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AN ANALYSIS OF TECHNOLOGY AND MANAGEMENT GAPS FOR GROUNDNUT PRODUCERS IN KENYA

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An Analysis of Technology and Management Gaps for Groundnut Producers in Kenya

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DEDICATION

This thesis is dedicated to my husband Peter, my daughter Alpha Theresia and my Mother Rosina for their moral and material support.

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ACRONYMS

NaSARRI	National Semi Arid Resources Research Institute
MTE	Mean Technical Efficiency
ATE	Average Technical Efficiency
FAO	Food and Agriculture Organization
FAOSTAT	FAO Statistics
GDP	Gross Domestic Product
GoK	Government of Kenya
KARI	Kenya Agricultural Research Institute
MSPF	Meta Stochastic Production Frontier
NGOs	Non-Governmental Organizations
NRF	Non-Research Farmers
PCRSP	Peanut Collaborative Research Support Program
RF	Research Farmers
SPF	Stochastic Production Frontier
TE	Technical Efficiency
TFP	Total Factor Productivity
TG	Technology Gap
US	United States
USAID	United States Agency for International Development

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CHAPTER 1: INTRODUCTION

The agricultural sector plays an important role in the economy of sub-Saharan countries by providing employment, food, and income for the majority of the work force. On average, 71% of the people in sub-Saharan Africa live in rural areas where agriculture is the main economic activity. In countries such as Ethiopia, Uganda, Tanzania, Malawi, Rwanda, Burundi, Ghana, and Nigeria, agriculture generates at least one-third of the GDP and employs at least 57% of the workforce (Table 1, FAO, 2009; World Bank Indicator, 2010).

Despite the importance of the role it plays in the economy, the agricultural sector's performance is below its potential. Sub-Saharan Africa achieved an annual productivity growth rate of 0.6% during the period 2000–2007, while Asian countries achieved an annual productivity growth rate of 2.9% during the same period (FAO, 2009). Bravo-Ureta et al. (2007) estimated a mean technical efficiency (MTE) of 74% for African agriculture. This indicates that there is still the potential to improve agricultural productivity in these countries using existing technology without increasing input bundles.

In order to improve agricultural production, human capital in terms of knowledge and skills is vital (Anderson 2007). Extension services, which provide education to farmers about new technology and efficient farming methods, can improve the welfare of farmers and rural people by helping them to improve their productivity. According to Anderson (2007), there are a half-million agricultural extension workers in the world: 80% are civil servants, 5% are from the private sector, and 12% are from universities, non-governmental organizations (NGOs), and 3% are from independent public organizations. Many researchers support the idea that investment in extension services is central to improving agricultural production and increasing farmers' incomes. Many articles in the literature acknowledge the presence of technology and management gaps.

The literature on technical efficiency (TE) and the technology gap (TG) on groundnut production is scant, despite the fact that adoption and adaptation of groundnut technology could have great advantages for human health and prosperity, as well as for the environment and food security. For example, in a meta-regression analysis by Bravo-Ureta et al. (2007) that covered the period 1995–2004, only two studies on groundnut production in West Africa were found, and none on groundnut production in East Africa.

In the major groundnut growing areas in Kenya, groundnuts account for a significant part of the diet of the community. Groundnuts are prepared mainly as a paste, and made into a sauce for consumption with traditional dishes. They are an excellent source of cooking oil, and can be consumed whole, either boiled or roasted. Groundnuts are a highly nutritious food, with 38.6 % protein content and 47% oil content; they have been shown to have specific health benefits, being associated with a reduced risk in the development of type II diabetes and cardiovascular disease. With the increasing costs of animal protein, groundnuts have become the most important source of protein in East Africa (Okello, 2010).

The groundnut plant has the ability to survive in areas of low rainfall (arid and semi-arid regions) and, because it is a legume, it increases soil fertility by fixing nitrogen in the soil. It requires fewer inputs than many other crops, giving a high return per unit of land, and hence is appropriate for small-scale farmers, including women, (Okello, 2010; Mutegi, 2010). The literature reveals that in African countries, groundnuts were originally cultivated by women to supplement their families' diet with protein. However, groundnut production can also be a way for women to earn income and participate in the cash economy. Women account for 70–80% of household food production in sub-Saharan Africa, growing crops to sell in the market, as well as preparing it for their families (Appendix 1, ICRISAT, 2001; Lastarria-Cornhiel, 2008). Thus, any improvements in technical efficiency and productivity will improve the welfare of African farm women and their families.

1.1. The Research Problem

In Kenya, medium- and large-scale farmers, who account for 30% of marketed agricultural produce, grow crops such as tea, coffee, maize, and wheat. In addition, many keep livestock for commercial purposes. The average medium-scale farmer works from 3 to 49 hectares for food crops. For large-scale farmers raising both crops and livestock, the average farm size is 50–30,000 hectares (Republic of Kenya, 2010). Such farmers have access to credit, and are interested in improved technologies. They tend to be receptive to technology, and to practice modern farm management practices, which results in increased productivity per land unit (Republic of Kenya, 2010).

However, the bulk of the agricultural sector consists of small-scale farms that average 0.2–3.0 hectares. Small-scale farmers produce over 70% of Kenya's maize, 65% of the coffee, 50% of the tea, 80% of the milk, 85% of the fish, and 70% of the beef and related products (Republic of Kenya, 2010). Small-scale farms account for 75% of the total agricultural output and 70% of marketed agricultural produce. Such farms have limited access to extension services (Republic of Kenya, 2010).

Kenya's production of maize, beans, and root tubers increased between 2002 and 2007 (Table 2); however, the production of other food crops declined, due to a combination of factors, especially sporadic drought, lack of quality planting material, pests, and diseases. Other factors limiting production include the high cost of items such as fertilizer; poor and long marketing chains; high transport costs; and a low level of mechanization. Taken together, these factors continue to make it difficult for most small-scale farmers to improve their management or technical efficiency (TE) and minimize the technology gap (TG). Most have limited access to extension agents who could help them bridge the technology and management gaps. Production of the main food crops, such as maize, wheat, and rice, is less than sufficient to meet the country's consumption requirements. However, there is significant potential for improving the production of food and commercial crops such as cotton, pyrethrum, sisal, and oil crops, including groundnuts.

Between 2002 and 2007, the annual fertilizer demand in Kenya increased from 329,449 tons to 410,214 tons, yet fertilizer use by the majority of small-scale farmers is minimal. Over the same period, production of certified seed for various crops also increased, from 12,998 to 34,682 tons. The volume of imported seed rose from 1,217 to 4,773 tons. Despite the availability of these inputs and the existence of a well-developed agricultural research system, the application of research and development results to the adoption and adaptation of new technology in agricultural production is low (Okoko et al, 1998; Rao et al. 2010; Republic of Kenya, 2010). This is due to poor distribution systems, and the monopoly of the supply of seed by the Kenya Seed Company, which concentrates its operations in high-rainfall areas. The volume of pesticide imports reached 7,000 tons (Republic of Kenya, 2010); yet most small-scale farmers do not have the knowledge and the skills to use pesticides safely. The use of improved inputs such as hybrid seed, concentrate feeds, fertilizer, and the use of pesticides and machinery by small-scale farmers has historically been relatively low (Okoko et al., 1998).

Because most agricultural research in Kenya is focused on the crops produced in high-rainfall areas, the potential for groundnut cultivation in arid and semi-arid lands has received little attention. The few available empirical studies for African groundnut farming show that there is a considerable gap between what farmers could achieve and their actual average yields in the field (Thiam and Bravo-Ureta, 2003). This suggests that there exists a significant potential for increasing groundnut yields using the available input and the existing technology.

Several groups are tackling the problems facing the groundnut industry to minimize the observed gaps in order to help small farmers increase groundnut productivity, and thus farm income. Among them is the Peanut Collaborative Research Support Program (PCRSP) in collaboration with the Kenya Agricultural Research Institute (KARI) and the National Semi- Arid Resources Research Institute (NaSARRI) in Uganda. PCRSP is supported by the United States Agency for International Development (USAID), several universities in the United States, and institutions in host developing countries. The program focuses on finding ways to reduce the constraints that limit sustainable peanut production and food delivery through an environmentally sound system.

1.2. Objective of the Study

The general objective of this study is to analyze the potential for increased household income through increased productivity in the groundnut farming system. The study analyzes the technology and management gaps between groundnut farmers who participated in on-farm trials conducted by KARI or otherwise had access to improved seeds and farmers who received limited or no exposure to research or extension. The former group of farmers is called "research farmers" (RF), while the latter is referred to as "non-research farmers" (NRF).

The specific objectives of this study are to analyze the average yield differences between farms in terms of: (1) the use of technology, specifically improved versus traditional seed varieties; (2) differences in farm management ability between research and non-research farmers; and (3) differences in farm management ability between male and female farmers.

1.3. Data and Methodology

The farm-level data were collected through a survey conducted by the Kenya Agricultural Research Institute (KARI) in cooperation with the Ministry of Agriculture between April and August 2010 for two growing seasons. The survey was carried out in the Ndhiwa district and covered three divisions (i.e., the Ndhiwa, Nyarongi, and Kobama divisions) that had received groundnut research interventions (mainly in lower midland

and upper midlands agro-ecological zones). The selection of the farmers to be surveyed was conducted through consultations between KARI researchers, the Ministry of Agriculture extension staff, local chiefs, and village elders. A random sample of 249 households was selected: 149 farms in Ndhiwa, 69 in Nyarongi, and 31 in Kobama. As indicated, these farms are categorized into two groups: research and non-research farmers. Research farmers (RF) are those who had at any time participated in on-farm groundnut trials and/or had direct interventions from researchers on groundnuts farming. Non-research farmers (NRF) are those who planted groundnuts but who had had no direct intervention from researchers and/or extension experts.

The data set includes socio-demographic data, land ownership data, and land use data on the farms for the two seasons of 2009. Other variables include the crop farming system (monoculture versus intercropping); the cost of purchased inputs; hired and family labor; cash expenses; total groundnut yield; net yield (after losses due to factors such as aflatoxin disease); household income from sources other than agriculture; farmer access to credit, networks, and markets; value addition; and the use of irrigation on the farm.

1.4. Organization of the Thesis

The remainder of the thesis is organized as follows: Chapter Two characterizes the agricultural industry in Kenya, with the geographical location, background of groundnut production, descriptions of the agro-ecological zones and the contribution of the agricultural sector to GDP. Chapter Three is a review of the literature, presenting an overview of the area studied and a discussion of the yield gaps for groundnut and other crops in Kenya and the TE performance for African farms. Chapter Four outlines the methodology used in this study to analyze the management gap (TE) and the technology gap (TG) among small-scale farmers. Chapter Five presents the results, and the last chapter offers some conclusions.

Table 1: Contribution of agriculture to GDP for selected countries in sub-Saharan Africa

Country	**Contribution to GDP (% total GDP)**	**% of workforce engaged in agriculture**	**Rural population (% total population)**	**Agricultural land (% of total land)**
Ethiopia	50	83	82	35
Ghana	35	57	62	65
Malawi	36	84	85	53
Nigeria	32	35	56	86
Tanzania	46	81	72	39
Uganda	48	85	86	65
Zambia	17	70	56	34
Botswana	2	30	41	46
Madagascar	26	82	71	70
Kenya	25	90	79	47
Burundi	35	-	90	89
Rwanda	36	-	82	78
Mozambique	28	-	64	62
Average	**32**	**67**	**71**	**59**

Source: FAO, 2009, data World Bank, 2010

Table 2: Production in kg for selected crops in Kenya, 2002–2006

Years	**2002**	**2003**	**2004**	**2005**	**2006**
Crop					
Beans, dry	480,792	428,796	277,501	382,307	531,800
Beans, green	28,818	33,000	37,000	37,500	37,000
Cassava	601,976	423,795	642,868	347,819	656,633
Cow peas, dry	59,428	46,967	29,321	36,184	87,808
Groundnuts, with shell	21,000	21,000	21,000	21,000	21,000
Leguminous vegetables	160	250	500	1,000	1,750
Maize	2,408,596	2,710,848	2,607,139	2,905,559	3,247,200
Roots and tubers	15,865	21,134	21,400	16,324	22,846
Sweet potatoes	434,774	615,458	571,293	230,723	724,646

Source: retrieved from FAOSTAT FAO Statistics Division, 17 February, 2011

CHAPTER 2: THE AGRICULTURAL INDUSTRY IN KENYA

In Kenya, as in other sub-Saharan countries, agriculture is the backbone of the economy and is a means of livelihood for most of rural population. It contributes 26% to the GDP directly and adds another 25% indirectly. It accounts for 65% of exports and provides informal employment to more than 70% of the population in rural areas (Republic of Kenya, 2010). The unemployment rate is 40%, and 50% of the population lives below the poverty line. This chapter provides a background on groundnut production in Africa, the location of the study area, and further provides details concerning agricultural sector in Kenya.

2.1. Geographical Location of Study Area

Kenya is located in East Africa, bordering the Indian Ocean, between Somalia on the northeast and on the southeast. To the north, northwest and west, it is bordered by Ethiopia, Sudan, and Uganda. According to the 2010 estimates from The World Factbook, Kenya covers a total area of 580,367 km^2, of which 569,140 km^2 is dry land and 11,227 km^2 is water. Of the 8.01% of the land that is arable, 0.97% is dedicated to permanent crops and 91.02% to other crops (World Factbook, 2010). In 2010, Kenya's population was estimated to be 40,046,566, of which 42.3% were less than 14 years, 55.1% are between 15 and 64 years, and 2.6% are over 65 years.

The Ndhiwa district, in the Nyanza Province, lies in the Lower Midland (LM3) agro-ecological zone between Latitude 0.73°S and Longitude 34º E. It is situated at an altitude of 1200–1400 meters above sea level, between the lower Lake Victoria basin and western Kenya. Ndhiwa receives, on average, about 1300 mm of rainfall annually, distributed in a bimodal pattern; the long rainy season is from February to June, with a peak in March–April, while the short rainy season is from August to November, with its peak in October. The division has three types of soils; black soil (vertisols–cotton soil), silt loam, and clay loam (luvisols). The vegetation is mainly of the savanna type, with thick bushes and open grass. However over the past 50 years, there has been a continuous decrease in vegetation cover due to increased agricultural activity (Okuthe, forthcoming). The area in this agro-ecological zone is suitable for the growth of groundnuts.

2.2. Background of Groundnut Production in Africa – Kenya

Groundnuts originated in Bolivia and Argentina, and were later exported to Africa, North America, and Asia during the wave of colonialism. China, India, Nigeria, and the United States are the largest producers. Worldwide, around 23.79 million hectares are planted to groundnuts, spread as follow: 49.9% in Asia, 44.54% in sub-Saharan Africa, 4.88% in America. In 1994, the world total was 22.23 million: 61.5% in Asia, 33% in sub-Saharan Africa, and 3.1% in America (Badine 1994). Thus, the proportion of land under groundnut cultivation has increased since 1994, while that of Asia has decreased. Groundnut is the world's fourth most important source of edible oil and the third most important source of vegetable protein. Groundnut seeds contain high-quality edible oil (50%), easily digestible protein (25%), and carbohydrates (20%) (World Agriculture).

In Kenya, groundnuts are grown in the coastal region and in Western Kenya in the Nyanza and Western provinces, with the bulk of production in the Lower Midland zones.

Groundnuts are grown both on a small scale, for subsistence, and as a cash crop. In the rural appraisal carried out in 1996 in the Ndhiwa and Oyuer provinces in southwest Kenya, farmers ranked groundnut production as their most important cash crop enterprise

2.3. Kenya's Agro-Ecological Zones and Land Use

Kenya is divided into seven ecological zones: Tropical Alpine, Upper Highland, Lower Highland, Upper Midland, Lower Midland, Lowland, and Coastal Lowland. Using rainfall patterns as a criterion, Kenya is divided into three main agricultural production zones. First is the high-rainfall zone, which receives more than 1000 mm of rainfall per year, occupies less than 20% of the productive agricultural land, and supports approximately 50% of the country's population. This zone produces food and cash crops as well as livestock, under semi-intensive and intensive systems. The main crops produced in this zone include tea, pyrethrum, potato, coffee, and vegetables. There are many dairy farms; nearly 75% of Kenya's milk is produced in this zone.

Second is the medium-rainfall zone, which receives between 750 mm and 1000 mm of rainfall per year. This zone occupies between 30% and 35% of the country's land area and supports about 30% of the population. Farmers in this zone keep cattle and small stock and grow drought-tolerant crops. There is a continuous, significant movement of population from the densely populated high-rainfall zone to this zone.

Third are the low-rainfall areas, which receive between 200–750 mm of rainfall per year. These areas support about 20% of the human population and 65% of the wildlife, and produce 80% of the country's livestock (Republic of Kenya, 2010).

2.4. Productivity Performance in Kenya

The productivity levels for agricultural produce, fish, livestock, and forest products are below potential; for the past five years, the yields of some agricultural products have either declined or remained constant (Figure 1). This is the case for groundnut production, as attested by FAOSTAT data (Figure 2). Much of the available cropland is under-utilized, with smallholders using only 60% of their land for agricultural production (Republic of Kenya, 2010).

The productivity of the agricultural sector is constrained not only by the under-utilization of the potential agricultural land, but also by high production costs; losses due to pests and drought; inefficiencies in the supply chain resulting from limited storage capacity; lack of post-harvest services; poor access to input markets; and lack of knowledge about how to add value to crops. Semi-processed, low-value produce constitutes 91% of all Kenyan agriculture-related exports; as such, they are not competitive in world markets. One of the ways that productivity could be increased is by adding value to agricultural produce, thus enhancing competitiveness in world markets and increasing market penetration.

Crop pests and diseases add another constraint to the improvement of agricultural productivity in Kenya. Sometimes as much as 40% of a harvest is lost due to the lack of appropriate storage structures and poor handling. In some parts of the country, post-harvest disease pathogens have resulted in disastrous effects, including some deaths among consumers. The high cost of pesticides and environmental control equipment is another big challenge to small- and medium-scale farmers. Measures to control and eradicate diseases and pests in livestock and crops could play a major role in improving productivity in Kenya.

Another major constraint is the limited availability of productive land in Kenya. Only about 16% of the total land area (576,000 km^2) receives adequate and reliable rainfall. This potentially arable land is primarily used for commercial agriculture, with cropland occupying 31%, grazing land 30%, and forests 22%. The increasing alternative land uses associated with the growing human population, such as game parks, urban centers, markets, homesteads and infrastructure occupy the rest of the land. About 84% of the country is either arid or semi-arid, receiving low and erratic rainfall, and is not suitable for rain-fed farming. Pastoralists, and agro-pastoralists use the arid and semi-arid lands as rangelands.

Despite unexpected changes in the weather, the impact of climate change, and other external factors, the agricultural sector achieved an average annual growth of up to 5.2% by 2007, with the highest being 6.2% in 2006. This range surpassed the set target of 3.1% for 2003–2007 (Republic of Kenya, 2010). Crop yields on smallholder farms have increased significantly over the last five years, especially from the high-rainfall agro-ecological zone. For example, the average yield of maize has increased from 1.5 to 3 tons per hectare. This gain is attributed to better technology transfer, adoption of high-yielding varieties, better agronomic practices and support from the extension services (Republic of Kenya, 2010). The yields for medium- and large-scale farmers have increased by an even higher margin.

2.5. Land Tenure in Kenya

In Kenya, land can be classified as communal land, government trust land, and privately owned land. The communal land ownership system is based on traditional customary rights, and all individuals born in a community with communal land have a right to use but not to sell the land. Government trust land is for public use such as buildings, forests, research, and national parks held by ministries, state corporations or other public institutions. Privately owned lands are registered; the owner holds the title under a freehold or leasehold system. The owner of such land can use it as collateral to access credit. Land tenure in Kenya is very important, as it determines the level of investment in and development of the land. Private ownership has encouraged investment and long-term improvements and development on farms to create a secure market for land.

2.6. Summary

Agriculture contributes significant portion to the GDP. It is a source of employment and a source of raw materials to the other sectors of the economy. However, there is a considerable gap between actual and potential production. Constraints hindering the agricultural sector can be categorized into weather problems, institutional problems, and technological problems. The next chapter provides the literature review relating to the study.

Figure 1: Productivity trend of main crops in Kenya: 2005–2009

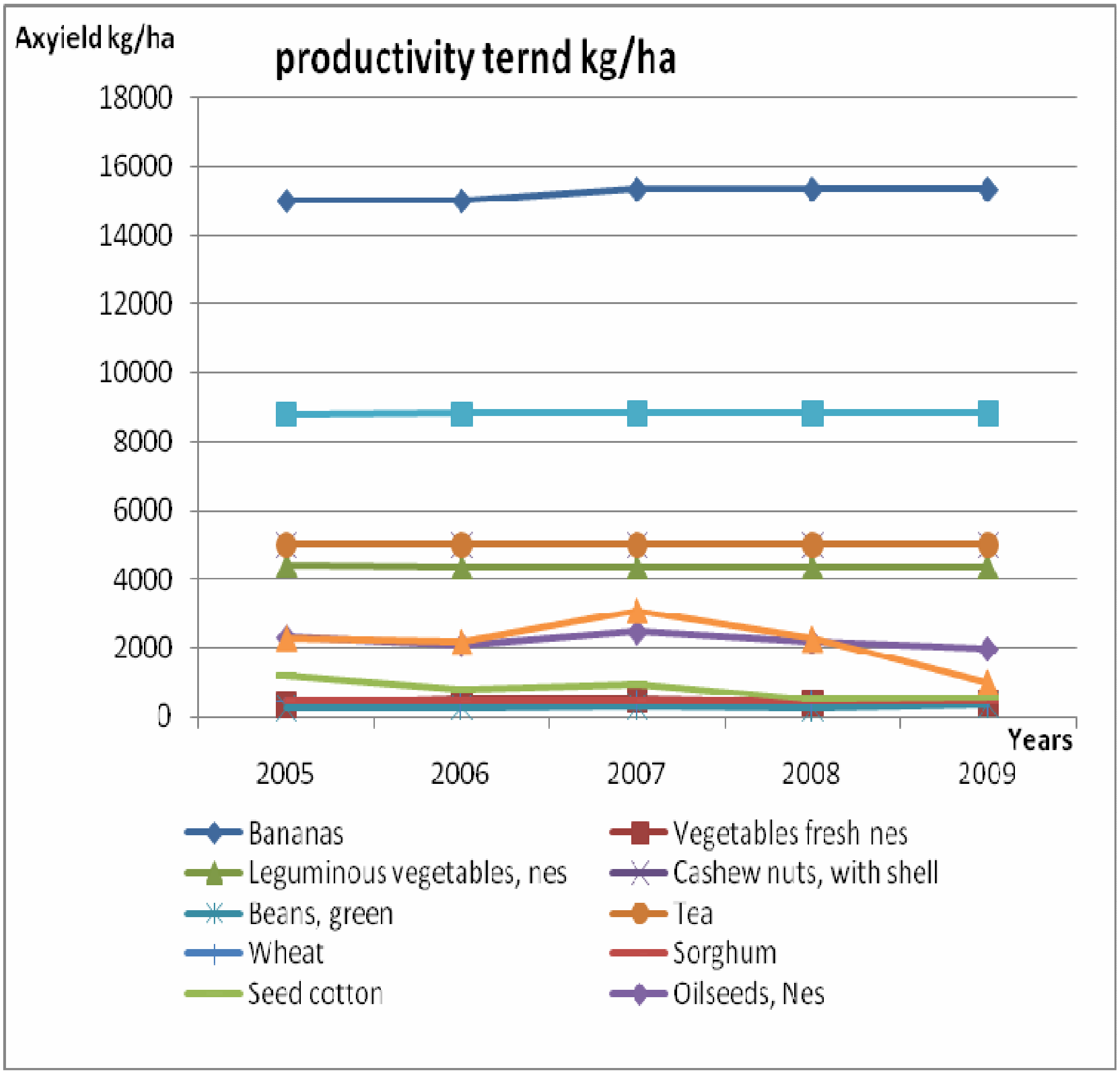

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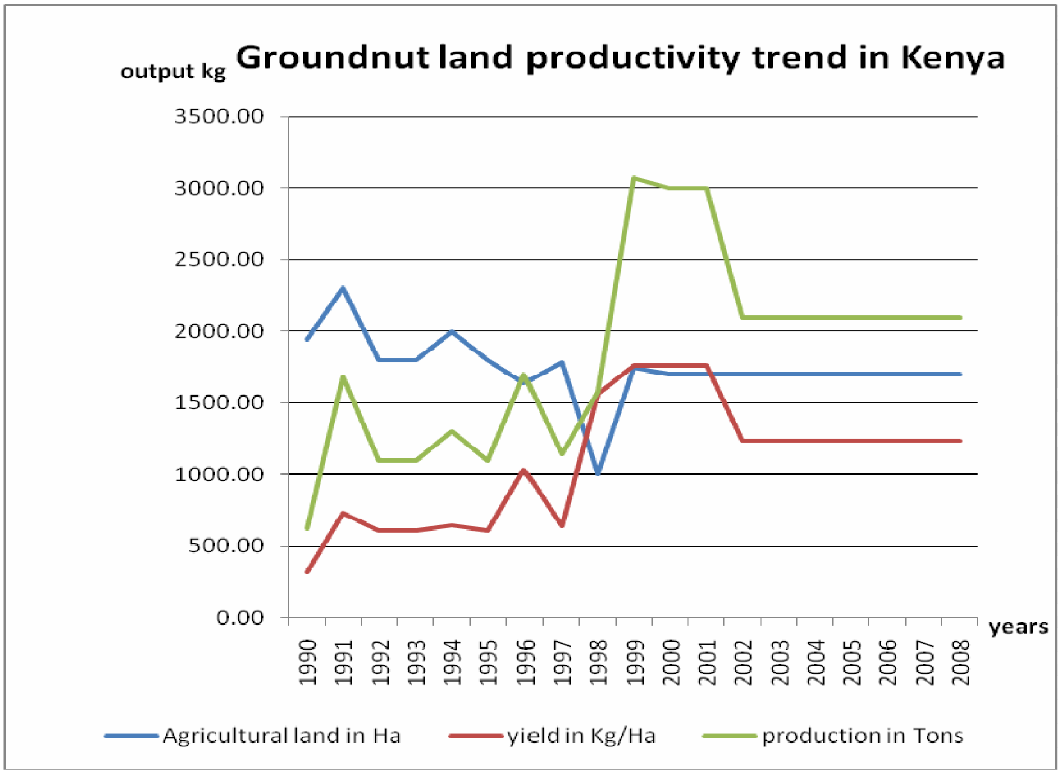
Figure 2: Groundnut area harvested (ha), yield (kg/ha), and production (tons)



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CHAPTER 3: LITERATURE REVIEW

This chapter gives an overview of the area under study, the statistics on groundnut productivity in Kenya, and the determinants of technical efficiency (TE) and the technology gap (TG).

3.1. Technical efficiency (TE) in sub-Saharan Africa

In terms of productivity growth, Africa is the weakest performer among the developing countries. Its annual TFP growth rate is only 0.6%. Asia has a much stronger annual TFP growth rate of 2.9% (Tim & Rao, 2003). Fulginiti and Perrin (1998) support other studies, which show that at least half of the least-developed countries (LDC) have experienced a decline in agricultural productivity in recent years.

For the years 1997–2007, the annual crop production growth for sub-Saharan Africa was 2.9%; for China and India it was 3.1%; for East Asia it was 3.3%; and for developed countries it was 0.7% (FAO 2009)

Productivity improvement is possible only if there is a differential between actual productivity and potential yields—what the farmers could produce with better knowledge, subject to farmers' preferences and resource constraints. The productivity differential can be classified into two types of gaps: a technological gap and a management gap. These gaps are defined by the differences between farmers' actual practices and the best practices that exist at any point in time. Best practices are an embodiment of the latest science-based developments designed to overcome the limitations imposed by traditional technology and practices and thereby enhance productivity. However, new technology must always be aligned to the agro-ecological and socioeconomic characteristics of the target area (Anderson, 2007). Bravo-Ureta (2002) explains that technical efficiency refers to a situation in which production is close to the production frontier—the maximum output attainable, given the level of technology. Changes in technical efficiency reflect the ability of producers to use best practices in the production process. Bindraban et al. (2000) view yield gaps as differences between achievable yield and the actual yield under optimal management practices. Technological change captures "jumps" in the production function that stem from the application of improved practices of research and development efforts.

Narrowing the technological gaps in order to improve productivity requires investments and entails recurring costs for inputs such as improved seed and fertilizers. At the same time, narrowing the management gap may offer low-cost means of raising productivity through the application of improved management practices (Anderson, 2007).

Researchers admit the presence of yield gaps between potential and farm-level yields across ecologies, regions, and countries (FAO, 2004). Some countries producing rice produce only 4–6 ton/ha compared to the potential yield of 10–11ton/ha; this represents a yield gap ranging from 10% to 60% (FAO 2004). In 1993, the average technical efficiency (ATE) index in 14 developing countries was 72%, while the allocative efficiency and economic efficiency were 68% and 43%, respectively (Bravo-Ureta and Pinheiro, 1993).

Similarly, in sub-Saharan Africa (SSA), most agricultural crops do not achieve their potential yields. According to FAOSTAT data (2011) the average yields of groundnuts for SSA, West Africa, South Africa and East Africa are 1027, 1705, 1207 and 668 kg/ha, respectively (Table 3). Although the first of these figures is high compared to the figure of 980 kg/ha in 2006 for SSA recorded by Bucheyeki et al. (2008), this level is less than the average world record of 1606.2 kg/ha (Table 3). In another study on groundnut production in Senegal, Thiam and Bravo-Ureta (2003) estimated the ATE for groundnut production to be 70.24%, which implies that groundnut production in Senegal could be increased by 29.76% on average, using current input and technology.

During the period of 1980's –2005, the MTE for dairy and beef cattle was 80.6%; for other animals 84.5%. The lowest MTE, 72.4%, was for rice. In terms of geographical locations, Africa has the second-lowest estimated TE when compared to the other regions (Table 4). Recent studies reveal a similar trend for African agriculture, showing a lower TE than the maximum expected potential output. Table 5 gives the summary of combined technical efficiency estimates from recent studies covering the period 2006–2010 as well as the TE estimates extracted from the study by Bravo-Ureta et al. (2007) for African farms. The summary shows information in both periods African farmers still produce below the expected potential.

From the table it becomes apparent that the results are not much different from the previous TE studies summarized by Bravo-Ureta et al. (2007). The result follows a similar trend, regardless of the methods and functional forms used to estimate the technical efficiency. This implies that still there is room to improve technical efficiency on African farms. There are several factors causing these yield differentials; some are within the farmers' capabilities to change, while others are beyond their capacity. The main factors as discussed by FAO (2004), Herdt and Mandac (1981), and Bindraban et al. (2000), are biophysical factors, cultural practices, socioeconomic conditions, technology transfers, and institutional and policy factors. Because these factors are quite variable, some farms always have higher yields (perform better) than others do, regardless of inputs used or management practices.

3.2. Overview on yield gaps for groundnut and other crops Kenya

According to FAO data (2011) on Kenya groundnut production, the total production in (tons), groundnut land productivity (kg/ha) as well as the land employed for groundnut has remained constant for the past seven years. Compared to other East African countries such as Tanzania and Uganda, Kenya is lagging behind in terms of total production (Figure 3); but in terms of productivity per hectare, it is more efficient than Tanzania and Uganda (Figure 4). In Western Kenya, the average yield ranges from 500-1100 kg/ha, depending on the farming system and type of seed farmers use (improved or local groundnut varieties).

Farmers obtain less than 30–50% of their potential yields. Okoko et al. (1998) observed an average yield of 1070 kg/ha for Valencia White (a high-yielding groundnut variety), while the farmers' traditional variety, grown in pure stands, yielded an average of only 710 kg/ha. When the traditional variety was intercropped with other species, the average yield was 730 kg/ha for Valencia White, and 510 kg/ha for the traditional variety.

Yield gaps can be attributed to various factors: biophysical and socioeconomic factors; access to technology and agents with agricultural expertise; and government and institutional policies (FAO, 2004). Farmers in Western Kenya attribute their own low groundnut production to several constraints, including lack of equipment for pest control, lack of high-yielding disease-tolerant varieties, and the low prices they are paid for their crops (Okoko et al., 1998). Diseases such as rosette virus and leaf spots, attacks by insect pests such as aphids and thrips, and poor intercropping systems also affect farmers' yields. The lack of an efficient market infrastructure, limited access to research extension agents, low adoption of improved technologies, and the lack of value-adding technologies along the groundnut value chain all limit the farmers' ability to improve their productivity and their income. Shrinking farm size, coupled with a population growth rate of 3% in Western Kenya, suggests that some agricultural interventions are needed to improve farm productivity and enhance sustained agricultural development.

Although groundnut contributes significantly to food security in Western Kenya due to its high nutritional value and cash crop value, the crop is highly susceptible to aflatoxin contamination. Mutegi (2010) found that in Western Kenya, as much as 7.54 % of the crop was contaminated with aflatoxin, based on KEBS standards. The Lower Midland 1 and Lower Midland 2 districts have higher levels of aflatoxin contamination than the Homa Bay district,[1] which in turn has higher levels than the drier Lower Midland 3. In areas where groundnut is an integral part of the diet, such as Nyanza, high levels of

[1] Homa Bay District is the one divided to form the Ndhiwa District

malnutrition and nutritional disorders have been linked to aflatoxin exposure (Mutegi 2010).

3.3. Factors influencing technical efficiency (TE) and technology gap (TG)

Variations in TE arise from managerial decisions and farm characteristics that affect the ability of farmers to adequately use existing technology. Njuki et al (2006) identified the factors that contribute to TE as (1) access to extension services, (2) gender of the farm managers, (3) education, and (4) age of the farmers; these factors all may influence the managerial ability of the individuals on farm decisions.

Variations in TG are mostly influenced by access to improved technology (application of research and development results). Several factors, such as socioeconomic and demographic factors, plot-level characteristics, environmental factors, and nonphysical factors, are likely to affect the efficiency of smallholder farmers, because these factors affect the extent to which the advice of extension services providers can be put into practice.

In any production process, human capital is crucial in the sense that the performance of the firm is dependent upon the inborn and learned skills of its workforce, including the ability to process information. In the process of improving agricultural productivity, extension services enhance human capital with knowledge as to how to invest in inputs to improve crop yields. The goal of extension is to transfer knowledge from researchers to farmers, advising farmers in their decision making, educating them on how to make better decisions and clarify their own goals and opportunities, and stimulating desirable agricultural development. It is clear that investment in extension services is an important tool for improving agricultural production and increasing farmers' income. The knowledge level of the farmer prior to consultation with an extension agent and the format via which the services are delivered determine the extent of the impact of the extension services (Anderson 2007).

Extension services help to reduce the differential between the potential and the actual yield in farmers' fields hence; they reduce the technological gap and help farmers to become better managers. Extension has a dual role in bridging blocked channels between scientists and farmers; it facilitates both the adoption and the adaptation of technology to local conditions. Adoption means translating information from the store of knowledge and from new research to farmers, and adaptation means using that knowledge to work with the real constraints faced by farmers (Anderson 2007)

Education is one of the important factors influencing adoption of technology. Weir and Knight (2004) investigated the impact of education on technical efficiency in Ethiopia and concluded that household education positively influences the level of technical efficiency. They found that there are substantial and significant benefits to education in increasing average production, which shifted out the frontier.

Parikh et al. (1995), using stochastic cost frontiers in Pakistani agriculture in a two-stage estimation procedure, found that education, the number of working animals, credit per acre, and the number of extension visits significantly increased cost efficiency, while large land-holding size and subsistence significantly decreased cost efficiency. This idea contradicted that of other researchers, who found that large-scale production influences productivity.

Tadesse and Krishnamoorthy (1997) also report significant differences in technical efficiency across farm size groups. The paddy farms on small- and medium-sized holdings operated at a higher level of efficiency than large farms. They argue that because accessibility to institutional finance depends on land ownership hence, small farms are forced to allocate their meager resources more efficiently. Coelli and Battese (1996), Wang et al. (1996), and Seyouma et al. (1998), found that the farmer's level of education negatively related to technical inefficiency, and suggested that this may be because educated farmers are more open to new technology. They found that technical inefficiency was positively related to the farmer's age, which suggested older farmers are less technically efficient than younger farmers. In addition, family size and per capita net income are both positively related to production efficiency. Off-farm employment was negatively related to efficiency, perhaps because farmers with off-farm employment have limited time for farm management. Seyouma (1998) added that the farmers in the project who have access to extension services are more technically efficient than those does not have such access. This shows the importance of extension services for improving productivity. The idea was also supported by Wadud and White (2000); they applied a stochastic translog production frontier in both one-stage and two-stage technical inefficiency models and found that inefficiency decreases with farm size.

Access to technology is critical. Rafael (2009) estimated the TE of crop production using the translog stochastic production frontier and first difference model. He observed that the variation in farm-household efficiency related to access to technology, especially improved varieties, as well as access to credit and extension services, was significant for most households. Ephraim (2007) also used the stochastic production frontier to estimate technical efficiency and analyzed the reasons for technical efficiency variations in Malawi. The observation was that inefficiency declined on plots planted to hybrid seeds and on the plots controlled by farmers who held membership in farmers' clubs or associations. This finding suggests that variations in output may be due to access to technology.

3.4 Summary

In general, the literature suggests various factors that determine variations in TE. These factors are: the age of the farm manager, which seems to be negatively related to TE; the number of years of schooling, which reflects the ability of the farmer to make good decisions on resource combination; per capita net income and credit, which permit economies of scale on a farm; and extension visits and membership in a farmers' club, which increase access to technology and accelerate its adoption. Family size (labor), farmer gender, size of land holding and geographical location also contribute to variation in TE. Good soil and the use of technology and working animals increase TE.

Table 3: Groundnut yield by region in (kg/ha) in 2009

World	1511.0
Africa	1026.7
Eastern Africa	668.7
Southern Africa	1704.7
Western Africa	1207.7

Source: Retrieved from FAOSTAT 2011 | 12 March 2011

Table 4: Summary of TE by regions

Region	**Min**	**Max**	**MTE**
Africa	43.00	98.80	73.70
Asia	24.00	100.00	74.00
L. America	17.00	96.00	77.90
N. America	55.00	94.20	70.00
W. Europe and Oceania	53.80	99.80	82.00

Compiled by Author: Source: Bravo-Ureta et al. (2007)

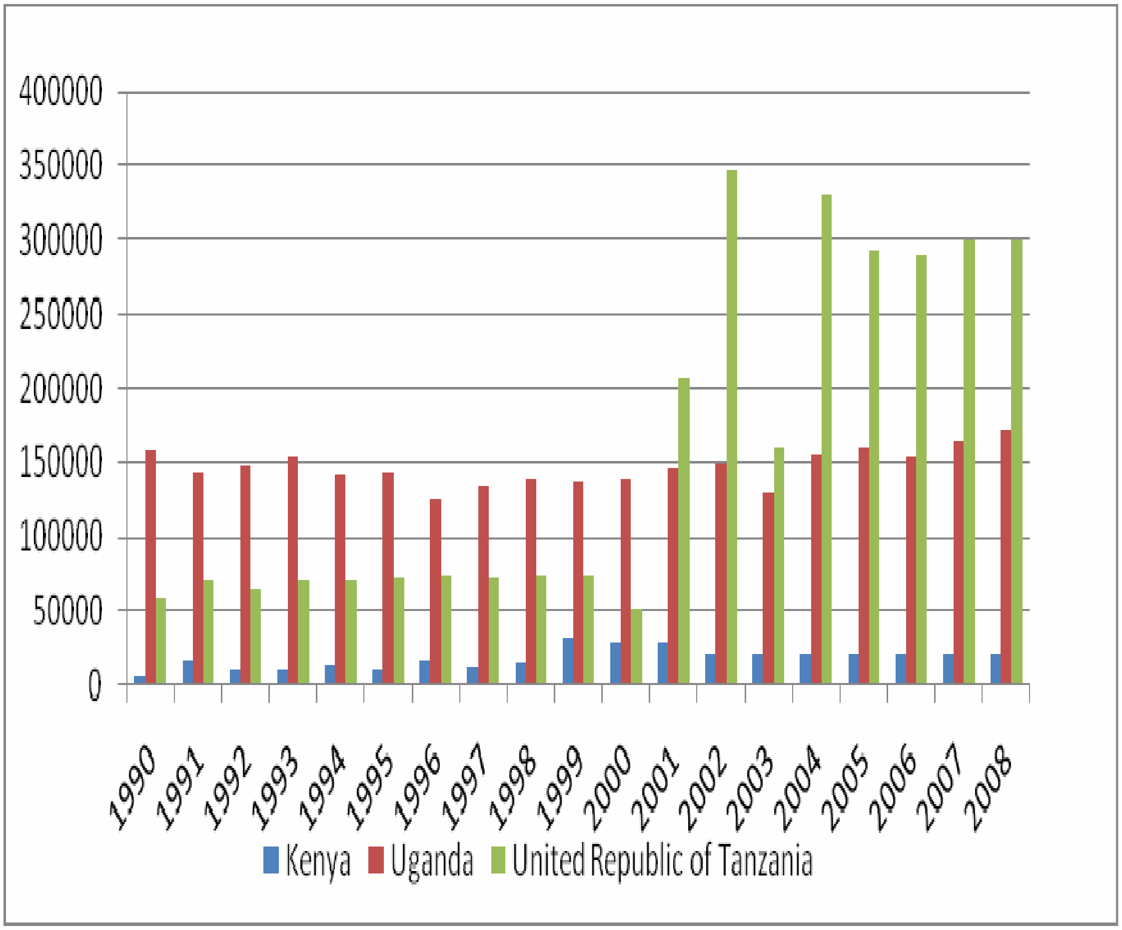
Table 5: Technical efficiency estimates for African farms

Author	Year	Country	Crop	Observation	MTE
Sherlund	2002	Côte d'Ivoire	Rice	464	35.0
Croppenstedt	1997	Ethiopia	Crops	344	41.0
Shapiro	1983	Tanzania	Cotton	37	66.0
Abdulai	2000	Ghana	Rice	120	73.0
Admassie	1999	Ethiopia	Crops	64	90.8
Aguilar	1993	Kenya	Crops	347	93.9
Ajibefun	1999	Nigeria	Crops	98	67.0
Ajibefun	2002	Nigeria	Crops	67	82.0
Amaza	2002	Nigeria	Crops	123	69.0
Audibert	1997	Mali	Rice	836	69.5
Thiami & Bravo	2003	Senegal	Groundnut	501	70.4
Binam	2004	Cameroon	Crops	150	75.0
Joachim et al.	2004	Cameroon	Groundnut	500	95.0
Heshmati	1996	Uganda	Plantain	144	65.3
Martine	1997	Niger, Mali,	Paddy	836	70.7
Seyoum	1998	Ethiopia	Maize	20	86.6
Sherlund	2002	Côte d'Ivoire	Rice	464	43.0
MTE					**70.2**

Author	Year	Country	Crop	Observation	MTE
Jean et al.	2005	Gambia	Food crops	120	85.2
Onwuchekwa et	2008	Nigeria	Cassava	160	77.0
Obafemi	2006	Nigeria	Rice	50	86.6
Kolawole	2009	Nigeria	Food crops	40	65.6
		Nigeria	Cash crops	9	80.6
		Nigeria	Livestock	15	75.4
Ojo et al.	2009	Nigeria	Honey	150	61.3
Amaza	2007	Nigeria	Other crops	123	69.0
Okoye et al.	2007	Nigeria	Cocoyam	120	96.0
Okoye et al.	2009	Nigeria	Cassava	90	75.0
Elizaphan et al.	2010	Kenya	Super market Vegetable	133	80.0
Elizaphan et al.	2010	Kenya	Traditional market Vegetable	269	54.0
Ephraim	2007	Malawi	Crops - maize	156	46.2
Stefania	2010	South Africa	Maize/Vegetables/Fruits	547	36.0
Rafael	2009	Mozambique	Crops	4104	65.0
Joachim et al.	2008	Côte d’Ivoire	Cocoa	1372	58.0
	2010	Ghana	Cocoa	1000	44.0
		Nigeria	Cocoa	1083	74.0
		Cameroon	Cocoa	1003	65.0
Xavier Irz et al.		Botswana	A/Agriculture	342	85.0
MTE					**68.9**
Overall MTE					**69.6**

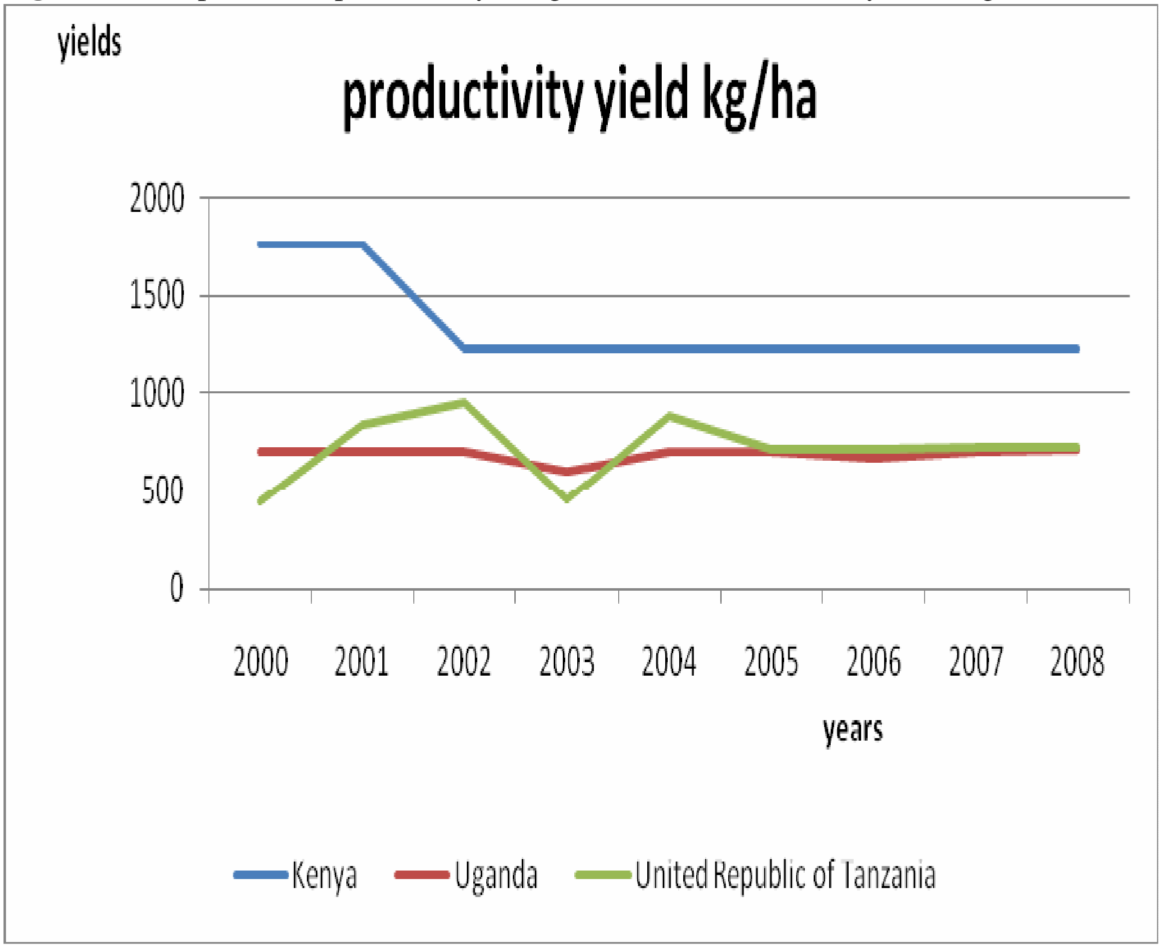
Compiled by the author 2011 from various sources

Figure 3: Comparison of groundnut production (kg) in East African



FAOSTAT | © FAO Statistics Division 2010 | 31 December 2010

Figure 4: Comparison of productivity in kg/acre for Tanzania, Kenya and Uganda



FAO Statistics Division 2011 | 12 March 2011

CHAPTER 4: METHODOLOGY AND DATA

This chapter is organized into three sections. The first section describes the conceptual framework used to address the objectives of the study and the second section presents the data and empirical model. Section three contains the model specification and estimation.

4.1 Conceptual Framework

The literature suggests several alternative approaches to measure productive efficiency; these approaches are parametric and nonparametric frontiers. Nonparametric frontiers use linear programming approaches. Unlike parametric frontiers, they do not impose a functional form and do not make assumptions about the error term. The most commonly used functional forms include the Cobb–Douglas and the translog (Bravo-Ureta et al., 2007, Battese and Coelli, 1995). Another distinction is between deterministic and stochastic frontier analyses. The deterministic frontier analysis assumes that all deviations from the frontier are a result of inefficiency while the stochastic frontier analysis makes allowance for statistical noise.

The stochastic production frontier model can be expressed in general terms as:

1) $Y_i = f(X, \beta) + \varepsilon_{i,} \quad i = 1, \ldots\ldots n$

where Y_i is the output of the i^{th} firm, X is a vector of inputs, β is a vector of parameters and

2) $\varepsilon_i = \nu_i - \mu_{i,} \quad i = 1, \ldots\ldots n$

The term v_i is the conventional two-sided random error reflecting measurement errors and statistical noise, and μ_i is a one-sided error that reflects farm-specific inefficiency (Forsund et al., 1980; Battese, 1992; Coelli et al., 1995, 1998, 2005).

Researchers propose two methodological approaches for analyzing the sources of technical efficiency and the technological gap based on stochastic production functions. The first approach is the two-stage estimation procedure in which (1) the stochastic production function is estimated to derive efficiency scores; and (2) the efficiency scores are regressed on explanatory variables. This approach has received considerable criticisms because the firm's knowledge of its level of technical inefficiency affects the choice of its input; hence, inefficiency may be correlated with the explanatory variables. The second approach is a one-stage estimation where inefficiency effects are an explicit function of a vector of farm-specific variables.

The analytical approach adopted in this study is the stochastic production frontier function as first developed by Aigner, Lovell, and Schmidt (1977) and Meeusen and van den Broeck (1977), and later extended by Battese and Coelli (1995). Battese and Coelli (1995) formulated a stochastic frontier model in which TE is a function of explanatory variables, Z, and both parts of the model are estimated in one step. If all parameters for the Z variables (δ) are equal to zero, then the TE is not related to such variables, and the model reverts to the original specification of Aigner, Lovell, and Schmidt (1977).

This study uses primary data for two groups of farmers, research and non-research farmers, and assumes the log-linear functional form (Cobb–Douglas). The SFP can be written as:

3) $\ln Y_i = f(\ln X; \beta) + v_i - \mu_i,$

where $\ln Y_i$ is the logarithm of total value product (TVP) for the i^{th} farm; $\ln X$ is a vector of inputs in log form; β is a vector of unknown parameters; v_i is assumed to be an identically and independently distributed N $(0, \sigma_v^2)$ random error, independent of μ_i; and μ_i is a one-sided identically and independently distributed term (μ_i, σ_u^2), where μ_{ij} is a measure of inefficiency. The inefficiency term can be expressed as a function of farm-specific variables, as follows:

4) $\mu_i = z_i\delta + \omega_i.$

The random term ω_i in equation (4) is defined by the truncation of the normal distribution with mean zero and variance σ^2. This is consistent with μ_i being a non-negative truncation of the $N(z_i\delta, \sigma_\mu^2)$ - distribution (Battese and Coelli, 1995).

Based on the distributional assumptions of the error terms μ and v, input and output data can be used to obtain maximum-likelihood (ML) estimates of the unknown parameters of the frontier (Battese and Coelli, 1995). The ML estimates the variance parameter as in equation (5):

5) $\sigma^2 = \sigma_v^2 + \sigma_\mu^2$ and $\gamma = \sigma_u^2 / \sigma_v^2 + \sigma_\mu^2$

where the γ parameter has a value between 0 and 1. The technical efficiency effects of the i^{th} farmer is defined by Equation (6):

6) $TE_i = \exp(-\mu_i) = \exp(- z_i\delta - \omega_i)$

This measure of TE takes values between zero and one. It measures the total value product (TVP) of the i^{th} farmer relative to the TVP that could be produced by a fully efficient farmer using the same input vector.

This study uses the analytical model, depicted in Figure 5, to test the possible presence of a technology gap. The corresponding frontier model can be expressed as:

7) $\ln Y_i = f(\ln X, T_D; \beta) + \nu_i - \mu_i$

where Y_i, X, β and error terms are as already defined, and T_D is a farm-specific dummy variable that captures the technology gap which equals one if farmers use improved varieties and zero otherwise. The null hypothesis to be tested for the technology gap is that the parameter for T_D is equal to zero (H_o: $\beta T_D = 0$). If it is found that the maximum total value product is unaffected by the use of improved seed, the null hypothesis is accepted. If there is a difference in output attributable to the use of improved seed, we reject the null hypothesis and conclude that there is an opportunity to expand TVP by minimizing the technological gap.

4.2 Data and Empirical Model

The data used in this study was collected from 249 groundnut-producing farms in the Ndhiwa, Nyarongi, and Kobama divisions of the Ndhiwa district in Kenya, where some farmers (mainly in lower midland and upper midland agro-ecological zones) had received groundnut research interventions (Appendix 2). Using a structured questionnaire (Appendix 3), KARI, in collaboration with the Ministry of Agriculture, collected the data from one production season in 2009 and another in 2010.

Various queries arose during the data-cleaning process, which sometimes necessitated consultations with the field researchers. Once the data were clean, the second step was to select the variables to be included in the model from the main questionnaire. The procedure was to identify the plots used to grow groundnuts in a pure stand, calculate their acreage, and then calculate the acreage devoted to groundnuts in plantings that were intercropped. This information allowed us to calculate the total land devoted to groundnuts. Total production was obtained by aggregating total output in the two seasons. TVP was then calculated by converting unshelled groundnuts to shelled using conversion scales received from field researchers (Appendix 4), and multiplied by net prices received by farmers. The expenditures on hired labor and seeds are calculated and introduced in the model as separate inputs.

SPSS and MINITAB were used for descriptive statistics. The program Frontier was then used to estimate the stochastic production frontier models using the maximum likelihood estimation technique (Coelli, 1995).

The selection of variables to be included in the model was based on economic theory and the data available. The variables used included days of family labor, the cost of hired labor, the cost of seeds, the varieties of groundnuts planted, location, farmer age, years of schooling, gender, and whether or not the farmer was a "research farmer." Estimations were based on 223 observations. Twenty-six observations had to be dropped because of clear errors or incomplete information (Appendix 5). The data for variables such as off-farm income, the use of credit (either cash or barter), and the use of fertilizer and pesticides were coded in 0 /1 format.

4.3 Model Specification and Estimation

The variables assumed to influence output were selected and fitted into the models represented in general terms in equations (3) and (4) above. The stochastic frontier models with inefficiency effects were estimated in one stage, using the Battese and Coelli (1995) model. The stochastic frontier is presented by equation (8) while the inefficiency effects model is expressed by equation (9) as follows:

8) $ln\ (Y_i) = \beta_0 + \beta_1 ln(L_{and}) + \beta_2 ln(famlab_i) + \beta_3 ln(hlab_i) + \beta_4 ln(seedexp + \beta_5(\mathrm{var}_{D1i}) + \beta_6(\mathrm{count}_{D3i}) + \beta_7(\mathrm{count}_{D4i}) + \beta_8(\mathrm{lndisrit}) + \beta_9 ln(\mathrm{fert}_{5Di}) + \beta_{10} ln(\mathrm{pesd}_{D6i}) + v_i + \mu_i$

9) $\mu_i = \delta_0 + \delta_1 z_{1i} + \delta_{2Z2i} + \delta_{3Z3D1i} + \delta_{4Z4i} + \delta_{5\ Z5i} + \omega_i$

All variables included in the model are defined in Table 6, along with descriptive statistics. According to the groundnut yield statistics presented in Table 7, farmers in the Dhiwa district produced 420 kg/acre. Female farmers produced more groundnuts per acre than male farmers, and among both groups—female and male farmers—research farmers produced more per acre than non-research farmers. Only 29% of the TVP was realized in cash from sales; hence, 71% of the TVP was consumed within the household.

4.4 Summary

This chapter provided the highlights of the conceptual and analytical framework of the model used to address the objectives of the study. It also gave information on the sample and sampling process, data management, and variable selection process as well as model estimation technique. The next chapter provides a detail analysis of the results.

Figure 5. The analytical model

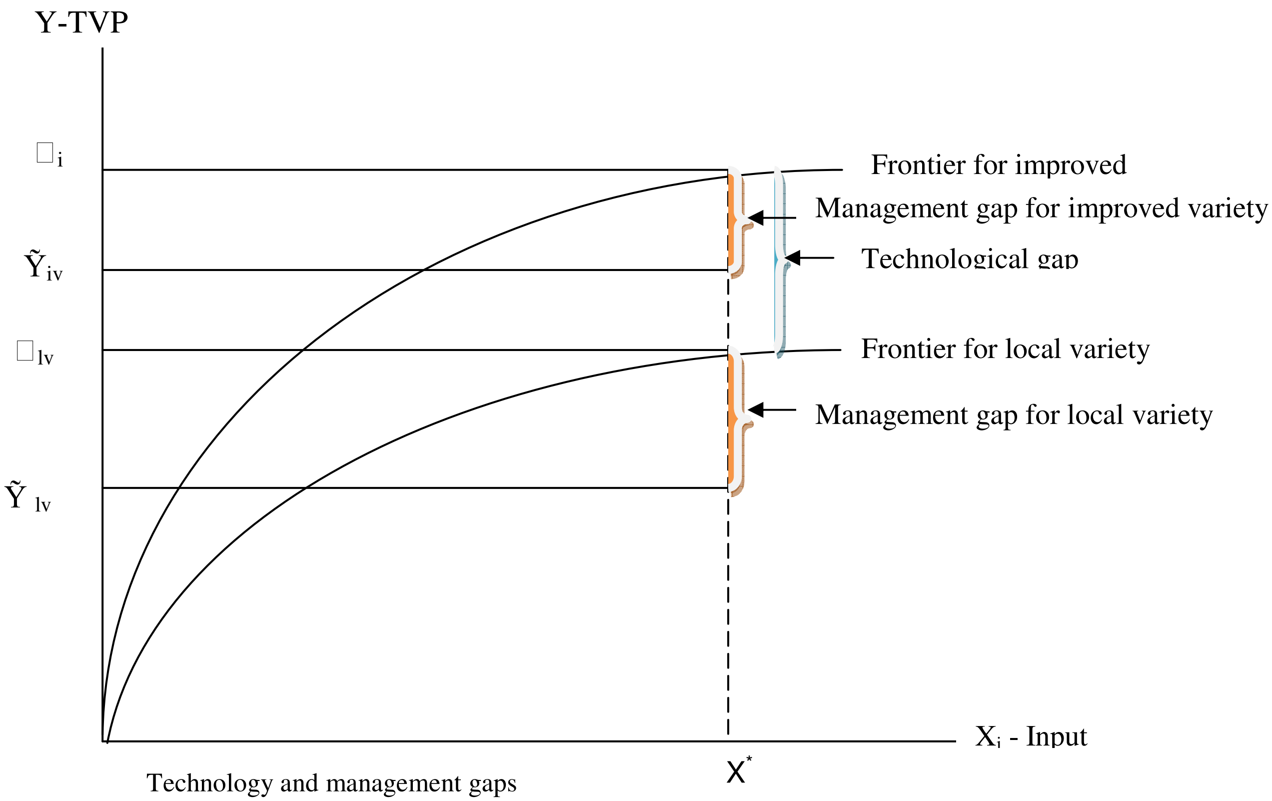


Table 6: Definition of variables and descriptive statistics

Variable	Variable definition	N	Mean	SDv	Min	Max
YGnut	Total value product of groundnut (Kshs)	22	78950	56240	3653	578571
Land	Log of land (acres)	223	1.65	1.28	0.13	7.50
Famlabor	Log of family labor (Kshs)	223	35.78	30.51	0.00	200.
Hlabor	Log of hired labor (Kshs)	223	2780	3440	0.00	24150
Seedc	Log of Seed expenditure (Kshs)	223	34.41	57.76	0.5	614
Location1	Dummy for Kobama county					
	D = 1 if the county is Kobama	30	109756	78449	59659	330750
	D = 0, otherwise	193	75559	81966	3653	578571
Location 2	Dummy for Ndhiwa county					
	D = 1 if county is Ndhiwa	130	75914	79664	3653	468000
	D = 0 otherwise	93	98217	90681	3960	578571
T_D tech	Dummy for technology					
	D = 1 if improved variety	209	672.5	573.8	45	2475
	D = 0 otherwise	14	491.3	372.4	45	1440
Fert	Fertilizer usage dummy					
	D = 1 if fertilizer used	10	748	687	108	2224
	D = 0 otherwise	213	657.1	559.6	45	2475
Pest	Pesticide usage dummy					
	D = 1 if pesticides used	12	589	543	183	1778
	D = 0, otherwise	211	665.3	566.6	45	2475
Disrchist	Distance to the nearest research institute in km	223	79.23	15.39	26	124
Z_{1D1}	Farmer type					
	D = 1 if research farmer	223	520.03	452.0	33	1440
	D = 0 if non-research farmer	223	464.21	407.89	39	1680
Z_2	Age of farm manager (years)	223	44.683	14.21	18	87
Z_{3i}	Farm size	223	4.71	3.78	0.00	25
Z_4	Education of farm manager (years)	223	7.277	3.32	0	16
Z_{5D2}	Gender of farm manager (dummy)					
	D = 1 if farmer is male	134	705.2	590. 4	45	2475
	D = 2 if farmer is female	89	594.4	518.6	45	2224

*All continuous variables are transformed into logs when incorporated into the model.

Table 7: Summary of average yield per acre of land

Variable	Mean Yield (kg/acre)	SDV	Min.	Max.
Farmer gender				
Male	481	359	33	1929
Female	508	380	39	1890
Farmer type				
NRF	460	342	33	1929
RF	528	392	39	1890
Farmer type x gender				
NRF male	469	365	33	1929
RF male	494	355	60	1333
NRF female	445	306	89	1440
RF female	575	440	39	1890

CHAPTER 5: RESULTS AND ANALYSIS

This chapter presents the results and analysis of the estimated stochastic frontiers. Various models were estimated and the results of two such models were retained for presentation here. All models were estimated as Cobb–Douglas specifications using the Battese and Coelli (1995) framework.

The maximum-likelihood estimates of the parameters for the two stochastic production frontiers (Model 1 and Model 2) to be discussed are presented in Table 8. Model 1 includes seven variables in the stochastic frontier model while Model 2 includes eight variables in the stochastic frontier model and an inefficiency effects component. These models can be expressed as:

Model 1: $Y_i = f(X_i,\beta) + \square_i$ $\qquad$ $i = 1, 2 \ldots 7$

Model 2: $Y_i = f(X_i,\beta) + \square_i - g(z_{i,\delta})$ $\qquad$ $i = 1,2 \ldots 8$

As shown in Table 8, the coefficients for land, labor, and seed expenditures have the expected positive signs for Model 1. The results show that a 1% increase in the land area cultivated will increase the TVP by 0.37%. A 1% increase in hired labor will increase TVP by 0.05%. A 1% increase on seed expenditure will increase the TVP by 0.25%. The parameter for the dummy variable for seed variety, which estimates the differences in the mean TVP of farmers using improved varieties and those using local varieties, is positive and significant. This result indicates that the TVP frontier of farmers using improved varieties is higher than that of farmers using local varieties. The estimated MTE is 55%.

Model 2 was estimated first by including ten variables in the stochastic frontier and five variables in the inefficiency model. Two variables, fertilizer and pesticide use, were dropped because the parameters were not significant and the model was re-estimated. The signs and significance level for the parameters in the production part of the model are very similar to those obtained in Model 1. The inefficiency component of Model 2 includes as the following as explanatory variables: farmer age, years of schooling; farmer type; gender; and farm size. Somewhat surprising, none of the parameters in the inefficiency component are significant. Moreover, MTE for Model 2 went down to 35%. The null hypothesis that all parameters of the inefficiency component are equal to zero is not rejected (Table 10); thus, it was concluded that Model 1 is preferable. Hence, the following discussion relates only to Model 1.

The γ-parameter has a value of 0.62 and a generalized likelihood ratio test shows that it is statistically significant at the 5% level (Table 9). Hence, technical inefficiency is a significant component of the total variability of groundnut TVP for farmers in the Ndhiwa District. Another test shows that the null hypothesis that $\beta_7 = 0$ is rejected at the 5% level, which mean that the technology gap is significant (Table 9).

As shown in Appendix 6, the TE for research farmers ranged from 0.23 to 0.80, with a mean of 0.56. For non-research farmers, technical efficiency ranged from 0.19 to 0.83, with the mean estimate of 0.55.

Table 11 and figure 6 shows the frequency distribution of TE for all farmers revealing that 1.8% had TE scores below 20%, while almost 48.0% had TE scores between 51 and 69%. Figure 7 shows a histogram with the distribution of TE again for all farmers, and this appears very close to normal.

Using the approach shown in Appendix 7, the farmers using improved varieties have an expected TVP of 80,821 Kenyan shilling (KES), while farmers using local varieties have a TVP of 40,387 KES. Hence, the technology gap is estimated to be 32,424 KES, which is equivalent to 40% for all of the Ndhiwa District. In addition, Model 1 indicates decreasing returns to scale for the sample equal to 0.664.

A comparison of the expected TVP by county indicates that farmers in Kobama have an expected TVP of 100,912 KES for improved varieties and 60,413 for local varieties. In Ndhiwa County, the expected TVP is 49,414for improved varieties and 29,584 KES for local varieties, while in Nyarongi County the expected TVP is 61,697 KES for improved varieties and 24,750 KES for local varieties. Thus, Kobama County produces the highest TVP, followed by Nyarongi and Ndiwa.

The overall TE results found in this study conform to a trend observed by other researchers. For example, Elizabeth et al. (2010) compared the TE of vegetable farmers who supply supermarkets with that of farmers who supply through traditional channels. They found that the supermarket suppliers had a TE of 85%, where the traditional suppliers had a TE of 54%. Bravo-Ureta et al., at (2011) estimated a higher TE for farmers participating in a natural resource conservation program compared to non-participants. The TE ranged from 0.67 to 0.75 for beneficiaries and from 0.40 to 0.65 for the control group. They also observed that beneficiaries exhibited not only higher TE but also higher frontier output than the control group. Nkamleu et al (2010) estimated the TE of cocoa farmers in West Africa as 58%, 44%, 74%, and 65% for Côte d'Ivoire, Ghana, Nigeria, and Cameroon, respectively. These studies show that there is considerable room for improvement in TE in African agriculture.

5.1. Summary

This chapter provided a detailed analysis of the results of the estimated models. The analysis reveals that farmers using improved varieties operate on a higher frontier than farmers using local varieties. However, no significant difference was found between the technical efficiency of research and non-research farmers. Overall average efficiency is estimated at 55%. The next chapter gives the summary and conclusion of the study.

Table 8: Maximum-likelihood estimates for parameters of the Cobb–Douglas stochastic frontier production functions for groundnut farmers in the Ndhiwa District[a]

Stochastic frontier model	**Parameter**	**Model 1**	**Model 2**
Constant	β_0	9.133(0.310) ***	6.677(1.201) ***
lnland	β_1	0.372(0.603) ***	0.354(0.100) ***
lnflabor	β_2	-0.001(0.094)	-0.010(0.012)
lnhlabor	β_3	0.05(0.011) ***	0.041(0.000) ***
lnseed exp	β_4	0.2420(0.22) ***	0.237(0.006) ***
Kobama	β_5	0.492(0.221) *	0.284(0.255) *
Ndhiwa	β_6	-0.222(0.139)	-0.184(0.139)
Variety	β_7	0.513(0.186) ***	0.696(0.247) ***
lndritute (km)	B_8		0.509(0.179) ***
Inefficiency model			
Constant	δ_0		0.925(0.839)
Farmer Type	δ_1		-0.127(0.178)
Age	δ_2		0.100(0.006)
Farm size	δ_3		-0.012(0.034)
Education	δ_4		-0.005(0.186)
Gender	δ_5		-0.054(0.197)
Variance			
Sigma-squared	σ	1.308 (0.417) ***	0.995(0.297) ***
Gamma	γ	0.618 (0.279) ***	0.743(0.193) ***
[b]Log likelihood function		-288.79	-283.91
Average TE		0.55	0.35

[a]The estimated standard errors of the coefficient estimators are given in parentheses following the estimates . *** Significant at 1% level, ** significant at 5% level, and *significant at 10% level

[b] Likelihood ratio test is given by $LR = -2(\ln_R - \ln_u) \sim \chi^2{}_{(2\alpha)}$

Table 9: Test for parameters of the two models

Models' hypothesis	LR-test statics	$\chi^2_{(.05, 2\alpha)}$	Decision
$Mode_l$ vs. $Model_2$	1.76	2.71	Not rejected
H_o:$\gamma = 0$ vs. H_1: $\gamma \neq 0$	14	2.71	Rejected
H_o: $\beta = 0$ H_o: $\beta \neq 0$	13.41	2.71	Rejected

Table 10: Descriptive statistics for models 1 and 2

	N	Min.	Max.	Mean	Std. Deviation
Model 1	223	0.194	0.829	0.554	0.142
Model 2	223	0.056	0.821	0.352	0.178

Table 11: TE distribution by observation

Category	Frequency	Percent	Cumulative /%
5 - 20	4	1.79	1.79
21-30	10	04.48	6.28
31-50	62	27.80	34.08
51-69	108	48.43	82.51
70-100	40	17.94	1.00
Total	**223**	**100**	

Figure 6: TE Distributions in pie chart

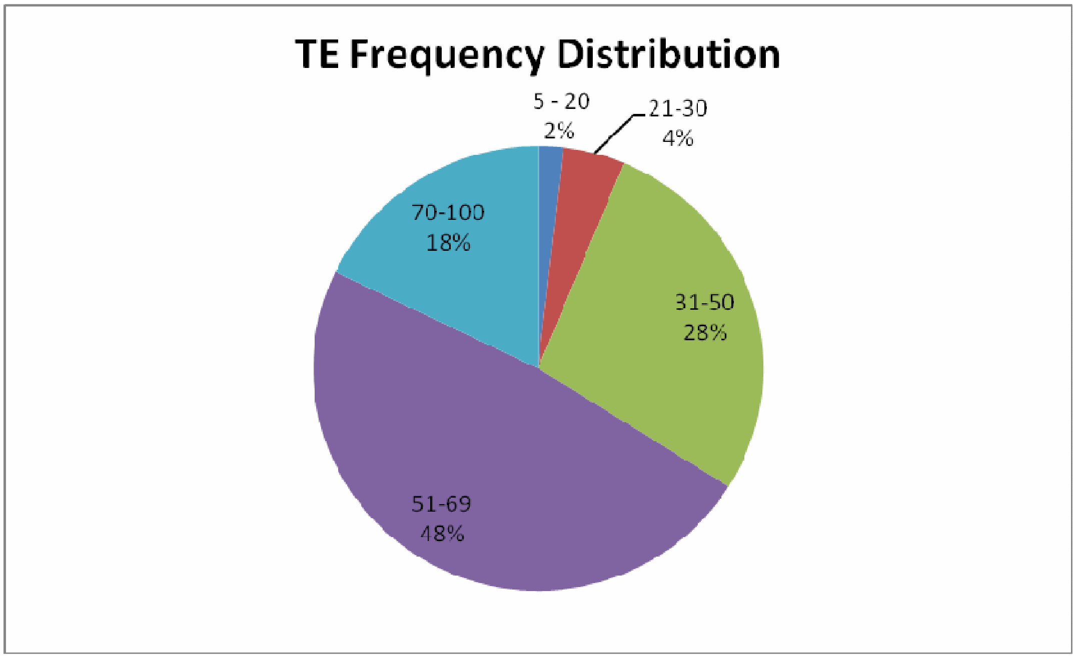
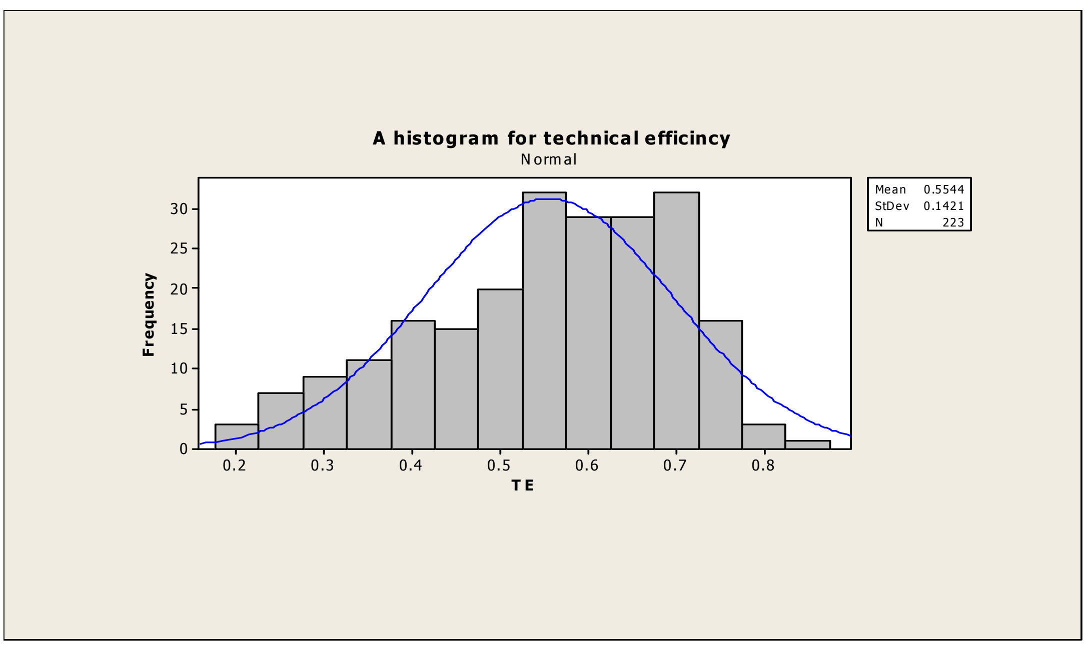


Figure 7: TE distributions in histogram



CHAPTER 6: SUMMARY AND CONCLUSIONS

This study estimates stochastic frontier production functions for a sample of 223 research and non-research farmers in the Ndhiwa district in Kenya. Cobb–Douglas specifications are used along with the Battese and Coelli (1995) framework.

The study presents an important contribution to the evaluation of the performance of research farmers and the performance of improved varieties. The dummy variable that captured the differences farm output between those using improved varieties and those using local varieties was positive and significant. Nevertheless, the mean TE of 55% is low compared to other studies. This result suggests that in the Ndhiwa district, groundnut output could possibly be increased by 45% using available inputs and existing technology.

The results confirm that there is a low level of average TE and thus a significant management gap. Moreover, this management gap is similar for research and non-research farmers. However, the study shows that there are significant differences between farmers using improved varieties and those using local varieties, i.e., there is a significant technology gap. The results also show that male farmers are more technically efficient than female farmers. Another important finding is that the farmers in the sample exhibit decreasing returns to scale.

The following conclusions can be derived from the results and analysis:

- It calls attention to the fact that farmers need to minimize the observed TE and technological gaps in order to improve their productivity and income.

- At present, the difference between the research and non-research farmers is not significant. This suggests that the extension systems in Ndiwa district are not effective in helping farmers to increase their efficiency. Improvement in the delivery of extension services may be necessary to improve technical efficiency.

- Female farmers appear to be less efficient than male farmers. Since many women tend to grow groundnuts in preference to other crops, it is important that their efficiency and productivity be enhanced. This will help to reduce malnutrition, increase income, and empower female heads of households.

- It is likely that agricultural groundnut production in Ndhiwa will need the continuing support of the government and international agencies until the level of production and efficiency of farmers is increased.

- Being closer to a research institute increased the TVP. Hence, more work is needed on how to link those marginalized farmers to the research and extension services.

- Farmers need more entrepreneurial/business skills so that they can better understand the importance of market oriented agriculture, since it seems that most of the produced groundnut is consumed at the household level.

In sum, farmers in Ndhiwa district can improve their productivity by narrowing the observed TE and technology gaps.

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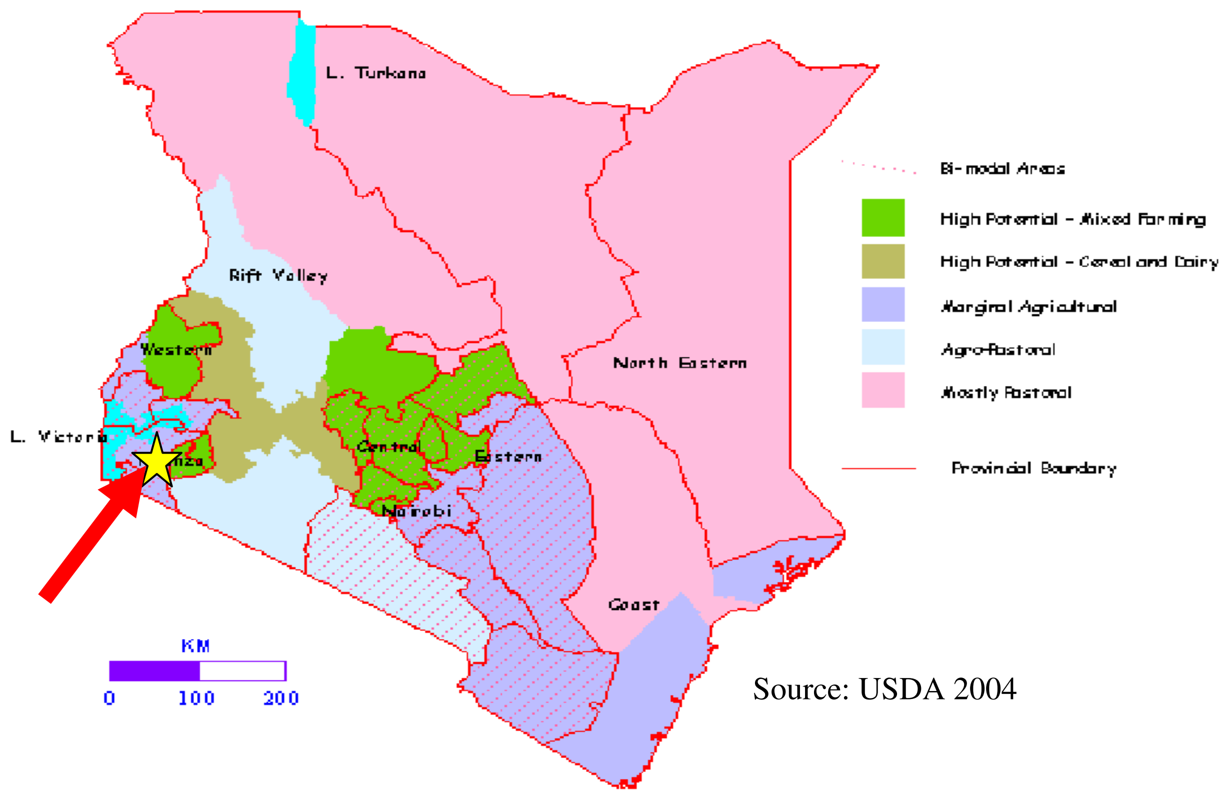
APPENDICES

Appendix 1: Women's groups help promote the production of groundnuts by women farmers in Ghana

http://www.euronet.nl/~fullmoon/womlist/countries/ghana

Appendix 2: Map of Kenya with the study site

Figure 1: Kenya's Production/Livelihood Systems



Source: USDA 2004

Appendix 3: Part of questionnaire used in the analysis

1.0: GENERAL INFORMATION:

District-------------------------------	Household ID (3 digit, provided by coordinator)----------
Division------------------------------	Distance to nearest Village market (Km) -----------------
Location-----------------------------	Distance to nearest main market (Km)---------------------
Village ------------------------------	Distance to nearest all-weather road (Km) ---------------
Distance to nearest ATC (Km)	Distance to nearest Research Institute (Km) -------------

<u>Note</u>: Target Person to be interviewed, in order: GNut Farmer; Spouse; Senior Adult

1.1 Did your Household produce GNuts in: Season I 2009? No=0, Yes=1: Season II 2009? No=0, Yes=1
<u>Note</u>: If No, take note and talk to the supervisor in order to get a replacement household.

1.2 Type of Farmer: Non Research = 0 Research with KARI/Collaborator(C-MAD/AEP/MOA) = 1

2.0: **SOCIO-DEMOGRAPHIC CHARACTERISTICS:**

2.1 Total Number of people that live in your Farm Household: ____

2.2 Number of Children 7 years old or younger: ____

2.3 For HH members **Older than 7:**	**Gender** M=1 F=2	**Age (yrs)**	**Educ. Yrs of schooling**	**Ability to read /write**	**Main occupation**	**Farm labor contribution**
Column # 1	**2**	**3**	**4**	**5**	**7**	**8**
1						
2						
3						

4.0 HOUSEHOLD ASSET OWNERSHIP

4.1a Do you have electricity: No=0; Yes=1

4.2 Land Holding in Season I (Feb-July, 2009) and Season II (Aug/Dec, 2009):

4.2a What is your land tenure system (Tick all that apply): 1. Owned with title ☐

2. Owned with allotment number ☐ 3. Communal ☐ 4. Leased ☐

4.2b How many Plots did you farm in Total in Season I 2009? _____ Plots. Acres _____

4.2c How many Plots did you farm in Total in Season II 2009? _____ Plots. Acres _____

Land	**Season 1 (Feb/July, 2009)**			**Season 1I (Aug/Dec, 2009)**		
	Cultivated (acres)	Fallow/grazing/ Homestead (acres)	Total (Acres)	Cultivated (acres)	Fallow/ grazing/ Homestead (acres)	Total (Acres)
Owned land used by Household (A)						
Rented in (B)						
Rented out (C)						
Borrowed in without pay (D)						
Borrowed out without pay (E)						
Total owned (A+C+E)						
Total Operated (A+B+D)						
Total area owned (Irrigated)						
Total area owned (Rainfed only)						

6-I. a CROP PRODUCTION (Season 1, 2009) – FARM GATE

Plot No.	Intercrop *No=0* *Yes=1*	*If tercrop,Reason* Codes A	Reasons for intercrop Codes B	Plot size in acres If *Intercrop with Gnut,*	Variety of *G/nut* Codes C	Plot managed by	Seed (Shelled equivalent for Gnuts)			Total Prod. (In Shell for g/nut) IN BAGS	Ave. crop price farm gate/kg, For Gnut,
	Which crop?			***Main(.75)=1, Equal(.5)=2, Minor(.2)=1***	**For other crops use *Local=0 Improved=1***	**M=1, F=2**	**Saved Seed , gift, from NGO (kg)**	**Bought(kg)**	**Total cost Sh/kg**	**With head=45kg, w/o head=42kg**	**Total Value**

Codes A (Col.3)	Codes B (Col.4)		Codes C (Col.7)	
0. Labor shortage	0. None	8. Cotton	1. Homa Bay local	8. Valencia red
1. Small land size	1.Maize	9. Bananas	2 JL 24	9. Valencia white
2. Inadequate seed availability	2. Beans	10. Sugarcane	3 CG 7	10. SM 99568
3.Pest management	3.Cassava	11. Sweet potatoes	4. CG 2	11. Mani Pinta
4. Variety of food	4. Sorghum	12. Groundnuts	5. ICG 12991-Brw	12. Grade
5. Soil management	5. Millet	13. Fruits	6. ICG 12988	13. ICGV 9991
6. Hired labor management	6. Cowpeas	14.Vegetables	7. ICGV 90704	14.Other, specify...
	7. Green grams	15. Other, specify…		

6-I.b Variable Costs Estimation by Plot for all Crops (Season 1, Feb-July, 2009) FARM GATE.

Cost item	Plot 1		Plot 2		Plot 3		Plot 4		Plot .5	
	Family Labor Days (FL)	Hired Labor (HL) Cost or Expense (Exp)	FL Days	HL/Cost or Exp	FL Days	HL/Cost or Exp	FL Days	HL/Cost or Exp	FL Days	HL/Cost or Exp
Crop codes. Use Codes D from 6.I a										
(If intercropped, use code for both crops)										
Plot Size (Acres)	XXXX		XX		XX		XX		XX	
Land Rental (Sh/Acre)	XXXX		XX		XX		XX		XX	
Land Clearing										
First Plowing										
Second Plowing										
Planting										
Fertilizer (Expense for Materials)	XXXX		XX		XX		XX		XX	
Labor. Fertilizer Application										
Manure (Expense)	XXXX		XX		XX		XX		XX	
Labor. Manure Application										
Field chemicals (expense for Materials)	XXXX		XX		XX		XX		XX	
Labor for Chemical Application										
Weeding 1										
Weeding 2										
Weeding 3										
Harvesting										
On farm transport expense	XXXX		XX		XX		XX		XX	
Drying/sorting										
Bagging material expense	XXXX		XX		XX		XX		XX	
Bagging Labor										
Shelling/threshing										
Storage chemicals expense	XXXX		XX		XX		XX		XX	

.0a GROUNDNUT MARKETING in 2009 [If one variety is sold to more than one buyer then record sales per buyer, by month and price] ***For month sold use Jan=1, Feb=2, March3, …. Dec=12 etc***

Variety **Codes A**	Total production Estimate 2009 (Kgs) Consistent Table 6		Form sold **Codes B**	Quantity sold **kg**	Who made decision to sell, *Both= 0M=1,F = 2*	Who sold *M=1,F = 2*	Why Sold **Codes C**	Month most sold	Buyer **Codes D**	Quality **Codes E**	Place Sold **Code F**	Net Price **(Sh/kg)**
	In shell	Shelled										
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**

Note to Col. 13: Net price is what the farmer receives at the end of the transaction.

Codes A (Col.1)	Codes B (Col.4)	Codes C (Col.8)	Codes D (Col.10)	Codes E (Col 11)	Codes F (Col.12)
1. Homa Bay local	1. Grain	1. Child education	1. Consumer/farmer	1. Above average	0. Farm gate
2 JL 24	2. In Shell	2. Family health treatment	2. Broker/middlemen	2. Average	1=Local mkt
3 CG 7	3. Roasted	3. Buy food	3. Farmer group	3. Below average	2.Urban/district mkt
4. CG 2	4. Paste/Peanut butter	4. Buy farm inputs (seed, fertilizer)	4. Rural retailer		3. CBO/NGO/
5. ICG 12991-Brw	5. Oil	5. Buy land	5. Rural wholesaler		4. Processing Center
6. ICG 12988	6. Other, Specify	6. Buy livestock	6. Urban wholesaler		5. Other, Specify
7. ICGV 90704		7.Buy mosquito nets	7. NGOs/ CBOs		
8. Valencia red		8. New house	8. Processor		
9. Valencia white		9. Improved house	9. Other, specify……		
10. SM 99568		10. Contributions (Associations)			
11. Mani Pinta		11. Gave as loan			
12. Grade		12.Bicycle			
13. ICGV 9991		13. Household equipment (Radio etc)			
14.Other, Specify		14. Clothing			

Appendix 4: Groundnut Conversions From Shelled/in-Shell in kg by Varieties.

Variety	Unshelled (wt /bag)	·lled gnut from the unshelled bag (wt)	Unit cost per kg
CG 7	38	22	100
SM 99568	44	28.6	100
ICG 12991	51	27	90
ICGV 9991	51	30.8	100
Homabay local	30	20	100
ICGV 90704	40	25	100
Valencia Red	42	25	90
Valencia White	41	23	90

Appendix 5: List of farmers dropped from the analysis

Household ID	G/nut plot size	Output	Commends
119		0	
123			Missing in tables 6 and 7
124		0	
146	0	0	
162			Missing in tables 6 and 7
164			Missing in tables 6 and 7
165	0	0	
175			Missing in tables 6 and 7
181			Miss other information (cost)
199	0	0	
203	0	0	
206	0	0	
210	0	0	
212	0	0	
216	0	0	
221			Missing in tables 6 and 7
231	0	0	
232			Missing in tables 6 and 7
1104	0	0	
1107	0	0	
1108	0	0	
1116	0	0	
1117	0	0	
1119	0	0	
1130	0	0	
1133	0	0	
1139	0	0	

Appendix 6: Mathematical calculations formulas used

i. Technology gap

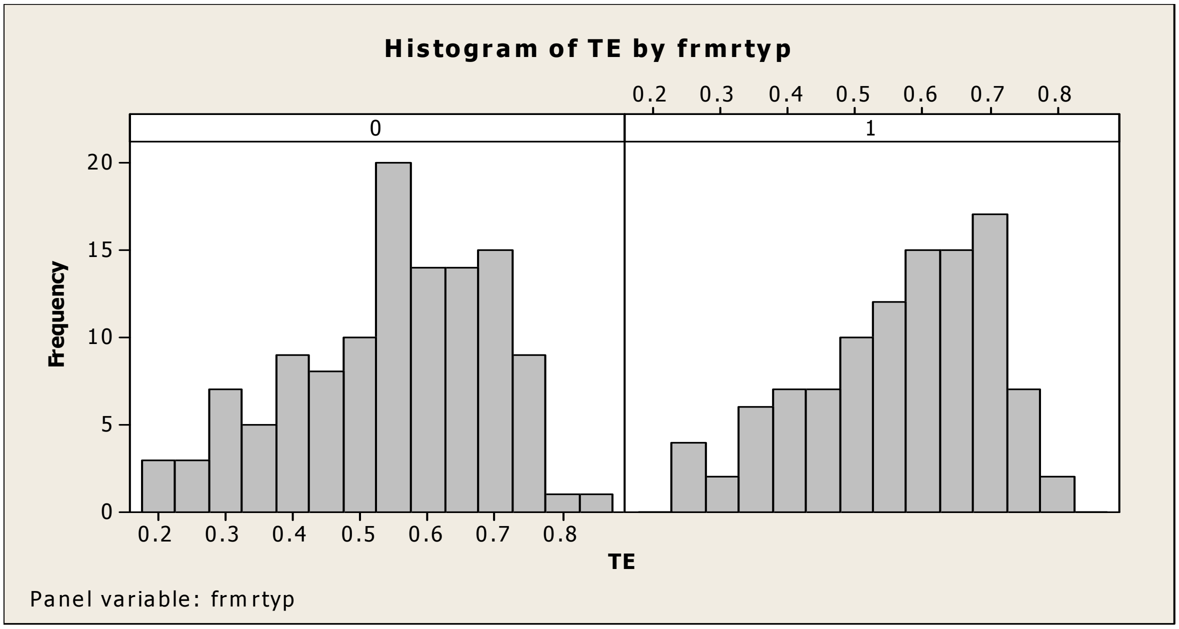
$\breve{Y}= e(A\beta_s)$ --------1, when dummy for variety =1 and (Holding other inputs at mean)

$\breve{Y}= e\,(A\beta s)$ --------2, where dummy for variety = 0 (Holding other inputs at mean)

Technology gap = (1) – (2)

ii. % of sold groundnut = TVP sold at the market/TVP equivalent consumed

Appendix 7: Distribution TE by of farmer type; 0=none research farmers, 1, research farmers



Appendix 8: Distribution of TE by gender (1 = male, 2 = female)