# Optimal Land Allocation of Maize, Cassava and Teak for Small Landholders in Southern Togo, West Africa

By

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The thesis, “Optimal Land Allocation of Maize, Cassava and Teak for Small Landholders in Southern Togo, West Africa” is hereby approved in partial fulfillment of the requirements for the Degree of MASTER OF SCIENCE IN FORESTRY.

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## TABLE OF CONTENTS

## List of Figures

## List of Tables

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**Abstract**

Smallholders in Togo depend on subsistence agriculture to meet their family's needs. Southern Togo has a high population density in urban and rural areas. Available agricultural land is becoming limited because of increasing population pressure. Maize and cassava are main staple food crops and are planted on the majority of smallholders' land. Despite limited land and the need to allocate land to maize and cassava for consumption, Togolese farmers are interested in planting teak plantations on their land as a way to generate income.

The purpose of this study was to examine optimal land allocation of maize, cassava and teak for smallholders. I hypothesized that teak production would not be a feasible enterprise for smallholders with a limited amount of land. A linear model was developed to calculate the optimal allocation for maize, cassava and teak. The linear program included decision variables representing the alternative management options, which defined the parameters necessary to solve the linear programming model. Household farm surveys were conducted of the study area to collect necessary data on cost, labor, and land area for producing cassava, maize and teak. The households where divided into five representative farmer types. The model evaluated different scenarios using farm survey data for cassava, maize and teak. The model was solved for each farmer type using fifteen- and thirty- year teak rotations, sold with black market and government market prices. Discount rates of eight, eleven and fifteen percent were applied to the costs and returns in the model to incorporate the costs involved with using resources over long periods.

The model shows that growing teak is most profitable for smallholders who grow teak on a short-term rotation with a discount rate of eleven percent or less and sell it on the black market, even when constrained by subsistence crop production and limited land. For land-rich and labor-poor farmers, teak is profitable under all regimes. Evaluating farm data with a linear model showed that although labor and land constrains the feasibility and scale of teak production, the greatest influencing factor on teak feasibility is the discount rate.

# Chapter One
# Introduction

One of the major reasons the Togolese government requested natural resource management (NRM) Peace Corps volunteers was to address the deforestation facing Togo today (Figure 1). In recent years, Togo's deforestation problem has been exacerbated by population pressure, the impacts of slash and burn agriculture, fuel wood needs and the general need for farmland (CIA 2007). Deforestation has contributed to other environmental problems including soil erosion and soil deterioration, which further negatively affects agriculture, Togo's main source of income and food.

**Figure 1. Large trees in the distance are remains of a forest in Southern Togo. Photo by Amber Lily Kenny.**

While I was a Peace Corps volunteer from 2004 to 2006, I was selected to participate in an interest group made up of Togolese governmental officials, farmers, Peace Corps administration and volunteers to rewrite the natural resource management country plan to address environmental degradation. Through discussion and analysis of the country's problems and statistics, reforestation was chosen as the major objective of the program. I soon found out that the only "problem" with the new country plan was the difference between Togolese and American definitions of "reforestation." Togolese people assume reforestation entails planting teak and only teak. For them, it does not involve planting native species in forests, or even in plantations, but planting tracts of land with teak seedlings. Many small landholders do not want to plant trees because they would compete for land with much needed food crops. However, teak, known as "Green Gold" among the farmers with whom I worked, was the one tree that everyone wanted to plant.

When people in my village discovered my "*domain*" was forestry, almost every farmer who approached me wanted to plant teak. They all knew of an uncle or friend or grandfather, or an "uncle's friend's grandfather" who planted teak and was now rich. Many of these same farmers did not have sufficient land to plant enough crops to eat and were not interested in planting trees prior to their mention of teak. I was mystified. Why would they want to lock up their land for twenty to thirty years with teak? The farmers who currently were involved in teak activities often did not follow prescribed management plans and sold short-rotation teak to black market buyers, instead of selling full-sized saw logs through legal channels. This also mystified me. Togolese government foresters assured me numerous times that the true money in teak was to be found by selling the big logs, thirty-year old large trees to European and Indian markets. If this was the case, why weren't smallholders cashing in on the same management plan?

Farmers in Togo are notoriously skeptical of long-term projects, viewing them as high risk. With little available land, and pressing economic needs, subsistence farmers often choose short-term activities to meet their needs (Mittelman 2000). Farmers must use resources to eat now; it is impossible to postpone resource use and eating in favor of making more money or food in the future. However, the smallholders I worked with were convinced they could win with teak and still grow food crops. I, however, was more skeptical. I questioned if the payoffs would be worth it; like their "uncle's friend's, grandfather," would they too be rich?

The objective of this study was to examine optimal land allocation of staple food crops and teak for small landholders in southern Togo. I hypothesized that available land and labor would have significant influence over the feasibility of a farmer to plant teak. In order to evaluate this problem, a linear programming model was devised to select optimal allocations of each crop.

Chapter two describes general information about Togo. Environmental, political and social factors are examined. The economy and farming sectors are also discussed. Chapter three provides background information on the study village of Agodokpé. Chapter four gives a general discussion on the biology and uses of maize, cassava and teak. Chapter five describes the methods used in this study. First, linear programming is explained, then the process of quantitative and qualitative data collection. Finally, the linear model devised to optimally allocate maize, cassava and teak between land and labor constraints is discussed. Chapter six presents the data used in this study including prices for maize, cassava and teak are presented. Land and labor constraints are explained and farm data are given.

Chapter seven examines the results and analysis of the study. It discusses the construction of the linear model as well as how discount rates affected the model. Optimal maize, cassava and teak allocations are evaluated for different smallholder scenarios. This chapter concludes with a summary of the feasibility of teak for smallholders. Chapter eight reviews literature relevant to resource allocation for smallholders using linear programming models and other methods of analysis. Chapter nine discusses the findings of the study and provides recommendations for smallholders considering teak production. Chapter ten concludes the paper with closing remarks on Togo.

# Section One

## General Background

## Chapter Two

## Background of Togo

The Republic of Togo, commonly known as Togo, is located on the southern coast of West Africa. A long, thin, sliver shaped country, Togo has 56 km of Atlantic Ocean coastline while stretching almost 600 km north to Burkina Faso. Lying at latitudes 6°10´ and 11°10´N and longitudes 0° and 1°40´E, the country is sandwiched between Ghana and Benin and has an area of 56,785 sq km (FAO 2003, CIA 2007) (Figure 2). The country has five political regions: Maritime, Plateau, Centrale, Kara, and the Savannes, with Maritime in the south and the Savannes in the north (Figure 3). These regions are loosely based on ecological zones and ethnic groups. The Atacora mountain ranges characterize the southwest to northeast regions of Togo, while a large plateau marks the north (FAO 2003). Togo has a population of 5,548,702 people with over one third of the population living in the Maritime region near the capital city of Lomé (CIA 2007).

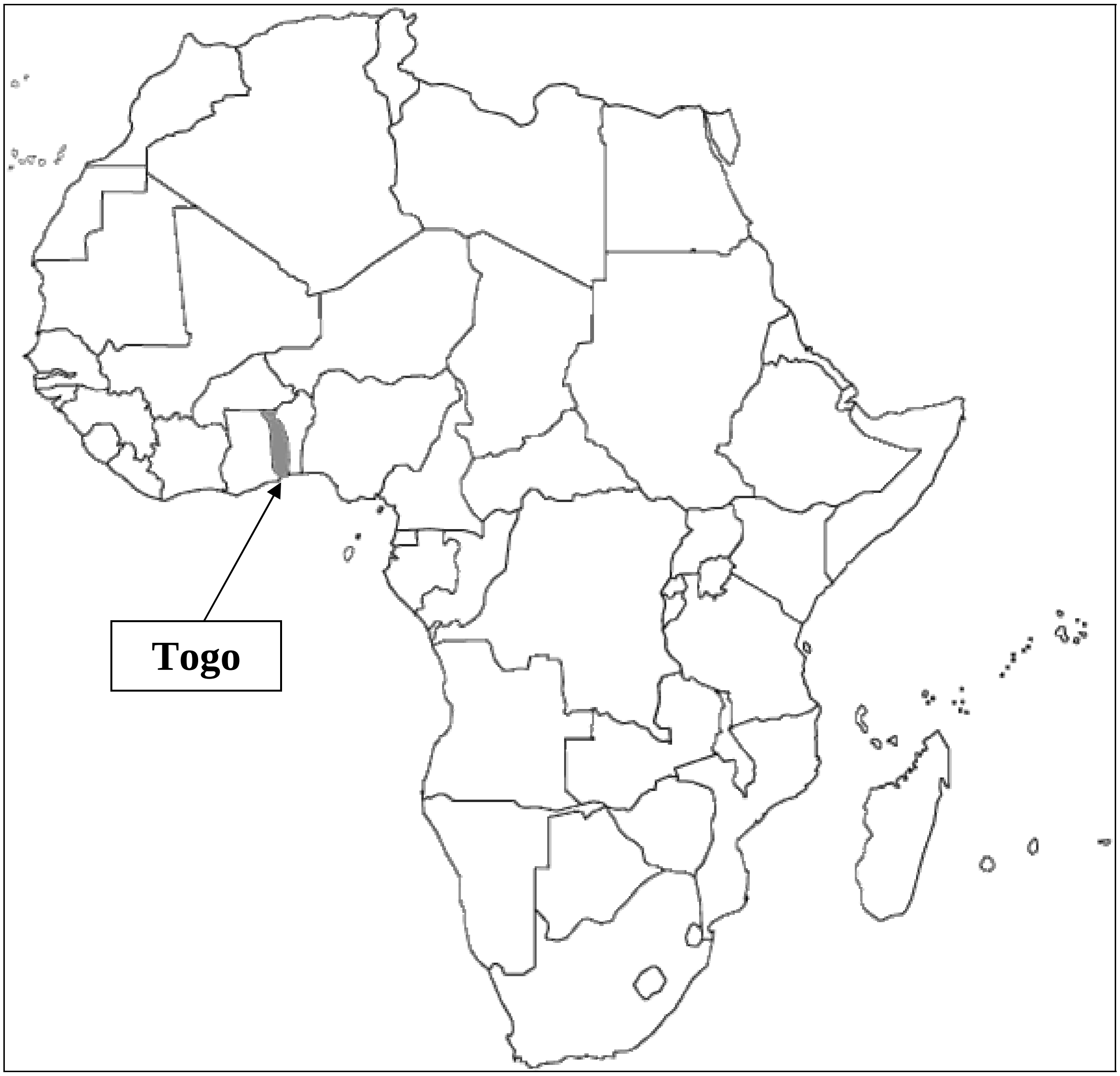


**Figure 2. Map of Africa with Togo Highlighted. Source: htpp://worldatlas.com/webimage/countrys/africa/afoutl.htm**

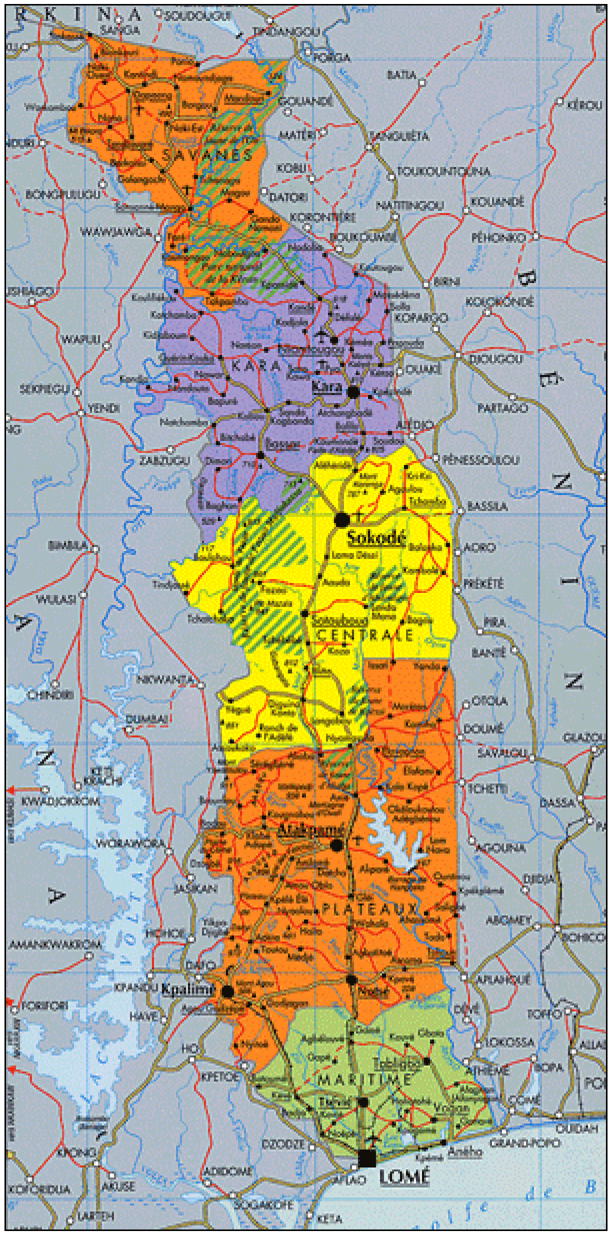

**Figure 3. Regional Map of Togo. Source: UNDP 2006.**

**Climate and Topography**

Togo has a tropical climate, humid in the south and semi-arid in the north (CIA 2007). The interaction between Togo's geographical location and land types heavily influence the local climate, causing it to vary from its neighbors, Ghana and Benin. The Atlantic Ocean cools air currents, while the mountain ranges create rain shadows, thus creating large disparities of rainfall among regions. As a result, the coastal region has two rainy seasons, while the rest of Togo has one rainy season (FAO 2003). In the south, the "*Grande saison de pluie*" usually starts in March or April and generally runs to July or August. Following this, a "*Petite saison sèche*" lasts one to two months, broken by rains, in late September. The "*Grande saison sèche*" spans mid December to March. Harmattan, strong dry winds from the Sahara, affects weather patterns during this season as well. Temperatures average around 27 degrees Celsius, with ranges of 22.9 to 30.4 degrees Celsius in the south, and 13.1 to 34.4 degrees in the north (UNDP 2006).

Togo's long south to north expanse allows for rich cultural diversity and a wide array of ecological and climatic diversity. Togo has six ecological zones: (1) *Savanne Seche Nord – Guinéenne* (the north Guinean dry savannah), (2) *Savane Seche Sud – Guinéenne* (The South Guinean dry savannah) dominated by the Oti River, (3) the *Savanne Derivée Seche* zone (The Derived Dry Savannah), (4) *Forêt decidue et Semi Decidue de Montagne* (the Deciduous and Semi-deciduous forest  Mountain zone), which are both characterized by the Atacora mountains (5) *Savane Derivée Humide* (the Humid Savanna zone) and finally, the southernmost zone, (6) *Savane Cotière* (Coastal Savannah zone), containing pre-coastal and coastal zones which border the Atlantic Ocean (World Bank 1997, FAO 2006). In the northern zone rainfall is generally less than 1000 mm/year. The middle zones have a rainfall average that ranges from 1000 to 1700 mm/yr and the coastal zones range from 900mm/yr on the coast to 1200 mm/yr inland (FAO 2006).

The soils in Togo are comprised of ferralsols (oxisols) in the south and lixisols (ultisols) in the north (FAO AGL 2006). These soils are considered heavily weathered and are moderately prone to erosion and leaching. Initially such soils have a high fertility status, but after several years of cultivation, land fertility deteriorates, requiring farmers to plant crops elsewhere (FAO 2006). As a result of continuous farming, most of the soils in Togo are considered degraded. The entire Maritime region is classified as having severely degraded soils (FAO AGL 2006).

**Politics and History of Togo**

Archeological artifacts found in Togo suggest people inhabited the area prior to 1000 BCE. The first ethnicities included the Akposso and Kabiyé who inhabited the Atacora Mountains; the Akpafou, the Bassar, the Lossa and Konkomba inhabited the north. The Bassar were also the first people in Togo to work with iron in the central region of the country (Goucher 1984). The origin of these groups is unknown, although according to local creation myths, humans in the area were the result of the violent impact of spirits hurtling from the sky and colliding with the earth. Togolese griots say this violent start destined humans to suffer for all of their existence.

Occupying the area between two strong West African kingdoms, the Ashanti to the west and Dahomey to the east, the region has always been a place of political discord, a power vacuum, largely inhabited by loosely organized villages and ethnic groups.

These villages were affected by the political activities and wars of the surrounding kingdoms (Decalo 1987) and did not form a solid political state.

During the eleventh century, an ethnic group migrating from Yorubaland (a region in modern day Nigeria) came to western Togo. This group settled in what is now southeastern Togo and intermingled with the local population to form the ethnic group the Aja. The Aja spread out to form the kingdom of Tado which was ruled by a series of rulers. The Tado kingdom was described as being powerful and prosperous by the Spanish Jesuit, Alonzo de Sandoval in 1627, in the first written record of Togo (Goeh-Akue 2006). During this time the kingdom of Tado experienced several ruler successions, which resulted in political conflicts. At the end of the sixteenth century, a new king, Agokoli, imposed mandatory hard physical labor to fortify the kingdom including the construction of a large protection wall still in existence in south central Togo (Posnansky 1982). During Agokoli's autocratic rule, child sacrifices were demanded and numerous acts of violence were inflicted upon the citizens of Tado. The resulting civil unrest and political violence caused waves of successive migration. The group of Aja immigrants who separated from the Tado kingdom resettled in a large part of modern day southern Togo and southeastern Ghana. This group is now known as the Ewé. According to Ewé oral history, the Tado kingdom was ruled by a tyrannical king whose cruelty and harsh treatment of his citizens continues to be remembered (Decalo 1987). For this reason Ewé continue to eschew central political control and prefer loosely organized chiefdoms than in contrast to the more centralized Kabiyé.

Historically, political strife not only affected southern ethnic groups, but northern groups as well. Ethnic groups migrating south from Burkina Faso clashed with preexisting tribes over economic interests, commercial concerns, hunting ground disputes and war. Ethnicities became so intermixed it was difficult to discern between ethnic groups and alliances (Decalo 1987, Goeh-Akue 2006).

During this period of migration, kingdom-building and ethnic conflicts, Portuguese explorers and traders were active in Togo. In the fifteenth century, European explorers arrived on the Togolese coast and were the first to expose the inhabitants of the area to Europe and to the European slave trade. Togo became part of the Slave Coast and for the next 200 years was a major supplier of slaves for the Atlantic slave trade. On July 4, 1894, Togoland became a German protectorate after a treaty was signed between Chief Mlapa of Togoville, and German Imperial Commissioner, Gustav Nachtigal. In exchange for territory along the coast, Germany agreed to protect the population from English annexation and the people of Togoville from other tribal groups (Decalo 1987, Goeh-Akue 2006). The protectorate eventually expanded to include interior lands. Togoland became one of Germany’s most valued possessions, as the colony provided Germany with free labor, taxes and natural resources. Many Togolese felt Germany’s regime too militaristic and oppressive and emigrated to neighboring countries (Amenumey 1969).

German rule of Togoland ended when the French and British militaries invaded and occupied the territory before World War I. Following the war, Togoland was declared a League of Nations mandate and was divided into two zones, with the United Kingdom controlling a smaller southeastern section of the colony, and France governing the remaining area (Anonymous 2000). Soon after, the British section of Togoland joined Ghana, while the French section voted to become an autonomous republic of France. In 1960, Togo proclaimed independence from France and elected Sylvanus Olympio as president. Four years after the election, Olympio was killed in a military revolt. This revolt facilitated the rise of power of a young Kabiyé officer Gnassingbe Eyedema. Already the Army Chief of Staff, he was rumored to have assassinated Sylvanus Olympio himself. Eyedema claimed presidential power in 1967 (Anonymous 2000).

Initially, President Eyedema banned political parties, until founding his own party, The Rassemblement du Peuple Togolais (RPT). Eyedema remained Togo's president for the next 38 years. Eyedema's regime was marked by numerous coup attempts, legislative changes, and a series of flawed elections, as well as political violence and intimidation. The RPT and most government offices were dominated by Eyedema's family members, and the Togolese army was comprised of Kabiyé officers (Manley 2003). Political dissidents were either jailed or exiled. In 1992, after a faction of the Togolese army held a newly elected legislature hostage for 24 hours, opposition groups and labor unions called for a strike that immobilized the country for the next several months, leaving lasting detrimental effects on the country and its economy. The strike was followed by periods of political and ethnic violence as well as mass emigration of Togolese refugees into neighboring countries (Manley 2003, State Department 2007). In response to political instability, the European Union, France, Britain, the United States and aid organizations suspended their foreign aid programs in order to encourage political transparency, democracy and free and fair elections.

After the unexpected death of President Eyedema in 2005, the military illegally appointed the president's son, Faure Gnassingbe, as the new president, bypassing constitutional legislation. This action resulted in international pressure by the African Union and United Nations as well as protests by the Togolese public, forcing Faure

Gnassingbe to step down from office. Abass Bonfoh, the National Assembly Vice President, then served as interim president (US State Department 2007). It was later discovered the interim presidency was a pretense and Faure maintained power during this time. Clashes between opposition members and the Togolese military occurred frequently while international pressures increased for Togo to hold elections. Following elections considered "deeply flawed," by the international community, Faure was declared President of Togo in April 2005 (State Department 2007). Periods before and after voting were marked by violence, protests, intimidation by both the opposition and the RPT, and vote tampering. Over 40,000 Togolese fled to Benin and Ghana where many stay to this day. Togo is considered to be the fourth most authoritarian state in the world after by Chad, Central Africa and North Korea (Kekic 2007).

**The People and Cultures**

Over 37 ethnic groups inhabit Togo, with the Ewé dominating the south and Kabiyé, Kotakoli, and the Moba as the prominent peoples in the north (World Bank 1997). Although French is the official language, over 30 languages are spoken, with Ewé and Kabiyé the most prevalent. Togo has an annual population growth rate of 2.72 percent which is one of the highest in the world. The average number of children born to each woman is five, while life expectancy at birth is 57.4 years. The median age is 18.3 years (CIA 2007).

Sixty percent of the population is under the age of twenty, evidence of an uneven age distribution (UNDP 2006) (Figure 4). Access to sanitation and clean water is poor and the risk of disease is high. Fifty percent of the Togolese people do not have access to clean water (Figure 5), one fifth of the population is undernourished, and 21 percent of children are affected by stunting (FAO 2006). According to 2003 estimates, Togo has an HIV prevalence rate of 4.1 percent (CIA 2007). Poverty is a factor that affects everyone in Togo. Togo is considered a low-income country and is one of the poorest countries in the world (World Bank 2005).

Religion plays an important role in Togolese society. Twenty-nine percent of the population is Christian, 20 percent Muslim, and 51 percent practice indigenous beliefs. Generally, coastal ethnic groups practice Christianity, while northern groups are Muslim. The Togo-Benin area is the birthplace of *vodun*, or voodoo, a religion that considers the interactions and influences of ancestors and spirits of everything animate and inanimate with living people. Although many people consider themselves Christian or Muslim, people also practice aspects of voodoo, incorporating them into Christian and Muslim belief systems. Many Ewé explain this duality as, “Christian by day, Voodoo by night,” in order to reconcile the two beliefs.

**Figure 4. Children comprise over half of the Togolese Population. Photo by Gabriel Nehrbass**

**Figure 5. Village water access site. Tovegan, Togo. Photo by Eric Snell**

## Economy and Resources

In 2004, Togo had an estimated Gross National Income (GNI) per capita of 380 US$, and a gross domestic product (GDP) of 2.1 billion US$ (World Bank 2006). Togo's economy is closely linked to its political environment. During times of political instability, the economy is also unstable. Following the 1992 strikes and the resulting cessation of donor funding, the GDP fell by 22 percent (World Bank 2006). State-run companies control a large part of the economy. These companies are stagnant, ill organized and perform poorly, thus negatively influencing the rest of the Togolese economy (World Bank 2006).

There are three major contributors to the Togolese economy: commerce, phosphates, and agriculture. As Togo has an international port and a major national highway, it is a pathway for goods going inland to northern Togo and land locked countries, such as Burkina Faso. However, the port's economic activity has declined during the past decade as a consequence of political instability. The world's richest calcium phosphate deposit is located in Togo and is its greatest export commodity (CIA 2007). The agriculture sector is the largest sector of the Togolese economy, employing close to 77 percent of the population (World Bank 1997). Subsistence agriculture employs the majority of farmers, which, combined with the cash crops of coffee, cocoa, and cotton, accounts for 42 percent of the gross domestic product (CIA 2007). Although agriculture has a large role in the Togolese economy and society, its performance has remained poor, thus impeding economic growth even further.

**Farming**

Like many other sub-Saharan African countries, crop yields in Togo are declining more and more as environmental degradation increases. Smallholders depend on their farms not only for their economic welfare, but also for their family's welfare and survival. Because of poor soil productivity, inconsistent rains and little governmental support, Togo's agriculture sector, environment, and population health will continue to decline (World Bank 1997) (Figure 6).

**Figure 6. Young farmers clearing a field, Agodokpé, Togo.**
**Photo by Amber Lily Kenny.**

Deforestation has long been a major environmental problem for Togo. German foresters reported heavy deforestation at the turn of the nineteenth century, partially as a consequence of the iron industry of the Bassari in northern Togo (Goucher 1984). Today, deforestation continues to be a problem; forest cover disappears at an annual rate of 15,000 ha/year (UNDP 2006, World Bank 1997). Between 1990 and 2000, Togo had an annual deforestation rate of 3.4 percent, one of the highest in West Africa. Already vulnerable to erosion and degradation, deforested land is cultivated, which further deteriorates soils. In the coastal regions there are no forested zones, although a few remnant large trees remain along rivers and in certain sacred areas. Extensive teak plantations have been established in the coastal region but, as they are on government land and are monocultures, they do not serve the same ecological function as natural forests. Teak plantations have lower levels of biodiversity and can be more vulnerable to disease and pest attacks than natural forests or mixed plantations (Pandey and Brown 2000).

The Togolese forestry sector contributes eleven percent to the country's GDP (Ouro Djeri 2001). Togo has 348,000 ha of modified natural forest and 38,000 ha of plantations (FAO 2005). Thus trees are not only an important contributor to Togo's environmental health, but also to its economy. Despite this, the problem of deforestation is not a major concern for the public. The Ministry of Environment is becoming aware of negative consequences resulting from the depletion of natural recourses. To address environmental and natural resource problems, the Togolese government has created a management program with the following objectives: intensify agricultural production, fight poverty, assure agriculture growth can be supported by the environment, develop agriculture programs which conserve forestry resources and introduce permanent crops that can replenish the fertility of soils (Sessi 2001). The majority of Togolese households depend on agriculture to make a living. Until recently, trees were seen as competition to farm success. However, the new resource management program is changing public perception on the importance of trees in farming system. Togolese smallholders are becoming more open to planting trees in their fields (Figure 7).

**Figure 7. Smallholders creating a tree nursery to alley crop in their fields.**
**Photo by Amber Lily Kenny**

Farm size in Togo ranges from small garden plots to large fields. Farms are often as small as 0.10 ha, especially in densely populated agricultural areas, whereas others can be as large as 10 or 12 ha. Land tenure contributes to land cultivated, but so does available labor. Most smallholders practice subsistence agriculture and only have access to manual labor to cultivate fields. Consequently farm size depends on hectares owned, as well as available labor. Major subsistence food crops include maize, cassava, yams, groundnuts, beans and sorghum in the north (FAO AGL 2006). In 1981, Togo cultivated 411,000 tons of cassava, 364,000 tons of yams, and 251,000 tons of maize in the south (World Bank 1997).

# Chapter Three

## Background of Study Area

This study took place in Agodokpé, a rural village in the Maritime region of Togo (Figure 8). Meaning, "Giant Stones," much of the village sits on top of large rocks, while farm fields are in the surrounding lower lying areas. Agodokpé has a population of 400 people and is comprised of about 50 households. Thirty-nine heads of households were interviewed for this study. The population is homogeneously comprised of Ewé people and all are farmers, although a few residents are trained or self-taught in trade skills such as carpentry, masonry and sewing.

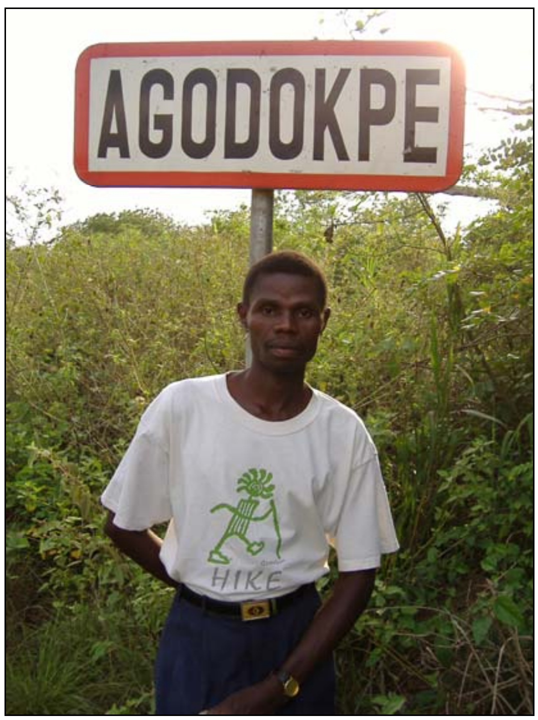


**Figure 8. Agodokpé, study site. Photo by Brian Henry**

Although Agodokpé is only 70 km from the nation's capital, the village is isolated and rural (Figure 8). Connected by rough dirt roads, Agodokpé lies equidistant between two major market towns more than 60 km apart. Agodokpé is one of five villages to have access to two bush taxis which only travel on market days. As the roads are often washed out in the rainy seasons, travel and transporting goods can be difficult. Agodokpé is in a county and prefecture that is considered to be the driving force behind the opposition movement against the ruling party. Residents claim it is for this reason their area is not as developed as other regions of similar background. There is no electricity, running water or cell phone reception for 35 km. Schools are understaffed and ignored. Roads leading to the village are not maintained (Figure 9).

**Figure 9.Village of Agodokpé. Photo by Elizabeth Renckens.**

Agodokpé, as with most rural villages in the Maritime Region, is characterized by a high population density. All residents depend on farming to feed themselves and their families. Because of this high population density the majority of land is owned and cultivated. Ownership of land is determined by family groups. Although a few families own large parcels of land, most landowners own small disjointed plots of inherited land that surround the village. Many farmers do not own land at all and must rent or depend on using land owned by members of their extended family. Ownership and access to land is a production constraint for smallholders.

Labor also constrains the production of food. There is no access to tractors or plow animals; all agricultural work is manual. Therefore, the area of land cultivated is directly related to the labor force available in the household. The average farmer in Agodokpé works one to two “squares” (0.05 ha) a day. Even if a farmer does own a large parcel of land, without enough labor, only part of the land can be cultivated.

The average farmer in Agodokpé makes about 200 US$ per year. Study participants made as little as 60 US$ per year whereas the most affluent made 500 US$ per year. Ideally, farmers grow enough cassava and maize to feed their families, and enough surplus to sell in nearby markets. This additional revenue covers living expenses such as farm tools, clothing, and school and medical fees.

## Chapter Four

## Farm Crops in Southern Togo

Smallholders in southern Togo grow a variety of crops for home consumption. These crops include peppers, tomatoes, sweet potatoes and plantains. Of all the crops cultivated, maize and cassava are the two most important. These two staples are grown in larger amounts and are the base of every Togolese meal. Smallholders would like to diversify their farming activities to include more than the production of cassava and maize for financial security purposes. It is possible for farmers to participate in the forestry sector of the economy by producing and selling teak. This chapter outlines the basic biology and uses of cassava, maize and teak.

### Cassava

Cassava (*Manihot esculenta)*, a tropical root crop with a high tolerance for various soil types, is an important food source for people in tropical Africa. Originating in the new world, the Portuguese introduced it to West Africa toward the end of the sixteenth century (Norman et al. 1995). Cassava is tolerant of acidic, degraded soils, low pH, drought conditions, and can be harvested year-round. Cassava performs better than most crops grown on soils with low fertility. Small landholders plant it on marginal lands and view it as a source of food security (Howeler 2002). Cassava contains cyanide compounds which prevent insect attacks. It is shade intolerant and is drought resistant, although prone to spoil in waterlogged soils. Cassava is cultivated as a security crop that will still produce in times of drought, civil unrest and other unfavorable crop conditions (FAO and IFAD 2000).

Cassava roots grow in clusters pointing outward just below the surface of the ground (Figure 10). Depending on the age of the plant, there are two to seven tuber roots per plant. Individual roots can range 20 to 50 cm in length. Cassava is propagated by replanting cut segments of the stem (Figure 11). Farmers use cuttings from stems of harvested cassava root.

**Figure 10. Harvesting Cassava. Agodokpé, Togo. Photo by Amber Lily Kenny.**

**Figure 11. Sprouted cassava cutting. Photo by Brian Satterlee.**

Because cassava produces harvestable yields in poor conditions it is an excellent crisis crop. However, it is not without its drawbacks. Nutritionally, cassava is low in protein, sugar, and vitamins; it is rich in starch, but not much else. As it is a significant part of the diet, children and many adults often suffer from malnutrition. Cassava roots contain 25 to 30 percent starch. Cassava roots are bulky tubers that have 70 percent moisture content, and can only be stored for three to four days before rotting. Additionally, cassava roots and leaves contain cyanide. In order to reduce toxicity and store cassava roots for storage, the tubers must be processed.

One of the most common processing techniques in Togo is peeling and boiling the tubers before eating. Tubers are also peeled, boiled, pounded into *fufu,* and then consumed (Figure 12). Boiling does not reduce cyanide content. Pounding into fufu marginally reduces cyanide content. Another common processing method transforms the cassava into *gari*, or flour. This process involves peeling, grating, pressing, fermenting, sifting, and roasting the cassava into large granules (Hahn et al 1988). *Gari* is often added to rice and bean dishes, or mixed with water and sugar to form porridge, usually eaten for breakfast. Cassava is also peeled, cut into pieces and slowly dried in the sun, which reduces cyanide content and makes it storable. Togolese get 38 percent of their calories from root crops. Cassava is a large contributor to these calories. In the south, people prefer cassava and say it makes the most palatable fufu. *Gari* has a long shelf life and is easily transported to markets. Despite its status as a crisis subsistence crop, cassava is becoming a cash crop for many farmers, and often economically out performs cereals (FAO and IFAD 2000).

**Figure 12. Fufu, Pounded Cassava. Photo by Amber Lily Kenny.**

Women are responsible for most production activities and cassava is considered a "female" crop. Because women are in charge of *gari* production as well as the sale of *gari* and cassava, they also retain control of the income generated by these activities.

## Maize

Maize (*Zea mays*) is an important food crop in Africa. It was probably introduced into West Africa by traders transporting the grain across the Sahara from the Mediterranean region (Norman, et al. 1995). Many farmers plant maize in small plots near their village (Figure 13). Farmers in southern Togo depend on maize as their main dietary staple. The average Togolese person consumes 136.9 g of maize per day, which contributes an average of 411 calories to their daily caloric intake (FAO 1992). After harvesting, Togolese dry the maize and convert it into flour, which they then use to make a thick porridge known as *"akplé"* in Ewé or *"pâte*" in French. *Akplé* is eaten with a spicy sauce.


**Figure 13. Maize Field. Agodokpé, Togo. Photo by Amber Lily Kenny**

Maize makes high demands of soil nutrients, especially nitrogen. Maize is sensitive to drought and water-logging, both of which can occur during the long and short growing seasons in southern Togo. Despite these potential obstacles, farmers continue to plant maize. Farmers believe maize is grown for eating, not for generating money, and feel they must grow it for food security. Many Togolese eat *akplé* two to three times a day. Across Africa, people love eating maize and do not even consider the possibility of not growing it (Trofimov 2005). In West Africa, maize is often grown in a mixed cropping system. A common system in southern Togo is planting cassava with maize, as cassava is a late maturing crop and maize an early maturing crop (Norman et al. 1995).

In Agodokpé, as with the rest of southern Togo, maize is considered a "male" crop. Men are responsible for growing, harvesting and selling maize. Women and children help with the planting and harvesting but are not considered "in charge" of the crop (Figure 14). The maize market at local markets is one of the few venues run by men.

Because male farmers manage maize production, they also retain and control the income generated from surplus maize.

**Figure 14. Young mothers and their children removing grain from maize cobs. Agodokpé, Togo. Photo by Amber Lily Kenny**

**Teak**

Teak (*Tectona grandis*), a deciduous tropical hardwood, is one of the premier timbers of the world. Its wood is highly valued for its color, fine grain, durability, strength, lightness and weather resistance (Keogh 1996). Native to Southeast Asia, teak has been an important plantation species since the early 20$^{th}$ century. Teak is most commonly used for shipbuilding, furniture, cabinetry and general carpentry (Weaver 1993). As teak remains one of the most valuable timbers in the world, demand and interest in this species continues as well. Teak is one of the few species of tropical hardwoods that grows well under plantation conditions (Keogh 1996) (Figure 15). With demand for teak increasing and natural supply decreasing, plantation teak is a way to address global timber needs without depleting natural reserves (Krishnapillay 2000).

**Figure 15. Five year old teak, Agodokpé, Togo. Photo by Elizabeth Renckens.**

Although naturally occurring at latitudes 23° N to 10°S, teak has the ability to grow between the latitudes of 28° N to 18° S, allowing teak plantations to occur throughout southeast Asia, west and east Africa, Australia, South and Central America, as well as the Caribbean. The estimated global net area of teak is 2,253,530 ha (Pandey and Brown 2000). While the majority of plantations are found in southeast Asia, approximately 4.5 percent of global teak plantations are found in Africa (Pandey and Brown 2000). Optimal growth of teak requires a warm tropical climate with an average rainfall of 1500 to 2000 mm and a dry season lasting three to five months (Keogh 1987). Teak can grow on numerous soil types, but grows best on fertile, well drained alluvial soils. Its growth is limited by heavy clays, poor drainage conditions and steep slope (Weaver 1993).

In response to deforestation problems in the early 20th century, Togo planted its first teak plantation in 1910 (Akakpo 2000). Togo's southern most regions, ecological zones four, five, and six, are suitable for teak production as they generally have enough rainfall (1000-1700 mm) to support teak. Northern zones not only lack adequate rainfall for teak but also have such poor soil that teak cannot grow well (Kokutse et al. 2004). Nonetheless, farmers continue to plant teak in these regions. The Togolese government has established extensive plantations and manages the majority of these plantations. Teak production is also considered a suitable endeavor for small landholders because of its high value, relatively fast growth and ease of cultivation (Mittelman 2000). Smallholders who do plant teak generally employ a fifteen-year rotation plan. Some farmers may wait to harvest trees until year 30, but most prefer to harvest and receive cash for their trees before this. State-run teak plantations are managed on a 30 or more year rotation.

Agricultural extension agents with the Togolese governmental agency ICAT (*Institut de Conseil et d'Appui Technique*, Technical Assistance and Support Institute) provide farmers with agriculture and agroforestry technical advice. In theory, each county in Togo has three to four agents living among farmers in rural areas. In reality, one agent sporadically lives in rural counties, helps farmers from time to time and is underpaid and under-supported. Along with forest technicians and foresters from the forestry branch of the Togolese Ministry of Environment, ODEF (*Office de Développement et Explotation des Ressources Forestières),* ICAT agents advise farmers on the best teak planting and management techniques. They suggest that farmers plant 2,500 trees per hectare with 2m by 2m spacing. Farmers should then follow a weeding regime of three times the first year (Figure 16), two times the second year, and one final time the third year. Additionally ICAT agents suggest thinning to 1250 trees between years five and ten and to 625 trees at years fifteen to twenty (Ayassou, 2006). Thinnings generate revenue.

In certain regions in Togo it is possible to buy teak seedlings or stumps from nurseries. Trees from these nurseries tend to have a better survival rate and faster growth rates than those not from nurseries (Ayassou 2006). Farmers would prefer to buy seedlings in order to establish teak plantations. However, it is expensive to buy seedlings and stumps, and most farmers do not have the resources necessary to purchase the teak. For a lower cost, one can buy teak seeds from ODEF and ICAT. Seeds from these agencies have a higher success rate (Yadjassan 2006) but as they are an additional cost, most farmers do not buy them. To establish teak stands, farmers (or their children) collect seeds out in "the bush" near teak stands or collect seedlings growing under the stands and replant them in their field (Figure 17). Although teak collection from the bush requires more labor, it is also financially costless and requires no travel to nursery sites or government forestry centers.

**Figure 16. Six month old teak after 2nd weeding**
**Photo by Elizabeth Renckens**

**Figure 17. Teak seedling. Photo by Elizabeth Renckens.**

# Section Two

## Research

# Chapter Five

## Methods:

As a Peace Corps extension agent, I lived in Agodokpé for 27 months. By working, living and participating in daily activities in the village I became familiar with community life and integrate into the community. Through numerous interactions, I was able to observe and process information necessary for this study. I learned that farmers grow cassava and maize for consumption and that many do not own large parcels of land but would like to plant teak despite this lack of land. From this information, I concluded that actual and desired farming activities in Agodokpé are limited by the physical constraints of land and labor. A linear programming was devised as a means to find the best allocation of these resources. Constructing a linear program defines the information necessary to run the model. For this particular planning problem, it was necessary to collect data on farming activities as well as social realities.

### Linear Programming

A linear programming model can aid in decision making by finding optimal allocations of constrained resources (Fawcett 2001). Linear programming uses a mathematical model to select the best allocations of resources under specific constraints. First developed in the 1940s for use in military operations, linear programming is widely used for agriculture planning purposes (Dent et al. 1986, Hillier and Lieberman 1986). Farming systems are constrained by the amount of finite resources available and are further affected by changing physical and economic conditions. By utilizing a linear programming model, one can plan farm activities in dynamic environments to obtain optimal results. Furthermore, linear programming allows for analysis of what allocations are possible if one manipulates the physical constraints of the problem.

All linear programs can be written in the following standard from:

Maximize $Z = c_1 x_1 + c_2 x_2 + \ldots c_n x_n$ (Objective function)

$a_{11} x_1 + a_{12} x_2 + \ldots a_{1n} x_n <= b_1$ (Problem constraints)

$a_{21} x_1 + a_{22} x_2 + \ldots a_{2n} x_n <= b_2$

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

and $x_1 >= 0, x_2 >= 0, x_n >= 0$ (Non-negative constraints)

The parameters, a, b, and c's are fixed real values. X variables are the decision variables to be determined using the linear program (Hillier and Lieberman 1986).

To effectively use linear programming as a tool for decision making, the objective function of the farmer must first be stated. The benefit or return of each activity is known as the objective coefficient. It is necessary to know these technical coefficients of the objective function (the $c_i$ values) as well as the technical coefficients for the constraints (the $a_{ij}$ values) and the constraint limitations (the $b_i$ values) on the fixed resources, before the model can be formulated. The amount of fixed resources constrains the activities, which compete for the same resources (Fawcett 2001).

In order to model how farmers might incorporate teak into the smallholdings a linear model of current farm operations was developed. The objective of the Togolese smallholder is to maximize income including the value of food grown for home consumption. The activities are defined as the cultivation of maize and cassava. By generating different scenarios based on farmer data, it was possible to find best allocations of maize and cassava on two land types using the linear programming model developed. After optimal allocations of maize and cassava were found for each farmer type, teak was added to the model, and scenarios for each farmer type were calculated again to see if growing teak was feasible given the constraints of land, labor and financial resources.

**Maize, Cassava, Teak Linear Model**

Max: $Z = Q_C * P_C + Q_M * P_M + Q_T * P_T$

Subject to:

$Y_{1C} L_{1C} + Y_{2C} L_{2C} = Q_C$

$Y_{1M} L_{1M} + Y_{2M} L_{2M} = Q_M$

$Y_{1T} L_{1T} + Y_{2T} L_{2T} = Q_T$

$L_{1C} + L_{1M} + L_{1T} \leq L_1$

$L_{2C} + L_{2M} + L_{2T} \leq L_2$

$V_{1C} L_{1C} + V_{2C} L_{2C} + V_{1M} L_{1M} + V_{2M} L_{2M} + V_{1T} L_{1T} + V_{2T} L_{2T} \leq V$

and all variables $\geq 0$

For the following Primary variables

L = Land area
Y = Yield expressed on a per hectare basis
Q = Total quantity
P = Price
V = Annual variable costs of production (excluding labor) per hectare

Subscripts

C = cassava
M = maize
T = teak

1 = high quality land
2 = low quality land

Note: the parameters associated with each teak land type were the same.

The model was solved using, “What’sBest!” (Lindo Systems Inc 2007) which solves linear problems in Microsoft Excel.

After the linear program was constructed, a questionnaire was designed to collect the data needed to solve the model.

## Data Collection

Data were collected through participant observation, individual informal and in-depth interviews. Participant observation entails living, participating and interacting with the community under study over an extended period of time (Nichols 2000). The primary information collected through participant observation guided the direction of the study, and allowed me to identify key informants, members of the community who are knowledgeable of certain situations and can provide reliable information (Nichols 2000) (Figure 18). I was able to interview key community members with various social standing on their experiences with teak, what growing it entails, and their advice for other farmers in the area who are interested in it. Finally with information gained from participant observation and key informants, I was able to assemble a questionnaire, which I used to conduct individual interviews with the heads of each participating household of the community (Figure 19). Thirty nine out of fifty households were surveyed, as eleven families were not in residence due to political problems, travel and palm wine collection.

**Figure 18. Key Informants. Photo by Elizabeth Renckens**

**Figure 19. Interview with typical smallholder household. Photo by Elizabeth Renckens**

Social and economic differences among farmers can significantly influence crop allocation, production as well as the feasibility of successful teak production. To those unfamiliar with Togo, the participants in the study may seem similar. Overall, they are all from the same area and are considered uneducated and poor. The most successful farmers make a dollar and half a day, while others make much less than that (World Bank 1997). Each smallholder has the same objectives: to grow enough food for him and his family to eat, as well as to have enough surplus income to send some of his children to school and to withstand emergencies. Yet, at the same time, each farmer has a set of individual social circumstances that affect how he achieves this shared objective. These differing social circumstances then influence the types of farm activities a farmer has available to try to achieve his objective. Decision making on how to best achieve the objective is affected by variables including labor availability, land tenure, skill and social status (Harris 1996).

Social status is a variable that can affect a small landholder's ability to take on new projects, like teak. Generally, in Agodokpé, the more land one owns, the higher social standing one has. Furthermore, the more land one has, the more crops one can grow, which can then feed more people and generate more income. Age, education level and community status also affect social standing. For example, across Togo there are younger men with little education and land, but who hold traditional village positions of high social standing. They can have as much social status as older, affluent, educated landowners, who own many hectares and have adult children. As in any community, others can be influenced by a person's degree of social standing which includes the ability to have access to credit and work attitude. With higher social status, a farmer is more likely to own extra land, or have access to other land. Also, he likely has some education or training contributing toward a stronger work ethic than other farmers with lower status. Finally, with higher social status, a farmer can have access to more labor to help find teak seedlings, or have access to surplus income to buy teak seeds. For these reasons it was necessary to construct a scale in order to factor how social status affects a smallholder's ability to plant teak. Farmer social categories were defined by the chief and village elders of Agodokpé. The categories ranged from levels one to five, with one as the lowest social status and five as the highest (Table 1)

Table 1. Generalized Social Status Scale for Togolese Small Holders, where 1 is low and 5 is high 0

| Level | Education | Landowner | Family | Income (US$/yr) | Notes |
|---|---|---|---|---|---|
| 1 | 0 | no, | no | <60 | Drinks a lot, does small jobs for food |
| 2 | <grade 2 | no, | yes | >60 | Has small family |
| 3 | >grade 2 | yes, | yes | >100 | Owns a small amount of land |
| 4 | <grade 6 | yes, | yes | >250 | Has education and/or training |
| 5 | >grade 6 | yes, | yes | >400 | Village elder and/or has education |

Source: Chief Vidzro and Village Elders, Agodokpé, Togo 2006

Through participant observation it was revealed that the two major staple crops cultivated in this region were cassava and maize. Not only were cassava and maize the major crops grown, they were also the most important food crops for consumption. Key informants and focus groups indicated that smallholders were interested in planting teak on their land as well as cassava and maize. During interviews an interpreter translated questions from French to Ewé to record responses accurately. The objective of the questionnaire was to acquire information necessary to determine optimal allocation among maize, cassava and teak. Accordingly, it was necessary to gather physical data on household and farm operations. Farmers were asked how many hectares of low quality land and high quality land they owned. Current allocations of land between cassava and maize were also asked as well as the labor involved in cultivating the crops. Expected yields for normal conditions were determined, as were the yields from the previous year's harvest, which had been affected by drought. Families gave information on average maize and cassava consumption, prices and labor. The survey concluded with an open-ended question which allowed farmers to share information on cultivating maize, cassava, teak and other farm crops.

The surveys were then reviewed and households were separated into five basic farmer types based on amount of land owned, amount of available labor and social status. The averages of social status, number of household members, available labor, ha owned, land quality, crop yields, consumption and income were then calculated to create a prototype representing each farmer type (Table 2).

Table 2 Farmer Type Averages for Social Status, Available Labor, Hectares Owned and Yearly Income

| Type | Social Status | Available Labor Variable | Ha Owned | Ha low qual | Ha high qual | Income US$ |
|---|---|---|---|---|---|---|
| 1 | 2-3 | 1.5 | 0.65 | 0.65 | 0.00 | 150.00 |
| 2 | 3 | 6.1 | 1.5 | 1.00 | 0.50 | 250.00 |
| 3 | 3-4 | 2.9 | 2.0 | 1.60 | 0.40 | 300.00 |
| 4 | 4 | 1.5 | 3.5 | 2.50 | 1.00 | 250.00 |
| 5 | 4-5 | 5 | 7.4 | 6.40 | 1.00 | 450.00 |

To gain additional agricultural information, interviews were conducted with Blaise Ayassou, the regional director of ICAT, Jackson Yadjassan Blidjoh, Chief Forester of ODEF, and numerous ODEF forestry extension agents. These interviews provided realistic information on maize and cassava production, as well as data on Togo government teak plantations, teak biology and best management techniques for teak.

## Chapter Six

## Data

### Prices

The prices of agricultural goods in local Togolese markets vary depending on the season, demand, supply and of course, bargaining skills. Through interviews with farmers and ICAT, Togo's governmental agricultural agency, it was found that prices of maize tend to hover around 0.20 US$/kg. Toward the end of the dry season, prices can rise to 0.50 US$/kg. During periods of political instability, prices rise even higher. For example, in February and March of 2005, the *coup d'etat* and dry season coincided, and prices of maize rose to 0.86 US$/kg. Cassava prices vary less. Almost all land types can grow cassava, and it does not depend on adequate rainfall as much as maize does. It is also possible to harvest cassava during the dry season for immediate consumption. An 80 kg sack of cassava costs 4.00 US$/kg. Cassava sold by the sack is usually processed into *gari* (flour). Most people do not buy cassava by the kilo as people often grow it themselves.

Pricing for teak is more complicated. There are two teak markets available to smallholders: the state market, managed by the Ministry of the Environment and ODEF, and the less structured, dynamic black market. If farmers pay an ODEF or government forester 20 US$, they can have their teak surveyed and receive an official document certifying the farmer as the official owner. When their teak is ready to harvest they can present this certificate to ODEF which will then harvest the timber and pay the farmer. This timber harvesting plan is legal, and ensures that the farmer who receives payment for the teak is the rightful owner. Most farmers do not follow this program. Farmers are often unaware that it is Togolese law that every plantation is required to be certified with the government. Togolese people refer to unregulated markets as “le marche noir” or “black markets”. Farmers often sell their teak on the black market. The differences between government teak and black market teak prices are displayed in Table 3.

Table 3. Teak Prices

| Year Harvested | ODEF price/tree (US$) | Black Market price/tree (US$) |
|---|---|---|
| 5 | 0.44 | 0.80 |
| 15 | 1.00 | 3.00 |
| 30 | 14.00 | 14.00 |

Buyers participating in the black market travel to small villages to inquire if there are any smallholders interested in selling teak. When a smallholder decides he is ready to harvest his teak, he and the buyer decide on a price for the trees. Depending upon the scale of harvest, this is either a flat rate/tree or prices for individually selected trees. The black market prices in Table 3 reflect the flat rate price. The buyer then supplies labor, machines and transportation for the harvest of teak. Occasionally local farmers are contracted to help harvest trees.

**Labor constraint**

For small landholders family size determines available labor (Harris 1996). A farmer with a large family has a larger labor pool and can provide workers for the field. A farmer who has adult or older children will have more available labor than a newly married smallholder with young children. In order to account for differences in work potential an equation was created to calculate available labor. Hardworking adult males were assigned the number 1.0, adult females were assigned the number 0.75, less productive men 0.5, and children ages twelve to eighteen, 0.5. Children under the age of twelve were not included in the work variable, as they do not make a significant contribution to farm work. A household which contains one hardworking man, two women and two older children, and two small children, has the work variable of 3.5.

Work Variable =

$$1 + 0.75 + 0.75 + 0.5 + 0.5 = 3.5.$$

In addition to labor, land is another constraint. Available land and quality of land also limits farm activities. A smallholder can only grow as much as the land has the capacity to produce (Kumar 1989).

The linear programming model constraints include the amount of cassava and maize produced. The cassava constraint was calculated by multiplying the weight one must eat per year by the average number of people in the farmer type's household. The constraint for maize was calculated in the same manner. For example, type 4 farmers are land rich and labor poor, with an average of three people per household. Based on household surveys and validated by FAO statistics, one person in southern Togo must eat 3.21 kg of cassava/week, or 167.07 kg/year. They must eat 1.24 kg of maize/week or 65.06 kg/year. Therefore the typical household in farmer type 4 consumes 501 kg of cassava and 195 kg of maize per year (Table 4).

Table 4 Average Cassava and Maize Required for Household Consumption for Farmer Type

| Farmer type | Average household size | Cassava required kg/year | Maize required kg/year |
|---|---|---|---|
| 1 | 3 | 501 | 195 |
| 2 | 10 | 1670 | 650 |
| 3 | 5 | 835 | 325 |
| 4 | 3 | 501 | 195 |
| 5 | 10 | 1670 | 650 |

Available land and labor were also constraints. Type 4 farmers have more land that most farmers with an average of one hectare of good quality land and 2.5 hectares of poor quality land. Additionally their available labor variable is 1.5. Farmers believed they should plant a certain amount of maize even if it would be more profitable to plant only cassava.

Because this model deals with subsistence farmers, variable costs for crop production were set at zero. The major inputs involved in producing maize and cassava are the land, maize grain, cassava cuttings and manual labor. Farmers keep a portion of the previous year's harvest for seed maize, and utilize the stalks of consumed cassava as cuttings for the next cassava planting. The man hours it takes to produce maize and cassava were calculated. A ratio was then calculated to represent the amount of labor per hectare each activity required.

These constraints were placed in the model using the price of maize at US$ 0.20/kg and price of cassava at US$ 0.05/kg. These prices are based on the average price of maize and cassava over several years, which fluctuate depending on season and supply.

ICAT agents stated that poor land could produce 3200 kg of cassava per ha and 8000 kg per ha on rich land. One hectare of maize planted on poor land can produce 600 kg, whereas one hectare of rich land can produce 1200 kg of maize. Household surveys agreed with the majority of this information, although many farmers stated they could only attain a yield of 700 kg of maize on good quality land. This could be a result of poor planting techniques or their recall of two recent years with unfavorable weather. ICAT yields were used in the model.

# Chapter Seven

## Results and Analysis

Smallholders must determine how to best manage their land while constrained by physical and economic conditions. The objective of every farmer in Agodokpé is to grow enough food to feed their family and to produce enough crops to sell on the local market. By selling surplus maize and cassava, farmers hope to generate enough income to purchase other food items as well as pay expenses such as school fees and medicines. Smallholders must allocate resources to various farming activities so as to best achieve their objectives. Any farming problem can be divided into three areas: a set of objectives, a range of possible activities and a set of resource and household constraints (Dent, et al. 1986). For farmers in Agodokpé, the major farming activities are cultivating maize and cassava. These activities are constrained by available land and labor.

Although each farmer participates in different farm activities and social conditions, patterns emerged from the households interviewed. Survey responses could be delineated into five basic farmer types. Available labor and social status were both incorporated, each helping to define the groups. The farmers' responses were then averaged to create a prototype to use in model calculations.

**Farmer Types**

**Type 1: Land poor, Labor poor** - 20.5 % of households are represented by this category. Type 1 farmers lack land and workers. On average they own less than one hectare of poor quality land. Households tend to be small with a labor variable of 1.5. Type 1 farmers have low social standing, rating an average between 2 and 3 on the social status scale. All single women (divorced, widowed, etc) interviewed fell into this category.

**Type 2: Land poor, Labor rich -** 17.9 % of farmers in Agodokpé are in this category. On average they own 1.5 ha of land and have an average work variable of 6.1. People in this category have a slightly higher social standing, 3 on the social status scale, than type 1 farmers.

**Type 3: Medium land, Medium labor -** The plurality of farmers, 38.5 %, fell into this category. This category represents farmers of middle to higher social status of 3 to 4, who have an average work variable of 2.9. Type 3 farmers generally own about two hectares of land.

**Type 4: Land rich, Labor poor -** Type 4 farmers were the least represented with 7.7 % of the farmers occupying this category. This is not surprising as farmers who own large parcels of land are rare. Farmers that do own larger amounts of land are usually part of a large household, thus making type 4 farmers who are land rich and labor poor even more uncommon. This farmer also has a higher average social status of four.

**Type 5: Land rich, Labor rich -** 15.4 % of those interviewed represented land rich and labor rich households. Farmers in this category represent the elite village members. The typical type 5 farmer has the highest social standing in the community at 4 to 5, an average of 7.4 hectares of land and a large available work force, 5 or greater on the worker variable scale. They have access to fertile lands and have the most capital.

The parameters for the farmer types were used in the linear model to find optimal allocations of cassava, maize and teak under different rotation plans and discount rates.

**Basic Land Allocation Models**

First, a linear programming model was solved for the optimal allocation of maize and cassava. The results for a land rich, labor poor farmer (type 4) maize and cassava constraints and allocation are shown in Tables 5a and 5b. The farmer meets the maize constraint and then allocates all remaining resources to cassava production on low and high quality land. Some land is left idle.

Table 5a Land rich, Labor poor (type 4) Constraints for Linear Model

| Quantity | Constraint | Dual |
|---|---|---|
| Cassava yield (kg) | 501 | 0.00 |
| Maize yield (kg) | 195 | -0.08 |
| Low quality land (ha) | 2.5 | 0.00 |
| High quality land (ha) | 1 | 240.00 |
| Variable cost | 0 | 0.00 |
| Labor | 1.5 | 340.43 |

Table 5b Land rich, Labor poor (farmer 4) Optimal Land Allocation

| Land allocation | low quality (ha) | High quality (ha) |
|---|---|---|
| Cassava | 1.85 | 1.00 |
| Maize | 0.33 | 0.00 |

For a household that is land rich and labor poor, the linear program finds the optimal land allocation is: 1.85 ha of cassava on low quality land, 1.00 ha of cassava of high quality land, and 0.33 ha of maize of low quality land. The model results also represent the typical farming pattern of farmers in the study area.

The model was run for the other four farmer types and results were similar to actual farming practices found in Agodokpé. Two years of field observations validate the results of the model. The model, therefore, accurately represents current farm management in Agodokpé.

The next step was to add a teak component to the model to determine if there were circumstances where smallholders could increase income using teak in an agroforestry system. As available farming land is limited for small landholders in Togo, most farmers are not sure how much teak they can and should plant. Adding teak to the model further divides land available and may change the allocation of resources. The amount of labor necessary for teak was also calculated. Because labor with teak varies with which establishment regime is employed, labor ratios were found for buying teak seedlings and finding teak in the bush.

Labor required for teak plantations differ in years zero, one and two. A more complicated four year model was used to solve this problem. The majority of labor involved with teak occurs in year zero as this is when a farmer must look for seeds or seedlings and transplant them to his field. In year one, the farmer is expected to weed three times a year. After year one the work involved declines. In order to compare the returns of teak, a long-term activity, with the annual returns of maize and cassava it was necessary to find discount rates for the monetary values involved.

## Discount rates

Growing teak requires land to be occupied with trees for years at a time. The earnings from teak can only be realized at the end of the rotation (Kumar 1989) (Figure 20). Discount rates were applied to the costs and returns in the model as to incorporate costs involved with using resources continuously. This enabled the model to reflect more accurately the true costs and returns of growing teak, cassava and maize. In order to calculate the discounted value of teak, a list of teak operations was created, which included the costs and revenues for operations in each year (Table 6). Each value was discounted in the appropriate year and the discounted values were added to give the present net worth.

**Figure 20. Fifteen year old teak plantation ready for harvest after bush fire. Agodokpé, Togo. Photo by Elizabeth Renckens**

Table 6. Cost and Revenues of Operation for Teak Production at a Discount Rate of 8% with Black Market Prices

| Operation | Cost/ha (US$) | Year | Revenue/ha (US$) | Discounted Values |
|---|---|---|---|---|
| Prepare Land | 5.00 | 0 | 0.00 | -5.00 |
| Weed | 12.00 | 0 | 0.00 | -12.00 |
| Seedlings | 0.00 | 0 | 0.00 | 0.00 |
| Plant | 0.00 | 0 | 0.00 | 0.00 |
| Weed | 15.00 | 1 | 0.00 | -13.89 |
| Weed | 0.00 | 1 | 0.00 | 0.00 |
| Weed | 0.00 | 1 | 0.00 | 0.00 |
| Weed | 0.00 | 2 | 0.00 | 0.00 |
| Weed | 0.00 | 2 | 0.00 | 0.00 |
| Weed | 0.00 | 3 | 0.00 | 0.00 |
| Thin | 25.00 | 5 | 1000.00 | 680.58 |
| Harvest | 0.00 | 15 | 3750.00 | 1182.16 |
| Total | 57.00 | | 4750.00 | 1862.74 |

Finally the equivalent annual annuity (EAA) was determined. The resulting number is the net value of teak per year used in the model. The equivalent annual annuity allows projects of different life spans to be compared at the same discount rate. Therefore it was possible to compare benefits of growing teak for a shorter rotation of fifteen years, with a longer rotation of thirty years and with the annual harvest of maize and cassava. Small landholders informally apply this practice to their farming activities. Subsistence farmers will often forego receiving small increments of income over time in order to get one larger return at the end of the time period (Bergert 2000). Planting teak is regarded as investing in the future among many study participants. Often, farmers feel the objective of growing teak is not so much to make a profit, but to have a guaranteed source of future capital. Several farmers referred to it as a “retirement plan.”

The discount rate employed gives a measure of the importance of the time element involved (Davis and Johnson 1987). For most people, particularly subsistence farmers, 100 US$ today is more valuable than 100 US$ in the future. In order to account for this with the production of teak, future values were discounted to reflect current values (Klemperer 1996). The further into the future the profit is realized the greater the impact of discounting. If the discount rate is high, current income is valued more than receiving additional income in the future (Davis and Johnson 1987). Pressing economic want can induce stakeholders to sacrifice the future profit in order to meet present needs (Price and Nair 1984). Individuals who live on subsistence incomes often have higher discount rates. For example, a farmer’s need for immediate money, perhaps to pay for medical bills, or buy food for his family, may overshadow the possibility of earning more money in the future by planting teak (Arnold and Deewees 1995). Conversely, farmers know they may have large unplanned expenses, so planting teak can store wealth for emergencies.

The discount rate depends upon individual time preference. This preference is influenced by factors such as age, degree of education, income as well as personal wants and needs (Davis and Johnson 1987). Most development economists utilize discount rates between eight and twelve percent (Lette and de Boo 2002). For most economic resource allocation problems a discount rate of ten percent is often used. Higher rates make it less likely that an undertaking with distant returns will be economically feasible (Pearce and Turner 1990). For this study discount rates of eight, eleven, and fifteen percent were used.

This study assumes farmers will apply proper silvicultural techniques to their plantations.

The following tables show optimal cassava, maize and teak allocation for each farmer type, under a fifteen year rotation plan, sold on the black market with an eight percent discount rate. These tables assume teak seedlings have been found in the bush as opposed to being purchased.

With a discount rate of eight percent it is profitable for land poor and labor poor farmers to plant a small amount of teak (Tables 7a and 7b). The majority of their land is allocated to cassava, while enough maize is planted to meet the maize constraint.

Table 7a. Constraints for Land poor, Labor poor Farmer (Type 1) for Cassava, Maize and Teak Following a 15 year rotation plan, Sold on the Black market with a Discount Rate of 8%

| Quantity | Constraint | Dual |
|---|---|---|
| Cassava yield (kg) | 501 | 0.00 |
| Maize yield (kg) | 195 | -0.067 |
| Low quality land (ha) | 0.65 | 160.00 |
| High quality land | 0.00 | 400.00 |
| Variable cost | 0 | 0.00 |
| Labor | 1.5 | 0.00 |

Table 7b. Land poor, Labor poor Farmer (Type 1) Land Allocation for Cassava, Maize and Teak Following a 15 year rotation plan, Sold on the Black market with a Discount Rate of 8%, over 4 years

| Year | Low Cassava | High Cassava | Low Maize | High Maize | Low Teak | High Teak |
|---|---|---|---|---|---|---|
| 0 | 0.16 | 0.00 | 0.33 | 0.00 | 0.17 | 0.00 |
| 1 | 0.16 | 0.00 | 0.33 | 0.00 | 0.00 | 0.00 |
| 2 | 0.16 | 0.00 | 0.33 | 0.00 | 0.00 | 0.00 |
| 3 | 0.16 | 0.00 | 0.33 | 0.00 | 0.00 | 0.00 |

Note: Once land is allocated to teak, it continues to get allocated to teak. Years 2 through 4 are the areas allocated to teak for the first time in that year.

Tables 8a and 8b represent farmers who have a large amount of labor, but have little available land. A household with a large labor force requires more food production to feed the family. Nonetheless, under a discount rate of eight percent, a land poor, labor rich farmer optimizes their resources by devoting 0.5 ha to teak, planting maize on both land types, and only planting a small amount of cassava for family consumption.

Table 8a. Constraints for Land poor, Labor rich Farmer (Type 2) for Cassava, Maize and Teak Following a 15 year rotation plan, Sold on the Black market with a Discount Rate of 8%

| Quantity | Constraint | Dual |
|---|---|---|
| Cassava yield (kg) | 1670 | 0.00 |
| Maize yield (kg) | 650 | -0.133 |
| Low quality land (ha) | 1.0 | 200.00 |
| High quality land | 0.5 | 400.00 |
| Variable cost | 0 | 0.00 |
| Labor | 6.1 | 0.00 |

Table 8b. Land poor, Labor rich Farmer (Type 2) Land Allocation for Cassava, Maize and Teak Following a 15 year rotation plan, Sold on the Black market with a Discount Rate of 8%

| Year | Low Cassava | High Cassava | Low Maize | High Maize | Low Teak | High Teak |
|---|---|---|---|---|---|---|
| 0 | 0.00 | 0.21 | 0.502 | 0.29 | 0.50 | 0.00 |
| 1 | 0.00 | 0.21 | 0.502 | 0.29 | 0.00 | 0.00 |
| 2 | 0.00 | 0.21 | 0.502 | 0.29 | 0.00 | 0.00 |
| 3 | 0.00 | 0.21 | 0.502 | 0.29 | 0.00 | 0.00 |

Note: Once land is allocated to teak, it continues to get allocated to teak. Years 2 through 4 are the areas allocated to teak for the first time in that year.

Type 3 farmers represent the typical smallholder found in Agodokpé. They own land, have a family and have limited education. According to the linear programming model, farmers in this category that require an eight percent discount rate should allocate their low quality land to teak production. The majority of their high quality land should be used for maize with the remaining devoted to cassava production (Tables 9a and 9b).

Table 9a. Constraints for Medium land, Medium labor Farmer (Type 3) for Cassava, Maize and Teak Following a 15 year rotation plan, Sold on the Black market with a Discount Rate of 8%

| Quantity | Constraint | Dual |
|---|---|---|
| Cassava yield (kg) | 835 | 0.00 |
| Maize yield (kg) | 325 | -0.133 |
| Low quality land (ha) | 1.60 | 200.00 |
| High quality land | 0.40 | 400.00 |
| Variable cost | 0 | 0.00 |
| Labor | 2.9 | 0.00 |

Table 9b. Medium land, Medium labor Farmer (Type 3) Land Allocation for Cassava, Maize and Teak Following a 15 year rotation plan, Sold on the Black market with a Discount Rate of 8%

| Year | Low Cassava | High Cassava | Low Maize | High Maize | Low Teak | High Teak |
|---|---|---|---|---|---|---|
| 0 | 0.00 | 0.13 | 0.00 | 0.27 | 1.60 | 0.00 |
| 1 | 0.00 | 0.13 | 0.00 | 0.27 | 0.00 | 0.00 |
| 2 | 0.00 | 0.13 | 0.00 | 0.27 | 0.00 | 0.00 |
| 3 | 0.00 | 0.13 | 0.00 | 0.27 | 0.00 | 0.00 |

Note: Once land is allocated to teak, it continues to get allocated to teak. Years 2 through 4 are the areas allocated to teak for the first time in that year.

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Tables 10a and 10b indicate it is most profitable for land rich, labor poor farmers (type 4) to allocate the majority of their resources to teak production. Farmers allocate 2.05 of 3.5 hectares to teak in year zero and an additional 0.45 hectares are allocated in year one. Additional labor is valued by the type 4 farmer, as the dual price shows an additional unit of labor is worth 340.43 US$. Maize and cassava have significantly better yields on high quality land, while teak performs the same, independent of land quality. The model allocates a portion of high quality land to maize and cassava, and the rest to teak production. The majority of resources are allocated to cassava while a small amount of maize is planted to meet the specified household constraints.

Table 10a. Constraints for Land rich, Labor poor Farmer (Type 4) for Cassava, Maize and Teak Following a 15 year Rotation Plan, Sold on the Black market with a Discount Rate of 8%

| Quantity | Constraint | Dual |
|---|---|---|
| Cassava yield (kg) | 501 | 0.00 |
| Maize yield (kg) | 195 | -0.08 |
| Low quality land (ha) | 2.5 | 0.00 |
| High quality land | 1 | 240.00 |
| Variable cost | 0 | 0.00 |
| Labor | 1.5 | 340.43 |

Table 10b. Land rich, Labor poor Farmer (Type 4) Land Allocation for Cassava, Maize and Teak Following a 15 year rotation plan, Sold on the Black market with a Discount Rate of 8%

| Year | Low Cassava | High Cassava | Low Maize | High Maize | Low Teak | High Teak |
|---|---|---|---|---|---|---|
| 0 | 0.00 | 0.84 | 0.00 | 0.16 | 2.05 | 0.00 |
| 1 | 0.00 | 0.84 | 0.00 | 0.16 | 0.45 | 0.00 |
| 2 | 0.00 | 0.84 | 0.00 | 0.16 | 0.00 | 0.00 |
| 3 | 0.00 | 0.84 | 0.00 | 0.16 | 0.00 | 0.00 |

Note: Once land is allocated to teak, it continues to get allocated to teak. Years 2 through 4 are the areas allocated to teak for the first time in that year.

With a low discount rate of eight percent it is advantageous for land rich, labor rich (type 5) farmers to allocate the majority of their land to teak production (Tables 11a and 11b) Farmers interviewed in this category had an average of 6.4 ha low quality land and 1.0 ha of high quality land. All of the low quality land was allocated to the production of teak. The remaining hectare of high quality land was allocated with almost equal amounts of maize and cassava. As with the other tables, the dual price of planting maize is negative, indicating that it would be more profitable for the farmer to plant less maize and more cassava or teak.

Table 11a. Constraints for Land rich, Labor rich Farmer (Type 5) for Cassava, Maize and Teak Following a 15 year rotation plan, Sold on the Black market with a Discount Rate of 8%

| Quantity | Constraint | Dual |
|---|---|---|
| Cassava yield (kg) | 1670 | 0.00 |
| Maize yield (kg) | 650 | -0.133 |
| Low quality land (ha) | 6.40 | 200.00 |
| High quality land | 1.00 | 400.00 |
| Variable cost | 0 | 0.00 |
| Labor | 5.0 | 0.00 |

Table 11b. Land rich, Labor rich Farmer (Type 5) Land Allocation for Cassava, Maize and Teak Following a 15 year rotation plan, Sold on the Black market with a Discount Rate of 8%

| Year | Low Cassava | High Cassava | Low Maize | High Maize | Low Teak | High Teak |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.46 | 0.00 | 0.54 | 6.40 | 0.00 |
| 2 | 0.00 | 0.46 | 0.00 | 0.54 | 0.00 | 0.00 |
| 3 | 0.00 | 0.46 | 0.00 | 0.54 | 0.00 | 0.00 |
| 4 | 0.00 | 0.46 | 0.00 | 0.54 | 0.00 | 0.00 |

Note: Once land is allocated to teak, it continues to get allocated to teak. Years 2 through 4 are the areas allocated to teak for the first time in that year.

When the model is solved with the same constraints as Tables 11a and 11b, (fifteen year rotation plan, with an eight percent discount rate) except with ODEF prices instead of black market prices, it is not profitable to plant teak for farmer type 5 (Tables 12 a and12b.). The majority of low quality land is allocated to cassava. One additional hectare of high quality land is occupied with cassava as well. Maize is only grown on low quality land to fulfill the maize constraint. No resources are allocated to teak.

Table 12a. Constraints for Land rich, Labor rich Farmer (Type 5) for Cassava, Maize and Teak Following a 15 year rotation plan, Sold on the ODEF market with a Discount Rate of 8%

| Quantity | Constraint | Dual |
|---|---|---|
| Cassava yield (kg) | 1670 | 0.00 |
| Maize yield (kg) | 650 | -0.067 |
| Low quality land (ha) | 6.40 | 160.00 |
| High quality land | 1.00 | 400.00 |
| Variable cost | 0 | 0.00 |
| Labor | 5.0 | 0.00 |

Table 12b. Land rich, Labor rich Farmer (Type 5) Land Allocation for Cassava, Maize and Teak Following a 15 year rotation plan, Sold on the ODEF market with a Discount Rate of 8%

| Year | Low Cassava | High Cassava | Low Maize | High Maize | Low Teak | High Teak |
|---|---|---|---|---|---|---|
| 0 | 5.32 | 1.00 | 1.08 | 0.00 | 0.00 | 0.00 |
| 1 | 5.32 | 1.00 | 1.08 | 0.00 | 0.00 | 0.00 |
| 2 | 5.32 | 1.00 | 1.08 | 0.00 | 0.00 | 0.00 |
| 3 | 5.32 | 1.00 | 1.08 | 0.00 | 0.00 | 0.00 |

Note: Once land is allocated to teak, it continues to get allocated to teak. Years 2 through 4 are the areas allocated to teak for the first time in that year.

Continuing to use the discount rate of eight percent, Tables 13a and 13b show the results for the type 3 farmer who owns a medium amount of land and has a medium amount of labor in comparison to other farmer types. This scenario considers teak grown on a thirty year rotation and sold on the black market. Under this scenario it is not beneficial to grow teak and maximize profits. A majority of low quality land is allocated to cassava (1.06 ha) with the remainder of low quality occupied with maize production. A portion of cassava (0.40 ha) is allocated to high quality land. The rotation length of teak has an influence over the profitability of teak. This same scenario generated with a fifteen year rotation plan instead of thirty is profitable (Tables 9a and 9b). What is feasible at fifteen years is no longer practical at thirty years.

Table 13a. Constraints for Medium Land, Medium Labor Farmer (type 3) for Cassava, Maize and Teak Following a 30 year rotation plan, Sold on the Black market with a Discount Rate of 8%

| Quantity | Constraint | Dual |
|---|---|---|
| Cassava yield (kg) | 835 | 0.00 |
| Maize yield (kg) | 325 | -0.067 |
| Low quality land (ha) | 0.4 | 160.00 |
| High quality land | 1.6 | 400.00 |
| Variable cost | 0 | 0.00 |
| Labor | 2.9 | 0.00 |

Table 13b. Medium Land, Medium Labor Farmer (type 3) Land Allocation for Cassava, Maize and Teak Following a 30 year rotation plan Sold on the Black market with a Discount Rate of 8%

| Year | Low Cassava | High Cassava | Low Maize | High Maize | Low Teak | High Teak |
|---|---|---|---|---|---|---|
| 0 | 1.06 | 0.40 | 0.54 | 0.00 | 0.00 | 0.00 |
| 1 | 1.06 | 0.40 | 0.54 | 0.00 | 0.00 | 0.00 |
| 2 | 1.06 | 0.40 | 0.54 | 0.00 | 0.00 | 0.00 |
| 3 | 1.06 | 0.40 | 0.54 | 0.00 | 0.00 | 0.00 |

Note: Once land is allocated to teak, it continues to get allocated to teak. Years 2 through 4 are the areas allocated to teak for the first time in that year.

The model was solved for each farmer type under a fifteen year rotation sold on the black market and the ODEF market with the discount rates of eight, eleven, and fifteen percent as well as a thirty year rotation plan with the same markets and discount rates. Table 14 shows which rotation lengths, pricing regimes and discount rates allow for teak production for each farmer type. If a fifteen year rotation plan is followed, teak is a financially optimal feasible venture for all farmer types while sold on the black market with a discount rate of less than eleven percent.

For fifteen year and thirty year teak sold through ODEF as well as the thirty year rotation black market plan, teak is only a feasible option for farmer type 4, who is characterized as land rich and labor poor. Seven percent of smallholders interviewed represented this category. Teak production was found to be feasible for farmer type 4 under every regime tested.

Farmer type 2, land poor and labor rich, has the lowest feasibility for teak production. Having an average of 1.5 ha and 10 members per household, they must allocate the majority of their land to food crops and do not have not have surplus land for teak production.

Table 14. Feasibility of Teak Production Under Various Assumptions. x indicates teak production is financially successful

| Rotation | 15 Year Rotation | | | | | | 30 Year Rotation | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Price Regime | Black Market | | | ODEF | | | Black Market | | | ODEF | | |
| Discount Rate | 8 | 11 | 15 | 8 | 11 | 15 | 8 | 11 | 15 | 8 | 11 | 15 |
| Farmer Type | | | | | | | | | | | | |
| 1 | x | x | - | - | - | - | - | - | - | - | - | - |
| 2 | x | - | - | - | - | - | - | - | - | - | - | - |
| 3 | x | x | - | - | - | - | - | - | - | - | - | - |
| 4 | x | x | x | x | x | x | x | x | x | x | x | x |
| 5 | x | x | - | - | - | - | - | - | - | - | - | - |

Note: Using seedlings/seeds found in the bush

The model shows that growing teak is only profitable for farmers who plant seedlings or seeds found in the bush, follows a fifteen year old rotation and sell trees on the black market. The discount rate is significant, as teak is only profitable with a discount rate of eleven percent or less. For type 4, land rich and labor poor farmers, teak is profitable under all regimes. Type 4 has the smallest number of farmers.

Teak plantations established with teak stumps grow faster, and produce hardier, higher quality timber than teak collected in the bush (Yadjassan 2006) (Figure 21). The cost of planting one hectare of land with teak stumps is 125 US$. This cost is more than many farmers make per year and more than most have available to spend on farming projects. Any excess money is used for school fees, medicine, funeral expenses and traveling. It is not possible for smallholders to recover the planting costs associated with improved teak seedlings and stumps.

**Figure 21. Planted teak stump after nine months, Agodokpé, Togo. Photo by Amber Lily Kenny**

In many of the scenarios, the model indicates that it is the most profitable to allocate the majority of the resources to cassava production. If not for the constraint, stipulating that maize must be produced, all resources would be allocated to cassava. However, smallholders do not allocate the majority of their resources toward cassava production. The Togolese truly love eating maize porridge, *akplé.* Many eat *akplé* three times a day if possible. Preparing *akplé* is less time consuming that preparing cassava dishes. Togolese farmers feel secure with maize production and it is an important part of their culture. Cassava is a woman's crop. Men may help in the cultivation of it but they do not process it, sell it on the market or retain the income generated from it. When asked why they do not only plant cassava since it is so profitable, male farmers responded with the question, "Well, then what would we [the men] do?" For the most part, men control the market of maize, and retain the resulting revenue. If there is a surplus produced of maize, men sell it at the market. Every year men generate a small amount of income this way. However, in most cases farmers would rather receive a single large payment after a significant amount of time, rather than getting annual increments, even if the sum of the small yearly increments is more than the large one time payment. Without the financial infrastructure, farmers rely on this large one time payment as a way to make large purchases. Teak is seen as an attractive investment by male smallholders who cultivate maize; it guarantees one future large payment.

Farmers do not always want to cultivate all their land. If they do not have enough labor to continually cultivate a parcel of land with food crops, farmers with high social standing can get extended family members to help with one time projects, like planting teak.

## Section Three

## Implications of Study

## Chapter Eight

## Comparisons with Other Studies

This study explores optimal resource allocation between maize, teak and cassava for Togolese smallholders. Evaluating farm data with a linear program showed that although labor and land constrain the feasibility and scale of teak production, the greatest influencing factor on teak feasibility is the discount rate.

Zanin (2005) determined the feasibility of teak production for smallholders in Panama using sensitivity analysis. She found that under various price scenarios, teak projects are feasible with a discount rate of ten percent or less. These results agree with the findings of this study: teak production is profitable for smallholders who have a discount rate of eleven percent or less. Unlike this study, Zanin's smallholders were not restricted by the production of subsistence crops and all had adequate land.

Mittelman (2000) describes a smallholder project in Nakhon Sawan, Thailand, where farmers participated in an on-farm teak planting project. Unlike Togolese farmers, who were eager to plant teak, the smallholders were initially reluctant to include teak production in their farming systems. Mittelman states that the Thai farmers' needs for immediate economic returns were more important to them than the future revenue of teak. Like smallholders in Togo, available land for crops was limited and Thai smallholders were reluctant to allocate land to teak, which would take a number of years to generate revenue. After local participant-project designers encouraged teak planting and facilitated planting arrangements with stakeholders, farmers were more amenable to teak production. Smallholders planted teak with the aim to diversify income benefits and maximize midterm income (through shorter rotations) for investment in farm and family development. Within seven years of project implementation, sales agents started approaching smallholders with offers for their teak. Mittelman concludes that the long term benefits of teak can be combined with the short-term benefits of annual crops resulting in significant income benefits for the smallholders.

Wojetkowski et al. (1988) use multiple objective linear programming (MOLP) to evaluate multiparticipant agroforestry systems. They examine optimal allocations of maize, cassava, leaucaena and teak in an agroforestry system implemented by a farmer and a forester. The MOLP model discounts the forestry costs and returns at a five percent discount rate. It does not discount farming costs and returns. The objective is to find the best mix and density of species that will be advantageous for all participants involved. The analysis was initially run with an original maize price and again with the maize price doubled. In both cases, the MOLP model found that it was not in the farmers' best interest to engage in agroforestry. The forester benefited from the farmer's activities by maximizing his income, but the farmer did not benefit from the forestry activity. The authors suggest this indicates that foresters need to provide some form of compensation to the smallholders to encourage participation in the agroforestry farming system.

The multiple objective linear program is employed to reconcile different attributes and constraints of two stakeholder groups, farmers and foresters, to solve for optimal resource allocation of agroforestry and agricultural activities. This aspect of Wojtkowski, et al.'s paper differs from this study, which considers one participant. In southern Togo, smallholders are the farmer and the forester; it is not realistic to separate foresters and farmers to evaluate agroforestry projects. Foresters work for the government; there are no private forestry companies. Because of limitations of the government, such as a lack of infrastructure, including payment of employees, transport services and program development, foresters and farmers do no collaborate on projects. Additionally, the Ewé, inhabitants of the study area maintain a distrust of centralized authority, which can be traced back to the Kingdom of Tado and its tyrannical king. This distrust has been augmented by almost 40 years of living under a totalitarian regime. Even if state foresters were interested in and had the infrastructure to work with local farmers, they may find it difficult to find willing participants. As long as the Togolese forestry sector, whether state-owned or private, is not organized and not in touch with local stakeholders, this multiple objective linear model worlds be misapplied when selecting the best allocation of crops and timber for Togolese smallholders.

The MOLP problem also differs from this study in that it uses a low discount rate of five percent for the forestry activity. This assumes that the foresters and the farmers have a high time preference. They would often forego current earnings for future earnings. Again, this component of the study may not be realistic for farmers who have a higher time preference due to subsistence needs. Wojtkowski et al. agree with this study in their final point, linear programming can be used as an effective tool for decision making to best allocate resources given a set of circumstance and that single participant agroforestry systems have fewer issues with conflicting goals.

Chaudhary and Jha (2004) analyzed the profitability of a teak plantation intercropped with local agricultural crops for subsistence smallholders in Nepal. Under a rotation plan of 35 years with a discount rate of 15 percent, they found that the cultivation of teak was profitable. However, as with Zanin's study, land was not limited and the relationship between subsistence crops and teak was not examined. Chaudhary and Jha's report advises that teak production should be compared with agricultural crops, but does not include them in their analysis of teak profitability. Subsistence smallholders do not have the option to consider teak production and crop production separately. There is no choice between planting timber crops and planting food crops. If a farmer is going to produce teak, both teak and crop activities must be considered together. A teak feasibility study designed for subsistence farmers that does not include the economic costs and benefits of growing agricultural crops along with the costs and benefits of growing teak is incomplete. A teak plantation may seem successful when analyzed apart from the cropping system, but how successful can it be if the farmer involved cannot produce food to eat? This study includes the agricultural crops necessary for family subsistence while also producing teak. Subsistence farming needs affect the feasibility of a smallholder to plant teak. Considering optimal allocations between staple crops and teak allows for better management decisions of current and future farm activities.

# Chapter Nine

## Recommendations and Conclusions

Togolese smallholders depend on maize and cassava cultivation to survive. Farmers would like to diversify their holdings to include teak production. I hypothesized that teak production would only be feasible for farmers who owned large amounts of land. According to the linear programming model used in this study, it is most profitable for smallholders to grow teak on a short-term rotation and sell it on the black market, even when constrained by subsistence crop production. This model is verified by the management plan farmers currently employ: a shorter rotation sold to buyers on the black market.

As the tropical timber market expands and native supply decreases, the demand for plantation teak is growing. More and more small landholders are incorporating teak into their farm systems to fulfill this demand (Varmola and Carle 2002). Thus far, the majority of teak research has concentrated on the technical and economic aspects of teak. Although there has been limited study on teak's influence on agricultural systems, there is a need for more. Research on the economic and ecological interactions of teak and agricultural crops in farming systems must be carried out to ensure the production of quality timber and profitability of teak plantations for smallholders (Nair and Souvannavong 2002).

Farmers are attracted to teak because of potential financial benefits (Nair and Souvannavong 2000). Many farmers currently plant teak in small plots for personal use, and would like to increase their teak production. Other farmers view teak as a savings account and want to start plantations as a way of having a guaranteed future income

(Bhat and Ok Ma 2004). Farmers who do not wish to utilize all their land with crops may also want to plant it with teak. With this model, it is possible to ascertain an optimal teak and crop ratio to make informed decisions on how much teak a farmer can plant and still grow an adequate amount of subsistence food crops.

An eight percent discount rate represents farmers who are more likely to forego current earnings for future earnings. It is not profitable to plant teak under discount rates higher than eleven percent in most cases, except for type 4 farmers who are land rich and labor poor. A discount rate of less than eleven percent reflects farmers who can afford to wait for a future profit from teak. Generally this included all land rich farmers. Discount rates can be assigned to different groups within the population to improve the ability to forecast the likelihood of systems being adopted (Hoekstra 1985). Farmers willing to plant teak have a lower discount rate than farmers unwilling to plant teak. For a farmer operating under a discount rate of eight percent it is worth waiting for a larger future profit than a smaller immediate profit. The discount rate of eleven percent reflects farmers who are open to the idea of teak, but also put a high value on their subsistence crops of maize and cassava. A discount rate of fifteen percent represents farmers unwilling to plant teak without a substantially higher return and who prefer to realize their profits sooner, whether in cash or in crops for food security.

Ultimately, the discount rate employed depends on a farmer’s preference, defined by his personality, interests and attitudes. During the course of this study, farmers with different preferences were interviewed. Seventy year old men opted to plant teak. Even though they would not personally benefit from the teak, it was worthwhile for them to invest in teak because it would financially benefit their children and grandchildren. Still other farmers, who were younger and owned larger parcels of land, were not interested in planting teak because they preferred to participate in activities with a shorter time frame and faster financial turnover.

If the government eliminated price regulations, it may be more profitable for smallholders to have longer rotations and larger trees. Selling teak trees to ODEF allows farmers to navigate through the legal channels of the Togolese timber industry, as well as ensures that the rightful owner is the actual seller of the teak. However, the governmental regulated market creates an economic environment within which it is not feasible for smallholders to produce teak successfully. The prices paid are not adequate to allow teak to compete with annual crops. Smallholders do not have access to international commercial markets. They must deal with a middleman: ODEF and the Ministry of Environment or buyers on the black market.

The government of Togo controls thousands of hectares of teak, and is the main competitor for smallholders selling teak. This study did not considered land tenure. The government has an eminent domain policy that allows state seizure of lands despite local and traditional ownership. In 2006, the Togolese Ministry of Environment notified the residents of Agodokpé that land surrounding the village will be claimed by the government for a national forestation campaign which involves planting hundreds of hectares of teak. Not only are smallholders upset by the potential loss of their land, they are also concerned about where they will grow crops for food.

Several farmers have participated in large teak planting projects with the Peace Corps and are worried that the government will benefit from the teak that they planted. ODEF explained the governmental seizure of land as a way for the Ministry of

Environment to work with farmers who want to grow teak as well as utilize uncultivated land to plant with teak.

If farmers choose to plant teak they may want to include other income generating activities into their farming system as well. While it is possible to find success with teak, it can take considerable planning. It is difficult to predict the financial viability of teak plantations. Success depends on many factors, including the costs of establishing and managing the plantations, and the prices that can be obtained upon harvesting (Keogh 2004). In addition to these considerations for teak, the farmers must consider how to achieve adequate crop production to fulfill his family's needs.

Teak production in Togo can be problematic because of lack of infrastructure, such as access roads and transportation, finding quality genetic stock and strict government regulations. Teak production may become even more difficult because the future risk of an encroaching teak pathogen (Nair and Souvannavong 2000). According to ODEF foresters, a fungus is spreading among teak plantations from Cote D'Ivoire through Ghana and could eventually infect trees in Togo. Researchers at ODEF recommend that teak be planted in mixed stands instead of plantations. They advise including other species such as *Terminalia superba* (limba) and *Chlorophora excelsa* (iroko) in plantations would help reduce the impact of this pathogen. Currently, this advice is unheeded and the Togolese government and smallholders continue to plant teak monocultures.

It can be difficult for Togolese smallholders to profit from teak. They often must act as the forester and the farmer. Information on teak establishment, management and prices are not readily available or easily accessed (Nair and Souvannavong 2002).

Government prices are much lower than international prices and are not adequate to cover costs of growing and establishing teak. Farmers who do sell on the black market are often unaware of fair teak prices and sell their teak for less than market value. It has been documented that villagers in West Africa have received prices less than one-quarter of the international value (Keogh 2004).

Despite limitations, teak can still be considered a viable income generating activity for the small landholder. Global demand for teak is increasing while native supplies are decreasing. As demand for teakwood increases, stakeholders in tropical countries are establishing more and more teak plantations to address the increasing demand (Keogh 2004). Plantations provide an alternative source of timber to meet the need for teakwood (Varmola and Carle 2002). International and domestic markets exist for Togolese teak. Farmers in the study area who have planted teak have found success with plantations and recommend it to others.

This study suggests that teak production is feasible for all farmer types under a discount rate of less than eleven percent. Teak, however, is not accessible to everyone and Togolese farmers are unsure of the correct silvicultural techniques to ensure maximum profitability from the trees. Every farmer I worked with expressed interest in working with teak, but some were apprehensive, thinking they would not have enough land to produce food crops. To address this concern, the linear programming model results presented in this paper can be used as a project planning tool for extension agents who work with small landholders. Natural resource Peace Corps volunteers often collaborate with farmers on teak plantation projects, but determining project size can be difficult and is often an impediment to the progress of the project. A farmer or volunteer can become overzealous in planning the project size. This linear program can serve as a guide to help Peace Corps volunteers ascertain realistic project dimensions. Furthermore, ICAT agents, whose responsibilities include aiding local farmers with agroforestry activities, can apply this model and its results to their work. Finally, the Togolese Ministry of Environment and its forestry branch, ODEF, can utilize the model to calculate appropriate allocations of land devoted to teak and crops for farmers, if the government is sincere about working with the smallholders to plant teak and are not using smallholder land for their sole benefit.

Linear programming allows for better, more informed decision-making of farming activities. Teak plantations may not be an option for all smallholders, but for those who would like to venture into teak production, this linear program is a tool that can aid in finding optimal resource allocation to achieve best outcomes. Contrary to my initial assessment, farmers can produce food crops for their families as well as teak. Furthermore, teak production can provide economic security for Togolese smallholders whose future economic and social wellbeing are already precariously dependent upon a dynamic unknown environment.

## Chapter Ten

## Concluding Remarks

The lives of Togolese smallholders are full of uncertainties and hardships. They must make decisions on what to plant and how much and then depend on the crops they grow to survive. The farmers must consider the unknown influences of weather, market demands and family needs in their decision-making processes. After planning, the smallholders must tirelessly work their land for months, hoping for a successful harvest so they can send their children to school and cover medical costs.

Contrary to popular "development" opinion, smallholders are not always risk averse and apprehensive of new projects. With increased access to healthcare and education, along with a deterioration of the environment, a subsistence existence can no longer cover the costs associated with contemporary Togolese life. Togolese farmers are open to and, in fact, desperate for new income generating activities. During my Peace Corps service I collaborated on numerous projects with smallholders. Whether it was raising bush rats, making tofu, or planting teak, I was constantly surprised at the determination and motivation of the farmers I worked with. In Togo, no matter how hard life gets, people continue through it with a dogmatic determination, embodied by the Togolese catch-phrase, "*Çava aller,*" literally meaning, "It's going to go." Said in response to all things good or bad, the Togolese use this phrase to signify how life travels on with or without you.

The privilege of living side by side with the people of Agodokpé has profoundly changed me. Through interactions and experiences with my friends and families in village, I have learned vast amounts about life, the world and myself. I wish it was possible to repay them for all the lessons and love they have given me. These gifts are priceless, but I hope, in some small way, this study on teak and resource allocation will help people in Togo in their quest to improve their quality of life. Like a departing rusty bush taxi on market day, the Togolese may feel that life attempts to travel on without them, but they are running as fast as they can to keep up and climb aboard. *Çava aller et miagadogoo!* (Figure 22).

**Figure 22. Miagadogoo Agodokpé. Road leaving village. Photo by Amber Lily Kenny**

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