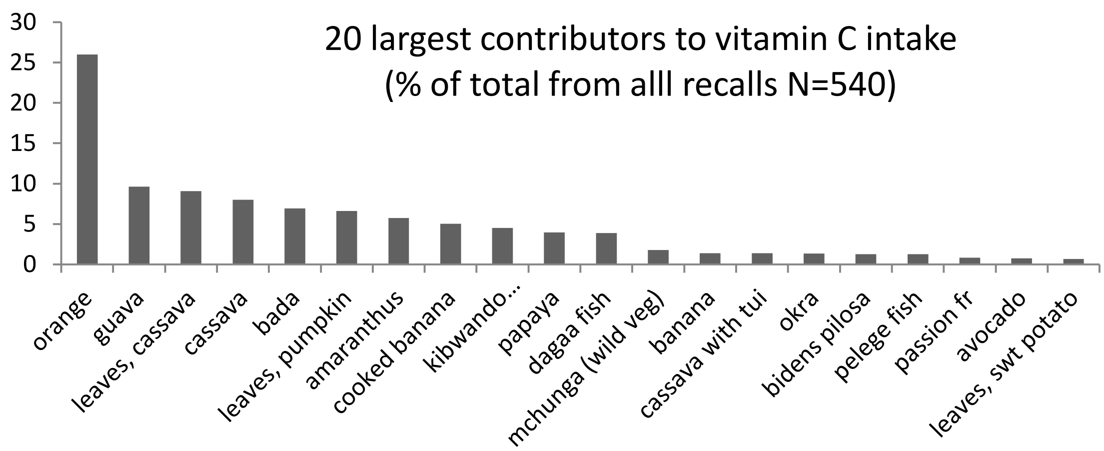
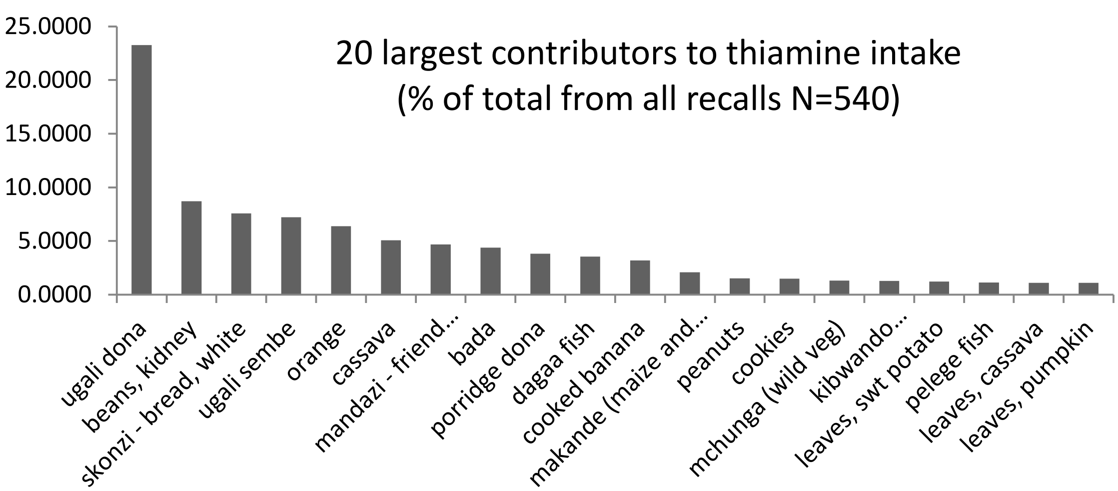


Figure A9 Foods contributing to thiamine intake



Appendix 5: Limiting Nutrients in the East Usambaran Diet

Because these intakes are based on only two days of recall they cannot be used to determine overall adequacy levels in the population. They can however, be used to compare individuals to each other based on their relative nutrient adequacy, as well as to compare nutrients, to get an idea of which nutrients are most likely to be deficient in the diet, or the limiting nutrients of the diet. Nutrient adequacy ratios (NARs) were calculated for each child's intake of each nutrient (mean/ USDA RDA appropriate to each child's age group and truncated at 1.0,). The means of these ratios for all children allow us to compare nutrients based on both the frequency and severity of potential inadequacy (if an individual failed to consume the RDA of a nutrient, and how far below the RDA they fall, is a proxy measure of potential inadequacy).

While an NAR was only calculated for 10 micronutrients, 4 of them had a mean NAR of greater than 0.9, suggesting a very low likelihood that these are a problem in this population (magnesium, niacin, thiamine and vitamin C). Intake of vitamin C and other micronutrients that suffer high losses in cooking may have been overestimated relative to other nutrients as no adjustments for loss in cooking were made. Compared to other nutrients, riboflavin and iron had moderate mean NARs and calcium, vitamin A (RAE), B_{12} and zinc had the lowest (zinc had the lowest mean NAR of 0.381).

For the macronutrients, 30.3% of the children had consumed < 10% of their energy from protein and 73.0% had <10% of their energy from fat. The mean percents of energy from protein and fat were 11.8% and 8.4% respectively and none exceeded the upper end of the AMDR range for percent of energy from protein or fat.

Table A1 Intake for mothers, children and Children's Mean NAR (Nutrient Adequacy Ratio) for important micronutrients and rank of likelihood of being a limiting nutrient

Nutrient	Mean Intake Mother N=272	Mean Intake Children N=274	Children's Mean NAR	Comment
Energy (kcal)	2048	1086	X	X
Protein (g)	50	32	0.951	9
% kcal from protein	10.0	11.8	X	X
Fat (g)	31	23	X	X
% kcal from fat	6.2	8.4	X	X
Calcium (mg)	516.7	377.8	0.656	4
Iron (mg)	17.1	10.3	0.726	5
Zinc (mg)	6.18	3.39	0.381	1
Magnesium (mg)	422.5	219.9	1.000	10
Vitamin C (mg)	160.3	97.7	0.951	9
Vitamin A (RAE) (µg)	493.5	315.8	0.584	3
Thiamine(mg)	1.214	0.646	0.909	8
Riboflavin (mg)	0.937	0.547	0.854	6
Niacin (mg)	12.59	6.94	0.860	7
B_{12} (µg)	0.69	0.57	0.488	2

Appendix 6: Nutrition in the Tanzanian Primary School Curriculum

<u>Grade 5, Science Curriculum, Chapter 2:</u>
Utunzaji wa mwili na afaya boda ***The needs/ uses of the body and good health***

Chalula na mapishi ***Food and Cooking***

Kila utamduni una msimamo wake juu ya nini kinafaa kuliwa na nini hakifai. Kwa mfano, watu wengine hupata taabu kula konokono, wadudu, ngadu, panya, mbwa, chaza, wakati huo huo tamaduni zingine ni kawaida kula vitu kama hivyo. Wakati mwingine, chakula huunganishwa na mila au dini; katika dini zingine, watu hawali nguruwe, ng'ombe au nyama ya aina yoyote. ***Every culture has its position on what is important to eat and what should not be eaten. For example, some people have a problem with eating snails, insects, oysters, crabs, rats, dogs, while in other cultures it is normal to eat these sorts of things. Other times, food is connected to cultural traditions or religion; in some religions people don't eat pig, cow or even any type of meat.***

Mambo ya kufanya - Kutafuta desturi za ulaji: Katika kikundi chako, jadili hoja ambazo watu huweza kuwa nazo juu ya vyakula vinavyofaa kuliwa na vile ambavyo havifai kuliwa na sababu zake. Kwa mfano, kwa nini wanawake wakatazwe kula mayai. Aina gani za vyakula vinakukera wewe kwa nini?
Things to do – Looking for traditional diet: In your group, discuss the concerns that people have about the foods they eat and if foods are fit or unfit to be eaten and the reasons why. For example, why do [some] women avoid eating eggs? What types of foods are offensive to you, why?

Kupika chakula huua vijidudu maradhi ambavyo heweza kuwemo kwenye nyama au mboga. Kupika pia huvunja vunja seli za chakula na kufanya view rahisi kumeng'enywa. Aidha, kupika hubadili ladha ya chakula. Lakini kupika kwa muda mrefu kupita kiasi huweza kuharibu ubora wa chakula, kama vile vitamin. ***Cooking food kills any parasitic diseases that could be in meat or vegetables. Cooking also breaks the cells of food and makes it easier to grind (may also mean chew). Additionally, cooking changes the taste of food. But cooking food for longer than normal can damage the quality of food, such as vitamins.***

Njia tatu kuu za kupika chakula ni kuchemsha, kukaanga, na kuchoma (kubanika). Kuchemsha maana yake kupika chakula kwenye maji katika halijoto ya 100 deg. C. Kukaanga maana yake kupika chakula kwenye mafuta au samli ya moto. Halijoto ya mafuta yanayochemka (kadiri ya 180 deg. C.) ni ya juu zaidi kuliko maji yanayochemka, kwa hiyo chakula kinachokaangwa huiva haraka. Kuchoma au kubanika maana yake kukiweka chakula moja kwa moja kwenye moto. Ukifanya hivi kwenye oveni, wakati mwingine huitwa kuoka. ***The three main ways to cook food are: to boil, to fry and to***

roast. 'Boiling' means to cook food in water at a temperature of 100 deg. C. 'Frying' means to cook food in hot oil or ghee/butter. The temperature of boiling oil (approximately 180 deg. C.) is much higher than that of boiling father, so food will be fried quickly. 'Roasting or toasting' means to put the food, one by one, directly in the fire. If you do this in the oven, it is sometimes called baking.

Kumbuka: ***Remember***

- Si lazima uwe tajiri ule mlo kamili wenye kuleta afya bora ***It is not necessary to be rich to have a complete diet which gives good health***
- Unaweza kuwa na nguvu na afya bora hata kama sehemu kubwa ya protini yako inatokana na mimea ***You can be strong and health even if most of your protein comes from plants***
- Unaweza kupata vitamin kwa gharama nafuu sana kutoka kwenye matunda ***You can get vitamins and for a very low cost from fruits***
- Vinywaji vitamu na pipi ni ghali na havina virutubisho vyovyote ***Sweet drinks and candy are expensive and don't have any nutrieints at all***
- Mchannyiko wa vyakula ni bora zaidi kuliko kula aina moja au mbili pekee za vyakula ***Mixing foods is better than eating only one or two types of food***
- Lishe mbaya husababisha magonjwa. Watoto wenye njaa hawawezi kufanya kazi vizuri ***Bad nutrition can cause disease. Children with hunger cannot do work well.***

Grade 6, Science Curriculum, Chapter 2:
Usafisha na usalama wa chakula (***Cleaning and safety of food***)

Lishe na hifadhi ya chakula (***Nutrition and the benefits of food***):

Ulijifunza kutoka katia Darasa 4 kuhusu aina tofauti za vyakula kama vile wanga, protini, vitamini na madini na jinsi ya kuvianisha vyakula unavyokula katika makundi haya. Katika Darasa la 5 ulijifunza maana ya mlo kamili, na jinsi ya kupika chakula bila kuharibu ubora wake. ***You learnt in grade 4 to classify the different types of food that you eat, such as starch [here they use wanga, not carbohydrate], protein, vitamins and minerals and how to put the food you have eaten into these groups. In grade 5 you learnt the meaning of a complete diet and how to cook foods without destroying their quality / benefit.***

Katika sehemu hii, utajifunza kuhusu athari ya vyakula mwilini mwako, jinsi ya kuzuia utapiamlo, na jinsi ya kuhifadhi chakula ili kisihaibiwe na wadudu waharibufu ambao huweza kudhuru mwili wako. ***In this section, you will learn to about the effect of food on your body, how to prevent malnutrition and how to store food to prevent infectious parasites, which can harm your body.***

Virutubisho ni viambato muhimu vilivyo kwenye chakula. Virutubisho hivi vinahittajika mwilini mwetu kwa ajili ua kukaa na kuwezesha mwili kufanya kazi. Lishe bora maana yake ni kupata kiasi kinachohitajika kwa kila kirutubisho katia mlo wako. Lishe dune (utapiamlo) maana yake ni kupata kaisi kidogo sana, au wakati mwingine kupata kiasi kilichozidi sana, cha viambato muhimu. Kama umekosa protini basi huwezi kula kabohaidreti ili kufidia upungufu huo. Picha zifuatazo hapa chini zinaounyesha watoto wenye aina mbalimbali za utapiamlo (tezi la shingo, unyafuzi, matege, kugundua unyafuzi). ***Nutrients and other important things are in food. These nutrients are needed by our bodies for growth and to be able to do work. 'Good nutrition' means to get the correct about of each nutrient in your diet. 'Inferior nutrition (malnutrition / hunger)' means getting a very small amount, or in other cases, getting too much of important ingredients. If you lack protein then you cannot eat carbohydrates to compensate. The following pictures below show children with different types of malnutrition (goitre, kwashiorkor, bowlegs, early kwashiorkor).***

Magonjwa tofauti husababishwa na aina tofauti za utapiamlo. Kwa mfano, ukila kiasi kigodo sana cha protini (nyama, samaki, maharage) unaweza kupata unyafuzi, kama vile mtoto anayeonekana kwenye picha hapa juu. Unaweza kumgundua kama mtoto mdogo ana unyafuzi kwa kupima mkono wake kama inavyoonyeshwa kwenye picha hii. ***Different diseases result from different types of malnutrition, For example, if you eat very little protein (meat, fish, beans) you can get kwashiorkor, like the child shown in the picture above here. You can discover, like this small child, they have kwashiorkor of measuring their hand as shown in this picture.***

Ni muhimu kwa watoto wadogo kupimwa uzito wao mara kwa mara. Kama watoto watapelekwa kliniki, watapimwa uzito wao kuhakikisha kuwa wanaongezeka uzito. Watoto wenye uzito mdogo wana uwezekano mkubwa wa kupata utapiamlo. ***It is important that small children are weighed regularly. If a child is sent to the clinic they will be weighed to make sure they are gaining weight. Underweight children have a bigger chance to get malnutrition.***

Aina nyingi za magonjwa haya ya upungufu husababishwa na ukosefu wa vitamini na madini. Mwili wako unahitaji kiasi kidogo sana cha viambato hivi, lakini ukivikosa kabisa viambato hivi unaweza kuugua. Kwa hiyo inakubidi ujue ni vyakula gani vitakupa vitamini muhimu. Jedwali hili linaonyesha baadhi ya vitamini hizi. ***Many types of diseases from deficiencies are caused by lack of vitamins and minerals. Your body needs a very small amount of these ingredients, but if you are missing them completely you can develop a deficiency. Therefore you need to know which foods give you important vitamins. This table shows you some of these vitamins.***

Mambo ya kufanya: Kutokana na jedwali hilo hapo juu, jadili na uandike kuhusu ugonjwa ambao unaweza kuupata kama haujakula kiasi cha kutosha cha nafaka, nyama na samaki na mazao ya maziwa.
Things to do: From the above table, discuss and write about diseases that you can get if you do not eat the correct amount of grains, meat, fish and dairy products.

Kuzuia utapiamlo

Mara nyingi, wazazi hujua namna ya kuwalisha watoto chakula chenye lishe bora, lakini hukosa uwezo wa kufanya hivyo. Hali hii huweza kutokea endapo mavuno mazuri na ya kutosha yatakosekana na ukame, au kwa kukosa fedha kutosha kununulia chakula bora. Matatizo ya utapiamlo yataweza kutatuliwa vilivyo kama watu watajifunza namna ya kushirikiana utajiri, ardhi na vyakula vyao kwa usawa. ***Often, parents know how to feed their children with good nutrition, but they lack the means to do so, because of poor harvest of crops and drought, or because of lack of enough money to buy good food. The problem of malnutrition would be solved if people learned to share their wealth, land and food equally.***

Lakini kuna mambo mengi ambayo hata maskini wanaweza kuyafanya ili waweze kula chakula bora na kuzuia utapiamlo. Yafutayo ni baadhi ya mambo hayo. ***But there are many things that even the less fortunate can do so that they are able to eat good food and prevent malnutrition. The following are some of those things.***

- Kula mara kwa mara. Milo mingi midogo ni bora kuliko mlo mjoa mkubwa. ***Eat regularly. Many small means is better than one large meal.***
- **Kula aina mbalimbali za vyakula**, sio chakula cha aina moja tu. Vyakula hivi ni pamoja na mboga za majani, jamii ya viazi, maharage, maziwa, na vyakula vingine vyenye protini. ***Eat many different types of foods, not only one type of food. Foods like this, together with leafy vegetables, tubers, beans, milk and foods with protein.***
- **Badilisha mimea shamabni kwako ili kulitumia vizuri shamba lako na panda aina mbalimbali za mimea** ***Change the plants in your field and plant your farm well with many varieties of plants.***
- Akina mama wawanyonyeshe watoto wao maziwa yao. Maziwa ya mama yana gharama ngodo sana, ni salama zaidi na yana virutubisho vingi zaidi. ***Mothers should breastfeed their children with their milk. A mother's milk doesn't cost anything, is safe and has more nutrients in it.***
- Fuga kuku au sungura kwa ajili ya mayai na nyama. Fuga nyuki kwa ajili ya asali. ***Raise chickens or rabbits for eggs and meat. Raise bees for honey.***
- Kama una bwawa au ziwa, fuga samaki kwa ajili ya kujipatia protini. ***If you have a pond or lake, raise fish to increase your protein intake.***
- Kula mboga za majani pamoja na mzizi ya mimea kama vile mihogo na maboga. Mimea hii ina kiasi cha kutosha cha protini pamoja na vitamini. ***Eat leafy vegetables together with the roots of plants such as cassava and pumpkin. This plant has enough protien and vitamins.***
- Punguza unywaji pombe na ulaji wa vyakula vyote hivi **huweza kuleta magonjwa ya moyo**, tumbo, maini, mapafu na meno. ***Reduce / limit alcohol consumption and all foods which can lead to heart disease, diseases of the stomach, liver, lungs and teeth.***

Mambo ya kufanya: Mwalimu wako anaweza kuwapeleka katika kliniki au kituo cha afya kukitembelea. Chunguza na andika mambo yote utakayoyaona yakifanyika kwenye kliniki ili kupima na kuzuia utapiamlo kwa watoto
Things to do: Your teacher can take you to visit a clinic or health college. Observe and record everything you see that they do to measure the weight and prevent malnutrition in children when you go.

Vitamini muhimu na magonjwa ya upungufu: *Important vitamins and deficiency diseases*

Vitamini	Baadhi ya vyanzo	Magonjwa kutokana na upungufu
Vitamini A:	Maziwa, siagi, jibini, mafuta ya samaki, majarini	Kutoona usiku
Vitamini B1 (Thiamini)	Nafaka isiyokobolewa, hamira	Beriberi (huweza kusababisha mabadiliko kwenye uti wa mgongo, au kushindwa kwa moyo)
Vitamini B2 (Riboflavin)	Maini, maziwa, mayai	Ugonjwa wa ngozi, uvimbe kwenye midomo na ulimi
(Niasini)	Nyama, samaki, nafaka isiyokobolewa	Pelagra (ugonjwa wa ngozi, kuhara nakichaa)
Vitamini B_6 (Piridoksini)	Nyama, maini, mbogamboga, nafaka isiyokobolewa	Uvurugikaji wa uchukujai wa asidi za amino katika mwili
Vitamini B_{12} (Siyanokobalamini)	Hakuna chakula kinachohusika	Anemia
Vitamini C (Asidi askobiki)	Matunda freshi na mbogamboga	Husababisha anemia, uvimbe wa fizi, michubuko na kutoka damu kwenye fizi
Vitamini D	Maziwa, mayai, siagi, mafuta ya samaki, majarini	Kulainika kwa mifupa
Vitamini K	Hakuna chakula kinachohusika	Kasoro kwenye mfomu wa ugandaji wa damu

Appendix 7: Local Use of Forests and Perceived Importance of Forests

Use of Forest and Local Perceptions of the Importance of Forests:

Of the surveyed household heads, 32.8% reported never having been to the forest, while 67.4%, 46.4% and 33.8% reported having visited the forest in the last year, month and week. The average number of trips for respondents having gone to the forest in the last month was 8.1±8.6 and the last week was 3.0±2.0. Figure J presents the reported reasons for the most recent trip to the forest, of which procurement of some sort of food (collecting vegetables or hunting) was the least common reason given. The figure shows only the primary reason reported: local people often collect and snack on wild fruits as they pass through a forest for other purposes and local women frequently also collect vegetables while they collect firewood.

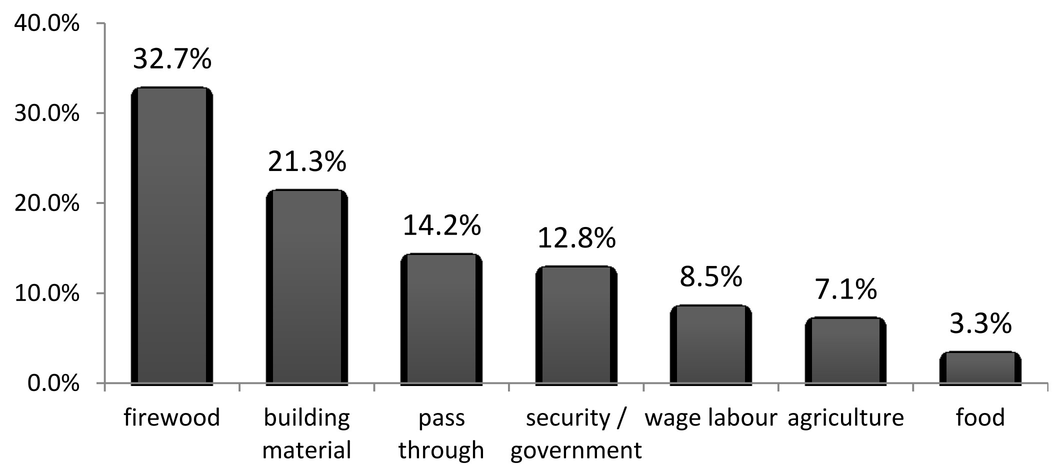


Figure A10 Reasons reported for the most recent trip to the forest (security / government refers to local people who are delegated responsibility for forest surveillance by the local village government)

Perceived importance of forest for food:

Qualitative data indicate that local people in the East Usambara Mountains perceived very little benefit from the forests, and even less benefit from the forest in terms of the provisioning of food resources. Especially in up-land and densely populated areas of the EUM (where virtually all remaining forest is under some degree of protection), when people are asked how the forest benefits them, most say for conservation, climate preservation, protecting water sources / supply or "making rain". Most only list access to firewood and building material as a secondary benefit of the forest. Procurement of food (fruits and vegetables) from the forest was often only noted as a benefit from the forest when informants were asked directly. People commented that some vegetables or fruit are collected on the way home with a load of firewood or when passing through. Interestingly, this mirrors the data related to purpose of last trip to the forest.

> *"I have not seen the importance [of the forest], because those forests don't help me with anything."* Tabea Dominic, woman from Misalai who runs a restaurant

> *"For me in my house first [the Forests or bush] helps by regulating the climate of the environment, it changes the air [local expression implying the creation of a breeze, the maintenance of lower temperatures and preservation moisture], oh and rain."* Ramadhani Juma, farmer, tailor and mason in Tongwe

> *"There [in the forest] we get traditional vegetables which are not available in the farm. We also get indigenous trees there which are not here around the home. We get firewood. We see different animals different from the ones that are here at home."* Ramadhan Juma, when asked if there were **any additional benefits** from the forest

> *"Benefits from the forest? Benefits are for example, getting firewood. Another benefit is that we get rain. We don't lack rain here; most of the time there is rain. Another benefit is for those who cut / split timber.*

> *Another benefit is getting medicine."* Zaina Housseni, farmer from Tongwe, her husband (Peter Martin) uses forest resource regularly
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> *"[The forest] is not very important to us, it's doesn't benefit us much... we only consider it important maybe when it comes to firewood.*" Rehema Amiri, Shambarangeda B, single mother farmer and shop owner
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> *"If you do not have a farm you cannot get firewood in your land, it means all the time you go there [to the forest or bush]. But if you have a place where you farm, you cut down trees [in the farm] then your need [for the forest or bush] will be reduced and you will do your work in your farm*." Beatirce Akida, Tongwe

In less densely populated areas, where there are areas of forest which are unprotected, there is more mention of the use of the forest for food.

> *We go to the bush. You start from here and go there and do work. There are many vegetables (and other ingredients for side dishes) which aren't available here but if you reach the bush/ forest like Lunguza, there are vegetables you will get. There are traps to catch fish. You can take your stuff and go to the bush/ forest to that river called Zigi. When you reach there you position your traps in the river in the morning, and later you return and you will get fish you can sell or use for a side dish."* Martin Peter, Tongwe, moved out of the forest as a child during *villageization*

In more remote areas such as Kwatango (21 people per square kilometre) (Tanzania 2002), meat (birds and mammals) is an admitted benefit of the forest. However, discussion of bush meat is a sensitive topic. It has been noted that many species, while valued for their meat, are primarily hunted to reduce their destructive impacts on crops (Feierman 1974, Powell et al. 2010). From trapping small rodents around field margins to pursuing wild pigs with dogs, guns and spears, hunting efforts are not highly successful and have the primary goal of removing the pest from the field, rather than filling the cooking pot.