PASTORALIST SOCIETIES IN FLUX: 
THE IMPACT OF ECOLOGY, MARKETS, AND 
GOVERNMENTAL ASSISTANCE ON THE 
MUKUGODO MAASAI OF KENYA

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A DISSERTATION PRESENTED 
TO THE FACULTY OF 
PRINCETON UNIVERSITY 
IN CANDIDACY FOR THE 
DEGREE OF DOCTOR OF PHILOSOPHY

RECOMMENDED FOR ACCEPTANCE 
BY THE DEPARTMENT OF 
ECOLOGY AND EVOLUTIONARY BIOLOGY 
Advisor: Daniel I. Rubenstein

April 2013
ABSTRACT

Pastoral livelihoods around the world are evolving. The majority of Africa’s pastoral populations have been settled for more than 30 years, and new studies generating old hypotheses about the consequences of settlement for pastoralists are no longer relevant. The emergence of globalized markets and the integration of globalized production in developing country settings have forced many pastoralists, along with the rest of the world’s consumers, to shift their economic strategies of production to accommodate these evolving markets. The aim of this dissertation is to illustrate the relationship between globalization and apparent transformations in pastoralist behavior (areas such as land use, herding, diet, disease patterns) in recent years. We specifically focus on the links among rainfall and vegetation, land use and herding, diets, and health for Mukugodo Maasai in rural northern Kenya. To do this, we use a novel conceptual framework that incorporates both traditional interactions between pastoral ecology and resource generation and modern opportunities. We accomplish this by linking pastoral families via their pastoral production and other economic activities to the cash economy, modern diets and nutritional status (health), and public and private assistance and programs (such as food aid).

Using this framework, we show that there is a significant relationship between rainfall and vegetation in Mukugodo, and this relationship is directly tied to livestock productivity. We also show that herders do not always behave in economically rational ways when making decisions about where to move their livestock during seasonal or crisis-induced migrations. These decisions in turn influence the production potential of households, such as whether they can generate subsistence products to meet their needs or quality stock to sell in the market. This is reflected in the striking degree of inequality, as measured by Thiel's T and the Gini Coefficient, that arises in the year following a major drought event among households. Rainfall, vegetation, and herding decisions also influence how Mukugodo pastoralists engage with the market. Dietary patterns, as reported by women using our pictorial diet assessment tool indicate that the majority of the population is chronically energy and protein deficient, with average calorie intakes ranging from 1200 to 1800 per day, partly due to unfavorable terms of trade for agricultural goods in local markets. Our analysis of nutritional indicators among Mukugodo children and adolescents aged 0-19 years revealed a population suffering from chronic, moderate malnutrition, we suspect in large part due to their highly deficient diets. When families don’t have cash or stock to sell in the market (or don’t want to because pricing structures are prohibitive) they must turn to an alternative source of calories, such as food aid from public or
private sources. Families who have access to subsidized rations for purchase from private ranches and conservancies have better dietary outcomes than families who do not. In conclusion, pastoralist societies are in flux, and the consequences of these changes, some of which we have highlighted in this dissertation, are likely to have far reaching effects on the livelihoods of pastoralist societies in the future.
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ACKNOWLEDGEMENTS

My PhD work has been carried out in two locations: Princeton University and Mpala Research Centre, Kenya. Princeton brought me back to New Jersey, where I first moved from California in 1999 to attend Rutgers University, and Mpala back to Africa, where I lived for 4 years in between my undergraduate and graduate school careers. My years in Kenya and elsewhere in Africa working with pastoralists have been some of the best (and hardest!!!) of my life. I have learned more about myself through their eyes than I ever could have on my own. I am convinced, after many years with them, that if I had been born in another lifetime, I would have been a pastoralist.

I am deeply and eternally grateful to the community members, school teachers, health workers, and community leaders of Ilmotiok, Tiamamut, Koija, Oldonyiro, Kimanju and II Polei Group Ranches for opening their homes and offices to me, sharing their lives with me, feeding me, providing free medical care, rescuing me from flooding rivers, and reassuring me that everything would be okay when I crashed my jeep during my very first field season in Tiamamut in 2007. There are few particular community members that I must thank: Chief Jacob Yianger- you were so gracious to me at all times and always supported our objectives without hesitation. Nicholas Piyiet, David Kipsuny, Agnes Manyaas, and Christian Leponoto worked with me side by side for 5 years as field assistants and ‘partners in research’. I am proud that we worked together for all these years and we will continue to do so for many more. I particularly thank my two female assistants, who broke cultural barriers to engage in this project. Thank you so much. I hope you learned as much from me as I learned from you. There is much more to do!

To all of the administrators, managers, and security at Mpala Research Center, thank you for providing essential support to my research program. In particular, I would like to thank Margaret Kinnaird, Mburu Tuni, Mike Littlewood, Julius, Patrick (for saving my life by pulling me out of the rushing river) and Mike Ntosho.

On the US side, I first must thank Dr. David Ehrenfeld. If he had not introduced me to Dan Rubenstein, I never would have ended up doing a PhD at Princeton in the first place. Thank you for believing in me when no one else seemed to; I hope I have made you proud. To Dan, words cannot express what this experience has meant to me. It has not been easy for either of us (me as student and you as advisor). I am headstrong and stubborn about my views on pastoralists and you taught me to think objectively (as a good scientist should) and use my intuition
(although I still think it’s usually correct) more appropriately. For this, and for everything else that I cannot summarize here, thank you from the bottom of my heart. I also thank my committee members: Henry Horn, Jeanne Altmann, and Bryan Grenfell (and Steve Pacala, during Generals). You have all challenged me in various ways and pushed me to be the best scientist and person that I could be. In particular, I thank Jeanne for letting me moonlight in her lab as a “hormone” scientist even if the study failed to generate usable results. This opportunity was the first I ever had to do laboratory science and I really enjoyed it. There are numerous other faculty members who have assisted me over the years that I want to thank: Andy Dobson, Andrea Graham, and Joe Amon.

Many thanks go to all of my friends and colleagues at Princeton, past and present for their friendship, scientific discussions, and support. In particular Jenni Peterson, Christina Faust, Jennifer Schieltz, Qing Cao, Sarah Batterman, Parviez Hosseini, Nathan Gregory, Jim Adelman, Cassandra Nunez, Audrey Dorelien, Ruthie Birger, Nita Bharti, Kristina Graff, Kristine Hatch, Corrine Kendall, Blair Roberts, Theresa Laverty, Sara Keen (honorary Princetonian), Kate Nowak, Nicole Basta, Nim Arinaminpathy, and many more who I am sure I must have left out. Thank you to all of the Princeton undergraduate students who have assisted with data entry over the years, especially Lydia, Christine, and Stephanie. You saved my life with your dedication to picture books (and prevented early onset of repetitive stress injuries).

A special thank to my parents, Jami Piper and Mark Hauck, who supported me during all these years and always pushed me to reach new goals and to cross new frontiers; I also want to thank my brother Matthew Hook for keeping me young and my husband’s family and friends for always being there to support me and treating me like a true daughter. My step-parents, Allen Mizer and MaryEllen Pratt-Hauck; you have both gone out of your way to provide me with love, affection, and understanding in ways only true parents can, and for that, and for all the things that cannot be said here, thank you from the bottom of my heart. You both know what amazing sacrifices you have made to assist me in achieving my goals. I also want to thank my grandparents, Tish and Neil Smythe, and Barry and Maejean Piper for their love and support. Some of you did not live to see this dissertation completed (RIP Barry Piper), but I know that you are very proud of what I have accomplished. Thank you. A warm thank you goes to my best friend for 15 years, Anna Foster, and to all the other special people who have walked down the path of my life.
Most of all, I extend the greatest love, appreciation, and gratitude to my husband, companion, and friend, Massimiliano Pala. Without you, nothing in my life would be possible. You are the key to my lock; I love you. In addition to the love and respect of my husband, I must thank my special furry life partner, Sangria, for always being a cute and supportive distraction during difficult times and snuggling up to me on my desk during late nights and rough days.

Finally, this dissertation is dedicated to the memory of my father, Mark Jeffery Phillip Hauck, who died from brain cancer on July 31st, 2012. He did not live to read this work, but I know that he is smiling down from heaven at my greatest of all accomplishments. Daddy, I love you and I miss you. We did it!
CHAPTER ONE:
Pastoralism in the era of global markets

Introduction

Pastoral livelihoods around the world are evolving. The majority of Africa’s pastoral populations have been settled for more than 30 years, and new studies generating old hypotheses about the consequences of settlement for pastoralists are no longer relevant. The aim of this dissertation is to illustrate the relationship between globalization and apparent transformations in pastoralist behavior (areas such as land use, herding, diet, disease patterns) in recent years. Today’s scientists have a prime opportunity to extend the field of pastoral research to include new themes and assemblages of scientific and indigenous knowledge that more accurately reflect the current lives of pastoralists around the world. In that vein, we ought to acknowledge pastoralism’s exposure to regional and global market processes and pastoralists to processes of globalization. By documenting the range and diversity of everyday experiences of pastoralists in today’s ecological and economic climates, we can present fresh ideas about how pastoralists manage their livelihoods in the face of new challenges and opportunities provided by markets. These experiences translate into a myriad of embedded social, political, and economic reasons for tapping into the global market, many of which represent new ways of minimizing or dealing with risk in a uncertain ecological and economic environment (Gertel and Le Heron 2011).

Market relationships are an integral part of today’s pastoral livelihoods. However, these new sets of pastoral actors are vulnerable to variation in social and political forces frequently outside of their control. In short, pastoralists cannot escape the market as their new arena of social and monetary exchange, nor can they transcend their traditional life ways or fully return to them. These factors make it necessary to call for alternative lines of questioning and hypothesis generation about pastoralism and pastoralist’s lives, particularly as we explore current livelihood practices and pastoral economics in our highly globalized world. As such, this dissertation examines how globalization and engagement with local and regional markets are transforming traditional pastoral behavior and livelihood outcomes, focusing on the links among rainfall and vegetation, land use and herding, diets, and health for Mukugodo Maasai in rural northern Kenya.
According to detailed ethnographic work compiled in the 1980’s and 90’s (Cronk 2004:23-63), the true “Mukugodo” are described as “people who lived in the rocks”. Until the mid to late 19th century, the Mukugodo lived in caves, hunted game, kept bees, foraged for plant foods, and herded a few goats in alliance with wealthier Kirrimani pastoralists. Archaeological evidence collected from caves inhabited by Mukugodo people reveals a diet largely comprised of honey, rock hyrax, antelope, giraffe, and buffalo. Families reportedly delineated fixed territories around their caves to ensure access to plant resources necessary for honey production. Honey, as well as game meat mixed with fat, was stored in special wooden containers covered with leather in cool, dry caves. These items did not rot when stored in this way, allowing the Mukugodo to subsist on these products year round. Because they did not consume the products of their hunting and foraging immediately, they can be identified as ‘delayed return foragers’ in juxtaposition to ‘immediate return foragers’ such as the Khoi-San of South Africa.

Although the Mukugodo herded small herds of goats and sheep in alliance with their neighbors, this activity was not historically important to their overall survival. Archaeological evidence suggests they used domestic livestock as a supplement to their diet and as a mechanism for trade with their neighbors (wild products for livestock and vice versa). The Mukugodo transitioned to a pastoral lifestyle between 1925 and 1932. Moreover, their intermarriage with non-Mukugodo peoples (who are in fact the subject of this dissertation), ensured admittance into pastoralism as a permanent livelihood practices. The Mukugodo social system, which Cronk (2004) describes as historically based on lineage exogamy, required them to marry outside of their lineage. This allowed the Mukugodo to acquire new territories just as marrying non-Mukugodo peoples ensured their access to livestock and grazing rights for pastoralism. Ultimately, Cronk (2004:50-63) explains that the Mukugodo’s willingness to incorporate other foods and/or peoples into their livelihoods is a key factor that eased the integration of their economic, social, and cultural practices with other ethnic groups in the region. In chapter two, we describe in detail the recent history of the Mukugodo and non-Mukugodo peoples of Laikipia and their connection to current populations of mixed pastoral peoples residing in the group ranches of Mukugodo Division, Laikipia County, Kenya.

In Chapter one, we review previous works on pastoralism, pastoral livelihoods, ecology of semi-arid grazing systems, markets and market interaction, diet in transitional contexts, nutritional status in children and adults, and health outcomes in order to direct the analysis, presentation, and interpretation of our results in subsequent chapters. In particular, we focus on relevant case
studies and examples from Kenyan pastoralist groups where possible. We then introduce a conceptual framework as well as some general postulates and theories that help us define the methods, study design, and theories applied to this study.

In Chapter two, we evaluate linkages and feedbacks between ecology (rainfall and vegetation), resource generation (pastoral productivity) and household wealth. To do this we investigate herder level strategies in Mukugodo so as to assess the ways in which intra-group herding decisions vary in response to a range of environmental conditions.

In Chapter three, we describe a new method for collecting dietary information from herding households that allows us to measure dietary intake over extended periods (months, years) without having to visit families daily or weekly to record those data. Here we provide a preliminary statistical validation of our pictorial method against other standardized measures of dietary intake.

In Chapter four, we tie new activities that pastoral households use (such as market involvement, use of food aid, and private resources) to more traditional ones (herding, mobility, production, offtake) in order to characterize current market opportunities and constraints under globalization and evaluate the consequences of these shifts on the diets and health of pastoral households.

In Chapter five, we provide a synthesis of chapters one through four, as well as discuss conclusions of our research program and directions for future research.

**What is Pastoralism? Historical and current classification systems and definitions**

Definitions of pastoralism vary widely, demonstrating the difficulty modern scholars have in clearly defining the practice. Roger Blench defines pastoralism as ‘the use of extensive grazing in rangeland systems for livestock production’ (Blench 2004). Other authors have defined pastoralism as ‘a finely honed relationship between local ecology, domesticated animals and people, particularly in resource scarce and ecologically variable environments, where they may or may not be living at the margins of survival’ (Hagmann and Ifejika Speranza 2010). Others define pastoralism as an economic production system where more than 50% of the gross household revenue is derived from livestock or livestock related activities (Swift 1986). As revealed by these varying definitions of pastoralism, it is difficult to provide a singular definition
of a practice that takes place in a wide range of ecological, economic, and social contexts (Hagmann and Ifejika Speranza 2010). Therefore, we concur that "pastoralism" and pastoralists represent a broad range of peoples and ecological, economic, and social conditions living in innumerable contexts, making the extrapolation of findings from one set of conditions to another difficult.

Embedded in this broad range of definitions of pastoralism and pastoral peoples are complex, context appropriate behavioral strategies that pastoralists use to make a living. In both historical and contemporary times, the majority of pastoralists raised livestock for milk rather than meat, which provides them with a reliable form of home based subsistence generation in ecologically unstable environments (Mace 1993). However, misunderstandings between pastoralists and range managers led to a series of claims by range managers that pastoralists behaved in irrational, ecologically inefficient and destructive ways (Hjort 1981; Livingstone 1991; Vetter 2005). After much debate among ecologists, a few key studies pointed out it was perfectly rational for individual households to keep larger herds than were required for subsistence alone to lessen the degree of major stock loss during disease epidemics or droughts (Ellis and Swift 1988; McPeak 2005; Swift 1986).

A major defining feature of pastoralism in dryland systems is the use of seasonal migration or mobility to ensure adequate forage and water for livestock herds under conditions of uncertainty (Butt 2011; Homewood 2008; Krätli and Schareika 2010; Scoones 1995; Thornton et al. 2007). The majority of pastoral populations in Africa live in dry, non-equilibrium ecosystems. Given the indeterminacy of such systems, many pastoral communities evolved contingent responses to uncertain events, such as opportunistic management of herds and active avoidance of risk (Scoones 1995:5). These contingent responses are crucial if a household is to survive in a hostile and unpredictable environment (Mace 1990; Mace 1993). If individuals are to respond flexibly to uncertain events, they need adaptive strategies, such as seasonal migration of livestock herds, to deal with the problem of ecological uncertainty.

Migratory pastoral systems, which aim to minimize production shortfalls caused by large variations in spatial and temporal resources, mitigate some of this uncertainty by exploiting heterogeneous patches of resources in areas outside of the home range and unequally distributed in time and space (Homewood 1995; Scoones 1995). All pastoral systems are constrained by similar sets of key environmental features, such as water, forage, minerals, and
disease, and precariously integrated into a wider set of alternative economic practices, evolving markets, and insecurity. When operating in arid environments, unpredictable rainfall and forage govern the types of decisions pastoral actors can make on the landscape. As such, most herders have two primary herding options: use local grazing patches in competition with their neighbors and minimize migration risks or use distant grazing patches and risk migration to areas of varying and/or unknown quality. Other examples of risk minimizing strategies for pastoralists are orientation towards subsistence rather than market production, reliance on multi-species herds, delaying breeding when conditions are poor, destocking through sales in bad years and restocking when times are good, sharing of resources (practiced as *osotua* among the Maasai; for a detailed definition, please refer to the introduction of chapter 2) and an emphasis on milk rather than meat production (Schwartz 2005: 69-70; Scoones 1995: 9).

Current and historical definitions of pastoralism thus depend on the degree to which we use mobility or migration as a defining feature of the practice. Historically, pastoralists managed livestock under three systems of varying mobility- complete nomadism, transhumance, and semi-sedentism- but these practices are changing in recent years (Adriansen and Nielsen 2005; Butt 2010; Moritz 2006; Okayasu et al. 2010). Complete nomadism is practiced by nomads, who are defined as highly mobile livestock herders who do not have a permanent home base and practice no agricultural activities (Fratkin, Nathan, and Roth 2006; Roth 1996). According to Homewood (2008: 83), transhumance is defined as "the seasonal movement of livestock herds between spatially distant sites so as to make the best use of pasture, water, and mineral resources; to minimize exposure to disease and risk of crop damage; and/or take advantage of temporary opportunities dictated by seasonally changing conditions". As such, transhumant herders are also highly mobile, but return to a seasonal, semi-permanent home base and may practice opportunistic cultivation of cereals and/or legumes (McCabe et al. 2010; Moritz 2006).

Most East African pastoralists, particularly in areas where the spatio-temporal pattern of rainfall is unpredictable, practice transhumance or semi-sedentism. Semi-sedentism may include a number of different movement strategies: some may move between a home base and a fixed set of grazing patches, while others may move in complex spatial patterns around key patches to avoid insecurity and raiding. Depending on the herd composition and structure, herders may move anywhere from a few kilometers (the micro-movements of some sedentary herders) to a few hundred (local-regional movements) to find suitable patches. Movements are usually altitudinal, categorical (catenary), or latitudinal. For example, the majority of Kenyan pastoralists
now use a seasonal or opportunistic approach to herd migrations, with semi-mobile or fixed housing scenarios instead of moving the whole household along with the herd (Fratkin and Roth 2005; Homewood 2008)

Contemporary pastoralists continue to use mobility as a strategy to ensure access to high quantity and quality forage for their herds. In Sub-Saharan Africa this generally means moving to highlands in the dry season, and lowland areas in the wet season (Bekure et al. 1981; Homewood 2008; Homewood and Rodgers 1991). Herd movements are also determined by local disease patterns; cattle are extra sensitive to disease exposure and need to be moved to drier pastures in wet seasons to avoid tsetse fly and other vector borne pathogens (Dahl and Hjort 1976). However, herders must weigh the relative costs of disease exposure against the benefits of increased forage and water resources elsewhere in the system (Herren 1987).

**Strategies of Pastoral Production and Survival: Then and Now**

Historical pastoral systems of production have been defined in a variety of ways, but there are a few general themes. Although the defining feature of pastoralism is the association of people with animals, there are many pastoral households that do not own any livestock of their own. Therefore, it is imperative for pastoralists to incorporate a diverse array of livelihood strategies beyond the production of income from livestock or livestock products. In this regard, a number of other economic and cultural features are used to define pastoral lifestyles, such as a focus on subsistence rather than market production, nomadic or transhumant mobility of the herd and household, unpaid (free) labor, weak market interaction, little or no formal education, egalitarian governance and well defined social welfare programs.

In the next section we compare and contrast various definitions of pastoralism as they apply in an East African context. For a more detailed review of these classifications as they appear in the text, please refer to Table 1.

*Pure pastoralism (milk based pastoralism or subsistence pastoralism)*

Until the 1980’s and 90’s, Ngisonyoka Turkana herders derived more than 80% of their diet from pastoral products, making them one of the “purest” milk based pastoral groups in Africa (Little and Leslie 1999). In the past, pastoral communities such as the Turkana relied mostly on their
own subsistence based pastoral products when these goods were in abundance (Homewood 2008). Nevertheless, this is the exception rather than the rule. Pure pastoralists do not really exist, nor have they ever. Milk is in theory a complete food if available in abundance year round. In practice, however, milk is only available at certain times of the year since milk production depends on calving and kidding rates, the duration of lactation, which species are lactating, the overall composition of the herd, forage and water availability and distance travelled (Homewood 2008: 86). Since pastoral families cannot maintain herd numbers that would fulfill all of their dietary needs on pastoral products alone, they must, by necessity, depend on other means of acquiring resources. In many African pastoral communities, this is achieved through a combination of wage labor, food aid, food for work, livestock trade, osutua, and other forms of small-scale diversification, such as selling alcohol, food stuffs, tobacco from home or a locally built store front. This is evident in the diverse and varied forms of pastoral production that evolved out of “pure” pastoralism in modern times, a few of which we describe below.
<table>
<thead>
<tr>
<th>Production Strategy</th>
<th>Household Security</th>
<th>Herd Size</th>
<th>Diet</th>
<th>Mobility Pattern</th>
<th>Use of Cash</th>
<th>Market Transactions</th>
<th>Social Welfare</th>
<th>Labor</th>
<th>Historical Examples in East Africa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pure Pastoralism &quot;Milk Based Pastoralism&quot;</td>
<td>high</td>
<td>large</td>
<td>&gt; 75% animal products</td>
<td>nomadic or transhumant</td>
<td>none</td>
<td>minimal</td>
<td>gifting and exchange to maintain social relationships</td>
<td>male herding labor; familial</td>
<td>Turkana, Nuer, Dinka</td>
</tr>
<tr>
<td>Exchange Pastoralism</td>
<td>moderate</td>
<td>large</td>
<td>≤ 50% animal products</td>
<td>transhumant</td>
<td>minimal, if any</td>
<td>minimal</td>
<td>gifting and exchange to maintain social relationships; also to obtain agricultural goods</td>
<td>male herding labor; familial</td>
<td>Maasai, Gabbra, Rendille, Somali, Mukugodo</td>
</tr>
<tr>
<td>Agro-pastoralism</td>
<td>moderate</td>
<td>small-medium</td>
<td>25-50% animal products</td>
<td>transhumant/seasonal</td>
<td>moderate</td>
<td>moderate</td>
<td>reduced gifting and exchange, but livestock still socially and spiritually important</td>
<td>male herding labor; female agricultural and herding labor; familial or hired</td>
<td>Maasai, Warusha, Rendille, Daasanetch, Oromo, Gabbra, Sukuma</td>
</tr>
<tr>
<td>Commercial Ranching</td>
<td>high</td>
<td>very large</td>
<td>varied</td>
<td>fenceless ranching or paddock raised</td>
<td>high</td>
<td>high</td>
<td>no longer important</td>
<td>mostly hired labor</td>
<td>Somali, British Settlers, Maasai</td>
</tr>
</tbody>
</table>

Exchange pastoralism

Exchange pastoralism is defined as the exchange or barter of milk and meat for grains and other cultivated goods, such as the exchange of a fixed amount of pastoral produce (with traders or other families) that is not enough to meet subsistence needs in isolation. Households primarily exchange excess products of pastoral production (such as milk, meat, hides, dung, or animal labor) with regional traders for cultivated goods to supplement their diet. Generally, this system only works appropriately as long as the terms of trade between livestock and agricultural goods remain favorable and household means of production are not seriously impacted by drought or disease (Homewood 2008:87).

Agro-pastoralism

Agro-pastoralism is defined as an economic practice or system that combines livestock rearing and small-scale farming. Communities engaged in these dual practices tend to retain their social, economic, and spiritual preferences for livestock irrespective of the degree to which they are involved in agricultural pursuits. Agro-pastoral households typically integrate farming with herding via cultivation of rain fed crops in dryland systems where irrigation is not possible. Some households nonetheless have access to limited irrigation for crops in ephemeral riverine zones while others cultivate in intensive, watershed accessible montane systems in the highlands of arid zones.

Agro-pastoralism among the Maasai of northern Tanzania is one of the best known examples of economic and social diversification due to sedenterization among African pastoralists (Homewood 2008; Homewood and Rodgers 1991; McCabe, Leslie, and Deluca 2010). These households combine herding with rain fed cultivation in montane zones during the wet seasons when cattle are taken for grazing in drier lowland areas. Increased sedentism among the Maasai strongly correlates with greater involvement in cultivation and a decreased dependence on livestock (Homewood 2008:88). Besides the obvious economic benefits of skipping the middleman and generating agricultural goods at home instead of selling stock in unfavorable markets or engaging in wage labor to acquire cash, there are also a number of costs associated with agro-pastoralism.
First, it is theoretically better to store wealth in livestock rather than grain because grain stores are easily damaged or lost due to improper storage or pestilence. This is not to say that livestock cannot get sick and die from exposure due to poor nutrition during dry seasons and disease epidemics during seasons of high herd mixing (Dahl and Hjort 1976). However, when livestock herds are well managed (low mixing and high quality forage), they tend to generate better rates of return than agriculture even in areas where modern banking and other forms of income generation are unavailable. Secondly, small-scale cultivators tend to settle around permanent water sites, such as watersheds or riverine systems. This leads to scramble competition between herders and cultivators for access to dry season water and grazing. Scramble competition for limited resources also facilitates new conflicts between community members who now must ensure that their livestock do not eat their neighbors’ crops or damage communal water points beyond repair. In theory, to reduce competition and conflict among households, a system of fences around cultivated areas should be generated to separate grazing areas from cultivation, but in practice this rarely if ever happens.

**Subsistence vs. Commercial Ranching Operations**

Subsistence and commercial pastoralism are defined via the following operational definition(s):

1. **Subsistence production**: local production for local use; < 25% of gross returns from sale or exchange
2. **Partly Commercialized**: local production for regional or national sale; 25-50% of gross returns from sale or exchange
3. **Commercial systems**: local production for external markets; > 50% gross returns from sale or exchange

These three levels of pastoral commercialization coexist side by side in most pastoral contexts. There is often no clear distinction between the two practices, since one market (the subsistence market) usually feeds the other (the commercial market). For example, in Laikipia County, Kenya, western style cattle ranches abut communally managed group ranches where the only division is often an artificial road barrier or historical cattle track. Surprisingly, private and communal ranchers cooperate in Laikipia’s ranching system by exchanging livestock between ranches to facilitate improved breeding opportunities or by allowing herders from communal ranches to rent grazing for cattle during dry seasons or droughts. Commercial marketing, however, exposes subsistence pastoralists to new hazards that private ranchers may have more experience in managing, such as unreliable price structures and fluctuating terms of trade for
their products relative to the cost of food purchases (Behnke 1983; Ellis and Swift 1988; McPeak 2004; Zaal 1999; Zaal and Dietz 1999). Thus, private ranchers and pastoralists have dissimilar skills when it comes to marketing their products. Furthermore, western style ranchers specialize in beef production, which is in high demand in the national market whereas pastoralists specialize in home based milk production, which is primarily used for personal consumption. These two types of ranching generate different types of specialized livestock offerings in the market, suggesting that although their livestock come from the same region they are not equivalent in their offerings on the market.

**Pastoral Realities in the 21st Century**

Globally, pastoral activities occur on more than 25% of the world’s land area, representing approximately 1 billion head of livestock, 10% of global meat production, and over 200 million households (Blench 2004). The emergence of globalized markets and the integration of globalized production in developing country settings have forced many pastoralists, along with the rest of the world’s consumers, to shift their economic strategies of production to accommodate continuously evolving markets. As noted in the pastoralist literature, scholars working in collaboration with development agencies proposed that in order to survive over the long term, pastoral economies and livelihoods should remain static rather than evolve into dynamic and diverse forms, thus reasserting the incorrect notion that pastoralists should remain undeveloped, amid unjustifiable conditions of non-market transactions, unpaid labor, and non-capitalist enterprises (Anderson and Broch-Due 1999; Galvin 2009; Homewood 2008; Illius and O’Connor 1999; Livingstone 1991; Scoones 1995). This perspective, although perhaps sensitive to the social and cultural desires of some pastoral populations, discounts the significant dynamics of production and exchange that are now dependent on and entrenched in our newly emerging global environment.

Bottom up perspectives on pastoral economics use elements of a “survival economy” approach to distinguish between different pastoral livelihood strategies (Gertel and Le Heron 2011). Under an economy of survival, insecure (read: poor) individuals use risk spreading techniques to “survive” rather than trying to maximize profits to improve their livelihoods. Poor and vulnerable individuals suffer precipitous declines in household food consumption under global market engagement, particularly during periods when food prices rise and livestock prices decline, leading to increased levels of food insecurity and malnutrition (Brinkman et al. 2009; Darnton-
Hill and Cogill 2009). In Amazonia, market integration has led to declines in protein consumption and growth levels among indigenous groups due to reductions in the use of hunted and foraged foods (Blackwell et al. 2009). In Tibet, rapid market integration and commercialization has led pastoral families to shift their herding practices away from milk production to accommodate market demand for meat and acquire cash to purchase cultivated or material goods from the market (Manderscheid et al. 2002). In Tanzania, declines in livestock production and mobility and shifts in dietary preferences has influenced some Maasai families to shift their production strategy towards cultivation in an attempt to remain pastoralists (McCabe et al. 2010). In Kenya, risky livestock markets and unfavorable terms of trade deters pastoral families from engaging in livestock transactions, reducing their ability to acquire cash to feed their families and save for the future (McPeak 2004).

Although we cannot deny that there are many benefits associated with global market opportunities, it is obvious from the above examples that these benefits are not equitably distributed or experienced by rural populations. However, several different, complementary economic practices may generate household revenues, and these revenues are often redistributed via social means to the entire family network. For example, numerous individuals in a single family may be simultaneously engaged in many economic activities, all of which contribute a small amount to overall household needs. Effectively, pastoral households diversify revenue streams much in the same way that stockbrokers diversify portfolios of stocks and bonds in the market to spread their risk.

Family members may migrate to urban centers or neighboring ranches to look for wage labor or other aid in order to send home remittances or food stuffs (Fratkin and Roth 2005; Huho, Ngaira, and Ogindo 2009; Huho, Ngaira, and Ogindo 2011). Pastoralists also engage in a variety of other activities outside of the pastoral sector to produce revenue for household expenses, such as charcoal production, petty trade in beads, alcohol production, and other forms of home based trade (Fratkin and Mearns 2003; Galvin 2009; Hogg 1986; Holtzman 2007; Thornton et al. 2007). These revenues, although meager, may be the only form of cash revenue to families devoid of livestock (Herren 1989). Individuals who cannot work for wage labor or generate cash revenue perform important social and familial functions/jobs, providing essential non-cash services to households. As such individuals in a single household can be oriented towards both subsistence and market-oriented production simultaneously (Fratkin and Roth 2005; Homewood 2008).
New Modes of Scholarship on Pastoralism

New scholarship on pastoralism would benefit from shifting its focus away from traditional views of pastoral economics to more modern approaches that incorporate the important links between globalization, local markets, migration, economic opportunities and traditional pastoral livelihoods (Gertel and Le Heron 2011). These new opportunities have subsequently generated new behavioral adaptations and economic strategies that require us to reclassify many of the livelihood tactics and approaches used by modern pastoralists we presented in Table 1. Although not discussed in detail in the text, we summarize a few of these strategies and opportunities as they occur in the Kenyan context in Table 2.
<table>
<thead>
<tr>
<th>Livelihood Designation</th>
<th>Residence</th>
<th>Household Security</th>
<th>Herd Size</th>
<th>Labor and Capital</th>
<th>Social Welfare</th>
<th>Use of Cash</th>
<th>Commercial Involvement</th>
<th>Economic Diversification</th>
<th>Education</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Traditional Pastoralists</strong></td>
<td>mobile</td>
<td>high</td>
<td>large</td>
<td>use family labor and gain capital from large herd</td>
<td>give out large numbers of animals</td>
<td>minimal</td>
<td>not active, but have non commercial investments</td>
<td>cultivation, milk sales, exchange pastoralism</td>
<td>little to none</td>
</tr>
<tr>
<td><strong>Marginal Pastoralists</strong></td>
<td>sedentary</td>
<td>low</td>
<td>very small</td>
<td>lack of capital and labor</td>
<td>usually receive animal gifts from others</td>
<td>moderate</td>
<td>not active, laborers not employers</td>
<td>cultivation, wage labor, seasonal jobs, petty trade, hired herders,</td>
<td>little to none</td>
</tr>
<tr>
<td><strong>Labor Migrants</strong></td>
<td>split home base/place of employment</td>
<td>moderate</td>
<td>small</td>
<td>use family labor when possible, access to cash can generate capital</td>
<td>usually receive animal gifts from others</td>
<td>high</td>
<td>not active, use market to generate subsistence</td>
<td>wage labor, cash livestock trade, remittances</td>
<td>some primary</td>
</tr>
<tr>
<td><strong>Pastoral Quitters</strong></td>
<td>sedentary</td>
<td>moderate</td>
<td>small</td>
<td>no family labor since children are in school; use animals as capital</td>
<td>not engaged in gifting or receiving social welfare</td>
<td>high</td>
<td>active, but only to trade animals for cash in market</td>
<td>wage labor, trade, small business, or employment</td>
<td>may obtain high level of education</td>
</tr>
<tr>
<td><strong>Commercial Pastoralists</strong></td>
<td>sedentary</td>
<td>high</td>
<td>large</td>
<td>use hired labor; capital generation is main goal</td>
<td>not engaged in gifting or receiving social welfare</td>
<td>high</td>
<td>very active, produce livestock for meat trade, offtake high</td>
<td>fenceless ranching, animal breeding, meat production, use of hired labor to cultivate crops</td>
<td>may obtain high level of education</td>
</tr>
</tbody>
</table>

Compiled from Gertel and Le Heron 2011, Chapters 3-6.

Table 2: Alternative Designations of Pastoral Livelihood Strategies and Opportunities in the Global Age of Pastoralism
As should be clear from a close look at Table 2, new economic, social, and educational opportunities and benefits derived from integration into global markets have to be weighed against the risks of dependency, loss of control, and the transfer of benefits to third parties, such as traders in regional and global markets, particularly for the most vulnerable groups (such as marginal pastoralists and labor migrants). Orienting production towards global markets is risky for modern pastoralists primarily because market structures are designed to respond to cash and not the needs of the most vulnerable or “cashless” members of society (Brinkman et al. 2009; Christian 2010; Darmon and Ferguson 2002). As such, integration into the market forces the poor to incur greater risk than they would under a system of subsistence only production. For example, producing milk for home consumption requires fewer labor inputs than producing steers for slaughter (Dietz et al. 2001), but is similarly subject to external shocks, such as drought (McPeak 2004).

As such, poor families who only own a few animals participate in the market in limited ways when they need food for their families, but not on a scale that allows them to generate savings or revenue to invest in other livelihood ventures (Anon 2008; Sellen 2003). Generally, we view pastoral integration into the market as an attempt to improve productivity and offtake without compromising pastoral social systems and societal structures, since it should be able to be accomplished along side more traditional subsistence practices (Gertel and Le Heron 2011; Holden, Coppock, and Assefa 1991; Zaal and Dietz 1999). In Chapter four of this dissertation, we interrogate the degree to which integration in to the market improves pastoral productivity and livelihood outcomes among Mukugodo pastoralists in Kenya.

**The New Normal: Pastoralism in the Globalized Era**

This dissertation uses a conceptual framework that incorporates more traditional notions of the interaction between pastoral ecology and resource generation to investigate recent transitions in pastoral livelihoods (Galvin 2009). Our model extends traditional models of pastoralism by linking pastoral families via their pastoral production and other economic activities to the cash economy, modern diets and nutrition, public and private assistance and programs (such as food aid), and clinics.

In this chapter, we offer a number of general theories and propositions in the form of hypotheses about the ways in which Mukugodo pastoralists function under current conditions of
globalization. These generalized statements are then developed into testable hypotheses in chapters two-four.

1. Although usually associated with livestock production, pastoralists engage in a wide range of varied economic and social activities not exclusive to livestock rearing, traditionally as well as today. Hence, pastoralism can be defined as a social/cultural identity as well as an economic practice of production.

2. Livestock herds and herding activities still act as a major determinant of overall household structure and function, even for families who have diversified into other economic opportunities.

3. The majority of pastoral households are now engaged in some form of contact or interaction with the global economy. Whether this engagement is achieved through purchases and sales at a local market or urban center is inconsequential.

4. Pastoralists still use a system of seasonal migration or mobility to maintain herd productivity where possible. This requires negotiation with neighboring communities for access and labor.

5. Social services and other resources provided by private and public partners are essential to the survival and functioning of pastoral communities in their current state of development.

6. Engagement with the global market has intensified existing disparities in wealth, social position, and educational attainment among pastoral households living in similar environments.

In order to contextualize our study within the broader range of research on pastoral livelihoods, we have generated a conceptual framework that ties new activities to traditional ones in order to depict the current socio-ecological and economic conditions and practices of pastoral livelihoods in Laikipia, Kenya. Our framework thus identifies activities and linkages that illustrate the process of rapid internal social and economic differentiation via access to cash. Under these conditions of rapid differentiation, differences among households in wealth (livestock or otherwise) and social position act as a filter that bins households into quantitatively distinct sets of social, economic, and ecological opportunities and strategies.

Evidence for this assertion comes from a number of studies focused on the impact of wealth differentials on pastoral livelihoods (Borgerhoff Mulder et al. 2010; Cronk 1991; Fratkin and Roth 1990; Grandin 1988; Herren 1989; Mulder and Beheim 2011; Ruttan 2000; Ruttan and
Borgerhoff Mulder 1999; Sellen 2003). Evidence from Kenya suggests pastoral integration into markets has overwhelmed existing social welfare programs and mechanisms of social redistribution, causing them to collapse (Herren 1988; Herren 1989). The collapse of traditional social systems has led to larger than ever increases in wealth inequality among the Mukugodo Maasai, generating some of the highest poverty levels reported among Kenyan pastoralists. In chapters 2 and 4, we investigate the impact of this increasing inequality on herding strategies, diet, nutritional status and health outcomes.

**Globally Integrated Pastoralism: A model of the New Normal**

Our conceptual framework works off what we call ‘the new normal of pastoralism’.

*Figure 1: Conceptual Framework of Current Study. Hatched lines indicate hypothesized linkages that are not tested in this dissertation. Shaded boxes indicate the traditional model of pastoralism we refer to in the text whereas the white boxes are the new elements that we have added to the framework in this study.*
Our framework makes a few assumptions. We accept the traditional view that pastoralists live in a world that continues to be structured by ecological factors outside of their control, aka “exogenous” factors such as rainfall, temperature, and climate, among others. Inside of this uncertain environment, pastoralists engage in various kinds of resource generation, whether via traditional livestock- forage interactions or newly adopted petty trade, wage labor, agriculture or a combination of these. The outcomes of these new resource-generating activities are then directed towards two primary outcomes: cash generation to meet basic needs, including agricultural goods and subsistence products to contribute to the diet and well being of their children and family.

As such, we hypothesize that some pastoral products are used for subsistence and others for sale in a local or regional market. We predict that weekly or bi-monthly regional markets are the most common source of market engagement. Pastoral actors bring their local products to market (milk, skins, whole animals) seeking to sell them for cash rather than exchange via trade. We predict this cash is then used to purchase much needed food items, basic needs, and health care. Sellers in effect should act as currency exchangers for rural producers who have no access to banking, allowing them to convert their products of pastoral production into cash to purchase non-pastoral goods. Since livestock sellers in theory gain cash in the local market and then use it to purchase goods from regional sellers, these pastoral actors effectively take currency out of rotation in their own local community and redistribute it back to urban centers, thereby tethering pastoral actors to agricultural and urban actors to generate capital for basic needs.

Pastoral families have two types of stock options they can sell to acquire cash in regional markets (Dahl and Hjort 1976; Herren 1989). They can sell small stock (goats or sheep) thereby gaining a small amount of cash (the equivalent to taking out cash from the bank to do the weekly shopping) or large stock (cattle and camels) thereby gaining a large packet of wealth to use for health care, education, or other needs that usually require large sums of cash. We recognize that some families also have savings accounts “off the hoof” they draw on to use for purchases in the market rather than selling stock. Therefore, we consider wealth in this model to be a composite measure of a family’s overall assets: labor (access to free familial labor via progeny), livestock (TLU), wages (monthly value), savings (in a bank, not on the hoof), and social position (person of status or power). Thus, we hypothesize that access to cash from
engagement with diversified practices and regional markets generates socio-economic differentiation among pastoral households under current economic conditions.

We predict that this differential access to cash will influence which households can access services required for family growth and survival, such as health care, education, affordable and safe housing, water, food, among others. In essence, our model extends traditional frameworks of pastoral livelihoods to include a new set of dynamic pastoral actors who are fully integrated into a cash market. Under the current global economic system, interaction with the cash market facilitates actors to both subsist on and supply local products to regional markets while simultaneously also consuming globally produced products, such as medicines, clothing, processed foods, etc.

Globalization, with its focus on the free movement of goods, services, technology, and capital, has influenced pastoral lifestyles in a number of ways: exposure to mass media, globalization of food processing, and global shifts in the use of technology and transportation (Popkin 1994; Popkin 2006). Adoption of western goods and global life ways are problematic for Kenyan pastoralists for two reasons: shifts in access to information and dietary choice/preference. We hypothesize that globalization and access to regional markets where global products are sold are likely to influence other aspects of pastoralist livelihoods as well. Increased use of cell phones, radios, and TV’s means that some, but not all households have up to the minute access to information, news, and media reports about goods and services from Kenya and beyond. For those who have access to information technology, new ideas for marketing, herd management, and migration routes differentiate household livelihood strategies via novel opportunities and constraints presented by regional markets under the process of globalization.

We hypothesize that exposure to regional markets, cash, and global products influences dietary choices among pastoral households as well. Traditionally, pastoralists in Kenya and Tanzania experienced regular hunger bouts associated with seasonal/regular declines in subsistence production of milk and meat products during dry conditions and droughts (Fratkin and Roth 2005; Galvin 1992; Homewood 1992; Little, Gray, and Leslie 1993; Roth 1996). For example, past research found an association between a lack of rainfall and the introduction of market based complementary foods for infants, cessation of breastfeeding, early weaning, growth faltering and malnutrition in children, and reproductive failures in women (Anderson and Broch-Due 1999; Gray, Wiebusch, and Akol 2004; Little, Gray, and Leslie 1993; Pike 2000; Sellen
Since previous evidence suggests an existing link between seasonality and nutritional status, we therefore predict that seasonal food availability, fluctuating terms of trade in regional markets, shifting dietary preferences, and lack of access to food storage and preservation, will be the primary forces influencing diets and nutritional status in present day Mukugodo.

Evidence for this prediction comes from studies of pastoral diet in Kenya (Benefice, Chevassus-Agnes, and Barral 1984; Grandin 1988; Galvin 1992; Hogg 1987; Homewood 1992; Little 1989; Nestel and Geissler 1993; Oniang’O 1999) where diets were historically comprised largely of milk based products (approximately 60%) and underemphasized external agricultural goods, except in the case of sedenterized households living in settlements or near village/group ranch centers. The shift away from nomadic to sedentary lifestyles was one mechanism by which pastoral diets changed from milk to a maize based diet. A second shift was observed in Kenyan communities that received food aid for the first time after the drought of 1983-84, such as the Mukugodo Maasai (Herren 1987). These communities shifted away from large stock to small stock after the drought to avert future large-scale herd losses, meaning that milk yields declined sharply from those prior to the drought. This shift also meant that cheap sources of calories, such as maize, became more abundant and could be acquired in all seasons via food aid or trade in local markets.

The nutrition transition, whereby diets shift with increasing integration with western markets and lifestyles, is a well-documented phenomena (Popkin 1994; Popkin 2001). Shifts in dietary intake, such as a rise in the consumption of saturated fats, sugars, and refined foods, are commonly associated with changes in economic production and market access (Christian 2010; Grandin 1988; Holden et al. 1991; Smith et al. 2010; Thornton et al. 2007). Increased access to cash to purchase varied food items in the market and a shift away from herding cattle to raising primarily goats and chickens means a similar shift in dietary patterns and trends as well (Herren 1989; Österle 2008). There is a dearth of information on how recent dietary shifts associated with the nutrition transition are influencing health outcomes among pastoralists. The primary objective in chapter 4 of this dissertation is to explore existing dietary practices among pastoral families in Kenya and to interrogate the consequences of dietary transitions for pastoralist health (Cordain et al. 2005; Duba et al. 2001; Sheik-Mohamed and Velema 1999).
Lastly, our conceptual framework of pastoral livelihoods predicts a high degree of mixing among private and public landowners in Laikipia County, Kenya in recent years. Pastoralists in Group ranches live adjacent to private ranchers and farmers. These households subsequently gain assistance in the form of grants, employment, rations, mobile clinics, and emergency transportation from private neighboring ranches. In turn, private ranchers use these assistance networks to negotiate with pastoral neighbors for developing wildlife conservancies and ecotourism and holistic management of grazing patches. We hypothesize that out of necessity, pastoralists and ranchers must engage in shared negotiations in order to find mutually acceptable solutions to the problem of shared access to local resources, particularly traditional grazing patches. In Laikipia county, pastoral families must compete with endangered species conservation and eco-tourism (Gadd 2005; Muthiani et al. 2011; Wambuguh 2007) for access to grazing. When forage dries up or droughts arise, Mukugodo families have to either rent grazing land from their neighbors or risk migrating across private/public parcels to distant pastures in western and southern highlands (Herren 1988; Huho, Ngaira, and Ogindo 2009; Huho, Ngaira, and Ogindo 2011). The primary objective of chapter two is to understand local herd movements, herding decisions, and patterns of negotiation and access to mixed-use parcels of land and grazing rights.

**Conclusion**

No one can ignore that the climate is changing, semi-arid systems around the world are drying out, and economic conditions are shifting (Huho, Ngaira, and Ogindo 2009; McMichael et al. 1998). Subsistence pastoralism, in isolation, no longer exists. It has declined as a practice in recent years because of increasingly erratic rainfall, dried out and dying grasslands, rapid population growth, and restrictions on household and herd mobility, such as sedenterization or privatization of land (Fratkin and Mearns 2003; Fratkin, Nathan, and Roth 2006; Fratkin and Roth 2005). The hypotheses generated in this dissertation help us to interrogate some of the environmental and economic circumstances that have led pastoral families to move outside of the pastoral sector and tap into the global economy. They do this by working for private ranches or conservation organizations, working as hired herd labor, engaging in non-pastoral activities such as charcoal production, migrating to cities to engage in education or wage labor, and/or investing in local eco-tourism ventures and other activities within their communities (such as government committees, leadership positions, managers). These diverse approaches are not mutually exclusive but complementary. By fighting to maintain local resources under their
immediate control, such as subsistence based pastoral products, historical social welfare systems and networks, and local food distribution and exchange programs, pastoralists seek reliability in an inherently unpredictable and harsh global world. It is the quantifiable outcomes of these different approaches to modern livelihood challenges that allow us to evaluate the impact of new economic opportunities on human health and well being for Mukugodo families.
References Cited


*Current Anthropology* 40:621–652

*Current Anthropology* 40:1–15

ITDG, London.

Sellen DW (2000) Seasonal ecology and nutritional status of women and children in a  
Tanzanian pastoral community.  
*American Journal of Human Biology* 12:758–781

East African Pastoral Population.  
*Journal of Human Lactation* 17:233–244

Sellen DW (2003) Nutritional Consequences of Wealth Differentials in East African Pastoralists:  
The Case of the Datoga of Northern Tanzania.  
*Human Ecology* 31:529–570

populations of sub-Saharan Africa.  
*Tropical Medicine & International Health* 4:695–707

Systems, Inheritance, and Inequality in Premodern Societies.  
*Current Anthropology* 51:85–94

In: Adamu M, Kirk-Greene A (eds.) Pastoralists of the West African Savanna: selected  
studies.  
Manchester University Press, Manchester, pp. 175–190.

Thornton PK, Boone RB, Galvin K a., BurnSilver SB, Waithaka MM, Kuyiah J, Karanja S,  
Households in East and Southern Africa: A Synthesis of Four Case Studies.  
*Human Ecology* 35:461–476

Vetter S (2005) Rangelands at equilibrium and non-equilibrium: recent developments in the  
debate.  
*Journal of Arid Environments* 62:321–341

Regarding Wildlife Damage , Ownership and Benefits in Laikipia District , Kenya.  
*Conservation and Society* 5:408–428

Activities in Kenya and Burkina Faso*.  

In *The poor are not use us: poverty and pastoralism in Eastern Africa*.  
London: James Currey Ltd.
CHAPTER TWO

Ecology of Herding and Land Use Strategies among Mukugodo Maasai of Kenya

Introduction

Dryland ecosystems are highly susceptible to degradation by drought and intensive grazing, resulting in possible desertification, deforestation or woody encroachment (Mcnaughton 1985; McNaughton et al. 1989). Drought is defined as a period of below normal rainfall that reduces soil moisture so that vegetation fails to grow (Dracup et al. 1980). Droughts also lower water supply to such an extreme degree that the productive and consumptive activities of a community or society are negatively impacted (Dracup et al. 1980). As such, the degradation of dryland ecosystems, whether from drought or other local causes, threatens access to fuel, forage, water and other resources essential for the survival of pastoral populations (Huho et al. 2009; Ngugi and Conant 2008). Detailed, local studies of the consequences of these environmental shifts for resource access by pastoralists are important, as it is impossible or misleading to extrapolate findings from one community to another (Herren 1988). Here we investigate herder level strategies in Mukugodo in order to evaluate how intra-group herding decisions vary in response to a range of environmental conditions, such as drought. From these data, we explore how variation in social and economic status leads to differences in herding decisions among households in response to environmental conditions.

In this paper, we use the pastoral household as the unit of measure. The household is important because it allows us to test the claim that households employ a wide range of herding strategies with qualitatively different outcomes and that these strategies have been altered via privatization of traditional grazing patches by colonial settlers and integration into national markets, among other things such as land reform and more frequent droughts. Swedish anthropologist Urs Herren’s previous fieldwork with Mukugodo families in the 1980’s demonstrated that poor families suffered higher livestock losses during drought, partly because they had trouble mobilizing labor for migration, forcing them to stay in the home area with their flocks when conditions are bad (Herren 1987; Herren 1988; Herren 1989). Herren found that poor households use two principal strategies to acquire capital: remittances and wages from working as migrant labor or opportunistic livestock sales to pay for basic needs. They rarely migrate, struggle to acquire sufficient labor for herding (especially since most children are in school these
days), and lose a disproportionate number of livestock during droughts. On the other hand, rich households were more dependent on commercial livestock transactions than wages for capital, tended to lose fewer total animals during drought, had access to external sources of labor, such as hired herders, and migrated with their herds to new areas when conditions were bad.

There is a long tradition of research in pastoral communities on differences in decision making and socio-economic strategies in face of environmental modification such as degradation and land use change (Fratkin and Roth 1990; Fratkin, Nathan, and Roth 2006; McCabe 1987). In Mukugodo, we apply a decision-making framework to assess household herding practices and land use patterns to determine the degree to which these household responses are influenced by ecological factors such as drought and geographic location (such as closeness to water) and/or social factors, such as wealth.

In Kenya in particular, the establishment of group ranches was a major change in pastoral land tenure (Oxby 1981), but we don’t know much about how this reform has influenced pastoral livelihoods in northern Kenya, as the majority of work done on pastoralism in group ranches has focused on Kajiado and Narok districts, near Masai Mara National Park (Bekure et al. 1981; Boone and Wang 2007; Butt 2011; Grandin 1988b; Homewood 1995; Homewood 2004; Homewood and Lewis 1987; Hughes 2005; Meikle and Thornton 1993; Nkedianye et al. 2011; Omosa 2005). We also sought to quantify the role of non pastoral sources of income on livelihood strategies, and we achieved this through our innovative dynamic wealth ranking system, which incorporates livestock, wages, labor, social status, and other factors to determine overall household economics. This dynamic wealth ranking system is explained in greater detail in the methods section of this chapter. In Mukugodo, we postulate that social and economic differentiation influences household perception and use of different livelihood strategies. As such, we want to know how recent modifications of traditional strategies have influenced herding decisions, herd composition and structure and mobility patterns, and the ability to recover from drought.

Our reasons for choosing to investigate these patterns of livelihood change in Mukugodo are myriad. First, there was limited previous material on decision-making and livelihood strategies in this particular pastoral system ( Aktipis, Cronk, and Aguiar 2011; Cronk 1991; Cronk 2004; Herren 1988; Herren 1989), making it difficult to contextualize the social, economic and, ecological problems that have arisen in recent years due to a long history of confinement.
isolation and marginalization. Secondly, there has been rapid market integration in this particular region of Kenya since the 1980’s (Gertel and Le Heron 2011; Herren 1989; Huysentruyt, Barrett, and McPeak 2009; McPeak 2004; McPeak 2005), leading to widespread changes in the character of production and the potential for food production, such as shifting production focus away from dairy cattle to trade in goats with urban meat houses. Thirdly, outmigration of labor to neighboring private ranches and urban centers has led to social and economic differentiation that influences household outcomes by increasing the divergence of strategies and interests among wealth strata (Kaye-Zweibel 2011). Lastly, no proper evaluation of wealth strata or wealth inequality has been carried out in Mukugodo since Herren used informant wealth ranking to stratify households in 1986.

We used a different strategy than Herren to classify households into different wealth categories (Grandin 1988a, as cited in Herren 1988). Informant wealth ranking is a ethnographic method for sorting households into wealth categories using local terms for wealth, community, and household (Grandin 1988a). The basic principle is that the name of each household in the community is written on a card and several (usually 3-4) key informants are asked to place the cards in piles according to the wealth rank of the household (poor, middle, rich). Then, the researcher uses the piles to facilitate in-depth discussion of the general features of each of these categories, such as type of household, level of resource endowment, production system, etc. This method, although useful for clustering households into ranks, provides only a qualitative, anecdotal assessment of inter-household heterogeneity. We believe that innate bias exists among key informants regarding household wealth, making this method less desirable than methods that use an objective, quantitative approach to assess household wealth without introducing the bias of subjective opinions.

We have a unique opportunity to evaluate the short-term response of pastoral families to a year-long drought inside of a longer-term study. The data we present here seek to investigate these potentially distinct patterns of recovery via an evaluation of environmental features, herding behavior, herd management, drought responses, and mobility patterns. One of our objectives is to better understand how local ecological factors, such as rainfall, interact with wealth dynamics to affect herding decisions as they occur spatially and temporally.

Heterogeneity in wealth has always been a prominent feature of herding cultures. According to Cronk (2004: 97), Mukugodo pastoralists were already at the bottom of “a regional hierarchy of
wealth...with the disparity being easy to document since the Mukugodo were last in their region to acquire livestock”. For pastoralists, wealth is usually counted in head of stock, with some herders amassing vast numbers of livestock, while others eek by with a few sheep and goats. It is often the wealthiest herders (e.g. those with the largest, most productive herds) who can marry the most wives and bear the most children, creating a disparity between rich and poor in not only wealth, but also production (access to labor) and reproductive success (Borgerhoff Mulder 1992; Cronk 1989; Cronk 2004; Fratkin and Roth 2005). However, it is not just wealth per se that leads to greater variability in success among pastoralists. Wealth, in modern times, translates into access to cash and the products of globalization, and most importantly, an increasingly diversified diet.

Previous research on the importance of wealth asymmetries for pastoral production has focused on quantifying the importance of social stratification and relations among herders in regards to wealth, labor, capital, and production (Dyson-Hudson and Dyson-Hudson 1980; Konczacki 1978; Little 1985; Spear and Waller 1993). Others have chosen to focus on the nutritional consequences of differences in household wealth among pastoralists and the influence that this may have on infant and child growth (Fratkin and Roth 2005; Galvin 1992; Grandin 1988b; Homewood 1992; Little, et al. 1993; Sellen 2001; Sellen 2003). In this dissertation, we use many of the same approaches as previous authors, but also include an analysis of the interaction between wealth and risk minimizing strategies such as herd mobility.

Weaving wealth differences into this analysis allows us to also evaluate existing social welfare systems, such as osutua and paran, and where and when they fail (Aktipis et al. 2011; Godoy et al. 2007; Smith 2011). Osutua literally means “umbilical cord” in Maa, making it a term that describes a “tied” relationship between two individuals (Cronk 2007). Osutua typically refers to a stock friendship or bond between two individuals that is permanent and can be passed onto their children. Bond partners reciprocate requests indefinitely, usually in the form of livestock, although in Mukugodo, virtually any good or service can serve as an osutua gift (Cronk 2007: 353), even cash. Paran, on the other hand, are gifts given to poorer members of the community, usually as a result of intense begging on the part of the receiver, or long term loans which the giver are unlikely to be repaid (Herren 1989). Gifts given under paran are not reciprocal; in fact, givers often complain that compliance with paran was a social necessity, but also a “veritable rip-off” (Chief of Ilmotiok, Tiamamut, and Mpala, personal communication, 2011).
Lastly, this study allows us to evaluate the dynamics of variation in new forms of herd management, particularly modified mobility patterns and shifts in herd structures. These changes alter in turn how families manage mobility in this mixed-use system, which is already constrained by private and public land patches abutting communally managed lands (Gadd 2005; Huho et al. 2011; Wambuguh 2007; see also Figure 9 in this chapter). Mukugodo are in a unique situation among Kenyan pastoralists, in that they live in a region surrounded by large-scale private cattle ranches that also engage in wildlife conservation and tourism, forcing them to compete and/or engage in risky negotiations with more powerful individuals for access to land. In this chapter, we evaluate how differential access to local resource distribution (grazing patches) affects production via herding and whether differences in wealth statistically interact with other main effects to shape household decisions and outcomes.

**Research Objectives**

In this paper, we will characterize i) the environmental conditions across both space and time of Ilmotiok and Tiamamut group ranches in Mukugodo Division, Laikipia, Kenya; ii) mobility and local/regional range use patterns by group ranch and wealth class; and iii) the influence of wealth differences on herding and production strategies that families use to cope with environmental variation or stress.

We do this via the following questions and hypotheses:

1. What environmental factors structure ecological dynamics in our local system? Is livestock productivity tied directly to local rainfall patterns?

   *We hypothesize that local rainfall patterns will affect livestock productivity via local variation in vegetation quality and accessibility. From this we predict that increases in rainfall will lead to improved vegetation quality, which will act to increase livestock productivity via higher birth and lactation rates.*

2. What migration strategies (seasonal or otherwise) are herders using in Mukugodo to manage local environmental conditions? Does wealth rank act as a social filter that differentiates households by these various strategies? (i.e. the ability to negotiate the
relationships necessary to move your animals to restricted areas or through restricted areas?

*We hypothesize that herders should migrate to distant grazing patches when local forage and water conditions decline, such as during droughts or dry seasons. Differences in herding strategy will be separated by wealth via differential access or use of grazing patches on and off group ranches.*

3. What are the consequences of environmental variation and herding differences stratified by wealth for livestock productivity (in terms of milk) and household livelihoods?

*We hypothesize that differences in herding strategy and herd management, such as herd size, composition, and structure will influence household production potential of milk. We predict that herders with access to resources essential for herd growth (such as high quality grazing patches whether local or distant or alternative sources of protein to minimize lactation effort in their herds) will have higher productivity (milk yields) than households without access to adequate resources for herd growth. This will be particularly important during dry seasons or droughts when forage and water resources become scarce in the local grazing area. Lastly, we predict that some herders will be able to rebuild their herds after dry seasons or droughts via herd building strategies, such as purchases or gifts (social redistribution).*

**The Setting**

This study was conducted in two Kenyan Group Ranches: Ilmotiok and Tiamamut, in western Mukugodo Division, Laikipia County, Kenya. The study was designed as a mixed longitudinal cohort study (Goldstein 1968) of socio-economic subsistence practices, diet, and health. Research was conducted with permission from the Kenyan Government (Permit Number: NOHEST13-001-29C80 VOLII) and local officials. Ethical approval was granted under IRB for the Ethical Treatment of Human Subjects at Princeton University (Protocol # 4051).
Mukugodo Division covers roughly 1,100 km2 in the northeastern edge of Laikipia County, representing the north-eastern edge of the Laikipia Plateau (Herren 1988; Herren 1989). On the edges of the plateau, elevation drops from 1800-2200 m to 1500-1600 m in Ilmotiok and Tiamamut Group Ranches (Figure 1). Central Mukugodo is rugged hilly terrain with acacia savanna vegetation. In the west, where Ilmotiok and Tiamamut Group Ranches are located, the terrain changes to undulating hills interspersed with acacia savanna and open grasslands (Muthiani et al. 2011) that abut the Ewaso Nyiro River, which is the administrative boundary of the Division.
Annual rainfall in Mukugodo Division is highly unpredictable and declines appreciably from east to west (700 m in the East and 400 m in the West; Herren 1989). The long rainy season usually occurs between the months of March and May. The short rains arrive (if they arrive at all) during
late October/early November and usually last until December. During the months of June and July, there is occasionally a third rainy season, with localized rainfall generated from non-monsoonal rains off the shores of Lake Victoria (for more detail, see Taylor et al. 2005). In drought years, the long rains are very short or do not come at all, and the short rains are absent. In wet years, the long rains are on time, last for 3 months, and are followed by a shorter dry season with occasional showers, with timely short rains. Forage levels (annual and perennial grasses) vary with the localized rainfall pattern and can literally grow over night in response to a good rain.

The are two perennial rivers in the system; the Ewaso Nyiro and Ngaare Ndare, which is unique in semi-arid pastoral settings (Borgerhoff-Mulder 1992; Butt 2010; Homewood 1995; Homewood 2004; McCabe, Leslie, and Deluca 2010; Scoones 1995; Sellen 1999; Sellen 2000; Sellen 2003; Thornton et al. 2007; Yanda and William 2010). These rivers provide a reliable source of water for livestock, wildlife, and human populations on the western boundary of the Division without necessitating borehole development.

Western Mukugodo is isolated from Dol Dol, the administrative center, in the north and Nanyuki, the district center, in the south. In the South, the Division is bounded in by large scale private ranches, most of which maintain closed electric fences along their perimeter and patrols on both public and private access roads (Herren 1989; Huho, Ngaira, and Ogindo 2011; Muthiani et al. 2011; Ngugi and Conant 2008). On the northern side of the Division there is a Livestock Holding Ground, which is now settled by Samburu pastoralists and a second Livestock Holding Ground in the southwest, which is now privately owned (Dan Rubenstein, personal communication, 2012). The Ewaso Nyiro River also creates an impassable boundary during wet periods (or when the flower farms downstream unload their dirty water onto pastoralists upstream), making Ilmotiok Group Ranch in particular an island for part of the year.

Mukugodo Division, which is made up of resettled Mukugodo Maasai pastoralists, was created in 1936 (Herren 1987; Herren 1988; Spencer 1959) as a Native Reserve for “Dorobo” pastoralists left behind on the Laikipia Plateau after the pastoral resettlements of 1914 (Spencer 1959). These individuals represent five distinct ethnic groups (Leuaso, Digirri, Mumonyot, Ilng’wesi, and Mukugodo; Cronk 2004) who differ in historical background, social organization, and ritual behavior, although they all speak Maa as a common language (Herren 1987). Only becoming livestock herders in earnest in the 1950s, they did so under duress; the majority of
their land was lost to war and colonial settlement in the 1920s (for the complete history of the Laikipia Wars, see Spear and Waller (1993)).

The catastrophic droughts of the 1980’s devastated the Mukugodo Maasai living in this Division (Herren 1987). Since then, the region has been characterized by high levels of outmigration, ecological problems, such as degradation and the influx of invasive species (King 2008), and the need for long term famine relief (Caritas Kenya, personal communication, 2010). However, these changes have not led to reductions in population size in the region: between 1987 and 2010, the human population grew from 11.7 persons/km2 to 36.69 persons/km2 (Herren 1987).

Pastoral families in this region currently raise four species of livestock: cattle, goats, sheep, and camels. They separate their herds into feeding groups, with cattle and camels herded in separate groups, and small stock herded together. When total herd numbers are very low (usually less than 15 individuals), these families will graze goats and cattle together, although this is not the preferred arrangement. In this region, animals are raised for the production of milk not meat. As such, herd owners do not typically sell female animals under any circumstance. Male animals, however, are used as short-term breeders, castrated and then sold or traded, and/or sold as juveniles for quick cash. Maasai herders historically traded with agriculturalists for grains and other foodstuffs during seasons when milk was less abundant (Spear and Waller 1993). In more recent years, semi-permanent settlement in trading centers and towns has turned seasonal dependence into complete reliance on neighboring agricultural groups and humanitarian aid organizations (such as USAID and WFP) for food.

Households are usually polygamous, consisting of a man, his wives, and children although in recent years, monogamy is becoming more common. Labor is divided among the members of a household along age and gender lines (Herren 1988). Households may choose to cooperate with their neighbors in a ‘meta-household’ structure. These meta-households normally consist of two or more families that share some degree of genetic relatedness, although this is not a necessary constraint. Meta-households that have chosen to cooperate will typically make ‘group’ decisions about the movement and management of their livestock herds. Decisions about herd management are centered on obtaining regular access to water and suitable vegetation for grazing.
Methods

Field research on the ecology of pastoral herding and production was conducted in Ilmotiok and Tiamamut Group Ranches, Mukugodo Division, Laikipia County, Kenya between June 2008 and July 2011. Thirty households, with a total of 400 subjects, were enrolled from 2008-2009 into a mixed longitudinal cohort study of pastoral populations in rural Northern Kenya. An initial cohort of 16 households was enrolled and visited monthly beginning in June 2008, with a second cohort of 14 households enrolled in July 2009. We conducted in-house field research with each cohort a minimum of five times over the course of a three-year period, for a total of fifteen months of contact time. Furthermore, two locally trained research assistants actively surveyed both of our enrolled cohorts once a month from September 2008 to July 2011.

Historical Rainfall and Vegetation Dynamics in Northern Laikipia

Rainfall and Normalized Difference Vegetation Index (NDVI) values recorded daily via the GLEWS (Global Livestock Early Warning System) database were uploaded for analysis. The database, which was developed by Zola Ryan in collaboration with Mpala Research Centre (MRC) in 2004, monitors climate data from 30 monitoring sites throughout Laikipia County (Ryan 2004). This database uses a coarse grid size of 8x8 km of land to calculate rainfall and NDVI values for each group ranch-monitoring site. Historical rainfall data (beginning in 1960) was derived from local rainfall recorded provided by MRC and the World Meteorological Organization. Current rainfall and NDVI data are downloaded every 10 days from NOAA RFE and NASA NDVI SAT, respectively.

Here we use the normalized vegetation difference index (NDVI) as a proxy for the green up of forage resources. NDVI is an index that parameterizes the contrast between PAR absorption and NIR reflectance as a gauge of plant productivity (Verbyla 1995). NDVI is calculated from the visible and near-infrared light reflected by vegetation.

The NDVI equation is:

$$NDVI = \frac{(NIR - RED)}{(NIR + RED)}$$

where RED and NIR are measures of reflectance in the red and near infrared bands of a sensor system, respectively.
Healthy vegetation absorbs most of the visible light that hits it, and reflects a large portion of the near-infrared light, giving these plants higher NDVI scores than unhealthy or sparse vegetation, which reflects more visible light and less near-infrared light, giving these types of plants low NDVI scores. The scale ranges from -1 to 1, where values of less than 0.1 indicate bodies of water or bare patches of ground and values above 0.35 indicate green, dense canopy cover of leaves and other source vegetation\(^1\). NASA only started collecting satellite NDVI data in our region in 1981; therefore, all NDVI-Rainfall analysis conducted here utilizes this restricted subset of data (1981-2012).

We used rainfall and NDVI data from GLEWS for Ilmotiok (KOI-1) and Tiamamut (TIA-1) group ranches to determine the degree of correlation between rainfall at time \( t = 0 \) (days) and time \( t = 31 \) (days) where NDVI value = time \( t = 0 \) (days) in these two communities. For ease of discussion, we refer to this as a “one”-month lag; however, to be precise, our analysis operates under 31 days as a month (21 day lag in rainfall + 10 days of observed rainfall) rather than 30 days.

Symmetric Nearest Neighbor Locally Weighted Regression (LOWESS; (Cleveland 1979)) was used to determine significant relationships between rainfall and NDVI and to establish patterns of correlation between rainfall and NDVI. LOWESS is a polynomial smoothing technique that fits weighted least squares linear regression lines to localized subsets of data to describe deterministic variation in the data point by point. The power of this technique is that it takes into account neighboring points of each point in determining the fit and repeats the entire procedure for each data point until it achieves the best fit.

**Short-term trends in Rainfall and NDVI: Effects of Drought on Semi-Arid Systems**

Once long term trends in rainfall and NDVI were established, a secondary analysis on a subset of the rainfall and NDVI data was conducted. We extracted these data from the GLEWS dataset mentioned in the previous section. Analysis was restricted to the years 2007-2012, which correspond to approximately +/- 1 years immediately proceeding and following the current study (2008-2011). Again, Symmetric Nearest Neighbor Locally Weighted Regression

\(^1\) For more information on NDVI, please see www.usgs.gov
(LOWESS;(Cleveland1979)) was used to determine significant relationships between rainfall and NDVI and to establish patterns of correlation between rainfall and NDVI.

**Products of Pastoral Production Survey**

To measure the extent to which pastoral products are available for consumption or sale within this population, we developed a survey technique called Herd Distribution Mapping. This technique quantitatively maps changes in herd composition and distribution for study households within each of the group ranches. We use a combination interview/direct observation technique, with a quantitative outcome. Each participating family was visited once a month where possible (either at the homestead where herds were directly observed and counted or at their dry season camp) and interviewed about the age, sex, and species composition of their complete herd, both those located at the permanent homestead and those out with affines or at dry season grazing zones.

We use these data, which are disaggregated by livestock species, sex, and age class, to calculate a family's dynamic TLU (Total Livestock Units, ILCA 1981) and LLU (Lactating Livestock Units, ILCA 1981) for comparison with other families in the population. To calculate TLU, multi-species herds are divided into their component parts- cattle, sheep, and goats, and ranked according to their value in the herd. Cattle are given a value of 0.71/head, and sheep and goats (shoats) a value of 0.17/head. Camels do not have an ILCA (1981) value. Therefore, we estimate their value to be twice that of a single cow (1.4/head). It is important to note however that camels do not figure prominently in the herds of our families and thus do not make up a significant portion of our calculations (less than 5%). Our observations of typical family herds in Laikipia indicates they can vary from <1 to >300, depending on the population. TLU, as a standardized measure, is usually a good indication of a family’s access to cash, and whether that cash is accessible in small (shoats) or large (cattle, camels) packets of wealth. Similarly, LLU divides multi-species herds into their component parts- cattle, sheep, and goats, and ranks them according to their dairy value. Camels are given a value of 1.4/head; cattle are 0.75/head, and shoats 0.15/head. The number of LLU in a herd varies from month to month and is a good indicator of a family’s ability to maintain a productive milking herd. Since most pastoral families do not sell lactating animals under any circumstance, LLU is a good indicator of a family’s subsistence value/wealth but not cash wealth.

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2 For more information, please visit Kenya's International Livestock Research Institute [www.ilri.org](http://www.ilri.org)
Data were also recorded monthly on the number and location of herd movements to locales outside of the home range for grazing, number of deaths, number of births, number of pregnant/lactating animals, number sold/bought and their value in the market\(^3\), transactions such as gifts and transfers, and animal slaughters. These data were used to determine household wealth (as measured in livestock units), access to small (shoats) and large (cattle and camels) packets of cash income, and production value of the herd (number of new individuals added to herd, number of lactating animals). This information was used to determine herd structure, composition, and mobility patterns.

We use these data on migration of livestock herds by households to determine if herders make migration decisions based on ecological factors, specifically rainfall and forage availability. Here we use linear regression to determine if the mean difference in rainfall between migration patches (Kirimun, Sukuton-Naibor, Rumuruti, Segera-Endana, and Mpala) and the home patch is a good predictor of where pastoral families should migrate with their livestock during dry seasons or droughts depending on which community they reside in. All of these grazing parcels are present on a map of Laikipia County included in this chapter (see Figure 9). To do this, we used the GLEWS database of rainfall values for Laikipia County to download data for each of the five migration patches listed above and calculate the mean difference in rainfall between the migration patch and the home patch. These differences were tested for significance using a simple regression model at 95% confidence and then plotted onto a graph. Migration patches were considered significantly different if the mean difference in rainfall was statistically significant and the confidence interval around the mean did not include zero. Significance is noted in the plots generated for this analysis.

Lastly, we measured monthly milk availability by family, which was measured as the amount of milk produced by each species in the herd for family use. To do this, we measured the amount milked in each household (morning and evening) by species. We then disaggregated this data for each family by number of animals milked by species for analysis. In this analysis, we also controlled for family size and lactating herd size when fitting regression models to our data by including these variables in the analysis. Family size is important since larger families would

\(^3\) If wives were surveyed on livestock transactions when husbands were absent, they often did not know the value of the livestock sold by their husbands or were not told the value of the transaction. In these cases, we did not record a transaction value for that animal. However, we can use market prices to estimate the value of animals sold based on age, sex, and month of transaction.
consume less milk per capita than smaller families, so we must control for family size in order to test for actual differences in consumption rates. Secondly, lactating herd size is important because families that have larger lactating herds will theoretically be able to produce and consume more milk than families with smaller lactating herd sizes. Hence, we control for lactating herd size and family size to control for variation in our analysis that may cloud our results.

**Wealth Classification Methods**

In order to determine the socio-economic status of individual families within the study area and the influence that status has on resource acquisition, we generated a numerical ranking system for wealth in this population, which is a linear combination of livestock (TLU/LLU), wages (cash/mth), children (labor availability), and status (social mobility and influence). In contrast to past approaches that use a single wealth value to calculate differences among families or an informant ranking approach, we used a novel approach that is dynamic and objective, as stated in the introduction to this chapter. It is important to note that we do not use a single wealth value for each household for all years of the study. Knowing that wealth and status can shift dramatically from one year to the next, we instituted a “dynamic wealth rank variable system” that calculates temporal changes in wealth rank from year to year to determine each household’s rank. These yearly values are then used to analyze relationships between wealth and herding strategies in our population.

Families were ranked according to an ordinal scale for status based on observational and numerical data from WHO Equity Assessments completed with each family member in a given household during the first two years of fieldwork (2008-2009). These status ranks are based on objective measures of social mobility, access to external resources, and leadership/government involvement: Status (0= No status; 1=Association with POS (Person of Status- either client or relative); 2= Community Leader; 3= Association with Private Ranch or other private institution (either employee, relative, or affine of management); 4=2+3).

Principal Components Analysis was used to calculate the eigenvectors associated with each wealth variable in the expression. Total Livestock Units and wages in cash weighted heavily in eigenvector 1, providing approximately 54% of the variation observed. Labor availability, as

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4 The World Health Organization Equity Assessment Tool is freely available on the internet (www.who.org).
represented by the number of children, explained approximately 27% of the variation. Lastly, status weighted heavily on axis 2 and explained approximately 19% of the total variation. These eigenvectors, as described above, were then used as constants to weight each variable according to its importance in the model. We labeled these weighting factors as \( A_1, A_2, \) and \( A_3 \) in our mathematical expression of wealth. Therefore, wealth rank is determined by the following linear expression:

\[
((\text{Livestock wealth} \ (\text{TLU by species} \times \text{cash value in KsH}) + (\text{wages in cash (monthly value in KsH)} \times A_1) + (\# \text{ of children} \times A_2) + (\text{status value} \times A_3))
\]

This expression generates a numerical value roughly equivalent to the cash value that a family has access to in a given month (TLU cash – LLU cash + wages), but also the relative cash value of a given household’s labor pool (children) to their overall wealth rank in the population. This information can then be used to calculate the income distribution, in local currency, of our sample families.

To further investigate the role of wealth in these communities, we plotted a simple Lorenz curve of income inequality by year to visually inspect income disparities. We then calculated two indices of inequality, the Gini Coefficient\(^5\) (which is based on the Lorenz Curve) and Theil’s T (which is similar to the Shannon Index), to provide a numerical estimate of the degree of income inequality we see in the Lorenz curves\(^6\). The Gini Coefficient is determined by the following expression (Deaton 1997: 139);

\[
G = \frac{N+1}{N-1} - \frac{2}{N(N-1)} \left( \sum_{i=1}^{N} P_i X_i \right)
\]

Where \( u \) is mean income of the population, \( P_i \) is the income rank \( P \) of person \( i \), with income \( X \), such that the richest person receives a rank of 1 and the poorest a rank of \( N \).

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5 The Gini Coefficient is a measure of statistical dispersion developed in Italy in 1912. It measures the degree of inequality in a frequency distribution of values, such as income. Worldwide values of Gini coefficients range from highly equal (Slovenia; 0.24) to highly unequal (South Africa; 0.70). Higher values indicate greater inequality. For more information, please see WorldBank Povcalnet http://iresearch.worldbank.org/PovcalNet/

6 Theil’s T is a measure of economic inequality developed in the Netherlands by Henri Theil (successor of Tinbergen). It is a special case of the generalized entropy theory, similar to a Shannon Index, where \( T = \) maximum possible entropy of the data – observed entropy of the data. The index measures the entropic distance (how far away) the population exhibits away from an idealized egalitarian state where incomes are equal. A higher Theil’s T index (ranging from 0 - \( \infty \)) means incomes are not evenly distributed among individuals. For a simple overview, please see Wikipedia (www.wikipedia.org)
The basic index for Theil’s T is represented by the following expression:

\[ T_T = T_{\alpha=1} = \frac{1}{N} \sum_{i=1}^{N} \left( \frac{x_i}{\bar{x}} \cdot \ln \frac{x_i}{\bar{x}} \right), \]

Where \( x \) = income/person.

To determine the statistical significance of changes between years in Gini or Theil’s T indices, we used a statistical package in Stata 12/SE (ineqerr) to calculate the mean Gini coefficient and Theil’s t index, standard error, and bias corrected confidence intervals for each year using the bootstrapping technique (100 repetitions; (Escudero and Gasparini 2000)).

**Herding Economy Survey**

In 2010, a single semi-structured interview was conducted with the managing head of household of the majority of families in our study (n=27) to evaluate decision-making and herding strategies among families (some families were unavailable during this time due to migration). We recognize that missing some families due to migration may introduce bias into our results for this survey. However, it is extremely common in the pastoralist literature to find missing data points in some analyses due to migration, loss of follow-up, and subject refusal to participate, among other reasons. Furthermore, the requirements set by the IRB on the treatment of ethical subjects requires researchers to exclude any data from subjects who do not give their permission to participate in a particular assessment, measurement, or questionnaire. Therefore, it is possible that all research on human subjects includes some bias if ethical principles and rules of conduct are respected accordingly.

We asked a range of quantitative and short answer, qualitative questions regarding herd structure and composition, shared herding and herding labor, herd splitting, breeding, migration, risks to herd survival (disease, theft, predation), renting of grass and squatting in absentee land, and herd decisions during drought. The answers from these surveys were then converted into binary (0,1), ordinal, and continuous data for analysis. We then used this data to determine if a herder’s decision-making pattern differs by wealth class. Qualitative data derived from this survey was also used to inform quantitative results regarding herding decisions and to better understand the perceptions of herders regarding local herding opportunities and constraints in Mukugodo.
GIS Tracking of Livestock and Statistical Analysis of Spatial Relationships among Wealth Classes

This part of the study focuses on the movement patterns of livestock herds in a normal rainfall year (2010). I chose to sample only goatherds, since their uniformity in grazing meant that I could control for forage preference differences among members of a herd. I chose to sample herds based on neighborhoods; one large neighborhood in Tiamamut and two smaller ones in Ilmotiok. Within these neighborhoods, I opportunistically captured data on families of different herd sizes and wealth classes; families in a neighborhood were often, but not always, related to each other. Overall, data was compiled on 4 rich families and 11 poor/middle class families. 6 of these families lived in Tiamamut; 8 in Ilmotiok. Each herd we sampled was managed as a single unit, either by a single house and herder or as part of a meta-household.

To obtain accurate data on movement, we affixed GPS collars (Savannah Tracking Ltd, 2012) on a single adult animal from each herd. Herders were given the right to choose which animal the collar was fixed to within their herd. Each herd was monitored with a GPS collar for an average of 4 consecutive days. Herds rarely if ever fragment during grazing bouts, so a single animal’s behavior was assumed to be representative of the overall herd’s behavior and location. The GPS collars obtained point fixes every fifteen minutes, capturing general movement parameters rather than micro movement data. Due to the limited number of collars available for sampling (2), each herd was monitored twice during the course of a seven-month field season in 2010.

All GPS data collected from herds was processed into tracks using ArcGIS 9. Many GPS fixes were taken before and after grazing when the animals were confined to the boma. I visually inspected each herd track in GIS to detect and remove these spurious points manually. Using ArcGIS, I calculated the daily distance to water, herding radius, and maximum distance travelled for each grazing path. The distance to water is defined as the shortest distance to a water point from the start of the herding path, i.e. the homestead. The herding radius is defined as the single furthest distance travelled by the herd from the homestead (often this point is the water source). Subsequent analysis of spatial data was performed in ArcMap (version 10, 2011) and Stata 12/SE.
All other statistical analysis found in this paper was performed with packages in JMP 9 (SAS Institute 2011) and Stata 12/SE (Stata Corporation 2011).

**Results**

**Short Term Rainfall and Forage Dynamics in Ilmotiok and Tiamamut Group Ranches**

Annual rainfall values\(^7\) for Ilmotiok and Tiamamut group ranches indicate that 2007 and 2008 were relatively dry years. Rainfall reached its lowest levels during the drought in 2009 (Figures 2 and 3). Total rainfall values in 2010 (recovery year) and 2011 (unusually wet year) were approximately three times that of 2009. In 2012, rainfall failed completely during the first part of the year, artificially increasing the dry period by one month (no rainfall events in March 2012). However, rainfall levels recovered substantially in April and May, with over 100 mm of rain during this key period, indicating that 2012 should be a wet year as well.

![Figure 2: Monthly rainfall and NDVI values for Ilmotiok Group Ranch over a five-year period (2007-2012). Yearly rainfall values for each year are superimposed on the graph in the upper right hand corner of each quadrant of the graph. The red connected line indicates NDVI whereas the black bars indicate average rainfall (cm).](image)

\(^7\) All rainfall data were taken from the Texas A& M Global Livestock Early Warning System (GLEWS) database for Laikipia, Kenya as previously explained in detail in the methods section. For complete datasets, please visit: http://glews.tamu.edu/eastafrica
NDVI values over the same period (2007-2012) indicate that when rainfall levels increase, forage levels ("greenness") also increase, but with a one month lag. As shown in Figure 4, NDVI peaks 1 month after a significant rainfall event. This indicates that pastoral families must wait for at least one month after the rains start to see significant improvements in the productivity of their livestock. Herds need about one month of feeding on improved pastures to improve the amount of milk each animal produces during that period. As such, livestock quality is improving as the grass greens up; however, rainfall must be frequent for this trend to continue.
Figure 4: Analysis of the influence of rainfall levels on forage production in Ilmotiok. The correlation between NDVI and rainfall is highest at a lag of one month ($R^2 = 0.72$, p < 0.05). Thus, forage levels increase dramatically within a lag of about one month following a major rainfall event.

An analysis of the correlation between the timing of rainfall events, NDVI, and livestock productivity (Figure 5) indicates that about one month after it rains, forage levels improve and milk production responds immediately. This effect carries over for one month, meaning that even if it doesn't rain again for a month, households will have enough forage to maintain production levels for one month. After two months, milk production falls by nearly half if it doesn't rain again (from $R^2 = 0.65$ to $R^2 = 0.4$). This represents a safety net for households in that they don't have to split their herds immediately when the rains fail, but can wait and allow for their families to uptake the milk before moving off again.
**Figure 5:** Livestock productivity, as measured by milk yields, correlates with a one-month lag in NDVI values ($R^2 = 0.65$, $p < 0.05$). Combining this result with that of Figure 3 means it takes one month for the grass to green up and a second month for stock to feed on this improved forage before productivity reaches its zenith.

**Long Term Trends in Laikipia’s Northern Rainfall Dynamics: The case of Ilmotiok and Tiamamut**

Annual rainfall values from Northern Laikipia, Kenya indicate that this region has undergone a progressive dampening of rainfall values over time (Figure 6). In the 1960’s, droughts were strongly episodic, with one drought occurring every four years (1961, 1965, 1969). This pattern changes in the 1970’s, starting with a three-year drought from 1971-1974 and a second drought after only one year in 1976. The 1980’s are then relatively stable, with a similar drought cycle as the 1960s (1980, 1985, 1987, 1989), although the pattern deteriorates as we enter the 1990’s. From 1991 onward, there is only one year where the average rainfall is over 300 mm (1998). When we aggregate the rainfall data by 16-year quadrants and calculate the coefficient of variation (CV) between quadrants (Figure 7), we find that CV is trending up over time (from 0.2 in Q1 to 0.4 in Q3), however this increase was not statistically significant ($p < 0.08$).
Figure 6: Fifty years of rainfall data (1960-2010) from Northern Laikipia, Kenya. The black boxes (annual mean rainfall) indicate years where rainfall was above 300 mm/year whereas the orange boxes (again, mean annual rainfall) indicate years where rainfall was below 300 mm/year. Capped bars indicate standard deviation around the mean.

Figure 7: Changes in coefficient of variation (CV) in rainfall for Ilmotiok and Tiamamut GR’s 1961-2008. Although CV increases linearly over time, the increases are not statistically significant (p < 0.08).

Our historical rainfall pattern suggests that this region is becoming progressively drier and more drought-prone over time. This assertion is further demonstrated in Figure 8, where a fitted LOWESS (Cleveland 1979) curve of rainfall against year clearly shows a sharp decline in rainfall values at or near 1990. As indicated by the LOWESS curve, median rainfall decreases by almost 50% over the 30-year period.
Figure 7: Median rainfall (mm) from 1960-2010. Superimposed on the plot in red is a LOWESS regression curve of rainfall against year. Note that this graph contains two separate axes: one for median annual rainfall and one for lowess smoothed annual rainfall. LOWESS is a polynomial smoothing technique that fits weighted least squares linear regression lines to localized subsets of data to describe deterministic variation in the data point by point. The power of this technique is that it takes into account neighboring points of each point in determining the fit and repeats the entire procedure for each data point.

**Trends in Forage Generation using Long Term Rainfall and NDVI Values**

As indicated in Figure 9, NDVI or "greenness" increases linearly with rainfall. There is a statistically significant correlation between NDVI and rainfall (at a lag of one month) indicating an improvement in forage availability during this time frame; $R^2 = 0.40$, $t_{(11311)} = 85.9$, $p = 0.000$). These regression results, when paired with a Pearson product moment correlation of 0.39 (CI: 0.370 - 0.403) indicates that our lag of 31 days sufficiently predicts the historical process of green up in these communities. However, a lag of 31 days more accurately predicts green up in the restricted 21st century subset (2007-2012) of data, with a higher correlation coefficient ($R^2 = 0.72$, $p < 0.05$) than the 30-year data set.
Figure 9: Symmetric Nearest Neighbor Locally Weighted Regression of NDVI as a function of rainfall (mm) ($p < 0.0001$).

Mobility Patterns: How do families deal with a mixed land use system?

Herders make decisions about where to migrate with their livestock based on a variety of social and ecological factors. Here we generated a map of Laikipia County (see Figure 10) with each land parcel labeled according to its status (Private, Public, Communal). Superimposed over this structure are public access roads and government designated cattle tracks. Our two group ranches (Ilmotiok and Tiamamut) are located in the upper right hand corner of the map in the patch of green land parcels designated by the government in the 1970’s as communally managed lands. They directly abut a large swath of private ranches and farms, many of which (such as Mpala and Ol Jogi) are engaged in endangered species conservation. Public lands dominate the western and southern portions of the county, where lands have been cut up into
many tiny parcels, most of which are owned by absentee landowners. Many of these lands are not fenced, making them easily accessed by migrating herds.

A few places stand out in the map. There are two communally managed lands; P&D and N/Approach that offer “safe zones” near frequently used squatter patches (such as Endana, near N/Approach and P&D near Kirimun; see Figure 11 and Table 4). Some absentee lands offer safe squatting grounds near other patches, such as Mathira 2 being a holding ground for Segera and Karashira as a holding ground for the Rumuruti approach to the Aberedere Mountains near Mifugo. Public roadways from communal lands through private lands provide access to public lands where pastoral families set up temporary camps for grazing during dry seasons (Hauck, personal observation, 2008-2011). Roads are only accessible during daytime hours so herders requiring nighttime transit through private ranches must negotiate those access rights in advance (Mike Littlewood, personal communication, 2011).

Private ranches usually charge a grass rental fee to herders from off property. The fee ranges from 50 KsH per head of cattle (Loisaba) to 200 KsH per head of cattle (Mpala). This rental fee also includes the provision of labor to herd the cattle. This is particularly important for poor herders, who generally have one or two cows but do not have the necessary labor to send them for off group ranch grazing. In effect, ranches like Mpala provide herders with subsidized grass and labor for cattle during dry seasons and droughts. All private ranches accept cattle as renters. However, in extreme cases (at Mpala only), a few herders may be able to negotiate access for sheep herds who are highly dependent on grass. Private ranches also place limits on the number of livestock that are accepted on their property, usually accepting no more than 100 from a given group ranch. Public lands, on the other hand, are usually unmonitored so herders can travel to these patches and squat without having to pay rent for the grass they consume. Many herders from around the region use these squatter patches so they are plagued by theft and banditry, making them unsafe for herders living there. For example, raiders stealing cattle gunned down the local chief’s son in one of these squatter patches. Although unsafe, these patches are important since they accommodate all species, even goats, which the private ranches will not accept for grazing.
Figure 10: Map of Laikipia County with Mixed Land Use Patches and Public Road Networks. Green patches are Group Ranches, designated by the government in the 1970’s as communally governed land. Red patches are Private Farms/Ranches, most of which originated during the colonial period (1890’s-1960’s). Yellow patches are either government owned or absentee owned lands, many of which have no fencing or regulation of their use or borders. Public roads are indicated in dark blue lines across the map. Although these roads traverse private properties, individuals have public access to these roads during daylight hours and by request to the landowner after dark.
Figure 11: Results of a linear regression model predicting where pastoral families should migrate with their livestock based on the mean average difference in rainfall between the home patch (Ilmotiok or Tiamamut GR) and one of five potential migration patches (Kirimun, Sukuton-Naibor, Rumuruti, Segera-Endana, and Mpala). Mean difference in rainfall is reported in centimeters.

Our results indicate that based on rainfall differences alone, herders in Ilmotiok should migrate to one of three places: north to Kirimun, where rainfall is 0.2 cm higher; southwest to Rumuruti, where rainfall is 1 cm higher; and south to Segera-Endana, where rainfall is about 0.7 cm higher (Figure 11). On the other hand, herders in Tiamamut should ideally all migrate to Rumuruti, since that is the only migration patch with significantly improved rainfall (approx. 1 cm higher). Mpala is the only other patch with significantly different rainfall than Tiamamut. Grazing on Mpala, however, is only open to those renting grazing for cattle, so goat and sheep herds are generally not allowed in, except under extreme duress. Herders from Tiamamut should not migrate to Kirimun, Sukuton-Naibor, or Segera-Endana based on rainfall differences, since rainfall and therefore, vegetation conditions are likely to be similar if not worse on average than in the home patch. Results of analyses of livestock movement records from 2008 to 2011 indicate that there are significant differences between group ranches in where they move their
livestock during dry seasons or droughts to access forage and water resources, with a few exceptions.

44.5% of Ilmotiok herders reported moving their cattle to Mpala in 2008 vs. 25% of Tiamamut herders (chi2= 14.11, p < 0.227) but the difference was not statistically significant. Similarly, 37% of both Ilmotiok and Tiamamut herders migrated to Sukuton in 2008. Tiamamut herders report migration to other areas in 2008, such as Endana (12.5%), Fois (6.25%), and Koija (6.25%). Herders in Ilmotiok do not cite using any other outside patches during this year; however, they do cite moving stock to affines or relatives in other neighborhoods in their own group ranch to acquire grazing access (Lorubay or Naserian). Herders who moved their stock to Mpala (Tiamamut) during this period behaved in accordance with our prediction based on ecological factors.

In 2009, there are significant differences between Ilmotiok and Tiamamut herders regarding migration location (Ilmotiok vs. Tiamamut; chi2= 46.05, p < 0.002). Tiamamut herders report migrating to a wide range of different grazing patches. 9.75% report migrating to Endana and Mount Kenya, whereas 17% report migrating to Kiperen (Mpala/Soit Nyiro property line), 15% to Sukuton, and 9.75% report sending their cattle to Mpala. Ilmotiok herders move their animals to similar locations, but with different frequency. 10% of families report making local migrations within Ilmotiok (from their home boma to an affine’s or relative’s boma). 34.33% report migrating to Kiperen and 26.8% sent cattle to Mpala. In contrast to 2008, Ilmotiok families report migrating to a few patches that Tiamamut herders do not report using: 2% to Loisaba Wilderness, 2% to Ngabolo, 5% to Male Ranch, and 3% to Maraka Farm. Herders from Tiamamut that moved their stock to Kiperen, Mpala, and Segera acted in accordance with our predictions. Similarly, herders from Ilmotiok who moved their herds to Loisaba and Ngabolo (near Kirimum) acted in accordance with our predictions.

In 2010, there are again significant differences between group ranches regarding migration behavior (Ilmotiok vs. Tiamamut; chi2= 15.023, p < 0.020). First of all, the number of locations that herders report migrating to with their livestock is significantly reduced from 2009 to 2010 (23 vs. 7, respectively). Here the majority of Ilmotiok herders report moving livestock back to their home patch (37%), to Ngabolo (36%), or to Sukuton (18%). In contrast, 31% of Tiamamut herders report moving to Fois, 16% to Ivan’s farm, 39% to Sukuton, and 8% to Ngabolo and Tiamamut, respectively. Note that only 8% of Tiamamut herders report returning livestock to
their home patch vs. 37% of Ilmotiok herders. Here Ilmotiok herders are making very good decisions based on our predictions by moving their stock to Ngabolo, but not by moving them to Sukuton. Similarly, herders from Tiamamut are making good decisions by migrating to Fois, which is next to Segera-Endana and Ivan’s, which is next to Mpala.

Lastly, in 2011, herders continue to report herd migrations, but once again the number of sites listed as being used is reduced from 7 to 5. 85% of Ilmotiok herders report sending cattle to Mpala for rented grass and 15% reported moving any remaining livestock back to Ilmotiok. Tiamamut herders report using 3 different patches during this year equally: 33% to Kere Farm, 33% to Muhammad Farm, and 33% to Sukuton. These differences are statistically significant (chi2 = 10.0, p < 0.04). Here neither set of herders seems to be moving stock based on rainfall differences alone.

*Wealth Inequality in Pastoral Families*

Using the linear expression described in the methods section, we calculated Lorenz curves using the income distribution of our sample families for each year of the study (2008-2011). Deep convexity in the overall distribution of incomes in our population indicates that incomes and assets are highly unequal, with 3-4 families controlling approximately 50 % of the wealth (see Figure 12).
Figure 12: Lorenz Curves of Inequality plotted for each year of the current study against an income equi-distribution line. Income inequality is quite high in our system, with greater inequality present during good than bad rainfall years (2009 vs. 2011).

Similarly, by plotting a different curve for each year, we can establish that wealth inequality contracts during poor rainfall years and expands during the first year following a drought. Our 2008 curve is assumed to be the quasi-“normal” distribution of incomes during normal years of rainfall and forage accumulation. In 2009, which was one of the worst droughts in the Horn of Africa in 100 years, incomes actually contract, moving more towards the equi-distribution line, meaning that everyone was affected by some loss during the drought, even the rich at the far right of graph. Most interestingly, in 2010, income equality expands dramatically from 2009, with the richest families controlling the largest percentage of incomes during the recovery year. In 2011, the curve starts to return to 2008 levels, but is actually less convex than 2008 on the upper half of the curve. This indicates that inequality contracts as the system moves away from crisis years and recovery years to more normal conditions.

Using both Theil’s T and the Gini Coefficient as our statistical markers of inequality, we can determine that incomes are highly unequal overall, with both high T and Gini values for all years (Figure 13). During 2008 and 2009, inequality values were roughly equivalent, with no
significant change between years (for example mean Gini in 2008: 0.56, 95%CI (0.413-0.634) versus mean Gini in 2009 of 0.55, 95%CI (0.466-0.627), which may reflect the universality of drought loss for families at all income levels during this period. In 2010, however, income inequality expands dramatically in both markers (see Figure 13 for numerical Gini and Theil's T values and standard error) and then declines precipitously in 2011 to pre-drought levels. This extreme shift in inequality may be due to differential access to livestock via *paran* (*social obligation or exchange*) or cash assets to re-purchase lost stock. The results of these two indices agree with our overall visual interpretation of the Lorenz Curves (Figure 12).

Figure 13: *Theil's T and the Gini Coefficient, two indices of inequality, plotted for each year of the study. Capped bars indicate standard error and confidence intervals around the mean. As we saw in Figure 12 inequality decreases in bad rainfall years (2009) and increases dramatically in the first year following a drought event. Inequality then declines in the second year following the drought event, either approaching or equivalent to pre-drought levels.*
Migration Choices during drought: Rich vs. Poor and Middle Class Herders

Results of a questionnaire completed in May 2010 with each male or female head of household in our study (n = 30) reveal some factors that act to differentiate herding decisions based on wealth, with some exceptions.

Results of our interviews with herders revealed that 95% of the poor and middle class families named rights of access to pasture as the most important feature defining movements during droughts (vs. rich; chi2 = 3.85, p < 0.05), second only to the risk of moving a herd to an area that is already devoid of grazing by the time you arrive (95% of poor/middle vs. rich; chi2 = 3.85, p < 0.05). Lower status families report having difficulty negotiating rights of access to some areas even if they can get good information about forage quality in distant patches; in effect, getting there is half the battle. Moreover, reduced competition for grazing, induced by rich families fleeing the system for distant patches when conditions are really poor, means that poor and middle class families, can find residual grazing at home to hold them over until it rains again. Hence these poor families who stay in the home patch should be the first to benefit from improved local forage when the rains return.

<table>
<thead>
<tr>
<th>Migration Patch</th>
<th>Rich(% using)</th>
<th>Poor/Middle (% using)</th>
<th>Pearson chi2</th>
<th>p &gt; chi2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kiperen</td>
<td>50</td>
<td>43</td>
<td>0.09</td>
<td>0.75</td>
</tr>
<tr>
<td>Sukuton</td>
<td>50</td>
<td>62</td>
<td>0.27</td>
<td>0.6</td>
</tr>
<tr>
<td>Mount Kenya</td>
<td>50</td>
<td>24</td>
<td>1.53</td>
<td>0.21</td>
</tr>
<tr>
<td>Endana</td>
<td>17</td>
<td>33</td>
<td>0.62</td>
<td>0.43</td>
</tr>
<tr>
<td>Mpala (rent)</td>
<td>17</td>
<td>19</td>
<td>0.01</td>
<td>0.89</td>
</tr>
<tr>
<td>Eluai</td>
<td>17</td>
<td>0</td>
<td>3.63</td>
<td><strong>0.05</strong></td>
</tr>
<tr>
<td>Kojia</td>
<td>17</td>
<td>0</td>
<td>3.63</td>
<td><strong>0.05</strong></td>
</tr>
<tr>
<td>Rumuruti</td>
<td>17</td>
<td>5</td>
<td>0.96</td>
<td>0.33</td>
</tr>
<tr>
<td>Fois Robo</td>
<td>17</td>
<td>5</td>
<td>0.96</td>
<td>0.33</td>
</tr>
<tr>
<td>Karashira (Rumuruti)</td>
<td>17</td>
<td>0</td>
<td>3.63</td>
<td><strong>0.05</strong></td>
</tr>
<tr>
<td>Ngarenyiro (Rumuruti)</td>
<td>17</td>
<td>0</td>
<td>3.63</td>
<td><strong>0.05</strong></td>
</tr>
</tbody>
</table>

Table 2: Results of Pearson Product Moment Correlation Analysis between Rich and Poor/Middle Class herders on migration patch use during the 2009 drought year. The
male or female head of each household enrolled in the study was interviewed regarding
drought season herd migrations in May 2010.

In general, rich and poor/middle class families report using the same migration patches during
the drought (in particular, Sukuton, Mount Kenya, Endana, and Mpala, see Table 2). However,
rich families mentioned a number of exclusive migration patches or grazing easements that poor
families did not use or have access to (Eluai, Kojja, Karashira, Ngarenyiro).

Local Movement Patterns: Group Ranch and Wealth Related Differences

We found significant differences between group ranches on two key herding parameters:
distance to water and herding radius. There was no significant difference between wealth
classes or group ranches in maximum distance travelled (HL estimator: 31.7 m, ns and HL
estimator: 847.3 m, ns). We do, however, observe a trend in the data that suggests herders in
Tiamamut travel shorter maximum distances than herders in Ilmotiok (mean difference: 847.3
m; almost 1 km, p < 0.07).

Significant differences exist between rich families and middle class families regarding two key
aspects of herding strategy. There were consistent differences between rich and poor/middle
class herders in distance to water and herding radius (see Table 3, 4, Figure 14, 15). Poor
herders travelled longer distances to water (864 meters) and used a larger area (400 meters) to
complete their herding path. These same two parameters were significantly different between
the two group ranches as well. Ilmotiok herders consistently travelled longer distances to water
(903 meters) and had longer overall herding radii (1439 meters).

| GIS Data Results of Differences between Rich and Poor/Middle Class Families in Local Herd
<table>
<thead>
<tr>
<th>Movements</th>
<th>Rich Mean +/- SD</th>
<th>Poor/Middle Mean +/- SD</th>
<th>MW U</th>
<th>z</th>
<th>p</th>
<th>HLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance to Water (m)</td>
<td>2000.48 +/- 740.61</td>
<td>2691.37 +/- 950.22</td>
<td>252</td>
<td>-2.909</td>
<td>0.0036</td>
<td>864.74</td>
</tr>
<tr>
<td>Herding Radius (m)</td>
<td>2092.21 +/- 774.32</td>
<td>2570.48 +/- 855.33</td>
<td>279</td>
<td>-2.46</td>
<td>0.0014</td>
<td>400.69</td>
</tr>
<tr>
<td>Maximum Herding Distance (m)</td>
<td>7035.94 +/- 1305</td>
<td>7039.9 +/- 1869.3</td>
<td>424</td>
<td>-0.082</td>
<td>0.9340</td>
<td>31.7</td>
</tr>
</tbody>
</table>

Table 3: Results of Mann Whitney U test with Hodges Lehman Effect Size Estimator.
GIS Data Results of Differences between Ilmotiok and Tiamamut Group Ranch in Local Herd Movements

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Ilmotiok Mean +/- SD</th>
<th>Tiamamut Mean +/- SD</th>
<th>MW U z p</th>
<th>HLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance to Water (m)</td>
<td>2973.64 +/- 776</td>
<td>1785.43 +/- 736.21</td>
<td>1708 4.418 0.0000 -903.6</td>
<td></td>
</tr>
<tr>
<td>Herding Radius (m)</td>
<td>2786.31 +/- 762.78</td>
<td>1906.03 +/- 723.43</td>
<td>1757 5.1  0.0000 -1439</td>
<td></td>
</tr>
<tr>
<td>Maximum Herding Distance (m)</td>
<td>7313.71 +/- 1896.2</td>
<td>6537.66 +/- 1386.27</td>
<td>1518 1.811 0.0700 -847.3</td>
<td></td>
</tr>
</tbody>
</table>

Table 4: Results of Mann Whitney U test with Hodges Lehman Effect Size Estimator.

Figure 14: Quadratic Fit of Maximum Distance Travelled as a function of Distance to Water by Wealth Rank. Wealthy families travel shorter distances to reach water, meaning they spend less time trekking to water and more time grazing.
Figure 15: Quadratic Fit of Herding Radius as a function of Distance to Water by Wealth Rank. Wealthy families travel shorter distances to complete their grazing circuit before returning home. They can do this since they spend less time trekking their herds to water.

Livestock Productivity as a Function of “Greenness” (NDVI)

Here we use milk availability as our variable of livestock productivity. Specifically, we use the amount of excess milk available to a household for human consumption. Regression analysis of the fit of milk availability by NDVI (Figure 16) indicates that milk availability significantly increases for all livestock species when greenness levels increase, with the highest overall yields (1250 mL per family/d) at NDVI values of 0.4 and above ($2313.852, t(560) = 5.30, p < .0001$).
Species Specific Analysis of Herd Productivity by Wealth and Year

As shown in table 5 below, small stock milk production differed significantly by year (2009, 2010, and 2011; all p < 0.001 but not 2008, n.s.) as well as by wealth rank (rich vs. poor; p < 0.001). There were also significant interactions between year and wealth rank, with higher milk outputs for poorer families in 2008 and richer families in 2009 and 2010. Similarly, increases in small stock output indicate commensurate increases in small milking stock (Small LLU: individuals switching from breeding to lactating; p < 0.001) in the herd. The overall model explains roughly 67% of the variation we see in small stock milk yields (R² = 0.67, F(8,79) = 19.74, p < 0.0000).
Table 5: Results of Linear Regression of Small Stock Milk Yield (per capita availability for human consumption), adjusted for lactating herd size and family size. Significant predictor variables were year, wealth rank, and total lactating herd size. Values reported in the table are beta coefficient and t value. Stars indicate degree of significance.

<table>
<thead>
<tr>
<th>Predictor Variable</th>
<th>Outcome: Small Stock Milk/Capita</th>
</tr>
</thead>
<tbody>
<tr>
<td>2009</td>
<td>589.481 (5.25)**</td>
</tr>
<tr>
<td>2010</td>
<td>748.148 (6.67)**</td>
</tr>
<tr>
<td>2011</td>
<td>675.488 (6.30)**</td>
</tr>
<tr>
<td>Wealth Rank</td>
<td>-544.297 (5.48)**</td>
</tr>
<tr>
<td>2008* Rank (poor)</td>
<td>704.832 (6.19)**</td>
</tr>
<tr>
<td>2009*Rank (rich)</td>
<td>-544.542 (5.05)**</td>
</tr>
<tr>
<td>2010* Rank (rich)</td>
<td>-696.351 (6.27)**</td>
</tr>
<tr>
<td>Small LLU</td>
<td>156.660 (8.52)**</td>
</tr>
<tr>
<td>Intercept</td>
<td>-96.481 (1.81)</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.67</td>
</tr>
<tr>
<td>$N$</td>
<td>88</td>
</tr>
</tbody>
</table>

* $p < 0.05$; ** $p < 0.01$

In table 6, we present similar results for large stock milk availability (camels and cattle). Large stock milk yields decreased sharply in 2009 and 2010 ($p < 0.001$), with year being a statistically significant predictor of decreases in milk yield. Wealth rank was also a significant predictor of reductions in milk yield by year, with rich families seeing the greatest reductions in milk yield in 2009 ($p < 0.05$) and 2010 ($p < 0.001$). Lactating herd size was not a significant predictor of milk availability for large stock species ($p > 0.05$). The overall model was statistically significant, explaining approximately 80% of the variation we observe in large stock milk yields ($R^2 = 0.80$, $F(7,14) = 7.94$, $p < 0.0006$).
Table 6: Results of Linear Regression of Large Stock Milk Yield/Capita, adjusted for lactating herd size and family size. Significant predictor variables were year and wealth rank. Values reported in the table are beta coefficient and t value. Stars indicate degree of significance.

<table>
<thead>
<tr>
<th>Predictor Variable</th>
<th>Outcome: Large Stock Milk/Capita</th>
</tr>
</thead>
<tbody>
<tr>
<td>2009</td>
<td>-574.243</td>
</tr>
<tr>
<td></td>
<td>(5.28)**</td>
</tr>
<tr>
<td>2010</td>
<td>-288.361</td>
</tr>
<tr>
<td></td>
<td>(2.48)*</td>
</tr>
<tr>
<td>2011</td>
<td>-333.333</td>
</tr>
<tr>
<td></td>
<td>(1.92)</td>
</tr>
<tr>
<td>Rank</td>
<td>-600.699</td>
</tr>
<tr>
<td></td>
<td>(2.66)*</td>
</tr>
<tr>
<td>2009 * Rank (rich)</td>
<td>-580.933</td>
</tr>
<tr>
<td></td>
<td>(2.43)*</td>
</tr>
<tr>
<td>2010* Rank (rich)</td>
<td>-813.974</td>
</tr>
<tr>
<td></td>
<td>(3.25)**</td>
</tr>
<tr>
<td>Large LLU</td>
<td>29.319</td>
</tr>
<tr>
<td></td>
<td>(0.86)</td>
</tr>
<tr>
<td>Intercept</td>
<td>1245.377</td>
</tr>
<tr>
<td></td>
<td>(4.96)**</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.80</td>
</tr>
<tr>
<td>N</td>
<td>22</td>
</tr>
</tbody>
</table>

* $p<0.05$; ** $p<0.01$

Considering that wealth rank and year are significant predictors of milk yields for subsets of livestock species managed by each household, we ran a regression analysis to determine if total milk available per capita is significantly different among households by year or wealth class, controlling for family size. Total milk yield available was significantly different among years for wealthy families ($p > 0.05$). Poor families suffered statistically significant decreases in milk yield during the drought year (2009), when compared to wealthier families ($p < 0.05$).
Figure 17: Total actual milk yields available per capita for all 4 years of the current study (n= 31 families). R indicates “Rich” households and P/M indicates “poor and middle class” households. Data is plotted by year from 2008-2011. Yields are low for all four years among poor/middle class families, with individuals having access to 200 mL per day. Milk yields only significantly improve for the rich in the years following the drought (2010-2011). Low sample size in 2011 among rich families did not allow for enough variation to calculate accurate standard error around the mean.

In 2008, rich families reported very low per capita milk yields (101.30 mL +/- 5.03) whereas poor/middle class families reported higher per capita milk yields (344.08 mL +/- 5.35). During the drought year, both sets of families report per capita yield less than 200 mL (rich: 178 mL +/- 4.72; poor/middle: 122.71 mL +/- 2.41). In 2010, differences in milk yield between rich and poor emerge, with rich families reporting an average of 503.42 mL +/- 8.48 and poor families reporting almost 50% less (296.17 mL +/- 3.58). In 2011, rich families report consuming 1720 mL +/- 41.47 of milk/day whereas poor and middle class families are still consuming per capita amounts less than 200 mL per day (171.30 +/- 3.63). In 2011, we were unable to accurately measure the majority of wealthy families in our sample due to loss of follow-up. Although we see
a trend towards increased consumption of milk by rich families (Figure 17), there are no significant differences between rich and poor/middle class families in per capita milk consumption in 2011 (U=14, 1.612, p< 0.10).

Differences between rich and poor/middle families in milk yields following drought may be due to differences in herd composition and lactation effort. In 2010, rich families held on average 77% of their lactation in small stock and 23% in large stock. These lactating herd compositions are almost identical to those in 2009 (75:25 for rich, 77:23 for poor), indicating a slow return to “normal” herd distributions following the drought. Poor families, however, held 90% of their lactation in small stock and 10% in large stock. These differences only increase in 2011, where rich families distribute their lactation efforts almost equally across species (small stock: 42%; large stock: 58%), but poor families invest all of their lactation efforts in small stock (95%), with only 5% of total lactation output coming from large stock.

The 2009 drought also had significant effects on the overall herd compositions (lactating and non-lactating) among families of different social strata (Figure 18). Wealthy families experienced larger absolute reductions in goats and sheep than poorer families (goats: U= 11, -2.235, p<0.03; sheep: U= 15, -2.445, p< 0.01). Similarly, wealthy families faced greater absolute losses in cattle and camels than poor families (cattle: U= 11, -2.922, p<0.0035; camels: U=17, -3.437, p<0.0006). Poor and wealthy families fared equally well with their chicken populations (U=37.5, -0.053, p<0.975); in fact, both groups increased their chicken numbers after the drought.
Figure 18: Absolute change in livestock numbers from 2008 to 2010 among 19 households in Ilmotiok and Tiamamut GR’s. Two primary factors explain these changes in livestock numbers after the drought of 2009: death due to forage loss/disease and transfer/sale by owners.

Data we collected on livestock births, deaths, transactions, and exchanges indicates that three primary factors drive changes in herd size and species composition during and after drought (Figure 19). For wealthy families, having larger absolute herd sizes means greater numbers of births (infants born: $U=1586, 6.016, p<0.00001$) and excess stock to slaughter for ceremonies and rituals (slaughters, all species: $U=33, 2.790, p<0.0053$). Wealthy families purchased stock to rebuild their herds, even when times were bad ($U=108.5, 2.592, p<0.0095$) suggesting that these households prioritize year round herd building via stock purchases.

Both poor/middle class families and rich families lost significant proportions of their herds to death, either from disease or starvation (deaths, total: $U=83.5, 1.029, p<0.30$). There were no significant differences between rich and poor/middle class in the numbers of livestock sold (sold, all species: $U=556.5, 1.460, p<0.64$) or gifted ($U=34, 0.667, p<0.50$).
Figure 19: Factors facilitating Livestock Change among Different Social Strata. 

Significant differences exist between rich and poor/middle class families regarding changes total livestock values under categories such as births, purchases, and slaughters.

Discussion

Conditions for pastoral families in Mukugodo Division are changing. Our data on recent trends in rainfall events in Laikipia suggest that rainfall events are becoming more erratic and the landscape is generally drying out. Furthermore, population size has tripled in the last 30 years, meaning there is less land for each person, each animal.

Our results demonstrate that there is a significant relationship between rainfall and vegetation potential in these communities, and this relationship is directly tied to livestock productivity. During the last five years, rainfall events have been highly erratic in Mukugodo, making it difficult, if not impossible for herders to predict when rain events will occur and generate adequate forage resources for their herds. Similarly, when we investigated rainfall patterns over the 60-year period prior to our study, we found a similar pattern. Rainfall events have been
highly variable over the last 60 years, with significant changes in rainfall levels after the 1980s. Conditions appear to be drying out over time; this is evident particularly in later part of the 20th century, where rainfall levels start to show a downward trend. Analysis of the correlation between NDVI and rainfall at a lag of one month (the time it takes for vegetation to respond to rainfall) indicates that vegetation growth is directly tied to rainfall events. Hence, we can reject that null hypothesis that there is no significant relationship between rainfall events and vegetation growth. Similarly, we can reject the null hypothesis that livestock productivity is not tied to vegetation. There was a strong correlation between milk production (our measure of livestock productivity) and NDVI, indicating that livestock productivity, in the form of milk yields, directly responds to improvements in vegetation.

Under these conditions, the ability to migrate to grazing areas rich in water and forage resources is crucial if rainfall levels in the home environment are not frequent or heavy enough to cause vegetation growth or improvement. As such, we evaluated the options of our herders based on rainfall differences between home patches and a number of important regional migration patches in Laikipia. Based on rainfall differences alone, we predicted that herders should use a fixed set of patches depending on which group ranch they originated from. Before and during the drought of 2009, herders do not behave according to environmental factors alone. This indicates that there are other factors, such as what type of herd an individual owns (cattle, sheep or goats or a mixture of the 3), their ability to acquire free labor to migrate to a squatter parcel rather than using rented labor, and access to private parcels of land that may be unavailable to other herds, which reduce competition for resources with other herders on crowded grazing lands. This analysis also showed us that herders behave more rationally after the drought (presumably in response to losses incurred during the drought due to poor migration decisions or lack thereof) in both communities. Both sets of herders seem to make more of their decisions based on rainfall and forage growth after the drought when regional parcels are less crowded and conditions less dire, making it easier for families to negotiate access or find the required labor to migrate.

Wealthy families have an advantage when it comes to access to grazing patches, both distant and local. For example, based on rainfall differences alone, no herder should move to Sukuton for grazing. However, given its close proximity to Mpala (which provides security patrols near the borders and nearby dams) many herders choose to move there, presumably because it is safer and closer to home than more distant patches that may have better quality grazing.
Grazing near home patches has been shown to limit milk production potential so ideally non-milking animals are moved seasonally to acquire better quality forage elsewhere (Dahl and Hjort 1976). Unfortunately in Mukugodo herd sizes are small enough that both milking and non-milking must be moved during dry seasons or droughts. This is further complicated by the fact that neighboring private ranches will only accept cattle on their land so households without cattle are unable to rent grass from their neighbors during seasons when local forage is depleted. Moreover, if a household does have a milking cow, but it is their only milking animal and they must move it to an inaccessible patch to survive; they cut off their only local source of milk. Similarly if a household does not own any cattle but they own sheep, which are also dependent on grass for survival, they must decide whether it is necessary to move those stocks to ensure their survival. Those who must move often eliminate milk access to the home base completely. In theory, families who move their animals to neighboring ranches for grazing should be able to access at least some of the milk produced by those herds. In practice, however, this rarely happens.

Secondly, wealthy families seem to be better at negotiating rights of access to high quality grazing patches outside of their home range, making it easier for them to reach these distant patches before they are used up. We suggest that dual access to private transportation and information via cell phone is the major difference between these two classes. Two of the wealthy families in our study owned private motorcycles and reported driving out to new grazing patches before sending affines or hired herders there to graze. Having their own transportation gives them an advantage over herders dependent on local information; timely access to better information about patch quality allows them to make more informed decisions about where to migrate or when. Access to transportation means they can also regularly visit their satellite stock camps and monitor the progress of the herd so as to make well-timed decisions about when to migrate, sell off improved stock, breed existing stock, among others.

We should not exclude the option that herders without access to transportation can also use telephones to call affines and relatives living near these distant patches, thereby gaining up to the minute information on patch quality. Families of all social strata own cell phones these days, making it easier for everyone to gain similar information about distant areas. In our study, wealthy families report exclusive access to patches close to optimal migration zones (for example in the Aberderes Mountains near Rumuruti Approach). These exclusive arrangements
may in part be facilitated by increased access to cash, labor, and/or transportation, which allows rich families to use superlative grazing patches to build their herds. There are two problems with this choice, however. Moving herds to distant patches to be herded by affines or outsiders means that immediate family members back at home will not have access to the benefits of their increased production. This means that although their herds can recover more quickly (such as in increased birth and/or lactation rates) than their compatriots back in the home patch, they lose the subsistence benefit the poor herders who do not move theoretically gain.

Wealth differences in grazing access exist at home as well. Herders in Tiamamut have greater access to watering places for their stock, meaning their overall travel time to water is shorter, leaving more time for grazing. Increased grazing time means healthier livestock, a higher market value, and more favorable terms of trade in the market when they go to sell. Herders in Ilmotiok travel longer distances to water, since their only major water point is the river on the western side of the ranch. Herders in Ilmotiok also travel longer herding radii to complete their grazing path, meaning the long treks to water reduce the amount of grazing they can access. Herders must stay out longer and move lengthier distances to achieve the same level of grazing. This limits poorer households, whose herd sizes are much smaller anyway, to reduced herd growth, lower market value, and decreased terms of trade in the market. This leads poor families to be dependent on social welfare programs to feed their families, since neither milk production at home nor livestock sales alone can sustain these families. Poor families must be accessing food aid programs, supplemental feeding programs, or other social programs to maintain their families when internal social structures breakdown. While rich families can use cash and smart herd growth to improve their livelihoods after drought, poor families will continue to be dependent on external aid for survival.

Unfortunately, it seems that many of the internal social structures that worked to reduce income inequality among households in the past may be breaking down. This was demonstrated during the recovery year in 2010, where we saw that income inequality among households increased. These increases (i.e. increased herd size or cash wealth) point to the ability of rich families to recover faster than poor and middle class households after critical events, such as drought. Similarly, lack of a significant difference between rich and poor households re gifts and exchanges revealed that gifting and exchange may no longer be a significant way for poorer individuals to replenish their milking herds after crisis or drought. In fact, over the entire study duration we only recorded 6 livestock gifts, 2 of which were from a poor family to a rich family.
who had assisted them during the drought. Again, this suggests that rich households are no longer giving out large numbers of stock to disadvantaged herders as a means to redistribute wealth.

For example, rich families reported distributing cash to families asking for paran instead of livestock; this shift disadvantages poor herders who gain a temporary cash benefit but not a long-term subsistence benefit from a gift of a lactating animal, as they would have in the past. This may indicate a break down in traditional practices in this system (Aktipis et al. 2011; Cronk 1991; Cronk 2007; Herren 1987). This result is not surprising since stratification and inequality usually appear in areas where there are alternative forms of resource and labor acquisition, such as access to land rights, permanent wells or dams, and cash (Dahl and Hjort 1976). Similarly, we suggest that the breakdown of social welfare systems may be due to greater access to cash or other necessary herd or household inputs among some families but not others. For example, rich families could distribute cash to poor families instead of livestock or use cash to buy alternative protein sources thereby milking their own livestock less, allowing for greater investment in calf growth since calves consume the majority of production (Dahl and Hjort 1976).

Our results on milk production indicate that milk yields of poor families do not improve in 2010 and 2011. We suggest this occurred because the majority of poor families divested themselves of large stock in exchange for 95% investment in small stock. Milk yields from small stock are generally low, but provide the majority of milk for human consumption in many parts of Kenya (Dahl and Hjort 1976). Goats yield on average 88 mL/day, but some breeds, such as the Nubian, can reach upwards of 500 mL/day (Dahl and Hjort 1976). The upper limit on shoo lactation is 150 days, with most producing milk for 90-120 days. Offspring consume approximately 50% of the total production. Sheep are constrained to lactate only after the long rains in May but goats can lactate at any time so they are an important source of milk in dry seasons. During normal lactation, goats can produce 0.69 L/day and sheep 0.52 L/day, although only 50% of this is generally removed for human use. If breeding at two cycles per year, herders can expect about 100-120 days of milk production. Lactation levels generally range between 16 and 60% in these herds, with max daily yields occurring 8-12 weeks after birth.
Shoats are good sellers in the market (Dahl and Hjort 1976). There is a high demand for goat meat from the few small urban centers in Laikipia making shoat production profitable (Zaal and Dietz 1999). However small stock production is risky; they are more prone to disease and death than cattle or camels, especially sheep. Sheep need constant water and grass making them very weak in drought and susceptible to disease. In particular, sheep are selective grazers that need grass that regenerates at regular intervals or they drastically drop milk levels. On the other hand, goats can be watered every 2-4 days. Goats don’t respond by dropping milk levels when drought or dry seasons occur because they can eat other vegetation (forbs, browse, tree cuttings, pods) making them more versatile and dependable. Goats recover faster after drought; within 5-6 months of rain they can be producing milk again, which is essential for poor families with limited stock numbers.

Small stock cannot produce as much milk per animal, so poor families who invest in small stock are disadvantaged in subsistence production in contrast to wealthy families who can invest 50/50 in large and small stock, yielding better overall milk yields. Milk production declines for all families during the drought in 2009. During this period, herd sizes and milk yields decrease precipitously for both classes in both group ranches. Significant differences in household production outcomes fully emerge during the recovery in 2010, where rich and poor herders both report improved yields. This points to the importance of local rainfall and vegetation for the maintenance of milk production at the household level.

Overall, herders in Mukugodo are using mobility as a strategy to improve livestock production during dry seasons and droughts. Some herders also move their animals to regional patches during good seasons, suggesting that they are seeking the highest quality patches to generate the fattest, healthiest stock for sale in the market rather than to generate high milk yields for home consumption. These herding differences separate families not only by group ranch, in that they behave differently based on where they live, but also by wealth class, where having access to resources external to the system provides herders with an advantage over their compatriots at home.
References Cited


CHAPTER THREE

A Dietary Assessment Tool for Use in Low Resource Settings: Self-Administered Food Intake Questionnaires with Pictorial Pages

Introduction

Maternal and child under nutrition is highly prevalent in developing countries, resulting in considerable increases in mortality and disease burden. Protein-energy malnutrition, starvation, and micronutrient deficiencies are the most serious health problems related to nutrition, with approximately 54% of all deaths in children under five directly or indirectly related to malnutrition (Black et al. 2008). Moreover, malnutrition accounts for 14% of the global burden of DALYS (Disability Life Adjusted Years; WHO 2002). Assessment of malnutrition in individuals or populations is usually performed through clinical, biochemical, or anthropometric methods (Bairagi et al. 1985). However, clinical and biochemical tests are expensive and difficult to standardize in low resource settings and anthropometric measurements of nutritional status, when used alone, are often confounded with other risk factors for malnutrition, namely infectious diseases. More importantly, a diagnosis of infectious disease such as endemic diarrhea or enteric disease in the population does not identify other risk factors, such as SES, social behavior and food or water insecurity that contribute to nutritional state.

Food insecurity is a major problem in the developing world, with more than one billion people suffering from some form of hunger. To lessen the burden of malnutrition in impoverished settings, we need reliable methods to estimate food availability and intake so that appropriate intervention schemes, such as supplemental feeding programs, can be developed. However, many of the measures we currently use to assess diet or dietary intake, such as food frequency surveys and 24-hour recall provide biased information about intake. For example, 24 hour recalls provide a good estimate of average group tendencies, but not particularly good estimates of usual intake for an individual member of the group (Beaton et al. 1979; Block 1982). As such, this method is often unsuitable for use in epidemiological studies, where individual intake rather than population averages are required to relate specific disease or health outcomes to one's nutritional state. According to Beaton (1979), if dietary intake is measured over a series of days rather than just a single day, a more accurate estimate of usual intake can be generated. In isolation, a single day's intake may grossly under or over estimate usual intake; for example if my dietary intake is measured during special events, holidays, or
times of unusual abundance, the subsequent intake values will greatly overestimate my normal dietary intake. Generally, at least 3 days of diet data are required to calculate stable nutrient patterns, such as the proportion of fat in the diet (Block 1982).

Multiple 24-hour recalls are difficult and expensive to perform, so researchers usually opt for short cut methods, such as food frequency questionnaires (FFQ). FFQ's ask about the consumption frequency of various food types, usually sorted into groups (Hu et al. 1999). It asks subjects to recall usual intake over a six month to one-year period and uses portion size to calculate intake. Because of human recall bias and error, responses to FFQ's are highly variable, with some subjects over estimating and others sharply under estimating intake, depending on the length of the recall period (Block 1982).

Here we describe a method for collecting estimates of dietary intake in households using a self-administered food intake questionnaire with pictorial pages. The goal of this survey method (hereto referred to as "SFRD") is to quantitatively assess dietary intake of macronutrients in mobile, illiterate populations consistently over an extended period but on a daily basis so that memory loss and the biases that such loss induces are avoided. In field-based studies of human populations, methods that require subjects to be interviewed at regular intervals or visited in the home are impractical. In particular, if the population migrates frequently to avoid seasonal drought, or is internally displaced by acts of violence or war, a method that can be self-administered by the subject on a day to day basis will yield large sets of data on usual dietary intake over a long period of time, without requiring frequent visits to each subject or hazy recall over long intervals. Our mixed method approach to measuring dietary intake compiles data from three different food survey techniques (direct measurement, 24-hour recall, and self administered dietary intake questionnaires) to construct nutrient profiles of individual households. This dietary assessment tool was developed in 2009 as part of a mixed longitudinal cohort study of socio-economic subsistence practices, diet, and health. Research was conducted with permission from the Kenyan Government (Permit Number: NOHEST13-001-29C80 VOLII) and local officials.

**Study Site: The Laikipiak Maasai Pastoral System in Northern Kenya**

This study was undertaken in two group ranches (Ilmotiok and Tiamamut) in Northern Laikipia District, which is located in the northern portion of the Laikipia Basin in North-Central Kenya,
East Africa (Lat 0.293282, Long 36.897483). These two group ranches contain approximately 3,500 residents, all of who are pastoralists. Ilmotiok and Tiamamut are largely decentralized settlements, with limited access to social services. Called Maasai pastoralists by their neighbors, the residents of these two communities speak Maasai, but actually belong to five distinct sub-sections of the Maasai; known as the Il ng’wesi, Mumonyot, Digirri, LeUaso, and Samburu (Cronk 2004).

The local topography is mostly flat with some small hilly areas. Annual precipitation in northern Laikipia ranges between 300- 600 mm, with two primary cycles of rainfall each year. The long rainy season usually occurs between the months of March and May. The short rains arrive (if they arrive at all) during late October/early November and usually last until December. During June and July, there is occasionally a third rainy season, with localized rainfall generated from non-monsoonal rains off the shores of Lake Victoria. In drought years, the long rains are very short or do not come at all, and the short rains are absent. In wet years, the long rains are on time, last for 3 months, and are followed by a shorter dry season with occasional showers, with timely short rains. Forage levels (annual and perennial grasses) vary with the localized rainfall pattern and can literally grow over night in response to a good rain.

Pastoral families in this region currently raise four species of livestock: cattle, goats, sheep, and camels. They separate their herds into feeding groups, with cattle and camels herded in separate groups, and small stock herded together. When total herd numbers are very low (usually less than 15 individuals), these pastoralists will graze goats and cattle together, although this is not the preferred arrangement. In this region, animals are raised for the production of milk not meat. As such, herd owners do not typically sell female animals under any circumstance. Male animals, however, are used as short-term breeders, castrated and then sold or traded, and/or sold as juveniles for quick cash. Maasai herders historically traded with agriculturalists for grains and other foodstuffs during seasons when milk was less abundant [8]. In more recent years, semi-permanent settlement in trading centers and towns has turned seasonal dependence into complete reliance on neighboring agricultural groups and humanitarian aid organizations (such as USAID and WFP) for food.

Households are usually polygamous, consisting of a man, his wives, and children. Labor is divided among the members of a household along age and gender lines. Households may choose to cooperate with their neighbors in a ‘meta-household’ structure. These meta-
households normally consist of 3 or more families that share some degree of genetic relatedness, although this is not a necessary constraint. Meta-households that have chosen to cooperate will typically make 'group' decisions about the movement and management of their livestock herds. Decisions about herd management are centered on obtaining regular access to water and suitable vegetation for grazing.

Pastoral Diet

Fifty years ago, Maasai herders subsisted on a diet of primarily milk, meat, fat and blood. Milk was, and continues to be, the preferred food (Coughenour et al. 1985; Jelliffe 1967). Animals were slaughtered irregularly for ceremonies, but most herders only ate meat if the animal died of natural causes or disease. During the dry season, herders would bleed cattle from the jugular vein in the neck and drink the blood as a meal, often together with milk. Sometimes, groups of warriors and old men would get together for “olpul,” where they would go off into the bush for days or weeks at a time and eat only meat, as part of a healing and strengthening exercise before war or after illness.

For a variety of ecological, economic, and social reasons (including sedenterization, economic transition, land degradation, climate change, and competition with other livelihood practices), the pastoral diet is now comprised mostly of maize, beans, sugar, tea, and milk, with very occasional sources of meat or blood. In fact, during seasons of poor pastoral productivity, many, if not all families are completely dependent on food aid packages (usually containing maize, soy blend flour, peas, and vegetable oil) from WFP, USAID, and the Government of Kenya.

Diet is also age dependent. Babies are fed milk butterfat and breastfeed, with supplemental foods being introduced as early as 3 months. Children, both boys and girls, are fed maize meal and porridge and/or beans, with some milky sugar tea or milk accompanying the meal. Most of the time, only maize is available, and dry maize meal is cooked slowly in water and eaten in a manner similar to polenta (locally referred to as "ugali"). Adults eat whatever is available, but men are preferentially fed maize meal. Women strictly control the distribution of milk and men must request milk from their wives. When milk is available, women will make soured milk and mix it with whole kernel maize- a drink called leshoro. Often, milk tea is the only food provided for breakfast, but is also served whenever there are guests, although in recent years this practice has deteriorated due to low milk yields.
Methods

Informed Consent and Protection of Human Subjects

Our research was reviewed by the Institutional Review Board, Princeton University and approved in June 2008 under Full IRP Review, Protocol no. 4051. Our research subjects were all provided with full disclosure of the intended research and their rights as human research subjects. A verbal consent form was recited to each subject before the start of a research activity, in the relevant local language (Kiswahili or Kimaasai; e.g. questionnaire, interview, or anthropometric assessment). Only if, and when they consented to the research did we proceed with interview or measurement. Mothers were provided with an oral consent form for the participation of their children in the research project. Mothers were provided information about the risks and benefits of participation and given full disclosure of all measures and data collected about their children. All oral consent procedures were conducted in the either Maasai or Kiswahili, depending on the preference of the subject. Consent of the subject was noted in written form on the survey document, and the translator provided a signature of witness. Our informed consent procedure provides subjects with full disclosure, a review of the risks and benefits of participation, and the ability to withdraw at any time without penalty. As such, our research complies with the Principles of the Helsinki Declaration of 2008.

Study Design

Thirty-one households, with a total of 389 subjects, were enrolled from 2008-2009 into a mixed longitudinal cohort study of two pastoral populations in rural Northern Kenya. An initial cohort of 17 households was enrolled and visited monthly beginning in June 2008, with a second cohort of 14 households (mostly internally displaced persons from the survey area) enrolled in July 2009. One household dropped out at the beginning of the study, leaving 30 families as active participants in our research.

The author conducted in-house field research with each cohort five times over the course of a three-year period, for a total of fifteen months of contact time. Furthermore, two locally trained research assistants actively surveyed both of our enrolled cohorts once a month from September 2008 to July 2011. The current study reports on data collected in subject households at one-month intervals from June 2008 to June 2010. Each household was visited before,
during, and after meal times to assess foods availability, local food vessels and utensils, and food preparation. In total, 53 women were recruited from the study population and trained to use the self-administered dietary intake questionnaire.

A mixed method approach to nutritional surveillance

Our mixed method approach to measuring dietary intake compiles data from three different food survey techniques (direct measurement, 24-hour recall, and self administered dietary intake questionnaires) to construct nutrient profiles of households and evaluate the use of a self-administered intake method to collect dietary intake in low resource settings.

We directly measured food stores in each household on a single day each month (which we will here-to refer to as the "Direct Method"). During a home visit, female heads of household (FHH) were asked to remove any and all food items from their pantry, including spices and place them in the center of the floor. Each individual item was then weighted with a Salter Kitchen scale to the nearest tenth of a gram and recorded in standardized data sheets. Subjects were also asked to recall the date they acquired the food item, where they acquired it (home, shop, relative, or affine), and who brought the item to their home.

At the same time as the direct measurement of food stores, we also administered a modified version of 24-hour recall (which we will here-to refer to as the "Recall Method"), where subjects were asked to recall food prepared at each meal in the last 24 hours. Subjects were asked to report the dry weight of each food item that was used in the preparation of meal. In turn, each food item was measured out by the subject and placed on the scale to estimate use. This was repeated until all three daily meals were recalled. Known quantities of certain items, such as a spoonful of oil (10 ml) or pinch of salt (3-5 grams), were reported in estimated gram weight without subject re-weighing.

Finally, we trained each FHH to use a self-administered, daily food intake sheet in a pictorial format (which we will here-to refer to as "SRFD") to record household intake (see Figure 1 for details). The SFRD asked subjects to record the estimated gram weight of each food item prepared at the morning, afternoon, and evening meal using a standardized measuring vessel (500ml tin cup) for each household. At enrollment, each FHH was given two of these measuring vessels, one for liquids and one for dry foods, to use while preparing all of their meals. Foods
were divided into the following amounts: 1/4 cup, 1/2 cup, 3/4 cup and 1 cup; this provided a recording range of 50-2500 grams per item, more than most people cook at any given meal. In order to convert the reported food data from cups to gram weight, all food items included in the SRFD were repeatedly weighed using a Salter Kitchen Scale to the nearest tenth of a gram and the average used as a constant value for each cup amount indicated on the sheet.

In our local setting, food is uncommonly eaten outside the home, except for beverages (which are served to all guests) and meals consumed at seasonal ceremonies/rituals or other important social events. We realize though that guests will consume meals in study households during certain key periods. To address this issue, we included a mealtime attendance questionnaire as part of the self-administered food diaries. This mealtime questionnaire asks subjects to report the number of individuals (adults and children) in attendance at each meal served in their home. If the number of resident members of each household is known, mealtime attendance records allow us to calculate the number of guests in attendance at each meal and isolate resident attendees. Total intake for the household can then be divided by the number of attendees for an estimated value of individual dietary intake. In the current analysis, however, we use total reported values of dietary intake including food prepared and given to guests, since these amounts are still deducted from the total food available to a given household on that measurement day.

There are inherent limitations in using methods such as 24-hour recall and direct measurements since we cannot divide total intake by the number of people in the household. In this sense, the SFRD method is superior because it can estimate the total resources available for each individual in the house, including that given to guests. However, we cannot estimate what resident members eat as guests at other households using the SFRD method. We assume symmetry in per capita consumption, whereby meals that a member of a household consumes, as a guest at another household, is roughly equivalent to the amount of food shared with guests. We are aware that some households are predisposed to sharing more of their resources than others; therefore, for those families there may be an inherent bias in our estimation. Further studies on the SFRD method may help to elucidate the mechanism by which food is divided among members and guests in households; however, this cannot be done with the other two methods, making it is out of the scope of the present study.
Data were entered into an SQL database and coded with identifiers linking date and household. Each unique household identifier was then matched across the three different survey methods for a single date. Compilation of data from the three survey methods generated 3,899 days of observation among 53 households. After restricting analysis to include only unique households with complete survey records on each date, 42 days of observation were available from the compiled dataset for analysis. We then used the Food and Agricultural Organization 2008 African Foods Table to convert individual food records based on their gram weight into their appropriate calorie, protein, carbohydrate, and fat values. These nutrient values were then summed to generate a single total intake value for the household for that day. To obtain a dimensionless index of dietary intake for each nutrient, we divided the amount of each nutrient by the total calories reported for that household. We then used these proportions to calculate the means, standard error, confidence intervals, and correlation coefficients among the three data sets.

Results

Each of the three methods reports similar proportions of nutrients in the diet, with some variation in carbohydrates and fat and very little variation in protein levels (see Table 1). Under the Direct Method, storage of fat (usual intake of fat) is lower (8.0%) and the confidence interval is wider, suggesting that this method under-estimates fat. In contrast, the Direct Method reports a similar proportion of carbohydrates in the diet (78.4%) to the SFRD method (79.6%), which may be explained by the decreased reporting of fat and the wide confidence interval around the mean. Protein is the most stable nutrient reported by the Direct Method, with a narrow confidence interval, low standard error, and biologically plausible mean proportion of protein (12.5%).

The 24-hour recall method reports higher consumption of fat (12.5%), but has a wide confidence interval; this may be due to sampling differences of milk consumption in this method. Protein levels under the 24-hr method are roughly the same as the Direct Method (12.9% vs. 12.5%, respectively), but slightly higher than the SFRD method (11.2%). The recall method also reports lower levels of carbohydrate consumption, but only by 3%- approximately the same amount of difference between the two measures of fat (Direct Method vs. 24-hour recall). This suggests that a proper estimate of fat is important to generate accurate values of the other two nutrients.
This issue of improper estimate carries over into the SFRD method. Here carbohydrates are over reported (79.6%), but not fat and protein levels. However, the SFRD method also reports the lowest standard error for all families, indicating that this method may provide more consistent reporting of mean values of intake than the other two methods. In theory, a larger deviation from the mean and wider confidence intervals, such as we see in the direct and 24hr recall methods, suggests that the SFRD method, given its values, provides a more tractable and perhaps more accurate estimate of usual intake over time.

Calculation of Pearson product moment correlation coefficients reveals the degree of linear dependence between the three sets of macronutrient profiles (Table 2). In Table 2, we provide the correlation coefficients for each set of nutrients from the three different assessment methods. A positive correlation coefficient (> 0 to 1.0) indicates a positive association among the measures, whereas a negative correlation coefficient (<0 to -1.0) indicates an inverse association among the measures. The SFRD method is significantly correlated to the 24-hr recall methods for protein and carbohydrates, indicating that the two methods accurately measure the same overall consumption patterns for these two nutrients in this population. However, these two methods do not agree on percentages of fat consumed (p value: 0.07). Similarly, neither the 24-hr recall nor the SFRD method correlate well with direct measures of food stores (see Table 2). For example, negative correlations among the different methods between carbohydrates and fat indicate that reporting of fat consumption tends to decrease as carbohydrate consumption increases, with exceptions. Similarly, direct measures of fat tend to increase when subjects recall increasing values of protein in the last 24 hours. The SFRD method also reports an increased rate of fat in the diet as direct measures of protein increase. Furthermore, when carbohydrate intakes increase, protein consumption tends to decline. As protein consumption increases, so does fat; in this sense, fat consumption is also tied to carbohydrate consumption. There is a strong negative association between carbohydrates (most likely sugar use) and fat. Overall, our three methods, report similar, but in some cases, significantly different values for each set of nutrients. They do however report a similar set of mean intake values among subjects (see Table 1), suggesting that the SFRD method provides concrete information about subject intake over time.
**Discussion**

The SFRD method provides an accurate estimate of household diets in northern Laikipia District when compared to the other standardized dietary intake measures used in this study. Milk consumption has been in decline among pastoral groups in East Africa over the last ten years, and meat almost non-existent. Since the SFRD method reports low levels of protein and fat, it provides a more realistic picture of usual dietary intake, given that there is a high degree of variation in the types of nutrients available to households. For example, when forage and water resources are scarce, milk levels decline to almost zero and families use carbohydrates sourced in local markets in place of protein and fat from household production (Hauck, personal observation). This leads to lower than average consumption of protein, which places households at risk for protein energy malnutrition.

Beaton and Swiss (1974) found that, in self-selected diets, percent protein ranged from 9% to 15%. Furthermore, epidemiological evidence suggests that healthy, well-fed populations tend to consume at least 10% or more protein in their diet. Given that all methods report protein values over 10%, it appears that protein is not a limiting factor in the majority of household diets. This result is surprising considering the extremely low levels of milk available to each household in the raw dataset. However, this suggests that low milk levels do not lead to protein limitation, but may instead lead to deficient levels of energy density (caloric or fat based dietary density). Beaton and Swiss (1974) and Block (1982) suggest that the energy density of the diet (aka fat) is more limiting than protein content. Observational data collected during the present study shows that pastoralists use sugar to increase energy density in household diets when protein sources are scare. But this works only as a temporary solution, as sugar is the highest priced commodity in the food market ("superfoods" per Jelliffe's definition (1967) and Hauck, personal observation). Proponents of the theory that energy supplies constitute the major limiting factor in human diets argue that the addition of sugar or fat would provide concentrated sources of energy, thereby improving the caloric density of diets, and are perhaps a more economical solution (in some cases) than providing an increase in overall food supply (quality over quantity).

When pastoral diets are deficient in fat (and heavy in simple starches and carbohydrates, see Table 1), nutritional interventions that provide increased levels of fat will be more effective than just protein since they would act to improve the caloric density of household diets without the
need for increasing food supply. Ultimately, given the local nutritional constraints outlined in this paper, we suggest that an increase in energy density (fat content) may be the best supplementation in settings where food supplies are limited and unlikely to increase in the future.

**Conclusions**

Our results suggest that the SFRD method of dietary assessment (when used alone or in tandem with other methods) is a reliable tool for quantifying usual dietary intake where the following criteria exist:

1) A simple diet of no more than 25 food items, a majority of which are used infrequently
2) A locally available, standardized unit of measure is used across all households to measure food
3) A single individual (such as the female head of household) manages food preparation and distribution for the household
4) The majority of subjects are illiterate

Given these criteria, the method is most suited to populations with a simple, relatively regular diet with mild variation in food type or frequency. A key component of this method is that it must be generated with a specific target population in mind. Participation in the preparation of meals, interaction with subjects at local markets, learning what tools they use for carrying, preparing, and serving food and collecting commonly used recipes is critical to the development of a successful diet assessment toolkit. Ultimately, the strength of the SFRD method is that it provides a simple, culturally sensitive, cost effective, and replicable procedure by which to measure dietary intake that can be applied in a wide variety of low resource settings.

We intend the SFRD method to be universally applicable, but also recognize the vital importance of incorporating culture and population specific information into the development of each diet assessment toolkit. If ethnographic principles are not followed during the development of the dietary assessment toolkit, attempts to quantitatively measure food intake will elicit erroneous or biased data. For example, we found that our Maasai subjects responded well to the pictorial method because it accurately captured the key food items used in their daily diet. Subjects also reported that the self directed nature of the SFRD method made them feel as
if they played a more active role in the research and were therefore more invested in accurately reporting their household food data. Moreover, subjects reported using the SFRD method to track their household food consumption- something many had never been able to do before since they were illiterate and uneducated. As such, some subjects viewed their participation in the study as an opportunity to gain new knowledge about managing their household affairs and food supply rather than just providing data for someone else’s research interests.

Subject training was an important component of this method; without clearly explaining the objectives of the SFRD method, it was easy for subjects to make reporting mistakes (such as measuring portion sizes instead of raw, dry food values). It is important to visit each household at least once a month to ensure subjects understand how to use the SFRD books during initial deployment. Once it is clear that subjects understand how to use the books, monitoring frequency can be decreased without sacrificing accuracy of reporting.

Although successfully implemented in a settled pastoral community in Kenya, the SFRD method has yet to be tested in a community with a complex diet, such as those living in urban centers or major cities. To ensure accuracy, this method should be tested in communities with more complex diets or those living in cities or urban centers, such as slums, prior to any long-term collection campaign.

In this paper, we have evaluated the use of a comprehensive, multivariate dietary assessment tool that quantifies nutrient intake of households and helps to identify which households may be at risk for developing malnutrition in the future. Our toolkit is cost effective (requiring simple, affordable equipment, such as a scale, pen, and paper) and easy to deploy in chronically deprived, low resource settings where both poverty and illiteracy levels are high, such as isolated drought and famine zones in semi arid ecosystems (Horn of Africa) and long-term war zones (DRC, Afghanistan). With detailed knowledge of food availability and consumption patterns of a community at risk, appropriate target groups can be identified and nutritional surveillance or intervention programs can be designed to focus on the most vulnerable members of the population.
References


Figure 1: Self Reported Food Pictorial Diary Sheet used in the current study.
<table>
<thead>
<tr>
<th>Assessment Method</th>
<th>Mean</th>
<th>Std. Err.</th>
<th>CI (95%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DM Protein</td>
<td>0.125</td>
<td>0.006</td>
<td>0.112 0.138</td>
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<tr>
<td>24hr Protein</td>
<td>0.129</td>
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<td>0.112</td>
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<td>0.071 0.090</td>
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<tr>
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<tr>
<td>SFRD Fat</td>
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<td>0.004</td>
<td>0.095 0.112</td>
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*Table 1: Mean, Standard Error, and Confidence Intervals of each macronutrient as measured by the three different assessment types (Direct= Direct Measurement of Food Stores, 24hr = Modified 24hr recall, SFRD= Self Reported Food Diary).*
<table>
<thead>
<tr>
<th>Variable (n= 42 obs)</th>
<th>Correlation Coefficient</th>
<th>CI (95%)</th>
<th>p value</th>
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<td>-0.35</td>
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Table 2: Pearson product moment correlation coefficients for each set of macronutrient values calculated by the three methods (DM= Direct Measurement of Food Stores, 24hr = Modified 24hr recall, SRFD= Self Reported Food Diary). Values highlighted in gray are the values used for comparing across the three assessment methods. Bold values indicate a significance level of p < 0.05. Italicized values near significance (0.06-0.07), but fail to achieve significance at p < 0.05.
CHAPTER FOUR

Coins and Calories: the effects of globalization, market involvement, and food aid on diet choice and nutritional status among pastoralists in northern Kenya

Introduction

“Ultimately, the lynchpin between socio-economic status, food security, and nutritional well-being lies in the ability of the individual, family and community to obtain good quality food at affordable prices all year round and to have good water resources and food preservation methods that ensure food and nutritional safety” (Amuna and Zotor 2008: 86).

What are the consequences of globalization for pastoralists, and how do we measure the costs and benefits of this large social transformation? Globalization, with its focus on the free movement of goods, services, technology, and capital, has influenced pastoralist lifestyles in numerous ways, such as increasing exposure to mass media, the expansion of global food distribution, access, processing and preferences, and shifts in the use of technology and transportation (Popkin 1994; Popkin 2006). Historical studies of pastoral diet in Kenya (Benefice et al. 1984; Galvin 1992; Grandin 1988b; Hogg 1987; Homewood 1992; Little 1989; Nestel and Geissler 1993; Oniang’O 1999) found that diets were comprised largely of milk based products (between 50 and 85%) and underemphasized external agricultural goods, except in the case of sedenterized households living in settlements or near village centers (Fratkin and Roth 2005). Pastoral households have always traded with agriculturalists for grains and other food stuffs during dry seasons or droughts to supplement their diet when milk yields decline below what is required for household subsistence (Holtzman 2003; Spear and Waller 1993). However, when pastoral families settled in group ranches, hunting blocks, and ‘villages’ across Kenya and Tanzania in the late 1970’s and early 1980’s, their reliance on agricultural grains swelled (Fratkin et al. 2006).

Traditionally, pastoralists in Kenya and Tanzania experienced regular hunger bouts associated with seasonal declines in subsistence production of milk and meat products during dry conditions and droughts (Fratkin and Roth 2005; Galvin 1992; Homewood 1992; Little et al. 1993; Roth 1996). Previous research among pastoralists in Kenya and Tanzania found an association between lack of rainfall and the introduction of market based complementary foods for infants, cessation of breastfeeding, early weaning, growth faltering and acute malnutrition in
children (Anderson and Broch-Due 1999; Gray et al. 2004; Little et al. 1993; Pike 2000; Sellen 2000; Sellen 2001).

Studies of market pricing and terms of trade for pastoral products in Kenyan markets (Adano et al. 2012; Dietz et al. 2001; Zaal 1999; Zaal and Dietz 1999) found that terms of trade between pastoral products and agricultural goods severely deteriorate during droughts and dry seasons, as well as in response to increases in global food and fuel prices. Purchasing power declines rapidly as grain prices increase due to seasonal declines in regional agricultural production (Gertel and Le Heron 2011). Households in turn must sell more animals (flooding the market with supply) which furthers decreases their market value (demand goes down) (Zaal 1999). Other factors, such as preemptive sales by some herders in response to impending drought, also lead to seasonal price collapses (Gertel and Le Heron 2011). Furthermore, herders must often sell breeding or lactating stock during seasonal droughts; evidence of this effect can be found in markets where there are high numbers of females being sold (Dietz et al. 2001). Lastly, integration of livestock production in markets can indicate that livestock is losing its social or economic value among herders, particularly when stock alliances or social redistribution mechanisms decline due to increased reliance on outsiders as hired herding labor (McPeak 2005).

Generalized deterioration of the terms of trade (TOT) between livestock and agricultural goods means households who sell a goat in a wet or good season gain ten times the return on their trade versus selling that same piece of stock in bad years or droughts. Wealthy herders can take advantage of unfavorable terms of trade in markets by buying up livestock when prices are low then move them to high quality patches to fatten for sale in meat markets (Zaal and Dietz 1999; Gertel and Le Heron 2011), to use for subsistence dairy production (Grandin 1988b; Holden et al. 1991; Sadler et al. 2010), or to redistribute to poorer herders to manage via stock alliances (Dahl and Hjort 1976; Herren 1988; Cronk 2004). We therefore predict that fluctuating terms of trade in regional markets shift dietary preferences towards low cost, reliable sources of food (such as maize) that are easy to transport and store.

Poor and vulnerable individuals suffer precipitous declines in household food consumption under global market engagement, particularly during periods when food prices rise and livestock prices decline, leading to increased levels of food insecurity and malnutrition (Brinkman et al. 2009; Darnton-Hill and Cogill 2009). Food price is an important determinant of diet choice and
dietary quality, especially among the poor (Darmon and Ferguson 2002). There are six main kinds of economic shocks that affect nutrition among vulnerable consumers simultaneously: droughts and other emergency climatic events, increases in global food prices, increases in fuel and transport costs, dysfunction of global financial systems, longer term climate change, and economic sanctions or state failure. Just one of these factors - increases in food prices - can potentially disrupt intra-household distribution and coping mechanisms, resulting in inadequate diets and poor health.

Little, et al (1993) speculate that the combination of caloric limitation, seasonal hunger, high levels of physical activity, high fertility, and longer than average durations of breastfeeding, limit the accumulation of energy reserves for reproductively mature women, with feedbacks on the growth and development of their children. Turkana children exhibit attenuated growth patterns, particularly in newly settled areas where their diet has shifted to market goods and away from a more nomadic milk and fat based diet (Little, et al. 1993). This shift from nomadic to sedentary lifestyles was the first mechanism by which pastoral diets changed: the shift from a milk to a maize based diet (Fratkin and Roth 2005).

This shift also led to a complete reversal in nutritional outcomes for nomadic vs. settled households. Because nomadic infants were fed a milk heavy diet, they weighed more and tended to increase in height during the wet season when milk was more abundant (Little, et al. 1993). Children who did not have access to adequate sources of protein based catch up calories, or who endured longer than normal periods of energy deficiency, did not experience similar gains in height or weight during good years. Seasonal growth faltering is not just based on calorie intake, however. A number of factors interact (increased levels of infection, deterioration of food availability and quality, and declining standards of care by caretakers) to facilitate faltering (Prentice and Cole 2007).

A second shift was observed in Kenyan communities that received food aid for the first time after the drought of 1983-84, such as the Mukugodo Maasai (Herren 1987). These communities shifted away from large stock to small stock after the drought to avert future large-scale herd losses, meaning that milk yields declined sharply from those of prior to the drought. This shift also meant that cheap sources of calories, such as maize, became more abundant and could be acquired in all seasons via food aid or in trade in local markets (Holtzman 2003; Holtzman 2007).
The nutrition transition, whereby diets shift with increasing integration with western markets and lifestyles, is a well-documented phenomena (Popkin 1994; Popkin 2001). Shifts in dietary intake, such as a rise in the consumption of saturated fats, sugars, and refined foods, are commonly associated with changes in economic production and market access (Christian 2010; Grandin 1988b; Holden et al. 1991; Smith et al. 2010; Thornton et al. 2007). Increased access to cash to purchase varied food items in the market and a shift away from herding cattle to raising primarily goats and chickens means a similar shift in dietary patterns and trends as well (Herren 1989; Österle 2008). Family members may migrate to urban centers or neighboring ranches to look for wage labor or other aid in order to send home remittances or food stuffs (Fratkin and Roth 2005; Huho et al. 2009; Huho et al. 2011). Pastoralists also engage in a variety of other activities outside of the pastoral sector to produce revenue for household expenses, such as charcoal production, petty trade in beads, alcohol production, and other forms of home based trade (Fratkin and Mearns 2003; Galvin 2009; Hogg 1986; Holtzman 2007; Thornton et al. 2007). These revenues, although meager, may be the only form of cash revenue to families devoid of livestock (Herren 1989).

In this chapter, we explore the consequences of a nutrition transition associated with globalization for pastoral households, with particular focus on diet choice, food pricing and terms of trade in local markets, availability and distribution of food aid, and clinical indicators of nutritional status. Specifically, we are not only interested in describing diets among pastoral households, but understanding causes or forces that led families to make shifts in their diets (such as market involvement or terms of trade) and the consequences of those choices for their health. In essence, we seek to identify the linkages and interconnections between diet, food pricing, and health that lead families to make similar choices with very different outcomes.

**Research Objectives**

In this chapter, we characterize i) the diet of Mukugodo households by season and wealth class; ii) the differences between households in terms of the use of staple (primary) and luxury (secondary) foods and the influence this has on their dietary choices/outcomes; iii) the nature of local market pricing structures for livestock and agricultural goods and the terms of trade for agricultural items from livestock sales in two local markets (Kimanju and Oldonyiro); iv) the
nature of food aid distribution and access among households; and v) nutritional status of children and adolescents.

We do this via the following questions and hypotheses:

*What are the current dietary practices of Mukugodo households? Are there significant differences among households in terms of food preferences or consumption patterns? How does seasonality influence the terms of trade in local markets for pastoral products? What influence does food aid have on diet choice, if any, in this system? What are the consequences of market integration and food aid dependency on nutrient intake and nutritional indicators for Mukugodo households?*

We hypothesize that diets will be largely comprised of agricultural goods, with an emphasis on maize rather than milk. Data from Chapter two indicate the majority of households have limited access to milk production, especially in dry seasons, leading us to predict diets should be heavier in carbohydrates in dry seasons when milk products are less available. Data from Chapter three suggests that fat is a limited nutrient in our system, especially in dry seasons. We predict that diets will be low in fat, high in carbohydrates, and relatively fixed in protein. Since protein usually makes up the smallest percentage of the diet (such as under a diet where 55% is carbohydrates and 30% fat), small changes in protein consumption generate large changes in carbohydrate use. Protein consumption is tied more to fat than carbohydrates, with many households trying to acquire much needed fat from carbohydrate heavy diets (Prentice 2005). Based on the results of Chapter two regarding seasonality of milk yields, we expect the inverse relationship in wet seasons, when milk yields should increase and families should have more access to non-agricultural sources of protein. Families with access to cash from remittances, wages, or savings should be able to reduce their dietary constraints by purchasing foods to diversify their diet.

We hypothesize that seasonality will effect the structure of livestock pricing in the market. From this we predict that unfavorable terms of trade in local markets during dry seasons will skew primary food consumption towards maize in all households, regardless of wealth or status. Items such as sugar and fat, which have high, relatively fixed market prices, should be difficult items to acquire, particularly in dry seasons. We predict that unfavorable terms of trade for energy dense foods will lead to dependency on government food aid among poor and middle
class households who cannot make up the deficit with cash or home production. We predict that this should counter intuitively lead to poor and middle class households having better nutritional status than rich households, since they gain extra calories during key seasons from a combination of remittances and/or food aid.

The Setting

This study was conducted in two Kenyan Group Ranches: Ilmotiok and Tiamamut, in western Mukugodo Division, Laikipia County, Kenya. Research was conducted with permission from the Kenyan Government (Permit Number: NOHEST13-001-29C80 VOLII) and local officials. Ethical approval was granted under IRB for the Ethical Treatment of Human Subjects at Princeton University (Protocol # 4051).

Mukugodo Division covers roughly 1,100 km² in the northeastern edge of Laikipia County, representing the north-eastern edge of the Laikipia Plateau (Herren 1988; Herren 1989). On the edges of the plateau, elevation drops from 1800-2200 m to 1500-1600 m in Ilmotiok and Tiamamut Group Ranches. Central Mukugodo is rugged hilly terrain with acacia savanna vegetation. In the west, where Ilmotiok and Tiamamut Group Ranches are located, the terrain changes to undulating hills interspersed with acacia savanna and open grasslands (Muthiani et al. 2011) that abut the Ewaso Nyiro River, which is the administrative boundary of the Division.

Annual rainfall in Mukugodo Division is highly unpredictable and declines appreciably from east to west (700 m in the East and 400 m in the West; Herren 1989). The long rainy season usually occurs between the months of March and May. The short rains arrive (if they arrive at all) during late October/early November and usually last until December. During the months of June and July, there is occasionally a third rainy season, with localized rainfall generated from non-monsoonal rains off the shores of Lake Victoria (for more detail, see Taylor et al. 2005). In drought years, the long rains are very short or do not come at all, and the short rains are absent. In wet years, the long rains are on time, last for three months, and are followed by a shorter dry season with occasional showers, with timely short rains. Forage levels (annual and perennial grasses) vary with the localized rainfall pattern and can literally grow over night in response to a good rain.
The are two perennial rivers in the system; the Ewaso Nyiro and Ngaare Ndare, which is unique in semi-arid pastoral settings (Borgerhoff Mulder 1992; Butt 2010; Homewood 1995; Homewood 2004; McCabe, Leslie, and Deluca 2010; Scoones 1995; Sellen 1999; Sellen 2000; Sellen 2003; Thornton et al. 2007; Yanda and William 2010). These rivers provide a reliable source of water for livestock, wildlife, and human populations on the western boundary of the Division without necessitating borehole development.

Western Mukugodo is isolated from Dol Dol, the administrative center, in the north and Nanyuki, the district center, in the south. In the South, the Division is bounded in by large scale private ranches, most of which maintain closed electric fences along their perimeter and patrols on both public and private access roads (Herren 1989; Huho, Ngaira, and Ogindo 2011; Muthiani et al. 2011; Ngugi and Conant 2008). On the northern side of the Division there is a Livestock Holding Ground, which is now settled by Samburu pastoralists and a second Livestock Holding Ground in the southwest, which is now privately owned (Dan Rubenstein, personal communication, 2012). The Ewaso Nyiro River also creates an impassable boundary during wet periods (or when the flower farms downstream unload their dirty water onto pastoralists upstream), making Ilmotiok Group Ranch in particular an island for part of the year.

Mukugodo Division, which is made up of resettled Mukugodo Maasai pastoralists, was created in 1936 (Herren 1987; Herren 1988; Spencer 1959) as a Native Reserve for “Dorobo” pastoralists left behind on the Laikipia Plateau after the pastoral resettlements of 1914 (Spencer 1959). These individuals represent five distinct ethnic groups (Leuaso, Digirri, Mumonyot, Iling’wesi, and Mukugodo; Cronk 2004) who differ in historical background, social organization, and ritual behavior, although they all speak Maa as a common language (Herren 1987). Only becoming livestock herders in earnest in the 1950s, they did so under duress; the majority of their land was lost to war and colonial settlement in the 1920s (for the complete history of the Laikipia Wars, see Spear and Waller (1993)).

The catastrophic droughts of the 1980’s devastated the Mukugodo Maasai living in this Division (Herren 1987). Since then, the region has been characterized by high levels of outmigration, ecological problems, such as degradation and the influx of invasive species (King 2008), and the need for long term famine relief (Caritas Kenya, personal communication, 2010). However,
these changes have not led to reductions in population size in the region: between 1987 and 2010, the human population grew from 11.7 persons/km² to 36.69 persons/km² (Herren 1987).

Pastoral families in this region currently raise four species of livestock: cattle, goats, sheep, and camels. They separate their herds into feeding groups, with cattle and camels herded in separate groups, and small stock herded together. When total herd numbers are very low (usually less than 15 individuals), these pastoralists will graze goats and cattle together, although this is not the preferred arrangement. In this region, animals are raised for the production of milk not meat. As such, herd owners do not typically sell female animals under any circumstance. Male animals, however, are used as short-term breeders, castrated and then sold or traded, and/or sold as juveniles for quick cash. Maasai herders historically traded with agriculturalists for grains and other foodstuffs during seasons when milk was less abundant (Spear and Waller 1993). In more recent years, semi-permanent settlement in trading centers and towns has turned seasonal dependence into complete reliance on neighboring agricultural groups, private ranches, and humanitarian aid organizations (such as USAID and WFP) for food.

Methods

Measuring Food in Subject Households

Our approach to measuring dietary intake compiles data from a daily pictorial self-administered dietary intake questionnaire to construct nutrient profiles of households. These pictorial data sheets collect information on two types of dietary information: primary (staple or main) and secondary (luxury or infrequently used) foods. For the five main food groups consumed in these communities, these sheets allow for a female head of household to record each meal that is cooked, for up to three meals a day and the number of individuals of each age and sex class that ate at that meal. We refer to these food items as primary foods. The second piece of information collected is Food Frequency. The pictorial sheet offers the users the choice of selecting the frequency of consumption for ten commonly consumed food items that are also available at the local market. We refer to these 10 food items as secondary foods. For a complete review of our methodology for collecting and validating dietary information, please refer to Chapter three.

During on-site measurements of survey households, we asked each female head of household
the following supplemental questions:

1. What is the cost per kilogram of each food item in your house?
2. Who collected each food item? Did you produce this item?
3. Who provided the cash to purchase this item if it was not produced?
4. When did you acquire this item?
5. Where did you acquire it?

This information was used to evaluate each family’s access to products of pastoral production and use of markets to purchase food for their families. We also determined if women were receiving benefits from their immediate family members (husband, father, brother) or distant relatives or affines (cousin, neighbor).

Data from these self-administered dietary intake questionnaires was entered into an SQL database and coded with identifiers linking date and household. Compilation of data from our survey method generated 3,134 days of observation among 53 houses within our 30 sample families from June 2009- December 2010.

We then used the Food and Agricultural Organization 2008 African Foods Table to convert individual food records based on their gram weight into their appropriate calorie, protein, carbohydrate, and fat values. These nutrient values were then summed and divided by the total number of individuals who ate at each meal to generate an average per capita total intake value for the household for that day. These final values were used to calculate means, standard error, and confidence intervals of intake by season and wealth rank. Absolute nutrient values were tested for significant differences between seasons and wealth ranks using Mann Whitney U tests with Hodges Lehmann Effect Size Estimators. All analysis was performed in Stata 12/SE (Stata Corp, Inc. 2011).

A Modern Representation of Pastoralist Diets: The Geometric Approach

The geometric framework (Simpson and Raubenheimer 1993; Simpson and Raubenheimer 1995; Simpson and Raubenheimer 2001; Simpson, et al. 2003; Simpson and Raubenheimer 2005; Simpson and Raubenheimer 2007), is a method of analyzing multiple nutrient requirements, the values of certain foods in relation to those requirements, the behavioral and
physiological consequences of consuming those foods, and the fitness consequences of being restricted to a particular set of dietary schemes.

In this framework, an individual’s relationship with its nutritional environment is plotted in an n-dimensional ‘nutrient space’, typically with each axis representing a single nutrient (or set of nutrients). The nutritional state of the individual is then plotted as a point within the nutrient space as well as a point indicating the ‘target intake’ for that individual. This ‘target intake’ is the rate that should ‘optimize inclusive fitness’ (Simpson and Raubenheimer 2007), or in the case of humans, provide an individual with an ideal ratio of nutrients that would allow for optimal allocation of energy to somatic maintenance and activities such as reproduction and growth. The different foods that comprise the diet are then superimposed on the graph as ‘rails’ or lines that radiate through a point that represents the ratio of nutrients that a specific food provides within the nutrient space. The closer a particular food ‘rail’ is to passing through the target intake point within the nutrient space, the closer this food is to satisfying the optimal state.

In contrast to this optimal nutritional state, how does a nutritionally imbalanced diet affect an individual’s nutritional status? According to recent analysis (in mice- Sorensen, et al. 2008; in humans- Simpson and Raubenheimer 2007; in humans- Simpson and Raubenheimer 2005; in humans- Simpson and Raubenheimer 2003; in locusts and caterpillars- Simpson and Raubenheimer 1995; in locusts- Simpson and Raubenheimer 1993), an imbalanced diet causes individuals to compromise between over-consuming one nutrient and under-consuming the other, depending on the types of food available. However, these experiments were conducted under normal conditions, were food was widely available to the population in question. In our setting, the majority of the population exhibits generalized wasting and stunting at mild to moderate levels. This suggests that some of the rules of compromise or leveraging that would apply in resource rich zones may not apply here.

For example, when individuals only have access to a carbohydrate rich diet that is protein limited, they tend to over consume foods rich in carbohydrates in an attempt to reach their protein target (which is approximately 15% of the total diet). This leads to a state of energy excess (carb/fat overload). On the other hand, individuals who do not have access to carbohydrates in sufficient quantities will over-consume foods rich in protein in an attempt to meet their non-protein energy requirements (approximately 85 % of the diet). This leads to a state of energy deficit (fat deficiency). The point of transition between these two states would be
a site of energy imbalance, where an individual struggles to find a rule of compromise that works within the resources available to it at any given time. However, as noted above, this over or under consumption of a particular nutrient can only occur in settings where food is widely available. Here individuals do not reach a state of energy excess due to low calorie levels, making them both calorie and protein deficient.

In this chapter, we utilize the geometric method to analyze nutrient intakes of different households by season and wealth class.

Market Survey

In order to determine the extent of market access/food availability in the region, we conducted a local market survey, starting in June 2009 and ending in July 2011. Every two weeks during field seasons, our Maasai research assistants (one male, one female) attended “market day” in one of the two local markets servicing our research communities: Kimanju Center Market and Oldonyiro Center Market. The author did not attempt to sample prices in the market alone since racial and social differences predispose outsiders to inflated market prices. Kimanju is located approximately 18 km from Ilmotiok Group Ranch and 7 km from Tiamamut Group Ranch. Oldonyiro Market is located in Isiolo District, approximately 30 km northwest of Ilmotiok and 15 km northwest of Tiamamut. Research assistants were given pre-printed data sheets with a list of commodities (stock/non-stock) to survey in the market. First, each assistant entered the livestock market and spoke with sellers to determine four key pieces of information about each species available for sale in the market on that day: age, sex, origin and price in KsH. Assistants were restricted to collect information about cattle, camels, sheep and goats for sale in the market. This information was used to generate an average price for stock in the market during each month of sampling.

Secondly, each assistant entered the food commodities side of the market to sample food items. The primary food items sampled included maize, beans, sugar, and fat, as well as other vegetables and fruits, but we will focus on the former four commodities in this analysis. For this set of commodities, our assistants collected three key pieces of information: standard weight of sale (glass of tea, kg scale, bucket, etc.), origin of seller, and item price in KsH.
Lastly, a random walking survey of buyers and sellers was completed at each market to determine where each set of market actors was originating. A minimum of 15 sets of interacting buyers and sellers were sampled at each market. This information was then used to map the locations of market transactions and determine the scale of access to food commodities in the group ranches under study.

Following (Zaal 1999; Zaal and Dietz 1999) we used this detailed market information to calculate monthly terms of trade between livestock and four main food commodities: maize, beans, sugar, and fat. The TOT was calculated (terms of trade; ratio of livestock price to cost of food item in kg weight) for each livestock species (cow, camel, goat, sheep). These calculations generate a kilogram conversion for each food item. These conversions were then used to run a series of multivariate regression analyses to determine if the terms of trade at Kimanju and Oldonyiro markets were sensitive to seasonal changes in livestock productivity and quality or if the ratio remained stable across seasons.

**Censusing Food Aid Distributions: Government Data and Household Surveys**

During the course of our research program, we developed close ties with Caritas International in Nyeri, Kenya. Caritas is an Italian Catholic organization that distributes food aid for the World Food Program (WFP), United States Agency for International Development (USAID), and the Government of Kenya (GOK). Food aid distribution officers at the Nyeri office provided us with monthly listings (from October 2008- July 2011) of the total number of beneficiaries and the kilogram weight of each item in the food bag: cereals, pulses, CSB (corn soy blend), oil. This information, combined with population figures for each group ranch were used to generate data on the percentage of individuals reached in each month and the percentage of total cereals and pulses available in each food bag.

During our in-house dietary intake sampling, we asked female heads of household to report where they acquired a given food item. During this sampling process, many families indicated they received a particular item via food aid and told us which organization was responsible for the assistance (WFP, USAID, or GOK). From these data, we calculated the percentage of families reporting food aid assistance from among our 30 study families each month. Families were disaggregated by wealth rank to determine the different rates at which rich and poor
families were utilizing government food aid support to supplement their household needs during the course of the field study.

**Anthropometric Indicators of Nutritional Status**

Nutritional status of children and adolescents was assessed using a series of standard anthropometric measurements (Frisancho 1990; Guermey and Jelliffe 1973; Jelliffe 1966). Individuals were measured a minimum of once per season, for an average of 5 observations per person. Since few birth records exist for this population, ages of children and adolescents were estimated using two methods: a local calendar of events (Leslie and Fry 1989) and estimated birth dates from clinic cards distributed to mothers by local clinics. For children less than 24 months, recumbent length was measured to the nearest millimeter using a SMM133 Pediatric Measure Mat manufactured by QuickMedical, Inc. Infants were weighed either using Seca 334 Portable Digital Baby Scale (QuickMedical, Inc) or by mother-caregiver difference using a LifeSource UC321 Precision Digital Personal Scale (LifeSource, Inc). For older children, barefoot standing height was measured using a HM200P Portstad Portable Stadiometer (QuickMedical, Inc). WHO Anthro Macro for Stata 12/SE (WHO 2011) for the Anthropometric Assessment of Children under 5 was used to compute height for age (HAZ), weight for age (WAZ), and weight for height (WFH) as standard deviations (z scores) from the WHO Multicentre Growth Reference Study (2006). WHO AnthroPlus Macro for Stata 12/SE (WHO 2011) for the Anthropometric Assessment of children ages 5-19 was used to compute WFA z scores for children ages 5-10, HFA z scores for children ages 5-19, and BMI for age z scores for children ages 5-19.

To test for significant differences among age intervals, group ranches, and season, we used a two-sample t test with unequal variances, calculating Welch’s degrees of freedom. We divided the samples into two seasons (wet vs. dry; the maximal expected variance between measurements) to preserve sample size and to test for these maximal differences in nutritional state.

**Data analysis**

Data entry and initial data cleaning was carried out in SQL and Microsoft Excel. Data transformation and statistical analyses were completed using Stata 12/SE procedures.
Relationships between various household measures were examined using parametric and non-parametric procedures, such as tables of association, t-tests for unequal variance, multiple regression, principal components analysis, and non-parametric ANOVA (Mann Whitney).

**Results**

Our results are divided into two sections. Part I characterizes household diets and presents results regarding market engagement and food aid dependency that point to some causes of diet choice among the Mukugodo. Part II presents indicators of nutritional status among children and adolescents as the consequences of diet choice and market involvement.

**Part I**

*Characterization of Household Diets by Season and Wealth*

First, we present the results of our analysis of diet by season and wealth class using geometric plots. All plots are reported in kilocalories. Carbohydrates and Fats (C+F) are plotted on the y-axis and Protein (P) on the x-axis. Each plot contains ‘nutrient rails’ superimposed over the data scatter, representing diets of 10-16% protein, respectively. We use a target dietary intake of 14-16% protein, whereby 86% of calories are derived from carbohydrates and fats and 14% from protein, for a total of 2000 kilocalories, as the “evolutionary point” for protein intake in humans (Simpson et al. 2003; Prentice 2005).

In graphs 1a-c, the same basic dietary pattern is repeated across seasons: both rich and poor/middle class households exhibit a diet that ranges between 10-12% protein, with poor/middle class households showing high levels of caloric variation. Most individuals, irrespective of wealth rank, are both protein and calorie deficient, although six outlying families show protein consumption levels at or near 14%. These six families consume carbohydrates and fats at levels that meet or exceed the minimum calorie levels indicated by our evolutionary optimum. Per se being able to reach a “target” intake of approximately 14% protein in some seasons seems to be the exception rather than the rule.
Figures 1a-c: State Space Graphs of Nutrient Intake Profiles of Study Households disaggregated by wealth rank (rich vs. poor/middle class) and season (dry in 2009, wet in 2010, and dry in 2010). Hollow circles are average nutrient intakes per rich household per season. Solid plus are average nutrient intakes per poor/middle class household per season. Gray lines 'nutrient rails' indicate diets that represent different percentages of protein: 10, 12, 14, and 16% protein, with 90, 88, 86, and 84% carbohydrates and fat, respectively. Target dietary intake is set as 2000 calories with 86% carbohydrates and fat and 14% protein. Target intake is represented by black dot with arrow indicating “target”. In all years, some families are able to approximate the intake target of 86/14. However, this is achieved through low fat and high carbohydrate consumption (average fat intake is 8%; Prentice 2005). Such populations typically exhibit a lean body profile and generally survive at a physiological deficit. Current WHO/FAO recommendations suggest that women and children eat no less than 15% fat in their diet in order to maintain proper brain and bone growth, hormone synthesis, and absorption of key fat-soluble micronutrients.

Average Protein Intake Constant Across Seasons

Evaluation of protein intake reports among households reveals that protein intake averages 11% across seasons. Although the shapes of the distributions are different in each season, we refer here to the average consumption of households since these values would indicate whether or not individuals set a theoretical “minimum” level of protein consumption when
making food choices. Because overall calorie levels are low in this population (except for our six exceptional households in Figures 1a-c) and food availability is highly variable, we suggest that there is little opportunity for households to access excess calories to make up for lost protein.

Figure 2: Mean Protein consumption remains constant among households across seasons, but at a lower level than has been generally hypothesized as the evolutionary point of compromise for humans. Recovery 2010 refers to Dec 09 to March 2010; Dry 2010 refers to June-October 2010; Wet 2010 refers to March-May 2010.

Diet Choice for Staple Foods Differs by Wealth Class

Means, standard errors, and confidence intervals were calculated in kilocalories for each primary (staple) food consumed by our study households by year and are presented in Table 2. Reported together with these values are the results of a Mann-Whitney Non Parametric ANOVA with a post hoc Hodges Lehmann Effect Size Estimator, which we used to test for significant differences between rich and poor families by year. Recall that our analysis of data from our self reported diet collection method is restricted to 2009 and 2010 due to variation in sampling protocols.
Mean kilocalorie consumption is higher in poor and middle class families than rich families in both years (HLE: 157.82 in 2009 and HLE: 252.12 in 2010). Poor and middle class families eat higher calorie amounts of maize and beans than rich families in 2009 (p < .001) but not higher levels of sugar or goat milk (p < 0.26 and p < .10, respectively). In 2010, poor and middle class families eat higher levels of calories for all staple foods reported (p < .001), indicating that sugar and goat milk was more limited (either due to cost or access) during the drought year in 2009 than they were in 2010.

We used Principal Components Analysis (PCA) to evaluate the relationship between wealth class and food choices revealed in our first analysis. Analysis of staple food consumption by rich and poor families indicates that poor and middle class families have very different primary diets than the rich. For the rich, eigenvector 1 was loaded heavily by maize meal and goat milk whereas sugar and beans loaded heavily in eigenvector 2. For the rich, Axis 2 was correlated with maize kernels and beans (githeri) whereas axis 2 for the poor was correlated with maize meal and goat milk (sour porridge or ugali with milk). In other words, rich households prefer to eat maize kernels and beans and the poor/middle class families prefer to eat porridge and/or ugali with milk. Axis 3 was weighted with sugar and explained approximately 17% of the variance among families. In total, Axis 1, 2 and 3 accounted for 77% of the variance in diet choice among staple foods.
<table>
<thead>
<tr>
<th>Year</th>
<th>Variable</th>
<th>obs</th>
<th>z, p value</th>
<th>HLE</th>
<th>Rich Mean +/- se</th>
<th>CI 95%</th>
<th>Poor/Middle Mean +/- se</th>
<th>CI 95%</th>
</tr>
</thead>
<tbody>
<tr>
<td>2009</td>
<td><strong>Kcal</strong></td>
<td>2299</td>
<td>-4.532, 0.0000</td>
<td>157.82</td>
<td>1354.67 +/- 30.92</td>
<td>1293.91 - 1415.43</td>
<td>1668.85 +/- 23.70</td>
<td>1622.36 - 1715.35</td>
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<tr>
<td></td>
<td>Macro</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Protein</td>
<td>2299</td>
<td>-4.556, 0.0000</td>
<td>28.22</td>
<td>151.28 +/- 4.33</td>
<td>142.76 - 159.8</td>
<td>192.14 +/- 2.88</td>
<td>186.5 - 197.78</td>
</tr>
<tr>
<td></td>
<td>Carb</td>
<td>2299</td>
<td>-3.422, 0.0006</td>
<td>127.44</td>
<td>24.60</td>
<td>1040.66 - 1137.42</td>
<td>1347.66 +/- 19.36</td>
<td>1309.69 - 1385.64</td>
</tr>
<tr>
<td></td>
<td>Fat</td>
<td>2299</td>
<td>-3.640, 0.0003</td>
<td>12.47</td>
<td>130.66 +/- 3.22</td>
<td>124.32 - 137.01</td>
<td>158.60 +/- 2.38</td>
<td>153.95 - 163.29</td>
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<td></td>
<td>Maize</td>
<td>2299</td>
<td>-6.328, 0.0000</td>
<td>109.98</td>
<td>28.22</td>
<td>252.12 - 1625.5</td>
<td>223.87 +/- 16.32</td>
<td>1153.72 +/- 1185.74</td>
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<td></td>
<td>Food</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Beans</td>
<td>2299</td>
<td>-1.118, 0.26</td>
<td>75.73</td>
<td>127.44</td>
<td>1089.04 - 1137.42</td>
<td>1347.66 +/- 19.36</td>
<td>1309.69 - 1385.64</td>
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<tr>
<td></td>
<td>Sugar</td>
<td>2299</td>
<td>-6.46, 0.0000</td>
<td>39.29</td>
<td>216.99</td>
<td>274.21 - 325.99</td>
<td>274.21 +/- 7.85</td>
<td>258.83 - 289.56</td>
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<td></td>
<td>Goat Milk</td>
<td>2299</td>
<td>-7.506, 0.0000</td>
<td>35.3</td>
<td>65.66 +/- 7.52</td>
<td>50.83 - 80.50</td>
<td>102.86 +/- 3.21</td>
<td>96.55 - 109.16</td>
</tr>
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</table>

Table 1: Summary of Results of Mann Whitney U Test of Significance with Hodges Lehmann Estimate (HLE) of Shift Parameters (Effect Size). Means, standard errors and confidence intervals of each nutrient category are presented by wealth rank and year.
Table 2: Frequency of Consumption for Secondary Food Items as reported by season and rank. Since data are ordinal in nature, we used gamma and Kendall’s tau-b as measures of association. Significance ranges from perfect negative association (-1) to perfect positive association (+1). Association between frequency of food consumption and rank is significant when gamma/ Kendall’s tau-b approaches +/-1.

<table>
<thead>
<tr>
<th>Season</th>
<th>Rich</th>
<th>Poor/Middle</th>
<th>Diff Rich vs. Poor/Middle</th>
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<tr>
<td></td>
<td>Frequency of Consumption (Servings per day)</td>
<td>Gamma</td>
<td>Kendall Tau</td>
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<tr>
<td></td>
<td>0</td>
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</tr>
<tr>
<td>Drought (2009)</td>
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<td></td>
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<tr>
<td>Meat</td>
<td>66.36</td>
<td>24.55</td>
<td>8.18</td>
</tr>
<tr>
<td>Potato</td>
<td>55.45</td>
<td>39.09</td>
<td>5.45</td>
</tr>
<tr>
<td>Leafy Green</td>
<td>61.82</td>
<td>34.55</td>
<td>3.64</td>
</tr>
<tr>
<td>Tomato</td>
<td>52.73</td>
<td>39.09</td>
<td>7.27</td>
</tr>
<tr>
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<td>30.00</td>
<td>43.64</td>
<td>23.64</td>
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<tr>
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<td>94.55</td>
<td>5.45</td>
<td>0.00</td>
</tr>
<tr>
<td>Oil</td>
<td>13.64</td>
<td>27.27</td>
<td>37.27</td>
</tr>
<tr>
<td>Tea</td>
<td>12.73</td>
<td>30.91</td>
<td>40.00</td>
</tr>
<tr>
<td>Candy</td>
<td>90.00</td>
<td>9.09</td>
<td>0.00</td>
</tr>
<tr>
<td>Salt</td>
<td>11.82</td>
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<td>35.45</td>
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<td>Wet (2010)</td>
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<tr>
<td>Meat</td>
<td>79.12</td>
<td>16.48</td>
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<tr>
<td>Potato</td>
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<td>3.30</td>
</tr>
<tr>
<td>Leafy Green</td>
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<td>28.57</td>
<td>4.40</td>
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<td>Tomato</td>
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<td>3.30</td>
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<td>52.75</td>
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<td>7.69</td>
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<tr>
<td>Flavored Drink</td>
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<td>0.00</td>
<td>0.00</td>
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<tr>
<td>Oil</td>
<td>36.26</td>
<td>35.16</td>
<td>26.37</td>
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<tr>
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<td>26.37</td>
<td>40.66</td>
<td>30.77</td>
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<tr>
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<td>95.60</td>
<td>2.20</td>
<td>1.10</td>
</tr>
<tr>
<td>Salt</td>
<td>31.87</td>
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</table>
Diet Choice for Secondary Foods Differs by Wealth Class

The frequency of consumption for secondary food items (10 items commonly used but not part of the core staple foods used at each meal; see methods) was measured using an ordinal scale, which required that we use Gamma and Kendall’s tau-b measures of association to determine statistically significant differences in the frequency of secondary food items consumed by wealth rank and season. Results of this analysis are presented in Table 2.

In 2009, significant differences in consumption of secondary foods by wealth class were found among flavored drinks, vegetable oil, candy, and salt. Once again, poor and middle class families reported consuming these items more frequently than rich families (see Table 2 for significance). Of particular interest is candy and soda consumption: approximately 3% of poor families report eating candy and flavored drinks 3 times a day during 2009’s drought.

In 2010, there are once again significant differences between rich and poor households in consumption of secondary foods. Rich families report zero consumption of flavored drinks whereas 16% of poor families report drinking at least one flavored drink per day. Rich families also report using less vegetable oil than poor families; the difference primarily lies in the 3rd meal, where rich households tend to use less oil than poor households. Poor families consume more salt, more candy, and more onions in 2010 than rich families (refer to Table 2 for significance). However, for meat, potatoes, leafy green vegetables, tomatoes, and onions, their consumption patterns are relatively the same (no significant differences; see Table 2), although there are some small differences in 2009 where rich families report higher overall frequency of use of vegetables and meat than the poor.

We used Principal Components Analysis (PCA) to evaluate the apparent relationship between wealth class and food choices revealed in our analysis of secondary food use. Analysis of secondary food consumption by rich and poor families indicates that poor and middle class families have different secondary diets than the rich. For both classes, leafy green vegetables, tomatoes, and potatoes loaded eigenvector 1 heavily whereas vegetable oil, salt, and tea loaded heavily in eigenvector 2. The primary difference between rich and poor families here is that vegetable oil, salt, and tea loaded positively (+ values) on axis 2 for the poor and negatively (- values) for the rich. Candy and soda weight load heavily in axis 3 for all classes, generating
what we call our “Junk Food” axis. Axis 4 is weighted by meat alone and generates the lowest explanation of variance in the diet (7%). In total, Axis 1, 2, 3, and 4 accounted for 77% of the variance in diet choice among staple foods.
Our GIS map of Buyer and Seller locations indicates that buyers of food items at our two market locations (Kimanju and Oldonyiro) originate from the group ranches surrounding the market and sellers originate from the three main agricultural production areas of the county. Sellers reported harvesting and processing their products in Nyahururu (bottom left corner of Figure 3), Rumuruti (center left), and/or purchasing goods in Nanyuki Town (urban center, bottom right) to sell in the group ranch markets. Buyers and sellers were reversed in the livestock markets, with all of the
sellers originating in the group ranches and the majority of buyers originating either from inside the group ranches or from large urban meat production houses in Nanyuki or Nairobi. Livestock buyers who came to market from the large production houses arrived with lorries to transport hundreds of animals at a time from these markets back to urban consumers.

What this GIS analysis of market actors reveals is that local livestock sellers are completely dependent on regional agricultural producers to exchange their livestock for foodstuffs and/or cash. Sellers in effect act as currency exchangers for rural producers with no access to banking. Since livestock sellers gain cash in the local market and then use it to purchase goods from the regional sellers, these sellers effectively take currency out of rotation in local communities and distribute it back to the urban centers. Also, since local buyers are dependent on distant regional production to feed their families with agricultural products, they do not have alternative market structures that they can use when commodities are scarce or prices rise due to crop failure generating unfavorable terms of trade.

**Market Price Structures by Market Location and Year**

Data collected from local markets indicates that prices of the four main staple foods vary with season. Maize prices fluctuate the most, with 100% increases during the drought in 2009 and again during a poor harvest in 2011. Prices are low in 2010, which corresponds to good harvests during both seasons. The prices of other commodities, such as fat and beans, are very stable throughout the drought and into 2011, indicating that their prices are less sensitive to climatic disturbances than maize. Sugar fluctuates as well, but not as wildly as maize, increasing by about 50% during the drought and by 75% in the dry season of 2011.
Livestock prices are highly volatile in our two local markets. Livestock prices are extremely low for all species in 2009, with cattle sellers reporting average sales of 5000 KsH +/- 250 KsH for an adult cow. Cattle prices increase from 5000 in 2009 to approximately 25,000 KsH in 2011; a four-fold increase in value. Camel prices are much more robust than cattle prices from 2009 to 2010, with prices only increasing by approximately 25% in 2010. This price resilience may be due to the high production potential of camels and reduced foraged costs during drought conditions. Goats and sheep also lose value during the drought year, but quickly regain it in 2010, peaking at an average price of 2500 KsH in 2011.
Figure 5: Market Prices for Livestock sold in local markets. Data are presented here from Kimanj and Oldonyiro Market. Values are combined average price for that year as reported by sellers in the two marketplaces. Prices were sampled twice a month from June 2009- July 2011.

Markets: Unfavorable Terms of Trade bias food purchases towards maize

We used multiple regression analysis to test if season significantly predicted terms of trade (TOT) between livestock and staple food items in our two markets (Kimanju and Oldonyiro).

Multiple regression analysis was used to test if season significantly predicted the terms of trade between cattle and the four main foods purchased in the Kimanj market (Figure 8). It was found that season significantly predicted TOT for cattle-maize ($\beta = 2.55, p < .0001$), cattle-beans ($\beta = .65, p < .0001$), cattle-sugar ($\beta = .47, p < .0001$), and cattle-fat ($\beta = .26, p < .01$). For cattle-maize TOT, season explained 92% of the variance, indicating that unfavorable terms of trade may bias consumer food purchases towards maize during dry seasons when other foods are less affordable.

Multiple regression analysis was used to test if season significantly predicted the terms of trade for goats and the four main foods purchased in the Kimanj market (Figure 6). It was found that season significantly predicted TOT for goats-maize ($\beta = .267, p < .0001$), goats-beans ($\beta = .052,$
p< .0001), and goats-sugar (β = .037, p< .0001), but not goats-fat (β = .013, p< .38). Again, for goats-maize TOT, season explained 92% of the variance, indicating that unfavorable terms of trade may bias consumers towards maize purchases since other food items are less affordable.

Similarly, we used multiple regressions to test if season significantly predicted the terms of trade for cattle and the four main foods purchased in the Oldonyiro market (Figure 9). It was found that season significantly predicted TOT for cattle-maize (β = 2.45, p< .001), cattle-beans (β = .65, p< .01), and cattle-sugar (β = .03, p< .002), but not cattle-fat (β = .12, p< .13). Just as with Kimanju market, the TOT for cattle-maize explained 89% of the variance, indicating that unfavorable terms of trade may bias consumers towards maize purchases.

Figure 6: Terms of Trade (TOT) at Kimanju Market between Goats and the four main food items acquired from the market. TOT for maize, the cheapest item in the market, is very low during the drought of 2009 (30 kg per goat) but improves steadily once the drought ends in January 2010, peaking at 140 kg per goat in July 2010, and declining back to drought like levels (50 kg per goat) by July 2011.
Figure 7: Terms of Trade (TOT) at Oldonyiro Market between Goats and the four main food items acquired from the market. TOT for maize, the cheapest item in the market, is very low during the drought of 2009 (30 kg per goat) but improves steadily once the drought ends in January 2010, peaking at 170 kg per goat in Oct 2010, and declining back to drought like levels (50 kg per goat) by Jan 2011.

Figure 8: Terms of Trade (TOT) at Kimanju Market between Cattle and the four main food items acquired from the market. TOT for cattle: maize is one order of magnitude greater than that for goats (1300 kg vs. 130 kg). Just as for goats, the terms of trade are unfavorable during the drought in 2009 and do not improve until May 2010, with a peak exchange occurring in Oct 2010, after which the terms of trade decline rapidly.
Figure 9: Terms of Trade (TOT) at Oldonyiro Market between Cattle and the four main food items acquired from the market. TOT for cattle: maize is one order of magnitude greater than that for goats (1500 kg vs. 150 kg). Just as for goats, the terms of trade are unfavorable during the drought in 2009 and do not start to improve until Jan 2010, with a peak exchange occurring in Oct 2010, after which the terms of trade decline rapidly, approaching drought levels in 2011.

Food Aid Census: Caritas Reporting less aid to Ilmotiok prior to the drought

Food aid distribution in Ilmotiok and Tiamamut is provided year round and is distributed according to a fixed percentage of the population considered to be vulnerable to food insecurity. According to Caritas officials, this fixed percentage changes seasonally and is set by the country office based on climate and food production predictions and data supplied by district officials. Therefore, distributions change dynamically and are irregular, occurring more frequently in the dry seasons, especially during the long dry/drought season of 2008 to 2009. During the long drought, distributions occurred monthly or bi-monthly for 17 months consecutively (Table 3). Furthermore, aid continues into the wet season of 2010, providing between 38 and 55 % of the population food support, even though overall environmental conditions for livestock and agricultural production have improved by this time (see Ch. 2).

Regional management staff at Caritas distributes food aid to Ilmotiok and Tiamamut according to a “percent ration” scheme. Food is packaged into nutrient bundles of cereals, pulses, corn-soy blend for children, and vegetable oil. These food bags are distributed in per capita amounts to each head of household, usually the resident female of each house in a given homestead.
During the 2009-2010 drought, rations were set at 70% of total intake (Caritas 2011, personal communication). 70% of total intake means the ration provided is only designed to provide 70% of a family’s required calories. As such, a family of 8 persons received 54.25 kg of food aid per month during the height of the drought. This measures out to 0.226 kg per person per day, which converts to a range of 900-1200 kcal/day.

The quality of food aid distributions by Caritas changes in 2010-2011. Pulses, which provide protein, formed 46% of the food bag during this period. Presumably individuals who lost the majority of their livestock holdings during the drought would need increased access to protein sources during recovery to counterbalance lost protein production at home. Lastly, Ilmotiok receives food assistance later into the drought than Tiamamut (May 09 vs. Nov 08), but maintains higher rates of distribution throughout this period (28-55% vs. 19-38%).

<table>
<thead>
<tr>
<th>Date</th>
<th># Beneficiaries</th>
<th>% Population</th>
<th>Food Bag (Kg)</th>
<th>% Pulses</th>
<th>% Cereals</th>
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<tbody>
<tr>
<td>Nov-08</td>
<td>517</td>
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<td>6.78</td>
<td>0.07</td>
<td>0.79</td>
</tr>
<tr>
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<td>0.36</td>
<td>6.78</td>
<td>0.07</td>
<td>0.79</td>
</tr>
<tr>
<td>Jan-09</td>
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<td>0.07</td>
<td>0.79</td>
</tr>
<tr>
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<td>5.21</td>
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<tr>
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*Table 3: Food Aid Distribution by Caritas International in Tiamamut Group Ranch. Food aid distribution skews towards cereals during dry seasons and pulses in wet seasons, except in the long dry season of 2010-2011, where pulses distribution reaches 46% of the total bag.*
<table>
<thead>
<tr>
<th>Date</th>
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<th>% Population</th>
<th>Food Bag (Kg)</th>
<th>% Pulses</th>
<th>% Cereals</th>
</tr>
</thead>
<tbody>
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<tr>
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<td>6.25</td>
<td>0.46</td>
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Table 4: Food Aid Distribution by Caritas International in Ilmotiok Group Ranch. Food aid distribution skews towards cereals during dry seasons and pulses in wet seasons, except in the long dry season of 2010-2011, where pulses distribution reaches 46% of the total bag. Note that food aid distributions don’t begin in Ilmotiok until May 2009, whereas in Tiamamut they begin as early as November 2008.

Food Aid Reports by Families reveal Rich families use less food assistance

Results of a three-year survey of subject households revealed that wealthy households do not report receiving regular distribution of government assistance. Rich households primarily report using food aid to supplement their diet during the height of the drought in 2009 (July, August, September). In contrast, poor and middle class families report receiving food aid in each distribution, regardless of season. Moreover, although families still receive aid during 2010 and 2011 when environmental conditions are good, the number of families reporting aid decreases to one, which corresponds with Caritas’s reporting of 19- 28% overall population coverage during this period.
## Percentage of Families Reporting Receipt of Government Food Aid Assistance

<table>
<thead>
<tr>
<th>Year</th>
<th>Month</th>
<th># Families</th>
<th>% Total study population</th>
<th>% Rich</th>
<th>% Poor/Middle</th>
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<td>4</td>
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<tr>
<td></td>
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<td>9</td>
<td>30</td>
<td>12</td>
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<tr>
<td></td>
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<td>40</td>
<td>8</td>
<td>92</td>
</tr>
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<td>Sept</td>
<td>7</td>
<td>23</td>
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<td></td>
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<td>100</td>
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<tr>
<td>2011</td>
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<td>3</td>
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<tr>
<td></td>
<td>June</td>
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<td>3</td>
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*Table 5: Household Survey Results of Families Reporting Food Aid Received from 2009-2011*
### Part II: Nutritional indicators by season and between group ranches

**Tiamamut (6a)**

<table>
<thead>
<tr>
<th>Age Interval</th>
<th>Season</th>
<th>Sex</th>
<th>n (obs)</th>
<th>WFA</th>
<th>SD</th>
<th>se (mean)</th>
<th>HFA</th>
<th>SD</th>
<th>se (mean)</th>
<th>BMI</th>
<th>SD</th>
<th>se (mean)</th>
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<tr>
<td>B0-2</td>
<td>D</td>
<td>M</td>
<td>17</td>
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<td>M</td>
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<td>1.333</td>
<td>0.262</td>
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<td>SD</td>
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<td>SD</td>
<td>se (mean)</td>
<td>BMI</td>
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*Table 6a-b: Comparison of mean nutritional and growth scores for infants, children and adolescents age 0- 19 by sex, season (D= 2009, W=2010-2011), and group ranch.*
In this section, we report the results of our analysis of nutritional status in children and adolescents between 0 and 19 years of age in Table 6a-b. Here we do not disaggregate individuals by wealth class since sample sizes in each age interval were too small, sometimes yielding only one child in that interval for that season. This would provide erroneous results. Instead we present average z scores for each age interval by season for each of our two group ranches. We divided the samples into two seasons (wet vs. dry; the maximal expected variance between measurements) to test for maximal differences in nutritional state. It was the constraint of sample size that dictated to what degree we could disaggregate and bin individuals into various roles for analysis.

On average, individuals in each age interval exhibit mild to moderate levels of malnutrition among Weight for Age (WFA), Height for Age (HFA), and BMI for Age (BFA)) across all seasons (Tables 6a and 6b). This means that all age intervals, whether rich or poor, exhibit some degree of under-nutrition in all seasons.

In general, infants under the age of 2 years are the least malnourished group as indicated by their low z scores, with infant girls in Ilmotiok approaching the 50th percentile for weight and height in both seasons (Table 6b). Girls and boys both exhibit higher levels of under nutrition once they reach weaning age (2-5 years old), suggesting that the primary difference between infants and toddlers in WFA and HFA is due to breastfeeding cessation between ages 2 and 3. Not surprisingly, boys of herding age (5-19 years) in both group ranches exhibit the highest levels of malnutrition in WFA (-2.167) in wet and (-2.528) in dry for Tiamamut and Ilmotiok, respectively, bordering on severe malnutrition during this period (Tables 6a and 6b; greater than -2, approaching -3 standard deviations from the 50th percentile). This age group also exhibits low height for age, indicating that they are subject to the dual problem of stunting and wasting simultaneously, which can lead to nutritional dwarfism (Waterlow 1972). Lastly, girls age 5-19 were found to have much lower height for age in Ilmotiok than Tiamamut (maximal difference; -1.923 SD below mean for Ilmotiok vs. -0.35 SD below the mean for Tiamamut).

There were significant differences in WFA z scores for 2-5 year old females living in Ilmotiok between the dry (M=-1.881, SD=0.935) and wet seasons (M=-1.516, SD=1.237); t (106.18)= -1.742, p = 0.04. Older male children, ages 5-19, also exhibited significant differences in WFA z scores between wet (M= -2.018, SD= 2.223) and dry (M= -2.528, SD= 1.499) seasons; t
We did not find significant differences in HFA or BFA among other age intervals in Ilmotiok and Tiamamut group ranches between wet and dry seasons.

Discussion

Diet choices among pastoral families in Mukugodo have shifted in recent years to a diet heavy in carbohydrates, low in protein, and very low in fat. Our analysis reveals that the principal diet among households is basically the same: maize flour or maize kernels as the base food (carb) with beans (protein and fat) and sugar (carb) as the adjoining staple foods. Separating families into different social classes revealed differences in diet preferences among the staple foods. Wealthy families preferred to eat maize kernels mixed with beans and poorer families preferred to eat maize flour porridge with sugar and goat milk or ugali with goat milk. Since maize kernels are bulky and difficult to digest, families showing a preference for maize and beans may be consuming less overall protein than families eating more easily digestible foods such as porridge (Prentice 2005). The shift to a diet containing a higher percentage of carbs and fat (well mostly carbs) is associated with a shift to a diet that is more accessible, more affordable, more palatable, and with greater variety than their historical alternatives (Simpson 2005).

Unfortunately, people who make the shift to a diet high in carbohydrates are locking themselves into a suboptimal diet because they must over consume C+F when possible to maintain protein intake. Since protein is such a minor component of the diet, a small decease in P results in big increases in the consumption of C+ F (Simpson and Raubenheimer 2005). In areas where food is readily available, the excess consumption of C+F would lead to large increases in obesity over time. However, current calorie values are so low that we do not expect to see any evidence of obesity among our sample families in the near future.

We also found that although the majority of families were unable to reach a target intake of 14% protein in all seasons, some families used a unique set of strategies that allowed them to achieve higher average calorie intakes than others. We utilized our existing database on each household to investigate possible causes for the observed increase in protein. First, after identifying which households represented the outlying points, we discovered a few common features that differentiated them from other households: place of residence, social relatedness, association with persons of status or private ranches, and food choice. Households in this quadrant of the graph were either related by blood or marriage or lived in the same boma. Ethnographic evidence from Mukugodo indicates that residing in the same boma means shared
herding and milking responsibilities as well as traveling to markets and/or collecting food aid or rations together and cooking meals together (Cronk 2004). Secondly, these outlying households were associated with labor migrants (either through marriage or family relation) or commercial pastoralists (usually by family relation or shared residence) who offered remittances, reduced cost food rations via Mpala Farm, and opportunities to reside in milk rich satellite herding camps.

For example, one household in the combined dry seasons of 2010 was able to reach an average seasonal protein intake of 14.2%- the highest reported for any household in the study. After reviewing their livestock transaction records, milk data, and diet composition data, we discovered that this household sent their one female cow to Mpala Farm in June 2009 for grazing. During this time, the household reports low levels of milk and bean consumption (8-10% beans; average 150 mL milk/day). In January 2010, they brought their one cow home from Mpala Farm and she was actively lactating (although they do not report what happened to her calf). Milk yields increase by four-fold for this household (average now 750-1000 mL) during this season, providing a plausible explanation for why this household was able to increase their protein levels, since they simultaneously report a decrease in bean consumption (now 3%). This case, however, is somewhat unique among the outlying households that we investigated.

A second set of 5 households (in Figures 1b & 1c) report seasonal protein values over 13%. These households, however, did not acquire cattle or other milk based forms of protein of their own during the recovery and short dry season of 2010, but performed two different strategies. One set (2) moved to a milk-rich satellite herding camp as ‘hired labor’ (which belonged to their brother in law) where they had access to high milk yields from cattle (>2500 mL/day), effectively increasing their protein intake during this season. The second set (3) increased their protein intake by increasing their consumption of beans. The three households with the highest protein values (straddling the 14% line in Figure 1c) all report consuming more than 30% beans in their diet during these periods. For comparison, these values are double that of households along the 10-12% lines, who report consuming a seasonal average of 15% beans in their diet. Secondly, the families reporting high consumption of beans all had one primary factor in common: affiliation with a labor migrant who worked at Mpala Farm. Mpala offers low cost rations for purchase to family members of employees on the 1st and 15th of each month. This link to Mpala for cheap rations provides a plausible explanation for why these households were able to consume higher levels of protein than others who may not have had these linkages.
In summary, these outlying households used unique and surprisingly novel coping mechanisms and strategies to acquire higher levels of protein than their neighbors. In one case, a poor family hedged their bets and sent their one and only milking animal of value to be herded on private land in hopes of surviving the drought, and she did, allowing them to engage in traditional behavioral strategies, such as prioritizing protein from milk. A second strategy is rooted in social welfare strategies, where poorer households attach themselves to wealthier households to acquire protein in exchange for herding labor at satellite camps. The last strategy requires that one or more members of the household migrate to farms or ranches to acquire cash or aid that they can send home (remittances) to their families who then use these resources to purchase protein replacements in the market or from private ranches.

A detailed analysis of food choices by frequency of consumption among households revealed that poor and rich households made similar choices in secondary foods, but with a few exceptions. Both wealth classes consumed vegetables (tomato, potato and greens) and meat with similar frequency, but differed in items such as oil, tea, salt, flavored drinks and candy. Poor families emphasized these luxury, junk items more than rich families, especially in good years, suggesting they are further along in the nutrition transition than other households due to their regular consumption of processed foods.

There have been five parts to the nutrition transition and they each affect a different component of livelihoods (Popkin 2006). Mukugodo pastoralists appear to be in between pattern 2 (famine) and pattern 3 (receding famine), but for different reasons. In terms of diet, our data shows that their diet is predominantly comprised of cereals, with little variation, indicating pattern 2. Food processing is still minimal, with drying and salting as primary methods of preservation and refrigeration non-existent. In terms of their economy, they are still largely dependent on animal husbandry or petty trade, but are not making any big investments in agriculture (see Chapter two). However, in terms of household production, income and assets, they are more closely following pattern 3. They use primitive water systems, clay stoves or wood stoves, with little advancement in cooking technology. There have been increases in income disparity and industrialization (use of tools). Residence is still chiefly rural, but some households are moving to cities (or farms) to obtain employment or educational opportunities for their children (Kaye-Zweibel 2011). What this description suggests is that Mukugodo families are stuck somewhere between famine and receding famine along the transition to “western style” diets.
Family livelihoods are more than ever tied to the use of markets as a mechanism for exchange between pastoral products and agricultural goods. Data collected on food and livestock prices in local markets indicates market pricing is highly volatile, with terms of trade between livestock and staple foods deteriorating sharply in dry seasons and droughts and increasing sharply in wet seasons or harvest seasons. Cattle lost the most value during the drought of 2009, reaching a low of approximately 5000 KsH in September 2009. Cattle prices rose sharply in 2010 when rains returned, from 5000 to 25,000 KsH. In turn, these sharp increases in stock value mean that the terms of trade between stock and food stuffs improve, allowing families to spend some of their income on more expensive and therefore seasonally limited items, such as sugar, fat, and beans.

When families don’t have cash or stock to sell in the market (or don’t want to because pricing structures are prohibitive) they must turn to an alternative source of calories. One possible source of calories is governmental and/or private aid. Government and private agencies provide year round food aid to Mukugodo families based on a local field assessment of food insecurity carried out by monitoring and evaluation teams. Our investigation into local forms of aid for pastoral households revealed that most government aid comes in the form of WFP or USAID rations. Our results reveal two interesting findings: rich families rarely access food aid and not all poor families had access to aid, even if they were vulnerable. Secondly, our results reveal that during the drought, food aid rations were skewed towards cereals, with only 7% pulses available in the food packs. In 2010, after conditions had improved locally for families, food rations were shifted, now comprising 46% pulses. This was surprising since we predicted that excess protein would be more useful during the drought when families were in initial food shock. However, an alternative hypothesis is that increased access to pulses during recovery seasons allows families to recover more effectively from the drought even if they do not recover their home production of protein. This increase in pulses in 2010 may also explain why some poor families seem to have access to excess sources of protein that the rich do not.

Measures of nutritional indicators among individuals of various age classes (from 0-19 years old) revealed a population suffering from chronic, moderate malnutrition. Seasonality influences nutritional outcomes, although not for all age classes. Significant differences existed in WFA for girls age 2-5 between wet and dry seasons and for older male children between the ages of 5-19 years of age. These children had lower levels of malnutrition in the wet season than the dry
season, indicating that food may be more plentiful in wet seasons. There were no significant
differences among other age classes or sexes in other categories. We believe that differences
exist in other age classes and categories but our sample sizes were too small to reveal
differences among classes. A simple power analysis conducted in Stata 12/SE revealed that our
sample sizes were too low in some classes to detect significant differences (estimated sample
size needed per age class: 25). We suggest that in order to detect significant differences
between rich and poor families we would have needed to enroll more rich families into the study
to increase sample sizes and balance out our age classes for analysis.

Overall, we can conclude that diet choices among Mukugodo families are changing in dramatic
ways, and these changes have consequences for the nutritional status of families, particularly
infant children of weaning age and young boys of herding age. Given the results generated here
we suggest that interventions that improve palatability and digestibility of local foods, increase
the variety and diversity of diet choices, improve food storage and preservation, and increase
overall calorie levels (e.g. increased energy density from fat would be the best option) will
improve nutritional outcomes for these families in the future. Lastly, we believe that interventions
or training in livestock marketing that allow pastoralists to improve their interactions with the
market actors and terms of trade for pastoral products will also allow families to afford a more
diverse and healthy diet.
**References Cited**


CHAPTER FIVE
Summary and Conclusions

Pastoral societies are in flux. The emergence of globalized markets and the integration of globalized production in developing country settings have forced many pastoralists, along with the rest of the world’s consumers, to shift their economic strategies of production to accommodate these evolving markets. Some scholarship on pastoral development has suggested that in order to succeed, pastoral economies and livelihoods should remain static rather than evolve into dynamic and diverse forms, thereby reasserting the incorrect notion that pastoralists should remain undeveloped (for further discussion, see Anderson and Broch-Due 1999; Galvin 2009; Homewood 2008; Illius and O’Connor 1999; Livingstone 1991). Whether we agree that transforming pastoralist livelihoods through development is correct or not, we cannot discount the significant livelihood changes that have occurred in our newly emerging global environment in favor of preserving old life ways and patterns of behavior.

This dissertation sought to examine how globalization and engagement with regional markets have transformed traditional pastoral behavior and livelihood outcomes. We have specifically focused on the links among climate, land use and herding, diets, and health for Mukugodo Maasai in rural northern Kenya.

In Chapter one, we proposed a new conceptual framework (‘the new normal of pastoralism’) that we have used throughout our research study to inform the generation of our hypotheses and predictions. This conceptual framework incorporates both traditional interactions between pastoral ecology and resource generation and modern opportunities by linking pastoral families via their pastoral production and other economic activities to the cash economy, modern diets and nutritional status (health), and public and private assistance and programs (such as food aid). This framework then enabled us to generate testable hypotheses about causes and consequences of recent transitions in pastoral livelihoods among the Mukugodo.

In Chapter two, we test the first part of our conceptual framework: the linkages and feedbacks between ecology (rainfall and vegetation), resource generation (pastoral productivity) and wealth. To do this we investigated herder level strategies in Mukugodo in order to evaluate how intra-group herding decisions vary in response to a range of environmental conditions. Here we show there is a significant relationship between rainfall and vegetation potential in these communities, and this relationship is directly tied to livestock productivity. Reductions in rainfall
act to reduce vegetation growth that in turn limits the amount of forage available to livestock. We demonstrate that there is a strong correlation between milk production (our measure of livestock productivity) and NDVI, indicating that livestock productivity, in the form of milk yields, directly responds to improvements in vegetation. If livestock do not have adequate access to forage or water requirements, they will most likely fail to breed and/or give birth to calves or kids, completing cutting off lactation to the herder, and therefore, the products of pastoral production.

This finding, that herd productivity is directly tied to ecological resources, allowed us to test the hypothesis that variation in social and economic status among households can lead to differences in herding decisions in response to environmental conditions. In order to ensure the survival of their livestock and to maintain production of milk products, herders must move their livestock to areas with adequate forage when local conditions are poor. Here we found herders do not always behave in economically rational ways when making decisions about where to move their livestock during seasonal or crisis induced migrations. Herd movements revealed that some herders moved their stock to areas that were not ideal in terms of grazing. This behavior was more prominent during times of crisis (during the 2009 drought) than during ‘normal’ years (such as 2010 and 2011). This suggests that herders behave in less rational ways when under extreme duress or that competition for resources forces herders to make suboptimal choices during times when everyone must migrate somewhere if herds are going to survive. In essence, they are operating under dual constraints of both scramble and contest competition, where resources are limited, and this limitation means that some individuals fail (their livestock die because they cannot gain access to limited resources) while others do not. Our data clearly shows that there are winners and losers when it comes to herding access. Wealthy families seem to be the winners since they can access grazing resources unavailable to their competitors at home.

Some herders (particularly poor families living in Ilmotiok) rely heavily on private conservancies and cattle ranches for grazing access. These herders are relying on a local strategy in contrast to neighboring households who move their herds to regional public squatter lands. Private ranches only accept cattle and charge a fee for renting grass, but herding labor is included in the rental price. Families whose children are in school or who cannot afford to hire outside labor or have too small of a family to split their household and move the herd are smart to use private ranches as a “cheap” source of labor. This is especially true for households who move only one animal to a private ranch for grazing. This strategy also frees up labor at home (such as that of
a wife) so that smaller stock that cannot be shifted to private lands can also be maintained. In contrast, herders who preferentially send their livestock to public lands are avoiding the cost of renting grass and labor from private ranches, but assuming a great deal of risk that their neighbors are not. Generally, it seems that poorer herding households avert risk by using easy, safe, local options for grazing access. Rich households, however, seem to accept risk as an inevitable consequence of being ‘herders’ and as such, they are more willing to seek out the best possible patches of grazing, even if it places them at greater risk or theft or death.

Lastly, this chapter demonstrated that differences in herding decisions influence production goals and outcomes, particularly after a drought. In 2009, milk yields are the same for both rich and poor families, suggesting that regardless of where families migrated too, their livestock still failed to produce the required amount of production for subsistence. This again points to the role of vegetation quality in generating productive stock. Secondly, the lack of a significant difference between rich and poor households re gifts and exchanges reveals that gifting and exchange is no longer a significant way for poorer individuals to replenish their milking herds after crisis or drought. It also indicates that rich families are not providing the same degree of aid or social welfare to others as in the past. Lastly, there were significant differences between rich and poor households in livestock births, purchases, and slaughters indicating that rich families are able to invest in resources necessary to rebuild their herds after drought. We were surprised however that there were no significant differences regarding livestock sales between rich and poor; this suggests that all households engage in livestock sales in all seasons regardless of wealth.

In Chapter three, we describe a new method for collecting dietary information from herding families that allowed us to measure dietary intake over extended periods (months, years) without having to visit families daily or weekly to record those data. This method allowed us to capture over 3000 days of observation on dietary intake for 53 homes over a 15-month period. The volume of information generated by this method is unparalleled in the pastoralist literature. In this chapter, we compare our method to two existing methods of dietary assessment (direct measurement of food stores and 24 hour recall) and provide a statistical validation of our new method. The general dietary finding from Chapter three is that fat is a limited nutrient in our system, especially in dry seasons. This finding allowed us to generate some hypotheses and predictions about the quality and character of diets in Chapter four. My development and deployment of a novel pictorial data sheet that could be easily understood by wives and mothers of herding households also allowed us to capture highly detailed information about food choices.
and preferences as well as the quality and quantity of dietary intake for individuals in a household. This approach is highly generalizable and can be extended to any rural population where researchers or aid workers are interested in recording regular dietary intake of a large number of households, particularly in areas where regular research access might not be possible (war zones, during droughts or crisis periods, etc.).

In Chapter four, we test the second part of our conceptual framework. In this analysis, we tie new activities that pastoral households use (such as market involvement, use of food aid, and private resources) to more traditional ones (herding, mobility, production, offtake) in order to characterize current market opportunities and constraints under globalization and evaluate the consequences of these shifts on the diets and health of pastoral households. Our analysis revealed that the principal diet among households was basically the same: maize flour or maize kernels as the base food (carb) with beans (protein and fat) and sugar (carb) as the adjoining staple foods. Separating families into different social classes revealed differences in diet preferences among staple foods. Wealthy families preferred to eat maize kernels mixed with beans and poorer families preferred to eat maize flour porridge with sugar and goat milk or ugali with goat milk. Since maize kernels are bulky and difficult to digest, families showing a preference for maize and beans may be consuming less overall protein than families eating more easily digestible foods such as porridge.

In general, dietary patterns in this area indicate that the majority of the population is chronically energy and protein deficient, with calories values ranging from 1200 to 1800 per day. We also found that although families were unable to reach a target intake of 14% protein in all seasons, some poor and middle class families used a unique set of strategies that allowed them to achieve higher calorie values than others. After examining our database of households, we found that these six outlying households used unique and surprisingly novel coping mechanisms and strategies to acquire higher levels of protein than their neighbors.

Secondly, analysis of food choices by frequency of consumption among households revealed that poor and rich households made similar choices in secondary foods, but with a few exceptions. Both wealth classes consumed vegetables (tomato, potato and greens) and meat with similar frequency, but differed in items such as oil, tea, salt, flavored drinks and candy. Poor families emphasized these luxury, junk items more than rich families, especially in good years, suggesting they are further along in the nutrition transition than other households.
Alternatively, we suggest that households who emphasize junk items such as candy or flavored drinks may be doing so because these items are cheap (one piece of candy is 1 KsH and a flavored drink 20 KsH) and they erroneously believe that these foods provide nourishment when in fact they do not. Likewise, items such as salt and tea are very cheap in the market. It makes sense for poorer households to emphasize these less costly items, even though they provide little to no nutrition, if cost is the only concern.

As we can see from the dietary characteristics of Mukugodo households, family livelihoods are more than ever tied to the use of markets as a mechanism for exchange between pastoral products and agricultural goods. Data collected on food and livestock prices in local markets indicates that market pricing is highly volatile, with terms of trade between livestock and staple foods deteriorating sharply in dry seasons and droughts and increasing sharply in wet seasons or harvest seasons. These deteriorating terms of trade may explain why poor families emphasize cheap, junk items whereas the rich do not. Although we can not provide direct quantitative evidence to the fact, we suggest that rich families must have access to cash or savings that poor families do not, allowing them to choose healthier food items (such as vegetables and fruits) in the market.

When families don’t have cash or stock to sell in the market (or don’t want to because pricing structures are prohibitive) they must turn to an alternative source of calories. Our investigation into local forms of aid for pastoral households revealed that most government aid comes in the form of WFP or USAID rations and private aid from Mpala Farm. Our results reveal two interesting findings: rich families rarely access government food aid and not all poor families had access to aid, even if they were vulnerable. Of our 30 sample families, not all of the poor/ middle class families reported receiving food assistance, even though they clearly were in need based on their dietary intake data. Secondly, our results reveal that during the drought, food aid rations were skewed towards carbohydrates, with only 7% pulses available in the food packs. In 2010, after conditions had improved locally for families, food rations were shifted, now comprising 46% pulses. This may explain why some households seemed to have more access to protein in 2010 than we expected given the abysmal livestock returns in milk production during this period. Labor migrants also play an important role in providing remittances and aid to their relatives and affines back at home.
Our results indicate that families who have access to subsidized private rations for purchase from Mpala have better dietary outcomes than families who do not. For example, some of these households reported higher protein levels than their neighbors, suggesting that informed use of private aid improves the livelihoods of some pastoral households. There may be social or economic reasons why some households who have relatives working outside the group ranch do not receive the same amount of aid as others. Women, who generally go to retrieve these rations each month, have very little control over how much food they can take home. Husbands set limits on how much wives can purchase from the ration truck, making it difficult for mothers with low purchasing limits to obtain the right balance of nutrients, since we expect them to emphasize the lowest cost items: maize kernels and maize flour. Given this scenario, we suggest that more research should be done on how food is obtained, transported, and distributed by women in order to better understand how social forces may be influencing the dietary choices we observe among families.

Lastly, our analysis of nutritional indicators among Mukugodo children and adolescents aged 0-19 years revealed a population suffering from chronic, moderate malnutrition. Although there were some small improvements in nutritional outcomes when ecological conditions improve, overall, individuals are unable to achieve energy balance at any time of the year. Infants of both sexes at weaning age (24-36 months) and boys of herding age (5-19) exhibit the highest degree of both wasting and stunting, suggesting that locally available weaning foods are not sufficient for the needs of infants. Young boys who herd or attend school regularly walk long distances (between 5 and 15 miles a day) and if herding, miss the noontime meal. Females in the same age group are generally home for the noontime meal, if one is provided. We cannot ignore that there are a number of disease related factors interacting with dietary intake in this population. There is much work to be done to investigate disease patterns in these communities in order to separate disease effects from diet effects. Our future research will focus on broadening our understanding of the linkages between diet, government and clinic based food aid and assistance programs, and health provision (vaccination, therapeutic feeding, access to clinical care) in these communities.

In conclusion, this dissertation has illustrated the various linkages between traditional pastoral behaviors and the transformative processes that are leading to shifts in herding, land use, market engagement, dietary preference and choice, and nutritional status. Given the results generated here we suggest that interventions that improve herding practices and patterns of
mobility and access to grazing are necessary to equalize competition and improve overall production outcomes. If pastoralists are more successful at raising quality stock, they will be better equipped to generate subsistence for themselves and competitive products for the market. Secondly, interventions or training in livestock marketing that allow pastoralists to improve their interactions with market actors and the terms of trade for pastoral products will permit families to afford a more diverse and healthy diet, which will in turn will reduce the high levels of chronic under nutrition we see in Mukugodo. Lastly, interventions that improve the palatability and digestibility of local foods, increase the variety and diversity of diet choices, improve food storage and preservation, and increase overall calorie levels (e.g. increased energy density from fat would be the best option) are definitely a first step towards improving dietary intakes and child health in the future.
References Cited


