2011

Farmer land allocation for maize, groundnut and cotton production in Chipata District, Eastern Province, Zambia

Kristina M. Denison
Michigan Technological University

Follow this and additional works at: https://digitalcommons.mtu.edu/etds
Part of the Forest Sciences Commons

FARMER LAND ALLOCATION FOR MAIZE, GROUNDNUT AND COTTON PRODUCTION IN CHIPATA DISTRICT, EASTERN PROVINCE, ZAMBIA

By

Kristina M. Denison

A THESIS

Submitted in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

Forestry

MICHIGAN TECHNOLOGICAL UNIVERSITY

2011

This thesis, “Farmer land allocation for maize, groundnut and cotton production in Chipata District, Eastern Province, Zambia,” is hereby approved in partial fulfillment of the requirements for the Degree of MASTER OF SCIENCE IN FORESTRY.

School of Forest Resources and Environmental Science

Signatures:

Thesis Advisor ____

Dr. Blair D. Orr

Dean ____

Dr. Margaret R. Gale

Date ____

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGEMENTS

First and foremost, I would like to express my sincere gratitude and thanks to my advisor, Dr. Blair Orr, without whom this thesis wouldn't have been possible. His support and commitment in all phases of my academic journey; pre, during, and post Peace Corps was unmatched by anyone and greatly appreciated. I feel so lucky to have had you as my advisor and your dedication and hard work has not gone unnoticed.

To my mom, dad and sister for your unconditional support and steady stream of mail which kept me going throughout my Peace Corps Master's International journey. Thank you for allowing me to embrace my wandering curiosity and always supporting my sense of adventure and curious nature.

Thank you to my committee members, Dr. James Pickens, Dr. Christopher Webster, Dr. Ann Maclean and Dr. Sarah Green, for your time and assistance during this process.

Peace Corps Zambia staff members Donald Phiri, Henry Chilufya, Nancy Yuill, and Thomas Kennedy for your continued support during and after my Peace Corps service. Fellow EP RPCV's Maggie Wenger, Tim McKinley, Michelle Melton and Julia Wenning for your support in a multitude of different mediums.

Zikomo kwambiri Chief Madzimawe for allowing me to live and work in your Chiefdom. Ku Gone Mudzi for welcoming me with open arms, adopting me as one of your own, naming me, teaching me, laughing with me, taking care of me, allowing me to interview you, and for making me feel at home. I am forever grateful. A special thanks to Tilowe Newa, my African *mbuya*, Bupe Miti, my African *amai*, Blackson Chulu, brother and friend, Mary Nzima, Bridget Nyau, Esther Phiri, and Mrs. Cisenga at the Serenje Orphans School Home. Tsalani bwino.

Zikomo kwambiri a Lyson Lungu, counterpart, translator, interpreter, teacher, student, farmer, and friend. To the *Chande* Section Women's group, and the late Miriam Miti, whose life was tragically cut short at the age of 36. Tidzaonana.

Last but not least, to my friends in Chipata and Serenje, nationals and foreigners, and my MTU officemates of 145, past and present.

ABSTRACT

Small-scale farmers in the Chipata District of Zambia rely on their farm fields to grow maize and groundnuts for food security. Cotton production and surplus food security crops are used to generate income to provide for their families. With increasing population pressure, available land has decreased and farmers struggle to provide the necessary food requirements and income to meet their family's needs. The purpose of the study was to determine how a farmer can best allocate his land to produce maize, groundnuts and cotton when constrained by labor and capital resources to generate the highest potential for food security and financial gains. Data from the 2008-2009 growing season was compiled and analyzed using a linear programming model. The study determined that farmers make the most profit by allocating all additional land and resources to cotton after meeting their minimum food security requirements. The study suggests growing cotton is a beneficial practice for small-scale subsistence farmers to generate income when restricted by limited resources.

CHAPTER ONE – INTRODUCTION

When I first arrived in Zambia in June of 2007, the first thing that struck me was how cold it was. In my preconceived ideas, Africa was never cold. Then, as I rode in a Peace Corps land cruiser along the Great East Road, I gazed out the window into the distance at fields of white fluffy cotton reaching as far as the eye could see. They grow cotton in Africa? The few expectations I had were quickly slipping away into oblivion as they were replaced by the reality of Africa, more specifically life in Zambia. In the next few weeks I would undergo intensive language and technical training to prepare myself for life in a Zambian village, a life a girl from a suburb of Minneapolis couldn't have imagined in her wildest dreams. Over the course of the following three years, a country I knew little about and the people that live there became an entity I would ultimately love and cherish, and a little mud hut with a grass thatch roof became a place I was proud to call my home.

As a Peace Corps Volunteer, I worked in conjunction with the Zambian Forestry Department under the Ministry of Agriculture as a Forestry Extension Agent and was placed in a small rural village with no running water or electricity called Gone, loosely translated as "to have slept" in the local language. The name refers back to a time when Gone Village was used as a rest stop for villagers from the Petauke and Katete regions traveling to the provincial capital.

I lived and worked in the community, interacted daily with farmers and villagers, and participated in the daily routines and activities of village life. After integrating into the community I was able to build trust among the villagers and acquire insights as to how rural farmers live and work on a day to day basis. I was surprised and curious about the amount of cotton production going on in this small village where some struggled to provide enough food for their families to last through the year. I was further thrown off by the large semi-trucks with flat beds that seemed to magically appear twice a year in the village towering over mud huts and looking completely out of place in this quiet "Sleeping" village. I watched as the villagers carried wheel pack after wheel pack stuffed full of cotton to the scale to be hung and weighed, some weighing over 100 kilograms, before being packed onto an already overloaded semi-truck. The semi-truck was gone as quickly as it came, swaying from side to side and threatening to tip over with the weight of the wheel packs on the uneven dirt road, off to the next rural village to collect more cotton.

It was through these observations as well as many individual conversations that led me to the current study and allowed me to successfully gain the necessary knowledge and information to proceed. I discovered that farmers spend most of their time engaging in seasonal field practices, most commonly a combination of maize, groundnut [peanut], and cotton production, in order to ensure food security and financial gain for their household. Consequently, I concluded that the farmers of Gone Village are limited by the physical constraints of land and labor which are further influenced by various social factors. I also learned farmers were drawn to cotton production because it generally provided them with a lump sum of cash at harvest time. As a result, it was necessary to obtain information regarding farming activities along with social measures for this study.

The purpose of the study was to determine how a farmer can best allocate his land to produce maize, groundnuts and cotton when constrained by labor and capital resources to generate the highest potential for food security and financial gains.

Chapter Two provides a general background of Zambia. It explains Zambia's climate and topography followed by a brief history. It describes the people along with some of their cultures and religions. It addresses some of the current health problems Zambian's face and concludes with a section about Zambia's economy.

Chapter Three takes a closer look at the study area emphasizing crops and agriculture. It also provides a detailed explanation of maize, groundnuts and cotton, the three crops used in the study.

Chapter Four explains the methods of the study. It covers linear programming and provides the model that was created for the study. It also addresses data collection techniques used in the study as well as the data compilation processes.

Chapter Five presents results and analysis from the study through a series of scenarios. Discussion of findings are provided with each scenario. The chapter concludes with the overall general findings of the study.

Chapter Six looks at this study in comparison to previous literature of similar studies. General conclusions for the findings of the current study are stated and the chapter closes by offering recommendations and suggestions for the farmers in the study area.

CHAPTER TWO – GENERAL BACKGROUND

With no coastline and seven international borders including Angola, Democratic Republic of the Congo, Malawi, Mozambique, Namibia, Tanzania, and Zimbabwe, the Republic of Zambia is found landlocked in the Southern Region of Africa (Figure 2.1) (CIA 2011). It has a land area totaling 743,398 sq km and measures slightly larger than the size of the State of Texas (U.S. Department of State 2010).

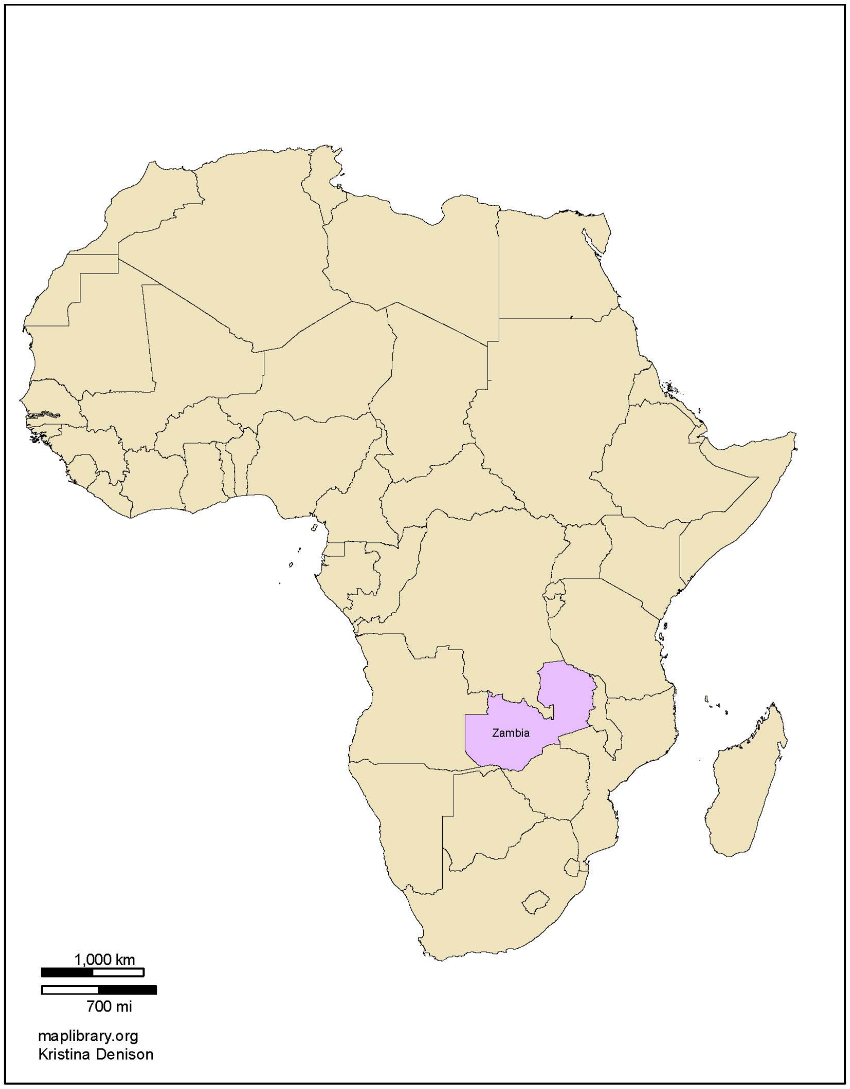

Figure 2.1 Zambia is located in the southern region of Africa.

Zambia is composed of nine administrative divisions called provinces: Central, Copperbelt, Eastern, Luapula, Lusaka, Northern, Northwestern, Southern and Western. Lusaka, the capital city, is located in the smallest province, Lusaka Province (Figure 2.2) (CIA 2011). The provinces are further divided into 72 sub-divisions called districts, housing a total population of 13,460,305 with 35 percent residing in urban areas and 65 percent residing in rural areas (U.S. Department of State 2010; CIA 2011; World Bank 2011).

Figure 2.2 Map of Zambia with capital city and provincial divisions.

2.1 Climate/Topography

Zambia's climate is tropical with climatic variations across the country due to altitude changes throughout the regions. Zambia has three seasons, cold-dry from April to August, hot-dry from September to October, and hot-wet from November to March, again varying slightly by region (Jenkins and Phiri 2009). The northern half of the country generally experiences higher rainfall, around 1,000 mm annually, while the southern half averages 700 mm. Luapula Province experiences the most rainfall days annually at 123, while the Southern Province experiences the fewest at 74 (Zimba 2007).

The terrain consists mostly of high plateaus ranging from 1,000 to 1,400 meters above sea level, savannas, hills and mountains. At its highest point in Mafinga Hills near the northwestern border, the elevation reaches 2,031 meters. Zambia's lowest point rests at 329 meters at the convergence of the Zambezi and Luangwa Rivers (Zimba 2007; CIA 2011).

Zambia has three main agro-ecological zones: Regions I, II, III (Zimba 2007; Jenkins and Phiri 2009). These zones take into account altitude, rainfall, climate, and soils, and are used to determine what types of crops will thrive in each area (Zimba 2007).

Region I encompasses the drought prone areas of Zambia including the Gwembe and Lusemfwa valleys of Zambia as well as the southern parts of Western and Southern Provinces (Saasa 2003; Jenkins and Phiri 2009). It is considered semi-arid and is the hottest and driest of the regions. It receives an average annual rainfall of 700 – 800 mm and has the shortest growing period ranging from 80-120 days. Elevations range from 300 – 1,200 masl (Zimba 2007).

Region II, with elevations ranging from 900 – 1,300 masl, contains the Sandveld plateau of Central, Eastern, Lusaka and Southern Provinces as well as the Kalahari sand plateau and Zambezi flood plains of Western Province (Saasa 2003). It is a medium rainfall zone, averaging 800 – 1,000mm a year (Jenkins and Phiri 2009). It is considered the most productive zone in the country and has a growing season ranging from 120-150 days (Zimba 2007).

Region III is the highest rainfall area with over 1,000 mm annually and a growing season up to 190 days (Jenkins and Phiri 2009). It covers the Central African Plateau crossing Northern, Luapula, Copperbelt, Northwestern Provinces and the northern most parts of Central Province with elevations ranging from 1,100 to 1,700 masl (Saasa 2003; Jenkins and Phiri 2009). Due to high rainfall, soils in Region III are generally highly acidic limiting the range of crops that can be grown in the region (Zimba 2007).

2.2 A Brief History

Estimates suggest ancestors of Zambia's current inhabitants displaced the indigenous hunter-gatherers about 2,000 years ago. From the 15th to the early 19th century, waves of Bantu-speaking immigrants from what are now the Democratic Republic of the Congo and Angola reached the northern and western borders of Zambia while the Ngoni peoples approached the southern boundaries. By the end of the 19th century, the tribal groups were settled into the areas they currently occupy today (U.S. Department of State 2010).

In the mid 19th century, Western explorers and missionaries began to make their way into the country. By the end of the century, Northern and Southern Rhodesia (now Zambia and Zimbabwe, respectively), were proclaimed a British sphere of influence. In 1953, although Zambian opposition was strong, the Federation of Rhodesia and Nyasaland (now Malawi) was formed (Holmes 2007).

In 1962, a two-stage election resulted in an African majority in the legislative council. It passed a resolution allowing Northern Rhodesia's secession from the federation and called for "full internal self-government under a new constitution and a new national assembly," (U.S. Department of State 2010). The federation was dissolved on December 31st, 1963, and the Republic of Zambia was formed on October 24th, 1964. Kenneth David Kaunda, under the United National Independence Party (UNIP), became the country’s first Republican President (Sinkamba 2010; U.S. Department of State 2010).

In 1972, Kaunda abolished all non-UNIP political parties. By December 1990, riots over rising food prices and increased demands for democratization forced Kaunda to legalize opposition parties and abolish the one party rule. In 1991, Frederick Chiluba under the Movement for Multiparty Democracy (MMD), its unifying principle solely the opposition to UNIP and Kaunda, defeated Kaunda in elections to become Zambia’s second President (Sinkamba 2010; Encyclopedia of the Nations 2011).

Chiluba enacted a 1991 constitution restricting a president’s tenure to two five-year terms and providing for a prime minister and cabinet as well as a National Assembly (Encyclopedia of the Nations 2011). Although Chiluba made attempts to liberalize the economy and endeavored to privatize industry, he left Zambia in a worse state than when he started and massive corruption allegations were the common focus towards the end of his administration (Holmes 2001; Sinkamba 2010; U.S. Department of State 2010).

In 2001, after Chiluba completed his second term, Levy Mwanawasa, MMD, became Zambia’s third President by a margin of 11,000 votes over Anderson Mazoka, United Party for National Development (UNDP) candidate (Encyclopedia of the Nations 2011). Mwanawasa took a strong stand against corruption and made efforts to set the country back on course economically. He was elected to a second term in 2006. As a result of Mwanawasa’s efforts, Zambia received substantial aid and debt relief and many believed Zambia was finally on track when Mwanawasa passed away on 19 August, 2008 during his second term (Sinkamba 2010; U.S. Department of State 2010).

Following Mwanawasa’s death, Vice President Rupiah Banda took over presidential powers. Complying with the constitutional requirement of an election within 90 days of Mwanawasa’s death, Banda held an election on 30 October, 2008. Banda defeated Michael Sata of the opposition Patriotic Front (PF) Party. Banda promised to continue in Mwanawasa’s footsteps; however, emerging corruption scandals have raised speculation about his commitment. Elections will be held again in 2011 (U.S. Department of State 2010).

2.3 The People, Cultures and Religion

The people of Zambia make up a diverse and culturally rich country. Consisting of over 70 tribes, Zambia recognizes eight official languages (Bemba, Nyanja, Tonga, Lozi, Lunda, Kaonde, Luvale and English). In addition, there are over 70 other languages and dialects spoken throughout the country. Although the majority of Zambians are of African descent, there is also a small but economically significant Asian population as well as a small Caucasian population (CIA 2011).

Each tribe has its own language, traditions, customs, ceremonies and history. For example, the Barotse people, commonly referred to as *Lozi's*, from the Western Province, celebrate their history through the *Ku-Omboka* pageantry. *Ku-Omboka* means "to emerge out of the water," as this ceremony began centuries ago after a great flood washed over the plains and wiped out animals, people and crops. In response, a man named Nakambela built a large barge, called *Nalikwanda* ("for the people"), which could carry people, animal dung and seeds. After the flood water receded, seeds were scattered over the land to grow crops and other vegetation while animals were created from the dung. Today's ceremony contains the royal barge *Nalikwanda,* along with additional canoes that transport the people from lower to higher ground. Announced by the roaring beat of the *maoma* royal war drums, the first beat from the King's own drum, the *Ku-Omboka* pageantry still follows centuries-old customs and practices (Guhrs et al. 2007).

Zambia recognizes Christianity as the official national religion. In addition, there are Muslim, Hindu, and indigenous beliefs (U.S. Department of State 2010; CIA 2011). The majority of Zambians consider themselves Christians, but most still have a strong affinity towards traditional beliefs. In rural areas especially, Christianity is commonly blended with indigenous beliefs.

2.4 Health

HIV/AIDS continues to have a large impact on Zambia's economic, political, cultural, and social development. Estimates suggest roughly 14 to 16 percent of Zambians are infected with HIV (U.S. Department of State 2010; USAID Undated). In addition to HIV and AIDS, Zambians are also affected by major infectious diseases including, but not limited to, bacterial and protozoal diarrhea, hepatitis A, typhoid fever, malaria, Schistosomiasis (Bilharziasis) and rabies (CIA 2011). Though illness rates are high and treatments often scarce, many Zambians still prefer to see a traditional healer for medicinal remedies rather than seeking treatment at a westernized public health clinic.

Life expectancy estimates range from 38 to 52 years, ranking Zambia as one of the lowest in the world (U.S. Department of State 2010; CIA 2011). Only 2.3 percent of the population is over 65 years old, with 52.6 percent in the 15 to 64 range, and 45.1 percent under 15 (CIA 2011). Though Zambia has an extremely high fertility rate with an average of 6.07 children born per woman and the fourth highest birthrate by country in comparison to the world (Figure 2.3), it also has an infant mortality rate of 70 deaths per 1,000 live births (U.S. Department of State 2010; CIA 2011). The estimated population growth rate for 2010 was 3.1 percent (CIA, 2011).

2.5 Economy

Zambia qualified for debt forgiveness under the Heavily Indebted Poor Countries Initiative (HIPC) in 2005 and benefited from nearly USD 6 billion in debt relief (Holmes 2007; U.S. Department of State 2010). By 2007, the economy had stabilized and entered single-digit inflation, it experienced decreasing interest rates, increasing levels of trade, and real GDP growth. However, major donors continue to play a significant role as Zambia received an estimated USD 1.181 billion in 2010 according to the Ministry of Finance and National Planning (U.S. Department of State 2010). In 2009, Zambia had an estimated Gross National Income (GNI) per capita of USD 970, and a gross domestic product (GDP) of USD 12.7 billion (World Bank 2011).

Figure 2.3 Zambian children. Photo by Kristina Denison.

Even with donors and what appears to be an improving economy, estimates suggest over half of Zambians are currently living below the poverty line (U.S. Department of State 2010; World Bank 2011).

Agriculture, mining and manufacturing, and the service industry comprise the three main sectors of Zambia's workforce (75 percent, 6 percent, and 19 percent respectively). The smallest sector, mining and manufacturing, encompasses copper mining and has had the largest impacts on Zambia's economy accounting for 64 percent of exports (Zimba 2007). The largest sector, agriculture, directly impacts Zambians as it provides the means for subsistence farming. Zambians, especially those in rural areas, rely on agriculture and farm practices to provide food security and generate income for their families. Products include maize, rice, peanuts, vegetables, tobacco, cotton, sugarcane, coffee, cassava, livestock, poultry, milk, eggs and hides. The agricultural sector aids the country in reaching its food security goals, allows farmers to generate income, and adds to the economy through exports including tobacco and cotton (CIA 2011).

CHAPTER THREE – STUDY AREA BACKGROUND

3.1 Study Area

The study took place in a rural village called Gone. Gone is located in the Chipata District in the Eastern Province of Zambia (Figure 3.1). It is situated 28 kilometers from the provincial capital, Chipata, and roughly 570 kilometers from Lusaka. The village lies in a valley at the end of a dirt path three kilometers west of the Great East Road, a paved road running from Lusaka to the border of Malawi (Figure 3.2).

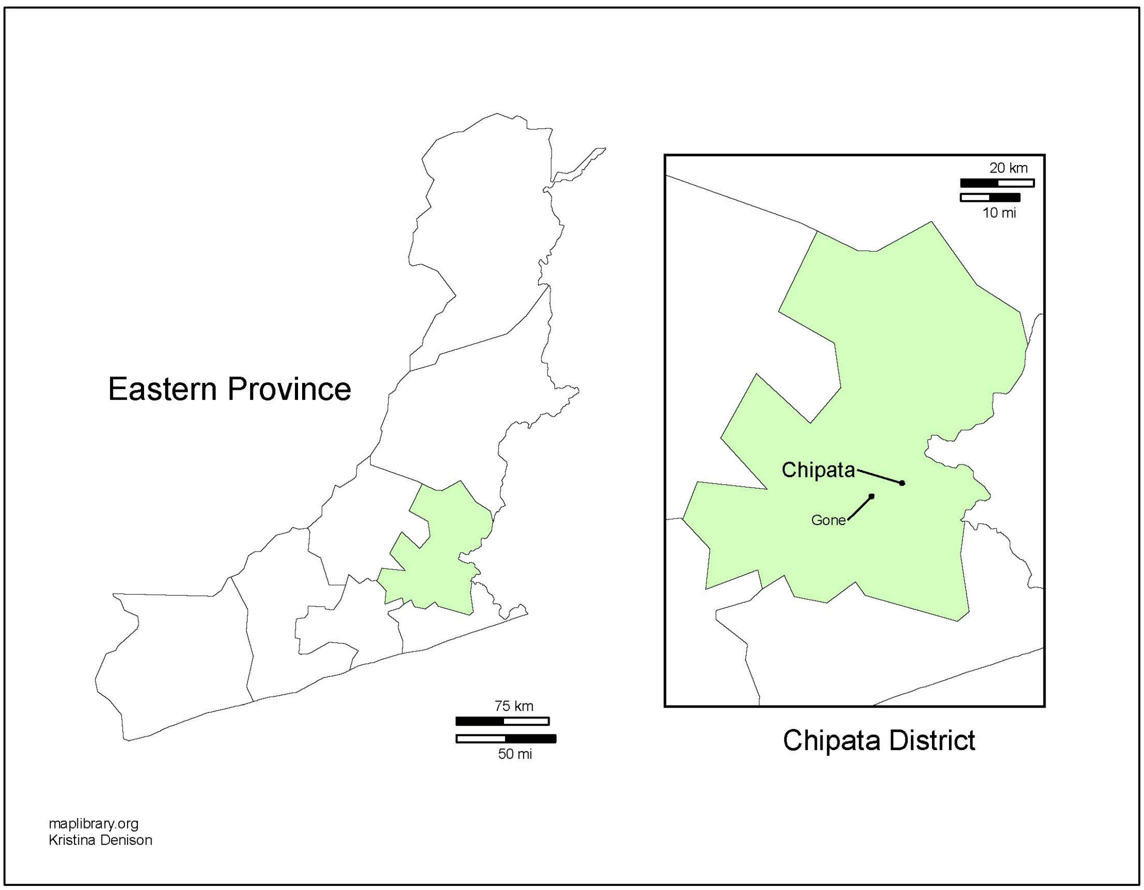

Figure 3.1 Map of study area located in Eastern Province.

Figure 3.2 The main entrance to Gone Village. Photo by Kristina Denison.

Gone has a population of about 240 people and is made up of approximately 50 household compounds. The villagers are descendants of the Ngoni and Nsenga Tribes and all speak one of the three main dialects of Nyanja (Cicewa, Cingoni or Cisenga). They are farmers and depend on the land they cultivate to provide cash resources and food year round for their families.

Gone Village is surrounded by adjacent fields that are cultivated by the farmers from the village. Land is owned by the Paramount Chief and is allocated to regional local chiefs who then delegate to the headman of each village. The majority of the land was allocated many years ago to villagers who are now elderly or have passed away. Since then, those individuals have passed down, divided up, or shared the land with their children or other family members. Some farmers own domestic fowl such as chickens and ducks and a few own small ruminants or pigs. Only the very wealthy or high status individuals own cattle. One farmer in the village owns equipment allowing him to use cattle to till his land in preparation for planting. The rest of the villagers rely solely on manual labor using a hand hoe.

The villagers of Gone have little income and few possessions. There is no running water or electricity in the village, though three farmers own small televisions that are powered using a car battery. Annual income in the village ranges from just over USD $20 to roughly USD $320. Money is most often spent on clothing, cooking needs such as salt, oil and sugar, school fees and incidentals.

3.2 Crops and Agriculture

The three main crops grown in the Eastern Province are maize, groundnuts [peanuts] and cotton. Maize and groundnuts are grown for food security unlike cotton which is grown for income generating purposes. Rain-fed cultivation prevails throughout the region as few can afford materials necessary for irrigation systems, especially among small-scale village farmers. This means there is only one growing season for small-scale farmers. The majority of small-scale cultivation is done by manual labor with a hand-hoe. While oxen and ploughs for tilling the land do exist, it is uncommon to find more than one or two farmers in a rural village who utilize them.

3.2.1 Maize

Maize (*Zea mays)* originated in Latin America and estimates suggest it was introduced to the African continent around 1500. By the time Zambia gained its independence in 1964, maize accounted for over 60 percent of the planting area of major crops and increased steadily throughout the 1970’s as the government offered chemical and fertilizer subsidy programs. Conversely, the production of sorghum and millet, crops that had been the staple prior to the introduction of maize, decreased by over 65 percent and 90 percent respectively (McCann 2001; JAICAF 2008).

Today, Zambia has the highest percentage of maize consumption in the national diet, accounting for 58 percent of total calories, and the Eastern province is the largest maize producer of the nine provinces (JAICAF 2008). Maize is the most important crop cultivated in the study area and every farmer in the study allocated some portion of their land to maize.

Maize is used to make the Zambian staple food *nshima.* It is pounded down to create maize meal flour which is then cooked in boiling water until it reaches a dough-like consistency. It is scooped out and served in "lumps" as the main part of the meal with other relishes or sides such as pumpkin leaves, rape, cabbage, beans or, on special occasions, meat. *Nshima* is served at the midday and evening meals while *nshima* porridge is eaten at breakfast. Zambians will claim they have not eaten if they haven't taken *nshima.*

Maize is also used to make various beverages both on a local and national level. *Munkoyo* or *maheyu,* a non-alcoholic drink from crushed, porridge-like maize is made locally for special occasions and *Chibuku,* a nationally brewed alcoholic beverage with maize as the main ingredient, is mainly consumed by the rural or low-income populations throughout Zambia. Because of its importance and valued uses, growing enough maize to last through the year is typically a farmer's highest priority (Figure 3.3).

Maize is sensitive to deprivation of water and water-logging, demands high levels of sunlight and also requires high soil nutrient levels, especially nitrogen. Failure to meet these demands will reduce the productivity of the crop (Webster and Wilson 1998; McCann 2001; JAICAF 2008).

Figure 3.3 Women shucking maize in Gone Village. Photo by Kristina Denison.

3.2.2 Groundnuts

Groundnuts (*Arachis hypogaea)* [peanuts] originated in South America and estimates suggest they spread eastward to Africa around four centuries ago (Smith 1950). Groundnuts typically thrive in hot temperatures and are intolerant of acidic soils (Webster and Wilson 1998). They are nitrogen fixing, making them ideal for crop rotation with maize (Jenkins and Phiri 2009).

Groundnuts play an important role in the Zambian diet as they can contain up to 38 percent protein and have various nutrients and antioxidants (Abbiw 1990). Groundnuts can be boiled, roasted, eaten fresh, pounded into paste and added to relish dishes or *samp* (breakfast dish made from pounded fresh maize), and occasionally are used to make *cimponde* (peanut butter).

3.2.3 Cotton

Archaeologists trace the origin of cotton to ancient civilizations on both sides of the world dating back as far as 3,000 B.C. (Prentice 1972). In Zambia, from 1977 until 1994, the state-owned cotton company Lint Company of Zambia (LINTCO) had a monopoly over all aspects of the cotton sector. This included buying seed cotton at a fixed price as well as supplying certified seeds, bags, pesticides, and sprayers to farmers. In addition, LINTCO distributed cotton inputs on credit and provided extension advice to farmers. In 1994, the market was privatized and LINTCO was sold to Lornho Cotton and Clark and other companies were able to enter the sector (Tschirley et al. 2004). Currently, in Eastern Province, the two largest companies involved in cotton production are American-owned Dunavant and Cargill, who entered the Zambian market in 2001 and 2006 respectively.

Cotton in Zambia is almost entirely a smallholder crop and its production in the Eastern Province accounts for roughly sixty percent of all the cotton grown in the country (Tschirley et al. 2004; Tschirley and Kabwe 2007). Smallholder farmers in the Eastern Province utilize cotton only for income generation and are not involved in any aspect of processing. It is a labor intensive crop that requires constant monitoring for pests and weeds in addition to multiple applications of pesticides (Tripp 2009).

Cotton requires light, heat, moisture and nutrients for growth. It is a heat-loving plant and grows best in seasons where temperatures are high. It is drought resistant to an extent and can be affected by water-logging. Normally rain-fed irrigation is sufficient as it is deep rooting and can tap soil moisture from as deep as three meters. Cotton can tolerate a wider range of soils than most crops in terms of acidity and high pH levels (Prentice 1972). The need for fertilizer is low as cotton makes fewer demands on soil nutrient levels when compared to maize (Tschirley et al. 2004; Tripp 2009). Cotton dislikes competition from other plants and in its younger stages can be affected by over-shading weeds (Prentice 1972).

Pests provide the greatest obstacle to successfully growing cotton and thus spraying of pesticides is necessary. Various leaf-suckers, bollworms, leaf-eaters, strainers, spider mites and aphids can all cause problems for cotton. Due to the promotion of cheap, broad spectrum insecticides and their wide use, insecticide resistance has been documented and many of the natural enemies have also declined or disappeared disrupting the original ecological balance (Tripp 2009). The misuse of insecticides has reportedly been linked to illness and death of cotton farmers and laborers and also adds to environmental pollution. In addition, cotton can also be affected by blight, wilt and leaf curl (Prentice 1972).

CHAPTER FOUR – METHODS

The objective of the study was to determine how a farmer can best allocate his land when constrained by labor and capital resources to generate the highest potential for food security and financial gains. Linear Programming is a tool that can be utilized to solve this type of problem.

4.1 Linear Programming

Linear Programming is a planning method that can aid in decisions where there is a choice of alternatives and the optimal allocation of a resource needs to be determined (Beneke and Winterboer 1973; Hiller and Liberman 1986). A linear programming model was constructed and solved to determine the best allocation of the farmer's land among maize, cotton and groundnuts.

A standard form of a linear programming model can be written as follows:

$$\text{Maximize } Z = c_1x_1 + c_2x_2 + \ldots + c_nx_n, \qquad \text{(objective function)}$$

Subject to the restrictions:

$$a_{11}x_1 + a_{12}x_2 + \ldots + a_{1n}x_{1n} \leq b_1 \qquad \text{(constraints)}$$

$$a_{21}x_1 + a_{22}x_2 + \ldots + a_{2n}x_{2n} \leq b_2$$

$$\ldots$$

$$a_{m1}x_1 + a_{m2}x_2 + \ldots + a_{mn}x_n \leq b_m$$

and

$$x_1 \leq 0, x_2 \leq 0\ldots, x_n \leq 0 \qquad \text{(non-negativity constraints)}$$

The *a, b,* and *c* values remain constant while the *x* variables are the decision variables to be solved within the model (Hiller and Liberman 1986).

For the purpose of this study, the following linear programming model was formulated using as the objective function: maximize profit while satisfying the minimum food security requirements of maize and groundnuts with available land, labor and capital.

Maximize Z = Maize Revenue + Groundnut Revenue + Cotton Revenue – Maize Costs – Groundnut Costs – Cotton Costs

Maize Revenue	=	$P_m *(Q_{m,n}*A_{m,n} + Q_{m,o}*A_{m,o} + Q_{m,p}*A_{m,p} + Q_{m,q}*A_{m,q})$
Groundnut Revenue	=	$P_g*(Q_{g,o}*A_{g,o} + Q_{g,q}*A_{g,q})$
Cotton Revenue	=	$P_c*Q_{c,n}*A_{c,n}$
Maize Costs	=	$A_{m,n,i}*F_{m,n,i} + A_{m,p,i}* F_{m,p,i} + A_{m,n,j}*(L_{m,n,j} + F_{m,n,j}) + A_{m,o,j}*L_{m,o,j} + A_{m,p,j}*(L_{m,p,j} + F_{m,p,j}) + A_{m,q,j}*L_{m,q,j}$
Groundnut Costs	=	$A_{g,o,j}*L_{g,o,j} + A_{g,q,j}*L_{g,q,j}$
Cotton Costs	=	$A_{c,n,i} *(S_{c,n,l} + L_{c,n,i} + B_{c,n,i}) + A_{c,n,j}*(S_{c,n,j} + L_{c,n,j} + B_{c,n,j})$

Subject to the Restrictions:

Maize Requirement:	$Q_{m,n}*A_{m,n} + Q_{m,o}*A_{m,o} + Q_{m,p}*A_{m,p} + Q_{m,q}*A_{m,q} \geq$ Quantity of Maize Required
Groundnut Requirement:	$Q_{g,o}*A_{g,o} + Q_{g,q}* A_{g,q} \geq$ Quantity of Groundnuts Required
High Quality Ha:	$A_{m,n} + A_{m,o} + A_{g,n} + A_{c,n} \geq$ Total Available High Quality Land
Low Quality Ha:	$A_{m,p} + A_{m,q} + A_{g,q} + A_{m,p} + A_{m,q} + A_{g,q} \geq$ Total Available Low Quality Land
Variable Costs:	Maize Costs + Groundnut Costs + Cotton costs ≥ Total Household Cash Resources
Household labor:	$H_m*(A_{m,n,i} + A_{m,o,i} + A_{m,p,i} + A_{m,q,i}) + H_g*(A_{g,o,i} + A_{g,q,i}) + H_c*A_{c,n,i} \geq$ Available Household Labor

Note: Variables that are consistently zero are not shown in the equation and all numbers .

For the following variables:

P	=	Price (ZMK)
Q	=	Quantity (kg)
A	=	Land area (ha)
F	=	Fertilizer costs (ZMK/ha)
S	=	Seed costs (ZMK/ha)
L	=	Paid labor price (ZMK/ha)
B	=	Pesticides (ZMK/ha)
H	=	Household labor per ha

And subscripts:

m	=	Maize
g	=	Groundnuts
c	=	Cotton
n	=	High quality land with fertilizer or chemical inputs
o	=	High quality land no fertilizer or chemical inputs
p	=	Low quality land with fertilizer or chemical inputs
q	=	Low quality land with no fertilizer or chemical inputs
i	=	Household labor
j	=	Paid labor

Where:

$$A_{t,u} = A_{t,u,i} + A_{t,u,j}$$

For all:

t	=	m, g, c
u	=	n, o, p, q

The model was solved using “What’s Best!,” a program designed to solve linear problems in Microsoft Excel. The model was also solved to calculate dual values. Dual values represent the rate of improvement of the objective function as the right-hand-side is increased by one unit, and thus represents the maximum price you should be willing to pay for an item (Lindo Systems Inc. 2009).

4.2 Data Collection

In order to collect the necessary data to run the model, participant observation, informal interviews, and structured interviews with a questionnaire were utilized. Participant observation involves the researcher living in a community and observing the daily life and activities of its members. The researcher participates in community life and is able to collect information slowly and informally, taking note of what they see and hear within the community while gaining a continuous flow of information (Loizos and Pratt 1992; Nichols 2000). Informal interviewing requires the researcher to recall conversations had during the day and record key points after the conversation has already occurred (Bernard 2002). The information gathered using these techniques guided the study and allowed for identification of necessary data to be collected and compiled into a questionnaire.

The questionnaire was compiled and submitted to the IRB for approval. It was used in structured interviews administered to each head of household in Gone Village. The definition of a household can vary dramatically depending on culture and the unit of analysis a study is using (Loizos and Pratt 1992). For the purpose of this study, a household is defined as a group of people who closely interact daily with each other and whose daily farming activities contribute to the same single household or compound. The head of household is defined as the member of the household who holds the highest social standing within the household through the eyes of the community. Typically, this is the eldest working male.

The questionnaire was divided into six segments, each administered within a two week time frame in the months of August 2008, October 2008, December 2008, February 2009, April 2009, and June 2009. Each segment asked questions regarding the previous two month's farming activities, building on the answers provided at the previous interview. In addition, during the administration of the August 2008 segment, questions were also asked regarding the 2007-2008 farming season as well as information about social factors and the household. The initial questionnaire took approximately two hours per household, while the subsequent interviews (October through June) took no more than one hour per household. Fifty-three of the fifty-six households in Gone were able to successfully complete the survey. Three households dropped out at various stages due to death, divorce, and relocation. The interviews were conducted in English with a Nyanja translator present at all times.

4.3 Data

4.3.1 Labor:

After observing the work habits and abilities of the community members, it was determined that adult men and women (17-50 years) have roughly the same work rate and ethic, while youth (13-16 years) work slightly slower than adults, and elderly (over 50 years) are the slowest. Labor values were assigned to each member that contributes to household labor by the three aforementioned categories. Adults were assigned a value of 1.00, youth a value of 0.75, and elderly a value of 0.50. Children under 13 years of age also help with labor but their contribution is minimal and therefore they were not assigned a value.

4.3.2 Social Status:

Many different factors influence the social status of a farmer, and this status can affect the resources or options a farmer has available within the community based on how he or she is viewed. Some examples include whether they are seen as credible, trustworthy, or if they can gain access to credit or other external resources. Measures were gathered in the categories of education, land owned, family size, annual income and non liquid assets (bicycle, livestock, oxcart, television, etc.) and compiled to create a generalized social status scale for a typical head of household in each category (Table 4.1).

Table 4.1

Generalized social status scale for head of household.

Level	Education	Ha Owned	Family Members	*Income (ZMK)	Non-Liquid Assets
1	0	<0.5	none	<200,000	1
2	<grade 2	<1	1-2	>200,000	>2
3	>grade 2	<1.2	>2	<600,000	>2
4	<grade 5	<2	>2	>800,000	>3
5	>grade 5	>2	>2	>1,000,000	>4

*1 USD = 4,840 ZMK per http://www.xe.com/ucc on 7 February 2011.

4.3.3 Farmer types:

Each household was grouped into a farmer type that could be used for the calculations in the linear programming model. This was necessary because not all farmers have the same resources available to them. For example, the optimal allocation for a poor farmer could differ greatly in comparison to the optimal allocation for a rich farmer based on the available resources of each. Factors that attribute to the farmer type categories include social status, available labor, total land available in both high and low quality, and income (Table 4.2).

Table 4.2

Generalized farmer type groupings by social status, labor, land and annual income.

Farmer type	Number of farmers	Social status	Available labor	Total Ha owned	Ha high quality	Ha low quality	Income (ZMK)
1	6	1-2	1	0.7	0.4	0.3	150,000
2	15	2-3	2	1	0.6	0.4	260,000
3	24	2-4	3	1.7	1	0.7	440,000
4	8	4-5	4	2.5	1.8	0.7	940,000

4.3.4 Available cash resources:

Farmers spend their cash resources on different things including school fees, medical expenses, foodstuffs and other incidental costs. Therefore, the available cash resources for farming activities and inputs for each farmer type is less than the annual income based on typical spending for each farmer type (Table 4.3).

Table 4.3

Available cash resources by farmer type (ZMK).

Type 1	120,000
Type 2	220,000
Type 3	380,000
Type 4	840,000

4.3.5 Price, variable input costs (excluding labor), production, labor requirement and consumption rates by crop:

Data was compiled from the survey to calculate crop prices, variable input costs, production values, labor requirements and consumption rates for each crop. Unless otherwise mentioned, all of the following values were calculated using the survey data collected for the 2008-2009 farming season.

Maize

Price: The price of maize is influenced by the market and the time of year purchased or sold (Table 4.4).

Town: Maize sold or purchased in town remained at a steady price throughout the year at ZMK 65,000 for a 50kg sack. However, a minimum transport cost of ZMK 10,000 is also associated with buying and selling maize in town and this number can increase depending on the amount requiring transportation. Note: A town buying price of ZMK 75,000 (65,000 to buy plus 10,000 to transport) and selling price of ZMK 55,000 (sell at 65,000 less 10,000 to transport) were used (Table 4.4).

Village: Maize sold or bought in the village is affected by season. During the "hunger season," from December to March, before crops are harvested and food storage from the previous year begins to run out, village maize prices reached ZMK 70,000 for a 50 kg sack. During "harvest season," from May-July, farmers are harvesting their crops and replenishing their storage, prices of maize dipped as low as ZMK 45,000 per 50 kg sack. The rest of the year, village maize prices hovered around ZMK 60,000 per 50 kg sack.

Table 4.4

Maize prices in ZMK per kg by market and season, town prices include transportation costs.

	Village (Buy/Sell)	Town (Buy)	Town (Sell)
Hunger Season	1,400	1,500	1,100
Harvest Season	900	1,500	1,100
Rest of Year	1,200	1,500	1,100

Annual changes: The market price of maize has seen fluctuations over the years and though the price of maize has not changed since the 2007-2008 growing season, there was initially talk of increasing prices to ZMK 85,000 per 50kg bag for the 2010-2011 growing season. Annual changes in the market price of maize may increase or decrease a farmer's incentive to grow maize beyond what is required for food security (Table 4.5).

Table 4.5

Yearly fluctuations in maize market prices in ZMK.

Year	50 kg sack	1 kg
2005-2006	45,000	900
2006-2007	50,000	1,000
2007-2008	45,000	900
2008-2009	65,000	1,300
2009-2010	65,000	1,300
2010-2011	65,000	1,300
2011-2012*	85,000	1,700

* Estimated.

Variable input costs (excluding labor): Because farmers save seed and store it for the next year of planting, the only variable input cost associated with maize is fertilizer. It was determined that three bags of fertilizer were required to cover one hectare of land. The cost of fertilizer was influenced by whether it was purchased from a cooperative or town. In order to purchase fertilizer from a cooperative, a farmer must be a member of that cooperative and pay a yearly membership fee.

Town price: The town price for one bag of fertilizer was ZMK 215,000. With three bags at this price, cost for fertilizer from town is ZMK 645,000 per hectare.

Cooperative price: The cooperative price of fertilizer was ZMK 60,000 per bag. An annual membership fee of ZMK 50,000 must be included in the cost as well. Though this fee is the same regardless of how many bags were purchased, farmers rarely bought more than three bags. Therefore, with three bags at ZMK 60,000 each and the membership fee, per hectare cost for fertilizer from a cooperative for the purpose of the study were calculated at ZMK 230,000. This assumes one hectare of maize production by a farmer.

Annual changes: Like the price of maize, the price of fertilizer is subject to annual changes. Fertilizer prices more than doubled from the 2007-2008 growing season to the 2008-2009 season which affected farmers' costs. Increase or reduction of fertilizer price directly affects the amount of fertilizer inputs farmers can afford.

Production: Production values for maize were calculated based on land quality and fertilizer inputs (Table 4.6).

Table 4.6

Typical maize production in kg per ha by land quality and fertilizer inputs.

	High quality	Low quality
With fertilizer	1000	500
Without fertilizer	500	250

Labor requirement: The most labor intensive part of the farming season for maize is at harvest time. The stalks must be cut down and collected from the field. The harvest season for maize runs from the end of April through the middle of June, roughly seven weeks. One person can harvest approximately 75 kg of maize per week working a five hour “half day.” To harvest an entire hectare the following labor values were calculated based on land quality and fertilizer inputs data and assuming a half day of work and a seven week harvesting period (Table 4.7). Because the differences are considered minimal, an average was taken and the maize labor value was set at 0.55 for the study.

Table 4.7

Labor value for one hectare maize by land quality and inputs.

	High quality	Low quality
With fertilizer	1.0	0.5
Without fertilizer	0.5	0.2

Consumption rates: According to the survey, on average, a family of four consumes 480 kilograms of maize per year, or 120 kg of maize per person annually.

Groundnuts

Price: Similar to maize, the price of groundnuts was influenced by the market and the season (Table 4.8).

Town: The price for groundnuts bought or sold in town remained constant at ZMK 40,000 per 50 kg throughout the year. Like maize, groundnuts bought and sold in town were subject to a minimum transport cost of ZMK 10,000. Note: For the calculation reported in Table 4.8, a town buying price of ZMK 50,000 (40,000 to buy plus 10,000 to transport) and selling price of ZMK 30,000 (sell at 40,000 less 10,000 to transport) were used.

Village: The price for village groundnuts varied by season. Hunger season prices reached ZMK 35,000 per 50 kg bag, harvest season prices sunk to ZMK 25,000 and the rest of the year they stayed at ZMK 30,000.

Table 4.8
Groundnut prices in ZMK per kg by market and season, town prices include transportation costs.

	Village (Buy/Sell)	Town (Buy)	Town (Sell)
Hunger Season	700	1,000	600
Harvest Season	500	1,000	600
Rest of Year	600	1,000	600

Variable input costs (excluding labor): There are no variable input costs associated with groundnuts. Farmers use stored seed from the previous harvest and neither fertilizer nor pesticides are used by farmers.

Production: Production values for groundnuts were calculated by land quality. High quality land typically produced 1,200 kg per hectare while low quality land typically produced 690 kg per hectare.

Labor requirement: The most labor intensive period for groundnuts occurs during harvesting. The groundnuts must be dug up from the ground with a hand hoe and collected. The groundnut harvesting season is the longest of the crops and ranges from the beginning of April and continues through the end of June. Similar to maize, groundnuts are typically harvested in five hour "half days" and a single laborer can harvest approximately 80 kg of groundnuts in one week. Labor values for groundnuts were calculated based on land quality and assuming a ten week harvesting period. Harvesting groundnuts on high quality land required a labor factor of 0.8 while low quality required 0.4. Due to the minimal difference, an average value of 0.6 was calculated and used for the study.

Consumption Rates: According to the survey, on average, a family of four consumes 600 kilograms of groundnuts per year, or 150 kg per person annually.

Cotton

Price: There has been no government mandated price or pricing guidelines for cotton since the industry was privatized in 1994. The price of cotton in Zambia follows the global market value and is set by the cotton companies and this typically fluctuates from year to year. Within each year, early versus late sale is the main factor influencing the price of cotton. The following are the actual prices offered to the farmers during the 2008-2009 growing season:

Early sale: Early sale of cotton occurs at the beginning of June. Cotton companies send their trucks to villages during this time and offer a buying price of ZMK 1,200 per kg. Farmers who need immediate cash will often opt for early sale.

Late sale: Late sale of cotton occurs at the end of July or beginning of August. Companies send their trucks a second time and offer a buying price of ZMK 1,450 per kg.

Yearly fluctuations: Farmers are at the mercy of the cotton companies when it comes time to sell their cotton. During the 2005-2006 growing season, Dunavant promised a pre-planting price of ZMK 1,200 but with the appreciation of the Zambian Kwacha, when it came time to purchase, they lowered their price to ZMK 850. Prices for the 2007 and 2008 seasons increased to ZMK 1,200 and ZMK 1,400 respectively and for the 2009-2010 growing season jumped to ZMK 1,800. Prices for the 2010-2011 growing season will be announced in May.

<u>Variable input costs (excluding labor):</u> Cotton requires the purchase of seed and pesticides to ensure a successful harvest. Seed and pesticides are offered on loan from the cotton companies and deducted from the final sale at harvest time. If the farmer has not produced enough cotton to cover these costs, he or she must pay back the loan in full.

Seed: Seed cost for one hectare of land is ZMK 50,000.

Pesticides: The cost of pesticides to cover one hectare was ZMK 180,000.

<u>Production:</u> All but one farmer grew cotton on high quality land and thus the production value for cotton was based strictly on high quality land. The typical per hectare production value was calculated at 1,000 kg.

Labor requirement: Like maize and groundnuts, the most labor intensive period for cotton occurs at harvest time. Cotton is picked by hand off the plant and stuffed into large bags called wheel packs that can hold over 100 kg. Unlike maize and groundnuts, because there is a time constraint, whole 10 hour days are devoted to picking cotton to ensure it is done on time. Cotton can be harvested as early as the middle of May but only farmers trying to prepare for early sale start at this time. This gives them two to three weeks to harvest their entire crop before the companies come out for early sale. For those who will sell late, harvest begins in June and finishes mid-July, lasting approximately six weeks. Labor requirements for cotton were calculated based on early or late sale with two week and six week whole day seasons respectively. Early sale cotton requires a labor factor of 9.5 while late season requires a labor factor of 3.2. An average was not used for cotton due to the difference between the two values.

Consumption rate: There is no consumption rate for cotton. It is grown strictly for income generation and is sold to the cotton companies for cash.

4.3.6 Labor cost:

Labor as described earlier in the chapter directly relates to household labor. There are no costs associated with household labor as the members contribute their labor and receive the benefits directly. In comparison, paid labor or hiring someone outside of the household to do work incurs a cost. Therefore, these two types of labor were separated within the linear programming model as household labor requires no cost while paid labor does.

The cost of paid labor is a set rate regardless of what crop is being harvested. Typically, hiring a "piece worker," an adult male or female to work in the field, costs ZMK 10,000 per half day and ZMK 20,000 per whole day or ZMK 50,000 and ZMK 100,000 per week respectively. Labor costs were calculated using these values and the labor requirements for each crop (Table 4.9). The labor costs for cotton were calculated for early and late sales and a ZMK 20,000 difference was found which was considered a minimal difference and thus the value for the more common late sale was used for the study.

Table 4.9

Labor costs per hectare by crop (ZMK).

Maize	192,500
Groundnuts	300,000
Cotton	1,920,000

CHAPTER FIVE – RESULTS AND ANALYSIS

The top priority of the farmers in Gone Village is to grow enough food to feed their families throughout the year. Their secondary objective is to grow a surplus of subsistence crops or cotton, or a combination of both, to generate income. Income is used to purchase basic foodstuffs such as oil, sugar, and salt, school fees, clothing, incidentals such as candles and matches, pay for medical care when necessary, or to be saved for inputs for the next farming season. The purpose of the study was to determine how a farmer can best allocate his resources to produce maize, groundnuts and cotton when constrained by land, labor and capital resources to generate the highest potential for food security and financial gains.

A linear programming model was used to solve this problem. Although farmers participate at different activity levels and have a varying degree of available resources, patterns emerged allowing the farmers to be grouped into the four types based on social status, available high and low quality land, labor and income. The model was solved for each farmer type in multiple scenarios. Each farmer type is restricted by the same constraints but on different levels (Table 5.1). The first scenario solves the model using typical constraints for each farmer type and data collected from the 2008-2009 growing season to determine the optimal resource allocation by type. The scenarios thereafter use the model to determine the effects changing each constraint can have on a farmer type. They include changes in market prices, land, household labor, cash resources, and food security requirements. These changes are important to look at because changes in constraints can alter the optimal resource allocation for one or more farmer types.

Table 5.1

Typical constraints (right-hand side values) used in the linear programming model for each farmer type.

Type	Size of household (people)	Available household labor	High quality hectares	Low quality hectares	Cash resources (ZMK)	Maize required (kg)	Groundnut required (kg)
1	2	1	0.4	0.3	120,000	240	300
2	3	2	0.6	0.4	220,000	360	450
3	5	3	1.0	0.7	380,000	600	750
4	5	4	1.8	0.7	840,000	600	750

5.1 Scenario One: Optimal land allocation using 2008-2009 price data (maize = ZMK 1,200, groundnuts = ZMK 600, cotton = ZMK 1,450).

The model was first solved for each farmer type using the 2008-2009 data with the constraint that food security requirements be met. The model determined the best allocation of land use and resource use for each farmer type with the goal to maximize profit while meeting the subsistence requirements. It was run twice for each farmer type, once with the low cooperative fertilizer price and once with the higher town fertilizer price which will hereafter be referred to as low and high fertilizer prices respectively.

According to the model, when high fertilizer prices are in effect, a type 3 farmer should allocate all of his low quality land (0.70 ha) to groundnuts, 0.66 hectares of high quality land to maize but apply fertilizer to only 0.55 of this, 0.12 hectares of high quality land to cotton, and 0.22 hectares of high quality land to groundnuts. Under this scenario, only the minimum food security requirements were met. The rest of the available resources were allocated to cotton (Table 5.2). This can be compared to the allocation calculated using low fertilizer prices where the pattern was the same, first meet the minimum food security requirements and then all additional resources were used to grow to cotton, but the allocation of resources was different because of the lower fertilizer cost (Table 5.3). By comparing the different allocations between high and low fertilizer prices, one can see the affect the increased price of fertilizer has on the farmer. In the case of low fertilizer prices, the farmer still has cash resources left over: other constraints are binding. When high fertilizer prices are in effect, the farmer has used all of his cash resources.

Dual values for each constraint were also calculated and are listed for high fertilizer prices and low fertilizer prices (Table 5.2 and Table 5.3 respectively). Dual values represent the rate of improvement for each constraint if it were increased by one unit (Lindo Systems Inc. 2009). For example, in Table 5.2, if a farmer increased his total high quality land by one unit (one hectare), he could increase his profit by just over ZMK 1,000,000. A negative dual value, such as the one listed for maize production, suggests that for every kilogram of maize a farmer grows, he is losing about ZMK 940. This assumes that dual values do not change when constraints are modified by one unit; this is not always true.

Table 5.2

Constraints and optimal resource allocation for type 3 farmers under high fertilizer prices with dual values for each constraint.

Constraint	Constraint quantity	Optimal model allocation	Dual value
Maize (kg)	600	600	-937.71
Groundnuts (kg)	750	750	-290.71
Total high quality land (ha)	1.0	1.0	1,068,857.14
Total low quality land (ha)	0.7	0.7	614,592.85
Cash resources (ZMK)	380,000	380,000	0.66
Household labor	3	1.3	0.00
Optimal model land allocation	**Maize**	**Groundnuts**	**Cotton**
High quality land with inputs (ha)	0.55	0	0.12
High quality land no inputs (ha)	0.11	0.22	0
Low quality land with inputs (ha)	0	0	0
Low quality land no inputs (ha)	0	0.70	0
Profit (ZMK)		968,122	

Table 5.3

Constraints and optimal resource allocation for type 3 farmers under low fertilizer prices with dual values for each constraint.

Constraint	Constraint quantity	Optimal model allocation	Dual value
Maize (kg)	600	600	-250.00
Groundnuts (kg)	750	750	-416.67
Total high quality land (ha)	1.0	1.0	1,220,000.00
Total low quality land (ha)	0.7	0.7	701,500.00
Cash resources (ZMK)	380,000	178,825	0.00
Household labor	3	1.5	0.00
Optimal model land allocation	Maize	Groundnuts	Cotton
High quality land with inputs (ha)	0.60	0	0.18
High quality land no inputs (ha)	0	0.22	0
Low quality land with inputs (ha)	0	0	0
Low quality land no inputs (ha)	0	0.70	0
Profit (ZMK)		1,248,550	

Although the values of the right-hand side constraints were different for each farmer type grouping, the optimal allocation patterns for farmer types 1 and 2 were the same as type 3 under high and low fertilizer prices. When fertilizer prices are high, it means that less fertilizer can be purchased so some high quality land is used to grow maize, but not fertilized. Because maize grown on high quality land with fertilizer produces more kilograms per hectare than maize grown on high quality land without fertilizer, the allocation of more land is required towards maize in order to meet the minimum food security requirement. In this scenario, all three farmer types first allocated their resources to ensure the minimum maize and groundnuts requirements were met and then allocated additional available resources to cotton. In the case of low fertilizer prices, farmers are able to purchase more fertilizer and cover the entire portion of maize grown on high quality land with fertilizer, thus generating a higher output on a smaller piece of land and allowing for more land to be allocated to cotton and resulting in an increase in profits. The land constraint was the only limiting factor for all three types and not all of the cash resources and labor were utilized. In the case of high fertilizer prices, land and cash resource constraints were limiting factors, but labor was not.

Similar to farmer types 1-3, type 4 farmers were limited by the land constraint in both scenarios. However, unlike the other types, they were never limited by cash resources, but they were limited by the labor constraint at both high and low fertilizer prices. With high fertilizer prices, the minimum maize and groundnut requirements were met first and additional resources were allocated towards cotton. Labor restricted type 4 farmers from producing the maximum amount of cotton under the land constraint while meeting the minimum maize and groundnut requirements. This forced type 4 farmers to slightly increase groundnut production because the labor requirement for growing groundnuts is lower. The same occurred with low fertilizer prices but instead of overcompensating in groundnut production, it was more profitable to overcompensate in maize production because the input costs for maize were lower in this scenario.

After solving the model for each farmer type under both fertilizer price scenarios, it was determined that land is a limiting factor for all farmer types as every farmer type utilized all of their land in all variations of the scenario. In addition, cash resources are a limiting factor for farmer types 1-3 when high fertilizer prices are in effect and labor is a limiting factor for type 4 farmers at both fertilizer price levels. All farmer types, after meeting the minimum food security requirements, will gain the most profit by allocating their additional resources to cotton.

These findings were consistent with the current farming practices in the study area. They first ensure they can meet their food security requirements before allocating any land to cotton. Farmers surveyed stated if they felt they would not be able to meet the food requirement they would not grow cotton, and four farmers surveyed did not grow cotton during the 2008-2009 because they ran out of maize and groundnuts after allocating a portion of their land to cotton in the 2007-2008 growing season.

The dual values reported suggest that changes in each constraint can impact all farmer types and change the optimal resource allocation depending on the change made. These guided how constraints were altered in the model for the rest of this study.

5.2 Scenario Two: Optimal land allocation using "normal" price data (maize = ZMK 1,200, groundnuts = ZMK 600, cotton = ZMK 1,200).

After the model was run for all farmer types in Scenario One, it was run again using the same constraints but replaced the 2008-2009 price data for maize, groundnuts, and cotton, with normal price data to see what the results would be under a normal market price year. The results under Scenario Two were identical to those in Scenario One except that overall profit was slightly less due to the reduction in the price of cotton. Therefore, the remainder of the scenarios were solved using normal prices for maize, groundnuts and cotton unless otherwise noted.

5.3 Scenario Three: Change in market prices.

Because relative prices may change annually or seasonally, it is important to consider optimal allocations under other price scenarios. Groundnut prices do not vary significantly in comparison to maize and cotton and therefore the price of groundnuts was kept constant at ZMK 600 for all scenarios. Looking at scenarios under varying price schemes enables one to gauge the relationship between maize and cotton prices and what affects changes in the relative market value of each can have. Increases or decreases in the price of cotton can affect the optimal allocation of a farmer's resources. In this scenario, the model was first solved for each farmer type under each fertilizer price using three different prices for cotton, low at ZMK 850, average at ZMK 1,200, and high at ZMK 1,450. At each level, the price of maize was manipulated until the price was found where the model no longer allocated any land to cotton. All constraints remained constant and the market price maize must reach to reduce or halt cotton production completely relative to the three cotton price levels was determined (Table 5.4).

Table 5.4

Market price maize must reach to stop cotton production when cotton prices are low, normal, and high by farmer type (ZMK).

Cotton Price:	Low (ZMK 850)		Normal (ZMK 1,200)		High (ZMK 1,450)	
Fertilizer Price:	High	Low	High	Low	High	Low
Type 1	0	0	1,770	1,201	2,140	1,500
Type 2	0	0	1,770	1,201	2,140	1,500
Type 3	0	0	1,770	1,201	2,140	1,500
Type 4	0	0	1,620/1,770	1,201	1,875/2,140	1,500

According to the model, when cotton prices are low, regardless of fertilizer prices, it is not beneficial for any farmer type to grow cotton. Instead, the minimum maize requirement is met and all additional resources are shifted to groundnut production. When the observed cotton prices are average or high, the model suggests maize prices must be higher than the price of cotton in order for growing maize to be more profitable than growing cotton at both fertilizer prices. In these two scenarios, the minimum groundnut requirement is met and additional resources are allocated to maize.

For type 4 farmers, two prices are listed when high fertilizer prices are used with the average and high cotton prices (Table 5.4). The first is the price at which reducing cotton production but not completely eliminating it becomes more profitable. In this case, the farmer grows as much maize as he possibly can on high quality land with fertilizer until he is restricted by cash resources and then he shifts the remaining high quality land to cotton production, only the minimum groundnut requirement is met. The second price is the price where it is no longer profitable to grow any cotton and this is the same price listed for types 1-3. Instead, the minimum groundnut requirement is met, maize is produced on high quality land with fertilizer until cash resources are exhausted and the remainder of high quality land is allocated to maize without fertilizer. The reduction but not complete elimination, of cotton allocation was only relevant for type 4 farmers.

The model was solved a second time to determine a “breakpoint” price of cotton. A breakpoint is defined as “a convenient point at which to make a change, interruption, or the like” (Random House College Dictionary 1975). For the purposes of this study, the breakpoint price is defined as the price where the cost becomes greater than or equal to the benefit. In other words, the price at which profits are no longer obtained and therefore are equal to zero. To determine the breakpoint price of cotton, the price of maize and groundnuts were entered into the model at zero. The model was solved for each farmer type under each fertilizer price by lowering the price of cotton until land allocation of cotton equaled zero. All other constraints remained constant. The result was the price at which the optimal allocation shifts from growing cotton to only growing maize and groundnuts (Table 5.5).

Table 5.5
Breakpoint price for cotton in ZMK by farmer type under high and low fertilizer prices.

	High fertilizer price	Low fertilizer price
Type 1	880	460
Type 2	880	460
Type 3	880	460
Type 4	240	240

For farmer types 1, 2, and 3, when fertilizer prices are high and the price of cotton drops below ZMK 880, they should no longer continue growing cotton because the cost outweighs the benefit. It is worth noting that this price is close to the low cotton price of ZMK 850 mentioned in the scenario above. When low fertilizer prices are in effect, farmer types 1-3 should discontinue cotton production if the price drops below ZMK 460.

The pattern for farmer type 4 is different than farmer types 1-3 because they are typically limited by labor and land where as types 1-3 are limited by cash resources and land. Regardless of fertilizer price, type 4 farmers can continue to make a profit on cotton until the price drops below ZMK 240.

5.4 Scenario Four: Change in available land.

When the model was solved to determine optimal land allocation using typical constraints and normal market price data, the result was that available land limits all farmer types. If farmers had access to more land they would be able to increase profits and utilize more of their resources such as labor or cash resources. The dual values for land reported using the typical data suggest that if farmers had access to more land they could significantly increase their profits (Table 5.6). If farmer types 1, 2, and 3 had access to one more hectare of high quality land they could increase their profits by approximately ZMK 885,000 when fertilizer prices are high and ZMK 970,000 when fertilizer prices are low. If they could access one more hectare of low quality land they could increase their profits by ZMK 509,000 at high fertilizer prices and ZMK 558,000 at low fertilizer prices. For type 1 farmers, a one hectare increase in high quality land would more than double the profits made at the typical optimal allocation, assuming dual prices remain constant with a one hectare change.

Table 5.6

Dual values for land constraint by farmer type with profit (ZMK).

Farmer Type	Land Type	Constraint quantity (ha)	Dual value (high fertilizer price)	Dual value (low fertilizer price)
1	High quality	0.4	884,571	970,000
	Low quality	0.3	508,628	557,750
	Profit		373,251	492,825
2	High quality	0.6	884,571	970,000
	Low quality	0.4	508,628	557,750
	Profit		549,302	711,350
3	High quality	1.0	884,571	970,000
	Low quality	0.7	508,628	557,750
	Profit		937,411	1,204,175
4	High quality	1.8	662,307	970,000
	Low quality	0.7	356,307	414,000
	Profit		1,826,185	2,035,800

Opportunities to purchase, rent, or receive extra land are rare in the study area. Land is a limiting resource because of increasing population and most land had been distributed many years ago by the chief. There is little or no opportunity to purchase land and requests for an additional parcel of land from the chief are almost always denied. According to the survey, most farmers utilize all of their land and are unwilling to rent a portion. Those that do have land to rent have a difficult time finding renters. Farmers who can afford to rent are hesitant to do so because even though the renter has paid for the land lease, the owner has the right to reclaim that land back at anytime as long as they repay the renter if the claim is made before the lease is up. This means that a renter may put in the time and energy to prepare, plant, and weed a crop, but before it comes time to harvest, the owner can claim that land back as well as whatever is on it at the time, and the renter will no longer legally be entitled to the crop on that field. There was only one farmer surveyed that rented land because he did not own any land and therefore had no other option.

The most common way a farmer can acquire land is through inheritance. When a son gets married it is tradition that his father will give the son a portion of his land. This reduces the total number of hectares available to the father, but increases the total number of hectares available for the son. Another way a farmer may gain land is through death. If a family member dies, their land may be distributed among living relatives, thus increasing the land available for the family members of the deceased. Gaining or losing land can impact the optimal allocation of resources, and because it is clear from the initial optimal allocation model solved that land is always a limiting factor, the following scenario focuses only on the impact of increasing land for each farmer type.

In this scenario, the model was solved to determine how many hectares of high quality land or low quality land each farmer type would need to possess in order for land to no longer be a limiting factor. In other words, to determine the point at which a farmer would run out of a different resource (cash or labor) before they were able to allocate all of their land. The model was first solved using the typical constraints for each farmer type to show what farming practices each type typically engaged in at high and low fertilizer prices (Table 5.7). To determine how many hectares a farmer would have to acquire, the model was solved for each farmer type under both fertilizer prices and for each land quality (high or low). For high quality land, the high quality land constraint was increased while the low quality value remained constant at the typical farmer type value until the total number of hectares allocated by the model became less than the sum of the high quality and low quality land constraints. For low quality land, the low quality land constraint was increased while the high quality value remained constant at the typical farmer type value until the total number of hectares allocated by the model became less than the sum of the low quality and high quality land constraints. The model was then solved by increasing the respective land constraint until the dual value was equal to zero. All other constraints remained constant. The point at which allocation shifts from growing cotton to eliminating cotton production was also noted, as well as the farming practices each farmer type engaged in at all three points (Table 5.8). All other constraints remained constant.

Table 5.7

Farming practices associated with typical optimal allocation by farmer type.

Fertilizer price	Farmer Type	Total ha available	Hire labor	Produce excess maize	Produce excess groundnuts	Use inputs
High	1	0.7	N	N	N	Y
Low	1	0.7	N	N	N	Y
High	2	1.0	N	N	N	Y
Low	2	1.0	N	N	N	Y
High	3	1.7	N	N	N	Y
Low	3	1.7	N	N	N	Y
High	4	2.5	N	N	Y	Y
Low	4	2.5	N	Y	N	Y

Table 5.8

Hectares of high or low quality land that must be obtained to stop cotton production, eliminate land as limiting factor, dual value = 0 and associated farming practices. (Yellow and pink boxes show examples where number of hectares do not change, blue and purple boxes show farm practice pattern shifts from the point where cotton production halts to land no longer limiting and dual = 0, and the green box shows an example where farm practice patterns remain consistent throughout.)

	Fertilizer price	Farmer type	Number of hectares a farmer must acquire to eliminate cotton production.	Hire paid labor?	Produce excess maize?	Produce excess groundnuts?	Use fertilizer?	Number of hectares a farmer must acquire for total land to no longer be a limiting constraint.	Hire paid labor?	Produce excess maize?	Produce excess groundnuts?	Use fertilizer?	Number of hectares a farmer must acquire for dual value land constraint to equal zero.	Hire paid labor?	Produce excess maize?	Produce excess groundnuts?	Use fertilizer?
High quality land (ha)	Low	1	**1.4**	N	Y	Y	Y	**1.4**	N	Y	Y	Y	**2.3**	Y	Y	Y	N
		2	**3.0**	N	Y	Y	Y	**3.0**	N	Y	Y	Y	**4.5**	Y	Y	Y	N
		3	**4.4**	N	Y	Y	Y	**4.4**	N	Y	Y	Y	**7.0**	Y	Y	Y	N
		4	**6.3**	N	Y	Y	Y	**6.3**	N	Y	Y	Y	**11.1**	Y	Y	Y	N
	High	1	**1.4**	Y	N	Y	Y	**2.0**	Y	N	Y	N	**2.3**	Y	Y	Y	N
		2	**3.0**	Y	N	Y	Y	**4.1**	Y	Y	Y	N	**4.5**	Y	Y	Y	N
		3	**4.4**	Y	N	Y	Y	**6.3**	Y	Y	Y	N	**7.0**	Y	Y	Y	N
		4	**6.3**	N	N	Y	Y	**10.3**	Y	Y	Y	N	**11.1**	Y	Y	Y	N
Low quality land (ha)	Low	1	**1.3**	N	Y	Y	Y	**1.4**	Y	Y	Y	Y	**1.4**	Y	Y	Y	Y
		2	**2.8**	Y	Y	Y	Y	**3.2**	Y	Y	Y	Y	**3.2**	Y	Y	Y	Y
		3	**4.1**	Y	Y	Y	Y	**4.8**	Y	Y	Y	Y	**4.8**	Y	Y	Y	Y
		4	**5.1**	Y	Y	Y	Y	**7.1**	Y	Y	Y	Y	**7.1**	Y	Y	Y	Y
	High	1	**1.3**	Y	N	Y	Y	**1.9**	Y	N	Y	N	**1.9**	Y	N	Y	N
		2	**2.8**	Y	N	Y	Y	**3.9**	Y	N	Y	N	**3.9**	Y	N	Y	N
		3	**4.1**	Y	N	Y	Y	**6.0**	Y	N	Y	N	**6.0**	Y	N	Y	N
		4	**4.9**	N	N	Y	Y	**9.3**	Y	Y	Y	N	**9.3**	Y	Y	Y	N

By looking at Table 5.8, one can see patterns emerge in the practices farmers engage in under each scenario and the changes as the total number of hectares of high quality or low quality land they have available increases.

5.4.1 Number of hectares of land a farmer must acquire for land to no longer be a limiting factor vs. the number of hectares a farmer must acquire for dual value to equal zero.

For increases in low quality land, the number of hectares that must be acquired for land to no longer be limiting and for the dual value to equal zero is the same. This is because even as low quality land increases, high quality land (which remains constant) will always be utilized first regardless of how much low quality land is added. The reason for this is because high quality land is more productive than low quality land. For high quality land however, as the number of hectares increases, the model stops allocating to low quality land first rather than high quality land. It is more efficient to leave low quality land idle and apply resources to the more productive high quality land. The point where the number of hectares of low quality land allocated by the model becomes less than the constraint value for low quality land is the point where land was no longer a limiting factor for high quality land because all land is no longer being utilized. Furthermore, the point at which the dual value equals zero is equivalent to the point where the number of hectares of high quality land becomes less than the high quality land constraint and at this point the number of hectares of low quality land allocated is zero.

5.4.2 Increases in available high quality land. [Yellow and blue boxes, Table 5.8]

If farmers can increase the number of hectares of high quality land available when fertilizer prices are low, the point at which all farmer types stop producing cotton is the same as the point at which land is no longer a limiting factor (Table 5.8, outlined in yellow). They do not hire labor but use fertilizer and produce excess maize and groundnuts. When they reach the point where the dual value equals zero, all farmer types allocate resources to hiring labor instead of using fertilizer. This means farmers are now growing maize on high quality land without inputs and hiring labor to increase the number of hectares of land they can grow maize on. In this scenario, profit made by growing maize by hiring labor on more land without using fertilizer is now more than the profits made while using fertilizer. This is not the case with high fertilizer prices.

When fertilizer prices are high, type 2 and type 3 farmers follow the same pattern changing from growing only excess groundnuts and using fertilizer at the point where cotton is no longer profitable to stopping the use of fertilizer and growing excess maize in addition to excess groundnuts when land is no longer limiting (Table 5.8 outlined in blue). At both points they use hired labor. Although the number of hectares required to reach a zero dual value is slightly higher, the practices remain the same. Type 1 and type 4 farmers have slightly different patterns. Type 1 farmers employ differing practices at all three points while type 4 farmers follow the same practices as types 1 and 2 after reaching the point where land is no longer a limiting factor.

5.4.3 Increases in available low quality land. [Red, green and purple boxes, Table 5.8]

When low quality land is increased under both fertilizer scenarios, the number of hectares required for land to no longer be a limiting constraint is the same as the point where the dual value becomes zero for all four farmer types (Table 5.8, outlined in red). When fertilizer prices are low, type 2, 3, and 4 farmers engage in identical practices at all points (Table 5.8, outlined in green). They hire labor, produce excess maize and groundnuts and use fertilizer inputs. Type 1 farmers differ from this only at the point where cotton production halts because they do not hire labor at this point.

At high fertilizer prices, farmer types 1-3 all follow the same pattern changes from halting cotton production to the point where land is no longer a limiting factor (Table 5.8, outlined in purple). At the point where cotton production halts, these farmers hire labor, produce excess groundnuts and use fertilizer. When land is no longer limiting, the only practice that changes is that they no longer use fertilizer. Type 4 farmers do not hire labor or produce excess maize at the point where cotton production is stopped, but they do use fertilizer and produce excess groundnuts. When the point is reached where land is no longer limiting, they continue to produce excess groundnuts but they now hire labor, produce excess maize and discontinue the use fertilizer.

Though the number of hectares of land each farmer type would have to acquire in order for these scenarios to be relevant is unlikely, the data provides a wider picture that can be used on a larger scale that may relate to areas of Zambia that are less populated and where land is not a limiting factor. It also suggests that cotton production may be a function of limited land, as the number of hectares of available land increases cotton production is halted.

5.5 Scenario Five: Change in household labor.

Various situations can cause an increase or decrease in household labor. The most common situation is the death of a household member. If there is a death of a contributing household member, the labor available is reduced. If a family member outside the household dies, the household may take in a relative as a result thus potentially increasing the amount of available household labor.

Farmer types 1, 2, and 3 are not typically restricted by labor. However, type 4 farmers were restricted by labor in the typical constraints optimal allocation model under both the high and low fertilizer scenarios. Changes in household labor could alter the optimal allocation of land and resources for type 4 farmers as well as the potential profit that could be gained. In this scenario, the model was solved by increasing the available household labor constraint for type 4 farmers under both fertilizer price scenarios to determine the effect it would have on profit. All other constraints remained constant (Table 5.9).

Table 5.9
Difference between constrained optimal allocation (Constrained) and the optimal allocation when labor is not a factor (Optimal labor) for type 4 farmers.

	Low fertilizer price		High fertilizer price	
	Constrained	Optimal labor	Constrained	Optimal labor
Profit (ZMK)	1,980,175	1,980,175	1,730,069	1,731,175
Household labor	4	4.0115	4	4.0115

The increase in household labor required for optimal labor resource allocation when limited by the other constraints is minimal and has little or no impact on profit (Table 5.9). An addition of 0.0115 of household labor is required to no longer limit a type 4 farmer in both low and high fertilizer scenarios, and the addition has no impact on profit at the low fertilizer price and provides a 0.0064 percent increase on profit at the high fertilizer price. Because the difference for type 4 farmers is minimal, and types 1, 2, and 3 are also not constrained by labor, it suggests that labor is readily available and not typically a constraining factor for any of the farmer types. This is consistent with what occurs in the study area, as people are often looking to be hired for “piece work” so that they can gain extra income because there are times when it is not necessary for them to be in their own fields.

5.6 Scenario Six: Change in available cash resources.

Farmers earn money throughout the year by selling produce grown in their gardens or excess subsistence crops, growing cotton, participating in other livelihood strategies such as beekeeping or making reed mats, and by doing piece work or other small jobs. Available cash resources that farmers have to put towards farming activities can change the optimal allocation.

Farmer types 1, 2, and 3 are all limited by cash resources when the price of fertilizer is high. If these farmers had access to more cash resources it could alter the optimal allocation of land and resources. In this scenario, the model was solved by increasing available cash resources to determine the amount of cash a farmer must obtain in order for cash resources to no longer be a limiting factor. This scenario assumed high fertilizer prices were in effect and was solved only for farmer types 1, 2, and 3. The model was not solved using the low fertilizer price scenario because cash resources were not a limiting constraint when the scenario was solved to find the optimal allocation. The model was not solved for type 4 farmers as they are not limited by cash resources regardless of fertilizer price. In order to solve the model, the cash resource constraint was increased until it reached the point where having additional cash resources no longer increased the profit. All other constraints remained constant (Table 5.10).

Table 5.10

Typical available cash resources and breakpoint cash resources with associated profits.

Farmer Type	1	2	3
Typical available cash resources	120,000	220,000	380,000
Profit with typical cash resources	373,251	549,303	937,411
Cash resource breakpoint	173,775	254,050	427,825
Profit at breakpoint	393,225	561,950	955,175
Increase of cash resources required (breakpoint cash resources - typical cash resources)	53,775	34,050	47,825
Increase of profits gained (breakpoint profit - typical cash resource profit)	19,974	12,647	17,764

The effect of increasing cash resources on the three farmer types is minimal (Table 5.10). Type 1 farmers would need a 14.4 percent increase in cash resources to reach the breakpoint which would only be a 5.1 percent increase in profit. Similarly, type 2 and type 3 farmers would need a 6.2 and 5.1 percent increase in cash resources resulting in a 2.3 and 1.9 percent profit increase respectively. Overall, the impact of gaining more cash resources when fertilizer prices are high for farmer types 1-3 is minimal.

5.7 Scenario Seven: Elimination of food security requirements.

Maize and groundnut requirements can also be considered constraints that affect the optimal land and resource allocation. If a farmer can purchase some or all of the food security requirements, it could change the optimal resource allocation because the farmer would not be forced to allocate land to grow maize and groundnuts to meet the requirements. In order for purchasing food requirements to be beneficial to the farmer, the profit of the allocation without the requirement constraint must be greater than the profit of having the requirement restraint less the cost of purchasing the minimum food security requirements.

The model was first solved for each farmer type to determine profit with typical food security requirement constraints under high and low fertilizer prices. It was then solved to determine profits for all farmer types at high and low fertilizer prices under three food security constraint scenarios, maize requirement = 0, groundnut requirement = 0, and both maize and groundnut requirements = 0. All other constraints remained the same.

A type 3 farmer would have to purchase 600kg of maize at ZMK 1,200/kg if he wanted to eliminate his maize food security requirement (maize requirement = 0) under both fertilizer scenarios. This means ZMK 720,000 (600kg*ZMK 1,200/kg) must be subtracted from the profit when the model is solved with the maize requirement at zero to determine the actual profit the farmer made because he is no longer satisfying his food security requirement by growing maize, but rather he is buying it instead. This calculated profit must be more than the resulting profit when the model is solved with the normal food security constraints in order for purchasing food requirements to be considered more beneficial.

The results from solving the model under both fertilizer price scenarios and using the three food security constraint scenarios determined that given the other constraints, there was no combination for any farmer type in which purchasing food requirements turned out to be more profitable than growing it. This is consistent with the study area as all farmers surveyed attempt to grow their food security requirements themselves and only purchase maize when their storage has run out because they did not grow enough and they are left with no other option.

5.8 General analysis.

Exogenous market prices and the resources farmers have access to act as constraints and changes in these constraints can determine the optimal allocation of resources for all farmer types. Land was the factor that limits all farmer types, while labor limited type 4 farmers and cash resources limited farmer types 1-3. Under both fertilizer prices for all farmer types, land was always a limiting factor (Table 5.11). While labor limited type 4 farmers, the additional labor a type 4 farmer must obtain to no longer be limited by this constraint was so small (0.0115) it had little or no effect on profit gained by the farmer (Table 5.9). Similarly, for farmer types 1-3, available cash resources were limiting under the high fertilizer scenario, but when the constraint was increased, it was found that the impact of adding cash resources also had minimal impact on the profit (Table 5.10).

Overall, the land constraint was the largest limiting factor restricting farmers. Land is the most difficult resource for farmers to obtain more of and thus the least likely constraint to be increased. Conversely, farmers may be provided with opportunities to increase their labor and cash resources. Nonetheless, the optimal increases in labor and available cash resources had little or no affect on profit gains. Lastly, solving the model with enough land to remove it as a limiting factor leads to the elimination of cotton production. This suggests production of cotton may be a function of limited land. However, under the current constraints that farmers face, the optimal resource and land allocations solved by the model suggest that cotton production should be included in the farm system, and is a valuable and beneficial practice for farmers who desire to maximize their financial gains.

Table 5.11

Limiting factors for each typical farmer type.

	Fertilizer Price	Land	Labor	Available Cash
Type 1	High	X		X
Type 2	High	X		X
Type 3	High	X		X
Type 4	High	X	X	
Type 1	Low	X		
Type 2	Low	X		
Type 3	Low	X		
Type 4	Low	X	X	

CHAPTER SIX – CONCLUSIONS

The study in Gone Village determined that farmers are making good decisions when it comes to the allocation of their land. Changes in market prices, available land, labor, and cash resources can influence the optimal resource allocation for each of the four farmer types. Previous studies have used methods like the ones used in Gone to solve similar problems. Other studies have also looked at some of the same problems such as changes in market prices and constraining resources in different settings. Some of the previous studies produced similar results to the Gone findings while others produced contradictory findings.

In Gone, after solving the linear programming model, under current and normal market prices and typical constraints for each farmer type, all farmer types will first meet only the minimum food security requirements and then allocate remaining land to cotton. A similar study analyzing teak and using a linear programming model focused on optimal land allocation for Togolese landholders growing maize (a subsistence crop), cassava (a subsistence crop), and teak (a cash crop). Results found that most farmers should meet their minimum maize requirement, exceed the minimum cassava requirement and allocate only a small portion of their land to teak (Kenny 2007). The findings were consistent with the current practices of growing teak in Togo, just as the findings in Gone were consistent with current farming practices, suggesting that linear programming is an effective tool for understanding problems like these. The author was surprised to find farmers making good decisions in regards to teak, similar to the unexpected results in Gone showing farmers tend to make good choices in regards to cotton production.

Another study looked at tobacco production in Malawi. Participation in tobacco production provided the highest potential for income generation available to smallholder farmers. In addition, farmers participating in tobacco production typically earned more than those who did not, regardless of the other livelihood strategies carried out by the farmers (Masanjala 2005). Though the Gone study did not look at other livelihood strategies, findings were consistent in that, with the available resources smallholder farmers currently have, all additional resources were allocated to cotton after meeting the minimum food security requirements to gain the most profit for each farmer type. Thus, the benefits of cotton production in Gone are similar to those of tobacco production in Malawi since the model in this study allocated all additional resources to cotton to provide the maximum profit gains for all farmer types.

Findings from Gone showed that changes in market prices determine whether or not farmers should grow cotton. A study of the livelihood systems of residents in the Soledad community in Oxaca, Mexico used a linear programming model to look at the effects of changing practices and market value of palm fronds (Wisley and Hildebrand 2011). Farmers changed palm frond collection from a traditional method to a practice that allows for certification and thus increased value on the market. The Gone study looked at the integration of a relatively new practice of incorporating cotton into the farming system and the effects change in market value can have on the profitability. Soledad residents were willing to collect palm fronds using practices that would allow them to sell at certification prices (higher market prices) and earn more than when using traditional collection methods. In Gone, increases in cotton prices relative to maize prices can increase the profit farmers make when allocating land to cotton. The more modern practices have higher commodity prices associated with them.

The Gone study dealt with one market in which prices change annually and found there were set market prices cotton must reach in order for it to be profitable to farmers. Kenny (2007) reported similar findings, growing teak was only profitable for Togolese farmers if they were able to sell it in the informal market even though a formal government market was available to farmers. These findings suggest price limitations can determine optimal allocations and practices.

In Sub-Saharan Africa intra-seasonal variation in market prices is inevitable (Poulton et al. 2006), which concurs with the variations in the price of maize and groundnuts at different times of the year in Gone. The inelastic demand for many staple crops in Sub-Saharan Africa, maize for example, and the imperfections of the commodity market can influence the affect it has on farmers from year to year. These findings are consistent with the Gone findings as the change in the price of maize can affect the optimal allocation and profit a farmer can earn based on the market prices.

In the same paper, prices in traditional export markets specifically relating to cotton were discussed. The paper stated, "Although world cotton prices are expected to remain below their historic (30-year) levels throughout the next decade, this is one commodity where African producers are believed to have a realistic chance of increasing market share," (Poulton et al. 2006). Data collected in Gone supports the suggestion that cotton is a profitable practice for farmers in the study area as cotton prices are currently on the rise, possibly reaching record highs, and the Gone findings show in most cases cotton production is the most profitable practice for all four farmer types.

The Kano Close-Settled zone of Nigeria is an area where all land is cultivated because of high population density, therefore farmers must practice efficient farming practices due to the limitations of land (Harris 1996). The Kano study determined that even though land is limiting in the area, farmers have been able to adapt current farm practices by making changes in resources they can control. These changes in resource allocation allow the farmers to continually increase outputs and be productive even under continued constraints and limitations. Farmers in Gone may benefit from adding or looking at alternative practices like those practiced in the Kano Close-Settled Zone. Unlike the Kano farmers, farmers in Gone do not have readily available access to oxen or oxcarts, but they can access manures and composting materials that could be applied in place of fertilizer which could potentially reduce the amount of fertilizer required, thus freeing up more cash resources.

In Gone, changes in household labor had little or no impact for all farmer types and did not change the optimal land allocation. Similar to the Kano study, the Gone study area has a high population density and extra labor is readily available. In the Kano Close-Settled Zone extra labor can be utilized to promote better inputs on land and better farming because farmers in the Kano Close-Settled Zone are able to hire people to collect or apply inputs such as manure or compost. In Gone, these practices are not seen as farmers typically allocate their additional cash resources to adding inputs rather than hiring additional labor.

The Gone study found that changes in food security requirements affect the allocation of land and whether cotton should be grown, but overall it was not beneficial for farmers to purchase their food security requirements as farmers saw greater profits if they continued to grow the requirements and only allocated additional land to cotton. Other findings suggest that food price instability encourages poor producers to prioritize production of food security crops before expanding to cash crops which potentially provide higher returns (Poulton et al. 2006). The Gone study determined that, for all farmer types, growing food security crops for home consumption before diversifying to cotton was more profitable than purchasing food security requirements and thus allowing more land and resources to be allocated towards cotton.

In Zimbabwe, farmers consumed the majority of maize produced at the household level. In contrast, 100 percent of cotton production was used for income generation and market sale only (Govereh and Jayne 2002). Results also determined that households involved in cotton production resulted in higher gross per capita crop incomes than those that were not. These findings are similar to the practices in Gone as it is generally the type 3 and type 4 farmers who grow cotton annually and they typically have higher income than type 1 and 2 farmers. In Zimbabwe, favorable conditions allowed farmers to purchase additional food security needs from local markets and thus farmers were able to allocate more land to cotton production. The Gone study was set up with the requirement that farmer types produce their food security requirements first. However, when the food security constraint was removed and the model was solved, results from Gone determined it was still more profitable for farmers to grow their own food security requirements rather than purchase them at the market.

Smallholders in eastern and southern Africa do not participate in the staple food grain markets on any significant scale (Barret 2008). These findings are consistent with the farming practices in Gone as farmers typically grow their food security requirements and turn to cotton if they want a crop to sell on the market, rather than growing excess maize.

In Malawi, when comparing livelihood strategies, smallholder farmers will only participate in tobacco production if they anticipate the returns will put them in a position higher than or equal to the status quo (Masanjala 2005). Similar to Gone, the decision of whether or not a farmer would participate in tobacco production had to be made at the beginning of the growing season. Thus, the anticipated growing season conditions, previous household activities and changes in market value all played a considerable role in this decision. For tobacco production in Malawi, farm size, farm capital, labor supply and experience with credit were all factors influencing farm decisions, suggesting these are good determinants in the Gone study for feasibility of growing cotton.

The farmers of Gone village rely on their land and available resources to provide food security as well as additional income for their families. Cotton is an attractive crop because it can potentially provide farmers with a large sum of cash. This money can be used to purchase farm inputs, clothing, and incidentals or for entertainment purposes as well as increasing the overall well-being for members of the household. Farmers who choose to allocate some or all of their land to cotton production are taking a potential risk. If the crop fails, the farmer is unable to sell, or cotton prices drop significantly from what was promised, it will decrease the farmer's expected returns. Land allocated to maize and groundnuts provides a safer and more reliable option. Even if the excess food security crops cannot be sold, they can be stored or consumed. However, lower risk means limited opportunities for profit gains, especially as commodity prices vary within and across seasons (Poulton et al. 2006).

The Gone study confirmed that the farmers of Gone Village are currently making wise choices when it comes to cotton production. Results from solving the model for each farmer type showed that under current market prices, optimal allocation includes cotton in the farm system to produce the maximum profit. The scenarios run in the model also determined land is generally the most restricting constraint that farmers face. While cash resources and labor have some impact as well, it is generally minimal. Ultimately, farmers must determine what is best for them and what they can manage with their given resources. It is important to look at the market influence of cotton and the factors that affect it as well as the potential positive or negative impact cotton production can have on a farmer. If cotton prices continue to rise, cotton appears to be a good option for small-scale farmers in Gone Village to continue or begin practicing with their additional resources.

The findings from Gone are likely relevant to farmers in nearby villages throughout the district and even other rural areas of Zambia where farmers face many of the same constraints and land limitations as the farmers in Gone Village. Beyond Zambia, the findings may also be expanded to other areas or regions throughout Africa where land and resource allocation could be studied to determine whether production of cotton or other cash crops may be a good option for rural farmers in order to obtain optimum benefits from their available resources.

LITERATURE CITED

Abbiw, D.K. 1990. Useful Plants of Ghana. Intermediate Technology Publications Ltd. London, UK. And Royal Botanic Gardens, KEW. Surrey, UK, pp. 31.

Barrett, C.B. 2008. Smallholder market participation: Concepts and evidence from eastern and southern Africa. *Food Policy.* 33, 299-317.

Beneke, R. and Winterboer, R. 1973. Linear Programming Applications to Agriculture. The Iowa State University Press. Ames, Iowa.

Bernard, H. 2002. Research Methods in Anthropology: Qualitative and Quantitative Approaches, 3rd ed. AltaMira Press. Walnut Creek, CA, pp. 188, 204, 323-333.

CIA (Central Intelligence Agency). 2011. The World Factbook: Zambia. Available online at: https://www.cia.gov/library/publications/the-world-factbook/geos/countrytemplate_za.html. Site accessed 13 January, 2011.

Encyclopedia of the Nations. 2011. Zambia – Political Background. Available online at: http://www.nationsencyclopedia.com/. Site accessed 21 January, 2011.

Harris, F. 1996. Intesnsification of Agriculture in Semi-arid Areas: Lessons from the Kano close-settled zone, Nigeria (Gatekeeper Series No. SA59). International Institute for Environment and Development, Sustainable Agriculture Programme.

Govereh, J. and Jayne, T.S. 2002. Cash cropping and food crop productivity: synergies or trade-offs? *Agricultural Economics.* 28, 39-50.

Guhrs, T., Kapwepwe, M., and Elbee, F. 2007. Ceremony! Celebrating Zambia's Cultural Heritage. Celtel Zambia PLC and Seka (Sensitisation and Education through Kunda Arts). Lusaka, Zambia, pp. 43-65.

Hiller, F. and Liberman, G. 1986. Introduction to Operations Research. Holden-Day, Inc. Oakland, California.

Holmes, T. 2007. The History of Zambia. The Zambian. Available online at: http://www.thezambian.com/art-culture-tradition/b/history/archive/2007/09/26/the-history-of-zambia.aspx. Site accessed 12 February 2011.

JAICAF (Japan Association for International Collaboration of Agriculture and Forestry), 2008. The Maize in Zambia and Malawi. Association for International Colloboration of Agriculture and Forestry, Minato-ku, Tokyo, Japan. pp. 3-23.

Jenkins, K. and Phiri, D. 2009. Peace Corps Zambia. LIFE Pre-Service Training Technical Manual.

Kenny, A. 2007. Optimal Land Allocation of Maize, Cassava and Teak for Small Landholders in Southern Togo, West Africa. Downloadable at: http://forest.mtu.edu/pcforestry/people/2003/Kenny.pdf.

Lindo Systems Inc. 2009. What's Best! The spreadsheet solver. LINDO Systems Inc. Chicago, Illinois.

Loizos, P. and Pratt, B. 1992. Choosing Research Methods: Data Collection for Development Workers. Oxfam Publishing, Oxford, pp. 22-26, 63-65.

Masanjala, W.H. 2005. Cash crop liberalization and poverty alleviation in Africa: evidence from Malawi. *Agricultural Economics.* 35, 231-240.

McCann, J. 2001. Maize and Grace: History, Corn, and Africa's New Landscapes, 1500-1999. Boston University, Society for Comparative Study of Society and History, pp. 246-272.

Nichols, P. 2000. Social Survey Methods: A Fieldguide for Development Workers. Oxfam Publishing, Oxford, pp. 12-13.

Poulton, C., Kydd, J. and Dorward. A. (2006) Overcoming Market Constraints on Pro-Poor Agricultural Growth in Sub-Saharan Africa. *Development Review Policy.* 24(3), 243-277.

Prentice, A.N. 1972. Cotton: With Special Reference to Africa. Longman Group Limited, London, pp. 1-36, 136-153, 175-185, 195-253.

Random House College Dictionary, Revised Edition Deluxe. 1975. Random House Inc. New York.

Saasa, O.S. July 2003. Agricultural Intensification in Zambia: The Role of Policies and Policy Processes (Macro Study). Institute of Economic and Social Research, University of Zambia.

Sinkamba, P.K.M. 2010. Zambia's Political Journey to Democracy – What Next? Available online at: http://www.suite101.com/content/zambias-political-journey-to-democracy-what-next-a295987. Site accessed 12 February 2011.

Smith, B.W. 1950. *Arachis hypogaea.* Aerial Flower and Subterranean Fruit. *American Journal of Botany.* 37(10), 802-815.

Tripp, R. 2009. Biotechnology and Agricultural Development. Transgenic cotton, rural institutions and resource-poor farmers. Routledge of Taylor & Francis Group. Abingdon, Oxon, pp. 31-42.

Tschirley, D., Zulu, B. and Shaffer, J. 2004. Cotton in Zambia: An Assessment of its Organization, Performance, Current Policy Initiatives, and challenges For The Future. FSPR Working Paper No.10. Food Security Research Project, Lusaka, Zambia. Downloadable at: http://www.aed.msu.edu/agecon/fs2/zambia/index.htm.

Tschirley, D. and Kabwe, S. 2007. Cotton in Zambia: 2007 Assessment of its Organization, Performance, Current Policy Initiatives, and Challenges for the Future. Working Paper No. 26. Food Security Research Project, Lusaka, Zambia. Downloadable at: http://www.aed.msu.edu/agecon/fs2/zambia/index.htm

World Bank. 2011. Data: By Country: Zambia. Available online at: http://data.worldbank.org/country/zambia. Site accessed 17 January, 2011.

USAID. Undated. HIV/AIDS Multisector. Available online at: http://www.usaid.gov/zm/hiv/hiv.htm. Site accessed 12 February, 2011.

U.S. Department of State. 2010. Bureau of Public Affairs: Background Notes: Zambia. Available online at: http://www.state.gov/r/pa/ei/bgn/2359.htm. Site accessed 12 January, 2011.

Webster, C.C. and Wilson P.N. 1998. Agriculture in the Tropics, 3rd ed. Blackwell Science Ltd. Oxon, United Kingdom, pp. 259-262, 269-270.

Wisley, D.S. and Hildebrand, P.E. 2011. *Chamaedorea* Palm Frond Commercialization and Certification Considered from a Smallholder Livelihood System Perspective. *Small Scale Forestry.* 10(1), 67-81.

World Bank. 2011. Data: By Country: Zambia. Available online at: http://data.worldbank.org/country/zambia. Site accessed 17 January, 2011.

Zimba, S,C. 2007. Historical Development of Forest Policy and Management Practices in Zambia. Copperbelt University School of Natural Resources Department of Forest Resources Management. Kitwe, Zambia.